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THE EFFECT OF CHANGES IN DIURNAL TEMPERATURE AND PHOTOPERIOD ON GROWTH AND YIELDING OF GARDEN DILL GROWN IN POTS

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Abstract. Temperature and light are important factors determining growth and development of plants. The difference between day and night temperature (DIF – defined as day temperature minus night temperature) influences plant morphology in a wide range of species. In this study, the effect of photoperiod and DIF on stem elongation and growth of dill plants was investigated. The first experiment included a comparison of different temperatures between day and night (DIF-5 – 20/25°C, DIF0 – 20°C and 25°C, DIF+5 – 25/20°C) for a 16-h photoperiod. The second experiment comprised the photoperiod of 16 and 24 hours for two constant temperatures – 20 and 25°C. Significant differences between DIF+5 and DIF-5 were observed in the case of plant height. Elongation growth was enhanced by positive DIF and was inhibited by negative DIF, although the strongest stem elongation inhibition was recorded at the temperature of 25°C and a 16-h photoperiod. Leaf area was greatly affected by the temperature and DIF, but only slightly influenced by the photoperiod. Leaf area in DIF-5 was smaller than that in DIF+5 or 0 (20°C). The highest essential oil content in the herbage was recorded for a constant temperature of 25°C as well as 20°C and a 24-hour photoperiod.

Key words: DIF, *Anethum graveolens,* growth rate, elongation

INTRODUCTION

Suppression of internode elongation is achieved by the manipulation of light quality, photoperiod, lighting direction, light intensity and all types of stress. Internode length may also be controlled by the manipulation of day and night temperatures (DIF). DIF can be described as the difference between day and night temperature (day temperature minus night temperature). A higher night temperature than the day temperature is termed negative DIF, while a lower night temperature than the day temperature is referred to as positive DIF [Erwin and Heins 1995]. Many reports, covering a wide range

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of plant species, discuss the effect of diurnal temperature alternations on plant morphology [Shimizu 2007]. Plant height is an important quality characteristic of herbs cultivated in pots. In the case of dill an excessive plant elongation is connected with both undue plant density in containers as well as a shortage of light during the winter period [Frąszczak et al. 2008]. In order to check the excessive elongation growth, different cultivation methods – among others, DIF – have been employed. Elongation growth is inhibited by the application of negative DIF, i.e. a higher temperature at night than during the day [Heins et al. 2000]. The advantage of this method stems from the possibility of its application at any moment of cultivation and after the termination of its application it has no influence on the subsequent growth of plants [Ito et al. 1997b]. In this study the effect of photoperiod and DIF on stem elongation and growth of dill plants was investigated.

MATERIAL AND METHODS

The experiments were carried out at the "Marcelin" experimental station of the Poznan University of Life Sciences, Poland. The object of the performed research was cv. Ambrosia of dill (*Anethum graveolens* L.). Seeds were obtained directly from growers – PlantiCo Zielonki. Plants were grown in growth chambers. One- and two-factor experiments were performed in eight replications, where one pot was treated as a replication. The investigations were conducted in two series. The first experiment included a comparison of different temperatures between day (DT) and night (NT). The plants were exposed to four different temperature regimes: positive – DIF+5 (DT/NT: 25/20°C), negative – DIF-5 (DT/NT: 20/25°C) and neutral – DIF0 (DT/NT 20/20°C and 25/25°C) for 16-h photoperiod. The other, i.e. two-factorial experiment comprised the photoperiod of 16 and 24 hours for two constant temperatures: 20 and 25°C (tab. 1). Photosynthetic photon flux density (PPFD) amounted to 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Artificial light was provided using 36W/84 fluorescent lamps by Philips Company (Poland).

