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PREFACE

The technological innovation in biology and agriculture often leveraging on innovation in computer science and engineering, pushed forward the process of integration among these disciplines. In particular, information technology (IT) provides common methodologies and tools for the automatic acquisition and analysis of the data that concern the management and optimization of the natural and territorial resources.

In agriculture, applications of IT enable the integration of interventions concerning its sustainability and productivity, by offering methods and tools to monitor, control, analyse and optimize the production while keeping it respectful of the environment. Similarly, the best practices for bio sustainability, for the management of bio-diversity and for the bioremediation of the environment (including soil, water etc…) are also progressively adopting IT, which enable more focused (and thus more effective) applications.

In this context, the conference "Technologies and innovation for sustainable management of Agriculture, Environment and Biodiversity" (TI4AAB), was held in July 2016 at the Natural History Museum of the University of Pisa located in the Calci Charterhouse (Calci, province of Pisa) in order to encourage the sharing of emerging knowledge about the above topics.

In fact, the conference was dedicated to fostering innovative cross-disciplinary research and applications and to stimulating the exchange of strategies and experiences, among academic and company experts from different disciplines (agriculture, biology, computer science and engineering and environmental decision making), in order to encourage a common, interdisciplinary discussion about the adoption and perspectives of IT in modern agriculture, environmental management, biodiversity and bio-sustainability in general.

The conference was held under the auspices of the municipality of Calci, the University of Pisa and of the "Ordine dei Dottori Agronomi e Dottori Forestali". It was also attended and supported by some leading national and worlwide industries, like CAEN RFID, OSRAM, STMicroelectronics, EBV Elektronik, Qprel Srl, AEDIT Srl, EMipiace Srl, and Zefiro Ricerca & Innovazione Srl, and by the Italian National Forestry Authority.

This volume constitutes a selection of the contributions presented at the conference and cover the aspects of innovation in agriculture, biology, and applied information technology. In particular, concerning innovation in agriculture, the paper by Nin et al. studies new soilless cultivation systems for wild strawberry growing in the Tuscan Appennine mountains. The paper by Prisa describes experimental research concerning the use of zeolites in combination with effective microorganisms, in order to improve the quality of olive trees. Finally, the paper by Lombardo et al. describes collaborative approaches to innovation in agriculture (co-generation of technology).

Concerning innovation in biology, the paper by Baldacci et al. describes the results of the preliminary phases of the AIS-LIFE project, which aims at developing aerobiological information systems in order to improve pollen-related allergic respiratory disease management. Still concerning the AIS-LIFE project, the paper by Natali et al. aims to describe the strategy used in AIS-LIFE project, to evaluate daily pollen concentration in the atmosphere produced by many allergic plant species. The use of data and GIS system are shown as an approach to assess allergy risk maps.

Concerning innovation in computer science applied to agriculture and biology, two contributions focus on modeling approaches, and two contributions provide a survey of information technology applied to agriculture and biology. Specifically, the paper by Bodei et al. describes the application of the IOT-LYSA formal modelling framework to a possible scenario of grape cultivation, in order to assess water consumption, and the paper by Barbuti et al. proposes a mathematical model of artificial reefs, in order to study the dynamics of algal coverage and of populations of fish in some Italian artificial reefs. Finally, the paper by Fresco et. al. explores the current challenges and IT solutions in order to realize a digital agriculture framework, intended as an evolution from Precision Farming to connected knowledge-based farm production systems, and the paper by Pucci et al. provides a survey on biologging methodologies for the collection of knowledge about animals' behaviour, making a review of some related common data analysis techniques.

All papers have been carefully reviewed by experts in the specific fields. Here is the list of the reviewers, that we thank for the collaboration.

