Scientia Horticulturae 119 (2009) 270–274

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Effect of interstock (M.9 and M.27) on vegetative growth and yield of apple trees (cv "Annurca")

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ARTICLE INFO

Article history:
Received 2 May 2008
Received in revised form 5 August 2008
Accepted 12 August 2008

Keywords:
Apple
Interstock
Grafting
Rootstock
Annurca

ABSTRACT

With the purpose of obtaining apple plants with reduced vigour but deep and expanded root apparatus, more adapted for establishment of apple orchards in dry, windy areas and higher altitudes, different interstem/rootstock combinations were compared, using seedling as rootstock and, alternatively, two weak interstocks (M.9 and M.27). For all treatments the plants were grafted at two height from soil (10 and 20 cm), interposing interstock 10 or 20 cm long. Plants with interstock showed lower vegetative growth in comparison with control plants with a reduction of 80% (M.27) and of 50% (M.9) of canopy growth. Moreover, use of interstock determined, as compared with the control plants, an increase of fruit production and average fruit weight. It was noted that increasing the interstock length, caused reduction of plants vigour and fruit production. The results showed that, the combination "Annurca Rossa del Sud"/M.9 (10 cm long)/seedling rootstock (20 cm high) was the most efficient for productivity, early maturing and plant vigour control.

1. Introduction

The need to control vegetative growth in apple trees has led to the development and wide acceptance of size controlling clonal rootstocks. Nevertheless, dwarf rootstocks are poorly anchored and because they are shallow rooted are more sensitive to nutrient and water stress. On the other hand, the use of seedling rootstocks offers some advantages, like higher resistance against drought, longer permanence and better anchorage in windy conditions. In order to plant at high densities and still take advantage of the strength of seedling rootstocks, vigour reduction can be achieved by grafting a dwarf interstem between the scion and the rootstock, called interstock. Many scientific works confirm the effectiveness of interstem to control the vigour of apple trees and, in some cases, to induce an early fruiting and an increased productive efficiency and fruit quality (Vercammen et al., 2007; Samad et al., 1999; Webster, 1995). Several authors (Loreti and Morini, 1986; Lord et al., 1985) suggested that using M.27 as interstock grafted on vigorous rootstock leads a reduction of the natural plant development, in fact, it speeds up plant cropping, minimize the need of pruning and support a simple and economic management of the orchard. This allows to carry out cultivation systems with higher densities. The influence of interstock on vigour of cultivar depends, firstly, on genetic factors, this means on chosen interstem and on agronomic factors such as the graft distance from collar and the length of interstem (Beakbane and Rogers, 1956; Marro, 1975; Morettini, 1949; Rufato et al., 2001). Further experiences showed that the decrease of growth induced by interstock depends on its vigour (Lockard and Lasheen, 1971), on the rootstock and cultivar used (Tukey, 1943; Carlson, 1965). Moreover, in apple there are some evidences that also the length of interstem and the height of grafting on the stem can affect the growth of the tree (Parry and Rogers, 1972; Parry, 1986) The aim of this work was to evaluate the use of stock/interstem combinations for cv "Annurca", to achieve new combinations with very strong and expanded root system (given by seedling rootstock) and a small canopy, using a size controlling clonal rootstock as interstem.

2. Materials and methods

The trial was carried out throughout 8 years, in an experimental orchard located in Caserta district (Southern Italy). Apple trees of Annurca Rossa del Sud previously grafted in a nursery, at the same time, on various rootstock/interstock combinations were planted. The Annurca apple is an autochthonous group of cultivars of Campania region (Southern Italy) which is widely cultivated,

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doi:10.1016/j.scienta.2008.08.019

Table 1
Effects of interstock type, interstock length and grafting point height on vegetative growth of apple "Annurca Rossa del Sud" cultivar.

