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EFFECT OF DROUGHT STRESS ON YIELD OF A DETERMINATE CULTIVAR OF BLUE LUPINE GROWN IN PURE SOWING AND IN MIXTURE WITH BARLEY

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Abstract. The study was carried out in 2007-2009 at the growth chamber of the Institute of Soil Science and Plant Cultivation – National Research Institute in Puławy, in Mitscherlich pots containing a mixture of 5 kg of hortisol and 2 kg of sand. 1st order factor was soil moisture: 30 and 60% of field water capacity (FWC), and 2nd order factor – a way of sowing: pure sowing of lupine – 5 plants, mixed sowing – 3 lupine plants and 6 barley plants and pure sowing of barley – 10 plants·pot^{-1}. Blue lupine of the cultivar Sonet and barley of the cultivar Johan were sown in the experiment. The aim of this study was to estimate the response of a determinate cultivar of blue lupine grown in pure sowing and in mixture with barley to drought stress occurring in the flowering period. A lower sensitivity to drought of the lupine-barley mixture than of lupine cultivated in pure sowing was observed. Under conditions of the optimal soil moisture (60% FWC) sowings of lupine with barley gave the highest yield, whereas under conditions of water deficiency in soil barley grown in pure sowing gave the highest yield. For the reason of a larger yielding stability, under conditions of expected water deficiency in soil it is better to cultivate blue lupine with barley than in pure sowing. Planing such sowings, it should be taken into account that in spite of high yields they provide less lupine seeds than pure sowings of this species.

Key words: lupine protein, root yield, leaf area, SPAD, soil moisture

INTRODUCTION

Inter-species mixture cultivation, including legume-cereal mixtures, is a long-established agricultural practice which allows rational utilization of the natural environmental resources. Species diversity results in a compensating growth and development of the cultivated species, a decrease in spreading diseases and pests, as

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well as reduction in weed infestation [Martin 1982, Gałęzewski 2006a, Poetsch 2006]. Mixtures of spring cereals with legumes play a crucial role in integrated and ecological production system [Noworolnik 2000, Księżak i Borowiecki 2001], where the care of the soil environment is of particular importance. Unfavorable course of the weather conditions, including mainly precipitation shortage, especially at the flowering stage, constitutes one of the most important factors limiting legume plant yielding [Xia 1997, Baigorri et al. 1999, Costa-Franca et al. 2000, Barrios et al. 2005, Podleśny and Kocoń 2006]. The breeding work resulted in obtaining genotypes of blue lupine of determined growth, earlier and even ripening, often referred to as determinate [Prusiński 2007]. The studies carried out to date the most often estimated the response of various cultivars and species of lupine cultivated in pure sowing to water deficiency in soil [Grzesiak et al. 1997, Podleśny 2001, Podleśny and Podleśna 2003]. Nevertheless, there are no results of studies indicating the response of determinate cultivars of blue lupine in mixed sowings with cereals to periodical water deficiencies in soil. This question is of growing importance, since in recent years, long drought periods occur more and more often in spring and summer months in our country [Łabędzki and Leśny 2008]. From the research conducted so far it follows that the yields of lupine-cereal mixtures are higher and more stable in the years than the mean yields of the suitable cereals and lupines in pure sowings [Rudnicki and Kotwica 2007]. This may result from a higher resistance of this type of sowings to drought stress, determined by a better utilization of water by different root systems of both species composing the mixture.

The aim of this study was to estimate the response of the determinate cultivar of blue lupine Sonet cultivated in pure sowing and in mixture with barley to drought stress occurring in the flowering period.

MATERIAL AND METHODS

The study was carried out in 2007-2009 at the growth chamber of the Institute of Soil Science and Plant Cultivation – National Research Institute in Puławy, in Mitscherlich pots containing a mixture of 5 kg of hortisoil and 2 kg of sand. Factor I of the experiment was soil moisture: 30 and 60% of field water capacity (FWC), varied in flowering and pod formation periods, and factor II order factor – the sowing method: pure sowing of lupine – 5 plants, mixed sowing – lupine plants and 6 barley plants and pure sowing of barley – 10 plants·pot^{-1}. Blue lupine of the cultivar Sonet and barley of the cultivar Johan were sown in the experiment. Before sowing the seeds were dressed with the preparation Sarfun T 450 FS (a.s. carbendazim, tiuram). The seeds sown were characterized by a high germinating capacity, amounting to 94% for lupine and 98% for barley. At the flowering stage the plants were treated once with the fungicide Sarfun 500 SC (a.s. carbendazim). Aphids were controlled with the preparation Pirimor 500 WG (a.s. pirimicarb). The fertilization applied was as follows (g·pot^{-1}): N – 0.3, P – 1.1 and K – 1.4. A precise irrigation appliance with a fertilizer dispenser was applied for soil watering and plant fertilization. The basic element of this appliance is a programmer which starts electromagnetic valves of particular sections of the irrigation system, according to the amount of the water needed. The amount of water necessary to maintain 30 and 60% FWC was determined with the weighing method, each time before programming the irrigation appliance. Fertilizers were applied in the liquid form during watering, at two dates – after emergence and at the stage of 1-2 lupine leaves. Detailed

observations of plant growth and development were conducted during the growing period. Measurements of plant height were made and the occurrence of diseases and pests were determined at several more important developmental stages. At the pod setting and seed filling stages, the leaf area was measured with the apparatus LI 3050A and the leaf greenness index with the apparatus N-Tester SPAD 502. During harvest at the full maturity stage, it was determined as follows: on the lupine plants – the number of pods and seeds, the weight of seeds and their moisture, thousand seed weight (TSW); and on the barley plants – the shoot number, the ear number, the number of grains per ear, the grain weight and their moisture and thousand grain weight (TGW). The results of the study constituting means from 3 pots were worked out statistically with the analysis of variance method, using Tukey's confidence half-interval at the significance level P = 0.05. Statistical calculations were made using the program Statgraphics Plus 5.

