

Effect of hydroponic and peat-free media in transplant production of *Rudbeckia hirta* varieties under different photoperiodic lighting and their photosynthetic parameters

Antal, G.¹, Kurucz, E.¹, Koncz, K.¹, Kaszás, L.² & Fári, M. G.²

¹University of Debrecen, Faculty of the Agricultural and Food Sciences and Environment Management, Institute of Horticulture, 138. Böszörményi str., Debrecen, H-4032, Hungary

²University of Debrecen, Faculty of the Agricultural and Food Sciences and Environment Management, Department of Applied Plant Biology, 138. Böszörményi str., Debrecen, H-4032, Hungary

Author for correspondence: antal.gabriella@agr.unideb.hu

Summary: The purpose of this research was to determine the effects of varieties, different light conditions (short day, long day, natural short day with light pollution), and different growing media (perlite, peat-free, peat-based, aeroponics system) on *Rudbeckia hirta* plant production under controlled conditions (greenhouse). The morphological effects of each treatment (photoperiodic lightings and media) on different *Rudbeckia* varieties determined at 11 weeks-old 'Nápfény', 'Toto Gold', 'Autumn Colors', 'Prairie Sun' and 16 weeks-old 'Nápfény'. Plantlets received 12 hours daylight did not initiate flowers, remained stage of the leaf rosette in case of all varieties. The 14 hours light treatment in the aeroponics system and the same treatment in perlite and control (natural short day with 14 hours light pollution) plantlets had developed inflorescences or flower buds. The inflorescence axis of 'Nápfény' was appeared at 13 weeks under long-day conditions, with 1.7 (perlite) - 2.7 (aeroponics) flower buds in 16 weeks. 'Toto Gold', 'Autumn Colors', 'Prairie Sun' varieties developed inflorescences at 8 weeks, 14 hours aeroponics system resulted in the most of flower buds ('Toto Gold': 6.5, 'Autumn Colors': 3.25, 'Prairie Sun': 4.8 flower buds) at 11 weeks. Long daylight manipulation could be minimized crop times and achieved flowering potted plants at 11 weeks. The peat-based and peat-free media effect was observed on 'Autumn Colors'. The number of leaves of peat-free 'Autumn Colors' transplants (16.8-20.3) was significantly higher than peat-based media (13.5-15.5). Other morphological parameters were not affected by the media treatments.

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Key words: *Rudbeckia hirta*, photoperiodic lighting treatment, peat-free media, aeroponics system, seedlings cultivation, photosynthetic pigment content

Introduction

The genus *Rudbeckia* consists approximately 30 annuals, biennial and perennial species, and it belongs to *Asteraceae* family (Palmer et al., 2009). *Rudbeckia hirta* L. (black-eyed Susan) is a native species in North America, it has been known as an annual ornamental plant (flowerbed, pot/container plants, cut flower). *Rudbeckia hirta* contains numerous flavonoid-, anthocyanin compounds, phenolic acids, etc. (Luczkiewicz & Cisowski, 2001; Hambäck, 2001; Michael, et al., 2014), traditionally it has been utilized as medicinal plant (e.g. colds, earache, sores or snakebites etc.) (Harkess & Lyons, 2019; Brakie, 2019). *Rudbeckia* species as long day plants are required for flower initiation more than 13 hours lighting per day. Numerous *Rudbeckia* species and varieties have been reported in experiments of photoperiodic and flowering treatments: *R. bicolor* var. *superba* and *R. speciosa* (Murneck, 1940), *Rudbeckia fulgida* 'Goldsturm' (Runkle et al., 1999; Elkins & van Iersel, 2020) and *Rudbeckia hirta* (Beckwith, 1991; Blanchard & Runkle, 2010; Werner et al., 2011).

Photosynthetic light inside a greenhouse or controlled environments can be a limiting factor, electric lamps (e.g. high-pressure sodium – HPS fixtures or light-emitting diodes – LEDs) are provided supplemental lighting in the horticultural

production. The efficacy of HPS or LEDs lighting ($\mu\text{mol/J}$) has increased intensely in the past decades resulted that indoor or light controlled plant production have recently become more economically viable (Kozai, 2016; Roberto & Runkle, 2017).

Ornamental cultivation basically depends on the quality of growing media. Peat-based media have been dominated in pot/bedding plants and nursery production of plants. Increased mining and utilization of peat, have been destroyed habitats and potentially contributed to climate change. Among of other countries, the UK government and European Union have increasingly encouraged to reduce peat uses for industrial and horticultural purposes (FAI, 2014; IUCN, 2018; European Commission, 2018; Bek et al., 2020).

One of the alternatives, hydroponic cultivation of plants has been a well-known and widespread technology also in ornamental plant cultivation (especially cut flowers, foliage and flowering production) (Sardare & Shraddha, 2013; Roberto & Runkle, 2017). There are a few online available literatures of hydroponic cultivation of *Rudbeckia hirta*, and primarily are focused on the effect of different nutrients to detection of secondary compounds (Almeida-Cortez et al., 2003).

The objectives of present paper are to characterize nursery production of different *Rudbeckia hirta* varieties depending on photoperiodic lighting treatments (short day, long day, natural short day with light pollution) and growing media (perlite, peat-free, peat-based, aeroponics system) considering morphological characterization and photosynthetic parameters.

