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Long-Term Culture of Cut Rose Plants in Perlite-Based Substrates

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ABSTRACT

Perlite is often used in soilless systems for horticultural crops but is rarely employed for pluriannal culture of ornamental species. The aim of this research was to test the changes in the physical and chemical properties of two perlite-based growing media during a 36-month greenhouse cultivation period and their effects on the production of cut roses. 'Anastasia', 'Nirpbredy' (New Fashion®), 'Nirpinwin' (Fenice®) and 'Sunluck' (Gold Strike®) roses were grown in 80L plastic bags filled with pure perlite or perlite mixed with coconut coir dust (1:1, v/v) in an open-loop system. Chemical and physical characteristics of the two substrates were determined at the beginning and at the end of the experiment. Bulk density and water holding capacity gradually increased, whereas total porosity and air content diminished. The mixture with perlite and coir dust provided higher water retention capacity throughout the trial, though pure perlite maintained a more stable physical condition. Number of rose stems/plant, stem length and thickness and flower bud height and width were monitored during the trial. The prolonged cultivation period was characterized in both media by an increase of yield (60%) and cut rose quality during the second year and by a decrease (26%) in yield in the third year. Growing media affected yield and qualitative traits: best results were achieved with plants grown in medium composed of perlite and coir dust as compared to pure perlite. The mixed medium had a higher number of flowers (21.2 vs. 16.3 stems/plant/year) and longer (63.2 vs. 57.5 cm) and thicker (7.5 vs. 6.8 mm) stems. Significant differences were also observed among cultivars: 'Anastasia' produced the highest number of stems (21.5 per plant) and the tallest buds (5.7 cm) and 'Nirpinwin' produced the longest (65.4 cm) and thickest (0.8 cm) stems.

Keywords: cultivars, growing media, hydroponics, prolonged cultivation, *Rosa hybrida*, soilless system
Abbreviations: CEC, cation exchange capacity; **EC**, electrical conductivity; **TPS**, total pore space

INTRODUCTION

The expansion of hydroponics in many countries of the world in the last few decades may be ascribed to the ability of soilless growing systems to avoid various problems arising from the use of the soil. In fact, the possible introduction of soil-borne pathogens at the start of the crop and the decline of soil fertility due to its continual cultivation for the same or a related crop species represent significant limitations of soil-based culture (Savvas 2003). A further advantage of hydroponics over soil cultivation is more precise control of nutrition and more efficient use of water and fertilizer. This is made possible by the limited volume of substrate per plant in a hydroponics system along with its typically standard, homogeneous composition. Another benefit of soilless systems, besides increasing yield and reducing prime costs (Maloupa *et al*. 1992) compared to soil cultivation, is the possibility to use irrigation water with moderate saline content (Savvas 2003).

Rose (*Rosa hybrida* L.) ranks third among the world's most cultivated cut flower species and is worth ~US$11 billion per year (International Trade Centre 1987; Short and Roberts 1991). Cut roses are generally grown in hydroponic systems under protected environments in Europe and elsewhere (Brun and Tramier 1988). The use of this innovative growing system is related to the necessity to increase yield, quality and have year-round production, factors essential for competitive modern cut rose culture. In fact, hydroponics can allow growers to achieve a continual and greater harvest of stems with superior qualitative characteristics, compared to traditional soil and substrate cultivation (Chaparro-Torres *et al*. 2006; Fascella *et al*. 2009).

Several studies were conducted on roses in hydroponic culture with the aim to clarify the key-factors affecting the physiological and productive performance of plants as well as to solve some technical and management problems. Many experiments focused on crop response to different irrigation methods (Oki *et al*. 2001; Lee *et al*. 2007) and frequencies (Chimonidou-Pavlidou 1998; Katsoulas *et al*. 2006). Numerous studies were carried out on assessing actual water requirement (Caballero *et al*. 1996) and macro and micronutrient uptake (van der Sart and de Visser 2005) in order to define irrigation regimes and fertilization strategies which allow for both high-quality production and high water and nutrient use efficiency. Aspects related to changes in composition (electrical conductivity, pH and ion content) (Cid-Ballarín *et al*. 1996) and nutrient solution management (Brun and Settembrino 1995) during the crop cycle were investigated.

