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EFFECT OF THE SOWING DATE ON THE SIZE AND QUALITY OF THE SEED YIELD OF YELLOW LUPINE (*Lupinus luteus* L.)

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Abstract. Introducing cultivars of yellow lupine that tolerate delays in the sowing dates (thermoneutral) or ones that ripe faster (self-completing) into agricultural practice makes it possible to broaden the cultivation of this agriculturally valuable species. The aim of the study was therefore the determination of the effect of the sowing date on the size and quality of the seed yield of yellow lupine in the mountain-foot region. It was hypothesized that cultivars Mister (conventional) and Taper (self-completing) would react differently to the applied study factor. Strict experiment was carried out in years 2011-2013 at the Cultivar Assessment Experimental Station in Dukla on 5th class soil of mountain oat--potato complex. Sowing date and diversified weather conditions in the study years had a significant effect on plant growth and development. The highest plant density before harvest was obtained on the second sowing date (second ten days of April), and the lowest on the first sowing date (first ten days of April), which was statistically significant. Sowing dates significantly modified such yield characteristics as the number of grains per pod and mass of 1000 grains, whereas the number of pods per plant was constant. On average in the study years, significantly higher yield was obtained after sowing the seeds in the first twenty days of April than in the last ten days of April. This relation was not, however, repeated in the study years. With the delay in the sowing date, total protein content in the seeds decreased. Cultivar Mister in comparison with cultivar Taper was characterized by a significantly higher pod number per plant, mass of 1000 grains, and seed yield. It was also proved that cultivar Mister contains significantly more crude fat in the seeds than cultivar Taper. Established percentage of total protein, ash, and fibre was not diversified between the studied cultivars.

Key words: chemical composition of seeds, conventional cultivar, grain yield, self--completing cultivar, sowing date, yield components, yellow lupine

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INTRODUCTION

Yellow lupine is one of the plants grown mostly for seeds, green matter, or as green fertilizer for ploughing. Perspective of increasing the cultivation area of this agriculturally valuable species resulted from the introduction of new cultivars into agricultural practice, the so-called sweet, self-completing, or thermoneutral ones. Podleśny [2005] noticed that more and more farmers decide to apply ecological and integrated production methods, in which legumes, including lupine, play a very important role. Moreover, there is a possibility to obtain subsidies for legume cultivation [Majchrzak *et al*. 2010, Czerwińska-Kayzer and Florek 2012], including qualified sowing material. Production of yellow lupine in Poland is, however, limited by fungus disease, anthracosis (*Colletotrichum gloeosporioides* Penz.), which occurs with various intensity throughout the years [Kurowski *et al*. 2005, Szukała *et al*. 2006], as well as seed yield variability, poor choice of plant protection means, and low market demand for seeds. Moreover, the effects of yellow lupine cultivation strongly depend on the habitat conditions of a given region. This concerns both the size [Pszczółkowska *et al*. 2003, Faligowska and Szukała 2008] and the quality of seed yield [Chiofalo *et al*. 2012]. In the mountain-foot regions with poorer soils, thermoneutral and self--completing cultivars may be particularly useful for growth for seeds. This is because thermoneutral cultivars are less sensitive to delays in sowing dates, whereas the self-completing ones have a shorter growth period. Podleśny [2007a] and Pytlarz-Kozicka [2010] demonstrated that different morphotypes of yellow lupine cultivars not only have different plant exteriors or biometric characteristics, but also different growth rates, and, consequently, different lengths of the growth period. Podleśny [2007b] stated that, in regard to seed yield, for both thermoneutral and non-thermoneutral cultivars, sowing in the first half of April is the most favourable. Podleśny [2008] also demonstrated that with the lack of vernalization, the decrease in generative organ yield was significantly lower in thermoneutral cultivars than in non-thermoneutral ones. Non-thermoneutral cultivars are better, however, for growth for green matter due to their more abundant vegetative mass [Podleśny 2008]. Podleśny and Strobel [2007] proved that with the delay in the sowing date, protein content in the seeds of yellow lupine decreases significantly. This relation was not confirmed only for cultivar Polo. Therefore, the issues in the discussed domain have an important practical aspect.