Table 1. Temperature and light conditions used in the cultivation of dill in pots
Tabela 1. Temperatura i warunki świetlne zastosowane w uprawie kopru ogrodowego w doniczkach

	Temperature (day/night) Temperatura (dzień/noc) °C	DIF	Photoperiod Fotoperiod h	Treatment (legend) Traktowanie (legenda)	Daily light integral (DLI) Dzienna suma światła $mol \cdot m^{-1}$	Average daily temperature (ADT) Średnia dobowa temperatura °C
The first experiment Doświadczenie pierwsze	20/25	-5	16	20/25	5.6	21.7
	25/20	+5	16	25/20	5.6	23.3
	25/25	0	16	25/25	5.6	25
	20/20	0	16	20/20	5.6	20
The second experiment Doświadczenie drugie	25/25	0	24	25-24	8.5	25
	25/25	0	16	25-16	8.5	25
	20/20	0	24	20-24	5.6	20
	20/20	0	16	20-16	5.6	20

The experimental plants were grown in pots of 280 cm^3 in volume and 49 cm^2 in cultivation area, filled with peat substrate for vegetable transplanting production. The number of plants grown in a pot was identical and amounted to 40 (± 5 plants). The plants were measured every 7 days during five weeks, for the first time at 7 days after emergence and later, on the 14th, 21st, 28th and 35th (harvest time) day of cultivation. Harvesting involved hand cutting of all plants in the pot, close to the surface of the substrate. After harvest the weight of fresh matter was determined for plants from individual pots. In addition, plant height, hypocotyl length and leaf area were measured (for 10 plants from every pot). A scanner ("Mustek 1200 UB") and the *Skwer* computer program ("IksmodaR", Poland) were used to calculate leaf area. Additonally, the content of essential oils in air-dried herbs was also determined (in plants harvested in 35th day of cultivation). Samples of herbage were distilled by water vapour using the Deryng apparatus. The content of essential oils was determined according to the Polish Standard PN-91 R-87019. The significance of the effect of light and DIF on plant height, hypocotyl length and yields was determined employing the ANOVA. Differences between means were estimated using the Newman-Keuls test at the significance level $\alpha = 0.05$. All statistical analyses were carried out employing the *Stat* program.

Relative growth rate (*RGR*), leaf area index (*LAI*), net assimilation rate (*NAR*) and specific leaf area (*SLA*) were calculated as described by Hunt [1982]. Values of indices refer to individual pots.

The index of the relative growth rate (*RGR*) was calculated on the basis of the following formula:

$$RGR = \frac{dW}{W \cdot dt}$$

where: W – weight of fresh plant material at the moment of harvesting, g
dW – fresh mass increment, g,
dt – unit of time, d.

The leaf area index (*LAI*) refers to the area of the leaf surface of all plants in relation to the pot area. It was calculated on the basis of the following formula:

$$LAI = A/P$$

where: A – plant assimilation area (dm^2),
P – pot area, dm^2.

The net assimilation rate (*NAR*) is the increment of biomass per unit of time and per unit of any measure of magnitude of the assimilation organs:

$$NAR = \frac{dW}{A \cdot dt}$$

where: A – area of assimilation organs, dm^2,
dW – fresh mass increment, g,
dt – unit of time, d.

Specific leaf area (*SLA*) is defined as the ratio of leaf area to the fresh weight of leaves.

$SLA = L_A/L_W$

where: L_A– leaf area, dm^2
L_W – fresh weight of leaves, g.

RESULTS

The applied temperature difference between day and night failed to exert a significant influence on hypocotyl length. Plants with the shortest hypocotyls were found both among those cultivated at DIF+5 and DIF-5 (tab. 2). Longer hypocotyls were observed in plants cultivated at the constant temperature when compared with those grown at DIF+5 and DIF-5. It should, however, be emphasised that plants cultivated at a 24-hour

Table 2. The influence of DIF on some morphological characteristics of garden dill
Tabela 2. Wpływ DIF na niektóre cechy morfologiczne kopru ogrodowego