Treatments	Circumference of rootstock (1) (cm)	Circumference of scion (1) (cm)	Plant height (1) (cm)	Pruning wood (2) (g/tree)	Canopy volume (2) (m^3)
Graft combinations					
Cv/M.27/SR	21.9 a	19.9 a	280.2 a	752.7 a	8.9 a
Cv/M.9/SR	29.4 b	26.2 b	356.1 b	2492.1 b	21.7 b
Cv/SR	55.4 c	45.9 c	483.5 c	10167.5 c	45.8 c
Interstock length					
10 cm	28.9 b	25.1 b	342.7 b	2035.8 b	19.3 b
20 cm	22.4 a	21.0 a	293.6 a	1209.0 a	11.2 a
Grafting point height					
10 cm	33.5 b	28.2 b	351.5 a	3290.3 a	21.1 a
20 cm	29.7 a	21.7 a	351.0 a	3372.5 a	21.7 a

(1) Values recorded at the 8th year. (2) Media of values recorded from 7th to 8th year. Different letters (a and b) indicate a statistically significant difference at $P \leq 0.05$ within the column and the treatment.

representing the 70% of apple yield, in this area. Three cultivars, named Annurca, Annurca Rossa del Sud and Annurca Bella del Sud are belonging to this group of apple which are known and appreciated for their taste and flavour. Indeed, they are characterized by a crispy and juicy flesh, sour taste and the high content of antioxidants. The cultivation of Annurca is traditionally located along the slopes of hills and only recently it has been introduced in more fertile areas, where the modern cultivation systems allow increasing the tree densities by using size controlling rootstocks, mainly M.9.

In the present experiment the treatments compared were trees of Annurca Rossa del Sud grafted on seedling rootstocks (SR) directly or using a dwarfing interstem (M.9 or M.27). In the interstock treatments the length of interstem (10 and 20 cm long) was also compared. Overall treatments included two different heights of grafting point from the soil (10 and 20 cm). The control treatments were represented by the cultivar grafted on seedling rootstock (SR) at the two heights (10 and 20 cm from the soil). Trees were placed in the field with different planting distances (4.0 m × 2.5 m for interstocked trees and 4.0 m × 3.0 m for control trees) to avoid the meddling among plants at different vigour, and trained as free palmette. The apple cultivar Hi-Early was used as polliniser, with a proportion of 25%. Experimental design was a complete randomized block, with three replications and four plants for block (12 trees/treatment). Every year the data regarding following characters were collected per tree: trunk diameters of rootstock, interstock and scion; plant height; width of canopy along the row and its depth; weight of wood removed with pruning; time of flowering; fruit drop and yield per tree. At harvest, a sample of 30 fruits/tree was weighed and the equatorial diameter was recorded. Using the data listed above the volume of canopy, the precocity index (as yield harvested on the former 2 years/cumulated yield to 8th year), the trunk cross sectional area of rootstock, interstem and scion, the yield efficiency (cumulative yield per tree/trunk cross sectional area at 8th year) were calculated. All data were used to perform an analysis of variance with GLM procedure in SPSS software (SPSS, Chicago, IL) and means comparison was carried out by Tuckey's test ($P \leq 0.05$).

3. Results

3.1. Effect of interstock

Different graft combinations induced important changes in vegetative and productive characteristics of 8-year-old plants of "Annurca". M.27 interstem treatments showed a smaller trunk circumference of stock (−60.5%) and scion (−56.4%) compared to the control (in absence of interstem). M.9 treatments showed similarly a decrease of 46.9% for rootstock and 42.9% for cultivar circumference compared to the control (Table 1). The highest plants were shown to be in control treatment (483.5 cm), whereas M.9 and M.27 interstem treatments showed a reduction of the tree height (−26.4% and −42.1%, respectively). Furthermore, the trees from both the interstem treatments showed a lower vegetative activity, confirmed by a lower amount of wood removed through the winter pruning (0.8 and 2.5 kg, respectively, for interstock M.27 and M.9, vs. 10.2 kg for control trees) and by a smaller canopy volume (21.7 m^3 for treatments with M.9 as interstock and 8.9 m^3 with M.27 vs. 45.8 m^3 for plants grafted directly on seedling).

The use of dwarfing interstocks induced an early cropping into plants and this effect was in some way related to the size controlling effectiveness of the interstocks. Indeed, the M.27 interstocked trees showed a higher precocity index (34.5%) than M.9 treatment trees (22.0%) and both performed better than the control plants (11.3%) (Table 2). Treatment with M.27, nevertheless, showed a higher fruit drop (20.3%), compared to M.9 (11.9%) and to seedling rootstock (8.7%). On the other hand, M.9 interstem treatments were the most productive since they produced the highest yield per tree (19.4 kg), followed by seedling rootstocks (11.6 kg) and M.27 (10.1 kg), respectively. The use of both interstocks assured a good balance between vegetative and productive activity, as showed by yield efficiency (0.27 kg/cm^2 for M.27 and 0.28 kg/cm^2 for M.9). On the contrary, control tree yield efficiency was very low (0.05 kg/cm^2), due to vegetative growth tendency instead of fruit production (Table 2). The use of M.27 as interstock determined also an increase of the average fruit weight (134.9 g) compared to M.9 (109.5 g) and to the control (88.1 g).

