EFFECTS OF TEMPERATURE ON YIELD AND PROTEIN CONTENT OF *LUPINUS ANGUSTIFOLIUS* CULTIVARS

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ABSTRACT

As a result of global warming, stress caused by high temperatures will become more common in temperate regions in the future. To get information on the effect of different temperatures on yield parameters and protein content of narrow-leaf lupin cultivars (Lupinus angustifolius) actually grown in Germany, cvs. 'Probor', 'Haags Blaue' and 'Boruta' were cultivated at 20°C in 13 cm pots in a green house. At the beginning of flowering, plants were transferred to growth chambers under long-day conditions at temperatures of 30°C/16°C (mean 25.3°C) and 20°C/16 °C (mean 18.7°C), or to an outdoor control at a mean temperature of 15.5°C. This long-term temperature stress was applied to get information on potential changes in yield and protein content of different cultivars. At 30°C/16°C pod set was nearly completely inhibited. Because of the very low pod and seed yield at higher temperatures a non-destructive specific NIR-method was used to determine protein content in single seeds. Lower temperature from flowering to pod ripening resulted in lower protein content in seeds of all investigated cultivars but in higher protein yield due to a higher seed yield.

KEYWORDS

Lupinus angustifolius, temperature stress, yield, protein content

INTRODUCTION

The future of agricultural productivity depends on the ability of field crops to grow and be productive in changing environments (Ulukan, 2008). One of the important environmental changes that will occur with global warming is rising temperature during the growing period. Different plant species have different temperature optima for normal growth and development. Excessively high day time temperatures can adversely affect growth and yield (Ulukan, 2008). This has also been reported for lupins. High temperatures at flowering time decreased pod set and reduced seed production and branching (Downes and Gladstones, 1984 a, b, c) of *Lupinus angustifolius* cultivars in Australia. Rising temperatures are also expected for temperate regions in Europe. New regional climate model calculations in Germany (Federal Environment Agency 2007) predict a rise between 1.8°C and 2.3°C by the end of this century, depending on the different emission scenarios.

Narrow-leaf lupins are grown on a small acreage in Germany for protein production. This study will focus on the analysis of the effect of rising temperature on yield parameters and protein content of lupins.

MATERIALS AND METHODS

Growth chamber experiment. *Lupinus angustifolius* cultivars 'Probor', 'Haags Blaue' and 'Boruta', actually grown in Germany, were used in our study. Seeds were supplied by Saatzucht Steinach (Bornhof, Germany).

One seedling per pot was planted in 13 cm square × 22.5 cm high pots containing standard soil (60% peat and 40% clay). The plants were cultivated up to the beginning of flowering at 20°C/16°C (day/night). At the beginning of flowering 15 plants per cultivar and temperature combination were transferred to growth chambers or outdoors. They were cultivated under long-day conditions with temperature treatments 30°C/16°C (day/night, mean temperature 25°C) and 20°C/16°C (day/night, mean temperature 19°C) from the beginning of flowering up to pod ripening. For outdoor control, lupins were cultivated in pots under long-day conditions with a mean temperature of 16°C. The temperature regime 30°C/16°C led to extremely low pod setting. Therefore, three weeks after beginning of pod setting the temperature regime was set to 20°C/16°C until harvest.

Determination of protein content in single seeds. The protein content of all single seeds was determined using a near infrared transmittance spectrometer (Foss, Infratec 1255) as described by Jansen and Kuhlmann (2007). Using this procedure the estimation of the protein content is possible in a range of 15-44% with a coefficient of determination (r^2) of 0.907 and a standard error of prediction (SEP) of 1.86. In a first step this method was used to estimate the protein content of approximately 800 single seeds of 'Probor', 'Haags Blaue' and 'Boruta', respectively. Based on these results, 45 seeds, i.e. 15 per treatment, with a mean

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protein content of 34% ('Probor'), 27% ('Haags Blaue') and 32% ('Boruta') corresponding to the average protein content of these cultivars were selected for our experiment. The same procedure was used for the determination of the protein content of harvested seeds. Protein content was estimated on about 300 single seeds (20°C/16°C) and 1000 single seeds (outdoor control) of 'Probor', 'Haags Blaue' and 'Boruta', respectively, except for the 30°C/16°C treatment in which only low pod setting was observed and only 10–100 seeds were measured.

