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Effect of electromagnetic stimulation of alfalfa seeds

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A b s t r a c t. In the conducted experiments the effect of pre-sowing He-Ne laser light, magnetic field stimulation or the combination of these two factors of alfalfa seeds on the field emergence, structure and yields in the year of sowing and during three following years of full land use were studied. The examined factors had a significant effect on the number of shoots per 1 m^2, plant height, mass of shoots, fresh and dry mass. Electromagnetic stimulation resulted in a significant increase in alfalfa seeds emergence (from 35% – control to 47.8% – magnetic field), number of shoots per 1 m^2 (from 608 – control to 813 – laser light in cut), but a decrease of the mass of the shoots (from 0.61 g – control to 0.50 g – laser light).

K e y w o r d s: seeds, alfalfa, yield, electromagnetic stimulation

INTRODUCTION

Under the conditions of 3-cut harvest it is possible to extend the period of exploitation of alfalfa to 3 years of full land use, apart from the year of sowing. In Poland alfalfa is cultivated as a single plant or as a mix with grasses for fodder, green fodder, hay, hay silage, dried material or as high protein concentrates (protein-xanthophyll concentrate PX). The cultivation acreage for small seed papilionaceous plants in Poland in 2010 amounted to 162 000 ha (CSO, 2011; Ćwintal *et al*., 2010).

Such a procedure extends the period of cultivation and causes a reduction of costs related with setting up a new plantation (Zając *et al.,* 2007). In the cultivation of small-seed perennial crops particular importance can be attributed to the sowing value of seeds which determine the structure of the canopy, yielding and fodder quality (Dziwulska *et al*., 2006; Zając *et al.,* 2007). Seed improvement is effected by means of a number of factors, both chemical (seed primers *etc*.) and physical (laser light, magnetic fields *etc*.), among which in recent years considerable interest has been focused on the physical treatments since those are considered to be safer for the environment (Hernandez *et al.,* 2010; Martinez *et al.,* 2009). The effects of their application in plant production are varied with relation to the methods and the biophysical parameters (Martinez *et al.,* 2009, Vasilevski, 2003). With relation to laser light, a positive effect of stimulation of seeds of various crop plants on germination, vigour, growth and development, resistance to stress, yielding and yield quality has been observed (Ćwintal *et al.,* 2010; Hernandez *et al.,* 2010; Yinan *et al.,* 2005). Positive effects were also observed in the case of laser light stimulation of seedlings (Aladjadjiyan, 2007; Hernandez *et al.,* 2010). Apart from laser stimulation, also magnetic and electromagnetic fields are used in plant production to improve seed germination and to achieve increased yields of crop plants (Aladjadjiyan, 2007; Martinez *et al.,* 2009; Pietruszewski and Kania, 2010).

Earlier studies on alfalfa confirmed a positive effect of laser stimulation of seeds, as a result of which an increase was observed in the efficiency of photosynthesis and respiration of plants, an increased density of plants per 1m^2 and an improvement of fodder quality (Ćwintal *et al.,* 2010; Ćwintal and Olszewski, 2007). Whereas, there is no information on the effect of electromagnetic field on that crop plant under production conditions. A majority of studies involving perennial plants were concerned primarily with their evaluation in the year of sowing and in the first year of full land use. Therefore, it appears to be interesting to get to know the response of the crop species in question to laser stimulation over further years of use, and also to stimulation with magnetic field.

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The aim of this work was to determinate the influence of pre-sowing seed stimulation with He-Ne laser light, magnetic field stimulation or the combination of these two factors on the field emergency, crop structure and cropping of sowing and hybrid lucerne in the sowing year and in three successive years of full land use. The innovatory elements in the presented studies were the application of alternating magnetic field as well as the combination of laser light and magnetic field treatments for stimulation of lucerne seeds. Additionally, the Polish sowing lucerne cultivar Ulstar and four successive years of full land use were included in the study.

Answers for the following experimental hypotheses were expected: do the effects of electromagnetic stimulation stay during the following years of crop usage and do they modify the growing pattern and yielding of lucerne plant? How the different species of lucerne, such as *Medicago x varia* T. Martyn. – *cv*. Radius and *Medicago sativa* L. – *cv*. Ulstar respond to the factors applied?

In the accessible literature sources there are no complete data on field experiments concerning the influence of the above mentioned factors on perennial plants belonging to *Fabaceae*, such as lucerne.

MATERIAL AND METHODS

The field experiment with alfalfa grown for fodder was conducted at the Experimental Farm Felin, in the years 2008-2011, on a soil classified in the good wheat complex (class IIIa). The experiment was realised with the method of random blocks in four replications, on microplots with harvest area of 1 m^2. The experimental factors were as follows:

1. two species of alfalfa: hybrid (*Medicago x varia* T. Martyn) – *cv*. Radius, and sowing (*Medicago sativa* L.) – *cv*. Ulstar;

2. pre-sowing stimulation of seeds in the following treatments: C – control (no stimulation), L – laser light with surface power density of 6 mW cm^{-2} applied 3 times, F – variable magnetic field with induction of 30 mT and exposure time of 30 s; L+F – laser light and magnetic field at the above doses.