Materials and methods

Germinations and pot experiments were conducted at University of Debrecen, Faculty of the Agricultural and Food Sciences and Environment Management, in Biological Research and Plant Experiment Greenhouse (Biodrome) from November 2020 to April 2021 (Hungary), during natural short-day conditions. The computer controlled air-temperature (Priva Climate Computer) was at least 20.5 °C at daytimes and at least 16 °C at nights during our experiment.

Plant material

Four *Rudbeckia hirta* varieties were investigated: 'Nápfény' variety was provided by National Agricultural Research and Innovation Centre (NARIC, Hungary), 'Autumn Colors', 'Prairie Sun', 'Toto Gold' were derived by Jelitto Staudensamen GmbH (Germany) (Benary, 2013, 2020; NARIC, 2020a,b).

Germination, nursery methods and media

Rudbeckia hirta seeds were surface sterilized in 100 ml Erlenmeyer flasks with 10% SteriClean Plant disinfectant (Pannon Trade Kft., Hungary) for 15 minutes and were rinsed with reverse osmosis (RO) water (tap water was cleaned by Power Grow 500 - Reverse Osmosis System, Growmax Water, USA) at three times. The surface sterilized seeds were sown in Petri-dish (10 cm diameter, polystyrene, VWR International Ltd., Hungary), into white filter paper (VWR International Ltd., Hungary) and were soaked with 5 ml RO water. Petri-dishes were placed on a heat mat (RootliT Heat Mat, Playgrowned.com, Hungary) with thermostat, to ensure constant temperature of 22 °C for germination. 5 ml of RO water was poured onto the filter paper at two times during germination stage. The seeds were germinated under 12 hours supplemental light (HortiLED Multi 4DIM, Hortilux, Netherlands) with light intensity of 150 $\mu\text{mol m}^{-2} \text{s}^{-1}$ PPFD (photosynthetic photon flux density).

Rudbeckia seeds were sowed on 26th November, 2020 ('Nápfény') and 4th January, 2021 ('Autumn Colors', 'Toto Gold' and 'Prairie Sun') for nursery treatments. 3 weeks of well-developed seedlings were transferred to Rockwool cubes (25x25x40 mm, Grodan, Playgrowned.com, Hungary) for soil-free, hydroponic (aeroponics system, perlite) and different photoperiodic lighting experiments. 'Nápfény' and 'Autumn Colors' were sowed on 16th January, 2021 and 3 weeks of well-developed seedlings were transferred to Jiffy-7 pellet (Playgrowned.com, Hungary) for the peat-based, peat-free media and different photoperiodic lighting experiments. The seedlings were grown under 12 hours light treatment by HortiLED with light intensity of 150 $\mu\text{mol m}^{-2} \text{s}^{-1}$ PPFD for 3 weeks.

Terra Aquatica Tripart advanced nutrient solutions (Micro, Grow and Bloom 3-Part Flora Series, General Hydroponics Europe - GHE) were utilized with RO water, according to the

user guide of products and development phases of seedlings (GHE, 2021). 0.5 ml/litre concentrates from each nutrient solution (Terra Aquatica, Tripart, GHE) were irrigated the seedlings every week (25 ml/ seedlings/ week) until 3 leaves and well-developed roots were appeared. 'Nápfény', 'Autumn Colors', 'Toto Gold', 'Prairie Sun' varieties were grown in Rockwool cubes planted into aeroponics system (GHE Rainforest 72, Playgrowned.com, Hungary), and into 9 cm diameter plastic pots (Gazdabolt.hu, Hungary) with horticultural perlite (particle size: 2-6 mm, Magyar Perlit Kft., Hungary). 'Nápfény' and 'Autumn Colors' varieties were grown in Jiffy pellet, planted into 9 cm diameter plastic pots (Gazdabolt.hu, Hungary) with peat based soil mixture (JÓFÖLD for plantlets, Pax96 Kft., Hungary) and peat-free soil mixture (OBI, Living Garden, for plantlets, Hungary).

Photoperiodic lighting treatments

LED light treatment (HortiLED Multi 4DIM, Hortilux, Netherlands) was utilized to the following photoperiodic parameters. Each variety with growing media of perlite, peat-based and peat-free soil mixture was grown under 12 hours, 14 hours artificial light conditions and natural short day with 14 hours light pollution (PPFD below 1 $\mu\text{mol m}^{-2} \text{s}^{-1}$ and 15 lux after sunset). Light intensity of short-day (12 hours) and long-day (14 hours) light treatments were 210 $\mu\text{mol m}^{-2} \text{s}^{-1}$ PPFD. *Rudbeckia* varieties in GHE aeroponics system were grown only under 14 hours artificial LED light.

Measurement of morphological parameters of plantlet cultivation

The following morphological properties were determined in the 11 weeks-old seedlings: number of leaves, number of shoots, plant height (cm), number of flower buds in each variety, depending on photoperiodic lighting treatment (short day, long day, natural short day with light pollution) and different growing media (perlite, peat-free, peat-based, aeroponics system). At least 5 plantlets of 'Toto Gold', 'Autumn Colors', 'Prairies Sun' and 'Nápfény' varieties were measured. Nápfény' variety was grown more slowly than others in our experiments of winter-early spring conditions, so were also evaluated by the end of 16-weeks-old 'Nápfény' plantlet in case of soilless and aeroponics experiment. Time of appearance of flower buds and reducible time of plantlet cultivation (weeks) of varieties determined depending on growing media and light treatments.