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EDGARDO GIORDANI (**)

INNOVATIVE TECHNOLOGIES FOR IMPROVED WILD STRAWBERRY PRODUCTION IN MARGINAL TUSCAN AREAS

ABSTRACT: S. NIN, W.A. PETRUCCI, M. DEL BUBBA, E. GIORDANI, *Innovative technologies for improved wild strawberry production in marginal Tuscan areas.*

The influence of soilless cultivation systems, year of production and cultivars on fruit yield and quality in wild strawberry (*F. vesca* L.) was studied. Peat-perlite mixture and grown bags filled with coconut-perlite were used as substrates in soilless culture. Performance of traditional field-grown plants (control) was compared to crop production on soilless media in open field and under protection during two production seasons. Strawberry yield was affected by the type of growing system, year and cultivar. Protected soilless culture produced significantly higher and/or earlier marketable yields. Production was highest for bag-grown 'Alpine' strawberries, but fruit appearance and quality was reduced compared to the control. Pomological parameters were differently affected by the considered factors. 'Alpine' gained a greater visual and organoleptic preference, resulting more suitable for soilless production.

KEY WORDS: *Fragaria vesca*; soilless cultivation, sustainability, fruit quality.

RIASSUNTO: S. NIN, W.A. PETRUCCI, M. DEL BUBBA, E. GIORDANI, *Tecnologie innovative per il miglioramento della produzione di fragoline di bosco in aree marginali in Toscana.*

Nel presente lavoro sono state valutate la produttività e la qualità di due cultivar di fragoline di bosco (*F. vesca* L.) in funzione di sistemi di coltivazione fuori suolo. Come substrato per la coltura fuori suolo sono stati impiegati un miscuglio di torba bionda/perlite e sacchi contenenti fibra di cocco/perlite. Il rendimento della coltivazione tradizionale in pieno campo (controllo) è stato comparato alla redditività dei sistemi fuori suolo all'aperto e sotto protezione durante due stagioni produttive. La resa è stata influenzata significativamente da tutti i fattori considerati. In coltura protetta fuori suolo la produzione di fragoline è risultata maggiore ed anticipata; la resa è stata massima per 'Alpine' allevata su sacchi, ma qualità e aspetto dei frutti sono risultati penalizzati rispetto al controllo. L'effetto esercitato dai fattori esaminati sui parametri pomologici è risultato invece molto diversificato. 'Alpine' ha ottenuto una maggiore apprezzamento visivo e organolettico, risultando più idonea per la coltura fuori suolo.

PAROLE CHIAVE: *Fragaria vesca*; coltura fuori suolo, sostenibilità, qualità dei frutti.

INTRODUCTION

Small fruits represent a valid sustainable alternative for marginal and inner areas of the Pistoiese Apennine Mountain, that may offer a high-quality production linked to the particular territorial context and at the same time an interesting additional income for family farms. In this study we focus on wild strawberry (*Fragaria vesca* L.), one of the most exclusive small fruits and a very important source of bioactive phenolics (Giordani *et al.*, 2016). *F. vesca* berries are widely and highly consumed fresh, in pastry-making and in processed forms, but are often difficult to find because of their small *s*cale production. Official data about cultivated country's land area have not been provided, but it's estimated that total acreage of land under *F. vesca* cultivation is actually about 100 hectares, being equivalent to about 400 t of annual production. Until now, successful commercial production has been developed in the most north of Italy where there is appropriate soil for wild strawberry growing, especially in the alpine zone of Piedmont and Trentino, between 400-1200 m a.s.l., where 'Regina delle Valli' is the main cultivated cultivar in open field with/without mini tunnel protection. Suitable land is found also in Sicily. A Slow Food Presidia has been set up for the integrated cultivation of the local variety 'Fragolina di Ribera' also called 'Fragolina di Sciacca'; cultivar 'Alpine' is also widespread in the southern island. In Lazio the wild strawberry cultivation is expanding in the surroundings of Rome with the variety 'Fragolina di Nemi'. In the middle west of the country, the most favorable soil and climatic

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conditions for growing some local ecotypes similar to 'Regina delle Valli' are found in the provinces of Salerno and Avellino (Doumett *et al.*, 2011). In Tuscany there are no cropped area devoted to this species, although soil type and climatic conditions would favour woodland strawberry. Considerable progress has been made recently in the development of economically viable soilless systems and a number of growers in suited areas of Trento and Marsala are using soilless culture commercially for the production in vases (on white peat, coconut, marc) of wild strawberry, the extend of which varies considerably and is not exactly documented. In fact, soilless culture is considered the most promising one for *F. vesca* commercial growing, since it offers more crops per year and enhanced off season production, reduction of labor requirement for harvest and easier harvest handling, cleaner fruit production, no need for soil sterilization, avoid of specific replant disease ('sick soil syndrome') (Cecatto *et al.*, 2013).

