*Fruits*, 2015, vol. 70(4), p. 249-256
© Cirad / EDP Sciences 2015
DOI: 10.1051/fruits/2015022

FRUITS

Available online at:
www.fruits-journal.org

Original article

# Bio-agronomic characterization of twelve plum cultivars on two clonal rootstocks in a semi-arid environment in Sicily

Filippo Ferlito[1,2], Alberto Continella[1], Elisabetta Nicolosi[1], Biagio Dimauro[3], Massimiliano Brugaletta[1], Antonio Cicala[1] and Stefano La Malfa[1,⋆]

[1] Dipartimento di Agricoltura, Alimentazione e Ambiente, University of Catania, Via Valdisavoia, 5 -95123 Catania, Italy
[2] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Centro di Ricerca per l'Agrumicoltura e le Colture Mediterranee (CRA-ACM), Corso Savoia 190, 95024 Acireale (CT), Italy
[3] Assessorato Regionale Risorse Agricole e Alimentari, Dipartimento Interventi Infrastrutturali, UOS Centro Colture Protette, Comiso (RG), Italy

Received 28 June 2014 – Accepted 28 February 2015

**Abstract – Introduction**. Plum cultivation in Southern Italy is of great interest due to the possibility of obtaining produce over an extended period using early and late varieties. The objective of this study was to choose the best combination of cultivars and rootstock to make the production period as long as possible. **Materials and methods.** The influence of two rootstocks *i.e*. Myrobalan 29C (*Prunus cerasifera* Ehrn.) and Montclar® [*Prunus persica* (L.) Batsch] on growth, yield and fruit quality of nine Japanese and three European plum cultivars was evaluated. **Results and discussion.** Four years after planting, the trees on Montclar® rootstock displayed higher vigour. The highest yield was recorded on Shiro and Obilnaya grafted on both rootstocks. Black Amber produced the largest fruit and Obilnaya the smallest. **Conclusion.** This research contributed to identifying the most promising cultivars to be successfully grown in Southern Italy.

**Keywords:** Italy / Sicily / European plum (*Prunus domestica*) / Japanese plum (*Prunus salicina*) / Myrobalan 29C (*Prunus cerasifera*) / Montclar® (*Prunus persica*) / fruit quality / rootstock

**Résumé – Caractérisation bio-agronomique de douze cultivars de pruniers greffés sur deux porte-greffes sous le climat semi-aride de Sicile. Introduction.** La culture du prunier dans le Sud de l'Italie présente un grand intérêt par la possibilité d'étendre la période de production en utilisant une gamme de précocité variétale. L'objet de cette étude portait sur le choix des cultivars et des porte-greffes permettant de produire la plus longue période possible. **Matériel et méthodes.** L'influence des porte-greffes 'Myrobalan 29C' (*Prunus cerasifera* Ehrn.) et 'Montclar®' [*Prunus persica* (L.) Batsch] a été testée sur la croissance, le rendement et la qualité des fruits de douze cultivars japonais et européen. **Résultats et discussion.** Quatre ans après plantation, les arbres greffés sur 'Montclar®' se sont montrés plus vigoureux. Les rendements les plus élevés ont été relevés avec 'Shiro' et 'Obilnaya' quelque soit le porte-greffe. 'Black Amber' a produit les prunes les plus grosses, tandis que 'Obilnaya' a produit les plus petits fruits. **Conclusion.** L'étude a contribué à identifier les variétés les plus prometteuses à recommander dans les régions du Sud de l'Italie

**Mots clés :** Italie / Sicile / prunier d'Europe (*Prunus domestica*) / prunier du Japon (*Prunus salicina*) / Myrobalan 29C (*Prunus cerasifera*) / Montclar® (*Prunus persica*) / qualité du fruit / porte-greffe

## 1 Introduction

Japanese (*Prunus salicina* Lindl.) and European plums (*Prunus domestica* L.) are amongst the most widely cultivated fruit species in temperate climates. Their production for fresh consumption has increased significantly in recent decades. This has been due to both the expansion of the cultivation area and the extension of the harvesting season by the adoption of several Japanese cultivars. In fact, these cultivars are better adapted to many warm climatic regions for both early and late production as compared to the European plums [1].

Among the regions potentially suitable for plum production in southern Italy is Sicily, characterized by hot and dry summers, with its rainfall concentrated during the winter season. These climatic variables have a strong influence on bud dormancy, growth activity and fruit ripening of deciduous species. Nevertheless, previous trials with raspberry and apricot gave evidence of the possibility to cultivate low chilling cultivars in Sicily, even in the coastal areas [2, 3].

⋆ Corresponding author: stefano.lamalfa@unict.it

Phenology of woody plants is strictly dependent on the species [4], rootstock and variety combination [5], tree age [6] and the interaction with other biotic and abiotic factors. As for rootstock, it has been reported that they can have profound effects on scions. These effects include the control of tree size, time of flowering [7], cold hardiness, disease resistance, and nutritional composition of the plant [8].

In warm climates the phenological phases are usually shorter. Insufficient winter chilling can severely reduce yields. When chilling requirements are not fulfilled, the flowering of trees is irregular and delayed, leading to non-uniform crop development. This results in variable fruit sizes and maturity stages and can substantially reduce yield [9].

For instance, a study on sweet cherry demonstrated that environmental factors such as photoperiod and temperature greatly affected bud opening and vegetative growth [10]. An earlier start of these phenological phases may have considerable implications for both the risk of frost damage and photosynthetic activity [11].

Although the chilling requirements for plum have not been studied much, it seems that most varieties exhibit a behavior similar to that of peach. Yields can be reduced in warm regions if the chilling hours are insufficient to break the rest period of both flower and leaf buds [1].

