Scientia Horticulturae 150 (2013) 278–282

Contents lists available at SciVerse ScienceDirect

Scientia Horticulturae

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

Performance evaluation of common clementine on various citrus rootstocks

Sajjad Hussain[a,c,*], Franck Curk[a], Muhammad Akbar Anjum[c], Olivia Pailly[a], Gilles Tison[a,b]

[a] INRA, UR1103 Génétique et Ecophysiologie de la Qualité des Agrumes, F-20230 San Giuliano, France
[b] AREFLEC Association Régionale d'Expérimentation Fruits et Légumes de la Corse F-20230 San Giuliano, France
[c] Department of Horticulture, Bahauddin Zakariya University, Multan – 60800, Pakistan

ARTICLE INFO

Article history:
Received 9 August 2012
Received in revised form
13 November 2012
Accepted 15 November 2012

Keywords:
Citrus
Rootstocks
Clementine
Yield
Fruit quality

ABSTRACT

Common clementine (*Citrus clementine* Hort. Ex Tan.) was budded on nine rootstocks i.e. Kryder trifoliate orange, Towne trifoliate orange, Rich trifoliate orange, Beneke trifoliate orange, Holansis trifoliate orange, AA18 trifoliate orange, Gou Tou sour orange, Da Hong Pao mandarin and Carrizo citrange and transplanted in field during 1992. The budded plants flowered in 1996 and these were evaluated for fruit yield and quality over a period of 12 years (1996–2007). Fruit yield was inconsistent with great variation when clementine scions were grafted on Gou Tou sour orange and Da Hong Pao mandarin. The rootstock Carrizo citrange resulted in significantly higher and Da Hong Pao mandarin in significantly lower average fruit yields for the last four years of trail. However, Holansis trifoliate orange gave maximum percentage of large sized fruits, followed by Kryder trifoliate orange and Towne trifoliate orange. Significantly higher percentage for medium sized fruits was recorded in case of Da Hong Pao mandarin, followed by Gou Tou sour orange. Maximum average fruit weight was recorded for Kryder trifoliate orange and Holansis trifoliate orange, followed by Towne trifoliate orange, Rich trifoliate orange, AA18 trifoliate orange, Beneke trifoliate orange, Carrizo citrange and Da Hong Pao mandarin. Juice percentage in clementine fruits was significantly higher for Carrizo citrange and all the trifoliate orange rootstocks except AA18 trifoliate orange which stood at par with Gou Tou sour orange and Da Hong Pao mandarin. Total soluble solids were also significantly higher for all the trifoliate orange rootstocks followed by the Carrizo citrange. No significant differences were found for acidity content of the juice for the rootstocks used. However, TSS: acidity was significantly higher for Carrizo citrange, followed by Kryder trifoliate orange and Towne trifoliate orange. These results indicated that Carrizo citrange performed better as compared to other rootstocks while Da Hong Pao mandarin and Gou Tou sour orange were not suitable rootstocks for common clementine.

1. Introduction

Rootstocks have a substantial role in the development of citrus industry. All commercially-cultivated citrus cultivars are grafted onto rootstocks. The utilization of rootstock help to reduce the adverse effects of abiotic stresses including drought, salinity, water logging and alkalinity, as well as conferring tolerance to biotic stresses such as *Phytophthora*, nematodes and citrus tristeza virus (CTV) (Soost et al., 1975). The selection of new rootstock is based on fruit production and quality as well as tolerance to biotic and abiotic stresses. Rootstocks have a large impact on scion growth habit and fruit yield and quality. The effect of rootstocks on fruit production and quality has been extensively mentioned in literature (Economides and Gregoriou, 1993; Fallahi and Rodney, 1992; Hussain et al., 2011, 2012; Jacquemond and Blondel, 1986; Jacquemond and Rocca Serra, 1992; Jacquemond et al., 2004; Wheaton et al., 1991, 1995; Zekri, 1996; Zekri and Al-Jaleel, 2004). Results clearly demonstrated the diverse effect of different rootstocks in different regions and climatic conditions.

