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Janusz PODLEŚNY[1] and Anna PODLEŚNA[2]

EFFECT OF HIGH TEMPERATURE IN THE FLOWERING PERIOD ON GROWTH, DEVELOPMENT AND YIELDING OF FABA BEAN (*Vicia faba* L. spp. *minor*)

WPŁYW WYSOKIEJ TEMPERATURY W OKRESIE KWITNIENIA NA WZROST, ROZWÓJ I PLONOWANIE BOBIKU (*Vicia faba* L. spp. *minor*)

Abstract: The research was conducted in the growth chambers and in a greenhouse of Institute of Soil Science and Plant Cultivation – State Research Institute in Pulawy. Faba bean var. Nadwislanski was cultivated in Mitscherlich pots. An experimental factor was air temperature during flowering: optimal and higher. After flowering pots with plants were transferred from growth chambers to the greenhouse where they stayed up to full maturity. Too high temperature at flowering caused decrease of leaf area, leaf greenness index, plant height and changed the course of some phenological phases of faba bean. High temperature decreased yield which resulted from a lower number of pods per plant, number of seeds per pod and a lower mass of a thousand seeds.

Keywords: faba bean, high temperature, flowering, plant development, leaf area, yielding

Legumes are characterized by very large dependence on the course of weather conditions. This consequence is greater than yielding variability in the years of some other crop species [1]. Availability of water conditioned by the amount of precipitations and irrigation is a factor which in the greatest degree influences the size of seed yields obtained by this plant group. Legumes are particularly sensitive to water shortage in the soil at two phenological phases: at germination – emergence and at flowering [2]. Various genotypes of each species show different sensitivity to periodic water deficit in the soil [3, 4]. However, in some years there is observed a considerable reduction of seed yield in spite of sufficient water supply in plants. It can be supposed, therefore that temperature, as another important weather factor, has probably a restrictive effect on the

[1] Department of Forage Crop Production, Institute of Soil Science and Plant Cultivation – State Research Institute, ul. Czartoryskich 8, 24–100 Puławy, Poland, email: jp@iung.pulawy.pl

[2] Department of Plant Nutrition and Fertilization, Institute of Soil Science and Plant Cultivation – State Research Institute, ul. Czartoryskich 8, 24–100 Puławy, Poland, email: ap@iung.pulawy.pl

level of obtained seed yield. This is all the more so as these observations concerned the years in which air temperature during flowering considerably exceeded values of means from many years. In attainable literature there is only some papers with results of experiments concerning studies on the response of a particular legume plant species to high temperature during flowering [5–8]. Most often it possible to find this information in relation to wheat [9–11], maize [12] or oilseed rape [13–14].

The aim of the present research was evaluation of the effect of high temperature in the flowering period on growth, development and yielding of faba bean.

Material and methods

Research was conducted at growth chambers and in a greenhouse of the Institute of Soil Science and Plant Cultivation – State Research Institute in Pulawy, in Mitscherlich pots contained mixture of soil and sand in the amount of 5 and 2 kg, respectively. The soil in the pots was slightly loamy sand with pH_{KCl} 4.8 and granulometric composition of 76, 16 and 8 %, for sand, silt and silt and clay, respectively. An experimental factor was air temperature in the period of flowering and pod setting: optimal (14 ^{o}C – night, 24 ^{o}C – day) and higher (18 ^{o}C – night, 30 ^{o}C – day). Relative air humidity at growth chambers was 85 %, and lighting 300 mikromol $\cdot$ $m^{-2} \cdot s^{-1}$. Ten seeds of faba bean var. Nadwislanski were sowed to every pot, and after emergence plants were thinned to 5 at each pot. Plants in the experiment were fertilized with the following NPK doses ($g \cdot pot^{-1}$): 0.1 N, 1.1 P and 1.4 K. Fertilizers were applied in a liquid form during plant watering at two terms: after emergence and at stage of 1–2 leaves. Moisture of soil during the vegetation was kept on the level 60 % of field water capacity. In the beginning of flowering plants were placed in growth chambers. After the end of this phase pots with plants were transferred to a greenhouse where stayed up to full maturity. Detailed observation of growth and plant development were conducted in the vegetation period. At green pod stage (BBCH 80) the measurement of leaf area was done by using leaf area measurer AM 300 (ADC BioScientific Ltd., UK) and measurements of SPAD index were performed with using Minolta Chlorophyll Meter SPAD-502. Values of SPAD units were measured on the first, second and third, fully developed leaf, counting from the top of a plant. Every measurement of SPAD index was a mean from 30 measurements performed on each plant. Just before the harvest of the plants, the measurement of their height was made and during the harvest the yield of particular faba bean organs as well as the following features of its structure were estimated: number of pods and number of seeds per plant, number of seeds per pod, a thousand seed mass and seed moisture content. Results of the research expressed as a mean from 3 pots were worked out statistically by using analysis of variance with the help of Tukey's confidence interval at the significance level $\alpha = 0.05$.