Many studies focused on the improvement of growing methods and on "arching" in particular, a technique developed by some Japanese rose growers in the late 1980's (Ohkawa and Suematsu 1999). This method bends early basal (primary) shoots and then weaker, crooked and unmarketable stems horizontally towards the pathway, maintaining them in a prostrate position. They eventually take on the form of an arch. Compared to removal via pruning, bending of non-salable shoots results in an increase of leaf area index and photosynthetically active radiation interception by the plant canopy (Catalayud *et al*. 2007). A rapid increase in canopy height is avoided (Blom 1999) and the formation of vigorous (thick and long) axillary basal shoots which are harvested as cut flowers is promoted (Tjosvold 2001). This technique has proven to be very successful and is used worldwide; plants have higher yield and better quality cut flowers compared to older conventional methods.

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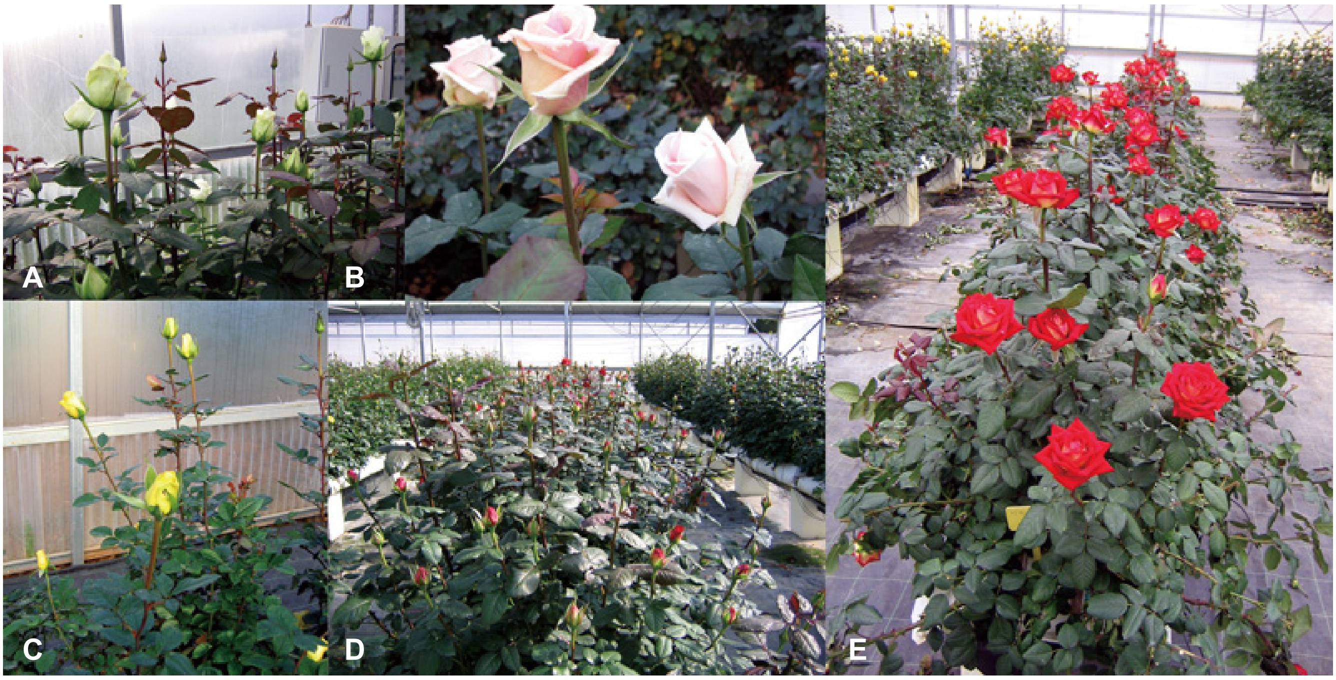

Fig. 1 Flower stems of the cultivars 'Anastasia' (A), 'Nirpinwin' (B), 'Sunluck' (C), and 'Nirpbredy' – before (D) and after (E) bud opening.

