doi: 10.17221/455/2015-PSE

# Production results of intensification of cultivation technologies in three lupin (*Lupinus* L.) species

**M. Borowska, J. Prusinski, E. Kaszkowiak**

*Department of Agrotechnology, UTP University of Science and Technology, Bydgoszcz, Poland*

**ABSTRACT**

The paper presents results of 3-year field studies carried out in a split-block design in four replications in the years 2012–2014 at the Agricultural Experiment Station in Mochełek (Poland). The effect of intensification of cultivation technologies on the yield of morphologically diversified cultivars of white (*Lupinus albus*), yellow (*L. luteus*) and narrow-leafed lupin (*L. angustifolius*) was examined. Traditional cultivars of white and yellow lupin gave significantly higher yields than the self-completing ones, as opposed to narrow-leafed lupin in which the self-completing cultivar had higher yields. Increasing expenses on industrial production means caused an increase in the yield of all the studied species. Seed yield of white and narrow-leafed lupin was significantly the highest in high-input technology, while that of yellow lupin in high- and medium-input technology. In all lupin species, insignificant diversification was observed in the number of pods per plant in medium- and high-input technologies as well as in low- and medium-input technologies. A significant increase in the seed yield along with an increasing intensity of the cultivation of traditional and self-completing cultivars of white and yellow lupin, as well as self-completing cultivars of narrow-leafed lupin, resulted mainly from developing a higher number of pods.

**Keywords**: legumes; fertilization; plant protection

Current share of legumes in the sowing structure in the EU is from 0.5–6.5% (FAOSTAT 2014) and is still decreasing, whereas outside Europe it is 15–25% (Cernay et al. 2014). Cultivation of leguminous plants, apart from numerous benefits for soil environment, may contribute to decreasing the deficit of plant protein in Europe and its currently common import (Nemecek et al. 2008).

Agronomic problems in lupin cultivation are various depending on the part of the world; the greatest importance in reducing the yield is attributed to water deficit and biotic stresses, while other factors such as extreme temperature or lack of nutrients usually play a lesser role (Jeuffroy and Ney 1997). Proper agricultural practices applied in legumes almost completely cover plant requirements for nitrogen (N) provided that there are strains of active symbiotic bacteria in the soil (Ayisi et al. 1992, Merbach and Klamroth 2011). Pre-sowing diversification in the doses of mineral N has no or slight effect on the content of dry matter in white lupin plants (Ayisi et al. 1992) and N content in narrow-leafed lupin plants (Fan et al. 2002), and both these traits in yellow lupin (Prusinski et al. 2014). In such cases, the main factor that reduces the yield of slowly growing leguminous plants are weeds, which may decrease seed yields even by 25–40%, the more so because of the observed continuous lack of post-emergence-applied herbicides (Koukolicek and Stranc 2013, Krawczyk 2013).

The research hypothesis assumes that fertilizing lupin with N will allow plants to avoid any possible N deficiency in case of not very high effectiveness of the symbiotic system. Moreover, it was assumed that supplying plants with other nutrients and chemical protection of stands affecting extension of photosynthetic activity would enable formation of a huge number of pods and plump seeds, contributing to a decrease in water deficit, which reduces the yield. The aim of our

Supported by the Polish Ministry of Agriculture and Rural Development, Project No. 149/2011.

doi: 10.17221/455/2015-PSE

research was evaluation of productivity of 3 lupin species under the effect of an increasing application of industrial means of production.

