LWT - Food Science and Technology 59 (2014) 964–972

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Effects of different organic and conventional fertilisers on flavour related quality attributes of cv. Golden Delicious apples

A. Raffo [a,*], I. Baiamonte [a], R. Bucci [b], A. D'Aloise [b], M. Kelderer [c], A. Matteazzi [c], E. Moneta [a], N. Nardo [a], F. Paoletti [a], M. Peparaio [a]

[a] Agricultural Research Council – Research Center on Food and Nutrition (CRA-NUT), Via Ardeatina, 546, 00178 Rome, Italy
[b] University of Rome La Sapienza, Department of Chemistry, P.le Aldo Moro, 5, 00185 Rome, Italy
[c] Research Centre for Agriculture and Forestry Laimburg, Laimburg, 6, 39040 Ora, BZ, Italy

ARTICLE INFO

Article history:
Received 16 December 2013
Received in revised form
17 June 2014
Accepted 18 June 2014
Available online 27 June 2014

Keywords:
Fertilisation
Organic farming
Malus domestica
Volatile
Organic acid

ABSTRACT

The effects of the application of different organic and conventional fertilisers on some flavour quality attributes (aroma volatiles, sugars and organic acids) of cv. Golden Delicious apples were investigated by an experimental field trial in two harvest years (2010 and 2012). Through a balanced randomised block design, five organic fertilisation treatments (three different fertilisers at the same nitrogen dose, increase and fractionation of dose for one of the fertiliser) were compared to each other, to a conventional treatment based on a mineral fertiliser and to a non-fertilised control.

Fertilisation treatments significantly affected the level in fruits of several flavour related compounds, such as some aroma volatiles, sugars and organic acids, but few of these responses were consistent across the two harvest years and of remarkable size. Even when treatments gave place to marked differences in the soil mineral nitrogen level, this reflected in a limited impact on flavour related compounds in the fruit, the strongest effect being a 45% change in C6-aldehydes level. The different organic fertilisation treatments weakly affected the considered fruit quality attributes. Significant differences were observed for several sensory attributes between apples coming from different fertilisation treatments and characterised by a quite similar chemical profile.

1. Introduction

The potential of the organic farming system as an environmentally and economically sustainable option for apple production under appropriate cultivation conditions has been the subject of recent investigations (Alaphilippe, Simon, Brun, Hayer, & Gaillard, 2013; Reganold, Glover, Andrews, & Hinman, 2001). Alto Adige is an Italian geographic area that has proved to be well adapted for apple growing, having developed in last decades a strong territorial specialisation for apple cultivation and, in particular, for organic apple production, with a production share estimated at about 35% within the European Union. One of the main issues for organic apple cultivation in this area is linked to the insufficient plant nutrient supply due to the organic form of nitrogen fertilisers, which are characterised by a slower nutrient release when compared to the mineral conventional counterparts. In particular, a limited nitrogen supply tends to lower fruit yields and prevents an appropriate exploitation of available arable land. This is a general drawback for organic crops cultivation (Lester & Saftner, 2011; Seufert, Ramankutty, & Foley, 2012), being exacerbated in this case by the relatively low soil average temperatures occurring in this geographic area at the beginning of spring. With a view to tackle this limitation, laboratory and field experimental trials have been undertaken in the last few years by comparing the performance of several organic fertilisers in terms of nitrogen mineralisation rates, in order to optimise the release of plant available mineral nitrogen from organic sources (Kelderer et al., 2008). However, if the application of organic fertilisers of different origin and chemical composition is expected to produce differences in the whole supply of all the plant mineral nutrients, little is known about the effects of mineral soil nutrition on apple fruit quality and, in particular, on flavour quality at harvest (Ferguson & Boyd, 2002; Pelayo-Zaldívar, 2010).

Flavour quality, though not a primary driver of choices of organic food consumers, still has a significant role in determining their preferences (Oughton & Ritson, 2007). Fruit flavour is a complex trait formed by several sensory attributes, most notably

* Corresponding author. Tel.: +39 0651494573; fax: +39 0651494550.
E-mail address: antonio.raffo@entecra.it (A. Raffo).

http://dx.doi.org/10.1016/j.lwt.2014.06.045
0023-6438/© 2014 Elsevier Ltd. All rights reserved.

aroma, taste, texture, appearance and chemesthetic sensations (Deibler & Delwiche, 2004). Considering, in particular, taste and aroma of apple fruit, sweetness is mainly due to sugars, such as fructose, sucrose and glucose, sourness is mainly related to the presence of malic acid (Harker et al., 2002), whereas olfactory sensations are evoked by a complex array of volatile substances (López Fructuoso & Echeverría Cortada, 2010). Even though more than 300 compounds have been identified in the volatile fraction of apple fruit (Nijssen, Ingen-Visscher, & Donders, 2011), only a few dozens of them have been recognised to significantly contribute to the perceived fruit aroma (Aprea et al., 2012; López Fructuoso & Echeverría Cortada, 2010; Mehinagic, Royer, Symoneaux, Rique Jourjon, Prost, 2006; Plotto, McDaniel, & Mattheis, 2000; Young, Gilbert, Murray, & Ball, 1996).