The aim of the study was the determination of the optimum sowing date of yellow lupine in the mountain-foot conditions. It was hypothesized that the conventional cultivar Mister in comparison with the self-completing cultivar Taper would show a different response to the variable seed sowing date.

MATERIAL AND METHODS

In years 2011-2013, strict field experiment was carried out using split-plot design at the Cultivar Assessment Experimental Station in Dukla (49°34′ N; 21°41′ E), which is part of the Research Centre for Cultivar Testing in Słupia Wielka. The study factors were: I – sowing date (first, second, and third ten days of April) and II – cultivar (Mister and Taper). For sowing, dressed qualified seeds were used from the Poznań Plant Breeding Ltd., Wiatrowo department. Lupine was grown on 5th class soil of mountain oat-potato complex. Contents of assimilable phosphorus and potassium were medium or

high, and soil pH was acid or lightly acid. Analysis of the chemical composition of the soil was carried out at the Regional Chemical and Agricultural Station in Rzeszów. Average annual temperature in the region is 7.7°C, and annual precipitation sum amounts to 584 mm. Seeds were sown on April 6, 18, and 26, 2011, April 10, 20, and 30, 2012, and April 10, 19, and 30, 2013. Lupine was sown at the row spacing of 21.4 cm, at the depth of 3-4 cm. Plot area was 19.5 m² (16.5 m² for harvest). Winter wheat was the forecrop. Cultivation and caring treatments were carried out according to the agrotechnical requirements of yellow lupine, taking into account the differences between the conventional cultivar (Mister) and the self-completing cultivar (Taper). Secondary infestation was removed manually. Phosphorus and potassium fertilization amounted to 26,2 kg $P \cdot ha^{-1}$ and 74,7 kg $K \cdot ha^{-1}$. Nitrogen mineral fertilization was not applied but Nitragina was used for seed inoculation. The assumed plant density was 100 plants per m² for cultivar Mister and 120 plants per m² for cultivar Taper. At technical maturity, plant density per 1 m^2 was calculated and 20 representative plants were picked from every plot in order to establish the following yield structure characteristics: number of pods per plant, number of grains per pod, and mass of 1000 grains (which was set at 12% humidity). Grain yield obtained from the plots was calculated per 1 ha at 12% humidity. Seed harvest was carried out at full ripeness with no plant desiccation. Elementary chemical composition of seeds was marked at the laboratory of the Department of Plant Production of the University of Rzeszów using SPEKTROMETR FT; NIR MPA by Bruker.

The obtained results underwent statistical analysis using the analysis of variance. Significance of the differences between the particular values was evaluated on the basis of the Tukey's confidence intervals, at the significance level of $P = 0.05$.

RESULTS AND DISCUSSION

Weather conditions in the study years were diversified (Table 1). In 2011, moderate monthly temperatures and precipitation sums were noted, with the exception of too humid July. The second study year was characterized by intensive precipitation in June and a hot July. In March 2013, high precipitation was noted (including snow), as well as minus temperatures. Seed sowing that was carried out in that year in the first ten days of April took place in unfavourable soil conditions. Moreover, in July and August 2013, monthly precipitation sums were low and differed significantly from the many-years' average. The configuration of humidity and thermal conditions had a significant effect on plant growth and development, the occurrence of plant pathogens, and seed yield. Bieniaszewski *et al*. [2000] and Faligowska and Szukała [2008] in earlier research confirmed that seed yield, yield components, and seed sowing value of yellow lupine [Januszewicz and Suchowilska 2003, Faligowska and Szukała 2012, Prusiński *et al*. 2012] highly depend on the weather conditions.

Entering the particular developmental stages by yellow lupine was very much diversified (Table 2). In 2013, emergence of cultivar Taper occurred already after eight days on the plots at the second and third sowing dates. Emergence was noted the latest (after 20 days) in 2011 for cultivar Mister sown in the first ten days of April. On average in the study years, plant emergence was noted after 16, 11, and 12 days, respectively, after sowing in the first, second, and third ten days of April. Podleśny

[2007b], by sowing on three dates (I, II, and III), obtained emergence on average after 23, 14, and 10 days.

