Scientia Horticulturae 122 (2009) 540–544

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Site and fruit maturity influence on the quality of European plum in organic production

M. Guerra [a,*], P.A. Casquero [b]

[a] Department of Agrarian Engineering and Sciences, University of León, Av. Astorga s/n, 24400 Ponferrada, León, Spain
[b] Department of Agrarian Engineering and Sciences, University of León, Av. Portugal 41, 24071 León, Spain

ARTICLE INFO

Article history:
Received 17 April 2009
Received in revised form 30 June 2009
Accepted 7 July 2009

Keywords:
'Green Gage'
Environment
Harvest date
Fruit quality
Maturity index
Calcium

ABSTRACT

Information available on the role of site and fruit maturity in the quality of European plums in organic production has not been studied to date. European plum cv. 'Green Gage' grown in organic production was harvested in order to study the effect of site and fruit maturity on fruit quality. At harvest, significant differences were found in fruit weight, colour, firmness and TSS between harvest dates, whereas significant differences were found in fruit weight, colour, firmness and fruit Ca content between sites. Differences remained during storage. Fruit weight loss during storage was affected by site. Fruit with high Ca content showed higher firmness both at harvest and during storage. Harvest moment should not be chosen according to date, since differences between sites at the same date have been found. Firmness and colour parameters a^* and h° would be useful to distinguish maturity at harvest between different sites and harvest dates. Linear regression between h° and firmness at harvest would allow the use of the h° colour parameter as a non-destructive measurement to distinguish maturity. Organic orchards should keep a minimum level of Ca in order to assure a slower fruit softening during storage.

1. Introduction

Agriculture is facing new challenges, including the development of organic production and the introduction of new regulations or private standards. Agriculture is also affected by sustainable development trends that make it necessary to minimise the environmental impact of cultural practices (Nesme et al., 2006). Population growth and expanding demand for agricultural products constantly increase the pressure on land and water resources (Spiertz, in press). Moreover, consumers have started to look for safer and better controlled foods produced in more environmentally friendly, authentic and local systems. Organically produced foods are widely believed to satisfy the above demands, leading to lower environmental impacts and higher nutritive values. However, to date, only a few studies have been conducted with plums, and the influence of site and fruit maturity in European plums in organic production have not been thoroughly investigated.

Many decisions will profoundly influence the postharvest quality of the fruit. Some of these decisions even predate orchard planting, such as location (climate), site (soil) and cultivar selection (Crisosto et al., 1995). Fruit quality depends on the cultivar, on the site where it is grown, on rainfall, on temperature range and on cultural practices (Silva et al., 2008). Soil can particularly affect plum fruit quality, mainly its firmness characteristics (Rato et al., 2008). Nutrients such as Ca can affect the quality of stone fruit (Lysiak et al., 2008; Plich and Wojcik, 2002). However, as observed by Wojcik (2001), Ca concentration in plum fruits may not correspond with soil Ca level. Tree density affects size, colour, firmness and N content of plums (Gurcharan et al., 2004). The fruit quality is related to weather. Correlation has been found between temperature and soluble solids content (Vangdal et al., 2005). Moreover, postharvest factors, such as harvest maturity, can affect stone fruit quality (Crisosto et al., 1995; Drake and Elfving, 2002; Díaz-Mula et al., 2008).

It is important to determine which maturity indices consistently reflect the quality of the harvested product for each cultivar in different growing locations (Crisosto, 1994). Size is one possible index of maturation, but it cannot be used alone since fruit size for any variety can be influenced by crop load, climatic conditions, and cultural practices. Flesh firmness for a given variety varies in relation to fruit size, climatic conditions, and cultural practices. Use of total soluble solids (TSS) as a maturity index alone is limited by variation among varieties, production sites and season. Titratable acidity (TA) is also affected by cultivar and seasonal variability. The ratio of TSS:TA has been found to be closely related to sensory quality in European plums (Guerra and Casquero, 2009). Changes in ground colour (background) or flesh colour are not affected by

* Corresponding author. Tel.: +34 987 442034; fax: +34 987 442070.
E-mail address: mgues@unileon.es (M. Guerra).

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doi:10.1016/j.scienta.2009.07.003

Table 1
Geographical and soil characteristics of the experimental sites where plum cv. 'Green Gage' was grown.

Site	Geographical characteristics			Soil characteristics					
	Lat.	Long.	Alt. (m)	pH	N (g kg^{-1})	P (mg kg^{-1})	Ca^{2+}	Mg^{2+} (g kg^{-1})	K^{+}
Cabañas	42°37′N	6°38′W	560	6.2	1.3	17.20	1.11	0.56	0.15
Bárcena	42°36′N	6°36′W	550	6.5	1.2	14.18	0.66	0.10	0.16
Villalibre	42°31′N	6°39′W	530	8.5	1.4	5.11	3.29	0.15	0.09

sunlight and, thus, are more dependable indices of maturity (Crisosto, 1994).