The aim of this study was to evaluate the potential of two soilless cultivation systems (both in open field and in greenhouse) in a healthy and suitable land for wild strawberry growing of the Tuscan Apennine zone to extend the marketing period of fresh strawberries, increase yield, facilitate the collection of healthy and clean fruits and improve their organoleptic quality.

MATERIALS AND METHODS

The decision to choose a growing system or soilless media depends on their cost, ease of use, and ability to enhance fruit quality and yields. In the present study two soilless open systems for wild strawberry (*Fragaria vesca*) production (based on different substrates) in open field and in greenhouse have been compared to traditional field cultivation, the last one considered in this experiment as the control. The study was performed in the private farm "Agraria il Sottobosco", located at Cireglio (PT) at about 500 m a.s.l. (N43°44.105'; EO12°06.013') in a harsh mountain territory without energy supply during 2011-2013.

Plant material

The everbearing wild strawberry (*Fragaria vesca*) varieties 'Regina delle Valli' (RGV) and 'Alpine' (ALP), both producing two crops, one in June - early July and another in fall, were used in the experiment. Frigo seedlings from Molari Nursery (Cesena) were used. Both cultivars are day neutral and do not produce runners. RGV is a vigorous old variety suitable for every conditions. Its fruit is extended and when it's ripe has a typical slightly green-colored tip. ALP, coming from California, has a bigger fruit compared to RGV and is more resistant to the root-diseases than other varieties. Both cultivars are largely cultivated in Italy.

Structure of the greenhouse

The experimental tunnel-greenhouse, with overall dimensions of 14 m × 8 m and maximum roof height of 3 m, covered 112 m^2. Constructed of galvanized steel structure supporting the tunnel roof, it was covered (both the roof and the walls) with a single layer of 4-year life UV-treated polyethylene (PE). Walls were provided with a pair of powered roll up side wall kits and the entrance had a sliding front door. Heat (for basal heating at 20-22°C) was provided by four solar heating panels of 3 m^2 each. A led tube lighting system emitting at 620-625 nm was installed over the culture ducts as supplemental lighting for off season crop growth in the greenhouse. The greenhouse was equipped with internal sensors as devices for measuring air temperature and humidity, and each duct was provided with a sensor for soil temperature, moister and conductivity. Photosynthetically active radiation, air temperature and relative humidity, rainfall and wind speed were hourly determined using a WatchDog 2700 weather station. All sensors were connected to a data logger for the data recording and storing over time and the broadcasting delivery in real-time of the information to both the scientific district and the place of farmer residence. The opening/closing of the lateral doors of the greenhouse were managed from any location provided by internet connection based on temperature and relative humidity sensors.

A phytoremediation system with a horizontal subsurface flow was built adjacent to the greenhouse for the removal of nitrogen and other water-soluble fertilizers present in the wastewater without side effects. Once the wastewater generated by crop cultivation in the greenhouse was drained from the substrate, it was accumulated in a well under the floor and subsequently introduced in the phytoremediation tub using hydrophyte plants, so called hyperaccumulators, like *Phragmites australis*, *Scirpus sp.*, *Typha latifolia*, *Iris pseudacorus* e *Schoenoplectus lacustris*, that have the ability to concentrate elements and compounds from the water and to metabolize various molecules in their tissues. Species were selected due to its ability to accumulate significant amounts of nitrogen, phosphorous and heavy metals on its roots. A wind turbine was installed close to the greenhouse to convert the wind's kinetic energy into electrical power.