Table 1. Weather conditions in the years 2011-2013
Tabela 1. Warunki pogodowe w latach 2001-2013

Month Miesiąc	Precipitation – Opady mm				Mean temperatures – Średnie temperatury °C			
	2011	2012	2013	many years' average wielolecie	2011	2012	2013	many years' average wielolecie
March – marzec	18.9	42.0	100.4	49.02	1.87	3.16	-1.15	2.13
April – kwiecień	37.4	43.6	42.8	66.66	8.95	9.21	8.91	8.29
May – maj	42.0	78.0	65.8	82.93	12.57	13.83	14.17	13.93
June – czerwiec	93.0	170.0	117.7	110.35	17.23	17.55	17.53	17.13
July – lipiec	188.0	98.6	30.7	119.83	17.60	19.73	18.04	18.75
August – sierpień	41.3	51.4	25.6	73.74	18.44	18.03	18.15	18.30

Source: Cultivar Assessment Experimental Station in Dukla – źródło: ZDOO in Dukla

Table 2. Lenght of developmental stages in days from sowing date
Tabela 2. Długość faz rozwojowych w dniach od daty siewu

Sowing date Termin siewu	Cultivar Odmiana	Emergence Wschody	Budding Pąkowanie	Flowering Kwitnienie	Full ripeness Pełna dojrzałość
2011					
1-10 April I dekada kwietnia	Mister	20	59	64	130
	Taper	19	58	61	126
11-20 April II dekada kwietnia	Mister	13	51	57	122
	Taper	12	47	53	117
21-30 April III dekada kwietnia	Mister	16	51	56	119
	Taper	15	48	52	114
2012					
1-10 April I dekada kwietnia	Mister	15	57	66	105
	Taper	15	54	62	102
11-20 April II dekada kwietnia	Mister	10	54	56	95
	Taper	11	49	52	91
21-30 April III dekada kwietnia	Mister	10	47	54	91
	Taper	12	43	52	89
2013					
1-10 April I dekada kwietnia	Mister	14	58	61	123
	Taper	12	55	59	120
11-20 April II dekada kwietnia	Mister	10	55	58	108
	Taper	8	52	55	105
21-30 April III dekada kwietnia	Mister	9	56	58	107
	Taper	8	53	55	103

In 2012, the budding of cultivar Taper started already after 43 days on the plot at the third sowing date. On the other hand, in 2011 on the plot with the first sowing date, cultivar Mister entered budding only after 59 days. The flowering stage was noted the earliest for cultivar Taper after 52 days, and the latest for cultivar Mister after 66 days

from the sowing date. Similar results concerning the entering of yellow lupine cultivars into the budding and flowering stages were given by Bieniaszewski *et al*. [2012] in earlier studies.

In 2012, for cultivar Taper, full ripeness was noted after 89 days on the plot at the third sowing date. The latest the full ripeness stage, namely after 130 says, was reached by cultivar Mister sown in the first ten days of April 2011. On average in the study years, delaying the sowing date until the second and third ten days of April resulted in the shortening of the growth period of the studied cultivars. It also results from the studies by Podleśny [2007a, b] that the sowing of yellow lupine seeds at later dates causes shortening of the growth period and modifies plant entering the particular developmental stages. However, it ought to be noted that the scope of those changes is strongly related to the weather conditions and cultivar. Prusiński [1997] also demonstrated diversified sensitivity of yellow lupine cultivars to delaying the sowing date.

It results from the present study that cultivar Taper (self-completing) usually reaches the particular developmental stages earlier and has a shorter growth period in comparison with cultivar Mister (conventional). Therefore, the studies by Pytlarz--Kozicka [2010] were confirmed, in which cultivar Taper in comparison with cultivar Mister reached a shorter growth period by 4 days.