## MATERIAL AND METHODS

Three two-way field experiments were carried out in a split-block design in four replications in the years 2012–2014 at the Agricultural Experiment Station in Mochełek (Poland) (53°13'N, 17°51'E). The experiments were set up on Haplic Luvisols of pH 6.4–6.5 with an average content of phosphorus and high content of potassium. The content of $N_{min}$ (mineral nitrogen) in the layer of 0–30 cm before sowing amounted from 8.9–13.3 mg/kg of soil each year. The object of research within lupin species were lupin cultivars (factor I): white: traditional cv. Butan and self-completing (i.e. restricted branching) cv. Boros, yellow: traditional cv. Mister and self-completing cv. Perkoz, and narrow-leafed ones: traditional cv. Zeus and self-completing cv. Regent. In the successive years, the experiments were set up on 3$^{rd}$, 16$^{th}$ and 1$^{st}$ April, respectively. 75 germinating seeds of cv. Butan and 86 of cv. Boros were sown, as well as 100 and 110 seeds of traditional and self-completing cultivars of yellow lupin and narrow-leafed lupin per 1 $m^2$, respectively, with row spacing of 20 cm, into a depth of 3–4 cm. The area of plots for sowing was 30 $m^2$, and for harvest 24.4 $m^2$. The applied agricultural treatments (factor II) are presented in Table 1.

Analysis of weed infestation was carried out with a gravimetric method two weeks before harvesting seeds. Weeds were collected from randomly selected areas of 1 $m^2$ from each plot; next they were dried and weighed. Directly before harvest from each plot 20 plants were also randomly selected for evaluation of the structural yield components. Seed yield and its components are given for 15% water content. Seed harvest in the successive years of research was carried out on the 30$^{th}$, 23$^{rd}$ and 28$^{th}$ August, respectively.

Analysis of variance developed by the UTP (Bydgoszcz, Poland) and figures (Excel 2010) were performed on the data recorded for each plot. Significance of differences in the plot means was evaluated using the Tukey's test at significance level $P \leq 0.05$. The evaluation of the effect of technology on the seed yield and its structural components was carried out with the use of relative increase of the studied traits and their share in increasing/decreasing seed yield (Rudnicki 2000).

## RESULTS AND DISCUSSION

One of the most important factors determining seed yield in legumes is the sum and distribution of rainfall in the plants' growing season (Podlesna et al. 2014). Rainfall deficit combined with a high temperature is particularly unfavourable during flowering and pod formation, resulting in shedding of flowers and pod sets, and as a consequence reducing the seed yield (Atkins and Smith 2004). On average, water and thermal conditions were quite good, when the Selianinov' index K (Molga 1986) exceeded 1.0 (Table 2), which was favourable for flowering and pod setting of all lupin species and cultivars studied. Among the studied species, the highest yields were obtained from white lupin (3.78 t/ha), then narrow-leafed lupin (2.54 t/ha). High yield range of both species was measured with a difference in yields in research

Table 1. The studied lupin cultivation technologies

| Agronomic practice | Technology | | |
|---|---|---|---|
| | low-input | medium-input | high-input |
| Seed conditioning | without dressing | carboxin, thiram, *Bradyrhizobium lupini* | carboxin, thiram, *Bradyrhizobium lupini* |
| Weed control | mechanical | mechanical, metamitron | linuron + clomazone, metamitron |
| Soil fertilization (kg/ha) | N – 0; P – 0; K – 0 | N – 15; P – 50; K – 70 | N – 30; P – 70; K – 100 |
| Foliar fertilization | without extra feeding | without extra feeding | multiple micro- and macroelements |
| Chemical plant control | without protection | chlorothalonil tetrachloroizo-ftalonitryl | chlorothalonil tetrachloroizo-ftalonitryl alfa-cypermethrin diqwat dibromide |

doi: 10.17221/455/2015-PSE

Table 2. Mean daily air temperature and total rainfall according to the Mochelek Agricultural Experiment Station, Poland (mean for 2012–2014)

| | April | May | June | July | August |
|---|---|---|---|---|---|
| Air temperature (°C) | 8.43 | 14.0 | 16.2 | 19.7 | 17.6 |
| Total rainfall (mm) | 26.9 | 60.9 | 76.0 | 83.3 | 55.2 |
| Sielianinov index (K) | 0.97 | 1.40 | 1.53 | 1.38 | 1.09 |

Selianinov index (K): < 0.5 – drought; 0.5–1.0 – semi-drought; 1.0 – border of optimal moisture; 1.01–2.0 – optimal moisture

years expressed in % of the mean yield, i.e. 42.7% and 57.2%, respectively. The lowest yield was obtained by yellow lupin (2.00 t/ha), with the lowest yield range of 18.4% (Figure 1).