Statistical analysis. All statistical computations were made using SAS version 9.1 for Windows. To test the effects of different growing temperatures and differences between cultivars the procedure GLM was used at $\alpha = 0.05$ and the means compared by the Tukey-test

RESULTS AND DISCUSSION

Higher temperatures during grain filling (beginning of flowering up to pod ripening) resulted in a remarkable decrease in seed yield of narrow-leaf lupins (Fig. 1). This decrease was significant for all temperatures and for all the cultivars investigated, i.e. 'Probor', 'Boruta' and 'Haags Blaue'.

Due to the fact that a mean temperature of 25°C inhibited pod setting nearly completely, the mean temperature in this treatment was changed to 19°C. However, only very few pods were set after changing temperature. The same effect and a reduction of seed weight were found by Reader *et al.* (1997). Besides plant growth, heat stress causes an array of morpho-anatomical and physiological as well as biochemical changes in plants (Wahid *et al.* 2007). Consequently, the effect of temperature on the protein content of lupin seeds was analysed.

Due to the very limited number of pods and seeds under higher temperatures the determination of the protein content was only possible by using the Near Infrared Reflectance method for single seeds. A low mean temperature (16°C) significantly reduced the protein content in all three cultivars investigated (Fig. 2). Nayyar *et al.* (2007) also described a marked reduction of the protein accumulation in chickpea genotypes (*Cicer arietinum* L.) due to low temperature during seed filling (day/night: 11.7°C/2.3°C).