Okie and Hancock [1] report that most European plums require relatively high numbers of 'Chilling Hours' (CH) (probably >1,000 h), whereas most Japanese plums need much fewer (~500–800 h).

The European plum, *Prunus domestica*, requires about 100 to 200 more chilling hours than the Japanese plum, *Prunus salicina* [12]. After CH accumulation, bud burst requires high temperatures defined as 'Growing Degree Hours' (GDH) [13]. Both CH and GDH accumulation models are important for forecasting the blooming and cross-pollination behavior of different cultivars [14] and to predict the fruit growth rate, as well as the ripening and harvest period [15]. 'Chilling Hours' is preferred to 'Chilling Units' in temperate zones as the latter is more suitable for cooler areas [16]. Temperature also influences flower bud abscission [17], pollen viability and stigma receptivity [18], fertilization [19], fruit growth and shape [20, 21] and anthocyanin synthesis during fruit ripening [22]. The study of climate effects is further complicated by the fact that rootstocks play a major role in the above mentioned phenological phases [23] by affecting tree growth, vegetative and reproductive behaviour [24, 25], fruit organoleptic characteristics [26], antioxidant activity [27, 28] and nutraceutical content [29]. Our research was undertaken to evaluate the performance of three European and nine Japanese plum cultivars on two rootstocks in a semi-arid climate in Sicily. Suitable cultivars are needed to extend the harvest season and to help the industry adapt to the manifestations of climate change.

## 2 Materials and methods

### 2.1 Plant materials, site description and experimental design

This research was conducted over two growing seasons (2010 and 2011) in an experimental orchard located in the Ragusa district (lat. 36.97 N; long. 14.45 E; elevation 123 m). Nine Japanese cultivars (Sorriso di Primavera, Early Golden, Black Amber, Shiro, Red Beaut, Angeleno, Obilnaya, Black Star and Friar) and 3 European cultivars (Stanley, Grossa di Felisio and President) were planted in 2007. Each cultivar was grafted on two clonal rootstocks: Myrobalan 29C (*Prunus cerasifera* Ehrh.) and Montclar® [*Prunus persica* (Batsch) L.] except for Black Amber and Early Golden which were grafted only on Myrobalan 29C and Montclar®, respectively. The soil in the study area is deep, sandy and well drained with the following characteristics: pH 7.8; calcium carbonate 7%; active calcium carbonate 0.8%; electrical conductivity 0.65 dS $m^{-1}$ (1:5, 25 °C); and organic matter content 1.3%.

The trees were spaced 5 m between rows and 3 m within the rows. The rows were oriented North-South and the trees were trained to an open vase with three main branches. Two identical plots, each containing 5 trees (10 trees per rootstock), were arranged in a completely randomized design. Trees were subjected to standard cultivation practices and were irrigated weekly from May to September. The total amount of water supplied was of about 200 mm $ha^{-1}$ $year^{-1}$. A traditional fertilization regime was applied, with 60 kg $ha^{-1}$ nitrogen, 30 kg $ha^{-1}$ phosphate and 90 kg $ha^{-1}$ potassium. Phytoprotection was based on treatments with copper sulphate to control leaf curl and other fungi, and with mineral oils combined with pyrethroids to control aphids.

### 2.2 Climate variables and phenology

Daily temperature and rainfall data were provided by the Sicilian Agro-meteorological Information Service (SIAS). The chilling requirements for breaking the dormancy of each cultivar were calculated for a decade as CH [30]. Heat requirements were calculated as 'growing degree hours' (GDHs) according to Richardson *et al.* [13]. For each cultivar, heat requirements were calculated as the number of GDHs accumulated between the end of dormancy and bloom (50% open flowers). The main phenological phases [31] were monitored for two years.

### 2.3 Growth monitoring

To calculate the 'trunk cross-sectional area' (TCA) values, the trunk circumference was measured at 10 cm from the ground level. This was done at the bud dormancy phenological stage (January 2010) and at the end of the harvest period (October 2011) and the percentage increase was calculated. Three fruiting shoots per plant were selected and their lengths and the number of buds were determined. The fertility index was obtained as the ratio between the number of productive buds and the length of the fruiting shoots. The weigth of wood removed during winter pruning was recorded for each tree.

### 2.4 Crop yield and plum quality

Fruit was harvested at commercial maturity. Total yield per tree (kg) and yield efficiency (kg $TCA^{-1}$) were recorded.

A sub-sample of 20 plums for each cultivar-rootstock combination was used to determine fruit and seed weight, flesh percentage, and fruit firmness. Firmness was evaluated using a TX-XT2i Texture analyzer (Stable Microsystems, Godalming, U.K.) equipped with a 2.0 mm diameter plunger at a speed of 10.0 mm $s^{-1}$ for a 2.0 mm distance. Two readings were taken from each fruit by puncturing two spots on opposite sides of the fruit. A second sub-sample of 20 fruits was used to determine the main qualitative parameters: total soluble solids (TSS) were measured (in °Brix) using a digital refractometer (RX-5000 Atago Co. LTD, Tokyo, Japan) with temperature correction; pH and titratable acidity (TA) were determined via an automatic titrater (Titrino model 798, Metrohm, Riverview, FL). The TA was measured using a 5.0 mL aliquot of juice and titrating against 0.1 N NaOH to pH 8.2 and was expressed as g $L^{-1}$ malic acid equivalent.

### 2.5 Statistical analysis

Analysis of variance (ANOVA) was carried out using STATISTICA 6.0 and used to test the significance of each variable ($P \leqslant 0.05$). Mean separations were made using Fisher's test. Significant rootstocks and genotypes effects were shown by a factorial analysis of variance (at $P \leqslant 0.05$, $P \leqslant 0.01$ and $P \leqslant 0.001$).