RESULTS AND DISCUSSION

Since the seeds sown were characterized by a very good seed quality, the emergence of lupine and barley plants were very even and occurred after 6 days from sowing. No differences were found between the course of plant emergence in pure and mixed stands. No occurrence of diseases and pests of lupine and barley appearing at the seedling stage were observed. The sowing method significantly influenced the growth and development of the plants. The first differences in the course of plant development stages were observed at the flowering stage. Blue lupine cultivated with barley came into flower 3 days earlier than that cultivated in pure sowing. A change in the date of the start and the duration of the phenological phases of plants cultivated in inter-species mixtures was also observed in previous studies concerning cultivation of pea with wheat [Podleśny 1994] and yellow lupine with spring triticale [Kotecki et al. 2001]. Legumes growing in the vicinity of cereals are exposed to an increased competition for light, water and nutrients, which leads to their accelerated generative development. The sowing method modified also the height of lupine and barley plants. Differences in the height of plants cultivated in pure and mixed sowing observed at the flowering stage remained until the full maturity stage (Table 1). Plants of blue lupine and barley cultivated in mixed stands reached a significantly smaller height as compared with those cultivated in pure sowing. This relation applied to both plants growing under conditions of drought stress and at the optimal soil moisture. A reduction in plant height due to mixed sowing for lupine plants growing under conditions of water deficiency in the soil and under the optimal conditions was 23.8 and 31.3%, respectively. For barley the values of those indexes amounted to 3.8 and 4.0%, respectively. Shortening of the height of yellow lupine plants growing in mixture with triticale was reported by Kotecki et al. [2001] also in field experiments. This confirms the opinion that relations occurring in pot experiments, are very often observed under conditions of field experiments. The study by Bieniaszewski et al. [2003a] indicated that the reduction in the height of plants cultivated in mixture, resulting from water deficiency in the soil, is different at particular phenological phases of plants. A decrease in plant height caused by water deficiency is larger at budding, flowering or pod setting than at maturing. Also Wanic et al. [2007] indicated that the competitiveness of cereals in relation to field peas is the highest at the ear formation stage and it decreases at the final stage of plant ontogenesis.

Table 1. Value of selected characters of lupine and barley plants depending on the sowing method and soil moisture

Tabela 1. Wartość wybranych cech roślin łubinu i jęczmienia w zależności od sposobu siewu i wilgotności gleby

Soil moisture (% FWC) Wilgotność gleby (% ppw)	Sowing method Sposób siewu	Plant height before harvest Wysokość roślin przed zbiorem cm		Leaf area per plant Powierzchnia liści na roślinie cm^2		Leaf greenness index Indeks zieloności liścia SPAD	
		lupine łubin	barley jęczmień	lupine łubin	barley jęczmień	lupine łubin	barley jęczmień
30	lupine – łubin	49.4	–	27.4	–	437	–
	lupine + barley – łubin + jęczmień	39.9	52.2	21.5	49.4	317	465
	barley – jęczmień	–	50.3	–	54.2	–	507
60	lupine – łubin	55.8	–	41.3	–	492	–
	lupine + barley – łubin + jęczmień	42.5	57.6	36.7	58.6	427	489
	barley – jęczmień	–	55.4	–	61.2	–	524
Lupine – Łubin		52.6	–	34.3	–	464	–
Lupine + barley – Łubin + jęczmień		41.2	55.0	29.1	54.0	372	477
Barley – Jęczmień		–	52.8	–	57.7	–	515
LSD I – NIR I for – dla: sowing methods – sposobów siewu		4.68	0.66	1.85	2.15	45.4	24.6
30% FWC – ppw		44.6	51.2	24.4	51.8	377	486
60% FWC – ppw		49.1	56.5	39.0	59.9	459	506
LSD II – NIR II for – dla: soil moisture – wilgotności gleby		1.44	2.16	8.45	5.64	28.4	14.5

Cultivation of lupine with barley had a limiting effect on the size of leaf area of both species. A decrease in the leaf area of lupine and barley cultivated in mixture as compared with their pure stands amounted to 17.9 and 6.8%, respectively and was higher under unfavorable conditions of soil moisture. A reduction in the leaf area of lupine and barley owing to their cultivation under conditions of water deficiency in the soil was 59.8 and 15.5%. A decrease in leaf area caused by water deficit in the soil was also reported by Barrios et al. [2005] with reference to another legume – bean. The authors also indicated that water deficiency in the soil reduces the area of leaves occurring on lateral shoots by 60.1%, whereas the area of leaves occurring on the main stem of the plant was reduced only by 10.4% .