The success of this method is commonly ascribed to the increased amounts of assimilates supplied to the flowering stem by the bent, photosynthesising leaves (Pien *et al.* 2001).

A major focus of past studies on soilless cultivation of roses has been to compare and characterize growing substrates. Roses were successfully grown both in natural and artificial materials: sand (Cadahia *et al.* 1998), gravel (Sarro *et al.* 1989), volcanic lapillus (Caballero *et al.* 1996), organic (Fascella *et al.* 2007) and inorganic (Maloupa *et al.* 1999) mixtures, rockwool (Brun and Settembrino 1995), perlite (De Pascale and Paradiso 2001), zeolite (Maloupa *et al.* 2001), pumice (Syros *et al.* 2001), coir dust (Blom 1999), etc. The choice of a particular material as a growing substrate for the grower relies heavily on local availability, cost and previous experience of the grower with that substrate (Maloupa *et al.* 1992). Growth response and yield of plants in hydroponic culture is strictly related to the properties of the growing media (Lemaire 1995). Each medium presents particular and often exclusive features which make it more or less suitable for specific environmental parameters. Some inert substrates are characterized by high porosity and low water holding capacity with high dispersal (leaching) of the nutrient solution, while others possess high water and nutrient retention but are expensive or problematic to remove. Some organic materials have high water retention capacity, but are easily degradable and then short-lasting and not easily available to replace.

Perlite is an inert medium frequently used in soilless flower and vegetable production systems, singularly or mixed with organic materials (e.g. peat or coir dust). However, it is rarely employed for pluriannal culture of ornamental plants. The possibility of finding affordable growing substrates suitable for long-term cultivation of cut flowers could allow for a reduction of prime costs for growers and avoid a short turn-over of plants and substrates.

Few studies on hydroponically grown roses have been conducted over a prolonged period of culture (Kool 1996; Kool and van de Pol 1996). There are several reports on the reuse of growing materials for vegetables (Hardgrave 1995; Acuña *et al.* 2005; Stepowska and Nowak 2008), but few on pluriannal cycles of ornamental species on the same substrates (Nowak and Strojny 2004; Särkkä *et al.* 2008).

In order to evaluate the changes in the physical and chemical properties of two perlite-based media during a three year-soilless cultivation cycle of cut roses and their influence on crop yield and quality, a study was accomplished at the Research Unit for Mediterranean Flower Species. Results comparing the initial properties of these substrates and performance of cut rose cultivars over the first year and a half were previously presented (Fascella and Zizzo 2005). The present work reports data regarding the evolution of substrate characteristics as well as rose response recorded during the second and third years of cultivation and compares them with data of the first year.

MATERIALS AND METHODS

Greenhouse environment and plant materials

The experiment was carried out in Bagheria, Italy (38° 5′ N, 13° 30′ E, 23 m above sea level) during the years 2003-2006 within an unheated double-span East-West oriented greenhouse (544 m^2). The structure was zinc-coated and covered with a single 0.15 mm layer of polyethylene film. The polyethylene film was white-washed in order to reduce inner light flux density and air and leaf temperature during the summer season (June-September). Moreover, a nebulization system was used in the same period to ensure a constant relative humidity (about 60%). Mean monthly air temperatures ranged from a minimum of 12°C and a maximum of 30°C.

Three-month old grafted plants ('Fun Jwan Lo' rootstock; syn. *R. indica major*) of *R. hybrida* 'Anastasia', 'Nirpbredy' (New Fashion®), 'Nirpinwin' (Fenice®) and 'Sunluck' (Gold Strike®) were used for this study (**Fig. 1**).

