

COMPETITION BETWEEN OAT AND YELLOW LUPINE IN MIXTURES OF THESE SPECIES PART II. INTENSITY OF COMPETITION DEPENDING ON SPECIES RATIO IN MIXTURE

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Abstract. The results of two-factorial field experiment conducted in 2002, 2004 and 2005 at the Research Station Mochełek near Bydgoszcz (53°13' N; 17°51' E) were applied to estimate mutual interactions between oat and yellow lupine. The factors were: sowing rate of oat (0, 140, 280, 420, 560 grains·m⁻²) and lupine (0, 25, 50, 75, 100 seeds·m⁻²). Combinations of levels of both factors gave 16 mixtures and four pure sowings of each of the species. Assessment of competition intensity was made based on indexes worked out by Rudnicki and Kotwica [2007]. Competition between oat and lupine in mixture stands is characterized by strong asymmetry. Oat was the dominant species and its competitive advantage over lupine resulted from a greater plant density. The competitive potential of a single yellow lupine plant towards oat turned out to be higher than that of a single oat plant towards lupine. Relations of the competitive strength of a single plant in mixtures were arranged according to the regularity that the stronger was competition between plants of species B and the weaker between plants of species A, the stronger competitors single plants of species A were for single plants of species B.

Key words: *Avena sativa*, index of competition intensity, inter-species competition, *Lupinus luteus*, sowing rate

INTRODUCTION

Effects of competition usually influence the individuals involved in the interactions to a various degree. Generally one of the species incurs higher costs of competition than the other, hence the effects of mutual interactions are characterized by asymmetry. The equal division of environmental resources between individuals is rather rare [Shipley and Eddy 1994, Falińska 1996]. Competitive ability of the species in inter-species interactions is determined first of all by the biological and physiological properties of the species, habitat conditions where it grows and plants adjacent to it. Apart from that,

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competition depends on the density of individuals, the duration of mutual interaction, priority of taking up the site etc. [Zarzycki 1965]. Therefore, creating in the stand equally favorable conditions for field crops from distant taxons and compensating their competitive chances in the case of cereal-legume mixtures is a large agroecological problem and agrotechnological difficulty. This results from the fact that these plants differ considerably in morphological features, the rhythm of growth and development and environmental and agrotechnological requirements. The selection of cultivars and the ratio of species co-occurring in the mixture are essential [Rudnicki 1997, 1999].

The aim of this study was to assess the intensity of competition between oat and yellow lupine plants depending on proportions of these species in mixed sowing.

MATERIAL AND METHODS

The source data come from a strict field experiment carried out in 2002, 2004, 2005 at the Research Station Mochełek near Bydgoszcz (53°13' N; 17°51' E) on a soil of the good rye complex of quality class IVb. The two-factorial experiment was established in the randomized complete bloc design in 4 replications in plots of an area of 24 m² (for harvest 18 m²). Mixtures and pure sowings were made as combinations of levels of factor: I – sowing rate of oat (0, 140, 280, 420, 560 grains·m⁻²) and factor II – sowing rate of lupine (0, 25, 50, 75, 100 seeds·m⁻²). The assessment of competitive interactions between oat and lupine was made in 16 mixtures with different proportions of the components, for which pure sowings of oat and lupine served as comparative treatments. Sowing material of both species was sown together in a row spacing of 12.5 cm. The experiment was conducted in the stand after spring barley. Pre-sowing fertilization was applied at the following rates: P – 30.5 kg·ha⁻¹, K – 66 kg·ha⁻¹ and N – 30 kg·ha⁻¹. The other nitrogen rate (30 kg·ha⁻¹) was applied at oat shooting stage. Stand cultivation involved weed control with the herbicide Afalon 450 SC, used directly after sowing at a dose of 1 dm³·ha⁻¹.

The assessment of mutual effect intensity was made based on indexes of competition worked out by Rudnicki and Kotwica [2007], the same as were used in the first part of this study. The values of these indexes were calculated based on mean yields of the three years of the study (Table 1). This made it possible to generalize conclusions about mutual effects between oat and yellow lupine irrespective of environmental conditions changing in particular years. Relation between yields and values of individual competition indexes was subjected to the analysis of simple correlation [SAS 9.1]. The results concerning the yield and morphological characters of the plants were presented in earlier studies [Rudnicki and Gałęzewski 2007a, b].