The sowing method and soil moisture modified also the value of the leaf greenness index SPAD, which reflects chlorophyll content in leaves. Both lupine and barley plants cultivated on the soil with a higher moisture were characterized by a larger value of the SPAD index than the plants growing under conditions of periodical water deficiency in the soil. Cultivation in mixture resulted in a decrease in the value of the leaf greenness index SPAD of lupine and an increase in the value of this index for barley. Probably the vicinity of a legume had an effect on nutrition of the cereal with nitrogen. These conjectures are confirmed by the study [Triboi 1985] which indicates that cereals cultivated with legumes can take up considerable amounts of fixed nitrogen. The process of biological nitrogen fixation and its moving from the legume to the cereal plant is widely described also by Fujita et al. [1992]. Kotecki et al. [2003b], in turn, reported that triticale cultivated with yellow lupine was more green and its growth was

prolonged by 3-4 days in relation to that cultivated in pure sowing, which also can prove a better nutrition with nitrogen. The results obtained are not confirmed by the study by Olszewska [2004], who showed that water deficit in the soil results in a growth of chlorophyll content in leaves of white clover and a decrease in photosynthesis intensity. According to the author, not all the chlorophyll contained in the plant takes part in the process of photosynthesis, but its considerable amount can play other functions, for instance defensive. Therefore, the plants exposed to stress probably contain its larger amounts. A change in chlorophyll content in leaves caused by drought stress may have a species, and even varietal, character.

Periodical water deficiency in the soil and the sowing method had a significant effect on the height of yield of plant vegetative and generative organs. Under conditions of the optimal soil moisture, of all the cultivation variants, the highest seed yields were obtained from stands of lupine with barley, whereas under conditions of water deficiency in the soil, barley cultivated in pure sowing gave the highest yield (Fig. 1). Kotecki et al. [2003a], conducting a field study concerning the cultivation of yellow lupine with triticale, under unfavorable weather conditions obtained also the highest seed yields from cultivation of triticale in pure sowing, and the lowest from the cultivation of lupine in pure sowing.

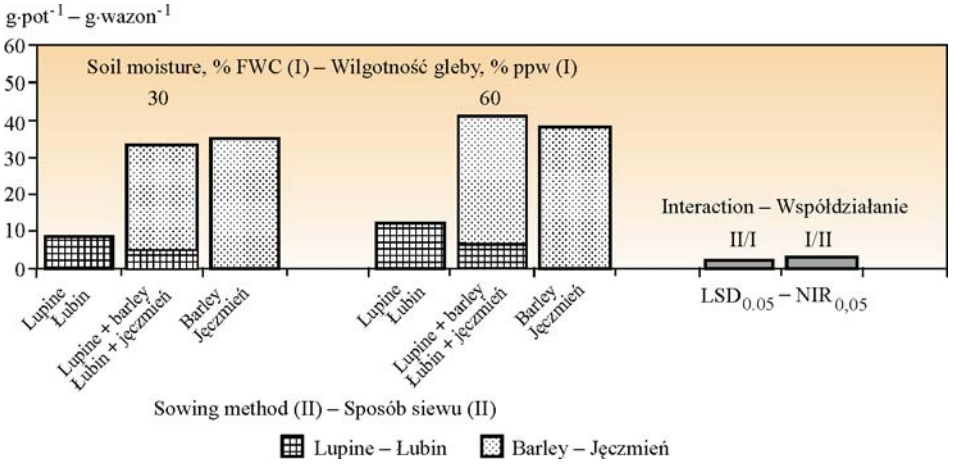


Fig. 1. Seed yield of blue lupine and barley grain depending on the cultivation system and soil moisture

Rys. 1. Plon nasion łubinu wąskolistnego i ziarna jęczmienia w zależności od sposobu uprawy i wilgotności gleby

The largest reduction in yield of lupine seed and barley grain owing to drought occurring at the flowering stage was observed on the treatments with mixed stands, and the smallest decrease in yield on the treatment with pure stands of those species. Nevertheless, mixed stands gave higher yields than pure stands of lupine. A decrease in the seed yield of lupine cultivated in pure sowing and the lupine-barley mixture – caused by water deficiency in the soil – amounted to 48.1 and 26.2%, respectively. The results of other studies [Lopez 1996, Mwanamwenge 1999, Podleśny 2001] indicate that drought occurring during the cultivation of legumes can cause considerably larger decreases in yield then those observed in the present experiments. The results obtained

show the explicitly less sensitivity to drought of the lupine-barley mixture than of lupine cultivated in pure sowing. This is also confirmed by the study by Kotwica and Rudnicki [2003], where lupine-cereal mixtures yielded quite steadily, since the variation coefficient of their yielding did not exceed 10-12%, that is was much lower than that of lupines cultivated in pure sowing.

A decrease in the seed yield of lupine grown under conditions of a lower soil moisture resulted from a smaller pod number per plant, smaller number of seeds per plant and thousand seed weight (Table 2), and in barley grain as a result of weaker tillering – from the smaller number of ears and grains per plant (Table 3). A significant effect of the sowing method on the formation of yield structure characters of lupine and barley was also observed (Table 3). Lupine plants cultivated in mixture with barley set fewer pods and gave less seed than those cultivated in pure sowing. At the same time, lupine seeds derived from mixed stands were characterized by a larger thousand seed weight than those from pure stands. It is worth noticing that a reduction in seed yield of lupine and its structure characters, caused by water deficiency in the soil, was larger when it was cultivated in mixture and definitely smaller – in pure sowing. A similar response of cereal-lupine stands to water deficiency in the soil occurs under conditions of field experiments. From the study by Gałęzewski [2006b], it appears that in dry years mixtures yield more poorly than pure sowings of cereals, whereas the reverse is the case under moist conditions.