Traditional open-field cultivation (control)

The open-field trial was carried out in a fallow land which was prepared with raised beds as soon as the ground could be worked in spring. Plants of strawberry cultivar RGV and ALP were planted in July 2011 in a fresh, acid soil rich in organic matter. The soil was also mulched with anti-algae mulching film. The plants were irrigated (1-2 times weekly with 1.5-2 l/m^2) using a dripping line (porous tube) along the rows, connected to a rain sensor, as a water conservation device that causes the automatic irrigation system to shut down in the event of rainfall. Plants were fertilized with organic manure (1.5 kg/m^2). All along the experimental period no methods for pest control was applied. In order to avoid the border effect influencing yield size estimation, one border row of strawberries was omitted during harvest from all sides of the experimental plots. Totally 312 plants (200 + 112 border plants) were planted at 30 x 100 cm spacing in 4 replicates, with 25 plants per plot in a randomized block design.

Open soilless cultivation systems

Two different substrates were used for the establishment of soilless culture: i) a mixture of white peat and perlite (both in open air and in greenhouse) and ii) grown bags filled with a mixture of coconut fibre and perlite (only in greenhouse).

i) Culture ducts made of heavy galvanized iron with a polyurethane based coating of 8 m length were used as containers for the substrate of peat and perlite. Duct's shaping had drainage channels at both sides to collect and convey at the end of the rows the excess solution. Transversal cross-section of the culture duct was trapezoidal, with the length of the bases of 8 and 30 cm and the height of 16.7 cm, providing a volume of 9 liter substrate for each plant. A plastic film lining was used to become watertight and chemically inert to the fertigation water flowing in it.

ii) Eight-meter long polypropylene ducts were used as support and draining structures for coconut/perlite grown bags. Bags had pre-cut plant and drainage holes.

All ducts were placed at a distance of 1.50 m from the level ground with a slope of 1:200 (5‰) for a good drainage of excess fertigation water. The spacing between adjacent duct's lines was 1 m. The automated drip irrigation system had laterals emitters in-line and plants received the same nutrient solution (based on a complete formulation with high biological activity, Az8 + Biomix) and volume with every irrigation cycle (flow rate of 0.5 l/min) throughout the growing season. Irrigation rates were applied according to soil volumetric water content registered by the moister sensors, rainfall was considered in open air cultures as well. The differences in nutrient consumption were due to different climate and soil conditions during the seasons. A total of 600 plants (100 per cultivar and soilless system) were transplanted in spring 2011, divided into 4 plots of 25 plants each, with a randomized block design.

Records

The efficiency of the soilless cultivation systems has been estimated both in terms of marketable plant yield (g/plant) and fruit quality (pomological and sensorial parameters). Finally, the sustainability of the various production processes has been derived from a cost-revenue analysis of the whole chain of wild strawberry production simulated over 10 years of activity.

Phenology and yield

One week after planting throughout all productive cycles, the phenological phases (onset/beginning of flowering, full bloom, fruit set and ripening) of the two strawberry cultivars were observed and the average yield (g/plant) as well as the amount of labor required for harvesting were registered weekly. Finally, cumulative plant yield was calculated over each harvesting season. Onset and full of flowering was recorded when at least 5% and 50% of flower buds, respectively, had bloomed.

Pomological evaluation

Observations on pomological characters (qualitative and quantitative) were scored each year for 20 ripe fruits per cultivar randomly selected from each cultivation system. Qualitative characters included fruit skin color, such as brightness (FSB) and chroma index (FSCI), flesh firmness (FFF) at the hardmeter, total soluble solids content (TSS) and total titratable acidity (TTA) of fruit flesh; while the considered quantitative characters were fruit height (FH), fruit diameter (FD), and weight of the fruit (FW). Also, some characteristics such as shape of the fruits and presence of defects were determined.

Statistics

Statistical analysis were performed using SPSS for windows version 22. The effects of cultivation system, year and cultivar were evaluated using one way ANOVA. Multiple comparison was done using Duncan's Multiple Range Test. Different at $p<0.01$ were considered to be significant.