The highest plant density after emergence and before harvest was obtained on the plot on which the seeds were sown in the second ten days of April, and the lowest on the plot with the earliest sowing date, that is the first ten days of April (Table 3). This was caused, among others, by late warming of the soil in the spring, which is usually noted in the region where the studies were conducted. Plant density before harvest for cultivar Taper (on average 101.40 plants per 1 m^2) was significantly higher than for cultivar Mister (on average 95.13 plants per 1 m^2). This resulted first of all from the applied norm of seed sowing. Smaller amount of seed sowing is recommended for the conventional cultivar Mister, and higher for the self-completing cultivar Taper. Bieniaszewski et al. [2012] quotes 60 plants per 1 m^2 as a sufficient density for yellow lupine because higher plant density in the lowland meadow does not cause a significant increase in grain yield.

The number of pods per plant was not modified by the sowing dates. On average, 7.13 pods per plant were obtained. On the other hand, diversified sowing dates had an effect on the average number of seeds per pod. Significant differences in the discussed characteristics were obtained between the first and third sowing dates. As the sowing dates delayed, seed shapeliness decreased significantly. The obtained difference in the mass of 1000 grains between the first and third ten days of April was 11.93 g. For the mass of 1000 grains, also significant relation was obtained between the studied factors. Podleśny [2007b] also obtained a significant decrease in the shapeliness of yellow lupine seeds as a result of delaying the sowing date.

As a result of the conducted experiment, it was found that cultivar Mister in comparison with cultivar Taper formed a greater number of pods per plant and more shapely seeds. Average mass of 1000 grains of the studied cultivars was low and amounted to 125.57 g for cultivar Mister and 114.04 g for cultivar Taper (Table 3). Pytlarz-Kozicka [2010] showed that cultivar Mister surpasses cultivar Taper in regard to the structural characteristics of yield, such as the number of pods per plant, number of grains per pod, and mass of 1000 grains.

Table 3. Number of plants after emergence and before harvest and yield components
Tabela 3. Liczba roślin po wschodach i przez zbiorem oraz elementy struktury plonu

Sowing date Termin siewu	Cultivar Odmiana	Number of plants – Liczba roślin (1 m^2)		Number of pods per plant Liczba strąków na roślinie	Number of seeds per pod Liczba nasion w strąku	Mass of 1000 grains MTN g
		after emergence po wschodach	before harvest przed zbiorem			
1-10 April I dekada kwietnia	Mister	95.25	93.69	6.67	3.47	132.75
	Taper	101.50	96.71	6.45	3.37	117.59
11-20 April II dekada kwietnia	Mister	96.75	94.69	8.60	3.41	126.89
	Taper	109.79	107.73	6.31	3.39	115.13
21-30 April III dekada kwietnia	Mister	98.00	97.00	7.83	3.25	117.07
	Taper	101.71	99.77	6.90	3.24	109.40
$LSD_{0.05}$ – $NIR_{0,05}$						
I × II		ns – ni	ns – ni	ns – ni	ns – ni	4.361
II × I		ns – ni	ns – ni	ns – ni	ns – ni	3.651
1-10 April – I dekada kwietnia		98.38	95.20	6.56	3.42	125.17
11-20 April – II dekada kwietnia		103.27	101.21	7.46	3.40	121.01
21-30 April – III dekada kwietnia		99.85	98.39	7.36	3.25	113.24
$LSD_{0.05}$ – $NIR_{0,05}$ I		3.681	5.523	ns – ni	0.168	3.472
Mister		96.67	95.13	7.70	3.37	125.57
Taper		104.33	101.40	6.55	3.33	114.04
$LSD_{0.05}$ – $NIR_{0,05}$ II		6.766	5.356	0.525	ns – ni	2.185

ns – ni – non-significant difference – różnica nieistotna

Seed sowing in the first and second ten days of April did not have a modifying effect on the average grain yield of yellow lupine. Significantly lower yield was obtained only after sowing in the last ten days of April. This relation was not, however, repeated in the study years (Table 4). Grain yield oscillated within the broad limits of 0.43 to 3.21 $t \cdot ha^{-1}$. Cultivar Mister surpassed cultivar Taper in regard to grain yield. The obtained difference was significant and amounted to 0.32 $t \cdot ha^{-1}$, that is 18.8%.