Sour orange (*Citrus aurantium* L.) was the first citrus rootstock used and even though it provides resistance to *Phytophthora*; however grafts remain sensitive to CTV (Bar-Joseph and Lee, 1989; Louzada et al., 2008). The damaging effects of CTV all over the world have impelled citrus-producing countries to conduct new rootstock selection trials to replace sour orange. Research on citrus rootstocks in Corsica (France) was begun in 1960 at Agronomical Research Station (SRA). Since then, more than 160 rootstocks were tested for their effect on citrus fruit production and quality. Sour orange was used extensively for last more than 20 years but needs to be replaced due to its sensitivity to CTV. Trifoliate orange (*Poncirus trifoliata*) and its hybrids are commonly selected because of their

* Corresponding author at: Department of Horticulture, Bahauddin Zakariya University, Multan 60800, Pakistan. Tel.: +92 342 5932933.
E-mail address: sajjad_h@yahoo.com (S. Hussain).

0304-4238/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scienta.2012.11.010

tolerance to CTV (Garnsey et al., 1987). In Corsica, trifoliate orange has been selected, not only for resistance to CTV, but also because of its capacity to improve clementine yield and quality under acidic soil conditions (Jacquemond et al., 2004). In recent times, Gou Tou sour orange (*C. aurantium* L.) and Da Hong Pao mandarin (*Citrus deliciosa* Tan.) were used for citrus production in different countries but its performance in Corsican climatic conditions were not evaluated.

Keeping in view, a research trial was initiated by using nine rootstocks including Kryder trifoliate orange, Towne trifoliate orange, Rich trifoliate orange, Beneke trifoliate orange, Holansis trifoliate orange, AA18 trifoliate orange, Gou Tou Sour orange, Da Hong Pao mandarin and Carrizo citrange to find a better rootstock for common clementine (*Citrus clementina* Hort. Ex Tan.).

2. Materials and methods

The present work was conducted at the INRA Research Station at San Giuliano in Corsica, France during 1990–2007. The rootstocks studied in this trial were as follows: Kryder trifoliate orange (*P. trifoliata* (L.) Raf.), Towne trifoliate orange (*P. trifoliata* (L.) Raf.), Rich trifoliate orange (*P. trifoliata* (L.) Raf.), Beneke trifoliate orange (*P. trifoliata* (L.) Raf.), Holansis trifoliate orange (*P. trifoliata* (L.) Raf.), AA18 trifoliate orange (*P. trifoliata* (L.) Raf.), Gou Tou sour orange (*Citrus autantium* L.), Da Hong Pao mandarin (*C. deliciosa* Tan.) and Carrizo citrange (*Citrus sinensis* (L.) Osb. x *P. trifoliata* (L.) Raf.). These nine rootstocks were propagated from seeds and after one year, plants were T-budded with Common clementine (*C. clementina* Hort. Ex Tan.) (SRA 92) free of viruses disease. All nursery germination was performed in a greenhouse, with a cooling system. In the green house the temperature was kept about 25 °C and the relative humidity maintained about 75%. Seedlings were transplanted 3 month after germination in individual plastics bags placed in a greenhouse with an electrical airing system. The substrate used was composed with recent alluvium. Seedlings were manually irrigated following the daily water balance. After one year, budded plants were transplanted in field. Randomized complete block design was used for this trail with seven replications for each of nine rootstocks. Trees were planted on 6 m × 4 m planting distance at the INRA Research Station in Corsica. The experimental plot was surrounded with one guard row. The soil used in this trial is classified as fersiallitic. Texture is 24% clay, 34% loam and 42% sand. pH of soil is 6 and San Giuliano is at latitude 42°17 N, 9°32 E with a Mediterranean climate. Three months before planting, the plots were prepared by tillage (70 cm deep). During the first two years, training, basin irrigation and a topsoil removing (15 cm) were performed. From the third year, trees were hand pruned for fruiting, the weeds were controlled with chemicals, and for water supply trickle irrigation (60 l/h) was adopted. Fertilizers (N and P) were calculated following annual soil testing results. 40% of N was applied in early spring and 60% in early summer. The clementine grove was only sprayed with 2% oil (4000 l/ha) just after pruning and at the end of the summer (against scales). No spraying against *Phytophthora*, or any other chemical was used. No fruit degreening was performed.