## 3 Results and discussion

### 3.1 Climate variables

The trial site's climate is characterized by mild and wet winters, while the summer is semi-arid; annual rainfall was 699 mm in 2010 and 619 mm in 2011. During the summer no rainfall was recorded from June to August. The annual average temperature was 17.4 °C (*figure 1*). During the two years the lowest minimum temperatures were recorded in February. As for mean temperatures, January was the coldest month whereas August was the hottest. Mean temperature values were always above 22 °C from June to September and above 15 °C from April to November. During the decade from 2002/2003 to 2011/2012 250 Chilling Hours per year were reached except for the period 2006-07 (data not shown). GDHs reached values of 3,327 in 2010 and 3,345 in 2011.

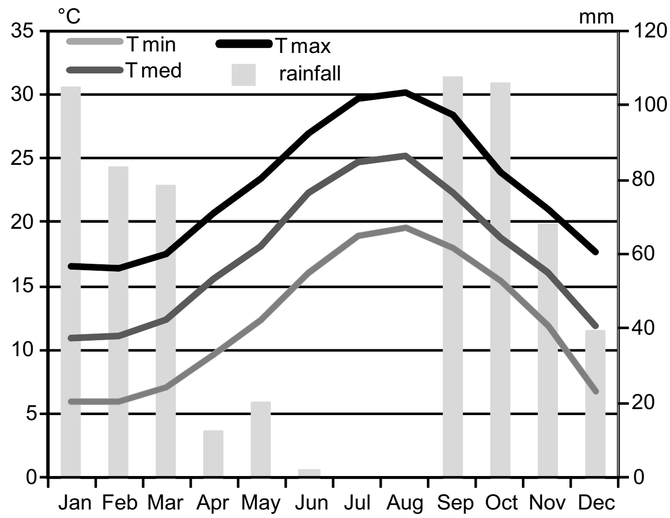


**Figure 1.** Monthly minimum, mean and maximum air temperatures and rainfall registered in the experimental field (Ragusa: lat. 36.97 N; long. 14.45 E; elevation 123 m). Each parameter represents the mean of two consecutive years (2010 and 2011).

### 3.2 Growth and phenology

The TCA measured in the pre-growing season for the trees on Myrobalan 29C was the highest for Shiro and Angeleno and the lowest for Grossa di Felisio (*table I*). Red Beaut and Shiro on Montclar® showed the highest TCA. In Black Star, Grossa di Felisio, Red Beaut and Sorriso di Primavera the vigor effect of Myrobalan 29C was evident; this result is consistent with those of Grzyb *et al.* [32] who observed a larger TCA in plum cultivars grafted on Myrobalan compared to other rootstocks.

A higher TCA increment in all the varieties, except for Sorriso di Primavera, was recorded for Montclar® rootstock (*table I*). This rootstock induced a significant increase of fruiting shoots length only in Friar and Grossa di Felisio (*table II*). Stanley and Shiro on Myrobalan 29C showed a higher fertility index than on Montclar® (*table II*).

The wood weight from winter pruning was significantly higher in Angeleno, Red Beaut, Shiro and Stanley grafted on Montclar®, whereas Sorriso di Primavera showed higher values on Myrobalan 29C (*table III*).

Phenological stages were comparable in both years. Among the tested varieties, Early Golden was the only one for which no flowering was observed, demonstrating that its higher chilling requirement is consistent with its cold area origin [33]. The harvest period ranged from early June to late September (*figure 2*).

### 3.3 Yield and quality

Black Star, Grossa di Felisio and Stanley did not produce sufficient fruit for evaluation. Red Beaut dropped all its production just after fruit set. Among the productive varieties, Obilnaya and Shiro showed the highest yield on both rootstocks in accordance with a previous observation [34]. Yield efficiency was rather poor in all of the other varieties. As formerly observed, Shiro was confirmed to be a suitable cultivar for warm and low latitude areas [18] (*table VI*).

Fruit weight, ranging from 30.6 g for Shiro on Myrobalan 29C to 58.2 g for Black Amber on Myrobalan 29C, was mainly affected by the genotype. The high fruit weight values of Black Amber were already described by Küden *et al.* [35]. The weight of the seed did not show significant differences but President, in both graft combinations, had the highest values. The flesh percentage was similar in both rootstocks (*table V*). Fruit texture ranged from 88.2 g on Obilnaya grafted on Myrobalan 29C to 278.2 g on Friar grafted on Myrobalan 29C. Higher texture properties were recorded for Obilnaya and Sorriso di Primavera grafted onto Montclar® both punctured with and without skin (*table VI*).

**Table I.** Influence of rootstock on pre-growing season 'trunk cross-sectional area' (TCA) in 2010 as compared with post-harvest TCA in 2011 and percentage increase ($\Delta$%). Means indicated by different letters are significantly different ($P \leqslant 0.05$; $n = 10$) based on Fisher's least significant different (LSD) test for each cultivar and parameter.