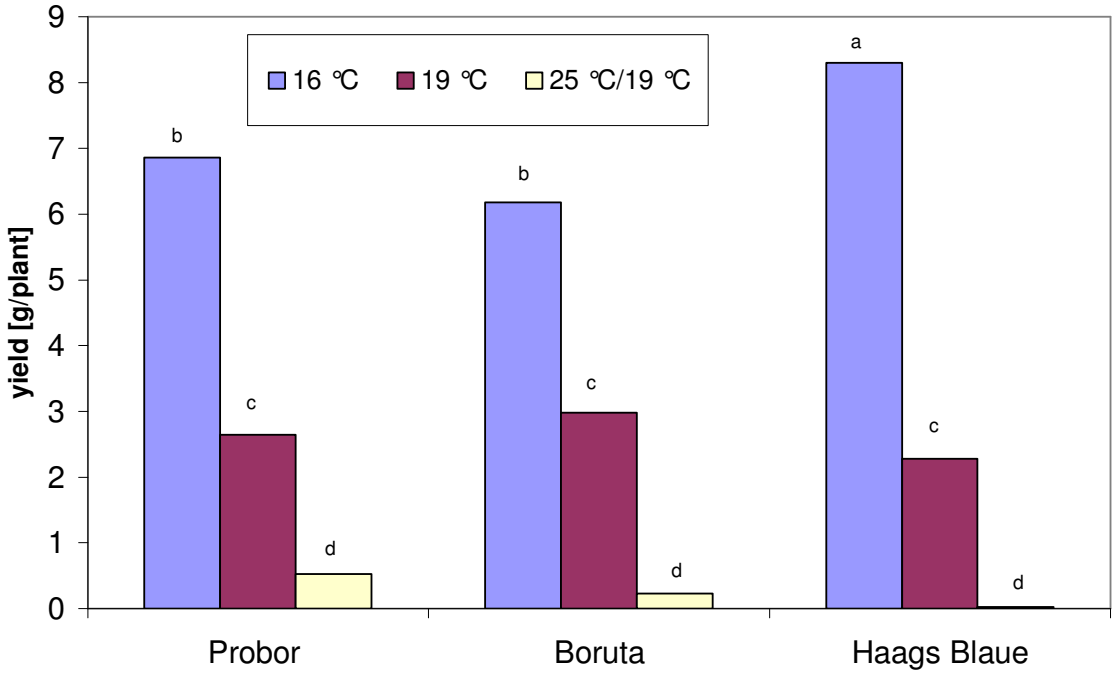

Fig. 1. Influence of the mean temperature from the beginning of flowering to harvest on the seed yield of narrow-leaf lupins (different lower-case letters indicate significant difference at $\alpha = 0.05$).

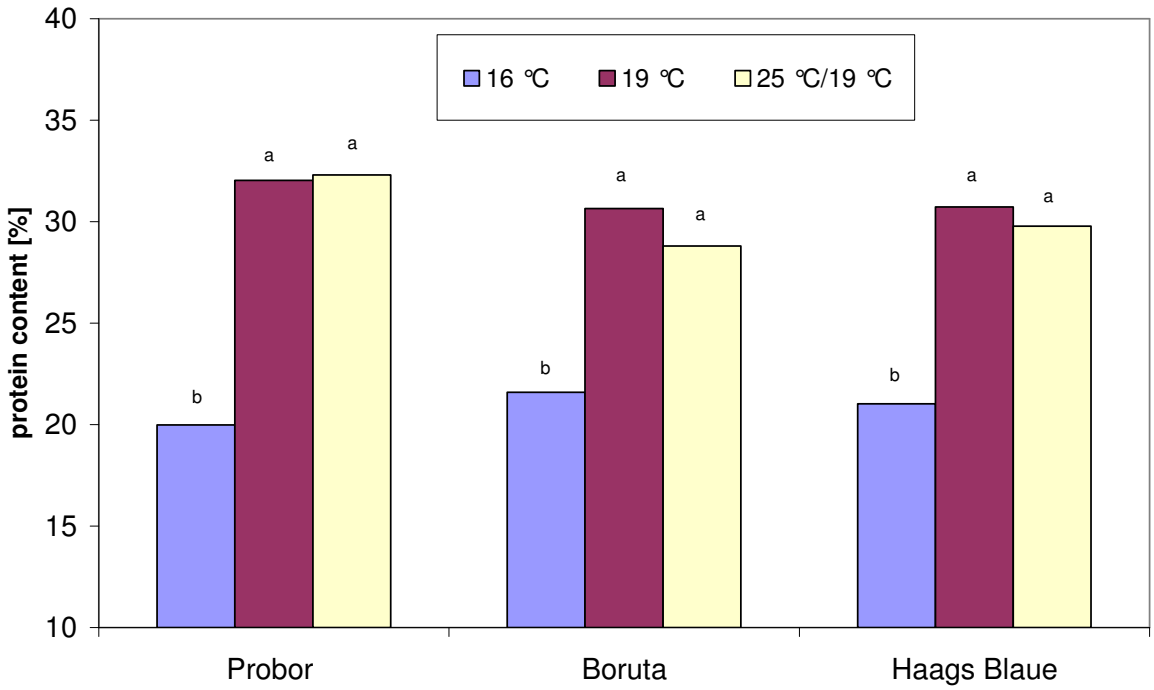

Fig. 2. Influence of the mean temperature from the beginning of flowering to harvest on the protein content of narrow-leaf lupins (different lower-case letters indicate significant difference at $\alpha = 0.05$).