Increased levels of nitrogen application usually enhance plant vigour and fruit yield, thus reducing fruit soluble solids concentration by dilution or shading effects (Ferguson & Boyd, 2002). In agreement with this general finding, reduced soluble solids levels have been observed in apple fruit in association with increased nitrogen leaf levels (Dris, Niskanen, & Fallahi, 1999). A relationship between fruit potassium content and acidity has been found in some apple cultivars (Marcelle, 1995). While previous observations related poor apple flavour quality to reduced nitrogen fertilisation (Somogyi & Childers, 1964), a more recent study (Fellman, Miller, Mattinson, & Mattheis, 2000) found little or no effect of nitrogen application on aroma production, even though an indirect effect on tree vigour and, consequently, on subsequent maturity stage at harvest was not ruled out as an influential factor. In particular, while branched-chain amino acids are precursors in the synthesis of branched-chain esters, which are important apple odorants, application of increasing levels of nitrogen did not affect amino acid precursors availability nor aroma production in apples (Fellmann et al., 2000). More recently, flavour quality of apples obtained under organic, conventional and integrated production systems has been compared (Peck, Andrews, Reganold, & Fellman, 2006; Reganold et al., 2001). Significant differences appeared for some sensory attributes: even though they were not clearly related to differences in chemical composition, they suggested the potential impact of differences associated to these farm management systems on fruit flavour quality, even when cultivar, soil, rootstock, plant age and all other conditions except management were kept constant. In addition, results from recent investigations have suggested that an insufficient nitrogen supply due to reduced release rates by organic fertilisers could stimulate plant stress responses, resulting in an enhanced accumulation of phenolic flavonoids in fruits of tomato, grapefruit and sweet pepper, thus potentially affecting both flavour and nutritional quality (Lester & Saftner, 2011).

The aim of this study was to evaluate the effect of the application of three different organic fertilisers on some flavour quality attributes of cv. Golden Delicious apples, in two non-consecutive harvest years. For one out of the three organic fertiliser a fractionation and an increase of the application dose was also tested. Fruits obtained by these fertilisation treatments were also compared with fruits from plants supplied with a conventional mineral fertiliser, and plants that did not receive any fertilisation treatment. To amplify all potential effects due to fertilisation treatments young trees were selected for the experimental field trial.

2. Materials and methods

2.1. Experimental field trial

The trial was part of an experimental apple orchard at the Research Centre for Agriculture and Forestry Laimburg (Laces: lat. 46°62′N, long. 10°86′E, alt. 640 masl), in the province of Bolzano. In 2009, four replicate plots for each of the seven fertilisation treatments were planted with cv. Golden Delicious apples (*Malus* × *domestica* Borkh.) on M9 rootstock, complying with a balanced randomised complete block design. Well feathered trees were planted, according to a common practice in this geographic area, where trees generally go into production one year after planting. Each plot was formed by five trees (rows spaced by 3.2 m apart, trees spaced 0.8 m apart). Three different organic fertilisers were used. Fertiliser 1 (OF1) was a commercial nitrogen enriched organic fertiliser formed by vegetable oil cakes, feather meal and horn-hoof mixture. Fertiliser 2 (OF2) was an experimental fertiliser formed by a mixture of digested slurry from biogas plants and compost. Fertiliser 3 (OF3) was a commercial organic fungal biomass based fertiliser, obtained by fermentation of a mixture formed by soya meal, sugar, syrups, cottonseed meal, trace elements and vitamins. Fertiliser 1 and 3 have been selected as products complying with organic production protocols adopted in this production area and on account of their relatively good mineralisation performance in laboratory test. Fertiliser 2 has been selected as a potential innovative product, also with a view to the optimisation of the use of local resources. In the first year, the three organic fertilisers were applied two weeks after planting, whereas in the following years they were given as a single dose early in the spring season. Two additional treatments were carried out by using fertiliser 1, the first by fractionating the same total dose in three one month-spaced applications (OF1 33% × 3), and the second by fractionating a 50% increased dose in three applications (OF1 50% × 3). A reference conventional treatment (CF) by application of ammonium sulphate as mineral fertiliser and a control non-fertilised treatment (NF) were also implemented. Details on number of applications and nitrogen doses used in the four years of the experiment for each treatment are reported in Table 1.

For all treatments common management practices (fruit thinning, weed control, pest and disease control) used in this area for production of organic apples were followed, with no marked differences between the two years 2010 and 2012.

2.2. Chemicals

Pure compounds of the volatile compounds, organic acids and sugars listed in Table 3, and of the internal standards (4-methyl-2-pentanol, allyl hexanoate), were purchased from Sigma–Aldrich Italia (Milan, Italy). Solvents and reagents were purchased from Carlo Erba Reagents (Milan, Italy).

2.3. Soil and leaves analyses

For soil analyses, five soil cores were collected from each plot at depths from 0 to 40 cm, as listed in Table 2. Plant available nitrogen

Table 1
Number of applications and nitrogen doses (g of N/plant/year) in the four years of the fertilisation experiment for each of the investigated treatments.

Fertilisation treatment	Number of applications	Application dose (g of N/plant/year)			
		1st year	2nd year	3rd year	4th year
Non-fertilised (NF)	–	–	–	–	–
Ammonium sulphate (CF)	1	16	20	24	24
Organic Fertliser 1 (OF1)	1	16	20	24	24
Organic Fertliser 1 (OF1 33% × 3)	3	16	20	24	24
Organic Fertliser 1 (OF1 50% × 3)	3	24	30	36	36
Organic Fertliser 2 (OF2)	1	16	20	24	24
Organic Fertliser 3 (OF3)	1	16	20	24	24