Photosynthetic pigment and relative chlorophyll content (SPAD value) determination

Relative chlorophyll content (SPAD value) of the leaves was measured with a Minolta SPAD-502 meter. SPAD values were determined from 6 average measurements (derived from a minimum of 3 measured data) in each variety depending on the treatments.

Photosynthetic pigment content and ratio were determined based on Duma et al. (2014) methods with spectrophotometer (Ultraspec 2100 pro, Biochrom) at 665, 649, 495, 480, 440 nm. 2-3 well-developed leaves were measured and collected from upper part of the shoots (a third or fourth leaves from shoot tips) at the end of 11 weeks after sowing of each variety (and as well as 16-weeks-old 'Nápfény' variety). Samples were lyophilized by Christ Alfa 1-4 LSC lyophilizer for

determination of different photosynthetic pigment content (mg/g). Chlorophyll *a* (*chl a*), chlorophyll *b* (*chl b*), carotenoids (*car*), xanthophyll (lutein) and SPAD-value were calculated in each variety depending on the treatments.

Data analyses

Descriptive statistical methods, including the mean, standard deviation and one-way and two-way ANOVA were used. The results were evaluated with Microsoft Office Excel and SPSS 22.0 (SPSS Inc., Chicago, IL) programmes. The significant differences between the variants were determined with Tukey's (if equal variances assumed) test at a probability level of 5%.

Results

Morphological parameters of aeroponics and soilless *Rudbeckia* plantlet cultivation with photoperiodic lighting treatments

The morphological effects of each treatment (photoperiodic lightings and media) on different *Rudbeckia* varieties ('Nápfény', 'Toto Gold', 'Autumn Colors', 'Prairies Sun') were shown in **Figure 1-4**. 11 weeks-old 'Toto Gold', 'Autumn Colors' and 'Prairies Sun' were already suitable for acclimatization or planting, furthermore due to slower growing of 'Nápfény', 11 and 16 weeks-old 'Nápfény' plantlets were also shown in results.

Plantlets were received 12 hours day light did not initiate flowers, remained stage of the leaf rosette without exception. In case of 14 hours aeroponics, 14 hours perlite and control (natural short day with 14 hours light pollution) plantlets were developed inflorescences or flower buds (**Figure 1-4**). Inflorescence axis of 'Nápfény' was appeared at 13 weeks also in light polluted control plantlets, in perlite was 1.7 and in aeroponics 2.7 flower buds were developed at 16 weeks in long day treatments (**Figure 1**). Other varieties (**Figure 2-4**) were developed inflorescences at 8 weeks, 14 hours aeroponics system resulted the most of flower buds: 'Toto Gold' was 6.5 (**Figure 2**), 'Autumn Colors' was 3.25 (**Figure 3**), 'Prairie Sun' was 4.8 (**Figure 4**) flower buds in 11 weeks. Long daylight manipulation could be minimized crop times and achieved flowering potted plants at 11 weeks.

Lengths of plantlets under 12 hours of light treatment were significantly smaller than long day supplemental lightings and light polluted control. Under long day, varieties were shown natural height characteristics. In aeroponics systems (GHE Rainforest72) with 14 hours supplementary lighting, plantlets were the highest, because of the appearance of inflorescences. Taller varieties with higher habitat, 'Nápfény' and 'Prairie Sun' produced 30.2 and 36.8 cm high plantlets, compact and well branched 'Toto Gold' was 22 cm, medium tall 'Autumn Colors' was 27 cm height in aeroponics system. There were not significant differences ($p=0.05$) between aeroponics and perlite media, except for 'Toto Gold' (**Table 1**).

Number of leaves of each variety responded differently. There were not significant differences ($p=0.05$) between perlite media depending on light treatments, except for 14 hours aeroponics treatment of 'Prairie Sun' (42.4). Most of leaves developed in aeroponics cultivation system, 'Toto Gold' was the highest (45.3), due to the branching growth of the variety (**Table 2**).

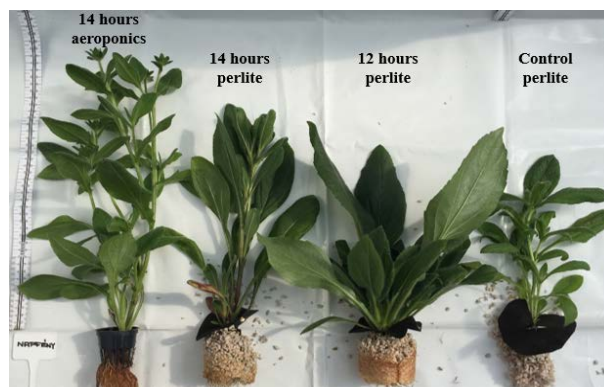


Figure 1. 16 weeks-old *Rudbeckia hirta* 'Nápfény' plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

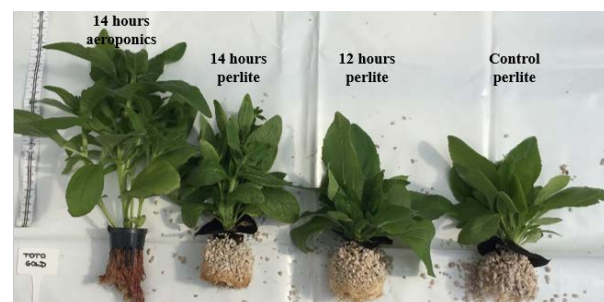


Figure 2. 11 weeks-old *Rudbeckia hirta* 'Toto Gold' plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).



