ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Agricultura 9(3) 2010, 37-44*

COMPETITION BETWEEN OAT AND YELLOW LUPINE PLANTS IN MIXTURES OF THESE SPECIES PART I. INTENSITY OF COMPETITION DEPENDING ON SOIL MOISTURE

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Abstract. A two-factorial pot experiment was carried out in 2005 to estimate the effect of soil moisture on competition intensity between oat and yellow lupine plants in mixtures Factor I was soil moisture: 40, 60, 80% of field water capacity, and factor II: the composition of oat and lupine mixture (pcs·pot^{-1}) respectively – 30 + 5, 20 + 5, 10 + 5, 0 + 5 (pure sowing of lupine), 10 + 0, 20 + 0, 30 + 0 (pure sowings of oat). Indexes worked out by Rudnicki and Kotwica [2007] were applied for the assessment of competition intensity. Competitive effect of oat on lupine increased along with a growing oat plant density in mixtures, in inverse proportion to the soil humidity. Lupine plants exerted a weaker competitive pressure on oat plants than vice versa, which resulted from their smaller density. Single oat plants turned out to be weaker competitors than single lupine plants in the mixture.

Keywords: index of competition intensity, inter-species competition, plant density, soil moisture

INTRODUCTION

Proportions of sowing mixture components are different from the composition of yield harvested. This results not only from a difference in the fertility of individual species but also from mutual interactions in the course of growing. Intensity of inter-species interactions in mixed crops depends on many factors. An access to environmental resources limiting the growth and development of plants may be assumed to be the most important of them. Under conditions of water deficiency in mixed cereal-legume sowings, fabaceae plants turn out to be more sensitive to this stress factor than in pure sowings and withdraw from the mixture stand [Paprocki 1961a, b, Kotwica 1994, Rudnicki 1999, Rudnicki and Kotwica 2002, Gałęzewski

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2006a, b, Rudnicki and Gałęzewski 2007a, b]. Results of many studies indicate a relatively good tolerance to spring triticale or spring rye, worse to spring barley and considerably worse to oat by lupine in mixtures [Paprocki 1961a, Kotwica 1994, Rudnicki and Kotwica 1999, Wenda-Piesik and Rudnicki 2000, Kotwica and Rudnicki 2003, 2004]. At the same time in barley-oat mixtures oat is a weaker competitor [Sobkowicz 2001]. In the light of this information, large water needs of oat, larger than in other cereal species, seem to be a probable cause of the reactions observed. The above premises induce to put forward the hypothesis that the competition intensity between oat and lupine depends on water availability in the environment and the number of plants competing for it.

The aim of this study was to find out the role of soil moisture in affecting competition intensity between oat and yellow lupine plants in mixtures.

MATERIAL AND METHODS

To realize the aim of the study, the results of the 2-factorial pot experiment conducted in 2005 in the randomized complete block design in 6 replications were used. The experimental factors and their levels were:

I – soil moisture in the whole growing period: 40, 60, 80% of field water capacity,

II – composition of oat-lupine mixture (pcs.·pot^{-1}), respectively: 30 + 5, 20 + 5, 10 + 5, 0 + 5 (lupine pure sowing), 10 + 0, 20 + 0, 30 + 0 (oat pure sowings), which corresponds to a density of about: 500 + 60, 350 + 60, 200+60, 0 + 60, 500 + 0, 350 + 0, 200 + 0 plants·m^{-2}.

In total, the experiment involved 21 treatments, distributed in 126 experimental units (pots).

They were carried out under shelter covered with colorless foil. The pots had a diameter of 28 cm and a depth of 22 cm. Each pot was filled with 15 kg of soil composed of light loamy sand with a natural content of P – 6.5 mg·100g^{-1}, K – 7.6 mg·100g^{-1}, carbon 0.641%, C/N ratio – 9.4, pH(KCL) = 6.4. Prior to sowing the seeds, mineral fertilization was applied in amounts of: N – 0.30 g, P_2O_5 – 0.44 g, K_2O – 0.56 g per pot.