| Rootstock cultivar | January 2010 TCA ($cm^2$) | | October 2011 TCA ($cm^2$) | | TCA $\Delta$% | TCA $\Delta$% |
|---|---|---|---|---|---|---|
| | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® |
| Angeleno | 17.45 ± 2.83 a | 14.14 ± 3.53 a | 24.17 ± 3.69 a | 22.26 ± 2.63 a | 38.48 b | 57.47 a |
| Black Amber | 6.66 ± 3.50 | – | 10.65 ± 4.76 | – | 59.95 | – |
| Black Star | 10.41 ± 2.62 a | 5.74 ± 4.23 b | 15.07 ± 3.56 a | 11.60 ± 2.80 a | 44.83 b | 102.26 a |
| Early Golden | – | 15.16 ± 6.79 | – | 20.16 ± 5.53 | – | 33.04 |
| Friar | 5.31 ± 2.64 a | 5.52 ± 2.36 a | 10.08 ± 3.30 a | 11.22 ± 1.75 a | 89.60 b | 103.38 a |
| Grossa di Felisio | 3.91 ± 1.74 b | 11.17 ± 2.32 a | 4.70 ± 1.29 b | 13.88 ± 1.40 a | 20.24 a | 23.86 a |
| Obilnaya | 12.61 ± 3.55 a | 10.99 ± 3.40 a | 13.91 ± 2.90 a | 13.54 ± 3.14 a | 10.30 b | 23.15 a |
| President | 7.14 ± 2.36 a | 9.65 ± 3.49 a | 7.91 ± 1.66 b | 12.07 ± 1.47 a | 10.77 b | 25.08 a |
| Red Beaut | 14.97 ± 4.92 b | 22.85 ± 5.05 a | 19.95 ± 2.75 b | 32.14 ± 4.77 a | 33.23 b | 40.65 a |
| Shiro | 17.88 ± 3.12 a | 17.34 ± 3.77 a | 23.49 ± 3.18 a | 27.27 ± 2.80 a | 31.39 b | 57.31 a |
| Sorriso di Primavera | 10.00 ± 1.70 b | 14.53 ± 2.34 a | 15.23 ± 2.05 b | 21.46 ± 1.58 a | 52.33 a | 47.67 b |
| Stanley | 7.61 ± 2.93 a | 6.73 ± 2.15 a | 10.37 ± 1.51 a | 10.16 ± 2.55 a | 36.21 b | 51.02 a |

**Table II.** Influence of rootstock on fruiting shoot length and on fertility index. Means indicated by different letters are significantly different ($P \leqslant 0.05$; $n = 30$) based on Fisher's least significant different (LSD) test for each cultivar and parameter.

| Rootstock cultivar | Fruiting shoot length (cm) | | Fertility index as number of productive buds per fruiting shoot (nb $cm^{-1}$) | |
|---|---|---|---|---|
| | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® |
| Angeleno | 42.83 ± 12.93 a | 37.00 ± 10.09 a | 0.20 ± 0.27 a | 0.18 ± 0.11 a |
| Black Amber | 55.60 ± 29.55 | – | 0.40 ± 0.40 | – |
| Black Star | 53.20 ± 14.81 a | 51.00 ± 24.27 a | 0.23 ± 0.19 a | 0.13 ± 0.13 b |
| Early Golden | – | 47.20 ± 13.18 | – | 0.00 ± 0.00 |
| Friar | 31.67 ± 12.30 b | 56.27 ± 26.38 a | 0.12 ± 0.08 a | 0.09 ± 0.06 b |
| Grossa di Felisio | 45.50 ± 18.18 b | 65.27 ± 21.28 a | 0.25 ± 0.27 a | 0.23 ± 0.19 a |
| Obilnaya | 54.07 ± 27.13 a | 45.00 ± 13.20 a | 0.44 ± 0.33 a | 0.45 ± 0.25 a |
| President | 40.13 ± 20.66 a | 49.47 ± 14.07 a | 0.25 ± 0.35 a | 0.22 ± 0.23 a |
| Red Beaut | 48.67 ± 20.12 a | 44.53 ± 11.07 a | 0.24 ± 0.18 a | 0.17 ± 0.14 b |
| Shiro | 47.33 ± 18.29 a | 44.00 ± 14.94 a | 0.63 ± 0.29 a | 0.24 ± 0.18 b |
| Sorriso di Primavera | 55.20 ± 15.83 a | 46.93 ± 11.94 a | 0.33 ± 0.23 a | 0.31 ± 0.18 a |
| Stanley | 51.78 ± 28.03 a | 59.78 ± 20.78 a | 0.52 ± 0.33 a | 0.36 ± 0.24 b |

**Table III.** Influence of rootstock on wood weight resulting from winter pruning. Means indicated by different letters are significantly different ($P \leqslant 0.05$; $n = 10$) based on Fisher's least significant different (LSD) test for each cultivar.

| Rootstock cultivar | Fresh pruning weight (kg per tree) | |
|---|---|---|
| | Myrobalan 29C | Montclar® |
| Angeleno | 2.80 ± 0.35 b | 3.10 ± 017 a |
| Black Amber | 1.70 ± 0.25 | – |
| Black Star | 1.50 ± 0.18 a | 1.70 ± 0.29 a |
| Early Golden | – | 2.90 ± 0.33 |
| Friar | 1.30 ± 0.23 a | 1.40 ± 0.17 a |
| Grossa di Felisio | 2.00 ± 0.26 a | 1.90 ± 0.31 a |
| Obilnaya | 1.70 ± 0.21 a | 1.80 ± 0.12 a |
| President | 2.20 ± 0.25 a | 2.10 ± 0.38 a |
| Red Beaut | 3.00 ± 0.47 b | 3.70 ± 0.24 a |
| Shiro | 3.10 ± 0.32 b | 3.30 ± 0.39 a |
| Sorriso di Primavera | 2.40 ± 0.11 a | 2.10 ± 0.27 b |
| Stanley | 1.80 ± 0.34 b | 2.00 ± 0.19 a |

Total soluble solids (TSS) values were always higher on Myrobalan 29C grafted plants even if this difference was significant only for Obilnaya and Shiro. The pH and titratable acidity values did not show significant differences between the two rootstocks. The highest values were recorded on Sorriso di Primavera and the lowest on Black Amber (*table VII*).