Experimental design and plant maintenance

Roses were planted (January 2003) in 80L polyethylene bags filled with perlite (3-5 mm diameter) or a mixture of perlite and coconut coir dust (1:1, v/v) in an open-loop system. Each bag (100 × 50 cm) supported ten plants of the same cultivar using two rows of five with a final density of 4.5 plants/m^2. Bags, arranged in rows and separated by pathways, were placed on polystyrene blocks with a 0.5% slope to allow free drainage of excess nutrient solution. A split-plot experimental design was used; the two substrates were main plots with the four cultivars as subplots; each treatment was replicated 4 times; each replicate was a group of 20 plants (2 bags) leading to a total of 640 plants (20 plants × 4 replications × 2 substrates × 4 cultivars).

Plants were maintained using the "arching" technique (bent shoots). Water, macronutrients and micronutrients were supplied to

Fig. 2 An overview of cut rose cultivation under a plastic greenhouse.

plants via a drip-system (1 dripper/plant, 2 L/h) which was automatically controlled by a fertigation computer (MCI-Ceo, Spagnol Greenhouse Technology, Vidor, Italy). The nutrient solution had the following composition (mg/L): 140 NO_3^-, 40 NH_4^+, 50 P^{---}, 200 K^+, 120 Ca^{++}, 30 Mg^{++}, 1.3 Fe^{+++}, 0.2 Cu^{++}, 0.2 Zn^{++}, 0.3 Mn^{++}, 0.2 B^{+++} and 0.03 Mo^{+++}. The pH and the electrical conductivity (EC) were maintained at 5.8–6.0 and 2.0 dS/m, respectively.

Irrigation scheduling was performed using electronic low-tension tensiometers that control irrigation on the basis of substrate matric potential. The number of daily irrigations varied from 4 to 8 (corresponding to 0.6 and 2.0 L/plant/day) and from 3 to 6 (0.4 and 1.5 L/plant/day) for perlite and perlite/coir dust, respectively. The duration of each delivery was adjusted when the leachate fraction exceeded, for each growing material, the range of 15-25%. This fraction was calculated by collecting the drainage solutions. An overview of greenhouse conditions appears in **Fig. 2**.

Evaluation of substrate properties and plant growth

The main physical properties (bulk density, total porosity, air content, water holding capacity and easy available water) and the chemical characteristics (pH, EC and cation exchange capacity) of the two substrates were determined according to De Boodt *et al.* (1974) and Sonneveld *et al.* (1974), respectively, at the beginning and at the end of the trial. Three bags of each substrate were randomly selected and analyzed before planting and another three bags randomly selected and analyzed after 36 months and removal of the 30 plants.

Nutrient content in the root zone was determined by a photometric test with Spectroquant (Merck KGaA, Darmstadt, Germany) and calculated, at the end of the first year of cultivation and at the end of the third one, as the difference between the concentration of each element in the supplied solution and in the collected leachate.

Rose stems were harvested by cutting to the second 5-leaflet leaf from their origin. Parameters as number of stems/plant, stem length, basal stem thickness and flower bud height and width were recorded throughout the trial on a per plant basis.

Data collection and statistical analysis

Collected data, over the 35 month-period (Apr ‘03-Mar ’06) were subjected to analysis of variance to test for significance of year, substrate, cultivars and their interactions. Means were separated at $P \leq 0.05$ using Duncan’s multiple range test using Statistica software (version 6.0 for Windows, Statsoft Inc., USA).

RESULTS

Changes in physical and chemical properties of the substrates during the growing cycle are shown in **Table 1**. The bulk density significantly increased in each medium after 36 months of culture; this increase was higher in perlite/coir dust than in pure perlite. Total pore space (TPS) during the cultivation period moderately decreased both in the mixture (-6.2%) and in the inert material (-4.7%) (**Table 1**). Air content of the two considered growing media significantly decreased from the start to the conclusion of the trial; the diminution was higher in the perlite/coir dust blend (-18.3%) than in perlite alone (-10.8%). In the same period, water holding capacity increased more in perlite/coir dust than in perlite (+15.6% and +6.3%, respectively) (**Table 1**). Easy available water of the studied growing media moderately improved after 3 years of cultivation (+2.2% and +6.2%, for perlite and perlite/coir dust, respectively).

