

The Effect of Air Temperature on Growth of Eight Herb Species

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Abstract

The effect of different constant air temperatures (18°C, 21°C, 24°C and 27°C) and variable temperatures (24°C/18°C and 27°C/15°C in 12 h/12 h periods) on basil, sage, thyme, lemon balm, cilantro, rosemary, oregano and rocket was studied. Supplementary lighting was given 16 h·day⁻¹ at a photon flux density (PFD) of 150 μmol·m⁻²·s⁻¹ (corresponding to 8.6 mol·m⁻²·day⁻¹ photosynthetic active radiation [PAR]). Including daylight the PAR was 29.6 ± 6.9 mol·m⁻²·day⁻¹ as a mean during the experimental period. Increasing the temperature from 18°C to 27°C increased the fresh weight in basil (106%), sage (95%), rosemary (126%) and rocket (62%), while an increase from 18°C to 24°C increased the weight in lemon balm (78%), cilantro (41%), oregano (40%) and thyme (58%). For the last four species the fresh weight was unaffected by a further increase to 27°C. No significant difference was found between the 24°C/18°C and 27°C/15°C treatments. These treatments gave a mean temperature of about 21°C, and no significant differences were found between these treatments and the constant 21°C treatment. The plant height generally increased in the same proportion as the fresh weight increased in the different species. No differences were visually observed between the treatments after two weeks under indoor conditions. All species remained green except cilantro and rocket, for which some leaf yellowing took place. A simple test indicated that the flavour increased with increasing temperature (from 18°C to 27°C) in all species except cilantro.

Keywords

Air Temperature, Basil, Cilantro, Growth, Lemon Balm, Oregano, Rocket, Rosemary, Sage, Thyme

1. Introduction

Relatively few studies have been done on the effect of temperature on herbs. Relatively low temperatures of 13 to 18°C have been recommended for herbs [1] [2], and temperatures below 20°C are used in the greenhouse production of herbs in Norway. General experience of the effects of climate on plant production in greenhouses

suggests that such a practice is strange. Usually CO₂ enrichment is applied in greenhouses, but the literature on herbs suggests that this factor is often neglected. Knowing that high temperatures in combination with high CO₂ concentrations might significantly increase photosynthesis in plants [3] an experiment with different herb species was recently carried out [4]. This study included mean temperatures ranging from 19.0°C to 22.5°C and showed a stimulation of growth with increased temperature. However, with the belief that higher temperatures than this could be beneficial for an experiment including temperatures ranging from 18°C to 27°C that was carried out in order to see if the productivity of herbs could be significantly increased. Combinations of high day and low night temperatures were included, bearing in mind that such a climate control would save energy [5] [6].

2. Materials and Methods

Eight herb species—basil (*Ocimum basilicum*), sage (*Salvia officinalis*), thyme (*Thymus vulgaris*), lemon balm (*Melissa officinalis*), cilantro (*Coriandrum sativum*), rosemary (*Rosmarinus officinalis*), oregano (*Origanum vulgare*) and rocket (*Eruca vesicaria*)—were sown in 11 cm pots by a drill at Gjennestad Gardener School and were germinated before start of the experiment. Six pots of each species were placed in six climate controlled growth chambers that were placed in a greenhouse compartment at Bioforsk Særheim, Norway (latitude 59° north). Four different constant air temperature treatments were applied: 18°C, 21°C, 24°C and 27°C, resulting in 18.2°C, 20.7°C, 23.5°C and 26.1°C as means for the 22-day experimental period. During the dark period the temperature decreased by 1°C to 2°C. In addition two variable temperature treatments were given: 24/18 (20.4°C as a mean) and 27°C/15°C (20.7°C as a mean) in 12 h/12 h periods (Figure 1). Supplementary lighting was given 16 h·day⁻¹ at a photon flux density (PFD) of 150 μmol·m⁻²·s⁻¹ (corresponding to 8.6 mol·m⁻²·day⁻¹ PAR) by means of high pressure sodium lamps (Philips SON/T). The light was measured by a Lambda LI-185B instrument with a quantum sensor above the plants. The dark period was 8 h·day⁻¹, and the 12 h low temperature treatment started two hours before and ended two hours after the dark period. Including daylight as measured at the Meteorological Station of Bioforsk Særheim (www.bioforsk.no, Agricultural Meteorological Service), the PAR was 29.6 ± 6.9 mol·m⁻²·day⁻¹ as a mean during the experimental period (27 April until 19 May) (Figure 2). The daylight was decreased 50% due to reduction by the greenhouse and growth chamber constructions. The CO₂ concentration was 880 ± 40 μmol·mol⁻¹ as measured by an infrared gas analyser, and the relative humidity was 80% ± 5%. Because of high growth rates five of the species were harvested after 15 days (on 12 May) while the three remaining species (oregano, thyme and rosemary) were harvested after 22 days (on 19 May). The fresh weight and plant height of four pots per treatment and per species were recorded. Two pots per treatment and per species were placed in a room under simulated indoor conditions at a temperature of 22°C ± 1°C, a relative