### 3.4 Rootstock and cultivar interaction

The results achieved in the present study have allowed us to identify the most promising varieties to be planted in a hot and semi-arid environment.

With the exception of Red Beaut and Early Golden, the CH and GDHs requirements for all the other cultivars were satisfied, allowing for the achievement of adequate vegetative growth, flowering, and production. Among the European varieties grafted on Myrobalan 29C, a delay in canopy shaping and in precocity was observed. This was mainly due to inherent characteristics but could also be attributed to the less than optimal satisfaction of chilling requirements.

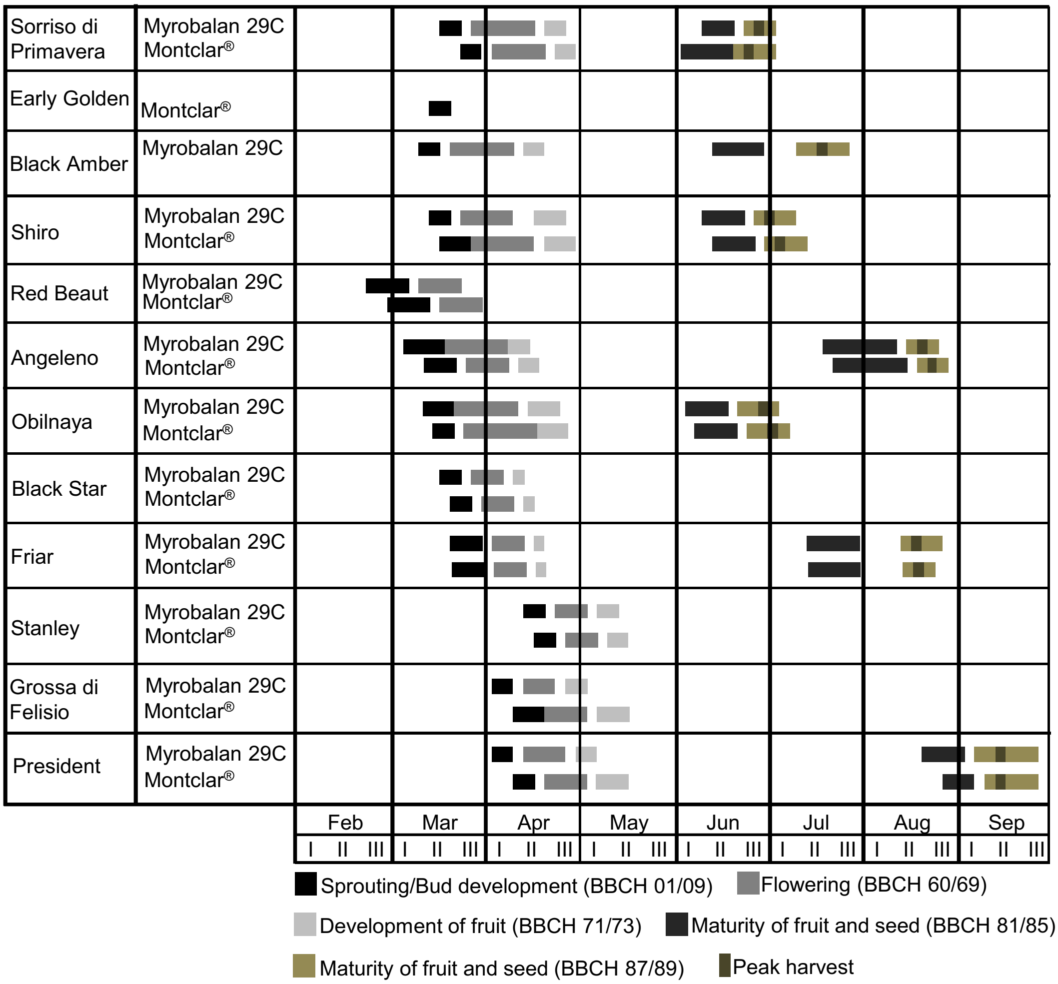


**Figure 2.** Main phenological stages according to BBCH registered in Ragusa district (lat. 36° 97' N; long. 14° 45' E; elevation 123 m asl) in 2011.

**Table IV.** Influence of rootstock on trees productivity and on yield efficiency. Means indicated by different letters are significantly different ($P \leqslant 0.05$; $n = 10$) based on Fisher's least significant different (LSD) test for each cultivar and parameter.

| Rootstock cultivar | Yield (kg tree$^{-1}$) | | Yield efficiency (kg TCA$^{-1}$*) | |
|---|---|---|---|---|
| | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® |
| Angeleno | 0.45 ± 0.10 a | 0.36 ± 0.20 a | 0.02 ± 0.01 a | 0.02 ± 0.01 a |
| Black Amber | 0.52 ± 0.09 a | – | 0.10 ± 0.04 a | – |
| Friar | 1.40 ± 0.12 a | 0.80 ± 0.13 b | 0.20 ± 0.01 b | 0.80 ± 0.01 a |
| Obilnaya | 4.76 ± 0.65 b | 5.98 ± 0.41 a | 0.36 ± 0.17 a | 0.44 ± 0.16 a |
| President | 0.37 ± 0.02 a | 0.46 ± 0.03 a | 0.06 ± 0.01 a | 0.05 ± 0.01 a |
| Shiro | 6.96 ± 0.78 b | 17.9 ± 0.89 a | 0.30 ± 0.04 b | 0.71 ± 0.3 a |
| Sorriso di Primavera | 2.56 ± 0.46 a | 1.46 ± 0.30 b | 0.10 ± 0.05 a | 0.14 ± 0.01 a |

* TCA: trunk cross-sectional area.

