

## Evaluation of yield and yield components of lamb's lettuce (*Valerianella locusta*) grown in thin layer soilless systems

DRAGAN ŽNIDARČIČ

Department of Agriculture, Faculty of Biotechnical, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia. Tel./Fax. +385-1320-227, email: dragan.znidarcic@bf.uni-lj.si

Manuscript received: 22 April 2016. Revision accepted: 10 May 2016.

**Abstract.** Znidarcic D. 2016. Evaluation of yield and yield components of lamb's lettuce (*Valerianella locusta*) grown in thin layer soilless systems. *Nusantara Bioscience* 8: 89-93. Growth and development of lamb's lettuce (*Valerianella locusta* L.) have been studied on thin layer soilless systems in plastic greenhouse on the Laboratory field of Biotechnical Faculty, University of Ljubljana. The trial lasted from 23<sup>rd</sup> of February till 10<sup>th</sup> of March 2016. The experiment was included cultivar 'Ljubljanski'. Four different substrates have been used: expanded clay aggregate, perlite, vermiculite, and peat. Seedlings were transplanted at distance of 10x10 cm. At the harvest the following parameters were measured: leaves fresh and dry yield, plant height, number of leaves per plant and the nitrate-N content in leaves. The overall effect of the type of substrate on lamb's lettuce growth and yield in the present experiment suggests that the examined materials are suitable substrates for lamb's lettuce soilless cultivation production. The outcomes of the research point to the fact that the lamb's lettuce in perlite treatments brings greater fresh yields compared to the other inert substrates. On the other hand, peat produced higher leaf dry mass as compared to other substrates. A quantitative analysis of the nitrate-N content in leaves showed that the peat is the most effective substrate in terms of low plant nitrate concentration.

**Keywords:** Lamb's lettuce, nitrate-N content, *Valerianella locusta*, yield, yield components

### INTRODUCTION

Consumption of horticultural food crops has increased over the last few decades, especially as a result of changes in the consumer's nutritional behavior (Ferrante and Maggiore 2007). Martín-Diana et al. (2011) pointed out, that consumers are more concerned about staying healthy and eating correctly.

Previous studies show that fruits and vegetables are a food source of several bioactive compounds (i.e. phytochemicals) (Hudina et al. 2012). Phytochemicals that possess antioxidant characteristics are believed to contribute to the improvement of human health and disease prevention (Dorais 2007). For example, leafy vegetables generally are a rich source of potent antioxidants (Negi and Roy 2000). Antioxidants are agents, which scavenge the free radicals and may, therefore, help delay or prevent oxidative damage (Subhasree 2009). It has been also shown that leafy vegetables are a valuable part of the diet owing to their nutritive values (Ali et al. 2009).

Lamb's lettuce (*Valerianella locusta* L.) is becoming increasingly popular as a fresh leafy vegetable. This vegetable is one of the crops more produced in winter months, because do not require high temperature and has easy preparation in the alimentation human (Žnidarčič and Kacjan-Maršič 2008). Despite a relatively large market for lamb's lettuce, alternative cultivation techniques such as hydroponics have not been sufficiently considered for improving its yield and quality (Osvald et al. 1998).

Over the recent two decades, hydroponic growing systems have become increasingly popular among

European commercial growers since they improve quantitative and qualitative characteristics of the final product. In comparison with traditional cultivation techniques in soil, the hydroponics has a lot of advantages. Most important are: production is very intensive, higher yields, crop-rotation is abandoned, less problems with pests and diseases, better crop quality if optimal nutrient solution is used, lower production costs and better control of the cultivation process. Major disadvantage of hydroponic production is that it demands a lot of knowledge and assets (Albaho et al. 2008).

There are many types of hydroponic systems which use a variety of substrates: rock wool culture, NFT – Nutrient Film Technique, PPH – Plant Plane Hydroponics, VPH – Vertical Hydroponic Systems, aeroponics, water beds ...

Osvald et al. (1998) described thin layer system as a cultivation technique with a thin layer of growing substrate (2 to 10 cm). Some inorganic substrates such as perlite, vermiculite or rock wool are used as solid substrates, as well as some organic substrate such as peat moss and wood fibers. The substrate is sandwiched between two sheets. The top sheet is made from white polyethylene and helps reduce evaporation of the nutrient solution. The nutrient solution is delivered at the top level of the cultivation area (Schröder 1994).