	DIF	Temperature (day/night) Temperatura (dzień/noc)	Subsequent day of cultivation Kolejny dzień uprawy				
			7th	14th	21st	28th	35th
Length of hypocotyls, cm Długość hipokotylu, cm	DIF0	20/20°C	4.9* b	5.6 a	5.6 a	5.7 b	6.0 b
	DIF0	25/25°C	5.3 a	5.7 a	5.7 a	6.4 a	6.5 a
	DIF-5	20/25°C	4.5 b	5.1 b	5.1 b	5.2 c	5.2 c
	DIF+5	25/20°C	4.1 c	4.7 c	4.7 c	5.0 c	5.0 c
The height of plants, cm Wysokość roślin, cm	DIF0	20/20°C	7.7 ab	9.2 b	14.4 b	19.2 a	21.2 a
	DIF0	25/25°C	7.7 ab	13.2 a	13.4 b	14.8 c	16.4 c
	DIF-5	20/25°C	7.9 a	10.0 b	14.5 b	16.2 b	18.8 b
	DIF+5	25/20°C	7.4 b	12.9 a	18.2 a	20.0 a	20.7 a
Fresh mass of herb per pot, g Świeża masa ziela z doniczki, g	DIF0	20/20°C	0.7 b	1.8 b	3.4 c	6.3 b	12.0 b
	DIF0	25/25°C	0.6 c	2.6 a	4.7 b	7.6 b	8.3 c
	DIF-5	20/25°C	0.8 b	1.8 b	4.4 b	5.7 c	10.6 b
	DIF+5	25/20°C	1.2 a	2.6 a	6.0 a	8.7 a	15.5 a

* Values followed by the same letters for individual dates do not differ significantly at α = 0.05
* Wartości poprzedzone tą samą literą dla poszczególnych dat nie różnią się istotnie przy α = 0,05

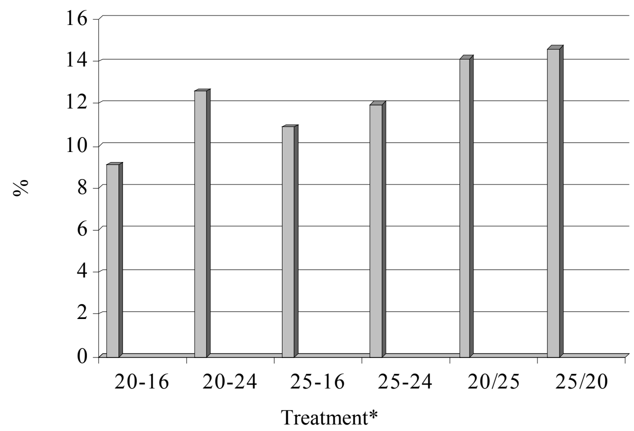
photoperiod were characterised by a shorter hypocotyl in comparison with those exposed to the 16-hour photoperiod (for the temperature of 20°C over the entire vegetation period, for 25°C – for the last 14 days) (tab. 3). Significant differences between DIF+5 and DIF-5 were observed in the case of plant height. Plants were found to be taller for DIF+5 than for DIF-5. The shortest plants were recorded in the cultivation regime of a constant temperature of 25°C and a 16 h photoperiod. The height of plants cultivated at 20°C and a 16-hour photoperiod was the same as that of plants cultivated at DIF+5. Plants cultivated at the temperature of 25°C and a 16-hour photoperiod were significantly lower in comparison with those cultivated at the same temperature and a 24 h photoperiod. Plants were found to grow taller when cultivated at the temperature of 20°C, irrespective of the length of daylight, in comparison with the cultivation at 25°C. The applied cultivation conditions exerted a significant impact on the herbage fresh mass. For the cultivation regime at a 16 h photoperiod the smallest herbage mass was obtained at the constant temperature of 25°C, while the highest – for DIF+5 (25/20°C). No significant differences in the amount of herbage mass were observed for DIF 0 at 20°C and for DIF-5 (20/25°C). It is worth noting that the herbage mass increment dynamics was identical for individual experimental combinations from the beginning of the cultivation. Plants cultivated at 20°C were characterised by a higher mass of fresh herbage in comparison with the cultivation at the temperature of 25°C, irrespective of the length of day. This was associated with an intensive increment of fresh mass during the last seven days of cultivation at the temperature of 20°C.

