POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 28(1): 17–30, Y. 2013

INFLUENCE OF COMPETITIVE INTERACTIONS BETWEEN SPRING BARLEY (*HORDEUM VULGARE* L.) AND ITALIAN RYEGRASS (*LOLIUM MULTIFLORUM* LAM) ON ACCUMULATION OF BIOMASS AND GROWTH RATE OF PLANTS DEPENDING ON WATER DOSES*

Maria Wanic, Marta K. Kostrzewska, Magdalena Jastrzębska, Kinga Treder

Department of Agricultural Systems
University of Warmia and Mazury in Olsztyn

Key words: competition, spring barley, Italian ryegrass, water, biomass.

Abstract

Competitive interaction between spring barley and Italian ryegrass was investigated in the pot experiment. It was evaluated on the base of the dry mass accumulation in over-the-ground parts and roots. The factors of the experiment were: 1. method of sowing the plants – pure crop and mixed crop (with identical share of both components), 2. supply of plants with water – optimal dose (of 17000 cm^3 during vegetation period) and decreased by 50% as compared to it (8500 cm^3).

Examinations were conducted during the following spring barley development stages (BBCH): leaf development (10–13), tillering (22–25), stem elongation (33–37), inflorescence emergence (52–55) and ripening (87–91). It was shown that both species under the influence of competitive interactions developed lower over-the-ground mass than in pure crop. Barley had stronger negative influence on Italian ryegrass than the other way round. The decreased water dose increased the competitive influences of the grass on the cereal during the stem elongation and inflorescence emergence stages. The accumulation of over-the-ground biomass of Italian ryegrass in the mixed crop was lower than in pure crop during the entire vegetation period. From the stem elongation stage, larger differences between sowing methods occurred in the object with lower water supplies while they were equalised during the remaining period. In case of the mixed crop, the roots of both species were developed poorer than in pure crop without the differentiating influence of water doses. Under the influence of joint cultivation, a slowdown in biomass accumulation during the period between tillering and inflorescence emergence occurred in case of barley while in Italian ryegrass that slowdown occurred from leaf development until inflorescence emergence. The crop growth rate did not depend on the water dose supplied.

Address: Maria Wanic, University of Warmia and Mazury, pl. Łódzki 3, 10-718 Olsztyn, Poland, phone: +48 (89) 523 48 39, e-mail: mwanic@uwm.edu.pl
* The work was carried out within the frameworks of the research project of the MoSHE No. N N310 082836.

WPŁYW ODDZIAŁYWAŃ KONKURENCYJNYCH MIĘDZY JĘCZMIENIEM JARYM (*HORDEUM VULGARE* L.) I ŻYCICĄ WIELKOKWIATOWĄ (*LOLIUM MULTIFORUM* LAM) NA AKUMULACJĘ BIOMASY I TEMPO WZROSTU ROŚLIN W ZALEŻNOŚCI OD DAWEK WODY

Maria Wanic, Marta K. Kostrzewska, Magdalena Jastrzębska, Kinga Treder

Katedra systemów rolniczych
Uniwersytet Warmińsko-Mazurski w Olsztynie

Słowa kluczowe: konkurencja, jęczmień jary, życica wielkokwiatowa, woda, biomasa.