RESULTS AND DISCUSSION

According to the climatic condition of the area of the Pistoia Apennines, mainly rainfall and temperatures, wild strawberry seedlings were planted in open air in early July and bloomed from August to September. Marketable fruit began ripening on mid September and finished by the end of October of the same year, while harvest occurred from the beginning of June till the end of July of the second and third year of production. Generally the fruit ripened within 45 to 60 days. Planting (early May) and blooming (June) were anticipated in open soilless culture, thus fruit ripening started on mid of July and continued throughout the summer for 80 days till the beginning of October of the first year of production. Hence, marketable production in year I occurred about 60 days earlier than in open field. In the greenhouse soilless cultivation systems it was possible to plant *F. vesca* seedlings in April and fruit harvesting occurred in the period of May-June of year I and in April-May of year II; fruit ripened within 30-45 days. Definitively, protected strawberry production allowed to harvest fruits about 90 days earlier in the first year of planting and approximately 60 days earlier in the second year compared to the control. Flowering in year II of indoor and outdoor strawberries began in February and April, respectively. A limiting factor was the lack of solar radiation that made it impossible to procrastinate the production in late autumn and winter. Productivity was strongly reduced in the third year of production, independently of the cultivation system, therefore a two-year profitable growing cycle was contemplated and only data of year I and II were considered for analysis of variance.

The productivity was significantly ($p < 0.01$) affected by the cultivation system, cultivar and year. In addition a statistically significant interaction between these factors was found. Plant yield was higher when strawberries were grown in the greenhouse, resulting in 32.6 g/plant and 75.8 g/plant on peat-perlite substrate and coconut grown bags, respectively (tab. 1), but plants grown in bags and in open field produced greater total plant yield over the whole marketable season. Differences between the years of production displayed a different trend according to the cultivation system: in contrast with the control, all soilless systems showed maximum yield in the first growing season. Besides the obvious role of the yearly productive season span, differences in the plant phytosanitary status might be the most plausible explanation for this result in the greenhouse, since lower yields may have been attributed to infestations of mildew and *Drosophila*. In 2-year experiment ALP strawberry yield was higher compared to RGV. Highest cumulative production (466.3 g/plant) occurred for indoor cv. ALP on grown bags, independently of the year of production (tab. 2).

All pomological parameters of wild strawberry were significantly affected ($p < 0.01$) by the cultivation system, except for pH and TTA (tab. 3). FW, FD and FH, all attributes related to fruit size, were also affected by the year and the cultivar, moreover a significant interaction between the considered factors was found for these traits. Compared to the control, fruit weight and diameter increased in greenhouse cultivation; while, predictably, plants grown under direct sunlight and especially control plants produced strawberries with higher FSCI, FFF and TSS content. The influence of cultivar on FFF and TTA was growing-system dependent (data not reported).

Yield is one of the basic factors which determine profitability of production, although the quality of yield is also important. Fruit production under protected cultivation, in comparison with outdoor cultivation (control), was higher, but fruits revealed a reduction in the accumulation of soluble solid, responsible for the intense sweetish impression of wild strawberries. Fruit color, firmness, aroma and fragrance were reduced, as well. In particular, strawberries obtained in coconut grown bags displayed the largest fruits (i.e. FW and FD, which are frequently used as measures of fruit size), but these were mostly lightly colored, deformed and affected by mildew.

In the world literature we found only few studies on the performance of wild strawberry cvs. D'Anna *et al.* (1994) reported August transplanting of cv. ALP in soil under an unheated plastic greenhouse in southern Italy to increase winter yields. In those pedoclimatic conditions, ALP featured an abundant and continuous reblooming process giving fruits spread over a period from December to May. A maximum cumulated fruit yield at the end of May of 1.6 kg/m^2 was achieved with double row crops and per unit investment of 8 $plants/m^2$, which might be inferred to correspond to ca. 200 g of cumulative plant production. This value was considered economically profitable and is comparable to our results obtained with a plant investment of 1.3 per m^2, although in our northern site climatic condition it was not possible to have off-season crop production during December - March. Average recorded fruit weight was 1.12 g, namely much lower than average values obtained under protection in our soilless trials.