Table 1. Seed yield of yellow lupine and grain yield of oat ($t \cdot ha^{-1}$) in mixtures and pure sowings of different sowing rate of both components (means of 2002, 2004, 2005)
 Tabela 1. Plony nasion łubinu żółtego i ziarna owsa ($t \cdot ha^{-1}$) w mieszankach i siewach czystych o różnej gęstości siewu obu komponentów (średnie z lat: 2002, 2004, 2005)

Sowing rate of lupine, plant·m ⁻² Gęstość siewu łubinu (B), szt·m ⁻²	Sowing rate of oat, plant·m ⁻² – Gęstość siewu owsa (A), szt·m ⁻²												Mean – Średnia	
	140			280			420			560				
	lupine łubinu	oat owies	oat owies	lupine łubinu	oat owies	oat owies	lupine łubinu	oat owies	oat owies	lupine łubinu	oat owies	oat owies	lupine łubinu	oat owies
25	0.41	4.24	0.25	5.21	0.18	5.23	0.15	5.25	0.15	5.25	0.25	4.98	1.37	
50	0.50	4.51	0.39	4.71	0.38	4.64	0.26	5.32	0.38	4.79	0.38	4.79	1.65	
75	0.59	4.23	0.42	4.74	0.36	5.07	0.33	5.03	0.43	4.77	0.43	4.77	1.77	
100	0.84	3.62	0.43	4.64	0.32	5.20	0.36	5.16	0.49	4.65	0.49	4.65	1.82	
Mean – Średnia	0.59	4.15	0.37	4.82	0.31	5.03	0.27	5.19	0.39	4.80	0.39	4.80	1.65	
Pure sowing of oat – Siew czysty owsa	4.84			5.65			6.00			5.81			5.57	
LSD _{0,05} – NIR _{0,05}	lupine in mixtures – łubinu w mieszankach			A 0.08			B 0.10			B/A 0.14			A/B 0.07	
	oat in mixtures – owsa w mieszankach			A 0.29			B 0.26			B/A 0.58			A/B 0.29	
	pure sowing – siew czysty			A 0.29			B 0.26			B/A 0.58			A/B 0.29	

source – źródło: Rudnicki i Gałeczewski 2007a, b

The meteorological conditions during the growth period of plants involved in the experiments were varied in the years of the study (Table 2). In 2002 the temperature from May to the beginning of August was higher than that in the long-time period and was accompanied by quite heavy precipitation, particularly in May and July. However, critical periods of the water demand of oat and lupine fell in the last twenty days of June, which were relatively dry and warm. The year 2004 was distinctly colder than 2002, with a lower total precipitation, whereas the rainfalls were distributed quite unevenly during the growing period, and the heavy rainfall at the beginning of August did not favor uniform ripening of lupine. In 2005 the first half of the growing period (April – May) was rather cool, with the total precipitation higher by about 35% than the mean. From the middle of June, in turn, the high temperature and the long-term drought period occurred. The total precipitation in June amounted to about 64% of the long-term mean, whereas in July only about 37%.

Table 2. Mean air temperatures and total rainfall during growing period of oat-lupine mixtures and in years of the study as compared with long-term period (data from agrometeorological point in Mochełek)

Tabela 2. Średnie temperatury powietrza i sumy opadów atmosferycznych w okresie wegetacji mieszanek owsa z łubinem i w latach badań, na tle wielolecia (dane z punktu agrometeorologicznego w Mochełku)

Month – Miesiąc	Year – Rok				Mean from 1996-2004 Średnia z lat 1996-2004
	2002	2004	2005	mean średnia	
Mean temperature – Średnia temperatura, °C					
April – Kwiecień	7.5	7.5	7.4	7.5	7.8
May – Maj	15.7	11.3	12.2	13.1	13.2
June – Czerwiec	16.3	14.7	14.9	15.3	16.1
July – Lipiec	18.9	16.4	19.4	18.2	17.7
1-10 August – Sierpień (I dekada)	20.5	19.8	15.3	18.5	18.9
April – 1-10 August Kwiecień – I dekada sierpnia	15.1	13.1	13.6	13.9	14.1
Total rainfall – Suma opadów, mm					
April – Kwiecień	17.7	32.1	34.8	28.2	27.6
May – Maj	111.5	54.4	82.6	82.8	59.5
June – Czerwiec	31.3	39.6	30.5	33.8	47.9
July – Lipiec	77.9	53.5	33.6	55.0	91.7
1-10 August – Sierpień (I dekada)	41.2	53.8	25.7	40.2	18.6
April – 1-10 August Kwiecień – I dekada sierpnia	279.6	233.4	207.2	240.0	245.3

RESULTS AND DISCUSSION

Comparing the values of competition index of oat plants towards lupine plants (IK_o) to the values of competition index of lupine plants towards oat plants (IK_l) in mixtures proves that oat is a definitely stronger competitor for lupine than lupine for oat (Table 3). The competition intensity of oat increased also with a growing density of its plants in mixtures. At 4-time higher density of oat sowing – from 140 to 560 grains·m⁻² – 2.2-fold increase in its strength of competitive effects towards lupine occurred.