Figure 3. 11 weeks-old *Rudbeckia hirta* 'Autumn Colors' plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

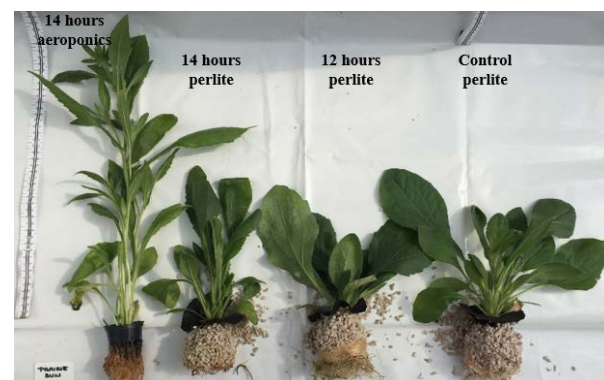


Figure 4. 11 weeks-old *Rudbeckia hirta* 'Prairie Sun' plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

Table 1. Lengths of 11 and 16 weeks *Rudbeckia hirta* L. plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

	14 hours - aeroponics	14 hours - perlite	12 hours - perlite	Control - perlite
'Nápfény' (11 weeks) ±SD	8.1 a ±5.61	9.3 a ±3.60	9.0 a ±3.61	7.7 a ±1.21
'Nápfény' (16 weeks) ±SD	30.2 b ±3.11	25.2 ab ±13.75	14.3 a ±1.53	22.0 ab ±2.00
'Toto Gold' (11 weeks) ±SD	22.0 c ±3.46	14.7 b ±2.30	8.3 a ±1.52	12.0 ab ±1.73
'Autumn Colors' (11 weeks) ±SD	27.0 b ±6.78	24.0 b ±7.55	10.3 a ±2.52	11.0 ab ±2.65
'Prairie Sun' (11 weeks) ±SD	36.8 b ±6.30	21.0 ab ±7.00	9.3 a ±1.53	14.7 ab ±0.58

Note: Values followed by the different letters represent significant differences depending on treatments, which were determined with Tukey's test ($p=0.05$).

Table 2. Number of leaves of 11 and 16 weeks *Rudbeckia hirta* L. plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

	14 hours - aeroponics	14 hours - perlite	12 hours - perlite	Control - perlite
'Nápfény' (11 weeks) ±SD	8.2 a ±4.52	6.5 a ±1.38	6.3 a ±1.15	6.3 a ±2.52
'Nápfény' (16 weeks) ±SD	31.5 a ±17.31	26.8 a ±7.66	29.0 a ±9.00	28.7 a ±8.50
'Toto Gold' (11 weeks) ±SD	45.3 a ±6.29	42.7 a ±6.49	32.7 a ±6.81	39.0 a ±6.56
'Autumn Colors' (11 weeks) ±SD	33.3 a ±7.57	19.8 a ±13.96	24.3 a ±8.96	15.3 a ±2.52
'Prairie Sun' (11 weeks) ±SD	42.4 b ±8.38	19.7 a ±2.52	20.7 a ±6.66	19.0 a ±6.00

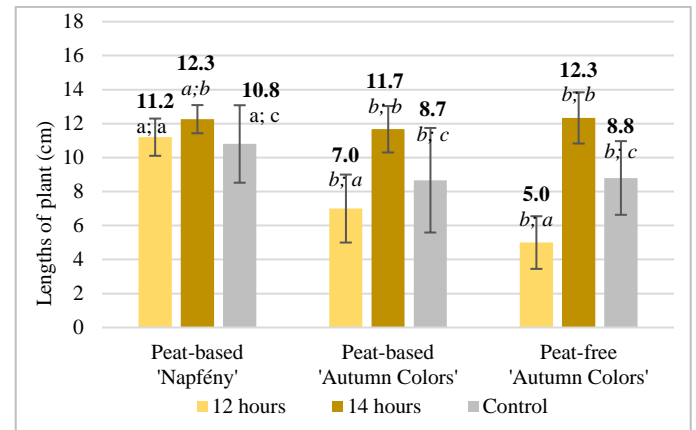
Note: Values followed by the same letter are not significantly different depending on treatments according to Tukey's test ($p=0.05$).

Table 3. Number of shoots of 11 and 16 weeks *Rudbeckia hirta* L. plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

	14 hours - aeroponics	14 hours - perlite	12 hours - perlite	Control - perlite
'Nápfény' (11 weeks) ±SD	1.6 a ±0.97	1.0 a ±0.00	1.0 a ±0.00	1.0 a ±0.00
'Nápfény' (16 weeks) ±SD	1.6 a ±0.79	3.2 ab ±1.79	4.0 b ±1.00	3.6 ab ±2.00
'Toto Gold' (11 weeks) ±SD	4.0 a ±0.82	5.7 ab ±0.58	7.3 b ±0.58	6.0 b ±1.00
'Autumn Colors' (11 weeks) ±SD	2.8 a ±0.95	4.0 a ±0.00	4.0 a ±1.00	3.7 a ±0.58
'Prairie Sun' (11 weeks) ±SD	4.2 a ±1.92	4.0 a ±0.00	4.7 a ±0.58	4.0 a ±1.00