Abstrakt

W doświadczeniu wazonowym badano oddziaływania konkurencyjne między jęczmieniem jarym i życicą wielokwiatową. Oceniano je na podstawie akumulacji suchej masy w częściach nadziemnych i korzeniach. Czynnikami doświadczenia były: 1. sposoby siewu roślin – w siewie czystym oraz w mieszance (o jednakowym udziale obu komponentów), 2. zaopatrzenie roślin w wodę – dawka optymalna (wynosząca w okresie wegetacji 17 000 cm^3) oraz obniżona w stosunku do niej o 50% (8500 cm^3). Badania wykonywano w fazach rozwojowych jęczmienia jarego (BBCH): wschody (10–13), krzewienie (22–25), strzelanie w źdźbło (33–37), kłoszenie (52–55) i dojrzewanie (87–91). Wykazano, że oba gatunki pod wpływem oddziaływań konkurencyjnych wykształciły mniejszą masę nadziemną niż w siewie czystym. Jęczmień wywierał silniejszy ujemny wpływ na życicę niż odwrotnie. Zmniejszona dawka wody nasilała oddziaływania konkurencyjne trawy na zboże w fazach strzelania w źdźbło i kłoszenia. Akumulacja nadziemnej biomasy życicy wielokwiatowej w mieszance była mniejsza niż w siewie czystym w całym okresie wegetacji. Do fazy strzelania w źdźbło większe różnice między sposobami siewu wystąpiły w obiekcie uboższym w wodę, a potem się wyrównały. W mieszance korzenie obu gatunków były słabiej wykształcone niż w siewie czystym, bez różnicującego wpływu dawek wody. Pod wpływem wspólnej uprawy u jęczmienia nastąpiło spowolnienie tempa gromadzenia biomasy w okresie między krzewieniem i kłoszeniem, a u życicy od wschodów do kłoszenia. Szybkość wzrostu łanu obu gatunków nie zależała od wielkości dawki wody.

Introduction

The beneficial influence of intercrops on the soil environment, sanitary status of standing crop and productivity of crops caused that they have become the inseparable component in organic farming also recommended in integrated farming (DOLTRA, OLESEN 2013, JASKULSKA, GAŁĘZEWSKI 2009, JASKULSKI, JASKULSKA 2006, KOSTRZEWSKA et al. 2011). Various species of plants can be sown as intercrops and various forms of them can be cultivated. Sown intercrops represent one of the forms. For the majority of vegetation period they grow together with the protected crop and after its harvest, they remain in the field until late autumn and next they are ploughed as green fertiliser or harvested for forage. Nevertheless, it should be taken into account that the intercrops may compete with the main crop for the environmental factors, particularly water, light and biogens contributing finally to the lower yields of the main crop (HAUGGAARD-NIELSEN et al. 2001). Theoretically, that competition can commence already during the initial period of vegetation and continue, with diversified intensity, until its end. The intensity of that process depends on the choice of species, their densities and the environment factors.

Italian ryegrass is one of the species used frequently as intercrop sown with cereals including spring barley. Its positive influence on the barley yield manifests, however, during the years of moderate or abundant rainfalls. During the dry seasons, the intercrop becomes a strong competitor for water for the cereal (WANIC et al. 2006). Hence, the research hypothesis was formulated assuming that shortage of water may intensify the competitive influences between spring barley and Italian ryegrass. Verification of that hypothesis was conducted on the base of the pot experiment aimed at evaluation of the competitive influences between those species under conditions of abundance and shortage of water on accumulation of biomass in over-the-ground parts and roots of the plants during the entire period of their vegetation.

Materials and Methods

The studies were conducted on the base of the closed pot experiment performed at the Greenhouse Laboratory of the Faculty of Biology and Biotechnology, University of Warmia and Mazury in Olsztyn. Three cycles of the experiment were carried out. The first continued from 18.03 until 30.06.2009, the second from 15.03 until 05.07.2010 and the third from 18.04 until 22.07.2011. Spring barley (*Hordeum vulgare*) – naked grain cultivar *Rastik* and Italian ryegrass (*Lolium multiflorum* LAM) – *Gaza* cultivar were the subject of evaluation.

The light typical brown soil formed of low clay sand with dusty sand in subsoil formed the medium for the experiment. It was characterised by slightly acid reaction, 0.71–1.11% organic carbon content and moderate abundance with phosphorus, potassium and magnesia. The soil with whichpots were filled was collected from the layer of up to 25 cm deep.

The factors of the experiment were:

I – plants sowing method: pure crop (C) and mixed crop (M),

II – water supply: dose consistent with the demand of the crops and dose decreased to 50% of it.

In case of the object with optimal water supply, the quantity of that component supplied to the plants during the vegetation season per pot was 17000 cm^3 while the decreased quantity (less by a half) was 8500 cm^3. During the vegetation period, the water dose was diversified depending on the development stage of the crops and soil humidity. The “optimal” water dose was determined on the base of the test experiment in which measurements of the soil humidity, transpiration and water content in plants were taken.