The low production levels displayed by several varieties may in part be due to the seasonal course but were mainly caused by the excessively high temperatures recorded in both years. According to the literature there are many different seasonal periods during which high temperatures can cause abscission [36].

Rootstock (R) and cultivar (C) are the factors that have played a significant influence on all the vegetative and yield components [37]. The rootstock × cultivar interaction (R × C) was highly significant for fertility index, yield per tree, yield efficiency and fruit weight parameters (*table VIII*).

No relevant pests and diseases were observed on either rootstock even if Myrobalan rootstocks were reported to have been more resistant to bacterial canker [38] and demonstrated good adaptability to different soil/climate conditions [39].

**Table V.** Influence of rootstock on yield components. Means indicated by different letters are significantly different ($P \leqslant 0.05$; $n = 20$) based on Fisher's least significant different (LSD) test for each cultivar and parameter.

| Rootstock cultivar | Fruit weight (g) | | Seed weight (g) | | Flesh percentage (%) | |
|---|---|---|---|---|---|---|
| | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® |
| Angeleno | 42.44 ± 7.40 a | 41.92 ± 9.92 a | 0.71 ± 0.02 a | 0.76 ± 0.02 a | 98.33 ± 0,45 a | 98.19 ± 0.31 a |
| Black Amber | 58.21 ± 12.91 | – | 0,86 ± 0.01 | – | 98.52 ± 0.91 | – |
| Friar | 42.95 ± 6.94 b | 52.76 ± 12.74 a | 0.78 ± 0.02 a | 0.81 ± 0.01 a | 98.18 ± 0.05 a | 98.46 ± 0.46 a |
| Obilnaya | 47.16 ± 11.94 a | 31.72 ± 9.23 b | 0.98 ± 0.03 a | 1.10 ± 0.02 a | 97.92 ± 0.78 a | 96.53 ± 0.18 a |
| President | 53.15 ± 10.82 a | 54.71 ± 10.53 a | 2.00 ± 0.02 a | 2.04 ± 0.03 a | 96.24 ± 0.31 a | 96.27 ± 0.49 a |
| Shiro | 30.63 ± 5.56 a | 31.82 ± 6.02 a | 0.97 ± 0.04 a | 0.90 ± 0.02 a | 96.83 ± 0,65 a | 97.17 ± 0.54 a |
| Sorriso di Primavera | 32.80 ± 5.37 b | 37.50 ± 6.64 a | 0.84 ± 0.04 b | 0.96 ± 0.01 a | 97.44 ± 0.23 a | 97.44 ± 0.35 a |

**Table VI.** Fruit texture obtained from puncture tests on fruits with and without skin. Means indicated by different letters are significantly different ($P \leqslant 0.05$; $n = 20$) based on Fisher's least significant different (LSD) test for each cultivar and parameter.

| Rootstock cultivar | Firmness (g) | | | |
|---|---|---|---|---|
| | With skin | | Without skin | |
| | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® |
| Angeleno | 253.42 ± 64.84 a | 272.11 ± 87.84 a | 49.10 ± 15.70 a | 46.61 ± 14.81 a |
| Black Amber | 269.49 ± 78.90 a | – | 55.10 ± 19.80 a | – |
| Friar | 278.22 ± 89.40 a | 269.42 ± 81.64 b | 51.77 ± 11.96 a | 53.28 ± 18.91 a |
| Obilnaya | 88.21 ± 23.35 b | 194.28 ± 61.79 a | 14.03 ± 5.42 b | 61.21 ± 34.70 a |
| President | 165.41 ± 47.78 a | 164.53 ± 37.70 a | 35.77 ± 16.92 a | 22.15 ± 9.85 b |
| Shiro | 139.54 ± 44.56 a | 130.51 ± 31.07 b | 22.29 ± 11.00 a | 21.79 ± 13.32 b |
| Sorriso di Primavera | 156.15 ± 55.24 b | 222.84 ± 56.95 a | 31.57 ± 16.46 b | 45.28 ± 16.71 a |

**Table VII.** Influence of rootstock on total soluble solids (TSS), pH, and titrable acidity content. Means indicated by different letters are significantly different ($P \leqslant 0.05$; $n = 20$) based on Fisher's least significant different (LSD) test for each cultivar and parameter.

| Rootstock cultivar | TSS (°Brix) | | pH | | Titatrable acidity (g 100 ml$^{-1}$) | |
|---|---|---|---|---|---|---|
| | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® | Myrobalan 29C | Montclar® |
| Angeleno | 12.91 ± 0.12 a | 12.30 ± 0.04 a | 3.56 ± 0.01 a | 3.57 ± 0.03 a | 0.60 ± 0.06 a | 0.63 ± 0.10 a |
| Black Amber | 12.00 ± 0.17 | – | 0,17 ± 0.02 | – | 0.20 ± 0.03 | – |
| Friar | 14.63 ± 0.15 a | 12.94 ± 0.10 a | 4.52 ± 0.01 a | 4.53 ± 0.02 a | 0.49 ± 0.04 a | 0.52 ± 0.01 a |
| Obilnaya | 11.81 ± 0.14 a | 9.80 ± 0.06 b | 3.38 ± 0.03 a | 3.09 ± 0.03 a | 0.96 ± 0.07 a | 1.00 ± 0.02 a |
| President | 21.40 ± 0.04 a | 20.11 ± 0.12 a | 2.93 ± 0.02 a | 2.98 ± 0.01 a | 0.47 ± 0.04 a | 0.54 ± 0.03 a |
| Shiro | 11.9 ± 0.09 a | 8.71 ± 0.03 b | 3.46 ± 0.04 a | 3.06 ± 0.03 a | 0.61 ± 0.03 b | 0.76 ± 0.01 a |
| Sorriso di Primavera | 11.41 ± 0.13 a | 11.32 ± 0.16 a | 3.01 ± 0.01 a | 3.42 ± 0.06 a | 1.18 ± 0.02 a | 1.01 ± 0.02 a |