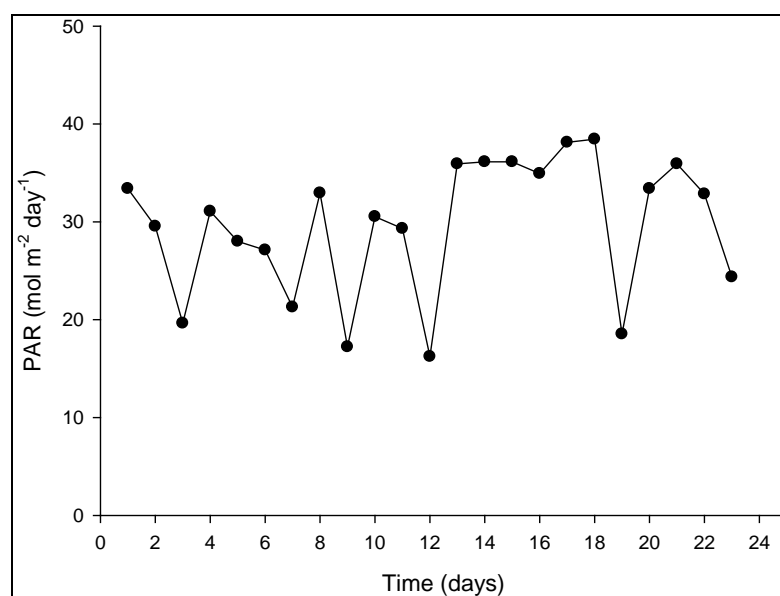


Figure 1. The PAR contributed by daylight during the experimental period from 27 April until 19 May.

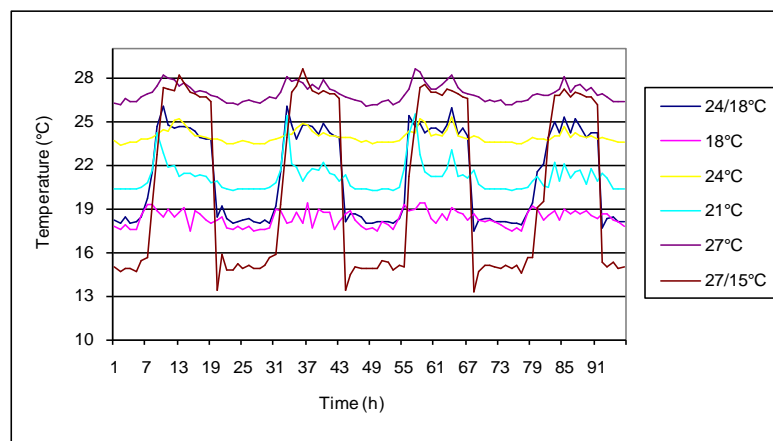


Figure 2. The air temperature recorded during four days in the six different treatments.

humidity of $50\% \pm 5\%$ and a PFD of $15 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, applied $12 \text{ h}\cdot\text{day}^{-1}$ by cool white fluorescent tubes (Philips TL33). The visual appearance of the plants was described after 14 days in the test room. Finally, a simple test was carried out by two people in order to get an indication of the relative flavour of the herbs at 18°C , 24°C and 27°C treatments.

The data were analysed by means of the Duncan multiple range test at $p = 0.05$ level with pots as replicates.