Research results indicate that growing leafy vegetables on soilless culture system is successful and interesting due to equal or even higher yield than in deep soil (Kacjan-Maršič-Osvald 2002). However, selecting the suitable growing substrate is imperative for production of high-quality vegetable crops. It is also important that the

cultivated plants get the appropriate amount and compound of nutrient solution according to the illumination and temperature. For appropriate drainage of the nutrient solution, it is important to have slope in a row and drain reservoir. Osvald et al. (1998) mentioned that thin layer soilless systems can be settled for a short production period in winter, in a place which well illuminated.

To the best of our knowledge, however, there is little information available in literature regarding the production of lamb's lettuce in thin layer systems under greenhouse conditions. Therefore, the aim of this study was to determine the effects of different growing substrate on the yield, biometric characteristics, and quality of lamb's lettuce.

## MATERIALS AND METHODS

The experiment was undertaken in a multi-span greenhouse covered with double PE-film and passive climate control on a laboratory field of the Biotechnical Faculty in Ljubljana, Slovenia (46° 04' N, 14° 31' W, 300 m asl.). The plants were grown under natural daylight condition, without additional illumination.

The treatments consisted of four growing substrates using vermiculite (grade 3-4 mm), peat (Humin substrate N2 Neuhaus), perlite (grade 2-5 mm) and expanded clay aggregate (grade 8-16 mm). The cultivar used was the commercially available 'Ljubljanski' (Semenarna, Ljubljana; Slovenia), which is the most popular in Slovenia. The experimental area was arranged in completely randomized block design with three replications and it was surrounded by border rows.

On the 23<sup>rd</sup> of February 2016, after 25 days in the seedbed, the plants (when the seedlings were about 3 cm in height) were transplanted in respective substrate. Seedlings were transplanted at distance of 10x10 cm.

The thin layer system was set up on bed, with a 2% longitudinal slope for the outflow of the nutrient solution in the drain channel. The ground was covered with a black PVC film. The cultivation area was divided into 12 plots that were separated with wooden barriers, to avoid the mixture of substrates. The dimension of each plot was 1m x 1m. The substrates were evenly strewed on the PVC film at a thickness of 5 cm, so there were 50 liters of substrate per plot. At the lowest point of each plot there was a drainage channel, with a slope towards the nutrient surplus collector tank. On the upper end of each plot, we left a 10 cm wide passage uncovered, with substrates, for adding nutrition solution.

Sonneveld nutrient solution with some modifications (more K and N, less Ca) was used. The nutrients were mixed with tap water (200 mL stock solution + 50 mL Ca(NO<sub>3</sub>)<sub>2</sub> for 12 L H<sub>2</sub>O). During the trial, the quality of nutrient solution was observed twice a week and adjusted as needed. The electrical conductivity value was measured with a portable EC meter and kept up around 1.9 mS cm<sup>-1</sup>. The pH of the solution was measured with a pH meter and balanced between 5.5 to 6.5 by addition of 30% sulphuric acid. Solution was aerated with an air pump and applied via

T-tape tube (T-tape TSX 500 Model, T-systems International) at the upper side of the plots. It was delivered on average three times per day according to the plant development stage and the weather conditions. General agricultural procedures were followed as used in commercial lamb's lettuce production.

Average minimum and maximum temperatures of 6.4 and 21.1°C, respectively, and average minimum and maximum relative humidity of 54.4 and 89.8%, respectively were recorded during the experiment. The average global radiation (GR) in day time was approximately 13.8 MJ m<sup>-2</sup> (Table 1). The data was obtained from a weather shelter located half meter above the flats at the center of the experiment benches.

At the end of 47-day culture experiment, a sample of 20 random plants from each replicate was taken to obtain yield (fresh and dry mass of leaves) and biometrical characteristics (number of leaves and rosette height). Leaf sub-samples for dry matter determination were oven-dried at 60°C in a ventilated oven to constant weight. In addition, the effects of different substrates on the nitrate-N content in leaves have also been investigated. The nitrate ion content was measured photometrical by an AutoAnalyzer II, SFA – Segment Flow Analysis system (Kmecl and Žnidarčič 2015).

