Scientia Horticulturae 129 (2011) 479–485

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Effects of cultural cycles and nutrient solutions on plant growth, yield and fruit quality of alpine strawberry (*Fragaria vesca* L.) grown in hydroponics

Gianluca Caruso[a,1], Gerardo Villari[b], Giuseppe Melchionna[c,2], Stefano Conti[c,*]

[a] Department of Soil Plant Environmental and Animal Production Sciences, University of Naples "Federico II", Via Università 100, 80055 Portici (NA), Italy
[b] Experimental Station for the Food Preserving Industry, Angri (SA) Branch, Via Nazionale 121/123, 84012 Angri (SA) Italy
[c] Department of Arboriculture Botany and Plant Pathology, University of Naples "Federico II", Via Università 100, 80055 Portici (NA), Italy

ARTICLE INFO

Article history:
Received 16 August 2010
Received in revised form 8 April 2011
Accepted 15 April 2011

Keywords:
Alpine strawberry
Nutrient film technique
Fruit production
Mineral nutrients
Sugars
Antioxidants

ABSTRACT

Alpine strawberry (*Fragaria vesca* L.) was grown in hydroponics with the nutrient film technique, in order to evaluate the effects of four buffer concentrations (1.3, 1.6, 1.9, 2.2 mS cm^{-1}) and two cultural cycles (summer-spring versus autumn-spring) in terms of growth, yield and fruit quality (dry and optical residues, sugars, acids, antioxidants, mineral composition). The longer summer-spring cycle gave a correspondingly higher yield than the autumn-spring one. The 1.3 mS cm^{-1} nutrient solution was the most effective in terms of overall and spring production. However, the autumn and winter yields were not affected by the buffer EC. Fruit quality did not change with the cultural cycle, but the berries harvested in the spring had higher vitamin C and sucrose content and lower nitrate content compared with berries picked up in the winter. Fruit quality was also improved when the nutrient solution concentration increased. From the productive point of view, the cultural cycle choice should be made considering that 71% of the yield of the more productive summer-spring cycle derived from the spring harvest. Moreover, as regards the nutrient solution strength, 1.3 mS cm^{-1} EC should be preferred during the spring season, whereas the 2.2 mS cm^{-1} EC proved to be best in the winter in terms of fruit quality.

1. Introduction

Alpine strawberry (*Fragaria vesca* L.) is to be considered a niche product which can provide interesting economic results in a wide range of climatic areas. It is an ever-bearing crop, characterized by a lower productivity compared with the more commonly grown garden strawberry (*Fragaria x ananassa* Duch.) and by higher production costs, owing to the prolonged hand harvest and smaller fruits. However, due to its intense taste and olfactory characteristics, alpine strawberry fruits are requested both by the fresh market and by the confectionery industry. Therefore, these fruits have a high market value which may encourage farmers to increase the cropped area devoted to this species. Nevertheless, as a consequence of the methyl bromide prohibition for soil disinfection, the cultural practices previously followed for this crop need to be improved.

Given its technical and economical advantages, the hydroponic cultivation of alpine strawberry could be promoted among producers. In fact, the soilless system facilitates harvest and results in earlier production of larger and more uniform fruits as preferred by the market.

Hydroponic cultivation allows farmers easily to control the nutrient supply, by adjusting the concentration of the hydroponic nutrient solution. This factor affects the plant water and salt relations and influences plant growth and quality. In fact, it was reported that salinity reduced strawberry vegetative growth but, at moderate levels, it improved fruit quality and antioxidant content (Awang et al., 1993; Awang and Atherton, 1995; De Pascale et al., 2001; Keutgen and Pawelzik, 2007a,b).

The choice of the crop cycle for strawberry hydroponic cultivation also plays a crucial role, since the seasonal environmental factors affect the crop productivity and quality in the following ways. Plant growth is favoured by increasing daylight and flowering is enhanced by moderate temperature (Chabot, 1978). Light intensity increase also leads to higher sugar and ascorbic acid contents in many fruits and vegetables (Lee and Kader, 2000). High temperatures enhance the fruit antioxidant capacity (Wang and Zheng, 2001); however, they have a negative effect on soluble solids, titratable acidity, and ascorbic acid contents (Wang and Camp, 2000).

* Corresponding author. Tel.: +39 081 7760104x46; fax: +39 081 7755114.
E-mail address: stefano.conti@unina.it (S. Conti).
[1] Tel.: +39 081 2539104.
[2] Tel.: +39 081 7760104x46.

0304-4238/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.scienta.2011.04.020

Table 1
Mean values of PAR, temperature and relative humidity from July 2004 to June 2005, in Portici (Naples, Italy).

	2004						2005					
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
PAR (MJ m^{-2} d^{-1})	9.8	9.0	6.2	4.2	2.6	2.0	2.7	3.1	5.7	6.9	8.9	9.7
Temperature (°C)												
Day	34.1	33.9	31.2	28.8	24.5	21.6	20.3	17.2	22.9	26.7	30.3	31.7
Night	18.4	19.8	16.8	15.3	9.6	8.6	3.9	1.9	5.6	10.2	15.0	16.5
Relative humidity (%)												
Day	95.5	96.2	97.0	97.3	98.6	99.0	99.7	99.4	98.2	97.2	96.6	96.3
Night	40.0	43.1	45.0	54.9	56.0	60.4	60.6	61.4	53.1	51.6	49.3	46.2

Environmental factors also influence the ratios between soluble sugars, organic acids and insoluble solids contents of the fruits (Awang and Atherton, 1995; Montero et al., 1996; Wang et al., 2002).