3. Results

Increasing the temperature from 18°C up to 27°C increased the fresh weight in basil (106%), sage (95%), rosemary (126%) and rocket (62%) (**Table 1**). An increase from 18°C to 24°C increased the weight in lemon balm (78%), cilantro (41%), oregano (40%) and thyme (58%), while a further increase to 27°C had no effect (**Table 1**). No significant difference was found between the $24^\circ\text{C}/18^\circ\text{C}$ and $27^\circ\text{C}/15^\circ\text{C}$ treatments. These treatments had about the same average temperature as the constant 21°C treatment, and no significant differences on the fresh weight were found between these treatments. The plant height generally increased in the same proportion as the fresh weight in the different species (**Table 2**). Calculating the fresh weight per cm height made it clear that there were no significant differences between the different treatments in all species (results not presented). After two weeks under simulated indoor conditions no differences between the treatments could be visually observed on the plants that remained green, with the exceptions of cilantro and rocket, for which leaf yellowing had taken place in all treatments (results not presented). A simple test indicated that increasing the temperature from 18°C to 24°C to 27°C strongly increased the flavour of all species except cilantro, which retained a mild flavour.

4. Discussion

The results were quite surprising given the commercial practise of growing herbs at temperatures below 20°C . A substantial increase in the fresh weights of all eight herbs (ranging from 40 to 126%) was found to correspond to an increase in temperature from 18°C to 24°C or 27°C . Previous results with sage have shown increased growth up to 30°C when growing the plants at a PAR level of $34.7 \text{ mol}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ [2], which is in accordance with the present results. In basil it was found that $30^\circ\text{C}/12^\circ\text{C}$ (mean temperature 24°C) gave a higher fresh weight than $24^\circ\text{C}/12^\circ\text{C}$ (mean temperature 20°C) [7]. When applying a low PAR of 2.9 to $3.8 \text{ mol}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$, it was not surprising that the growth of herbs was found to be better at $15^\circ\text{C}/10^\circ\text{C}$ than at $20^\circ\text{C}/15^\circ\text{C}$ day/night temperature [8]. By increasing the PAR level, the temperature for maximum growth will increase. It is important to be aware that high-temperature production (24°C to 27°C) in herbs requires PAR levels of at least 15 to $20 \text{ mol}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$, similar to what was found for miniature roses at higher temperatures [9]. When plants are grown at high CO_2 concentrations the optimum temperature for growth is likely to increase [3], and they will also be protected against high-temperature damage [10]. The present results show that the mean temperature determined the growth rate of the herb species, since both a constant temperature of 21°C and a mean temperature of 21°C achieved with variable temperature treatments of $27^\circ\text{C}/15^\circ\text{C}$ or $24^\circ\text{C}/18^\circ\text{C}$ gave the same fresh weight. This is in

Table 1. Fresh weight per pot (g) as affected by different temperature treatments in eight different herbs. Values followed by different letters are significantly different according to Duncan's multiple range test at $p = 0.05$ level.

Species	Temperature (°C)					
	18	21	24	27	27/15	24/18
Sage	37d	50c	62b	72a	54bc	56bc
Lemon balm	18b	22b	32a	37a	20b	24b
Cilantro	63c	74b	89a	88a	85a	81ab
Rocket	55c	53c	71b	89a	74b	64bc
Basil	52d	63cd	85b	107a	82b	68c
Rosemary	19d	23cd	31b	43a	30bc	30bc
Oregano	45c	53bc	63ab	68a	59ab	59ab
Thyme	45b	44b	71a	76a	70a	56b
Mean	42d	48cd	63ab	72a	59b	55bc

Table 2. Plant height (cm) as affected by different temperature treatments in eight different herbs. Values followed by different letters are significantly different according to Duncan's multiple range test at $p = 0.05$ level.

Species	Temperature (°C)					
	18	21	24	27	27/15	24/18
Sage	9c	13b	17a	18a	14b	14b
Lemon balm	7d	9c	10b	12a	8c	9c
Cilantro	17b	17b	20a	19ab	21a	19a
Rocket	8b	10ab	10ab	12a	12a	10ab
Basil	8e	9de	14b	18a	13c	10d
Rosemary	4e	5de	8ab	9a	7bc	6cd
Oregano	7c	8b	11a	11a	11a	9b
Thyme	9b	9b	11b	11b	12b	15a
Mean	8d	10cd	13ab	14a	12ab	11bc

accordance with previous findings, which show that the mean temperature (within some limitations) usually determines the growth rate of greenhouse plants [5] [6]. The content of volatile oil has been found to be strongly increased when basil is grown at 25°C to 30°C instead of 15°C [11] [12]. Therefore, the flavour and taste of the herbs is increased by increased temperatures, as indicated in the present study. The climate-dependent spiciness of herbs should be further investigated, since this is important for the consumer.

Acknowledgements

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