The experiment was established according to the additive model in which the number of plants in the mixed crop is the sum of the numbers of plants in pure crop sowing (SEMERE, FROUD-WILLIAMS 2001). In total, each round of the experiment consisted of 120 Kick-Brauckmann pots: 3 sowing methods (pure barley, pure Italian ryegrass and together in mixed crop) x 2 levels of water supplies to the plants x 5 development stages x 4 repetitions. Each pot 22 cm in diameter and 28 cm deep was filled, one week before sowing of plants, with 8 kg of soil applying once mineral fertilisation at the dose of pure components ($g \cdot pot^{-1}$): N – 0.5 (in the form of urea), P – 0.2 (monopotassium phosphate), K – 0.45 (potassium sulphate).

In each pot, 18 germinating seedlings of barley or Italian ryegrass or in case of the mix 18 germinating seedlings of barley and 18 germinating seedlings of Italian ryegrass were sown. Using patterns, they were positioned in equal distances from one another on the surface of the soil medium and then then immersed in it to the depth of 3 cm. The pots containing barley, Italian ryegrass and the mixed crop were isolated from each other using partitions of aluminium film.

During almost the entire duration of the experiment, the air temperature at the laboratory was maintained within 20–22°C. To allow the plants going through the full vernalisation process, during the peak of leaf development stage the temperature was decreased to 6–8°C for the period of 9 days. Soil medium humidity measurements were taken daily (using the Easy Test device by the Institute of Agrophysics in Lublin).

The competitive influences between species were examined during five periods determined by the development rhythm of spring barley as pure crop growing under conditions of optimal water supply during the BBCH stages of leaf development (10–13), tillering (22–25), stem elongation (33–37), inflorescence emergence (52–55) and ripening (87–91).

Every year, when spring barley reached the appropriate development phase, all plants were removed from pots projected for that stage, roots were separated from over-the-ground parts from which, according to the development stage the leaves, stems and heads were separated (in case of barley only as in case of ryegrass they were not developed). The separated parts of plants were dried to air-dry mass and weighted. Based on the yields of over-the-ground dry mass the computations of standing crop growth rate were made using the following formula (PIETKIEWICZ 1985, RADFORD 1967):

$$CGR = \frac{dWc}{dt} \cdot \frac{1}{P}$$

where:
CGR – crop growth rate,
dWc – crop biomass increase (g dry mass),
dt – period of time during which the increase occurred,
P – pot surface (m^2).

The results were processed statistically by applying the variance analysis method for the system of factors at the error probability of $\alpha = 0.05$, applying the *Statistica* software. Statistics were computed for each growth phase and individual plant parts separately. Duncan's test was applied for evaluation of differences between objects.

Results

The over-the-ground biomass of spring barley increased until the inflorescence emergence phase and then during the ripening phase it was reduced (by 7.6% as compared to the inflorescence emergence phase; Table 1). The factors of the experiment diversified the biomass across the entire vegetation period. Plants growing in mixed crop with Italian ryegrass were characterised by significantly lower mass than those from pure crop (except for mixed sowing during barley tillering when only the tendency for obtaining lower productivity was recorded). The largest differences between the methods of sowing appeared at the inflorescence emergence stage when the yield of the over-the-ground mass of that cereal growing together with ryegrass was lower by 22.2% than in pure crop. Limitation of mass increase of that crop in the mixed crop as compared to pure crop at the stem elongation phase was more pronounced in the leaves than in the stems. During the inflorescence emergence stage, it was more pronounced in case of the leaves and heads than in the stems. During the ripening stage, it concerned mainly the yield of grains as the mass of stems, leaves and heads did not show significant diversification resulting from the method of sowing.

In case of optimal water dose, plants of spring barley developed higher mass than in case of the decreased water availability. The favourable influence of the water dose was the most pronounced at the stem elongation stage. The productivity of plants at that object was in average more than 2.5 times higher than of those growing under conditions of water shortage. During the final period of vegetation, as a consequence of the decreasing demand of barley concerning water, the influence of water doses proved to be smaller. Water shortage during the stem elongation phase decreased the growth of stems the most while during the phases of inflorescence emergence and ripening – the growth of heads.