Table 2. Value of selected characters of lupine yield structure depending on the sowing method and soil moisture

Tabela 2. Wartość wybranych cech struktury plonu łubinu w zależności od sposobu siewu i wilgotności gleby

Soil moisture (% FWC) Wilgotność gleby (% ppw)	Sowing method Sposób siewu	Number – Liczba			Thousand seed weight Masa 1000 nasion g	Mean lenght of pod Średnia długość strąka mm
		pods per plant strąków na roślinie	seeds per pod nasion w strąku	seeds per plant nasion na roślinie		
30	lupine – łubin	4.34	3.81	14.1	149	6.61
	lupine + barley – łubin + jęczmień	3.12	2.42	7.7	190	6.15
60	lupine – łubin	4.91	3.74	17.2	141	6.64
	lupine + barley – łubin + jęczmień	4.14	3.56	15.2	150	7.00
Lupine – Łubin		4.62	3.77	15.6	145.0	6.62
Lupine + barley – Łubin + jęczmień		3.63	2.99	11.4	170.0	6.57
LSD I – NIR for – dla: sowing methods – sposobów siewu		0.451	0.256	1.14	14.3	ns – ni
30% FWC – ppw		3.73	3.11	10.9	169.5	6.38
60% FWC – ppw		4.52	3.65	16.2	145.5	6.82
LSD I – NIR I for – dla: soil moisture – wilgotności gleby		0.254	ns – ni	4.24	16.7	ns – ni

ns – ni – non-significant differences – różnice nieistotne

It was also observed that barley grown in mixture with lupine formed more shoots, ears and grains per plant than that grown in pure stands. The results obtained are confirmed by the field study concerning cultivation of yellow lupine with triticale [Kotecki et al. 2003a] which indicated that the triticale plants derived from mixed stands formed a larger number and weight of grains per ear than the plants from purer

stands. The response of particular cereal species to mixed sowing with lupine is not the same. For example, Rudnicki and Gałęzewski [2007] showed that barley cultivated with yellow lupine was characterized by weaker tillering and formed less developed panicles and a less seed weight per panicle than that from pure sowing.

Table 3. Value of selected characters of barley yield structure depending on the sowing method and soil moisture

Tabela 3. Wartość wybranych cech struktury plonu jęczmienia w zależności od sposobu siewu i wilgotności gleby

Soil moisture (% FWC) Wilgotność gleby (% ppw)	Sowing method Sposób siewu	Number – Liczba				Thousand grain weight Masa 1000 ziaren g
		shoots per plant pędów na roślinie	ears per plant kłosów na roślinie	grains per ear ziaren w kłosie	grains per plant ziaren na roślinie	
30	barley – jęczmień	4.81	4.10	14.4	66.3	49.3
	barley + lupin – jęczmień + łubin	5.74	5.74	16.6	82.1	48.6
60	barley – jęczmień	5.15	4.93	15.4	82.7	45.8
	barley + lupin – jęczmień + łubin	7.20	6.85	16.9	104.7	45.9
Barley – Jęczmień		4.98	4.51	14.9	74.5	47.5
Barley + lupine – Jęczmień + łubin		6.47	6.29	16.7	93.4	47.2
LSD I – NIR I for – dla: sowing methods sposobów siewu		0.842	1.264	0.76	16.4	ns – ni
30% FWC – ppw		5.27	4.92	15.5	74.2	48.9
60% FWC – ppw		6.17	5.89	16.1	93.7	45.8
LSD II – NIR II for – dla: soil moisture wilgotności gleby		0.542	0.466	ns – ni	11.54	1.47

ns – ni – non-significant differences – różnice nieistotne

Water deficiency in the soil had also a limiting effect on the weight of lupine hulls and barley ears (Fig. 2). The ear weight obtained from barley plants grown both under conditions of limited and optimal soil moisture was larger than the hull weight of lupine cultivated in pure sowing and the weight of hulls and ears of the mixture. Reduction in the hull weight of lupine cultivated in pure sowing and from lupine cultivated in pure sowing and with barley, resulted from water deficiency in the soil, was: 28.2 and 34.6%, respectively, and it was slightly higher than a reduction in ear weight, which for barley cultivated in pure sowing and in mixture amounted to: 26.1 and 26.2%, respectively.

Decreasing the soil moisture also had a limiting effect on the stem weight of lupine and barley (Fig. 3). Reduction in the stem weight of lupine cultivated in pure sowing and with barley as a result of water deficiency in the soil amounted to 23,6 i 29,7%, respectively, and was considerably larger than the reduction in stem weight of barley, which for barley cultivated in pure sowing and in mixture amounted to 14.3 and 13.5%, respectively. It should be stressed that a reduction in the weight of the vegetative organs of lupine and barley, resulting from water deficiency in the soil, was considerably smaller than a reduction in the seed yield. Similar relations, but concerning the effect of drought stress on bean yielding, were obtained by Barrios et al. (2005).

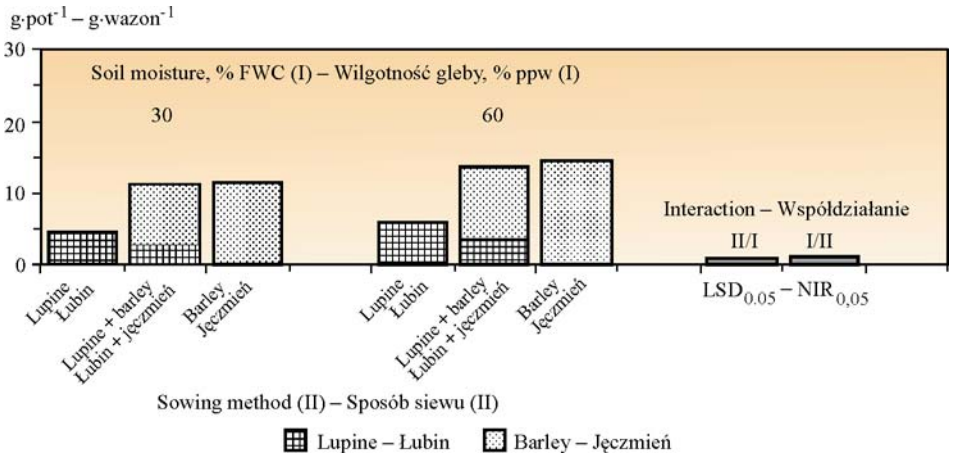


Fig. 2. Weight of blue lupine hulls and barley ears depending on the cultivation system and soil moisture