The observed instability of yields in legumes over the years, including lupin (Koukolicek and Stranc 2013) may be the result of shedding flowers and pod sets as a result of water deficit. However, it also depends on changes in the content of endogenous growth regulators (Bangerth 1989) or competition for nutrients between acceptors of assimilates at the time of generating seed yield (pods, intensively growing main shoot apex, lateral branch apex and root nodules), which in turn may cause disturbances in the nutrition balance in plants (Atkins and Smith 2004). Significantly the highest seed yields of white and narrow-leafed lupin were obtained in high-input technology (III). Changing a low-input technology (I) into medium-input one (II) affected yield increase, but the observed yields did not differ significantly. Yellow lupin had significantly the highest yields when it was cultivated with a medium (II) and high (III) level of intensity of industrial production means application (Figure 2).

Increase in the seed yield of legumes in more intensive technologies may be the result of dressing the seeds and better plant health (Koukolicek and Stranc 2013), lower competition from weeds (Krawczyk 2013), a positive response of plants to seed inoculation (Ayisi et al. 1992, Podlesny 1999, Merbach and Klamroth 2011), better seed supplementation with nutrients in the period of decreasing effectiveness of symbiosis (Podlesny 1999, Prusinski et al. 2014), more effective photosynthesis in plants, and protection against Colletotrichum sp., the causative agent of anthracnose (Prusinski 2005). According to Krawczyk (2013), in the cultivation of legumes, a particular role is played by post-emergence herbicides used when the state of weed infestation is already known. In our research, on average the highest dry weight of weeds was observed in narrow-leafed lupin stands, while the lowest in white lupin stands. As was presumed, within each species significantly the mostly weed-infested plots were those with only mechanical treatment. Application of chemical treatment in medium-input technology (II) and high-input technology (III) significantly, 5–7 times, reduced weed infestation of all lupin species, and the dry weight of weeds before harvest (Figure 3). Additional application of clomazone after sowing and metamitron at post-emergence in high-input technology however did not significantly affect decrease in the dry weight of weeds.

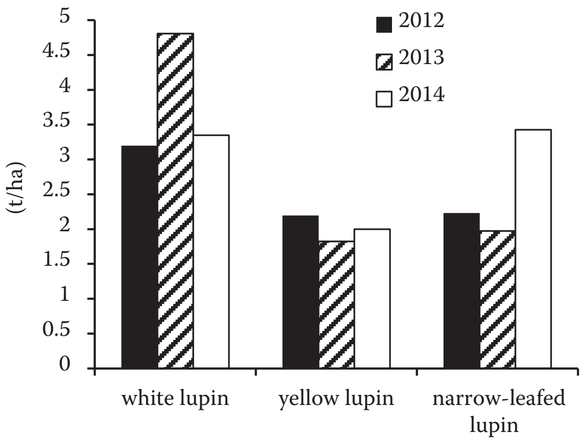


Figure 1. Lupin yields in the research years

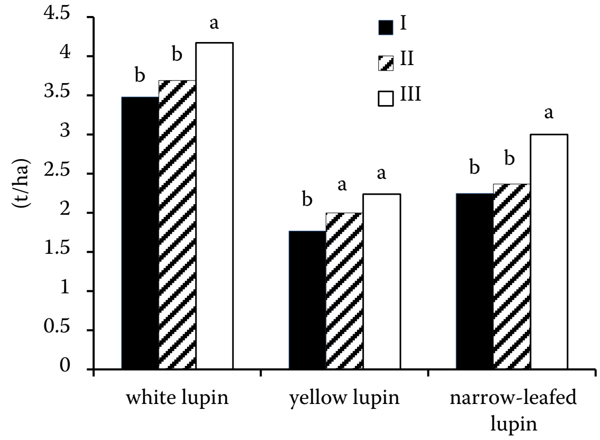


Figure 2. Lupin seed yields depending on the intensity of cultivation technology (I, II, III). Different letters within columns indicate significant differences between entries ($P \leq 0.05$)