Thus, although the effects of these individual factors have already been documented in the related species *F. x ananassa*, there remain little information about their effect on the productive results of *F. vesca*.

Given the scarcity of research on the subject, we planned an experimental protocol that aimed to define both the most effective nutrient solution strength (within the 1.3–2.2 mS cm^{-1} EC range) and cultural cycle (summer-spring versus autumn-spring) on the yield and quality performances of alpine strawberry grown in hydroponics in southern Italy.

2. Materials and methods

2.1. Plant materials and growth conditions

Alpine strawberry plants (*F. vesca* L.) cultivar Regina delle Valli were grown at the experimental site of the University of Naples at Portici (NA) in southern Italy, in 2004–2005. Plants were grown in hydroponics using the nutrient film technique (NFT) under a 300 m^2 polyethylene tunnel. The monthly means of PAR, temperature (day/night) and relative humidity (day/night) recorded at the plant level are reported in Table 1. The NFT equipment consisted of rigid PVC gullies (each 12 cm wide, 10 cm deep and 300 cm long), with a 1% slope. The gullies were at 70 cm above ground level and each gully was fed by a separate 220 l plastic reservoir tank containing the nutrient solution (NS). Continuous circulation (3 l min^{-1}) of the NS was provided by a 90 W submerged pump into each reservoir tank. The volume of NS in each tank was constantly monitored and it was completely replaced at weekly intervals.

Plants were exposed to four levels of NS concentration, resulting in electrical conductivities (EC) of 1.3, 1.6, 1.9 and 2.2 mS cm^{-1} (Table 2), in factorial combination with two crop cycles (summer-spring and autumn-spring). The experimental treatments were randomized in a split-plot design, assigning the crop cycles to the main plots and the NS concentrations to the sub-plots. Each treatment included 12 plants and it was repeated three times.

Fresh plants (75 days old) were transplanted on 22 July for the summer-spring cycle or on 21 October for the autumn-spring crop. Both crop cycles ended on 10 June in the following year. All plants were transplanted in 10 cm black plastic pots filled with lapil (5–6 mm). Pots were placed on the NFT gullies through a pierced white polyethylene film. The gullies were arranged in double rows which were spaced by 100 cm. Within each double row the plant spacing was of 40 cm between the rows and 25 cm along the row. Fruit harvest began on 16 September and 18 February, for the summer-spring and for autumn-spring cycles respectively and it continued until the end of the crop cycle, on 10 June.

2.2. General analytical methods

Ripe, undamaged fruits of regular shape were classified as "marketable". At each harvest, the weight and number of marketable ripe fruits in each plot was recorded. The weight of fruits unsuitable for the market was also recorded in order to monitor total biomass production for each treatment. Cumulative plant biomass was calculated as the sum of the above ground plant biomass at the end of the experiment plus the total fruit production from the beginning of the harvest period. Dry residue was assessed after dehydration of the fresh samples in an oven at 70 °C under a vacuum until they reached constant weight. Leaf area was measured at the end of the cycle, using a bench top LI-COR leaf area meter.

2.3. Plant water consumption and nutrient uptake

Plant water consumption was monitored during the whole cultural cycle. This was calculated as the difference between the NS volumes in the hydroponics reservoir at the beginning and at the end of the weekly cycle.

The uptake of nutrients from the hydroponic solution was assessed in May when the maximum values of water consumption were also recorded. Nutrient uptake was estimated as the difference between the concentration of each nutrient in the fresh NS compared with the residual concentration in the exhausted solution after one week, when this was replaced with fresh NS. The concentration of nutrients in the NS was measured by directly analyzing samples of the NS using the methods described below for the analyses of cations and of anions.

2.4. Fruit sample preparation

In order to evaluate the quality of berries produced during the winter and the spring, marketable ripe fruits were sampled on

Table 2
Chemical composition of the hydroponic nutrient solutions.

EC (mS cm^{-1})	Macronutrients (mmol l^{-1})							Micronutrients (μmol l^{-1})					
	N	P	K	Ca	Mg	S	Cl	Fe	Cu	Mn	Zn	B	Mo
1.3	6.1	0.5	2.6	2.0	1.6	1.3	1.0	45.0	20.0	25.0	38.0	12.0	1.0
1.6	7.8	0.7	3.3	2.4	1.8	1.8	1.0	45.0	20.0	25.0	38.0	12.0	1.0
1.9	9.5	0.9	4.1	3.0	2.1	2.4	1.0	45.0	20.0	25.0	38.0	12.0	1.0
2.2	11.3	1.0	4.8	3.6	2.3	2.8	1.0	45.0	20.0	25.0	38.0	12.0	1.0

For all treatments pH was adjusted to 5.8 and NH_4/NO_3 ratio was 1/9.