Table 1

Dry mass of over the ground parts of spring barley (g · pot^{-1})

Development phase (BBCH)	Parts of plants	Higher water dose			Lower water dose			Average		
		Sowing method								
		*C**	*M**	average	*C*	*M*	average	*C*	*M*	average
Leaf development (10–13)	leaves	0.94^{a}	0.80^{b}	0.87^{a}	0.75^{b}	0.63^{c}	0.69^{b}	0.85^{a}	0.72^{b}	0.79
Tillering (22–25)	leaves	5.26^{a}	4.73^{a}	5.00^{a}	2.68^{b}	2.35^{b}	2.52^{b}	3.97^{a}	3.54^{a}	3.76
Stem elongation (33–37)	stems	8.15^{a}	7.41^{b}	7.78^{a}	3.02^{c}	2.38^{d}	2.70^{b}	5.59^{a}	4.90^{b}	5.25
	leaves	6.21^{a}	4.97^{b}	5.59^{a}	2.83^{c}	2.19^{d}	2.51^{b}	4.52^{a}	3.58^{b}	4.05
	total	14.36^{a}	12.38^{b}	13.37^{a}	5.85^{c}	4.57^{d}	5.21^{b}	10.11^{a}	8.48^{b}	9.30
Inflorescence emergence (52–55)	stems	9.08^{a}	7.95^{b}	8.52^{a}	4.39^{c}	3.16^{d}	3.78^{b}	6.74^{a}	5.56^{b}	6.15
	leaves	7.07^{a}	4.93^{b}	6.00^{a}	4.15^{c}	3.39^{d}	3.77^{b}	5.61^{a}	4.16^{b}	4.89
	heads	2.83^{a}	2.22^{b}	2.53^{a}	0.96^{c}	0.52^{d}	0.74^{b}	1.90^{a}	1.37^{b}	1.64
	total	18.98^{a}	15.10^{b}	17.05^{a}	9.50^{c}	7.07^{d}	8.29^{b}	14.25^{a}	11.09^{b}	12.67
Ripening (87–91)	stems	6.43^{a}	6.22^{a}	6.33^{a}	5.77^{a}	4.14^{b}	4.96^{b}	6.10^{a}	5.18^{a}	5.64
	leaves	5.07^{a}	4.72^{a}	4.90^{a}	3.76^{b}	3.35^{b}	3.56^{b}	4.42^{a}	4.04^{a}	4.23
	heads, including grain	2.94^{a} 2.34^{a}	$1.98^{a,b}$ 1.84^{b}	2.46^{a} 2.09^{a}	1.38^{a} 1.25^{c}	1.09^{b} 1.01^{c}	1.24^{a} 1.13^{b}	2.15^{a} 1.80^{a}	1.54^{a} 1.43^{b}	1.85 1.62
	total	14.44^{a}	12.92^{b}	13.67^{a}	10.91^{c}	8.58^{d}	9.76^{b}	12.68^{a}	10.76^{b}	11.71

**C* – pure crop, *M* – mixed crop

a, *b*, *c*, d – homogenous groups: values marked with the same letter within the individual factors or their combined influence do not differ significantly at $p = 0.05$

The ryegrass growing together with barley limited the mass increase of the over-the-ground parts of barley in similar way on both objects with different soil humidity during the phases of leaf formation and inflorescence emergence. During stem elongation and ripening, its negative influence was more pronounced under conditions of water shortage. During the stem elongation phase, the difference between the mixed crop and pure crop at the object with the water dose lower by a half relative to the needs of barley was 21.9% while in case of optimal water supply that difference was 13.8%. During ripening, those differences were 21.4% and 10.5% respectively. During the tillering stage, the sowing method did not diversify the biomass of that cereal significantly in case of both moisture levels. Analysis of the individual parts of barley showed that mixed sowing limited growth of its stems significantly more at the object offering lower availability of water. During leaf formation and stem elongation, the difference in the mass of leaves between the mixed and pure crop at both water doses was similar and during inflorescence emergence cultivation of both species together limited growth of the leaves more in pots watered with more quantity of water. During the phases of tillering and ripening, the sowing method was without influence on the mass of leaves at both objects. During the inflorescence emergence stage, larger differences in the mass of heads between sowing methods were encountered on the object with the lower water dose while at the ripening stage the relations were the opposite. Joint cultivation of species in combination with the lower water dose did not diversify the grain shapeliness while in combination with the higher water dose it confirmed the advantage of pure crop over the mixed crop cultivation.