Data were collected for each tree and computed every year since 1996–2007 for following parameters: Total fruit yield, average fruit weight, acidity content, total soluble solids, average juice % age, TSS/TA ratio, caliber of fruits. From November to the end of December, the crop of each tree was harvested and weighed. One or two harvest per year were realized according to fruit coloring (APRODEC, 2003). Fruit diameter was measured at each harvest date with a mechanical calibrator (Greffa; Sammo Inc.) and the percentages of different calibers of fruits (0–8) were calculated. Sizes of fruits according to the caliber are given in Table 1.

Data on fruit quality parameters were also recorded at each harvest from 2004 to 2007. Twenty fruits, which had the same color and almost the same diameter (medium sized), were weighed and their juice was extracted. The juice retrieved was weighed to calculate the juice percentage (JP). Total soluble solids (TSS in °Brix) were measured using an ATC-1E ATAGO hand-held refractometer from the translucent part of the juice after decantation. Titratable acidity (TA) was measured according to the AOAC method (NaOH, 0.1 N and end pH = 8.1) using a DL25 Metler titrator (AOAC, 2000). Results were expressed in grams of anhydrous citric acid/100 ml of juice. Maturity index (TSS:TA ratio) was also calculated.

Data on yield, fruit size, JP, TA, TSS, maturity index, were subjected to an analysis of variance means were separated by Student *t* test.

Table 1
Different caliber used for different sizes of clementine fruits.

Caliber	Size of fruits
>1	63–74 mm
2	58–69 mm
3	54–64 mm
4	50–60 mm
5	46–56 mm
6	43–52 mm
7	41–48 mm
<8	39–46 mm

3. Results

3.1. Fruit yield

Trees started bearing fruits at the age of four years. Fig. 1A shows cumulative fruit production of clementine trees over a period of nine years for all the nine rootstocks. All rootstocks were ranked in ascending order according to cumulative fruit production and this ranking was used in all other graphs and tables. Statistically significant differences were observed for cumulative fruit production among the rootstocks. Carrizo citrange (337 kg) was identified as the most productive rootstock, showing more than 60% higher cumulative fruit production then Da Hong Pao mandarin (95.8 kg) and Gou Tou sour orange (127.1 kg) which were the least productive rootstocks for clementine. All trifoliate orange rootstocks for cumulative fruit production were in between Carrizo citrange and Da Hong Pao mandarin. Average production of fruit per plant for the period of nine years (Fig. 1B) showed the similar trend and Carrizo citrange (37.4 kg) produce more fruits per plant as compared to other rootstocks and Da Hong Pao mandarin (10.6 kg) and Gou Tou sour orange (14.1 kg) produced significantly lesser fruits per plant.

Results when compared for the average production of fruits per plant for the period of first five years (Fig. 1C), Rich trifoliate orange (18.6 kg) and Holansis trifoliate orange (18.5 kg) were identified the most productive rootstocks and were statistically different from Da Hong Pao mandarin (0.9 kg) and Gou Tou sour orange (2.9 kg) but the differences were statistically insignificant form all other trifoliate orange rootstocks and Carrizo citrange. Average clementine fruit yield for last four years also differed significantly for trifoliate orange rootstocks (Fig. 1D), Carrizo citrange (60.1 kg) and AA18 trifoliate orange (50.9 kg) performed significant better than other rootstocks. Average clementine fruit yield on Carrizo citrange was significantly different from Kryder trifoliate orange, Holansis trifoliate orange, Gou Tou sour orange and Da Hong Pao mandarin. No significant difference was observed between Towne trifoliate orange, Rich trifoliate orange, Beneke trifoliate orange and AA18 trifoliate orange. Least average clementine fruit yield was observed for Da Hong Pao mandarin (22.5 kg) followed by Gou Tou sour orange (28.1 kg) rootstocks (Table 3).