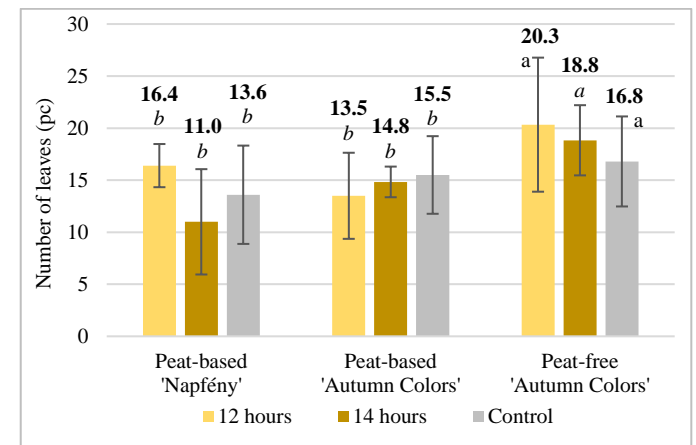
Note: Values followed by the different letters represent significant differences depending on treatments, which were determined with Tukey's test ($p=0.05$).

Figure 5. Lengths of 11 weeks-old *Rudbeckia hirta* L. varieties ('Nápfény', 'Autumn Colors') depending on photoperiodic lighting treatments, peat-free and peat-based media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).



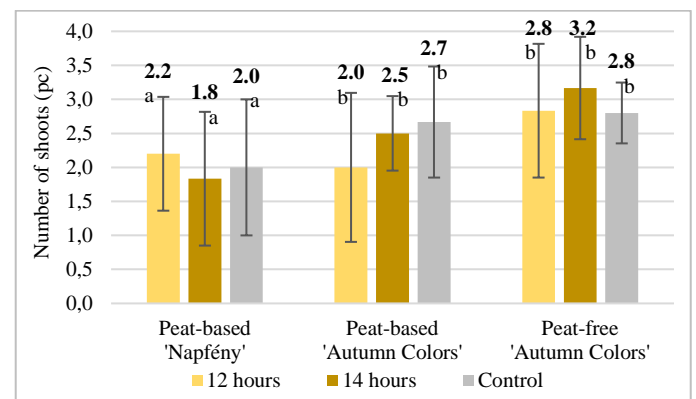
Notes: First different letters represent significant differences depending on media/varieties, second different letters represent significant differences depending on photoperiodic light treatments, which were determined with Tukey's test ($p=0.05$). There is an interaction effect between lighting treatments and media (P -value of lighting*media/varieties is 0.013).

Figure 6. Number of leaves of 11 weeks-old *Rudbeckia hirta* L. varieties ('Nápfény', 'Autumn Colors') depending on photoperiodic lighting treatments, peat-free and peat-based media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).



Notes: Different letters represent significant differences depending on media/varieties, which were determined with Tukey's test ($p=0.05$). No significant differences between photoperiodic lighting treatments.

Figure 7. Number of shoots of 11 weeks-old *Rudbeckia hirta* L. varieties ('Nápfény', 'Autumn Colors') depending on photoperiodic lighting treatments, peat-free and peat-based media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).



Notes: Different letters represent significant differences depending on media/varieties, which were determined with Tukey's test ($p=0.05$). No significant differences between photoperiodic lighting treatments.

Figure 8. 11 weeks-old *Rudbeckia hirta* 'Napfény' plantlets depending on photoperiodic lighting treatments in peat-based media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

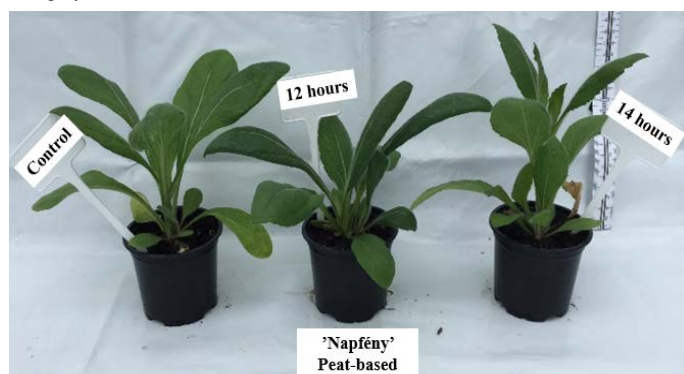


Figure 9. 11 weeks-old *Rudbeckia hirta* 'Autumn Colors' plantlets depending on photoperiodic lighting treatments in peat-based media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

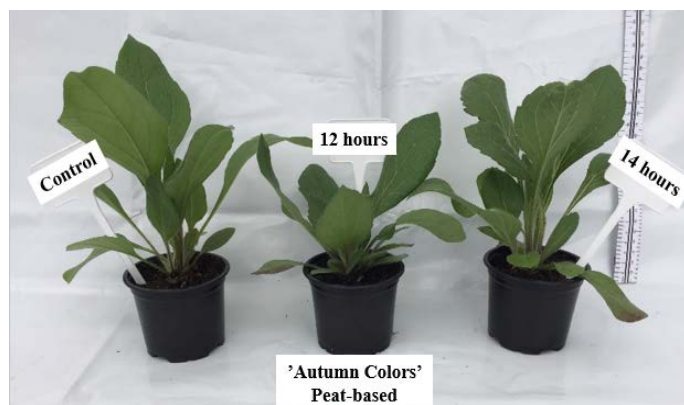
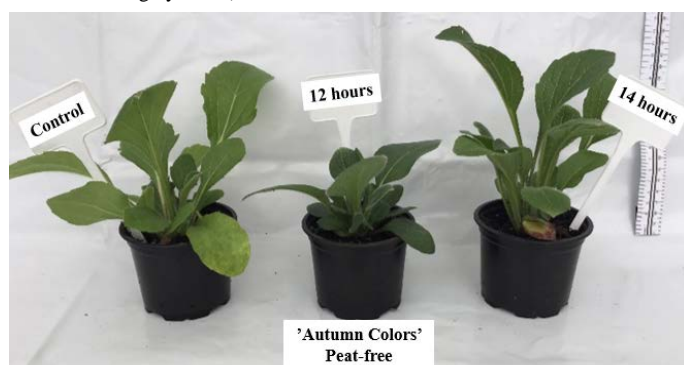