doi: 10.17221/455/2015-PSE

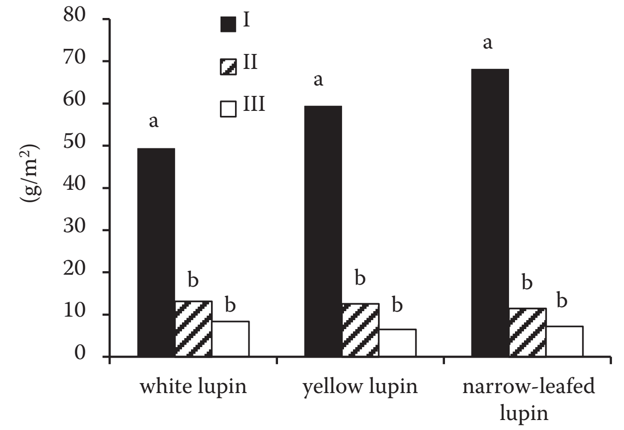


Figure 3. Dry weight of weeds in lupin stands depending on the intensity of cultivation technologies (I, II, III). Different letters within columns indicate significant differences between entries ($P \leq 0.05$)

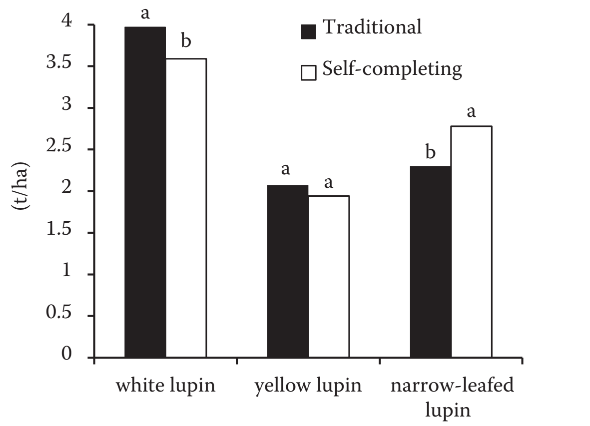


Figure 4. Seed yield of morphologically differentiated lupin cultivars

According to Merbach and Klamroth (2011), inoculation of narrow-leafed lupin seeds affects increase in N2 fixation with the deficiency of N in the soil. In case of a significant amount of N in the soil, the effect of lupin inoculation is usually insignificant and most probably does not significantly affect the yield. Also, in case of white lupin, fertilization with high doses of N or seed inoculation did not significantly vary the seed yield, although high doses of mineral N reduced nodulation and $N_2$ fixation, though they did not support plant growth (Ayisi et al. 1992). It should be highlighted that on the plots where the experiments were set up, there was previously lupin cultivation, and $N_{min}$ content (low to medium) in the period from sowing to the start of symbiosis was sufficient to satisfy the requirements of plants in the initial growth stages. Hence the effectiveness of lupin seed inoculation with rhizobium only manifests itself with the lack of active strains of symbiotic bacteria in the soil or on soils deficient in N, especially that plants do not effectively utilize mineral N whose availability is most often depleted in the stage of grain filling when additional requirement for this nutrient comes from the symbiotically fixed nitrogen (Kessel and Hartley 2000).

Differences were observed in the yield of the cultivar types studied in the experiment (Figure 4). Traditional white lupin cv. Butan, as in the studies of Coboru (2004–2006) and yellow lupin cv. Mister (Coboru 2015) gave significantly and insignificantly higher yields: 9.80% and 11.6%, respectively, than the self-completing cultivars of these species. They were distinguished from the self-completing cultivar of narrow-leafed lupin, cv. Regent, which gave yields by 20% higher than the traditional cultivar in the research, i.e. in accordance with the latest results of Coboru (2015).