However, intensifying of oat competition towards lupine increased disproportionately to its sowing rate. A particularly large increase in competition index occurred after increasing oat sowing rate from 140 to 280 grains·m⁻². After crossing this sowing rate oat competition still increased, but to a gradually smaller degree, which should be attributed to growing intra-species competition between oat plants at their high density.

The larger the ratio of oat sowing rate to lupine sowing rate was in mixtures, the stronger competitor oat was for lupine (Table 3). This competition was relatively weak when a small number of oat plants (140 grains·m⁻²) competed with a large number (100 seeds·m⁻²) of lupine plants (IK_o = 2.17). At the sowing ratio of those species of 560 : 25 oat turned out the particularly strong competitor for lupine (IK_o = 9.13). Such results caused that lupine seed yield in mixtures was in about 75% determined by oat competition measured with the IK_o index (r = -0.87).

Table 3. Indexes of competition intensity of oat towards yellow lupine (IK_o) and of yellow lupine towards oat (IK_i) in mixtures

Tabela 3. Wskaźniki intensywności konkurencji owsa względem łubinu żółtego (IK_o) i konkurencji łubinu żółtego względem owsa (IK_i) w mieszankach

Sowing rate of lupine in mixtures, plants·m ⁻² Gęstość siewu łubinu w mieszankach, szt.·m ⁻²	Sowing rate of oat, plants·m ⁻² – Gęstość siewu owsa, szt.·m ⁻²								Mean Średnia	
	140		280		420		560		IK _o	IK _i
	IK _o	IK _i	IK _o	IK _i	IK _o	IK _i	IK _o	IK _i		
25	3.34	1.14	5.48	1.08	7.61	1.15	9.13	1.11	6.39	1.12
50	3.30	1.07	4.23	1.20	4.34	1.29	6.35	1.09	4.55	1.16
75	3.00	1.15	4.21	1.19	4.92	1.18	5.36	1.16	4.37	1.17
100	2.17	1.34	4.23	1.22	5.69	1.15	5.06	1.13	4.29	1.21
Mean – Średnia	2.95	1.16	4.54	1.17	5.64	1.19	6.47	1.12	4.90	1.16

Yellow lupine plants showed a small competitive potential towards oat plants (Table 3). This mostly results from a relatively small density of its plants in mixtures in relation to oats. However, increasing the sowing rate of lupine in mixtures caused that it became a slightly stronger competitor for oat, in spite of growing intra-species competition of lupine plants. In mixtures where lupine plants slightly more efficiently competed with oat also better lupine yields were observed (r = 0.60).

Similar regularities were indicated by Kotwica [1994] in competitive interactions between spring triticale and yellow lupine, but triticale competed with lupine to a less degree than oat in the present study.

Considering the competition intensity of oat towards lupine in mixtures, one must take into account the fact of different plant density of those species making the mixtures. Ratios of oat sowing rate to lupine sowing rate in mixtures ranged from 1.4 to 22.4. Thus oat plants considerably predominated over lupine plants and consequently, the total intensity of their competition with lupine in the stand was high. A regularity is observed that along with an increase in oat sowing rate the competitive strength of its single plants towards lupine decreased, whereas it increased along with growing lupine sowing rate (Table 4). Thus it was the lowest in the mixture composed of 560 oat grains and 25 lupine seeds·m⁻², and the highest in the mixture of 140 oat grains and 100 lupine seeds·m⁻². Single oat plants turned out to be stronger competitors towards single lupine plants only in mixtures with a oat to lupine ratio of: 140/75, 140/100, 280/100, 420/100. Thus, there is a regularity that the stronger the competition is between lupine plants and

the weaker between oat plants, the stronger competitors single oat plants are for lupine plants in mixtures.

The competitive potential of single lupine plants towards oat plants in mixtures turned out to be high (Table 4). When the proportions of sowing of particular species in the mixture are more balanced (140 oat grains + 100 lupine seeds·m⁻²), a single lupine plant is a weaker competitor for oat ($SK_1 = 0.78$), but it strongly competes with oat ($SK_0 = 1.16$) in the mixture composed of 420 oat grains + 50 lupine seeds·m⁻². Thus the general regularity is similar to that formulated above in the case of oat. The more intense is the competition between oat plants and the less intense between lupine plants, the stronger competitors single lupine plants are for oat plants in mixtures.