**Table VIII.** Main effects and significant interactions of rootstock, cultivar and year on tree vegetative and yield components.

| | January 2010 TCA | October 2011 TCA | Fertility index | Yield tree$^{-1}$ | Yield efficiency | Fruit weigth | Plums with skin firmness | Plums without skin firmness | TSS$^{y}$ | pH | Titatrable acidity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rootstock (R) | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| Cultivar (C) | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| Year (Y) | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* |
| R × C | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| R × Y | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* |
| C × Y | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* |
| R x C x Y | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* | *ns.* |

*, **, *** statistically significant at $P \leqslant 0.05$, $P \leqslant 0.01$, $P \leqslant 0.001$ respectively; [y] Total soluble solids.

The effect of rootstocks on plum quality has yet to be adequately studied [40, 41]. Studies on rootstock effects on fruit quality need to take into account the different sources of variability such as variety, type of soil, fertilization and orchard management [42]. In our study the quality of the fruit was mainly affected by ripening time. The early plum cultivars showed lower TSS values than the late ones. In fruit harvested before their optimal maturity, the content of TSS was correlated not only with the perception of sweetness but also with the richness and intensity of aromas. It appears that further investigation is needed [43]. The TA content was not closely related to the time of harvest.

## 4 Conclusion

Plum cultivation in Southern Italy is of great interest because of the possibility of obtaining marketable fruit during a rather long period by growing both early and late varieties that are well adapted to this environment.

The possibility to extend production areas of selected fruit tree species into semi-arid areas is of great importance for the development of fruit culture in South Europe. Our research contributed to the identification of some plum cultivars that can be successfully cultivated in this region. Of the cultivars studied, Obilnaya and Shiro displayed satisfactory adaptability in our soil/climate conditions and can be used for high quality production. However, the development of the most appropriate management techniques, including thinning, summer pruning, and fertigation will be necessary.

As for rootstock, both Myrobalan 29C and Montclar® proved satisfactory for plum cultivation in this region and did not show any limitations. At the time of this evaluation no apparent graft-incompatibility was recorded.

*Acknowledgements.* This research was supported by Regione Siciliana, project "Sviluppo di sistemi colturali innovativi per la coltura del susino e dell'albicocco nel territorio siciliano in ambiente protetto".

## References

[1] Okie W.R., Hancock J.F., Plums, in Hancock, J.F. (Eds.), Temperate fruit crop breeding, Springer Science&Business Media B.V., Dordrecht, NL, 2008.
[2] Cicala A., Continella A., Ferlito F., Preliminary results of primocane-fruiting red raspberry cultivars in Sicily, Acta Hort. 585 (2002) 191–195.
[3] Sottile F., Monte M., Impallari F., Vegetative and reproductive behaviour of young apricot trees cv. 'Ninfa' as affected by rootstock, Acta Hort. 717 (2006) 79–82.
[4] Heide O.M., Daylength and thermal time responses of bud burst during dormancy release in some northern deciduous trees, Physiol. Plant. 88 (1993) 531–540.
[5] Myking T., Heide O.M., Dormancy release and chilling requirement of buds of latitudinal ecotypes of *Betula pendula* and *B. pubescens*, Tree Physiol. 15 (1995) 697–704.
[6] Ununger J., Ekberg I., Kang H., Genetic control and age-related changes of juvenile growth characters in *Picea abies*, Scand. J. For. Res. 3 (1988) 55–66.
[7] Layne R.E.C., Prunus rootstocks affect long-term orchard performance of 'Redhaven' peach on brookston clay loam, HortScience 29 (1994) 167–171.
[8] Boyhan G.E., Norton J.D., Pitts J.A., Establishment, growth, and foliar nutrient content of plum trees on various rootstocks, HortScience 30 (1995) 219–221.
[9] Visser L.J.M., Holleman M.E., Warmer springs disrupt the synchrony of oak and winter moth phenology, Proc. R. Soc. Lond. B: Biol. Sci. 268 (2001) 289–294.
[10] Besford R.T., Hand P., Richardson C.M., Peppit S.D., Photoperiod effect on bud burst in *Prunus* in phase dependent: significance for early photosynthetic development, Tree Physiol. 16 (1996) 491–496.
[11] Hanninen H., Tanino K, Tree seasonality in warming climate. Trends Plant Sci. 16 (2011) 412–416.
[12] Gil-Albert F., La ecologìa del àrbol frutal, Serie tècnica, M.A.P.A., Madrid, ES, 1986.
[13] Richardson E.A., Seeley S.D., Walker D.R., A model for estimating the completion of rest for 'Redhaven' and 'Elberta' peach trees, Hort. Sci. 1 (1974) 331–332.
[14] Campoy J.A., Ruiz D., Allderman L., Cook N., Egea J., The fulfilment of chilling requirements and the adaptation of apricot (*Prunus armeniaca* L.) in warm winter climates: an approach in Murcia (Spain) and the Western Cape (South Africa), Europ. J. Agron. 37 (2012) 43–55.
[15] Mounzer O.H., Wenceslao C., Nicolas E., Tapia L.M., Vera J., Abrisqueta J.M., Ruiz-Sanchez M.C., Growth pattern and phenological stages of early-maturing peach trees under a Mediterranean climate, HortScience, 43 (2008) 1813–1818.
[16] Dennis F.G. Jr. Problems in standardizing methods for evaluating the chilling requirements for the breaking of dormancy in buds of woody plants, Hort. Sci. 38 (2003) 347–350.
[17] Alburquerque N., Burgos L., Egea L., Apricot flower bud development and abscission related to chilling, irrigation and type of shoots, Sci. Hortic. 98 (2003) 265–276.
[18] Rumayor-Rodríguez A., Multiple regression models for the analysis of potential cultivation areas for Japanese plums, Hortscience 30 (1995) 605–610.
[19] Leinonen I., Kramer K., Applications of phenological models to predict the future carbon sequestration potential of boreal forests, Clim. Change 55 ( 2002) 99–113.
[20] Corelli-Grappadelli L., Lakso A.N., Fruit development in deciduous tree crops as affected by physiological factors and environmental conditions, Acta Hort. 636 (2004) 425–441.
[21] Blanpied G.D., N.D. O'Kennedy. A study of the relationship between climate and apple fruit growth, HortScience 2 (1967) 155–156.
[22] Curry E.A, Temperatures for optimum anthocyanin accumulation in apple tissue, J. Hort. Sci. 72 (1997) 723–729.
[23] Monselise S.P., Goren R., Preharvest growing conditions and postharvest behavior of subtropical and temperate-zone fruits. HortScience 22 (1987) 1185–1189.
[24] Loreti F., Massai R. I portinnesti del pesco, Informatore Agrario 6 (1999) 39–44.
[25] Barden J.A., Marini R. P. Rootstock effects on growth and fruiting of a spur-type and a standard strain of "delicious" over eighteen years, Fruit Varieties Journal 53 (1999) 115–125.
[26] Caruso T., Giovannini D., Liverani A. Rootstock influences the fruit mineral, sugar and organic acid content of a early ripening peach cultivar, J. Hortic. Sci. 71(1996) 931–937.
[27] Di Vaio C., Buccheri M., Graziani G., Ritieni A., Scalfi L. Attività antiossidante di frutti di pesco (cv. Maycrest), Rivista di Frutticoltura e di Ortofloricoltura 7–8 (2001) 83–86.