Over-the-ground mass of Italian ryegrass increased until the end of the experiment duration and changed under the influence of the experiment factors more evidently than spring barley (Table 2). The cereal had negative influence on the grass already from the beginning of vegetation. The reaction of ryegrass to the presence of barley became more pronounced at the phase of inflorescence emergence when the dry mass yield was 72.3% lower than in pure crop. At the end of vegetation, the difference between the mixed crop and pure crop decreased slightly (to 63.6%). During the stem elongation and inflorescence emergence phases, barley had stronger negative influence on the mass of ryegrass stems than the leaves and during ripening, it limited their growth to a similar extent.

Under water shortage conditions, ryegrass generates significantly less dry mass than when optimal water supply was assured during the entire vegetation period. During leaf emergence, at the object with lower water supply, its

Table 2

Dry mass of over the ground parts of Italian ryegrass (g · pot^{-1})

Development phase (BBCH)	Parts of plants	Higher water dose			Lower water dose			Average		
		sowing method								
		*C**	*M**	average	*C*	*M*	average	*C*	*M*	average
Leaf development (10–13)	leaves	0.15^a	0.14^b	0.14^a	0.11^c	0.10^c	0.11^b	0.13^a	0.12^b	0.13
Tillering (22–25)	leaves	2.55^a	1.17^b	1.86^a	1.03^c	0.40^d	0.72^b	1.79^a	0.79^b	1.29
Stem elongation (33–37)	stems	4.18^a	0.79^c	2.49^a	1.39^b	0.44^d	0.95^b	2.79^a	0.61^b	1.71
	leaves	3.97^a	2.00^c	2.99^a	2.82^b	0.84^d	2.57^b	3.40^a	1.42^b	2.41
	total	8.15^a	2.79^c	5.47^a	4.21^b	1.28^c	3.52^b	6.19^a	2.04^b	4.12
Inflorescence emergence (52–55)	stems	7.74^a	1.88^c	4.81^a	3.55^b	0.90^d	2.23^b	5.65^a	1.39^b	3.52
	leaves	13.11^a	3.91^c	8.51^a	6.98^b	2.00^d	4.49^b	10.05^a	2.96^b	6.51
	total	20.85^a	5.79^c	13.32^a	10.53^b	2.90^d	6.72^b	15.70^a	4.35^b	10.03
Ripening (87–91)	stems	7.61^a	2.62^c	5.15^a	3.44^b	1.32^d	2.38^b	5.53^a	1.97^b	3.75
	leaves	15.02^a	5.53^c	10.28^a	8.80^b	3.21^d	6.01^b	11.91^a	4.37^b	8.14
	total	22.63^a	8.15^c	15.40^a	12.24^b	4.53^d	8.39^b	17.44^a	6.34^b	11.89

**C* – pure crop, *M* – mixed crop

a, *b*, *c*, *d* – homogenous groups: values marked with the same letter within the individual factors or their combined influence do not differ significantly at $p = 0.05$

productivity was lower than at the object with abundant water supply by over 20%, and during the tillering stage the difference was over 60%. That difference decreased during the stem elongation phase (to 36%) to increase again during further vegetation (to almost 50%. Lowered water availability limited mass increase of stems more than that of the leaves, particularly during the barley stem elongation phase.

Until the barley stem elongation phase, the negative influence of mixed sowing was slightly more pronounced at the object less abundant with water. During the remaining phases of vegetation, the water dose had no influence on the size of differences between the sowing methods. At stem elongation phase, in the mixed crop, higher water dose limited the mass of ryegrass more than the lower water dose. In case of the leaves, the relations were the opposite. During the other periods, the size of differences between sowing methods in dry mass of stems and leaves was similar.