Figure 10. 11 weeks-old *Rudbeckia hirta* 'Autumn Colors' plantlets depending on photoperiodic lighting treatments in peat-free media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).



12 hours daylight resulted in vegetative growth of plantlets, most of the shoots developed in short-day treatment: 16 weeks-old 'Napfény' and 11 weeks-old 'Autumn Colors' were developed 4 shoots under 12 hours. Because of natural short days in the winter-early spring season, varieties in control perlite media were developed fewer shoots than 12 hours.

11 weeks-old 'Toto Gold' was produced the most of the shoots (7.3), and the number of shoots of 'Prairie Sun' was 4.7 in 12 hours perlite treatments. In the aeroponics system with 14 hours of lighting, the number of shoots of 'Toto Gold' and 'Napfény' were 4.0 and 1.6, significantly less than 12 hours of lighting. In the case of 'Autumn Colors' and 'Prairie Sun' were not significant differences ($p=0.05$) between treatments (Table 3).

Morphological parameters of peat-free and peat-based *Rudbeckia* plantlet cultivation with photoperiodic lighting treatments

Due to the similar habitats and longer crop times of 'Napfény' and 'Autumn Colors' were selected for peat-free and peat-based media and photoperiodic lighting experiments.

Peat-based 11 weeks-old 'Napfény' were significantly higher (11.2) than peat-based (7.0) or peat-free (5.0) 11 weeks-old 'Autumn Colors' varieties. There were significant differences in plantlet length between each lighting treatment (12 hours, 14 hours, light-polluted control), so both media/varieties and lighting has affected height of plants. Length of control plantlets were between 8.7-10.8 cm, plantlets treated 14-hours lightening were significantly higher than other treatments (11.7-12.3 cm) (Figure 5).

Number of leaves of peat-free 'Autumn Colors' plantlets were significantly higher than peat-based media/varieties. Depending on the daylight hours, it was between 16.8-20.3. Photoperiodic lighting treatments did not affect significantly the number of leaves none of the varieties. The peat-based 'Napfény' plantlets had least number of leaves (between 11.0-16.4) (Figure 6).

Number of shoots of peat-based and peat-free 'Autumn Colors' plantlets were significantly higher than peat-based 'Napfény'. There were not significant differences between peat-free and peat-based media of 'Autumn Colors' or photoperiodic lighting treatments (14 hours, 12 hours, light polluted control) in case of number of shoots. Most of the shoots were grown peat-free 'Autumn Colors' plantlets (between 2.8-3.2) depending on light conditions, the highest was 14-hour lighting (3.2 shoots). The lowest number of shoots (1.8) was observed in the 14 hours lighting peat-based 'Napfény' (Figure 7).

The morphological effects of control, 12 hours, 14 hours supplementary lightings and peat-free, peat based media on 'Napfény' and 'Autumn Colors' varieties were shown in Figure 8-10. Similar to aeroponics and perlite experiments, plantlets received 12 hours light treatment did not develop inflorescences or flower buds. 11 weeks-old 'Napfény' and 'Autumn Colors' varieties under 14 hours supplemental lighting and control were initiated inflorescence axis (Figure 8-10).

Photosynthetic parameters of *Rudbeckia* varieties depending on different treatments

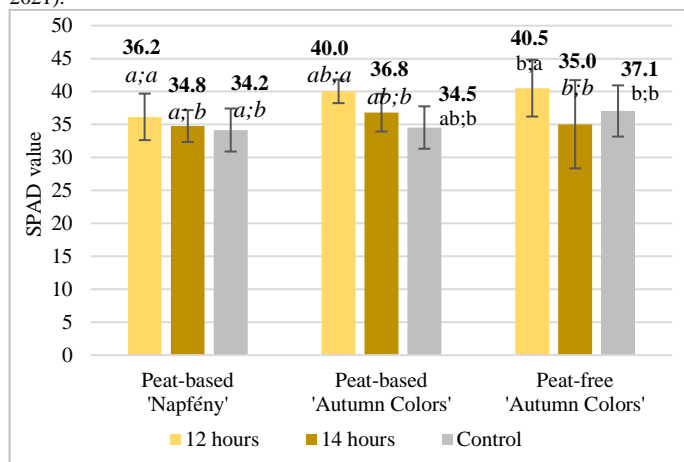
Relative chlorophyll content (SPAD value) of *Rudbeckia hirta* L. varieties depending on photoperiodic lighting treatments and media were concluded in Table 4 and Figure 11.