Unfortunately, there is no detailed information available on the role of site and fruit maturity in the quality of European plums in organic production. The objective of this work was to study the effect of site and fruit maturity of European plums grown in organic production on fruit quality at harvest and during cold storage, analysing which quality parameters are independent of site.

2. Materials and methods

2.1. Plant material and storage conditions

European plum cv. 'Green Gage' (*Prunus domestica* Lindl.) from 19-year-old trees on St. Julien rootstock, planted on 5 m × 5 m spacing and trained to an open vase conformation, was harvested during the commercial harvesting period on three dates from 27 July to 2 August 2005 from three commercial unirrigated orchards managed by organic agricultural practices since 2002. The orchards, located in Cabañas Raras, Bárcena and Villalibre (León, Spain), were situated in close proximity (Table 1) ensuring comparable growing conditions and similar microclimate conditions. Cultural practices at the three sites were similar to one other. The experiment was laid out by following a randomized complete block design. Three replicates of three trees each were selected for this study in each site.

All fruit were transported on the day of harvest to the Postharvest Laboratory at the University of León, Ponferrada. Fruit of every orchard and harvest date were selected and distributed randomly in plastic containers. No postharvest chemical treatments were used. Then, the fruit was stored at 2 °C, with an RH of 90% for 40 days. Plums were sub-sampled at each storage removal, every 10 days, and 20 fruit of each experimental unit were used to analyse the fruit's physico-chemical characteristics. Another 25 fruit of each experimental unit were identified in order to analyse non-destructive weight loss measurements and skin ground colour during storage.

2.2. Fruit quality evaluations

Fruit was assessed at harvest and during storage for weight (g), skin ground colour, firmness (N), TSS content (%), TA (% malic acid) and weight loss (%).

Skin ground colour was measured in each fruit with a colorimeter (Minolta, CR-200) and was expressed as L^*, a^*, and b^* system. These colour parameters were converted to the hue angle ($h°$) measurement. Three determinations of the colour parameters were made along the equatorial axis of each fruit.

Flesh firmness was determined, using an Effegi penetrometer mounted in a hand-operated press and fitted with a 7.9 mm diameter plunger. Measurements were taken at three equatorial positions on each fruit at 120°.

After assessment of fruit firmness, fruit juice was extracted by homogenising fruit flesh in a blender. TSS values of the juice were measured in each fruit with a digital refractometer (Atago, DR-A1).

TA of every 5 fruit was determined by titrating 10 ml of juice with NaOH 0.1N up to pH 8.2. The ratio TSS:TA was determined.

Fruit for each site was prepared to mineral extraction and analysis. Ca content was estimated by inductively coupled plasma atomic emission spectroscopy (ICP-AES technique).

2.3. Soil analysis

Soil samples were taken using a soil probe to a depth of 50 cm randomly in each orchard. These soil cores were mixed to make a composite sample. Soil analyses were performed in the Laboratory of Instrumental Techniques of University of León. Total N was analysed by Kjeldahl method. Potassium, Ca and Mg were estimated by ICP-AES technique. Phosphorus (Olsen) was determined using the extraction method.

2.4. Statistical analysis

Data were subjected to ANOVA. Mean comparisons were performed using the LSD test to examine differences ($P < 0.05$) among sites and harvest dates. Linear regressions were performed between instrumental parameters. All analyses were performed using SAS software (SAS Institute Inc., Cary, NC, USA).

3. Results and discussion

Ca level was higher in 'Villalibre' site soil compared with 'Cabañas' and 'Bárcena' soils (Table 1). As expected, this fact affected Ca fruit level, so 'Villalibre' site fruits showed the highest Ca level (Table 2). According to Engelkes et al. (1990), fruit Ca concentrations are affected by the environment.

There were significant differences in weight at harvest between sites (Table 3). Fruit weight of 'Villalibre' site at harvest was the lowest (Table 2). Lower fertility of 'Villalibre' soil in terms of P and K of this site compared with the others could have affected fruit weight. Mean fruit weight has been found positively affected by P or K fertilizer applications (Ortiz et al., 2007; Si-smail et al., 2007; Tachibana and Yahata, 1998). As previously reported (Guerra and Casquero, 2008), fruit weight was significantly affected by harvest date too, so fruit weight increased from earlier (24.6935 g) to the last harvest date (27.3154 g), but because of the strong interaction site × harvest date, fruit weight would not be an useful harvest maturity index.

Fruit weight loss during storage was affected by site (Table 4). 'Bárcena' fruits showed lower weight loss than the other two sites during the whole storage period. According to the general

Table 2
Calcium content and quality parameters of plum cv. 'Green Gage' from different sites at harvest.

Site	Ca (g kg^{-1} DW)	Fruit weight (g)	TSS (%)	TA (%)
Cabañas	1.14a	27.0315b	21.9756a	14.5964a
Bárcena	0.63b	28.3710a	22.3522a	14.5773a
Villalibre	1.27a	22.5752c	22.5124a	14.4385a

Different letters within the same column indicate significant differences according to LSD test ($P < 0.05$).