Table 3. The influence of temperature and photoperiod on some morphological characteristic of garden dill
Tabela 3. Wpływ temperatury i fotoperiodu na niektóre cechy morfologiczne kopru ogrodowego w okresie wzrostu

	Treatment (temp.-photop.) Traktowanie (temp. – fotop.)	Subsequent day of cultivation Kolejny dzień uprawy				
		7th	14th	21st	28th	35th
Length of hypocotyls, cm Długość hipokotylu, cm	20°C-16 h	4.9 b	5.6 ab	5.6 a	5.7 bc	6.0 b
	20°C-24 h	4.0 c	4.9 c	5.4 b	5.5 c	5.5 c
	25°C-16 h	5.3 a	5.7 ab	5.7 a	6.4 a	6.5 a
	25°C-24 h	5.3 a	5.3 ab	5.9 a	5.9 b	6.2 b
The height of plants, cm Wysokość roślin, cm	20°C-16 h	7.7 b	9.2 c	14.4 b	19.2 a	21.2 a
	20°C-24 h	7.5 b	11.9 b	17.0 a	19.3 a	21.5 a
	25°C-16 h	7.7 b	13.2 a	13.4 b	14.8 c	16.4 c
	25°C-24 h	8.8 a	9.9 c	16.6 a	16.9 b	18.1 b
Fresh mass of herb per pot, g Świeża masa ziela z doniczki, g	20°C-16 h	0.7 b	1.8 b	3.4 c	6.3 b	12.0 a
	20°C-24 h	0.8 b	2.9 a	7.1 a	8.1 a	13.3 a
	25°C-16 h	0.6 c	2.6 a	4.7 b	7.6 ab	8.3 b
	25°C-24 h	1.1 a	1.4 b	5.3 b	7.7 ab	9.1 b

* Values followed by the same letters for individual dates do not differ significantly at $\alpha = 0.05$
* Wartości poprzedzone tą samą literą dla poszczególnych dat nie różnią się istotnie przy $\alpha = 0,05$

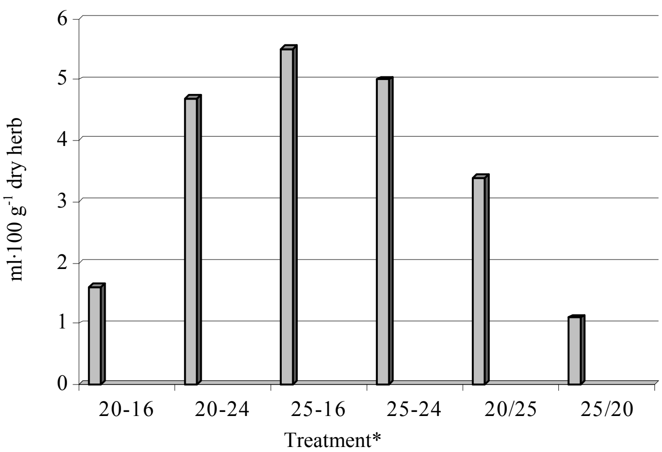
The highest dry matter content in the herbage was determined for plants cultivated at different temperatures of day and night in the case of both positive and negative DIF (fig. 1). Plants cultivated at a 24 h photoperiod were characterised by a higher dry matter content in comparison with those grown at a 16 h photoperiod, irrespective of the applied temperature.



*Note: see treatment in Table 1 – zobacz opis Tabela 1

Fig. 1. The percentage of dry matter in the herb of dill harvested in 35th day of cultivation in depended of temperature and photoperiod

Ryc. 1. Procentowa zawartość suchej masy w zielu kopru ogrodowego zebranego w 35 dniu uprawy w zależności od temperatury i fotoperiodu