Under the influence of competition, barley and ryegrass also developed poorer roots (Table 3). In case of the mixed crop, their combined mass was lower than the combined mass of the roots of both species from pure crop. During the individual phases the differences were as follows: leaf formation (by 33.9%), stem elongation (by 41.5%) inflorescence emergence (by 42.1%) and ripening (by 44.8%). No significant differences were observed during barley tillering only.

Table 3

Dry mass of spring barley and Italian ryegrass roots in pure and mixed crop ($g \cdot pot^{-1}$)

Barley development stage (BBCH)	Plant	Water dose		
		higher	lower	average
Leaf development (10–13)	barley (*C**)	0.54	0.54	0.54
	Italian ryegrass (*C*)	0.05	0.04	0.05
	barley + Italian ryegrass (*M**)	0.33	0.44	0.39
	average	0.31	0.34	0.33
Tillering (22–25)	barley (*C*)	1.76	0.95	1.36
	Italian ryegrass (*C*)	0.67	0.49	0.58
	barley + Italian ryegrass (*M*)	2.41	1.41	1.91
	average	1.61	0.95	1.28
Stem elongation (33–37)	barley (*C*)	3.06	1.67	2.37
	Italian ryegrass (*C*)	2.39	1.65	2.02
	barley + Italian ryegrass (*M*)	3.01	2.13	2.57
	average	2.82	1.82	2.32
Inflorescence emergence (52–55)	barley (*C*)	2.09	1.75	1.92
	Italian ryegrass (*C*)	6.75	3.62	5.19
	barley + Italian ryegrass (*M*)	4.79	3.45	4.12
	average	4.54	2.94	3.74
Ripening (87–91)	barley (*C*)	1.80	0.94	1.37
	Italian ryegrass (*C*)	5.63	3.58	4.61
	barley + Italian ryegrass (*M*)	4.06	2.54	3.30
	average	3.83	2.35	3.09

**C* – pure crop, *M* – mixed crop

The water dose did not diversify the mass of roots during the plants leaf formation phase. However, already during tillering its influence became visible. In average, for the sowing methods, decreasing its supply resulted in 41.0% limitation in roots mass increase. During the stem elongation phase those differences decreased to 35.5% and they remained at a similar level until the end of vegetation.

Mixed sowing was more limiting to dry mass accumulation in the roots of both species during the leaf development stage at the objects more abundant with water. During further development phases, water doses had similar influence on the size of the differences in the mass of roots between sowing methods.

Spring barley achieved the fastest crop growth rate (CGR) in the over-the-ground parts during the tillering-stem elongation interphase (Table 4). For the sowing methods and water doses it averages 0,49 $g \cdot day \cdot pot^{-1}$. Between inflorescence emergence and ripening, however, the reduction of it was detected. No influence of sowing method on crop growth rate between leaf formation and tillering was found. It became visible during the later period where in the mixed crop significantly slower rate of growth was recorded; in relation to pure crop it was: from tillering until stem elongation 18.5% and from stem elongation until inflorescence emergence 37.5%. At the end of vegetation, the differences between sowing methods were levelled.

The halved water dose decreased growth of barley field during the entire period of its vegetation. It was the most pronounced between tillering and stem elongation phase.

Table 4

Spring barley field growth rate ($g \cdot day \cdot pot^{-1}$)

Development stage	Sowing method	Water dose		
		higher	lower	average
Leaf development – tillering	pure mixed average	0.27^a 0.25^a 0.26^a	0.12^b 0.10^b 0.11^b	0.20^a 0.18^a 0.19
Tillering – stem elongation	pure mixed average	0.79^a 0.67^a 0.73^a	0.28^b 0.20^b 0.24^b	0.54^a 0.44^b 0.49
Stem elongation – inflorescence emergence	pure mixed average	0.18^a 0.11^b 0.15^a	$0.14^{a,b}$ 0.09^b $0.12^{a,b}$	0.16^a 0.10^b 0.13
Inflorescence emergence – ripening	pure mixed average	-0.17^b -0.08^b -0.13^b	0.06^a 0.09^a 0.08^a	-0.06^a -0.01^a –0.03

a, b – homogenous groups: values marked with the same letter within the individual factors or their combined influence do not differ significantly at $p = 0.05$

During almost the entire vegetation period, the doses of water had no significant influence on the size of differences in dry mass accumulation rates caused by sowing methods. Only during the stem elongation – inflorescence emergence interphase at the object more abundant in water, barley cultivated as pure crop accumulated biomass faster than in the mix with ryegrass.