## RESULTS AND DISCUSSION

### Nutrient solution

During the growing period overwatering was used to ensure sufficient irrigation of plants and to stabilize nutrient content of the substrate. However, at the end of the growing period, the plants needed more nutrient solution for growth and development. In the current experiment, we added a total of app. 840 L of nutrient solution, which is app. 70 L to each parcel. The highest volume of the drain nutrient solution was in peat (app. 4.6 L parcel<sup>-1</sup>) and the lowest volume was in clay aggregate (app. 3.8 L parcel<sup>-1</sup>). The highest average conductivity value was in drain nutrient solution with peat (4.6 mS cm<sup>-1</sup>) and the lowest average value was with vermiculite (2.9 mS cm<sup>-1</sup>). With pH measurements of the drain nutrient solution, the highest average value was in perlite (8.1). At high pH value was also present in drain nutrient solution from vermiculite (8.0). A lower pH value was measured in drain nutrient solution from the peat (7.4). In all substrates, all pH values of the drain nutrient solution were higher than in the added nutrient solution (data not shown).

**Table 1.** Some climatic data recorded in the greenhouse during the experimental period

Day	Tmin (°C)	Tmax (°C)	RHmin (%)	RHmax (%)	GR (MJ m <sup>-2</sup> )
1-10	3.8	15.6	52.3	95.2	10.5
10-20	6.2	20.3	48.6	92.1	12.6
20-30	7.1	23.6	55.4	87.5	15.4
40-47	8.6	24.8	61.5	84.7	16.7

### Leaves fresh mass

At harvest, the plants showed excellent visual quality in all treatments. No symptoms of nutrient disorders or water stress were recorded. Moreover, choice of substrate made a substantial impact on the rate of plant development. In general, the plants grown in the perlite were much higher and heavier than that grown in other substrates.

The data showed that different growing substrates had a significant effect on the lamb's lettuce leaves fresh mass (Figure 1). Perlite showed significantly higher mean fresh mass compared with the other substrates. Our findings agree with previous investigations, which have been reported that perlite has excellent performance when used as a substrate in hydroponic culture (Djedidi et al. 1997). For example, in similar studies in tomato (Martinez and Abad 1992), melon (Radhouani et al. 2010), watermelon (Yetişir et al. 2006), cucumber (Kacjan-Maršič and Jakše 2010) and strawberry (Jafarnia et al. 2010), it was showed that perlite had better results than other types of substrates. Kacjan-Maršič and Jakše (2010) mentioned that better performance of perlite compared to other substrates can be related to higher water holding capacity. The low water holding capacity characterized for some substrates might have decreased the humidity in rooting zone (Gül et al. 2007). On the other hand, perlite which is one of the most popular artificial growing substrate worldwide, has also provides improved aeration ability, powerful capillarity, and low heat conductivity when compared to other substrates (Gül and Sevçican 1994). Furthermore, perlite is physically stable and growers could use it for more than one growing cycle.

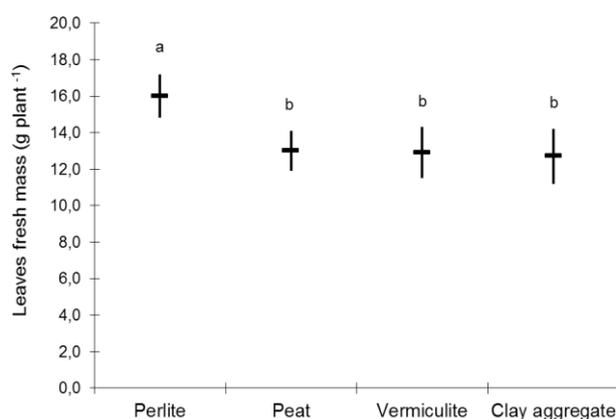
### Leaves dry mass

Dry matter accumulation in leaves was significantly affected by type of substrate (Figure 2). Peat substrate produced higher leaf dry mass as the other substrates. The clay aggregate resulted in significantly lowest leaf dry mass. These findings are not in agreement with data obtained by previous researches. For example, Fotouhi Ghazvini et al. (2007) pointed out that low water retained in substrate decreased plant water level, which caused an increase of dry weight. On the other hand our results agree with those from Islam (2008) for tomatoes who reported that organic substrate produces higher leaf dry matter as compared to other substrates. However, it should be mentioned that the major drawback of peat is that it decomposes over a period of time. Thus, the grower must be aware of not only the growth of the plant but the changes in the substrate.