'Napfény' plantlets treated with 12 hours light conditions were significantly higher relative chlorophyll content than other daylight (11 weeks-old was 35.3, 16 weeks-old was 46.8). SPAD values of Benary-bred varieties were the highest in 12 hours lightings (40.3-40.8), significantly higher than control plantlets in each variety. There were not significant differences between aeroponics and perlite media in 14 hours supplementary lighting in the case of either variety (Table 4).

Depending on media/varieties, did not significant differences between the SPAD value of peat-based 'Napfény' and peat-based 'Autumn Colors' (between 34.2-36.2 and between 34.5-40.0, consequently). SPAD values of peat-free 'Autumn Colors' were significantly higher (35.1-40.5) than peat-based 'Napfény'. Depending on the light treatment, SPAD

values of 12 hours daylight plantlets (36.2-40.5), was significantly higher than others (**Figure 11**).

Figure 11. Relative chlorophyll content (SPAD value) of *Rudbeckia hirta* L. varieties ('Nápfény', 'Autumn Colors') depending on photoperiodic lighting treatments, peat-free and peat-based media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).



Notes: First different letters represent significant differences depending on media/varieties, second different letters represent significant differences depending on photoperiodic light treatments, which were determined with Tukey's test ($p=0.05$). There is no interaction effect between lighting treatments and media.

Table 4. Relative chlorophyll content (SPAD value) of *Rudbeckia hirta* L. plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

	14 hours - aerponics	14 hours - perlite	12 hours - perlite	Control - perlite
'Nápfény' (11 weeks) ±SD	32.9 ab ±7.16	30.9 ab ±3.22	35.3 b ±6.64	28.8 a ±1.83
'Nápfény' (16 weeks) ±SD	40.1 b ±1.95	40.4 b ±2.45	46.8 c ±1.56	35.9 a ±2.06
'Toto Gold' (11 weeks) ±SD	36.4 bc ±1.3	33.8 ab ±1.2	40.5 c ±4.2	31.6 a ±1.9
'Autumn Colors' (11 weeks) ±SD	34.7 a ±2.8	37.7 ab ±4.9	40.3 b ±4.0	34.3 a ±3.3
'Prairie Sun' (11 weeks) ±SD	39.9 b ±3.2	40.1 b ±1.1	40.8 b ±3.6	33.3 a ±2.5

Notes: Values followed by the different letters represent significant differences depending on treatments, which were determined with Tukey's test ($p=0.05$).

Different photosynthetic pigment content (chlorophyll a, chlorophyll b, chlorophyll a+b, carotenoids and xanthophyll/lutein - mg/g) of *Rudbeckia* varieties were evaluated depending on treatments in **Table 5**. In case of 'Toto Gold', different treatments (lighting and media) had no significant effect on each photosynthetic pigment content of the variety, except for the xanthophyll content of control plantlet, which was significantly lower, than other lighting treatments. 12 hours perlite lighting treatment of 16 weeks-old 'Nápfény' resulted significantly higher chlorophyll a, chlorophyll b, chlorophyll a+b, carotenoids and xanthophyll (lutein) content (8.16, 3.39, 11.5, 3.58 and 2.19 mg/g, consequently). Between the treatments, had no significant differences in any of the photosynthetic pigment content of 'Autumn Colors' In case of 'Prairie Sun', were obtained different results compared to 'Toto Gold', 'Nápfény' or 'Autumn Colors' varieties. The

content of chlorophyll a of 14-hour aerponics treatment was one of the highest among the varieties (7.20 mg/g). There was no significant difference between treatments of photosynthetic pigment and xanthophyll (lutein) content of 'Prairie Sun', but high photosynthetic pigment content of 14 hours aerponics 'Prairie Sun' could have resulted by the rapidly growing of variety (**Table 5**).

Table 5. Photosynthetic pigment content (mg/g) of *Rudbeckia hirta* L. plantlets depending on photoperiodic lighting treatments and media (University of Debrecen, Biological Research and Plant Experiment Greenhouse - Biodrome, Debrecen, Hungary, 2021).