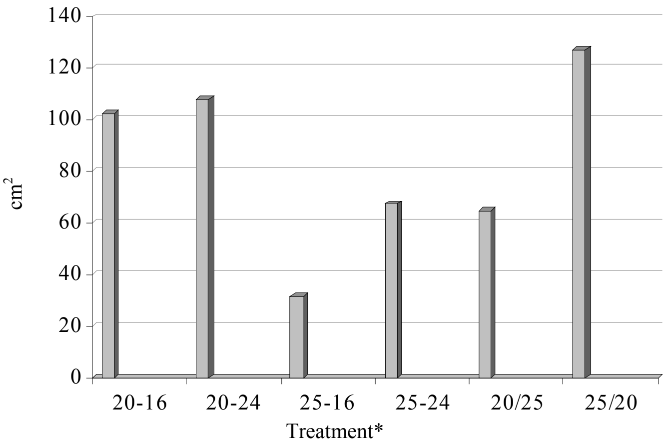


*Note: see treatment in Table 1 – zobacz opis Tabela 1

Fig. 2. The content of essential oils in air-dry herb of dill harvested in 35th day of cultivation in depended of temperature and photoperiod

Ryc. 2. Zawartość olejków eterycznych w powietrznie suchym zielu kopru ogrodowego zebrane-go w 35 dniu uprawy w zależności od temperatury i fotoperiodu

The highest essential oil content in the herbage was determined for a constant temperature of 25°C as well as 20°C and a 24 h photoperiod (fig. 2). On the other hand, the strongest effect on the leaf blade area increment was exerted by DIF+5 and DIF 0 for the temperature of 20°C and both photoperiods (fig. 3).



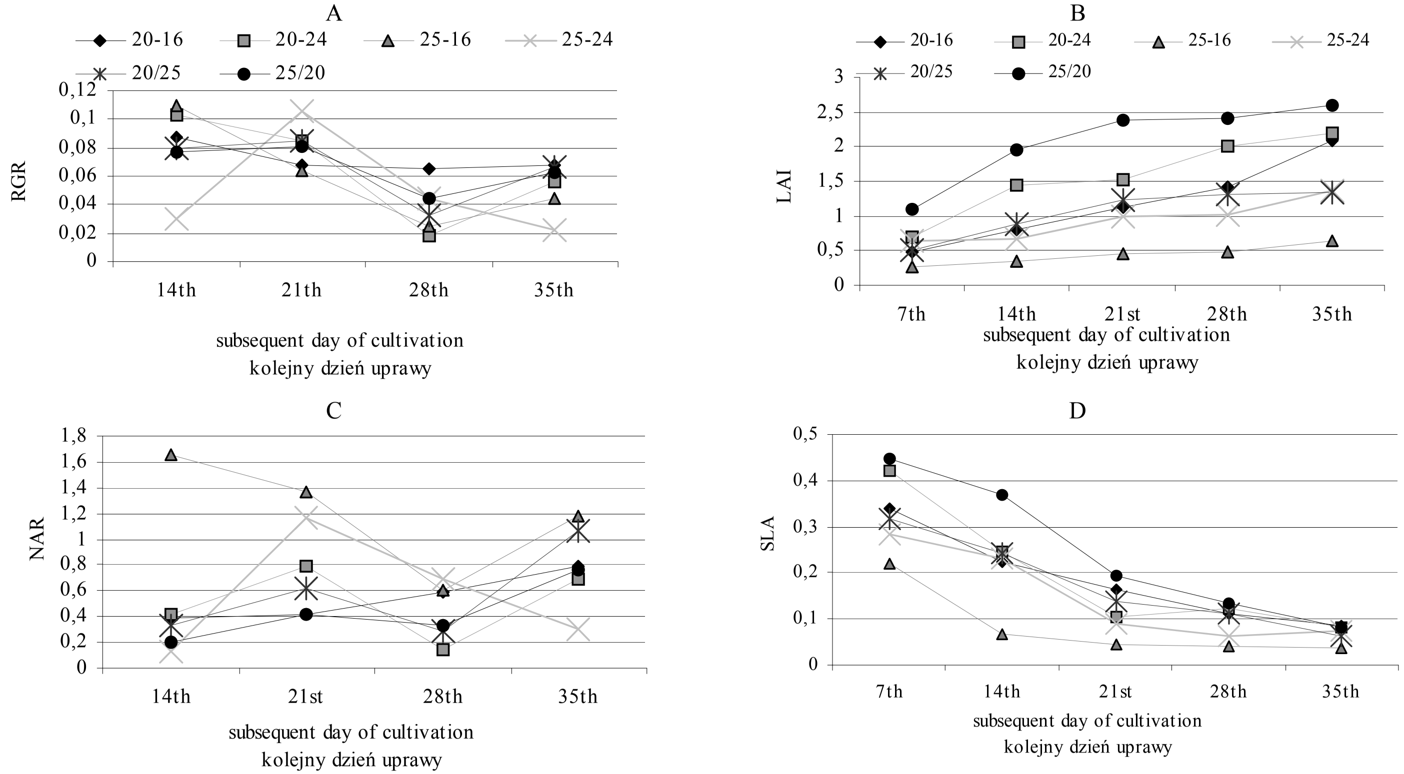
*Note: see treatment in Table 1 – zobacz opis Tabela 1