During the growing cycle, the pH of both substrates did not vary considerably, whereas the EC significantly increased (**Table 1**); no difference in the cation exchange capacity (CEC) of the two materials was recorded from the beginning to the end of the experiment. A diminution in the content of macro and micronutrients in the root zone of the tested media was also evidenced from the first to the third year of culture (**Table 2**).

The effects of the duration of the growing period on flower yield are shown in **Fig. 3**. Prolonged cultivation was characterized in both media by an increase in yield (60%) during the second year and by a decrease (26%) in the third year. Higher production was achieved by roses cultured in perlite/coir dust (21.2 stems/plant/year) compared to those grown in pure perlite (16.3). In particular, each plant in perlite/coir dust yielded an average of 16.9 stems during the first year of cultivation, 27.2 in the second and 19.6 in the

Table 2 Effect of perlite-based substrates on nutrient content (mg/L) in the root zone recorded at the end of the first and of the third year growing cycle.

Element	First year		Third year	
	Perlite	Perlite/Coir dust	Perlite	Perlite/Coir dust
N	68.8 c	118.4 a	36.9 d	90.5 b
P	40.1 b	58.0 a	25.2 c	41.6 b
K	96.0 b	130.2 a	68.3 c	107.1 b
Ca	41.0 b	72.9 a	29.4 b	64.0 a
Mg	15.1 c	33.2 a	2.7 d	22.3 b
Fe	0.7 b	1.2 a	0.2 c	0.6 b
Cu	0.1 a	0.2 a	0.04 b	0.11 b
Zn	0.09 b	0.15 a	0.03 c	0.08 b

[z]Within a row, means followed by the same letter do not differ significantly using Duncan’s multiple range test at $P \leq 0.05$.

Table 1 Physical and chemical characteristics of perlite and perlite:coir dust (1:1, v/v) recorded at the beginning and at the end of the three year growing cycle.

Characteristics	Start of cultivation		End of cultivation	
	Perlite	Perlite/coir dust	Perlite	Perlite/coir dust
Bulk density (g/cm^3)	0.08 c[z]	0.13 b	0.14 b	0.24 a
Total pore space (% vol.)	96.8 a	95.2 a	92.1 ab	89.0 b
Air content (% vol.)	73.1 a	58.5 b	62.3 b	40.2 c
Water holding capacity pF 1 (% vol.)	23.5 c	33.2 b	29.8 bc	48.8 a
Easy available water pF 1-1.7 (% vol.)	2.8 c	11.2 b	5.0 c	17.4 a
pH	7.2 a	6.4 ab	6.5 ab	5.3 b
Electrical conductivity (dS/m)	0.02 b	0.6 b	1.7 a	2.2 a
Cation exchange capacity (meq/100 g)	1.3 b	45.2 a	0.7 b	36.1 a

[z]Within a row, means followed by the same letter do not differ significantly using Duncan’s multiple range test at $P \leq 0.05$.