3.2. Effect of interstock length

As interstock length increased the trees were less vigorous; in fact, in the longer interstocks (20 cm long) both the circumferences of rootstock and scion lowered with a reduction of canopy size and, consequently, a lower need of pruning (−40.6% of wood removed) (Table 1).

They showed besides, an earlier fruiting, with a precocity index of 30.1%, compared to 26.4% of the shorter interstocks (Table 2). Instead, the 10 cm long interstocks induced an increase of production (17.3 kg) compared to the 20 cm long (12.3 kg). For all treatments the use of longer interstocks increased the yield efficiency of trees (0.31 kg/cm^2 vs. 0.25 kg/cm^2) (Table 2), achieving a good equilibrium among vegetative and productive activity. No statistical difference was detected for the average fruit weight between the two chosen interstock lengths.

Table 2
Effects of interstock type, interstock length and grafting point height on yield of apple "Annurca Rossa del Sud" cultivar.

Treatments	Fruit drop (%)	Precocity index (%)	Yield (kg/tree)	Yield efficiency (kg/cm^2)	Fruit weight (g)
Graft combinations					
Cv/M.27/SR	20.3 b	34.5 c	10.1 a	0.27 b	134.9 c
Cv/M.9/SR	11.9 a	22.0 b	19.4 b	0.28 b	109.5 b
Cv/SR	8.7 a	11.3 a	11.6 a	0.05 a	88.1 a
Interstock length					
10 cm	12.2 a	26.4 a	17.3 b	0.25 a	116.4 a
20 cm	18.9 b	30.1 b	12.3 a	0.31 b	127.9 a
Grafting point height					
10 cm	14.9 a	23.8 a	13.8 a	0.15 a	123.2 a
20 cm	13.9 a	25.8 a	13.8 a	0.20 b	114.1 a

Media of values recorded from 7th to 8th year. Different letters (a and b) indicate a statistically significant difference at $P \leq 0.05$ within the column and the treatment.

3.3. Effect of grafting point height above the ground

The position of the grafting point as height above the ground level affected mainly the rootstock and scion circumference, which were larger in the combinations grafted at 10 cm (Table 1). Even though the yield was not affected by the grafting point, the yield efficiency was increased on the trees grafted at 20 cm from collar (+33.3%) and also the precocity index resulted higher (25.9% vs. 23.8%).

3.4. Effects of interactions between interstock length and grafting point distance from soil

The analysis of the circumference of rootstock, interstock and cultivar showed a different growth among the treatments. The trees grafted onto seedlings showed to be more vigorous than other combinations, by means of trunk circumference, tree height and canopy volume (Table 3). All the treatments including M.27 resulted less vigorous particularly in the 20/20 combination. The trees grafted onto M.9 showed to be more vigorous than the ones grafted onto M.27 and the 20/10 combination was the most efficient in controlling plant vigour. Since the 3rd year the trunk growth of the trees grafted on seedlings was the highest (Fig. 1). Whereas comparing the two interstocks used, the controlling vigour effect of M.27 was evident only since the 6th year. Both of the interstocks (M.9 and M.27) affected the flowering time compared to the control (Table 4). Furthermore, the trees grafted on M.27/seedlings, particularly in the combination 20/20, showed a precocity in flowering (14.5 vs. 19.3 of SR 0/20) and cropping, as indicated by the values of precocity index (43.4% vs. 8.6% of trees onto 0/20 seedlings). Interstock type affected yield per tree and yield efficiency (Table 4). Indeed the trees grafted onto M.9/seedlings were more productive than the trees grafted onto M.27/seedlings, which were more efficient in controlling the tree size. Both the M.9 combinations grafted at 20 cm from soil level (M.9 10/20 and M.9 20/20) had significant higher yield efficiency compared to all other treatments (Table 4). On the other hand,