[28] Giorgi M., Capocasa F., Scalzo J., Murri G., Battino M., Mezzetti B. The Rootstock effects on plant adaptability and production, and fruit quality and nutrition, in the peach (cv. Suncrest), Sci. Hortic., 107 (2005) 36–42.

[29] Wang H., Cao G., Prior R.L., Total antioxidant capacity of fruits, J. Agric. Food Chem. 44 (1996) 701–705.

[30] Weinberger J.H., Chilling requirements of peach varieties, Proc. Amer. Soc. Hort. Sci. 56 (1950) 122–128.

[31] Meier U. (Ed.), Growth stages of mono-and dicotyledonous plants, BBCH Monograph, 2nd ed. Federal Biological Research Centre for Agriculture and Forestry, 2001.

[32] Grzyb Z.S., Sitarek, M., Kozinski, B. Effect of different rootstocks ongrowth, yield and fruit quality of four plum cultivars (in central of Poland), Acta Hort. 478 (1998) 239–242.

[33] Okie W.R, Introgression of *Prunus species in Plum*, New York Fruit Quarterly 14 (2006) 29–37.

[34] Liverani A., Giovannini D., Versari N., Sirri S., Brandi F. Japanese and European plum cultivar evaluation in the Po valley of Italy: yield and climate influence, Acta Hort. 874 (2010) 327–336.

[35] Küden A., Küden A.B., Türkmen O., Özgüven A.I., Rehber Y., Sayginer E., Imrak B. Peach, nectarine and plum growing possibilities under subtropical conditions of Turkey and north Cyprus, Acta Hort. 662 (2004) 119–126.

[36] Alburquerque N., Burgos L., Egea J., Influence of flower bud density, flower bud drop and fruit set on apricot productivity, Sci. Hort. 102 (2004) 397–406.

[37] Jiménez S., Pinochet J., Romero J., Gogorcena Y., Moreno M.T., Espada J.L. Performance of peach and plum based rootstocks of different vigour on a late peach cultivar in replant and calcareous conditions, Sci. Hort. 129 (2011) 58–63.

[38] Cao T., De Jong T.M., Shackel K.A., Kirkpatrick B.C., Johnson R.S. Influence of rootstock, temperature and incubation duration on bacterial canker severity caused by *Pseudomonas syringae* pv. *syringae* in peach, Fruits 68 (2013) 45–55.

[39] Mezzetti B., Sottile F. Mi.P.A.F. Targeted project for evaluation of European and Japanese plum rootstocks in Italy: results of six years of observations, Acta Hort. 734 (2007) 149–156.

[40] Sottile F., Monte M., De Michele A., Effect of different rootstocks on vegetative growth of Japanese and European plum cultivars in southern Italy: preliminary results, Acta Hort. 734 (2007) 375–380.

[41] Miloševíæ T., Miloševíæ N., The physical and chemical attributes of plum influenced by rootstock, Acta Aliment. 41 (2012) 293–303.

[42] Daza A., Garcìa-Galavìs P.A., Grande M.J., Santamarìa C., Fruit quality parameters of 'Pioneer' Japanese plums produced on eight different rootstocks, Sci. Hortic. 118 (2008) 206–211.

[43] Crisosto C.H., Crisosto G.M., Echeverria G., Puy J., Segregation of plum and pluot cultivars according to their organoleptic characteristics, Postharvest Biol. Technol. 44 (2007) 271–276.

**Cite this article as:** Filippo Ferlito, Alberto Continella, Elisabetta Nicolosi, Biagio Dimauro, Massimiliano Brugaletta, Antonio Cicala, Stefano La Malfa. Bio-agronomic characterization of twelve plum cultivars on two clonal rootstocks in a semi-arid environment in Sicily. *Fruits* 70 (2015) 249–256.