Rys. 2. Masa strączyn łubinu wąskolistnego i kłosów jęczmienia w zależności od sposobu uprawy i wilgotności gleby

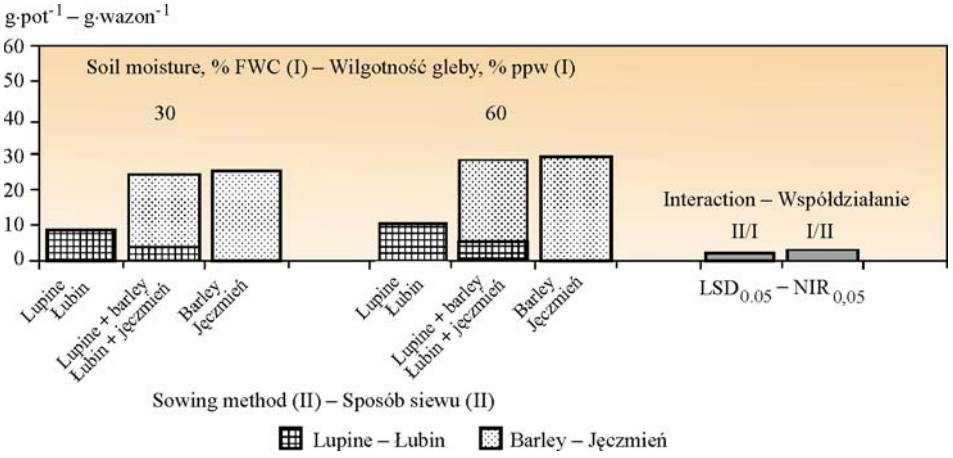


Fig. 3. Straw yield of blue lupine and barley depending on the cultivation system and soil moisture

Rys. 3. Plon słomy łubinu wąskolistnego i jęczmienia w zależności od sposobu uprawy i wilgotności gleby

The root weight of lupine and barley formed quite different from the weight of the aboveground part organs (Fig. 4). Although water deficiency in the soil reduced the weight of lupine roots, it stimulated the weight of barley roots. The root weight of barley grown on soil of a moisture of 30% FWC and cultivated in pure sowing and with lupine was larger than the root weight of barley grown on soil of a moisture of 60% FWC, by: 19.3 and 45.4%, respectively, whereas the root weight of lupine decreased by: 50.0 and 40.9%, respectively. Thus the results obtained confirmed the known rule

that the water deficit in the soil stimulates growth of the root system [Starck 2002], but only in relation to barley plants.

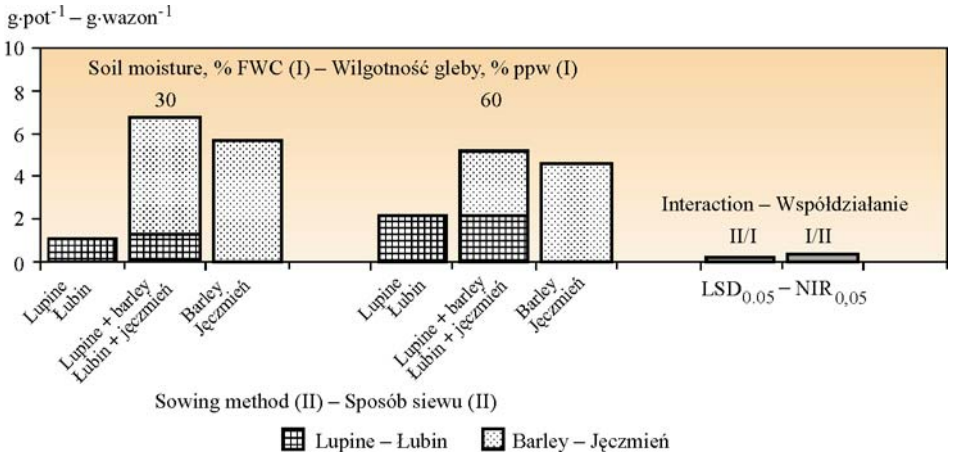


Fig. 4. Root yield of blue lupine and barley depending on the cultivation system and soil moisture

Rys. 4. Plon korzeni łubinu wąskolistnego i jęczmienia w zależności od sposobu uprawy i wilgotności gleby

Soil moisture and sowing method had a significant effect on the amount of protein yield, which constituted a product of seed yield and the content of this component in seeds (Fig. 5). Differences between individual treatments of the experiment concerning protein yield were considerably smaller than those found concerning seed yield. This resulted mainly from a much higher protein content in lupine seeds than in barley grain. Under conditions of water deficiency in the soil the highest protein yields were obtained from cultivation of barley in pure sowing, whereas under conditions of the optimal moisture – from the mixture of lupine and barley. Soil moisture and the sowing method modified the protein content in lupine seeds and barley grain. Seeds obtained from plants grown under conditions of water deficiency in the soil contained more protein than those from plants grown on the soil of a higher moisture. Similar results, but in relation to yellow lupine, were presented by Bieniaszewski [2003b]. Additionally, barley grains obtained from plants cultivated in mixture with lupine contained considerably more protein than those derived from pure sowings (Table 4). Increasing protein content in grain of cereals cultivated with legumes was also observed in the study by Kotecki et al. [1997, 2003b]. This most likely results from a better nitrogen supply of the cereal plant cultivated with the legume [Triboi 1985, Fujita et al. 1992]. Fat content decreased along with a growth in protein amount in lupine seeds and barley grain, just as in other species of agricultural crops.