Pod number per plant and 1000 seed weight, both for traditional and self-completing cultivars are determined by the conditions providing plants with sufficient water supply (Jeuffroy and Ney 1997, Podlesna et al. 2014) and nutrients (Koukolicek and Stranc 2013), hormone regulators (Bangerth 1989) and sustaining as long photosynthetic activity of the ageing leaves or those affected with diseases or

Table 3. Share (%) of structural yield components in determining seed yield in traditional lupin cultivars

| Yield component | White lupin | | Yellow lupin | | Narrow-leafed lupin | |
|---|---|---|---|---|---|---|
| | I–II | II–III | I–II | II–III | I–II | II–III |
| Pod number per plant | – | 100 | 38.3 | 98.0 | 10.9 | 89.8 |
| Seed number per pod | 34.8 | – | 44.2 | – | 73.3 | – |
| 1000 seed weight | 65.2 | – | 17.5 | 2.0 | 15.8 | 10.2 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

doi: 10.17221/455/2015-PSE

Table 4. Share (%) of structural yield components in determining seed yield of the self-completing lupin cultivars

| Yield component | White lupin | | Yellow lupin | | Narrow-leafed lupin | |
|---|---|---|---|---|---|---|
| | I–II | II–III | I–II | II–III | I–II | II–III |
| Pod number per plant | – | 100 | 48.8 | 100 | – | 42.7 |
| Seed number per pod | – | – | 34.6 | – | – | 47.2 |
| 1000 seed weight | – | – | 16.6 | – | – | 10.1 |
| Total | – | 100 | 100 | 100 | – | 100 |

pests (Prusinski 2005), while the seed number per pod is conditioned genetically or determined just after pollination (Tischner et al. 2003). According to Rudnicki (2010) the production of the number of pods per plant, number of seeds per pod and weight of 1000 seeds is equal to or close to the amount of seed yield. A method of estimation of participation of specific plant yielding elements in an increase or decrease of seed yield allows to determine reason-result relationship in a sequence: experimental factor (use of production means) – yielding elements used – yield. The biggest increase in the seed yield in traditional (Table 3) and self-completing cultivars (Table 4) along with an increasing intensity of cultivation of the studied lupin species was mainly the result of an increase in the number of pods per plant – 89.8–100% for traditional cultivars and 100% – for self-completing, except of narrow-leafed cultivar. The impact of number of seeds per pod on seed yield was smaller and did not exceeded 73.3% in narrow-leafed lupin and 44.2% for other cultivars. 1000 seed weight did not change the seed yield much except of traditional white lupin cultivar.

In conclusion, the application of industrial production means (mineral fertilization with N, P and K as well as crop-protection preparations) in medium- and high-input technologies allowed increasing productivity of the studied lupin species compared with the low-input technology. It should be considered unjustifiable to apply additional chemical treatment in high-input technology. Traditional cultivars of white and yellow lupin gave higher yields than the self-completing ones, while in narrow-leafed lupin lower yields were recorded than in the traditional one. Higher yields in traditional and self-completing cultivars of white lupin and yellow lupin as well as the self-completing cultivar of narrow-leafed lupin resulted mainly from developing a higher number of pods on plants.

## REFERENCES


Atkins C.A., Smith P.M. (2004): Regulation of pod set and seed development in lupin. In: van Santen E., Hill G.D. (eds.): Proceedings of the 10th International Lupin Conference, 19–24. June 2002, New Zealand, 275–278.

Ayisi K.K., Putnam D., Vance C.P., Graham P.H. (1992): *Bradyrhizobium* inoculation and nitrogen fertilizer effects on seed yield and protein of white lupin. Agronomy Journal, 84: 857–861.