Fig. 3. Dill leaf area per pot harvested in 35th day of cultivation in depended of temperature and photoperiod

Ryc. 3. Powierzchnia liści kopru zebranego w 35 dniu uprawy w zależności od temperatury i fotoperiodu

The value of the relative growth rate (*RGR*) for all the examined combinations was of a sinusoidal nature (fig. 4). With the exception of the 25°C and 24 h photoperiod combination, all the remaining treatments were characterised by a decline of the *RGR* value from day 14 to day 28 and its slow increase during the last week of growth. The 20°C and 16 h photoperiod combination was characterised by the smallest fluctuations in *RGR* values during the consecutive weeks of cultivation. The highest fresh mass increment during the initial period of cultivation was observed for the DIF+5 (25/20°C) and DIF 0 (20°C/24 h photoperiod) combinations, while later on both these combinations were characterised by the strongest decline in the herbage mass increments. The determined leaf area index (*LAI*) was the highest for the DIF+5 (25/20°C) and for the 20°C/24 h photoperiod combinations. The lowest *LAI* value was recorded in the case of the 25°C/16 h photoperiod combination. These trends remained unchanged throughout the cultivation period.

The value of the specific leaf area (*SLA*) decreased with the progress of the vegetation period. The highest *SLA* value was recorded for the DIF 0 (20°C) combination for both lighting periods, whereas plants cultivated at DIF 0 (25°C/16 h photoperiod) were characterised by the lowest *SLA*. During the final period of the cultivation differences



Note: see description of legend in Table1 – Zob. objaśnienie przy tabeli 1

Fig. 4. Effect of temperature and photoperiod on the value of: A – relative growth rate index RGR ($g \cdot g^{-1} \cdot d^{-1}$), B – leaf area index LAI ($dm^2 \cdot dm^{-2}$), C – net assimilation rate NAR ($g \cdot dm^{-2} \cdot d^{-1}$), D – specific leaf area SLA ($dm^2 \cdot g^{-1}$)

Ryc. 4. Wpływ temperatury i fotoperiodu na wartość: A – wskaźnika wzrostu RGR ($g \cdot g^{-1} \cdot d^{-1}$), B – wskaźnika pokrycia liściowego LAI ($dm^2 \cdot dm^{-2}$), C – jednostkowej produktywności liści NAR ($g \cdot dm^{-2} \cdot d^{-1}$), D – ciężaru jednostki powierzchni liści SLA ($dm^2 \cdot g^{-1}$)

between the experimental combinations were considerably smaller than during the initial phase of growth.

The value of the net assimilation rate (*NAR*), similarly to *RGR*, was characterised by a seven-day, sinusoidal distribution. The DIF 0 (25°C/16 h photoperiod) combination was characterised by a high *NAR* value throughout the vegetation period.