The analysis of numerous measures describing the phenomenon of competition [Weigl and Jolliffe 2003] resulted in adopting the model worked out by Rudnicki and Kotwica [2007]. Initial competition indexes relating to the whole population of the given species in the mixture stand are based on the quotient of yields of the given species in pure sowing and in mixture, at the equal sowing rate in both cases. The competitive ability of a single plant of the given species towards a single plant of the other species in the mixture is determined by SK indexes, which has a character of competitive equivalents. The above indexes have the following form:

$$IK_i = \frac{PC_o}{PM_o}$$

$$IK_o = \frac{PC_i}{PM_i}$$

$$SK_i = \frac{G_o \cdot IK_i}{G_o + G_i}$$

$$SK_o = \frac{G_ł \cdot IK_o}{G_o + G_ł}$$

where:

PC – grain yield (seeds) of a species in pure sowing,
PM – grain yield (seeds) of a species in mixture at the same sowing rate as in pure sowing,
IK_o – competition intensity of oat for lupine in mixture,
$IK_ł$ – competition intensity of lupine for oat in mixture,
SK_o – competition strength of a single oat plant towards a single lupine plant in mixture,
$SK_ł$ – competition strength of a single lupine plant towards a single oat plant in mixture,
G_o – oat sowing density in mixture,
$G_ł$ – lupine sowing density in mixture,
o – oat,
ł – lupine.

Statistically calculated results of oat and yellow lupine yields (Tables 1 and 2) and total mixture yields and its composition were published in the study by Gałęzewski [2006b], in this study they constitute only initial data for calculations of the appropriate indexes.

Table 1. Seed yield of yellow lupine in pure sowing and in mixtures with oat under various conditions of soil moisture (g·pot^{-1})
Tabela 1. Plony nasion łubinu żółtego w siewie czystym i w mieszankach z owsem w różnych warunkach wilgotności gleby (g·wazon^{-1})

Lupine and its mixtures with oat, no of plants·pot^{-1} Łubin i jego mieszanki z owsem, liczba roślin·wazon^{-1} (M)	Soil moisture – Wilgotność gleby (W) % ppw			Mean Średnia
	40	60	80	
Lupine – Łubin (5)		42.7	48.7	38.7
Lupine (5) + oat (10) – Łubin (5) + owies (10)	11.9	20.6	32.0	21.5
Lupine (5) + oat (20) – Łubin (5) + owies (20)	7.8	21.3	30.9	20.0
Lupine (5) + oat (30) – Łubin (5) + owies (30)	4.1	14.7	28.1	15.6
Mean – Średnia	12.1	24.8	34.9	24.0
$LSD_{0.05}$ – $NIR_{0.05}$ for – dla:				
mixtures – mieszanek (M) 5.5				
soil moisture – wilgotności gleby (W) 4.3				
interaction – interakcji:				
W/M ns – ni M/W ns – ni				

source – źródło: Gałęzewski 2006b
ns – ni – non-significant differences – różnice nieistotne

Table 2. Oat grain yields in pure sowings and in mixtures with yellow lupine under various conditions of soil moisture (g·pot^{-1})

Tabela 2. Plony ziarna owsa w siewach czystych i w mieszankach z łubinem żółtym w różnych warunkach wilgotności gleby (g·wazon^{-1})

Type of sowing Rodzaj siewu (S)	Oat density, no of plants·pot^{-1} Obsada owsa, liczba roślin·wazon^{-1} (O)	Soil moisture – Wilgotność gleby (W) % ppw			Mean Średnia
		40	60	80	
Pure Czysty	oat – owies (10)	32.7	72.9	61.0	53.3
	oat – owies (20)	40.2	78.7	73.3	64,1
	oat – owies (30)	42.3	91.7	105.2	79.7
Mean – Średnia		36.2	81.1	79.8	65.7
Mixed Mieszany	oat (10) + lupine (5) owies (10) + łubin (5)	26.0	70.1	79.8	60.9
	oat (20) + lupine (5) owies (20) + łubin (5)	35.8	77.3	66.9	60.0
	oat (30) + lupine (5) owies (30) + łubin (5)	36.3	88.7	66.7	63.9
Mean – Średnia		34.9	78.67	71.1	61.6

$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:

type of sowing – rodzaju siewu (S) ns – ni

oat density – obsady owsa (O) 10.1

soil moisture – wilgotności gleby (W) 10.1

interaction – interakcji:

O/S 14.3 S/O 11.9 W/S ns – ni S/W ns – ni W/O ns – ni O/W ns – ni

source – źródło: Gałęzewski 2006b

RESULTS AND DISCUSSION

Responses of oat and yellow lupine plants to their quantitative composition in mixtures and water conditions indicate that intensive competition for water takes place between plants of these species. A distinct negative response of lupine plants to the presence of oat plants is more strong than vice versa. Those negative interactions decrease along with a growing soil moisture. The effects of competition is related to the proportion of both mixture components relative to each other.