Table 4. Competitive strength of a single oat plant (SK_0) towards yellow lupine and of a single yellow lupine plant (SK_1) towards oat in mixtures of those plants

Tabela 4. Siła konkurencyjna pojedynczej rośliny owsa (SK_0) względem łubinu żółtego i pojedynczej rośliny łubinu żółtego (SK_1) względem owsa w mieszankach tych roślin

Sowing rate of lupine in mixtures, plants·m ⁻² Gęstość siewu łubinu w mieszankach, szt.·m ⁻²	Sowing rate of oat, plants·m ⁻² – Gęstość siewu owsa, szt.·m ⁻²								Mean Średnia	
	140		280		420		560		SK_0	SK_1
	SK_0	SK_1	SK_0	SK_1	SK_0	SK_1	SK_0	SK_1		
25	0.51	0.97	0.45	1.00	0.43	1.08	0.39	1.06	0.44	1.03
50	0.87	0.79	0.64	1.02	0.46	1.16	0.52	1.00	0.62	0.99
75	1.05	0.75	0.89	0.94	0.74	1.00	0.63	1.02	0.83	0.93
100	0.90	0.78	1.11	0.90	1.09	0.93	0.77	0.96	0.97	0.89
Mean – Średnia	0.83	0.82	0.77	0.96	0.68	1.04	0.58	1.01	0.72	0.96

These regularities correspond to the facts quoted in the literature that for the dominant species – oat – the results of inter-species competition are smaller than those of intra-species competition, and for the dominated species – lupine – the reverse is the case [Shipley and Eddy 1994, Falińska 1996]. When comparing the indexes of competitive effects of single plants of oat (SK_0) and lupine (SK_1) in various mixtures, a regularity can be observed that an increase in the competitive strength of oat in the mixture is accompanied by a decrease in competitive strength of lupine and vice versa. This probably results from the relation between an increase in intra-species and inter-species competition in mixtures, yet it also suggests mutual fitting of the species and their aspiration to use ecological niches in the stand. The basis for such an interpretation can be found in the study by Begon and Motrimer [1989], who claim that in mixtures a partial division of environmental resources occurs, as well as utilizing by species A resources not utilized by species B. This confirms the results obtained in the present study. The smaller sowing rate in the mixture of one species, the more niches it left to the other, thus single plants of the other species, using those niches, less strongly competed with the first species.

CONCLUSIONS

1. Competition between oat and lupine in mixture stands was characterized by strong asymmetry. Oat was the dominant species and its competitive advantage over lupine resulted from a higher plant density.

2. Competitive potential of a single yellow lupine plant towards oat turned out to be greater than that of a single oat plant toward lupine. However, this strength of inter-species competition depended on the intensity of intra-species competition and the sowing ratio of those species in mixtures.

3. The stronger was the competition between lupine plants and the weaker between oat plants, the stronger competitors single oat plants were for lupine plants in mixtures. The stronger was the competition between oat plants and weaker between lupine plants, the stronger competitors single lupine plants were for oat.

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**KONKURENCJA MIĘDZY ROŚLINAMI OWSA I ŁUBINU ŻÓŁTEGO
W MIESZANKACH TYCH GATUNKÓW
CZ. II. INTENSYWNOŚĆ KONKURENCJI W ZALEŻNOŚCI
OD UDZIAŁU GATUNKÓW W MIESZANCE**

Streszczenie. Do określenia wzajemnych oddziaływań między owsem i łubinem żółtym posłużyły wyniki dwuczynnikowego doświadczenia polowego zrealizowanego w latach 2002, 2004 i 2005 w Stacji Badawczej Mochełek koło Bydgoszczy (53°13' N; 17°51' E). Czynnikiem były: gęstość siewu owsa (0, 140, 280, 420, 560 ziaren·m⁻²) i łubinu (0, 25, 50, 75, 100 nasion·m⁻²). Kombinacje poziomów obydwu czynników dały 16 mieszanek i po cztery siewy czyste obu gatunków. Oceny intensywności konkurencji dokonano w oparciu o wskaźniki opracowane przez Rudnickiego i Kotwicę [2007]. Konkurencję między owsem i łubinem w łanach mieszanek cechuje silna asymetria. Gatunkiem dominującym był owies, a jego przewaga konkurencyjna nad łubinem wynikała z większej obsady roślin. Potencjał konkurencyjny pojedynczej rośliny łubinu żółtego względem owsa okazał się większy niż pojedynczej rośliny owsa względem łubinu. Relacje siły konkurencyjnej pojedynczej rośliny w mieszkach układały się wedle prawidłowości, że pojedyncze rośliny gatunku A były tym silniejszymi konkurentami dla roślin gatunku B, im silniejsza była rywalizacja między roślinami gatunku B, a mniejsza między roślinami gatunku A.

Słowa kluczowe: *Avena sativa*, gęstość siewu, konkurencja międzygatunkowa, *Lupinus luteus*, wskaźnik intensywności konkurencji

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