In the studies by Bieniaszewski *et al*. [2012], higher grain yield (by 16.2%) was reached by conventional cultivars in comparison with self-completing ones. Poorer yield of self-completing cultivars in relation to the conventional ones was found also by Podleśny and Podleśna [2008]. Prusiński [1997] additionally demonstrated that delaying the sowing date in non-thermoneutral cultivars, in comparison with thermoneutral ones, results in a higher decrease in grain yield. Podleśny and Podleśna [2008], on the other hand, proved that a decrease in the grain yield of yellow lupine as a result of the lack of seedling vernalization resulted from a decrease in the number of pods per plant and the number of grains per pod, as well as poorer seed shapeliness. Meanwhile, Majchrzak *et al*. [2010] pointed out that the yield of yellow lupine seeds is unreliable through the years, which may result in the unprofitability of the production, even after taking into account great value of lupine in crop rotation and adding cultivation subsidies.

With the delay in sowing, total protein content decreased significantly in the seeds. The remaining components did not undergo such modification (Table 5). Podleśny and Strobel [2007] demonstrated that diversified sowing dates (in the majority of yellow lupine cultivars) cause significant changes in the chemical composition of seeds. They

found that with the delay in the sowing date, protein content in the seeds decreases, and the amount of fat, fibre, and ash increases.

Table 4. Seed yield, $Mg \cdot ha^{-1}$
Tabela 4. Plon nasion, $Mg \cdot ha^{-1}$

Sowing date Termin siewu	Cultivar Odmiana	2011	2012	2013	Mean from the years Średnia z lat
1-10 April I dekada kwietnia	Mister	2.58	2.43	1.74	2.25
	Taper	2.14	1.93	1.65	1.91
11-20 April II dekada kwietnia	Mister	3.21	1.76	1.79	2.25
	Taper	2.41	1.51	1.63	1.85
21-30 April III dekada kwietnia	Mister	2.79	0.75	1.19	1.57
	Taper	2.32	0.43	1.32	1.36
$LSD_{0.05} - NIR_{0,05}$					
I × II		ns – ni	ns – ni	ns – ni	ns – ni
II × I		ns – ni	ns – ni	ns – ni	ns – ni
1-10 April – I dekada kwietnia		2.36	2.18	1.69	2.08
11-20 April – II dekada kwietnia		2.81	1.64	1.71	2.05
21-30 April – III dekada kwietnia		2.55	0.59	1.25	1.47
$LSD_{0.05} - NIR_{0,05}$ I		0.423	0.386	0.215	0.426
Mister		2.86	1.65	1.57	2.02
Taper		2.29	1.29	1.54	1.70
$LSD_{0.05} - NIR_{0,05}$ II		0.260	0.135	ns – ni	0.126

ns – ni – non-significant difference – różnica nieistotna

Table 5. Chemical composition of seeds, %
Tabela 5. Skład chemiczny nasion, %

Sowing date Termin siewu	Cultivar Odmiana	Białko Protein	Tłuszcz Fat	Popiół Ash	Włókno Fibre
1-10 April I dekada kwietnia	Mister	44.10	4.53	6.02	12.81
	Taper	43.90	4.19	6.01	12.15
11-20 April II dekada kwietnia	Mister	43.19	4.41	5.85	13.13
	Taper	43.04	3.88	5.96	13.05
21-30 April III dekada kwietnia	Mister	42.83	4.57	5.96	12.90
	Taper	42.63	4.17	6.01	13.01
$LSD_{0.05} - NIR_{0,05}$					
I × II		ns – ni	ns – ni	ns – ni	ns – ni
II × I		ns – ni	ns – ni	ns – ni	ns – ni
1-10 April – I dekada kwietnia		44.00	4.36	6.01	12.48
11-20 April – II dekada kwietnia		43.11	4.14	5.90	13.09
21-30 April – III dekada kwietnia		42.73	4.37	5.98	12.96
$LSD_{0.05} - NIR_{0,05}$ I		0.889	ns – ni	ns – ni	ns – ni
Mister		43.38	4.50	5.94	12.95
Taper		43.19	4.08	5.99	12.74
$LSD_{0.05} - NIR_{0,05}$ II		ns – ni	0.230	ns – ni	ns – ni

ns – ni – non-significant difference – różnica nieistotna

Cultivar Mister in comparison with cultivar Taper was characterized by a significantly higher crude fat content in the seeds. The contents of total protein, ash and fibre in the seeds of the studied cultivars were at statistically equal levels. Podleśny and Strobel [2007], however, obtained higher protein content in the seeds of the conventional cultivar in relation to the self-completing cultivar.