Over-the-ground mass of Italian ryegrass, similar to spring barley, increased the fastest between tillering and stem elongation and the slowest between inflorescence emergence and ripening (Table 5). Significantly lower crop growth rate was determined in the mixed crop during the period from barley leaf development until inflorescence emergence. The average for water doses daily dry mass increases were lower there than in pure crop by from 54.5% to 80.9%. At the end of the vegetation period, the higher dry mass accumulation rate was determined in case of the mixed crop.

Table 5

Italian ryegrass field growth rate (g · day · pot^{-1})

Development stage	Sowing method	Water dose		
		higher	lower	average
Leaf development – tillering	pure mixed average	0,16^{a} 0,07^{b} 0,11^{a}	0,05^{b,c} 0,02^{c} 0,04^{b}	0,11^{a} 0,05^{b} 0,08
Tillering – stem elongation	pure mixed average	0,66^{a} 0,10^{c} 0,38^{a}	0,28^{b} 0,08^{c} 0,18^{b}	0,47^{a} 0,09^{b} 0,28
Stem elogation – inflorescence emergence	pure mixed average	0,39^{a} 0,13^{c} 0,26^{a}	0,24^{b} 0,06^{d} 0,15^{b}	0,32^{a} 0,10^{b} 0,21
Inflorescence emergence – ripening	pure mixed average	0,04^{a} 0,06^{a} 0,05^{a}	0,04^{a} 0,04^{a} 0,04^{a}	0,04^{a} 0,05^{b} 0,05

a, b, c – homogenous groups: values marked with the same letter within the individual factors or their combined influence do not differ significantly at $p = 0.05$

The lower water dose decreased the ryegrass growth rate until the barley inflorescence emergence phase, particularly during the initial period of vegetation. With the passage of time, the influence of water shortage was decreasing. Water doses were without significance for the size of differences between sowing methods.

Discussion

It has been shown in own studies that in the mixed crop spring barley and Italian ryegrass developed lower over-the-ground biomass than in case of pure crop sowing and Italian ryegrass showed stronger negative reaction to that sowing method. This is similar to the results obtained by SOBKOWICZ (2003), SOBKOWICZ and PODGÓRSKA-LESIAK (2009) and TREDER et al. (2008), who show that spring barley is the species with strong negative influence on other species. According to MOLLA and SHARAIHA (2010), SOBKOWICZ (2003) and SOBKOWICZ and PODGÓRSKA-LESIAK (2009), domination of barley results from its fast initial growth rate causing uptake of biogens from the soil and relatively short vegetation period. Different opinions are presented by GALON et al. (2011), KÄNKÄNEN and ERIKSSON (2007) and RAHETLAH et al. (2013). Their studies indicate that *Lolium multiflorum* is a strong competitor for both spring barley and other species. In own studies, the negative influence of the mixed crop components on dry mass accumulation in their over-the-ground parts increased until the barley inflorescence emergence phase and then, at the end of vegetation, it weakened. Also, SATORRE and SNAYDON (1992) showed that the highest intensity of competitive influences between cereals and *Avena fatua* occurs during the Zadoks periods from 30 until 70, which is reflected to a large extent in the here-presented experiment. On the other hand, the studies by LAMB at al. (2007) indicate that the negative effects of joint cultivation manifest more clearly in younger plants than in those with advanced vegetation. BULSON et al. (1997), MICHALSKA et al. (2008), SOBKOWICZ (2003) and TREDER et al. (2008) inform about weakening of the negative mutual influences of species at the end of vegetation. The quoted authors also link it to the different maturing times of the components. At the final stage of vegetation of one of the species, its life needs become small which causes that the available pool of growth factors is used mainly by the second species.