Table 1 - Effects of principal factors on wild strawberry yield calculated over a two-year production cycle

Factor/Parameter	**PY (g/plant)**	**CPY (g/plant)**
Cultivation system:		
Traditional in open air (control)	29.4 ± 0.9 b	186.5 ± 15,7 b
Soilless in open air on peat/perlite	6.3 ± 1.4 c	65.0 ± 10.8 d
Soilless in greenhouse on peat/perlite	32.6 ± 1.6 b	148.1 ± 19.8 c
Soilless in greenhouse on grown bags	75.8 ± 1.8 a	291.0 ± 24.6 a
Year:		
1st year of production	39.8 ± 2.6 a	193.4 ± 26.6 a
2nd year of production	32.2 ± 2.8 b	151.9 ± 26.3 b
Cultivar:		
Regina delle Valli	20.3 ± 4.6 b	109.1 ± 16.2 b
Alpine	51.7 ± 3.2 a	236.2 ± 28.3 a
Main average	*36.0 ± 0.7*	*172.7 ± 14.4*

ns = non-significant; Means are given with standard deviation. Mean separation within columns by Duncan's multiple range test ($p < 0.01$). Legend: PY = Plant yield (g/plant); CPY = Cumulative plant yield over a growing season (g/pant)

Italian *F. vesca* production was examined by Faedi (1997) and plant yield was reported to vary between 100 and 300 g/plant per month according to growing season and plant density in the South (Sicily) and North (Trento) of Italy, respectively. In the South the cultivation covered the period from November to June (8 months) with 2-3 $plants/m^2$, while in the North the growing season was ex-

Table 2 - Effects of the interaction between cultivation system, year and cultivar on wild strawberry cumulative yield (g/plant) calculated over a two-year production cycle.

Cultivation system	**Cultivar**					
	Regina delle Valli			**Alpine**		
	1st year	**2nd year**	**Average**	**1st year**	**2nd year**	**Average**
Traditional in open air (control)	53.8	298.9	176.3 ± 9.8 b	59.5	333.7	196.6 ± 12.7 a
Soilless in open air on peat/perlite	74.2	46.3	60.2 ± 12.4 ns	95.3	44.4	69.8 ± 14.5 ns
Soilless in greenhouse on peat/perlite	120.4	47.5	83.9 ± 13.9 b	280.1	144.4	212.3 ± 23.6 a
Soilless in greenhouse on grown bags	153.4	78.1	115.8 ± 14.6	710.3	222.3	466.3 ± 25.8 a

Means are given with standard deviation. Mean separation within rows by Duncan's multiple range test ($p < 0.01$).

Table 3 - Effect of the cultivation system on pomological parameters of wild strawberries

Cultivation system	FW (g)	FD (mm)	FH (mm)	FSCI	Fruit FSB	FFF (g)	TSS (°Brix)	pH	TTA (meq/100 g)
Traditional in open air (control)	1.3 ± 0.2 c	13.3 ± 2.9 c	18.0 ± 3.2 a	46.7 ± 6.6 a	39.7 ± 5.1 c	49.0 ± 12.6 a	10.1 ± 1.7 b	3.6 ± 0.2 ns	11.6 ± 3.1 ns
Soilless in open air on peat/perlite	0.9 ± 0.3 d	11.5 ± 1.8 d	17.2 ± 3.2 b	46.4 ± 13.9 a	39.0 ± 8.3 c	37.7 ± 10.9 b	11.1 ± 1.7 a	3.5 ± 0.2 ns	13.0 ± 3.3 ns
Soilless in greenhouse on peat/perlite	1.5 ± 0.5 b	15.1 ± 2.8 b	16.4 ± 3.0 c	39.6 ± 5.5 b	42.2 ± 6.0 b	35.3 ± 8.0 b	8.1 ± 1.3 c	3.6 ± 0.2 ns	14.1 ± 1.1 ns
Soilless in greenhouse on grown bags	1.9 ± 0.4 a	15.8 ± 3.3 a	17.0 ± 2.9 bc	40.5 ± 6.9 b	45.5 ± 6.2 a	39.0 ± 9.7 b	8.3 ± 1.4 c	3.6 ± 0.1 ns	12.1 ± 3.4 ns
Main average	*1.4 ± 0.2*	*13.5 ± 3.1*	*17.4 ± 3.2*	*43.3 ± 6.0*	*41.3 ± 5.9*	*39.5 ± 9.4*	*9.6 ± 1.6*	*3.6 ± 0.2*	*12.4± 1.7*