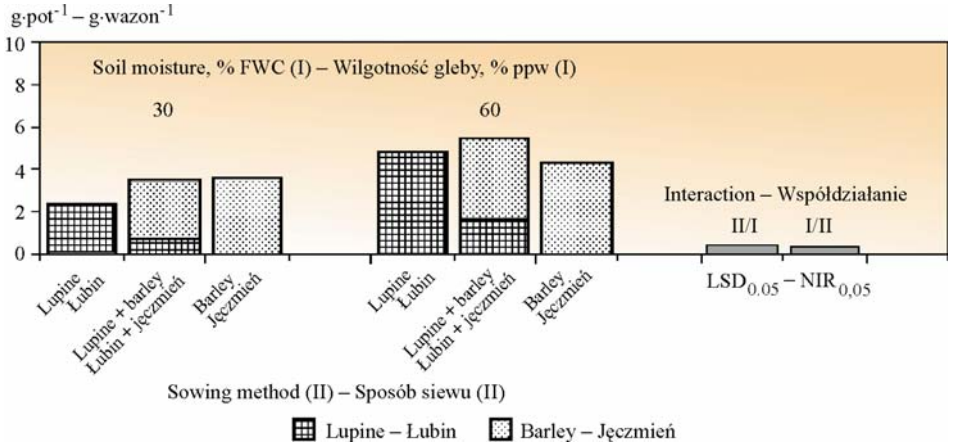


Fig. 5. Protein yield from blue lupine seeds and barley grain depending on the cultivation system and soil moisture

Rys. 5. Plon białka z nasion łubinu wąskolistnego i ziarna jęczmienia w zależności od sposobu uprawy i wilgotności gleby

Table 4. Protein and fat content in lupine seeds and barley grain depending on the sowing method and soil moisture

Tabela 4. Zawartość białka i tłuszczu w nasionach łubinu i ziarnie jęczmienia w zależności od sposobu siewu i wilgotności gleby

Soil moisture (%FWC) Wilgotność gleby (% ppw)	Sowing method Sposób siewu	Content – Zawartość, g·kg^{-1}			
		lupine seeds nasiona łubinu		barley grain ziarno jęczmienia	
		total protein białko ogólne	crude fat tłuszcz surowy	total protein białko ogólne	crude fat tłuszcz surowy
30	lupine – łubin	321	65.1	–	–
	lupine + barley – łubin + jęczmień	324	63.4	128	18.4
	barley – jęczmień	–	–	116	24.5
60	lupine – łubin	305	58.2	–	–
	lupine + barley – łubin + jęczmień	302	56.6	114	17.4
	barley – jęczmień	–	–	112	2.10
Lupine – Łubin		313	6.16	–	–
Lupine + barley – Łubin + jęczmień		313	6.00	12.1	17.9
Barley – Jęczmień		–	–	11.4	22.7
LSD I – NIR I for – dla: sowing methods sposobów siewu		ns – ni	ns – ni	1.40	1.24
30% FWC – ppw		322	64.2	12.2	21.4
60% FWC – ppw		303	57.4	113	19.2
LSD II – NIR II for – dla: soil moisture – wilgotności gleby		12.4	2.46	4.20	0.84

ns – ni – non-significant differences – różnice nieistotne

CONCLUSIONS

1. Reduced water content in soil strongly limited the development and yield of plants. The highest reduction of seed yield as a result of drought occurring in the flowering period was observed in blue lupine cultivated both in pure sowing and in mixture with barley, and the lowest – in barley cultivated in pure sowing.
2. Lupine-barley mixtures gave the highest yield under conditions of the optimal soil moisture, whereas barley cultivated in pure sowing – under conditions of water deficiency in soil.
3. A decrease in seed yield of lupine growing under conditions of lower soil moisture resulted from a smaller pod number per plant and smaller number of seeds per plant, and a decrease in grain yield of barley due to weaker tillering – from a smaller number of ears and grains per plant.
4. Due to a larger yield stability, under conditions of predicted water deficiency in soil it is better to cultivate blue lupine with barley than in pure sowing. Planning such sowings, one should take into account that in spite of high yields they provide less lupine seeds than pure sowings of this species.
5. Lupine seeds and wheat grain obtained from plants grown under conditions of water deficiency in soil contained less protein than those from plants grown on the soil with the optimal moisture. Barley grain obtained from plants cultivated in mixture with lupine contained more protein than barley grain from pure sowing.

REFERENCES

Baigorri H., Antolini M.C., Sanchez-Diaz M., 1999. Reproductive response of two morphological different pea cultivars to drought. Eur. J. Agron. 10, 119-128.Barrios A.N., Gerrit Hoogenboom G., Nesmith D.S., 2005. Drought stress and the distribution of vegetative and reproductive traits of a bean cultivar. Sci. Agric. 62(1), 18-22.

Bieniaszewski T., Fordoński G., Kurowski T., Szwejkowski Z., 2003a. Wpływ poziomu wilgotności gleby na wzrost i plonowanie tradycyjnych i samokończących form łubinu żółtego. Wzrost, rozwój i zdrowotność roślin [Influence of soil moisture on the growth and development of traditional and epigonalcultivars of yellow lupin. Influence of soil moisture on the growth, development, yield and health of plants]. Zesz. Prob. Post. Nauk Rol. 495, 95-106 [in Polish].