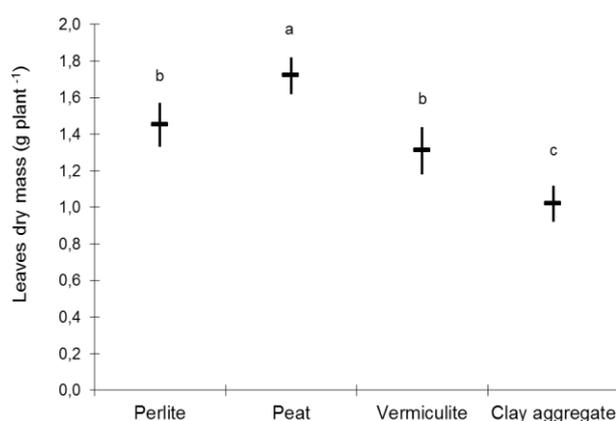
### Yield components

As a function of plant growth, leaves number per plant was significantly affected by substrates. As the previous report mentioned 40, numbers of fully expanded leaves often reflect the technological maturity of lamb's lettuce plants. The data of leaves number is depicted in Figure 3.

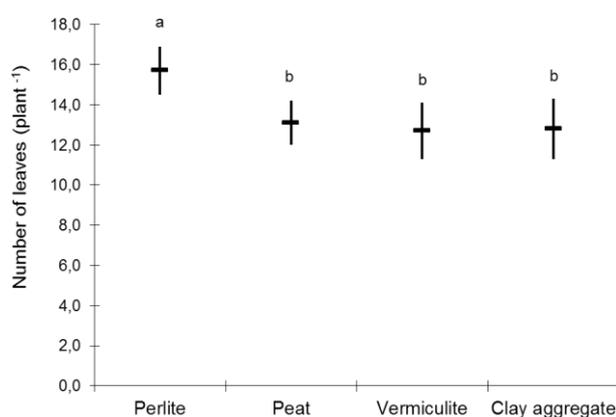
Our result showed that a perlite substrate significant increased the number of leaves per plant. After harvest, it was also noticed that leaves from plants grown in perlite were significantly higher (Figure 4), than those from other



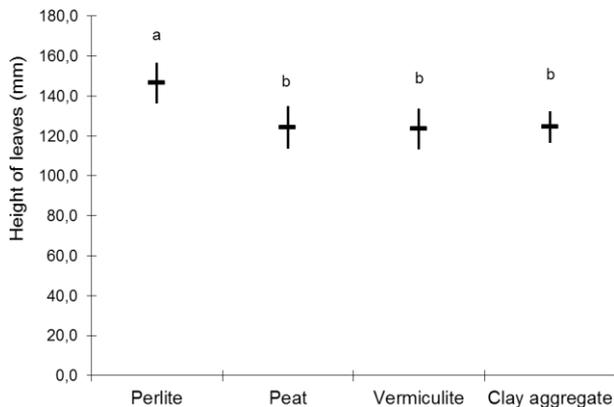
**Figure 1.** The lamb's lettuce fresh mass (g plant<sup>-1</sup>) depends on soilless substrate. Means with the same letter are not significantly at  $p \leq 0.05$ . The vertical bars represent  $\pm S.E.$



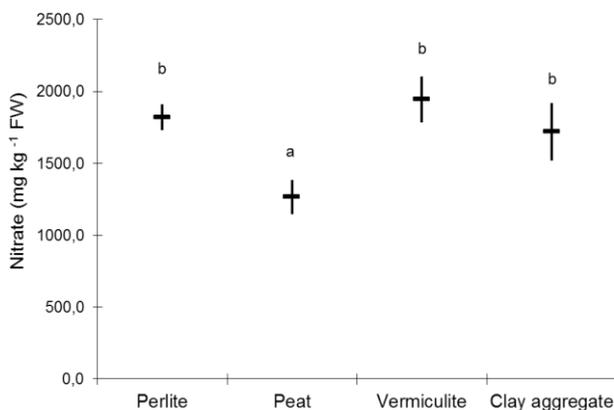
**Figure 2.** The lamb's lettuce dry mass (g plant<sup>-1</sup>) depends on soilless substrate. Means with the same letter are not significantly at  $p \leq 0.05$ . The vertical bars represent  $\pm S.E.$



**Figure 3.** The number lamb's lettuce leaves (plant<sup>-1</sup>) depend on soilless substrate. Means with the same letter are not significantly at  $p \leq 0.05$ . The vertical bars represent  $\pm S.E.$



**Figure 4.** The height lamb's lettuce leaves (mm) depend on soilless substrate. Means with the same letter are not significantly at  $p \leq 0.05$ . The vertical bars represent  $\pm$ S.E.