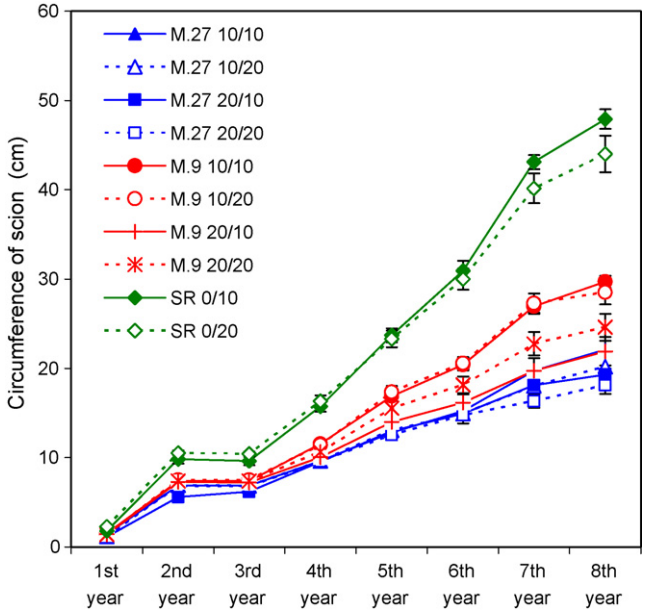

Fig. 1. Effects of interactions among interstock type and length and grafting point height on circumference of scion of apple "Annurca Rossa del Sud" cultivar, from 1st to 8th year. Average values ± S.E. (n = 12).

Table 3
Effects of interactions among interstock type and length and grafting point height on vegetative growth of apple "Annurca Rossa del Sud" cultivar, values recorded at the 8th year.

Treatments	Circumference of rootstock (cm)	Circumference of interstock (cm)	Circumference of scion (cm)	Plant height (cm)	Pruning wood (g)
M.27 10/10	27.8 d	31.2 b	22.1 c	311.3 d	708.1 ab
M.27 10/20	20.8 b	28.9 a	20.2 b	284.2 bc	515.6 ab
M.27 20/10	21.7 b	30.9 b	19.3 b	268.8 ab	563.1 ab
M.27 20/20	17.4 a	28.0 a	18.1 a	256.7 a	386.0 a
M.9 10/10	35.3 f	50.4 d	29.7 f	392.2 f	1703.6 cd
M.9 10/20	31.9 e	53.0 e	28.5 e	383.0 f	1882.3 d
M.9 20/10	26.0 c	45.0 c	21.9 c	301.0 cd	830.8 ab
M.9 20/20	24.5 c	49.2 d	24.6 d	348.0 e	1119.0 bc
SR 0/10	56.8 h	–	47.9 h	484.0 g	5003.0 e
SR 0/20	54.0 g	–	44.0 g	483.0 g	5540.8 e

Different letters (a–h) indicate a statistically significant difference at $P \leq 0.05$ within the column.

Table 4
Effects of interactions among interstock type and length and grafting point height on flowering time and yield performances of apple cv "Annurca Rossa del Sud".

Treatments	Flowering time days from 4/1 (cm)	Precocity index (%)	Yield (kg/tree)	Yield efficiency (kg/cm^2)	Fruit weight (g)
M.27 10/10	15.3 a	31.9	11.2 ab	0.22 b	134.7 de
M.27 10/20	15.1 a	31.0	10.6 ab	0.36 c	116.4 bc
M.27 20/10	15.3 a	31.6	11.3 ab	0.40 cde	136.1 e
M.27 20/20	14.5 a	43.4	7.4 a	0.39 cde	121.2 c
M.9 10/10	14.7 a	16.1	22.1 cd	0.28 b	123.0 cd
M.9 10/20	15.3 a	26.4	25.1 cd	0.43 de	111.2 abc
M.9 20/10	15.0 a	25.4	14.0 ab	0.36 c	122.0 cd
M.9 20/20	14.7 a	20.1	16.4 bc	0.45 e	114.3 bc
SR 0/10	18.4 b	14.0	13.4 ab	0.07 a	100.5 a
SR 0/20	19.3 c	8.6	9.8 ab	0.05 a	107.3 ab

Data are average values recorded from 7th to 8th year. Different letters (a–e) indicate a statistically significant difference at $P \leq 0.05$ within the column.

there were no significant differences between seedlings and M.27 treatments.

The influence of interstock on fruit weight and size was also highlighted (Table 4). Since the relationship between these two parameters resulted very high (r^2 = 0.98) the data concerning fruit diameter were not shown. Indeed fruit harvested on M.27 grafted at 10 cm from the soil level (M.27 20/10 and M.27 10/10) showed a higher average fruit weight than fruits harvested on the other combinations (136.1 and 134.7 g, respectively). Both of M.9 combinations M.9 10/10 and M.9 20/10 produced largest fruits (123 and 122 g, respectively) among M9 treatments (Table 4).