Bieniaszewski T., Fordoński G., Kurowski T., Szwejkowski Z., 2003b. Wpływ poziomu wilgotności gleby na wzrost i plonowanie tradycyjnych i samokończących form łubinu żółtego. Skład chemiczny nasion [Influence of soil moisture on the growth and development of traditional and epigonalcultivars of yellow lupin. Influence of soil moisture on chemical compositon of grain]. Zesz. Prob. Post. Nauk Rol. 495, 107-119 [in Polish].

Costa-Franca M.G., Thi A.T., Pimentel C., Pereyra R.O., Zuily-Fodil Y., Laffray D., 2000. Differences in growth and water relations among *Phaseolus vulgaris* cultivars in response to induced drought stress. Environ. Exp. Botany 43, 227-237.

Fujita K., Ofosu-Budu K.G., Ogata S., 1992. Biological nitrogen fixation in mixed legume-cereal cropping system. Plant and Soil 141, 155-175.

Gałęzewski L., 2006a. Reakcja łubinu żółtego w siewie czystym i jego mieszankach z owsem na wilgotność gleby [Response of yellow lupine on soil moisture in sole crop and in intercrop with oat]. Rocz. AR w Poznaniu 66, 55-65 [in Polish].

Gałęzewski L., 2006b. Wpływ wilgotności gleby na plonowanie łubinu żółtego i owsa oraz ich mieszanek [Effect of soil moisture on the yield of yellow lupine and oat and their mixtures]. Rocz. AR w Poznaniu 66, 67-73 [in Polish].

Grzesiak S., Filek W., Grzesiak M., 1998. Wpływ stresu wodnego na wzrost korzeni różnych odmian roślin strączkowych różniących się wrażliwością na suszę [Effect of water stress on the root growth of different drought tolerance cultivars of legume species]. [In:] Ecophysiological aspects of plant responses to stress factors, International Scientific Meeting, Institute of Plant Physiology Cracow, 63-68 [in Polish].

Kotecki A., Grządkowska A., Steinhoff-Wrześniowska A., 1997. Ocena przydatności odmian łubinu wąskolistnego do uprawy w mieszankach ze zbożami [The pure and mixture effect on the seeds of blue lupin]. Mat. Konf. Łubin we współczesnym rolnictwie, Olsztyn-Kortowo, ATR Olszyn, 261-271 [in Polish].

Kotecki A., Kozak M., Malarz W., 2003a. Ocena przydatności odmian łubinu żółtego do współrzędnej uprawy z pszenżytem jarym [The evaluation of use of yellow lupin cultivars for mixed cultivation with spring triticale]. Zesz. Probl. Post. Nauk Rol. 495, 129-143 [in Polish].

Kotecki A., Kozak M., Malarz W., 2003b. Wpływ współrzędnej uprawy łubinu żółtego z pszenżytem jarym na skład chemiczny i gromadzenie składników mineralnych w nasionach i resztkach pozbiorowych [The effect of yellow lupin and spring triticale mixed cultivation on chemical content and mineral component accumulation in seeds and harvest residues]. Zesz. Probl. Post. Nauk Rol. 495, 145-161 [in Polish].

Kotecki A., Kozak M., Wincewicz E., Zawadzki W., 2001. Uprawa łubinu żółtego na nasiona w siewie czystym i współrzędnym z pszenżytem jarym [Yellow lupine growing for seeds in pure and mixed sowing with spring triticale]. Zesz. Nauk. AR we Wrocławiu, Rolnictwo 426, 73-92 [in Polish].

Kotwica K., Rudnicki F., 2003. Komponowanie mieszanek zbóż jarych z łubinem na glebie lekkiej [Mixture of spring cereals with legumes in the light soil]. Zesz. Probl. Post. Nauk Rol. 495, 163-170 [in Polish].

Księżak J., Borowiecki J., 2001. Rośliny strączkowe w rolnictwie ekologicznym [Legumes in organic agriculture]. Zesz. Nauk. AR we Wrocławiu, Rolnictwo 426, 93-100 [in Polish].

Lopez F.B., Johansen C., Chauhan Y.S., 1996. Effect of timing of drought stress on phenology, yield and yield components of a short-duration pigeon pea. J. Agron. Crop Sci. 177, 311-320.

Łabędzki L., Leśny J., 2008. Skutki susz w rolnictwie – obecne i przewidywane w związku z globalnymi zmianami klimatycznymi [Results of droughts in agriculture – present and predicted owing to global climatic changes]. Wiad. Melior. Łąk. 1, 7-9 [in Polish].

Martin M.P.L.D., Snaydon R.W., 1982. Intercropping barley and beans. I. Effects of planting pattern. Expl. Agric. 18, 139-148.

Mwanamwenge J., Loss S.P., Siddique K.H.M., Cocks P.S., 1999. Effect of water stress during floral initiation, flowering and podding on the growth and yield of faba bean (*Vicia faba* L.). Eur. J. Agron. 11, 1-11.

Noworolnik K., 2000. Mieszanki zbożowo-strączkowe w systemie rolnictwa zrównoważonego [Importance of cereal-legume mixtures in integrated system of crop production]. Pam. Puł. 120/II, 325-330 [in Polish].

Olszewska M., 2004. Reakcja koniczyny białej uprawianej na dwóch typach gleb na stres wodny [Reaction of white clover grown on two types of soil to water stress]. Acta Sci. Pol., Agricultura 3(2), 203-213 [in Polish].