Means are given with standard deviation calculated for 40 fruits per cultivation system. Mean separation within columns by Duncan's multiple range test ($p < 0.01$). ns = non significant. Main averages (in italic) represent the mean and its SD calculated for 160 fruits.

tended to September with 3-5 plants/m^2. Similar RGV fruit yield has been obtained in polyethylene vases raised above the ground under protection in Sicily with a density of 2 plants/m^2 during 8 months (Bonomo, 2003). Caruso *et. al.* (2004) studied RGV under plastic tunnel using the nutrient film technique (NFT) in Campania region, but in this study no plant yield information are given. Finally, Preeda *et al.* (2009) reported significant difference in fruit yield among 9 cultivars tested in forcing culture, with cv. 'Alba' showing the highest value of 183.4 g of total yield over 5 months when planted in autumn, but the authors didn't specify both plant density and climatic condition of experimental site. It is evident that the few available information related to cropping systems and productivity are not easy to compare because of different applied plant density, planting time, light and temperature conditions, chemical fertilizers, but also because of different times of measurements of total plant fruit weight per week used.

Differences in cultivar performance were not particularly evident when they were grown in open air. On the contrary, ALP strawberries gave higher yield compared to RGV and were less affected by biotic and abiotic stresses in protected culture, resulting to be more suitable for soilless cultivation systems according to D'Anna *et al.* (1994). This can be related to the fact that bud differentiation of ALP is accomplished along the entire crop season allowing an uniform fruit growth. For its low sensitivity to photoperiod and temperature, ALP represents a good choice under protected cultivation. Moreover, ALP fruits gained a greater visual and organoleptic preference, both in traditional and soilless cultivation systems. Other recently introduced cultivars including 'Cecilia', (similar to ALP), 'Elba' (with very compact fruits), 'Heidi' (highly productive, with runners) should be tested in soilless culture as well.

Early forcing in greenhouse might ultimately permit the production of high early marketable wild strawberry fruit yield through a careful evaluation of the planting date and cultivar. The use of ducts for soilless production provided benefits for the grower, as it kept the fruit clean and made collecting easier. In fact, harvesting, which represents the most labor-intensive activity of *F. vesca* growing season, was reduce to a great extend in soilless systems (from 5,220.00 Euro for the traditional soil system to 940,00 and 490,00 Euro for the outdoor and indoor soilless system, respectively over a 10-year period). On the turn, fruit quality was reduced mainly due to insufficient diurnal light, humidity condensation on plants, reduced pollination, incidence of insect and disease pest. Thus, before wide scale applications are adopted, further investigation is needed in order to optimize the fertilization level, to adjust planting date according to light and temperature conditions and to control interactions between plant and environment. Other research confirms the vital importance of fertilization in greenhouse strawberry production which affects both fruit yield and quality (Anttonen *et al.*, 2006). Also supplementary light an temperature may have a significant impact on fruit yield and quality as reported for strawberry (*F. x ananassa*) (Watson *et al.*, 2002; Wang *et al.* 2011). Moreover, LED's and their spectral property have been reported to have a great potential for crop production (Massa *et al.*, 2008), but the effect of light quality has never been investigated on strawberries up to now.

The performance of the tunnel-greenhouse in the considered territorial area was adequate. The solar panel turned the light energy into useful heat used by the basal heating system to maintain the substrate temperature constant at ca. 18-20 °C over the coldest months (October-February), while the automatic opening system of the side walls kept the air temperature during the warm summer months (June-August) under 30 °C, which is the maximum limit of tolerance for strawberry growth. The remote control was perfectly working and enabled the distance modulation of heating and opening of lateral doors. The use of hydrophytes plants adjacent to the greenhouse for the absorption of the mineral salts given in fertigation reduced its concentration in the waste water. The analysis of the nutrient solution in entrance of the ducts showed a pH value of 6.8 and an electrical conductivity (EC) of 440 µS/cm, while those in output accumulated in the well varied from a minimum of 550 to a maximum 1080 µS/cm; the output water from the phytoremediation tub showed an EC of ca. 46 µS/cm. The energy consumption of the greenhouse structure was about 600 kWh per year, equal to an average of about 50 kWh/month, while average energy produced by the wind turbine was nearly the triple, ca. 150 kWh/month.

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