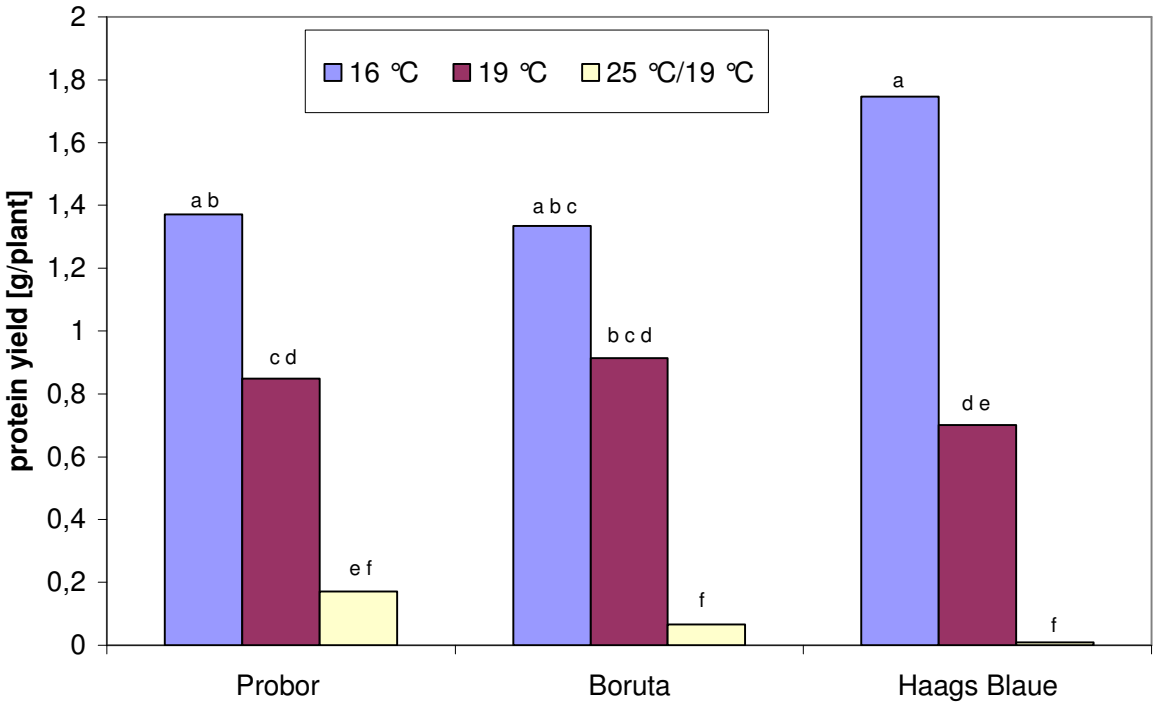

Fig. 3. Influence of the mean temperature from the beginning of flowering to harvest on the protein yield of narrow-leaf lupins (different lower-case letters indicate significant difference at $\alpha = 0.05$).

The differences between the protein content of the harvested seeds grown at temperatures of 19°C and 25°C/19°C were not significant. A slight decrease of the protein content at mean growing temperatures of 25°C/19°C was found for the varieties 'Boruta' and 'Haags Blaue'. These results are in agreement with Reader *et al*. (1997), who reported that percentage N of narrow-leaf lupins did not change, or slightly decrease, in response to heat treatment at 36°C in comparison to 20°C.

Effects of high temperatures are often influenced by effects of water deficits. Cavalho *et al*. (2004, 2005) investigated the influence of water stress on crude protein content of one variety of *Lupinus albus* and *Lupinus mutabilis*, respectively. Water deficit imposed at the beginning of seed production (15 days to 35 days after anthesis) did not affect protein content significantly.

In our experiment higher temperatures led to a decrease in yield but a rise in protein content. But, despite the lower protein content at lower temperatures in this experiment, the protein yield was higher due to the higher seed yield at lower temperatures (Fig. 3). It should be borne in mind, though, that the use of lupins as a protein source in animal and human nutrition depends on high seed protein content. Therefore, future breeding programs should aim at increasing yield and protein content simultaneously. These results clearly show that evaluation of lupin lines should be done under standard conditions, since yield and protein content are strongly influenced by temperature during pod set and grain filling.

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