Complex influence of different humidity and temperature regime on pea photosynthetic indices in VI–VII organogenesis stages

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The aim of the study was to investigate the influence of different humidity and temperature regime on pea photosynthetic indices. Vegetative experiments were carried out in the phytotronic complex of Plant Physiology Laboratory at the Lithuanian Institute of Horticulture in 2007. There was investigated pea cultivar ‘Pinochio’ (Pisum sativum L.). Peas were grown under conditions of different temperature (21/16 °C and 30/23 °C day/night) and humidity (40–45 % and < 10 % normal/dryish) regime. Different combinations of temperature and humidity regime significantly influenced plant physiological processes. There was established the smallest clear photosynthesis productivity, relational growth speed, fresh and dry weight of the pea, which grew in dry substratum at the temperature of 30 °C. High temperature and the lack of humidity also inhibited the synthesis of chlorophylls a and b. At the temperature of 30 °C under both humidity regimes the accumulation of carotenoids in pea became more intensive.

Key words: lack of humidity, photosynthetic pigments, photosynthesis indices, temperature.

Introduction. More and more attention to the influence of climatic changes on plants is paid in the world (Bray et al., 2000; Fuhrer, 2003). Plant injures and the decrease of their productivity most often depends on unfavourable factors, which exist naturally in the environment. Plant physiological processes are directly connected with the regime of temperature and humidity and their change. These factors are among the most important ones – the plant growth and development processes and productivity depends on them (Alexeieva et al., 2003). Higher temperature distinguishes itself with stress effect. Temperature, which is even a few degrees higher than the usual one, influences the function of many ferments and causes protein expression of heat stress (Jenkins et al., 1997). The ratio of photosynthesis and respiration determine plant growth. When temperature increases, the intensity of respiration increases also,
therefore energetic plant resources are lost (Kirnak et al., 2001). Higher temperature quickens plant growth and development, shortens the duration of different development stages, therefore the final biomass production may decrease. The first and the most sensitive plant response to water deficit is the decrease of turgor and slowing down of growth processes (Kirnak et al., 2001). The lack of water worsens carbon assimilation, which depends on opening and shutting of jaws. Moreover, the lack of water and high temperature can stimulate the formation of free radicals and active oxygen derivatives, which disturb the processes of plant metabolism (Alexieva et al., 2003; Chaves et al., 2003). In order to support the growth and productivity, plant must adjust itself to stress conditions and develop the specific tolerance mechanisms (Wang et al., 2003). Plant reaction to the changes of temperature and humidity depends on plant type, cultivar, genetic properties, age and the level of development (Yamaguchi-Shinozaki et al., 2002). Plants of the different level of development react on the stress factors differently (Lawlor, 2002; Lawlor and Cornic, 2002). It was observed that plants, which adjusted to one stressor, became more resistant to the complex influence of stressors also (Duchovskis et al., 2003). Nevertheless, the complex influence of the limited duration change of temperature and humidity regime on the productivity of agricultural plants is investigated insufficiently.

**Aim of investigation – to analyze the influence of the complex humidity and temperature regime on pea photosynthetic indices in VI–VII organogenesis stages.**

**Object, methods and conditions.** Vegetative experiments of the complex influence of humidity and temperature regime were carried out in the phytotronic complex of Plant Physiology Laboratory at the Lithuanian Institute of Horticulture. There was investigated pea cultivar ‘Pinochio’ (*Pisum sativum* L.). Plants were grown in vegetative pots of 5 l. Substratum was prepared from peat of neutral acidity (6–6.5 pH) and sand (3 : 1). There were grown twenty pea plants per each vegetative pot. From germination up to VI–VII organogenesis stage plants were grown in the greenhouse, and then transferred to phytocameras, where 16 h photoperiod was created and for the illumination Son-T-Agro (PHILIPS) lamps were used. Organogenesis stages were established according to F. Kuperman (Куперман et al., 1982). Four variants of experiment were carried out in five replications each. Under two temperature regimes (21/16 °C and 30/23 °C day/night) there was investigated the effect of humidity and drought (< 10 %) of normal (40–45 %) substratum. Humidity of substratum was measured with Delta-T Devices soil humidity measurer HH2. Duration of the effect was 10 days. Right away after the effect plants were transferred back to the greenhouse, where uniform conditions to all plants were created and their regeneration was observed for 7 days. During investigations, biometrical measurements were carried out. The amount of photosynthesis pigments in fresh weight was established preparing 100 % acetone extracts and analyzing them by spectrophotometrical Wettstein’s method (Гавриленко et al., 2003). There was used spectrophotometer Genesys 6 (ThermoSpectronic, JA V).

Assimilation area was measured with leaf area measurer CI-202 (CID Inc., USA). Plant dry weight was established drying at the temperature of 105 °C.

Pure photosynthesis productivity (F\(_{\text{pr}}\)) was calculated according to the formula:

\[
F_{\text{pr}} = \frac{2(M_2 - M_1)}{(L_1 + L_2)}T
\]  

(1)
Here ($M_2 - M_1$) – increase of dry weight during certain period;
$L_1$ and $L_2$ – leaf area at the beginning and at the end of the period;
$T$ – duration of period in 24 h (Bluzmanas et al., 1991).

Relational speed of growth ($R$) was calculated according to the formula:
\[ R = \frac{W_2 - W_1}{t_2 - t_1} \]
Here $W_1$ and $W_2$ – dry weight at the beginning and at the end of the period;
$t_1$ and $t_2$ – the beginning and the end of the period in 24 h (Coombs et al., 1985).

Standard deviation of the investigation data average was calculated using program MS Excel.