Comparing the values of competition index of all the oat plants towards all the lupine plants growing in the mixture (IK_o) with the analogous 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). Such a result is largely the effect of a different number of plants of both competing species. Therefore, the competition intensity of oat towards lupine is growing along with increasing density of oat plants in mixtures. It turned out that under condition of constant moderate drought (40% FWC) the values of the Ik_o index are almost proportionally to the ratio of the number of oat and lupine plants in mixtures. When the number of oat plants is 2 times larger than that of lupine, then IK_o= 2.07, and when the ratio of those plants in the mixture is 6, IK_o= 6.04 (Table 3). Suitably to the construction of the index, this means that an addition of oat to lupine in mixtures results in about 2- or 6-fold reduction in lupine seed yield, respectively, as compared with its seed yield in pure sowing. However, along with a higher soil moisture the competition of oat is getting weaker and

much out of proportion to the oat plant density in mixtures. This clearly indicates that the subject of competition between oat and lupine under conditions of the experiment was mostly water. The results obtained do not have direct reference to the field conditions, due to a considerable decrease of the role of competition for light in the pot experiment. Also a development of the root system in both species in ground cultivation is different, just as the temperature distribution. In spite of the mentioned drawbacks in realization of the aim with the method of pot experiment, the results obtained confirm the regularities occurring under the field conditions, presented in the second part of this study. The data obtained correspond to the results of experiments by other authors [Paprocki 1961a, b, Kotwica 1994, Kotwica and Rudnicki 1999]. Unfavorable effect of oat plants on lupine and of triticale plants on lupine was indicated in the quoted studies. These effects were increased under dry conditions. Responses of the cereal component to the presence of yellow lupine were weaker.

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

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

Plant density of oat and lupine plants no of plants·pot^{-1} Obsada roślin owsa i łubinu liczba roślin·wazon^{-1}	Soil moisture – Wilgotność gleby, % ppw					
	40		60		80	
	IK_o	$IK_ł$	IK_o	$IK_ł$	IK_o	$IK_ł$
Oats (10) + lupine (5) – Owies (10) + łubin (5)	2.07	1.26	2.08	1.04	1.52	0.76
Oats (20) + lupine (5) – Owies (20) + łubin (5)	3.17	1.12	2.00	1.02	1.58	1.10
Oats (30) + lupine (5) – Owies (30) + łubin (5)	6.04	1.17	2.91	1.03	1.73	1.58

Lupine plants exert a weaker competitive pressure towards oat plants than vice versa, but also their number in mixtures was less than that of oat. Nevertheless, lupine competing with oat, caused a decrease in oat grain yield in mixtures as compared with oat in pure sowing. The strongest competition ($IK_ł$ = 1.58) was shown by lupine under conditions of high soil moisture and when it competed with a 6 times higher number of oat plants (oat 30 + lupine 5) and under moderately dry conditions, when it competed with a 2 times higher number of oat plants. It should be noticed that under conditions of constant moderate soil moisture (60% FWC) the presence of lupine in mixtures was almost harmless to oat plants, and at (80% FWC) and the density of ten oat plants, the neighborhood of lupine turned out to be favorable for this cereal (Table 3).

Whereas all the oat plants totally showed rather strong competitive action towards 5 lupine plants in the pot, the competitive strength of a single oat plant turned out to be relatively small. Adding 1 oat plant to 5 lupine plants in the pot caused the competitive effect equivalent to adding 0.25-0.86 of a lupine plant (Table 4). In other words, it may be concluded, that one additional lupine plant turned out to be equal competitor for the other lupine plants as 1.16-4.0 oat plants, depending on water conditions and the composition of the mixture in its pure sowing. The more water supply both species have, the weaker competitor a single oat plant is for lupine. At plenty of water, in turn, the higher oat sowing rate in the mixture, the more weakly oat plant competes with lupine, which can be attributed to increasing intra-species competition between oat plants for nutritions and other living factors. This intra-species competition decreases the competitive potential of a single oat plant towards lupine.