CONCLUSIONS

1. Plant growth and development was modified by the sowing date and the course of weather conditions in the study years. Significantly higher plant density before harvest was obtained by sowing the seeds in the second ten days of April in comparison with the first ten days of April.

2. Sowing date significantly diversified such characteristics of the yield structure as the number of grains per pod and the mass of 1000 grains but had no effect on the number of pods per plant.

3. In the region where the study was conducted, the sowing of yellow lupine seeds ought to be carried out in the first or second ten days of April. Delaying the sowing date until the last ten days of April results in a decrease of seed yield and total protein content in the seeds.

4. Cultivar Mister (conventional) in comparison with cultivar Taper (self--completing) was characterized by a significantly higher number of pods per plant, mass of 1000 grains, grain yield, and raw fat content in the seeds. Response of the studied cultivars to a variable sowing date was usually similar. Significant interaction between the sowing date and the cultivar was only noted for the mass of 1000 grains.

5. On the basis of the obtained results, it may be stated that for growth for seeds in the studied mountain-foot region, cultivar Mister is the recommended one.

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WPŁYW TERMINU SIEWU NA WIELKOŚĆ I JAKOŚĆ PLONU NASION ŁUBINU ŻÓŁTEGO (*Lupinus luteus* L.)

Streszczenie. Wprowadzenie do praktyki rolniczej odmian łubinu żółtego tolerancyjnych na opóźnienie terminu siewu (termoneutralne) czy szybciej dojrzewających (samokończące) pozwala na rozszerzenie uprawy tej cennej rolniczo rośliny. Celem podjętych badań było więc określenie wpływu terminu siewu na wielkość i jakość plonu nasion łubinu żółtego w rejonie podgórskim. W hipotezie badawczej założono, że odmiany Mister (tradycyjna) i Taper (samokończąca) wykażą odmienną reakcję na zastosowany czynnik badawczy. Doświadczenie ścisłe założono w latach 2011-2013 w Zakładzie Doświadczalnym Oceny Odmian w Dukli na glebie V klasy, należącej do kompleksu owsiano-ziemniaczanego górskiego. Na wzrost i rozwój roślin wyraźnie wpłynęły: termin siewu oraz zróżnicowany układ warunków pogodowych w latach badań. Największą obsadę roślin przed zbiorem uzyskano w drugim terminie siewu (II dekada kwietnia), zaś najmniejszą w pierwszym terminie siewu (I dekada kwietnia), co zostało udowodnione statystycznie. Terminy siewu istotnie modyfikowały takie cechy struktury plonu, jak: liczba nasion w strąku i MTN, natomiast liczba strąków na roślinie utrzymywała się na jednakowym poziomie. Średnio w latach badań istotnie wyższy plon uzyskano po wysiewie nasion w pierwszej i drugiej dekadzie kwietnia niż w trzeciej dekadzie kwietnia. Zależność ta nie była jednak powtarzalna w latach. Wraz z opóźnieniem terminu siewu zmniejszała się zawartość białka ogólnego w nasionach. Odmiana Mister w porównaniu z Taper odznaczyła się istotnie większą liczbą strąków na roślinie, MTN oraz plonem nasion. Udowodniono również, że odmiana Mister zawiera istotnie więcej tłuszczu surowego w nasionach niż odmiana Taper. Oznaczony procent białka ogólnego, popiołu i włókna nie był zróżnicowany pomiędzy badanymi odmianami.

Słowa kluczowe: komponenty plonu, łubin żółty, odmiana samokończąca, odmiana tradycyjna, plon nasion, skład chemiczny nasion, termin siewu

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