**Results.** Different combinations of temperature and humidity regime significantly influenced pea photosynthesis system (Fig. 1). The least amount of chlorophyll $a$ was established in pea, grown in dry substratum at the temperature of 30 °C.

![Fig. 1. Photosynthetic pigment content in different temperature and humidity combinations. N – substratum of normal humidity (40–45 %), S – dryish substratum (< 10 %). A – chlorophyll $a$; b – chlorophyll $b$; c – carotenoids.](image)

The smallest amount of chlorophyll $b$ accumulated pea, which suffered the lack of humidity under both temperature regimes. The biggest amount of carotenoids was established in pea grown at the temperature of 30 °C. After 7 days of regeneration period the amount of chlorophylls $a$, $b$ and carotenoids strongly decreased. The smallest amount of photosynthetic pigments was in pea, which had suffered humidity lack and
high temperature of 30 °C (Fig. 1). Both the lack of humidity and high temperature negatively influenced pea assimilation area, fresh and dry weight (Fig. 2, 3, 4). After 10 days of humidity and high temperature of 30°C there was established the smallest pea assimilation area, fresh and dry weight. After 7 days of regeneration period in all the combinations of temperature and humidity regime, assimilation area, fresh and dry weight strongly increased (Fig. 2, 3).

Fig. 2. Pea assimilation area in different temperature and humidity combinations.
N – substratum of normal humidity (40–45 %),
S – dryish substratum (< 10 %).

Fig. 3. Pea fresh weight in different temperature and humidity combinations.
N – substratum of normal humidity (40–45 %),
S – dryish substratum (< 10 %).
Independently on substratum humidity after 10 days of effect, peas, which were grown at the temperature of 30 °C, produced essentially smaller above-ground part (Fig. 5). After regeneration period pea height almost didn’t change (Fig. 5).

Temperature and humidity regime influenced pea pure photosynthesis productivity and relational growth speed (Fig. 6). After 10 days of effect the biggest pure photosynthesis productivity and relational growth speed was of the pea, which grew under optimal conditions (at the air temperature of 21 °C and substratum humidity...
The smallest pure photosynthesis productivity and relational growth speed was established in pea, which suffered the lack of humidity and high temperature of 30 °C (Fig. 6).

**Fig. 6.** Pea photosynthesis productivity (a) and relational growth speed (b) after 10 days effect in different temperature and humidity combinations.

N – substratum of normal humidity (40–45 %),
S – dryish substratum (< 10 %).

Discussion. The effect of biotic and abiotic factors significantly influences plant physiological processes. Some of them are trophic, causes plant nutrition, others have side effect, which often is harmful. When factors are unfavourable or the level of trophic factors unsuitable, this causes unusual reaction in plants – stress. Stress determines changes in the normal plant physiological processes. Draught and extreme temperatures are among environmental factors, which most often inhibit plant productivity (Chaves et al., 2003; 2004; Flexas et al., 2004). Photosynthesis is one of the main physiological processes, which determine plant productivity. The efficient work of photosynthesis apparatus is guaranteed only by optimal amount and ratio of photosynthetic pigments. Our results show that, when pea suffered the lack of humidity, the amount of chlorophylls \(a\), \(b\) significantly decreased and at the high temperature the negative influence revealed itself even more. At the high temperature the amount of carotenoids very increased. Carotenoids participate as antioxidants, which preserve plant cells from oxidation stress (Alexieva et al., 2003), therefore it is possible to think that pea developed defence mechanisms against draught and stress, caused by high temperature. Plants have unique mechanisms to react to the continually changing environmental conditions: they feel the environment and accommodate their physiological and metabolic processes for the preserving of homeostasis. Reaction to stressors is determined by plant genome and the interaction of the changed environmental conditions (Pastori, Foyer, 2002).

One of the most important photosynthesis indices is pure photosynthesis productivity. It is expressed by dry matter amount, which is produced during 24 h by plant per leaf assimilation area unit (Bluzmanas et al., 1991). Pure photosynthesis productivity best of all reflects the effect of environmental factors on plant growth.
and development (Ничипорович, 1987; Третьяков, 1998). The obtained results of the investigations showed that the lack of humidity and high temperature decreased pure photosynthesis productivity and relational speed of growth. This means that plant for the preserving biological vitality used more energy and assimilates than created them during photosynthesis process.

Many authors indicate, that stress caused by draught negatively influence the activity of assimilation apparatus, accumulation of dry matter, violate metabolism (Kage et al., 2004; Grzesiak et al., 1999).

One of the elements of productivity is to keep high photosynthetic potential. Our investigations showed that pea sensitively reacted on the stress caused by draught and high temperature. The lack of humidity inhibited the accumulation of fresh and dry weight and the growth of assimilation area. Peas under the optimal conditions regenerated themselves.

**Conclusions.** 1. Pea reaction to the stress of the lack of humidity and high temperature manifested itself in the decrease of chlorophylls $a$ and $b$ synthesis and increase of carotenoids.

2. The lack of humidity at the temperature 30 °C decreased pea photosynthesis productivity, relational growth speed and dry weight.

3. High temperature of 30 °C inhibited the growth of the above-ground part.

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**References**


19. Гавриленко В. Ф., Жыгалова Т. В., 2003. Большой практикум по фотосинтезу. Москва, Академия..
22. Третьяков Н. Н. 1998. Физиология и биохимия сельскохозяйственных растений. Москва.
Skirtingo drėgmės ir temperatūros režimo kompleksinis poveikis žirnių fotosintetiniams rodikliams VI–VII organogenezės etapuose

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Santrauka


Reikšminiai žodžiai: drėgmės deficitas, fotosintetiniai pigmentai, fotosintezės rodikliai, temperatūra.