Table 4. Competitive strength of a single oat plant (SK_o) towards a single yellow lupine plant and that of a single yellow lupine plant (SK_l) towards a single oat plant in mixtures

Tabela 4. Siła konkurencyjna pojedynczej rośliny owsa (SK_o) względem pojedynczej rośliny łubinu żółtego i pojedynczej rośliny łubinu żółtego (SK_l) względem pojedynczej rośliny owsa w mieszankach

Plant density of oat and lupine plants no of plants·pot^{-1} Obsada roślin owsa i łubinu liczba roślin·wazon^{-1}	Soil moisture – Wilgotność gleby, % ppw					
	40		60		80	
	SK_o	SK_l	SK_o	SK_l	SK_o	SK_l
Oats (10) + lupine (5) – Owies (10) + łubin (5)	0.69	0.84	0.69	0.69	0.51	0.51
Oats (20) + lupine (5) – Owies (20) + łubin (5)	0.63	0.90	0.40	0.81	0.32	0.88
Oats (30) + lupine (5) – Owies (30) + łubin (5)	0.86	1.00	0.42	0.89	0.25	1.35

A single lupine plant turned out to be the equal or stronger competitor for oat as oat for lupine in analogous experimental treatments. The case of the mixture consisting of 10 oat plants and 5 lupine plants under conditions of a high soil moisture is worthy of note. On this treatment, competitive potentials of single plants of both species turned out to be symmetrical, this is proved by the same value of the SK_o and SK_l indexes amounting to 0.51 (Table 4). This symmetricalness means that adding 2 oat plants to 5 lupine plants results in such a competition effect as adding 1 lupine plant in its pure sowing and adding 2 lupine plants to 10 oat plants gives the effect equivalent to increasing the oat density in pure sowing by 1 plant per pot.

CONCLUSIONS

1. Intensity of oat competition towards lupine increased along with a growing oat plant density in mixtures, in inverse proportion to the size of resources of available water.
2. Lupine plants exert weaker competitive pressure towards oat plants than vice versa, and under conditions of constant moderate soil moisture (60% FWC) the presence of lupine in mixtures was almost harmless to oat plants.
3. Higher competitiveness of oat in mixtures results from its larger density, single oat plants have lower competitive abilities than single lupine plants in the mixture.
4. In the case of a mixture consisting of 10 oat plants and 5 lupine plants, under conditions of high soil moisture, competitive potentials of single plants of both species are symmetrical.

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KONKURENCJA MIĘDZY ROŚLINAMI OWSA I ŁUBINU ŻÓŁTEGO W MIESZANKACH TYCH GATUNKÓW CZ. I. INTENSYWNOŚĆ KONKURENCJI W ZALEŻNOŚCI OD WILGOTNOŚCI GLEBY

Streszczenie. W 2005 r. wykonano dwuczynnikowe doświadczenie wazonowe w celu określenia wpływu wilgotności gleby na intensywność konkurencji pomiędzy roślinami owsa i łubinu żółtego w mieszankach. Czynnikiem I była: wilgotność podłoża: 40, 60, 80% ppw, a czynnikiem II: skład mieszanki owsa i łubinu (szt.·wazon^{-1}) odpowiednio – 30 + 5, 20 + 5, 10 + 5, 0 + 5 (siew czysty łubinu), 10 + 0, 20 + 0, 30 + 0 (siewy czyste owsa). Do oceny intensywności konkurencji zastosowano wskaźniki opracowane przez Rudnickiego i Kotwicę [2007]. Konkurencyjny wpływ owsa na łubin wzrastał wraz ze zwiększającą się obsadą roślin owsa w mieszankach tym silniej, im mniejsza była wilgotność gleby. Rośliny łubinu wywierały słabszą presję konkurencyjną na rośliny owsa niż odwrotnie, a wynikało to z ich mniejszej obsady. Pojedyncze rośliny owsa okazały się słabszymi konkurentami niż pojedyncze rośliny łubinu w mieszance.

Słowa kluczowe: konkurencja międzygatunkowa, obsada roślin, wilgotność podłoża, wskaźnik intensywności konkurencji

Accepted for print – Zaakceptowano do druku: 05.09.2010