**Figure 5.** The lamb's lettuce nitrate content (mg kg<sup>-1</sup> FW) depends on soilless substrate. Means with the same letter are not significantly at  $p \leq 0.05$ . The vertical bars represent  $\pm$ S.E.

substrates. This explains why experiment showed significance in mean fresh mass yield from plants grown in perlite. However, leaf number and rosette height were significantly correlated with leaves fresh mass yield,  $R = 0.82$  and  $R = 0.84$ , respectively (data not shown).

#### Nitrate-N content

The concentration of nitrogen compounds in fresh yield of lamb's lettuce is another important parameter of the lamb's lettuce quality besides the biometrical characteristics. According to the literature (Tamme et al. 2006), the accumulation of nitrate in plants depends on their genetic characteristics as well as on environmental factors (atmospheric humidity, temperature, day or light intensity, photoperiod) and agricultural factors (type of soil, temperature or water supply, harvesting time, nitrogen supply and chemical forms, availability of other nutrients, use of herbicides). All factors influencing the nitrate uptake, translocation and assimilation processes may affect nitrate concentration in plant tissue (Mirecki et al. 2015).

Nitrate, once ingested, may be converted to nitrite, resulting in the formation of a compound, harmful to human health (methemoglobinemia and nitrosamines). Acceptable leaf nitrate concentrations in vegetables are set by legislation. For example, guidelines have been set for nitrate content for lamb's lettuce in Germany (2.500 mg NO<sub>3</sub> kg<sup>-1</sup> fresh weight) and Belgium (3.500 mg NO<sub>3</sub> kg<sup>-1</sup> fresh weight) (Santamaria 2006).

As we have seen in Figure 5, the nitrate content was significantly lower in the leaves of plants grown in peat than that in other substrates. This observation indicated that the nitrification in organic substrate was seriously inhibited. According to Bill et al. (2010), the difference of nitrification between in organic and inorganic substrates should be attributed to the difference of the porosity between those substrates because the inorganic substrates are very porous and rich in O<sub>2</sub>.

In conclusions, the development of soilless culture for vegetables in Slovenia is strongly linked to the accurate choice of growing media from technical, economical and ecological reasons. Our experiment indicates that lamb's lettuce production in greenhouse on artificial substrates could be an alternative at the soil culture because it allows the possibility of improved yields and provides better management of inputs, adapted to specific conditions of substrates.

#### REFERENCES

- Albaho M, Thomas B, Christopher A. 2008. Evaluation of hydroponic techniques on growth and production of greenhouse-grown beet pepper and strawberry. *Intl J Veg Sci* 14: 23-40.
- Ali MB, Khandaker L, Oba S. 2009. Comparative study of functional components, antioxidant activity and color parameters of selected colored leafy vegetables as affected by photoperiods. *J Food Agric Environ* 7: 392-398.
- Bill G, Evans WB, Spiers JM, Witcher LA. 2010. Effects of organic and inorganic fertilizers on marigold growth and flowering. *HortScience* 45: 1373-1377.
- Djedidi M, Grasopoulos D., Maloupa E. 1997. The effect of different substrates on the quality of Carmello tomatoes (*Lycopersicon esculentum* Mill.) grown under protection in a hydroponic system. *Cahiers Options Mediterranean* 31: 379-383.
- Dorais M. 2007. Effect of cultural management on tomato fruit health qualities. *Acta Hort* 744: 279-293.
- Ferrante A, Maggiore T. 2007. Chlorophyll a fluorescence measurements to evaluate storage time and temperature of *Valerianella* leafy vegetables. *Postharvest Biol Technol* 45: 73-80.
- Fotouhi Ghazvini R, Peyvast G, Azarian H. 2007. Effect of clinoptilolite-zeolite and perlite mixtures on the yield and quality of strawberry in soil-less culture. *Intl J Agr Biol* 9: 885-888.
- Granado-Lorenzo F, Olmedilla-Alonso B, Herrero-Barbudo C, Blanco-Navarro I, Pérez-Sacristán B, Blázquez-García S. 2007. In vitro bioaccessibility of carotenoids and tocopherols from fruits and vegetables. *Food Chem* 102: 641-648.
- Gül A, Kidoğlu F, Anaç D. 2007. Effects of nutrient sources on cucumber production in different substrates. *Sci Hort* 132: 216-220.
- Gül A, Sevgican A. 1994. Suitability of various soilless media for long-term greenhouse tomato growing. *Acta Hort* 366: 437-444.
- Hudina M, Štampar F, Oražem P, Mikulič Petkovšek M, Veberič R. 2012. Phenolic compounds profile, carbohydrates and external fruit quality of the 'Concorde' pear (*Pyrus communis* L.) after bagging. *Can J Plant Sci* 92: 67-75.
- Islam S. 2008. Evaluating performance of ecologically sound organic substrates under different temperature regimes. *Intl J Agr Biol* 10: 297-300.