The sowing method not only diversified the total volume of over-the-ground biomass of barley and ryegrass but also its structure. In spring barley, during almost the entire period of vegetation, the largest limitation in dry mass accumulation was found in the leaves and the smallest in the stems, which is consistent with the results by TREDER et al. (2008). Only during ripening, biomass accumulation in the leaves, stems and heads did not show any significant correlation with the sowing method. Also, SOBKOWICZ (2003) did not record changes in biomass accumulation in the individual over-the-ground parts of plants under the influence of mixed sowing. In case of the mixed crop, in case of Italian ryegrass the lower than in pure crop yield of dry mass was found for both the stems and the leaves. The size of the difference between sowing methods in case of those parts of plants depended on the development phase. The studies by LUCERO et al. (2002) showed no influence of mixed sowing of *Trifolium repens* with *Lolium perenne* on the mass of leaves developed by that grass as well as its positive influence on shapeliness of its stems. In the analysed experiment, in case of the mix, the total mass of the roots of both species was lower than in pure crop by ca. 40%. Similar scale of clover and ryegrass roots reduction was recorded by LUCERO et al. (2002). Also TREDER et al. (2008), studying the process of competition between spring wheat and spring barley found out a decrease in the mass of roots of both those cereals. The size of that decrease was similar to that of the over-the-ground parts.

In of own studies, in case of mixed crop, the water dose decreased by half in relation to the need of plants increased the competitive influence of ryegrass on barley during the phases of stem elongation and inflorescence emergence and that of barley on ryegrass from leaf development to stem elongation. During the other periods of joint vegetation, water doses had no influence on the size of differences in dry mass between the sowing methods. There are differences of opinions in the literature as concerns the influence of water doses on productivity of plants in case of mixed crops. LUCERO et al. (2000), investigating competition between *Trifolium repens* and *Lolium perenne* showed that in both species dry mass increases were the smaller the higher the deficit of the water was. Consistency with the above is shown by the studies of SEMERE and FROUD-WILLIAMS (2001), which showed that under conditions of drought the competitive influence of peas on maze was more intensive than in case of water excess. Decrease in competition with the increase of soil humidity was also found by MOLLA and SHARAIHA (2010). WRIGHT et al. (1999), investigating the process of competition between two cultivars of wheat and *Sinapis arvensis* showed that the cereal was more competitive than the weed on the dry soil than on the moist soil. TSIALTAS et al. (2001) in turn showed that species growing in mixed meadow communities make more effective use of the water taken from the soil and the competition among them is less fierce. Similar conclusions can be found in the work by LAMB et al. (2007). A different opinion is presented by KOLB et al. (2002), who proved that water deficit decreases the force of mutual influence of barley and ryegrass. A still different opinion is presented by CASPER and JACKSON (1997), who claim that in dry ecosystems there is no intensified competition for water between plants. WANIC et al. (2006), investigating changes in the water level in soil under spring barley and Italian ryegrass showed that the grass became a strong competitor for water to barley at the stem elongation phase of the cereal, which shows consistency with the presented results.

Conclusions

1. In the mixed crop, spring barley and Italian ryegrass developed lower over-the-ground dry mass than in the pure crop. Italian ryegrass showed stronger reaction to joint cultivation.

2. Mixed sowing on the object supplied with a dose of water lower by a half than the needs of the plants limited spring barley over-the-ground biomass growth during the phases of stem elongation and inflorescence emergence, and of Italian ryegrass from leaf development to stem elongation more that optimal water supply.

3. Among the analysed over-the-ground parts of spring barley, leaves and heads showed stronger negative reaction to cultivation in mixed crop while the stems showed weaker negative reaction.

4. Mixed sowing had the most limiting influence on dry mass accumulation in the leaves of ryegrass during the barley stem elongation stage, in its stems during the inflorescence emergence phase and proportionally in the stems and leaves during ripening.

5. The mass of roots of both species in the mixed crop was smaller than in pure crop without the diversifying influence of water doses.

6. In the mixed crop, spring barley had the lower rate of biomass accumulation during the period between tillering and inflorescence emergence. In case of Italian ryegrass, the lower rates were recorded from leaf development until inflorescence emergence without the diversifying influence of the water doses.

Translated by Jerzy Gozdek

Accepted for print 29.01.2013

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