Results and discussion

The emergence of plants occurred after 9 days from sowing. Faba bean seeds were characterized by germination capacity on the level 95 %, so it was possible to obtain

very good emergence which was measured as the number of seedlings per pot. Seedlings were characterized by good forming and big vigor. Faba bean plants grew from these seedlings produced a great mass of vegetative organs at initial stage of development. Placing the plants during flowering period in high temperature caused significant reduction of leaf area, decrease of leaf greenness and height of plants (Table 1).

Table 1

Mean values of chosen features of faba bean plants

Air temperature	Green pod [BBCH 80]		Full maturity [BBCH 90]
	Leaf area [cm^2 per plant]	Leaf greenness index [SPAD]	Height of plants [m]
Optimal	628^{b*}	584^{b}	1.12^{b}
High	514^{a}	445^{a}	0.97^{a}

* Numbers in columns denoted with the same letters do not differ significantly.

The same changes caused by higher temperature were found in case of lupine and barley [8]. Previous studies showed that thermal stress appearing in flowering period significantly restricts plant leaf area size as result of enhanced leaf senescence at conditions of higher temperature [6, 8, 15]. It was observed also that heat stress reduces chlorophyll content what was explained as effect of enzyme inhibition in this conditions [16]. In the case of faba bean, as legume plant, probably occurred disturbed supplying with nitrogen because high temperature affects nitrogen fixation [17]. Furthermore, in our experiment was observed a change the course of some developmental phases. The plants which at flowering grew in higher temperature conditions considerably earlier ended flowering and started pod setting as well as ripened about 3–4 days earlier than the plants cultivated at optimal air temperature. Mian et al [18] also observed changes of developmental phases of wheat caused by high air temperature. According to Rahman et al [15] higher temperature enhances plant growth and forces the maturity, so different growth and development stages occur earlier compared with optimal temperature.

Thermal conditions had also an effect on dry matter yield accumulated by particular organs of plants (Fig. 1). High temperature during plant flowering influenced negatively the size of vegetative and generative organs yield, while positively affected root mass. The decrease of the dry mass yield of faba bean which was grown during flowering at higher temperature was: 25.2, 32.5, 28.3 and 34.8 %, for stems, leaves, siliques and seeds, respectively, while the increase of roots dry mass yield was 10.3 %.

Roots play an important role in plant adaptation to high temperature by their significance in water and nutrient uptake, as well as their involvement in hormone synthesis affecting shoot growth and development [19]. However, physiological processes that are essential for root growth include carbohydrate metabolism. Maintaining high carbon-use efficiency at high temperatures is of fundamental importance, because roots depend solely on shoots for the supply of assimilates. Carbon supply to roots typically decreases while root respiratory carbon consumption of assimilates increases at high temperatures. So, excessive consumption of assimilates for the

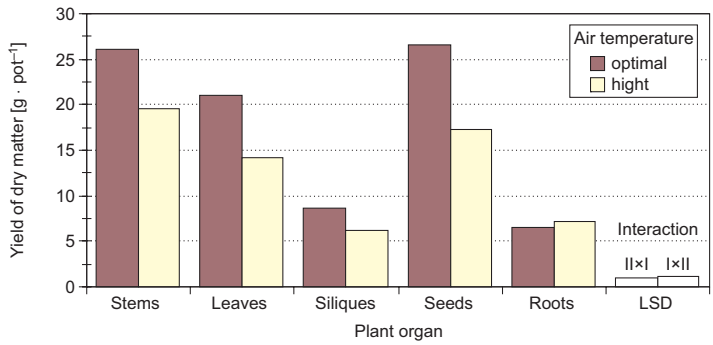

Fig. 1. Yield of dry matter of faba bean plant organs at full maturity

maintenance of roots may be a significant factor limiting plant productivity, particularly under stressful environments [20]. It is in accordance with studies of Lahti et al [21], who found that in the higher temperature treatment, carbon allocation to root growth may have been favored at the expense of shoot growth.

The results of experiments with pea, lupine and barley [6, 8] demonstrate that a short period of thermal stress causes aboveground biomass yield reduction in consequence of photosynthetic productivity decrease. Photosynthesis is closely related to plant growth and crop yields, and photosystem II (PS II) is considered as the most heat-sensitive component of the photosynthetic apparatus [22]. As an effect of higher temperature was observed the decrease of transpiration and stomatal conductance values [8]. According to Yan et al [22] photosynthesis is mainly limited by stomatal conductance and reduced transpiration led to increase in leaf temperature and subsequent negative effects on photosynthesis. The studies of Podlesny and Podlesna [8] and Rahman et al [15] showed that the final biomass and grain yield of wheat and lupine-barley mixture significantly decreased in high compared with optimal temperature.