DISCUSSION

Hypocotyl length of dill plants was affected both by photoperiod and DIF. However, it was interesting to observe that a greater impact on the elongation inhibition was exerted by both alternations in daily temperatures than by a constant temperature. In experiments conducted on many species and cultivars of horticultural plants the strongest effect on the inhibition of stem elongation (SE) was exerted by negative DIF, whereas a positive DIF was found to stimulate elongation growth in plants. In studies carried out by Ito et al. [1997a] the influence of DIF on plant height and the first internode length was greater than that of average daily temperature (ADT). Elongation growth and the first internode length was enhanced by a positive DIF, while it was inhibited by a negative DIF. Similar results were obtained by the author with respect to plant height, although the strongest SE inhibition was recorded at the temperature of 25°C and a 16h photoperiod. Experiments conducted by other researchers [Pollet et al. 2009] showed that DIF, especially at high temperatures, strongly inhibits plant elongation growth. The sensitivity of plants to temperature also changes with the photoperiod. Stem elongation is not constant during the period of 24 hours [Shimizu and Heins 2000]. Stems elongate mainly in the light; however, some elongate in the dark. In studies performed by Shimizu et al. [2008] the plant stems in *Chrysanthemum paludosum* remarkably grew in length at an increase of temperature during the light period at all DIF combinations. On the other hand, in *Brassica oleracea* var. *acephala* SE in the light was small in all DIF combinations; however, SE increased as the temperature decreased in the darkness. On the basis of our own experiments it may be presumed that, as in the case of *Brassica oleracea* var. *acephala*, also for dill elongation growth it is the temperature during the night that is important. A higher night temperature or a high constant 24 h temperature caused a significant elongation inhibition in dill plants. According to Langton and Cockshull [1997], internode extension growth is determined by the absolute day temperature and night temperature rather than by DIF. Pearson et al. [1995] found that an appropriate adjustment of DIF may be provided by assuming two distinct responses, one to the day temperature and one to the night temperature, and two different optimum temperatures for extension growth, a higher optimum for day temperature and a lower optimum for night temperature. In their studies DIF appears to work in chrysanthemum because a low day temperature is sub-optimal for extension growth, whilst a high night temperature is supra-optimal. Referring to the above remark, the inhibition of plant elongation growth in our experiments may have been caused by a night temperature being higher than optimal (25°C).

It is known that the plants from the negative DIF combination accumulated less dry mass than those grown at a positive DIF. A previous study showed that a negative DIF significantly reduced the total dry mass content compared to plants grown under a positive DIF [Miller et al. 1993, Stavang et al. 2010, Xiong et al. 2011]. Similar results were recorded in our study. However, the differences between positive and negative DIF values were not large. According to Vogelezang [2000], the DIF-strategy had no significant influence on dry matter percentage. A higher dry matter percentage was obtained from plants grown at a 24 h photoperiod when compared to the 16 h photoperiod. The results from this study are similar to those reported by Jeong et al. [1996]. A long photoperiod led to an increase in dry weight of herbs.

Leaf area was greatly affected by the temperature and DIF, but only slightly influenced by the photoperiod. Leaf area in DIF-5 was smaller than that in DIF+5 or 0 (20°C). Smaller leaves were also obtained in the case of plants growing at the constant temperature of 25°C, irrespective of the photoperiod. In their studies Jeong et al. [1996] reported a greater leaf area of round-leaved mint at a 16h photoperiod and DIF+9 and 0 in comparison with the 8h photoperiod and DIF-9. Similar results were also obtained by Kozai et al. [1995] and Pollet [2009]. In our investigations the application of the 24 h photoperiod inhibited the increase of leaf area. A constant 24 h temperature stimulates root growth in comparison with negative or positive DIF [Pollet et al. 2009]. This could have been one of the causes of a marked leaf growth inhibition at DIF 0 (25°C) in our experiments.