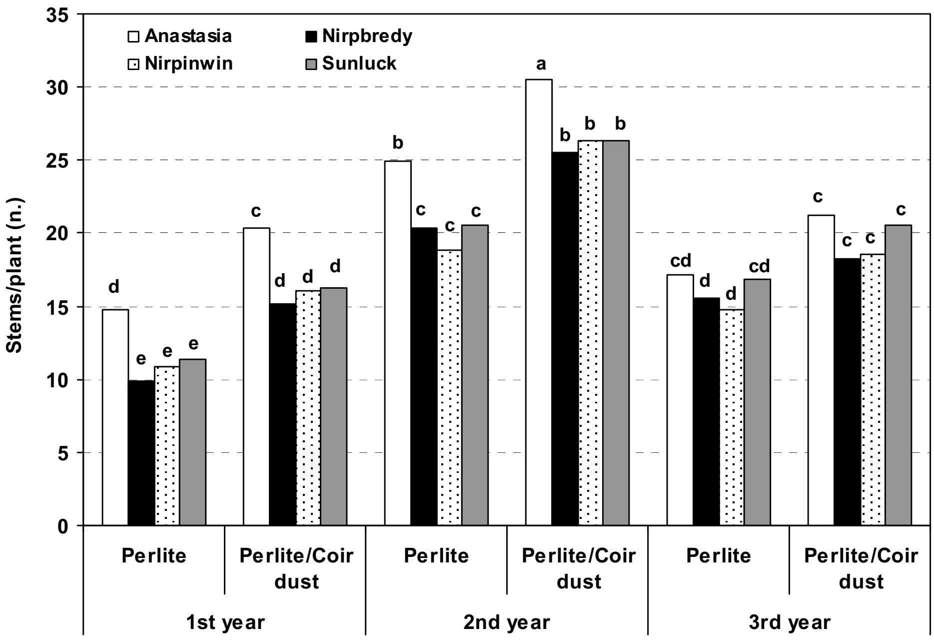

Fig. 3 Effect of growing media and cultivars on cut rose production during three years of soilless culture. Bars with the same letter do not differ significantly using Duncan's multiple range test at *P*≤0.05.

Table 3 Effects of perlite-based substrates and cultivars on cut rose quality related traits during the three year growing cycle.

Year	Substrate	Cultivar	Stem length (cm)	Stem thickness (mm)	Bud height (cm)	Bud width (cm)
One	Perlite	Anastasia	55.1[z] e	8.2 b	5.7 b	4.4 de
		Nirpbredy	46.5 g	6.7 d	4.4 e	4.1 e
		Nirpinwin	65.6 bc	8.2 b	4.9 d	4.6 d
		Sunluck	61.8 cd	6.7 d	4.9 d	4.5 d
	Perlite/Coir dust	Anastasia	64.6 c	9.6 a	5.8 b	4.7 d
		Nirpbredy	50.8 fg	7.6 c	4.3 e	4.3 de
		Nirpinwin	76.3 a	9.7 a	5.2 c	4.7 d
		Sunluck	69.1 b	7.5 c	4.9 d	4.6 d
Two	Perlite	Anastasia	61.7 cd	7.0 d	6.1 a	5.7 b
		Nirpbredy	55.8 e	7.3 cd	5.2 c	5.7 b
		Nirpinwin	65.0 c	7.8 bc	5.7 b	6.0 ab
		Sunluck	59.0 d	5.7 f	5.1 cd	5.1 c
	Perlite/Coir dust	Anastasia	66.5 bc	7.7 c	6.2 a	6.1 ab
		Nirpbredy	60.0 d	7.8 bc	5.4 c	6.0 ab
		Nirpinwin	70.4 b	7.7 c	5.8 b	6.0 ab
		Sunluck	65.4 bc	6.2 e	5.2 c	5.2 c
Three	Perlite	Anastasia	53.8 ef	6.4 e	5.2 c	6.4 a
		Nirpbredy	52.6 ef	5.6 f	4.4 e	5.5 bc
		Nirpinwin	60.1 d	6.9 d	4.8 d	6.3 a
		Sunluck	56.3 de	5.4 f	4.5 e	5.7 b
	Perlite/Coir dust	Anastasia	56.3 de	6.7 d	5.3 c	6.3 a
		Nirpbredy	57.5 de	6.2 e	4.4 e	6.0 ab
		Nirpinwin	63.8 cd	7.9 bc	5.0 cd	6.2 a
		Sunluck	62.3 cd	6.3 e	4.6 de	5.8 b
	Significance	Year (Y)	*	**	**	**
		Substrate (S)	*	*	ns	ns
		Cultivar (C)	**	**	**	ns
		Y x S	ns	ns	ns	ns
		Y x C	**	**	**	**
		S x C	ns	ns	ns	ns
		Y x S x C	*	*	*	ns

[z]Within a column, means followed by the same letter do not differ significantly using Duncan's multiple range test at *P*≤0.05.
ns = not significant, * = significant at *P*≤0.05, ** = significant at *P*≤0.01

third, while plants grown in perlite produced 11.7, 21.1 and 16.1 cut stems during the first, second and third year, respectively.