The main indicator of plant productivity is seed yield which is depended on genotype and different stresses during vegetation period. At our studies was found the negative effect of higher air temperature conditions on faba bean seed yield and its structure features (Table 2). The decline of the seed yield was caused by decreasing of the pod number per plant and the number of seeds per pod as well as a lower mass of a thousand seeds.

Table 2

Mean values of faba bean yield structure

Air temperature	Full maturity [BBCH 90]			
	number of pods per plant	number of seeds per pod	number of seeds per plant	weight of 1000 seeds [g]
Optimal	4.2[b*]	3.3[b]	13.9[b]	382[b]
High	3.3[a]	2.1[a]	8.9[a]	337[a]

* Numbers in columns denoted with the same letters do not differ significantly.

Research by other authors also prove the negative effect of high temperatures during flowering on generative development of plants, which in consequence, is a reduction of size and yield quality as well as yield structure features [6, 10, 12]. The negative effect of high temperature is probably, the disturbance of assimilates transport and, most of all, changes of direction of its distribution which decreases of their export to flowering branches and fruit [23]. The periods of flowering and seed set are clearly critical stages for exposure to heat stress. Development of male (pollen, anthers) and female (stigma, ovary) parts are the most sensitive organs to abiotic stress in reproductive biology [17]. So, high temperature effects at flowering are related to another development, pollen sterility and pollen production what reduce pollen germination. According to Porch and Jahn [24] pollen sterility is one of the key factors limiting legume yield under high temperature. Therefore flower abortion is caused by male sterility resulting from abnormal pollen development. Studies of Rahman et al [15] showed that high temperature may effects the pollen viability and fertilization and thereby reduce the number of set fruit and developed seeds. Individual seed weight which is considered as one of the major yield components is also significantly influenced by higher temperature because it enhances plant maturation causing reduction in seed growth duration which ultimately resulted in smaller seeds.

Conclusion

1. Too high temperature at flowering caused reduction of leaf area and decrease of plants height as well as changed the course of some phenological phases of faba bean.
2. Plants which grew at higher temperature conditions considerably earlier ended flowering and started pod setting and ripened a few days earlier than plants cultivated at optimal air temperature.
3. High temperature at flowering negatively influenced on yield of vegetative and generative faba bean organs, limited in the greatest degree the size of seed yield.
4. Decline of faba bean seed yield at higher air temperature conditions was a consequence of a lower number of pods per plant, a lower number of seeds per pod and weaker filling of seeds.

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WPŁYW WYSOKIEJ TEMPERATURY W OKRESIE KWITNIENIA NA WZROST, ROZWÓJ I PLONOWANIE BOBIKU (*Vicia faba* L. spp. *minor*)

[1] Zakład Uprawy Roślin Pastewnych, [2] Zakład Żywienia Roślin i Nawożenia
Instytut Uprawy Nawożenia i Gleboznawstwa
Państwowy Instytut Badawczy w Puławach

Abstrakt: Celem podjętych badań było określenie wpływu wysokiej temperatury w okresie kwitnienia i zawiązywania strąków na wzrost, rozwój i plonowanie zróżnicowanych genotypów bobiku. Badania prowadzono w fitotronach oraz w hali wegetacyjnej Instytutu Uprawy Nawożenia i Gleboznawstwa – Państwowego Instytutu Badawczego w Puławach, w wazonach Mitscherlicha zawierających mieszaninę 5 kg ziemi ogrodowej i 2 kg piasku. Wysiewano bobik odmiany Nadwiślański. Czynnikiem doświadczenia była temperatura powietrza w okresie kwitnienia: optymalna (noc: 14 ^{o}C, dzień: 24 ^{o}C) oraz podwyższona (noc: 18 ^{o}C, dzień: 30 ^{o}C). Następnie wazony z roślinami przeniesiono do hali wegetacyjnej i utrzymywano je do dojrzałości pełnej. Przez cały okres wegetacji utrzymywano wilgotność gleby na poziomie 60 % ppw. Zbyt wysoka temperatura w okresie kwitnienia powodowała redukcję powierzchni liściowej i zmniejszenie wysokości roślin oraz zmianę przebiegu niektórych faz fenologicznych bobiku. Rośliny, które przetrzymywane były w warunkach podwyższonej temperatury, znacznie wcześniej kończyły kwitnienie i rozpoczynały zawiązywanie strąków oraz dojrzewały o kilka dni wcześniej niż rośliny rosnące w optymalnej dla bobiku temperaturze powietrza. Wysoka temperatura zmniejszała plon co było konsekwencją mniejszej liczby strąków na roślinie i liczby nasion w strąku oraz istotnego zmniejszenia masy 1000 nasion.

Słowa kluczowe: bobik, wysoka temperatura, rozwój roślin, powierzchnia liści, plonowanie