4. Discussion

In our experiment both the dwarfing rootstocks used as interstock (M.27 and M.9) showed a dwarfing influence on the vigour of the tree. Indeed the graft combinations including as interstem the two dwarfing rootstocks decreased the tree size and the amount of pruning wood on mature trees of Annurca Rossa del Sud compared to the control trees. It has been already demonstrated that the root systems of vigorous rootstocks are reduced in size when an interstem of a dwarfing rootstock is used (Swarbrick et al., 1946; Parry and Rogers, 1968) and that this lower vigour of roots contributes to control the vigour of the scion.

The M.27 clone was more effective than M.9 clone in controlling tree size as demonstrated by the circumferences of all the stems and by the canopy volume, tree height and the amount of pruning wood. These results confirmed studies on apple trees of cultivars Cox and Worcester Pearmain which were dwarfed by using as interstock stem materials from the Malling series in rough proportion to their dwarfing effects as rootstocks (Parry and Rogers, 1968; Swarbrick et al., 1946).

In apple the influence of dwarfing rootstock clones, used as interstocks, on scion vegetative growth has been demonstrated (Parry and Rogers, 1972). Furthermore, it is known that the longer is the length of interstock the greater is the effect (Parry and Rogers, 1972; Lockard and Lasheen, 1971; Lockard, 1974). Also our results confirmed this state and overall 20 cm long interstock resulted to reduce in a significant way the size of the trees. The influence of a dwarfing interstock on scion flowering and fruiting has been reported in several studies. Webster (1995) reported that the choice of the rootstock/interstock can influence the floral and the yield precocity, the floral density and the floral quality, as ability of the flowers to set fruit and ability of the trees to retain them. We did expect to find a precocity of yield in the two dwarfing interstock treatments higher than in the control trees, and in some way related to the size controlling effectiveness. It is known that dwarfing rootstocks which produce smaller trees usually produce, at maturity, yields per tree less than those from larger trees on intermediate or vigorous rootstocks. The data we presented regarding yield per tree suggest that the M.9 treatments perform better than seedling rootstock, but also better than M.27 treatment trees. This is possibly related to the relative small canopy volume of the M.27 treatment trees, but also the high fruit drop percentage we observed could partly explain the lack of differences in yield per tree between the M27 interstocked trees and the control trees. Parry and Rogers (1972) reported that the total yield per tree of Cox' Orange Pippin/M.26/M.2 was the highest overall, whereas the Cox/M.9/M.2 performed similarly to the control, when the interstock was 35 cm long. Probably as Webster (1995) asserted the interstock vigour and the tree yield don't go parallel always. Nevertheless, the yield efficiency of M.9 and M.27 treatments resulted similar and quite higher than the control.

The height of graft on the stem has been reported to affect the growth of the scion (Parry, 1986) and we did find a significant influence of this parameter on the circumferences of rootstock and scion and consequently on scion TCSA of 8 years trees. None of the other vegetative variables, neither the yield, considered in our trial was affected by the height of graft above the ground level.

5. Conclusions

Modified tree vigour and productive parameters of cv Annurca Rossa del Sud, grafted onto seedlings using an interstock (M.9 or M.27), seems to justify its use. The use of a combination including the dwarfing interstock on a vigorous rootstock allows obtaining less vigorous and more productive trees than the ones grafted onto seedlings directly. These trees join cropping precocity and higher fruit yield (in terms of average fruit weight) characters to the advantages of seedling rootstocks like wide, deep and vigorous root apparatus. The tested interstocks modified the vegetative and productive behaviour trees of cv Annurca Rossa del Sud. Both of them reduced significantly plant vigour compared to the plants grafted onto apple seedlings, demonstrated by the reduction of canopy volume (80% and 50% with M.27 and M.9, respectively). The use of M.9 as interstock induced increased yield per tree and yield efficiency, whereas M.27 interstock determined cropping precocity and increased fruit weight. The best treatment resulted in Annurca Rossa del Sud/M.9/seedling 10/20, showing good productivity, cropping precocity and vigour together with dwarfing effect. It appears to be suitable for establishment of middle and high density Annurca orchards in some dry and windy areas or higher altitudes.

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