During the initial period of vegetation the relative growth rate (*RGR*) was not affected by temperature. Similar results were obtained by Pollet et al. [2009] and Xiong et al. [2011] in cucumber plants, where DIF did not affect RGR. Greater differences in *RGR* values were recorded for the 16- and 24-h photoperiods. The *RGR* value for plants cultivated at the 24 h photoperiod was considerably smaller than for the cultivations grown at the 16 h photoperiod. *NAR* is the rate of an increase in biomass per unit of leaf area, reflecting the whole-plant balance between photosynthesis and respiration. In cucumber [Agrawal et al. 1993, Xiong et al. 2011] a negative DIF (19/25°C) was shown to reduce the net photosynthetic rate when compared to a positive DIF (25/19°C). Cucumber is a tropical plant and the day temperature of 19°C may lead to a lower photosynthetic rate than the temperature of 25°C, which is close to the optimal day temperature [Wien 1996]. In the discussed experiment the highest NAR value during the initial period of growth (the first 21 days) was determined for DIF 0 (25°C) and the 16h photoperiod. *NAR* values did not differ in the other combinations. Also on the harvest day (the 35th day) the highest NAR was recorded under DIF 0 (25°C) and 16 h photoperiod. The lowest *NAR* for dill was recorded under DIF 0 (25°C) and a 24 h photoperiod. In the case of DIF 0 and the temperature of 20°C a higher *NAR* was obtained for the 16 h than for the 24 h photoperiod, which indicates that cultivation under a 24 h photoperiod reduces considerably the net assimilation rate.

Stavang et al. [2010] showed that the reduction in plant biomass production of pea grown under a negative DIF was a result of the net effect of reduced photosynthesis during daytime and increased respiration during the night. In our investigations plants cultivated at DIF-5 were characterised by greater *NAR* values than those cultivated at DIF+5. This could have been associated with a considerable increment of dill leaf blade area for DIF+5 in comparison with the increase of fresh mass. Plants cultivated at DIF+5 were characterised by the highest value of leaf area index (*LAI*) throughout the entire period of cultivation. The lowest value of this parameter was recorded at DIF 0 25°C and a 16 h photoperiod. The same values were observed in the case of specific leaf area (*SLA*) during the first 14 days of vegetation. At the moment of harvest there were no differences in *SLA* between individual experimental combinations.

CONCLUSIONS

The use of a negative DIF resulted in a significant inhibition of elongation in plants. Its application is most justified during the initial period of cultivation in order to inhibit the excessive growth of hypocotyls. Cultivation at a constant temperature was the least favourable variant as it results in an excessive hypocotyl elongation of plants. However, plant cultivation under DIF+5 is more favourable in the course of later stages of plant production. The 16 h photoperiod turned out to be more advantageous to produce desirable plant characters (height, hypocotyl length, fresh biomass) than the 24 h photoperiod, because at the moment of harvest there were no significant differences between the two photoperiods, thus its application is not economically justified.

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WPŁYW ZMIAN W DOBOWEJ TEMPERATURZE I FOTOPERIODZIE NA WZROST I PLONOWANIE KOPRU OGRODOWEGO W POJEMNIKACH

Streszczenie. W przeprowadzonych doświadczeniach badano wpływ fotoperiodu i DIF na elongację i wzrost roślin kopru ogrodowego. W pierwszym doświadczeniu porównywano zróżnicowaną temperaturę dnia i nocy (DIF-5 – 20/25°C, DIF0 – 20°C i 25°C, DIF+5 – 25/20°C) dla 16-godzinnego fotoperiodu. W drugim doświadczeniu czynnikami były: fotoperiod – 16 i 24 godziny oraz dwie stałe, dobowe temperatury – 20 i 25°C. Stwierdzono istotne różnice w wysokości roślin dla DIF+5 i DIF-5. Dodatnie DIF wpływało stymulująco na wysokość roślin, natomiast ujemne DIF obniżało wartość ej cechy. Jednak największe zahamowanie wzrostu elongacyjnego roślin stwierdzono dla temperatury 25°C przy 16-godzinnym fotoperiodzie. Powierzchnia liści zależała od temperatury i DIF, a w znacznie mniejszym stopniu od okresu świetlnego. Mniejszą powierzchnię liści uzyskano dla DIF-5 w porównaniu z DIF+5 i DIF0 (20°C). Najwyższą zawartość olejków eterycznych w zielu stwierdzono w uprawie w stałej temperaturze 25°C oraz w temperaturze 20°C i 24-godzinnym okresie świetlnym.

Słowa kluczowe: DIF, *Anethum graveolens,* dynamika wzrostu, elongacja

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