Photoperiodic treatments	14 hours - aerponics	14 hours - perlite	12 hours - perlite	Control - perlite
Chl a (mg/g)				
'Toto Gold' ±SD (11 weeks)	7.05 a ±0.693	6.02 a ±0.983	7.15 a ±1.143	6.01 a ±1.121
'Nápfény' ±SD (16 weeks)	6.40 a ±1.141	5.58 a ±0.714	8.16 b ±0.305	6.15 a ±0.769
'Prairie Sun' ±SD (11 weeks)	7.03 a ±0.379	5.27 bc ±1.02	6.79 ab ±0.513	5.14 c ±0.996
'Autumn Colors' ±SD (11 weeks)	6.25 a ±0.697	5.41 a ±1.136	6.79 a ±1.020	6.78 a ±1.281
Chl b (mg/g)				
'Toto Gold' ±SD (11 weeks)	3.08 a ±0.385	2.40 a ±0.433	2.77 a ±0.509	2.28 a ±0.457
'Nápfény' ±SD (16 weeks)	2.62 a ±0.406	2.24 a ±0.388	3.39 b ±0.166	2.36 a ±0.289
'Prairie Sun' ±SD (11 weeks)	2.80 a ±0.163	2.11 ab ±0.406	2.71 ab ±0.235	2.04 b ±0.432
'Autumn Colors' ±SD (11 weeks)	2.70 a ±0.370	2.15 a ±0.487	2.68 a ±0.415	2.52 a ±0.428
Chl a+b (mg/g)				
'Toto Gold' ±SD (11 weeks)	10.14 a ±1.075	8.43 a ±1.146	9.93 a ±1.650	8.30 a ±1.577
'Nápfény' ±SD (16 weeks)	9.03 a ±1.540	7.82 a ±1.101	11.55 b ±0.468	8.52 a ±0.058
'Prairie Sun' ±SD (11 weeks)	9.84 a ±0.527	7.38 bc ±1.424	9.51 ab ±0.747	7.18 c ±1.427
'Autumn Colors' ±SD (11 weeks)	8.95 a ±1.064	7.56 a ±1.623	9.47 a ±1.702	9.30 a ±1.702
Car (mg/g)				
'Toto Gold' ±SD (11 weeks)	3.17 a ±0.204	2.62 a ±0.361	3.12 a ±0.486	2.50 a ±0.475
'Nápfény' ±SD (16 weeks)	2.85 a ±0.444	2.51 a ±0.348	3.58 b ±0.140	2.64 a ±0.315
'Prairie Sun' ±SD (11 weeks)	3.08 a ±0.090	2.34 bc ±0.391	2.90 ab ±0.224	2.23 c ±0.434
'Autumn Colors' ±SD (11 weeks)	2.71 a ±0.297	2.09 a ±0.242	2.88 a ±0.418	2.58 a ±0.614
Xant - lutein (mg/g)				
'Toto Gold' ±SD (11 weeks)	1.68 a ±0.144	1.59 a ±0.268	1.79 a ±0.273	1.08 b ±0.226
'Nápfény' ±SD (16 weeks)	1.61 a ±0.273	1.53 a ±0.280	2.19 b ±0.091	1.63 a ±0.199
'Prairie Sun' ±SD (11 weeks)	1.56 a ±0.028	1.41 a ±0.256	1.59 a ±0.134	1.32 a ±0.305
'Autumn Colors' ±SD (11 weeks)	1.40 a ±0.172	1.20 a ±0.262	1.64 a ±0.249	1.48 a ±0.266

Notes: Values followed by the different letters represent significant differences depending on treatments, which were determined with Tukey's test ($p=0.05$).

Discussion

Based on the results of the soilless seedling cultivation experiments and literature data (Luczkiewicz & Cisowski, 2001; Almeida-Cortez et al., 2003; Elkins & van Iersel, 2020), the investigated *Rudbeckia hirta* varieties ('Napfény', 'Toto Gold', 'Autumn Colors' and 'Prairie Sun') are suitable both in the aeroponics system (GHE Rainforest72) and in 100% perlite for growing with the adequate nutrient solutions. The soil-free, hydroponic cultivation of *Rudbeckia* may be contributed to utilize widely as indoor and outdoor flowering plants, even in controlled or vertical cultivation systems, or in facilities (e.g. hospitals) where terrestrial media are prohibited (Salas et al. 2010). In addition, due to various ingredients of the plant: polysaccharides, flavonoids, phenolic acids, anthocyanin compounds, polyacetylene derivatives, etc. (Michael et al., 2014; Palmer et al., 2019) could utilize as medicinal purposes. These compounds are obtained primarily on the roots, therefore hydroponic cultivation systems and media can facilitate easier extractions (reducing contaminants and root loss). With the adequate nutrient solution and light treatments, even the amount of these secondary metabolites and various compounds could be influenced (Almeida-Cortez, 2003; Moldovan et al., 2017).

Morphological properties were determined basically kind of varieties, in our experiments photoperiodic lighting treatments and media also affected habitats and the development of plantlets. Different habitats of plantlets were confirmed the photoperiodic sensitivity of investigated *Rudbeckia* varieties. Each variety was grown under 12 hours light conditions (short daylight) did not initiate flowers, remained in stage of leaf rosette. In case of 14 hours or control (natural short day with 14 hours light pollution) plantlets were developed inflorescences and/or flower buds. Inflorescence axis of varieties were produced from 8 weeks. 11 weeks-old plantlets were suitable for acclimatization or planting in case of aeroponics or perlite media treatments. Foreign and domestic descriptions of *Rudbeckia* varieties (Benary, 2013, 2020; NARIC, 2020a,b) included that growing time of *Rudbeckia hirta* is at least 12 weeks, but in (early) spring, potted or annual flowerbed *Rudbeckia* plantlets mostly do not have flower buds in Hungarian conditions. 14 hours of long-day treatment can be shortened the cultivation time of plantlets by up to 3-4 weeks (depending on the variety and other production conditions). However, the utilization of LEDs or HPS fixtures increases the production costs, but light manipulation as a growth regulation tool is resulted to produce preferable quality products and minimize crop times. Depending on the light treatment, more branching, compact plantlets can be produced with more leaves, the number of shoots and flower buds with higher chlorophyll content.

Our experiments with peat-free media with *Rudbeckia* varieties resulted that seedling cultivation in peat-free soil media without peat can be also possible and effective (peat-free 'Autumn Colors' resulted in more shoots and leaves). Large scale utilization of peat-free growing media, even based on domestic fibre sources (urban and other green waste, various biomass crops, etc.), would provide a shift towards sustainability and circular farming, which could also reduce GHG emissions and also help to protect and preserve peatland ecosystems. It would be suggested to continue our lighting and media experiments with other *Rudbeckia* varieties and other ornamental plants.

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