Poetsch J., 2006. Pflanzenbauliche Untersuchungen zum ökologischen Anbau von Körnerleguminosen an sommertrockenen Standorten Südwestdeutschlands. Dissertation zur Erlangung des Grades eines Doktors der Agrarwissenschaften. Universität Hohenheim.

Podleśny J., 1994. Możliwości zmniejszenia strat nasion grochu poprzez zastosowanie rośliny podporowej i różnych sposobów zbioru [Potential to reduce pea seed losses by planting a supporting crop and by using different methods of harvests]. IUNG Puławy, Seria R 318, 1-71 [in Polish].

Podleśny J., 2001. The effect of drought on the development and yielding of two different varieties of the fodder broad bean (*Vicia faba minor*). J. Appl. Genet. 42 (3), 283-287.

Podleśny J., Kocoń A., 2006. Wpływ stresu suszy na rozwój i plonowanie dwóch różnych genotypów bobiku [The effect of soil drought on the development and yielding of two different genotypes of faba bean]. Zesz. Prob. Post. Nauk Rol. 509, 125-131 [in Polish].

Podleśny J., Podleśna A., 2003. Wpływ różnych poziomów wilgotności gleby na rozwój i plonowanie dwóch genotypów łubinu białego (*Lupinus albus* L.) [The effect of different levels of soil moisture on development and yielding of two different genotypes of white lupine (*Lupinus albus* L.)]. Biuletyn IHAR 228, 315-322 [in Polish].

Prusiński J., 2007. Ilościowy i jakościowy potencjalny postę p biologiczny w łubinie (*Lupinus* sp.) – rys historyczny i stan aktualny [Biological progress in lupin (*Lupinus* sp.) – present state and historical background]. Zesz. Probl. Post. Nauk Rol. 522, 23-37 [in Polish].

Rudnicki F., Gałęzewski L., 2007. Reakcje owsa i łubinu żółtego na uprawę w mieszankach o różnym składzie ilościowym oraz efekty produkcyjne uprawy mieszanek [Response of oat and yellow lupine to their various participation in intercropping and their productivity in intercrops]. Zesz. Prob. Post. Nauk Rol. 516, 161-170 [in Polish].

Rudnicki F., Kotwica K., 2007. Oddziaływanie konkurencyjne między zbożami jarymi i łubinami w mieszankach oraz efekty produkcyjne uprawy mieszanek na glebie kompleksu żytniego bardzo dobrego [Competitive interaction between spring cereals and lupines in mixtures and mixture growing production effects on very good rye complex soil]. Fragm. Agron. 4(96), 145-152 [in Polish].

Starck Z., 2002. Mechanizmy integracji procesów fotosyntezy i dystrybucji asymilatów a tolerancja roślin na niekorzystne warunki środowiska [Mechanisms of integration of photosynthesis and asimilate distribution processes and plant tolerance to unfavorable environmental conditions]. Zesz. Probl. Post. Nauk Rol. 481, 111-123 [in Polish].

Triboi E., 1985. Détermination in situ de la quantité d'azote fixée symbiotiquement par la vesce en culture associée avec l'avoine. Les Colloques de I'INRA 37, Paris, 265-270.

Wanic M., Michalska M., Treder K., 2007. Konkurencja pomiędzy jęczmieniem jarym a grochem siewnym i pszenicą jarą. [Competition among spring barley, field peas and spring wheat]. Zesz. Probl. Post. Nauk Rol. 516, 267-275 [in Polish].

Xia M.Z., 1997. Effect of soil drought during the generative development phase on seed yield and nutrient uptake of faba bean (*Vicia faba* L.). Aust. J. Agric. Res. 48, 447-451.

WPŁYW STRESU SUSZY NA PLONOWANIE SAMOKOŃCZĄCEJ ODMIANY ŁUBINU WĄSKOLISTNEGO UPRAWIANEGO W SIEWIE CZYSTYM I W MIESZANCE Z JĘCZMIENIEM

Streszczenie. Badania prowadzono w latach 2007-2009 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. Czynnikiem I rzędu była wilgotność podłoża: 30 i 60% polowej pojemności wodnej (ppw), a czynnikiem II rzędu – sposób siewu: siew czysty łubinu – 5 roślin, siew mieszany – 3 rośliny łubinu i 6 roślin jęczmienia oraz siew czysty jęczmienia – 10 roślin·wazon^{-1}. W doświadczeniu wysiewano łubin wąskolistny odmiany Sonet i jęczmień odmiany Johan. Celem badań było poznanie reakcji samokończącej odmiany łubinu wąskolistnego uprawianego w siewie czystym i w mieszance z jęczmieniem na stres suszy występujący w okresie kwitnienia. Stwierdzono mniejszą wrażliwość na suszę mieszanki łubinu z jęczmieniem niż łubinu uprawianego w siewie czystym. W warunkach optymalnej wilgotności gleby (60% ppw) najwyżej plonowały zasiewy łubinu z jęczmieniem,

natomiast w warunkach niedoboru wody w glebie najwyżej plonował jęczmień uprawiany w siewie czystym. Ze względu na większą wierność plonowania, w warunkach przewidywanego niedoboru wody w glebie lepiej uprawiać łubin wąskolistny z jęczmieniem niż w siewie czystym. Planując takie zasiewy należy uwzględniać to, że mimo wysokich plonów dostarczają one mniej nasion łubinu niż czyste zasiewy tego gatunku.

Słowa kluczowe: białko łubinu, plon korzeni, powierzchnia liści, SPAD, wilgotność gleby

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