- Jafarnia S, Khosrowshahi S, Hatamzadeh A, Tehranifar A. 2010. Effect of substrate and variety on some important quality and quantity characteristics of strawberry production in vertical hydroponics system. *Adv Environ Biol* 4: 360-363.
- Kacjan-Marsic N, Jakse M. 2010. Growth and yield of grafted cucumber (*Cucumis sativus* L.) on different soilless substrates. *J Food Agric Environ* 8: 654-658.
- Kacjan-Maršič N, Osvald J. 2002. Effects of different nitrogen levels on lettuce growth and nitrate accumulation in iceberg lettuce (*Lactuca sativa* var. *capitata* L.) grown hydroponically under greenhouse condition. *Gartenbauwissenschaft* 67: 128-134.
- Kmeck V, Žnidarčič D. 2015. Accreditation of the analytical method used for nitrate determination in vegetables. *Arch Biol Sci* 67: 295-302.
- Martín-Diana AB, Rico D, Barry-Ryan C, Frías JM, Henehan GTM, Barat JM. 2007. Efficacy of steamer jet-injection as alternative to chlorine in fresh-cut lettuce. *Postharvest Biol Technol* 45: 97-107.
- Martinez PF, Abad M. 1992. Soilless culture of tomato in different mineral substrates. *Acta Hort* 323: 251-259.
- Mirecki N, Ilić SZ, Šunić Lj. 2015. Nitrate content in carrot, celeriac and parsnip at harvest time and during prolonged cold storage. *Fresenius Environ Bull* 24 (10): 3266-3273.
- Negi PS, Roy SK. 2000. Effect of blanching and drying methods on beta-carotene, ascorbic acid and chlorophyll retention of leafy vegetables. *Food Sci Technol* 33: 295-298.
- Osvald J, Gantar M, Petrovic N. 1998. Hydroponic growing lettuce (*Lactuca sativa* L.) using a thin layer system with different substrates. *Res Rep Biotech Fac* 71: 151-158.
- Radhouani A, Bekkay ME, Ferchichi H. 2010. Effect of substrate on vegetative growth, quantitative and qualitative production of muskmelon (*Cucumis melo*) conducted in soilless culture. *Afr J Agric Res* 6: 578-585.
- Sanatamaria P. 2006. Nitrate in vegetables: toxicity, content, intake and EC regulation. *J Sci Food Agric* 86: 10-17.
- Schröder FG. 1994. Technological development, plant growth and root environment of the plant plane hydroponic system. *Acta Hort* 361: 201-209.
- Subhasree B, Baskar R, Laxmi Keerthana R, Lijina Susan R, Rajasekaran P. 2009. Evaluation of antioxidant potential in selected green leafy vegetables. *Food Chem* 115: 1213-1220.
- Tamme T, Reinik M, Roasto M, Juhkam K, Tenno T, Kiis A. 2006. Nitrates and nitrites in vegetables and vegetable-based products and their intakes by the Estonian population. *Food Addit Contam* 23: 355-361.
- Yetişir H, Sari N, Aktaş H, Karaman C, Abak K. 2006. Effect of different substrates on plant growth, yield, and quality of watermelon grown in soilless culture. *Am.-Eurasian J Sustain Agric* 1: 113-118.
- Žnidarčič D, Kacjan-Maršič N. 2008. Corn salad (*Valerianella olitoria* L.) yield response to cell size of plug trays. *Acta Agric Slovenica* 91: 59-66.