Bangerth F. (1989): Dominance among fruits/sinks and the search for correlative signal. Physiologia Plantarum, 76: 608–614.

Coboru (2004–2006): Results of Post-registered Varietal Experiences. Legumes. Słupia Wielka. (In Polish).

Coboru (2015): Registration Synthesis of Experimental Results. Legumes 2014. Słupia Wielka, 128: 1–51. (In Polish)

Cernay C., Ben-Ari T., Pelzer E., Meynard J.-M., Makowski D. (2014): Estimating variability in grain legume yields across Europe and the Americas. Scientific Reports, 5: 1–11.

Fan X.H., Tang C., Rengel Z. (2002): Nitrate uptake, nitrate reductase distribution and their relation to proton release in five nodulated grain legumes. Annals of Botany, 90: 315–323.

FAOSTAT Production – Crops. Grain legume production areas EU countries and Switzerland for 2000 and 2011, 2014. Available at http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID =567#ancor

Jeuffroy M.-H., Ney B. (1997): Crop physiology and productivity. Field Crops Research, 53: 3–16.

Van Kessel C., Hartley C. (2000): Agricultural management of grain legumes: Has it led to an increase in nitrogen fixation? Field Crops Research, 65: 165–181.

Koukolicek J., Stranc P. (2013): Experiment with the cultivation of different varieties of lupin in the area of Dobris. MendelNet, 20: 82–88.

Krawczyk R. (2013): Control of weeds in narrow-leafed (*Lupinus angustifolius* L.) and yellow lupin (*Lupinus luteus* L.) depending on their biological differences and agroecological factors. Rozprawy Naukowe, 28: 1–94. (In Polish)

Merbach W., Klamroth A.K. (2011): Influence of mineral fertilization on field and symbiotic fixation of blue lupins (*Lupinus*

doi: 10.17221/455/2015-PSE

*angustifolius* L.) in field experiment. In: Proceedings of the Lupin crops – an opportunity for today, a promise for the future. 6–10 June, Poznan, 60.

Molga M. (1986): Basics of Agricultural Climatology. Warszawa, Powszechne Wydawnictwo Rolnicze i Leśne, 544–547. (In Polish)

Nemecek T., von Richthofen J.-S., Dubois G., Casta P., Charles R., Pahl H. (2008): Environmental impacts of introducing grain legumes into European crop rotations. European Journal of Agronomy, 28: 380–393.

Podleśna A., Podleśny J., Doroszewski A. (2014): Usefulness of selected weather indices to evaluation of yellow lupine yielding possibility. Agricultural Water Management, 146: 201–207.

Podlesny J. (1999): Comparison of productivity and economic efficiency of various technologies in white lupin cultivation. In: Proceedings of the International Conference Lupin in Polish and European Agriculture. Przysiek, 101–105. (In Polish)

Prusiński J. (2005): Traditional and self-completing white lupin (*Lupinus albus* L.) cultivars yielding depending on foliar plant fertilization and chemical protection. Electronic Journal of Polish Agricultural Universities, 8: 41.

Prusiński J., Borowska M., Kaszkowiak E. (2014): Effect of $N_{min}$ content on nodulation in yellow lupin (*Lupinus luteus* L.) in the presence of *Bradyrhizobium lupinii* and genistein. Journal of Central European Agriculture, 15: 49–63.

Rudnicki F. (2000): Determining the impact of specific yield components on differences in yields between experimental objects. Fragmenta Agronomica, 3: 53–65. (In Polish)

Tischner T., Allphin L., Chase K., Orf J.H., Lark K.G. (2003): Genetics of seed abortion and reproductive traits in soybean. Crop Science, 43: 464–473.

Received on July 14, 2015
Accepted on September 1, 2015

*Corresponding author:*

Prof. dr. hab. inż. Janusz Prusinski, UTP University of Science and Technology, Department of Agrotechnology, 20 Kordeckiego str., 85 225 Bydgoszcz, Poland; e-mail: janusz.prusinski@utp.edu.pl