Among cultivars, 'Anastasia' showed the highest flower production (21.5 stems/plant/year) when cultured in perlite (18.9) as well as in the mixture (24.0), followed by 'Nirpbredy' (average across substrates of 18.7 stems/plant/year), 'Nirpinwin' (17.6) and 'Sunluck' (17.4) (**Fig. 3**). 'Anastasia' produced 17.6 stems/plant during the first year of cultivation, 27.7 in the second year, 19.2 in the third year and the difference between its yield and the overall production of the other three cultivars diminished by year three (+4.3, +4.7 and +1.7 stems/plant during the first, second and third year, respectively).

The annual variations of traits related to flower quality are reported in **Table 3**. Length of cut stems had a relatively constant value (overall average 61.6 cm) during the first two years of culture, but decreased in the third year (57.6 cm). Stems were overall longer in cut roses harvested in perlite/coir dust (63.7 cm) than in perlite alone (57.5 cm).

'Nirpbredy' was characterized by shorter stems (53.9 cm) than those produced by 'Anastasia' (59.7 cm), 'Sunluck' (62.3 cm) and 'Nirpinwin' (67.0 cm).

A progressive decrease of stem thickness was seen in pure perlite and the mixture from the beginning (average across substrates of 8.0 mm) to the end (6.4 mm) of the trial (**Table 3**). Cut stems from roses grown in perlite/coir dust were on average thicker (7.5 mm) compared to those harvested from plants cultured in perlite (6.8 mm); stem thickness was higher in the cultivars 'Anastasia' and 'Nirpinwin' (7.8 mm) than in 'Nirpbredy' and 'Sunluck' (6.8 and 6.3 mm, respectively).

Overall flower bud height in both growing media increased from the first to the second year (from 5.0 to 5.6 cm) of cultivation but diminished in the last year (4.8 cm) (**Table 3**). Bud height was comparable across growing media (overall average of 5.1 cm), but differed according to cultivar. 'Anastasia' had taller flower buds (5.7 cm) than 'Nirpinwin' (5.2 cm) and both were taller than 'Sunluck' and 'Nirpbredy' (4.8 cm).

Progressive increases of bud width (from 4.5 to 6.0 cm) in the tested substrates were annually recorded throughout the experiment (**Table 3**). No significant differences were found between the two substrates (5.6 and 5.8 cm for perlite and perlite/coir, respectively). No differences were recorded among the four cultivars (overall average of 5.7 cm).

DISCUSSION

Triennial rose yield response, characterized by an increase of flower yield from the first to the second year and by a decrease in the third one, is in line with results reported in a 2.5 year-study with gerbera on different substrates (Särkkä *et al*. 2008). Kool and Van de Pol (1996) report that during a normal 5 year cultivation cycle of greenhouse cut roses, the most productive years are generally the second and third. The trend of declining production within our experiment in year three would be expected to continue in subsequent years.

Different productive and qualitative outcomes of roses grown in perlite-based media over time are probably related to the evolution of the physical and chemical characteristics of the growing media throughout the cultivation period. Actually, numerous changes in main physical and hydrological properties of the tested substrates occurred during the 36-month culture: bulk density of both media increased while TPS significantly decreased (**Table 1**). Lower TPS was associated with a diminution in air content and an increase in water holding capacity and easy available water. These results are in line with outcomes recorded by Nowak and Strojny (2004) during an 18-month cultivation of gerbera in different substrates.

The coarse texture of perlite is likely altered (fragmented) during establishment (bag filling and transplanting) and cultivation, resulting in increasing rates of particles smaller than 3 mm in the substrate (Orozco and Marfa 1995). This alteration may lead to a decrease in the percentage of macropores (spaces containing water that is easily drained by the force of gravity) and an increase of micropores (spaces containing less easily drained water that consequently can increase the total available water content of the growing medium) (Samartzidis *et al*. 2005). The properties of perlite alone tend to be more stable over time than those of substrates including organic matter, although perlite alone is associated with reduced yield. The current study confirms the general opinion that inorganic substrates when used over extended periods of time tend to last longer (e.g. perlite for 5 years; Wilson 1988) than organic media (Bævre 1980) which are characterized by changeable biostability (Yoon *et al*. 2007).

Higher yields and greater quality for roses grown in perlite/coir dust than pure perlite during the three-year study support similar results recorded by other authors (Blom 1999; Maloupa *et al*. 2001) where inert and organic substrates were compared. Superior performance obtained with the coir mixture is most likely linked to the physical and chemical properties of coir dust. In particular, this material of plant origin has higher water holding capacity and CEC than perlite, factors important for plants during the more extreme environmental conditions typically experienced in the greenhouse during summer. Actually, the greater moisture level in the coir dust-based blend together with a sufficient degree of aeration may together contribute to establish an improved environment in the root zone that is also characterized by a higher content of nutrients.

Coir dust is produced in several tropical countries and has been shown to vary in physical properties according to the quantity of fibrous particles contained: increased fibre is generally associated with increased porosity and decreased bulk density and water holding capacity (Evans *et al*. 1996). Coir dust characteristics were investigated by multiple authors (Konduru *et al*. 1999; Nelson *et al*. 2004) who reported this material to be an effective substitute for sphagnum peat moss for many container crops. In fact, it may present some chemical and hydrological features (organic matter content, CEC and water retention) similar to peat, but with a higher pH and greater durability (Prasad 1997).

Perlite, on the other hand, is a relatively inert (low buffering capacity and CEC) aluminosilicate of volcanic origin characterized by a closed cellular structure. The majority of water is retained superficially and released slowly at a relatively low tension (Maloupa *et al*. 1992). Therefore, it provides excellent drainage of the medium and aeration of the rhizosphere, but requires frequent irrigation to prevent fast developing water stress.

Length of the growing period also affected the quality of cut roses produced. There was a progressive decrease in stem length, stem thickness and floral bud height from the start to the conclusion of the experiment. Särkkä *et al*. (2008) reported that prolonged cultivation of cut gerbera reduced the yield quality in all growing media tested. On the contrary, the continuous increase in bud width over the trial might be linked to its water potential which is generally higher than that of the stem and leaves (Plaut *et al*. 2006). Plaut *et al*. (2006) also reported increased flower bud width in roses that is linear with time, regardless of season, while stem elongation is logarithmic and then levels off.

This trial demonstrated the importance of cultivar selection for important productive and qualitative traits and, therefore, economic success. Depending on trait prioritization and pricing differentials for cultivars with superior traits, growers can make their choices accordingly.

To summarize, perlite/coir dust is more suitable for cut rose production than pure perlite during a three year soilless culture. The mixture results in higher yield and quality, even though perlite alone had greater physical and chemical

Appendix 1 Salts typology and used amounts for the preparation of the nutrient solution.

Salt	g/L
Iron-EDTA	0.04
Ammonium nitrate	0.15
Potassium nitrate	0.18
Calcium nitrate	0.4
Magnesium nitrate	0.15
Potassium monophosphate	0.5
Magnesium sulphate	0.6

Appendix 2 Total amount (**mg/L**) and recipe (single element amount and percentage) of micronutrients mid used for the preparation of the nutrient solution.

Micronutrients (commercial prepared mid)	41.0
Zn	2.0 (5%)
Mn	1.5 (4%)
Cu	0.4 (1%)
B	0.1 (0.4%)
Mo	0.04 (0.1%)

stability over time. So, further studies are necessary to test the effect of different perlite/coir ratios on rose response in order to find a combination that optimizes the balance between medium stability and productive and qualitative traits. Perhaps a reduced amount of coir dust in the mixture could be sufficient to ensure good yield and quality as well as a relatively long turn-over of plants and substrates.

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