Laser stimulation was performed using the device constructed by Koper and Dygdała (1993), the basic element of which is a He-Ne laser with wavelength of 632.8 nm, and the magnetic field was generated by means of the Pietruszewski electromagnet (utility pattern 2003). Seeds were laser irradiated during free fall. The time of a single exposure to laser light was 0.1 s. The stimulation of seeds was performed a day before sowing (seed moisture 12%). Alfalfa seeds, calculated as 100% of germination capacity, were sown on May 8, 2008, in the amount of 800 seeds m^{-2}, into rows spaced at 20 cm, to the depth of 1 cm. Mineral fertilization was applied pre-sowing and before the start of vegetation in the successive years, at the doses of 35 P and 100 K kg $ha^{-1}\cdot year^{-1}$. After emergence, the density of plants per 1 m^2 was determined and the field emergence capacity of alfalfa was calculated. In the year of sowing two cuts were harvested, and in the years of full land use three cuts were harvested per year, each in the phase of the start of blooming of the plants. For the successive cuts and years of use determinations were performed of the yield of fresh and dry mass per 1 m^2, the number of shoots per 1 m^2, the mean mass of a single shot and of the percentage share of leaves in the yield of dry matter. The yield structure elements and the proportions between the leaves and stems in the yield mass were determined on the basis of 1 kg samples that were collected during the harvest of the consecutive regrowths. The samples were also used for the determination of dry mater with the gravimetric method, after drying at temperature of 105°C for 4 h.

The weather conditions during the vegetation of the particular regrowths of alfalfa in the year of sowing (2008) and in the successive three years of full land use (2009-2011) were elaborated on the basis of data from the Meteorological Station at Felin (Table 1). In the year of sowing the vegetation of the first regrowth lasted for 78 days and proceeded at higher air temperature and higher precipitations compared to the second. In the years of full land use the period of vegetation of alfalfa harvested in 3 cuts varied from 141 to 149 days and was characterized by the longest vegetation of the first regrowth (50-56 days), those of the second and third regrowth being shorter and similar to each other. Vegetation of the first regrowth proceeded at higher air temperature and lower precipitations in the years 2009 and 2011 as compared to 2010. The second regrowth had the most favourable thermal conditions in 2010, and the least favourable in 2011. The years 2009 and 2010 were characterized by notably higher precipitations during that period of alfalfa vegetation. During the vegetation of the third regrowth of alfalfa the highest air temperature occurred in the years 2010 and 2009, and precipitations in 2011 and 2010. Analysing the whole period of vegetation we should emphasise that in the years 2009 and 2010 the mean air temperature was higher compared to the year 2011. In turn, the lowest amounts of rainfall were recorded in 2009, and the highest in 2010.

The results were processed statistically using the analysis of variance and $LSD_{0.05}$ according to the Tukey test, with the use of the STATISTICA.pl.6.0 software package.

RESULTS

The field emergence of the sowing alfalfa *cv.* Ulstar was significantly higher than that of the hybrid alfalfa *cv*. Radius (Table 2). All treatments of seed stimulation caused a significant increase in the rate of emergence compared to the control treatment. The highest rate of emergence (47.8%) was recorded after seed stimulation with variable magnetic field. The number of alfalfa plants after emergence varied from 265 to 410 plants m^{-2} and was significantly higher in the case of *cv*. Ulstar and in the treatment with magnetic field.

T a b l e 1. Meteorological profile for year of sowing year and three years of full land use during vegetation season

Specification	Year (Date)	Cut crop			$\sum/\overline{X}$	
		I	II	III		
Sowing start of vegetation	2008 (08.05)	25. 07	29. 09	–		–
	2009 (02.04)	26. 05	10. 07	28. 08		–
	2010 (26.03)	21. 05	08. 07	20. 08		–
	2011 (02.04)	27. 05	11. 07	22. 08		–
Vegetation period (days)	2008	78	66	–	144	
	2009	55	45	49	149	
	2010	50	48	43	141	
	2011	56	45	42	143	
24 h temperature mean (°C)	2008	16.6	15.0	–		15.8
	2009	11.3	15.2	18.4		15.0
	2010	9.7	16.8	18.7		15.1
	2011	11.0	13.5	16.4		13.6
Total rainfall (mm)	2008	229.9	154.6	–	384.5	
	2009	58.9	156.0	93.9	308.8	
	2010	174.0	87.2	161.3	422.5	
	2011	66.9	138.2	186.4	391.5	

T a b l e 2. Emergence and number of alfalfa plants

Specification		Electromagnetical stimulation of seeds				$\overline{X}$
		C	L	F	L+F	
Seedlings (%)						
Variety	Radius	33.1	40.8	44.5	42.6	40.2
	Ulstar	36.9	46.2	51.2	50.8	46.3
$\overline{X}$		35.0	43.5	47.8	46.7	–
$LSD_{0.05}$		4.81				3.70
Number of alfalfa plants per 1 m^2						
Variety	Radius	265	326	356	341	322
	Ulstar	295	370	410	406	370
$\overline{X}$		280	348	383	373	–
$LSD_{0.05}$		40.4				33.7

C – control, untreated seeds, L – seeds subjected to laser stimulation (in three series during free fall of seeds from the charging Hopper chute) with He-Ne light of λ = 632.8 nm and density power of 6 mW cm^{-2}, F – seeds stimulated with alternating magnetic field (50 Hz) of an intensity of 30 mT during the exposure time of 30 s, L+F – seeds subjected to both laser and magnetic field stimulation, LSD – least significant difference.

The elements of yield structure and the yielding of alfalfa in the year of sowing are presented in Table 3. The number of shoots per 1 m^2 varied significantly with relation to the factors studied and was higher in the case of *cv*. Ulstar and in the second cut. The experimental factors of seed stimulation caused a significant increase in the number of plants per unit of area as compared to the control. The highest density was observed in the treatment with laser light stimulation, where it was significantly greater than in the treatment with variable magnetic field.

The mean mass of a single shoot decreased significantly under the effect of all stimulation factors in relation to the control. Besides, it was significantly lower after seed stimulation with laser light and after laser light stimulation

T a b l e 3. Characteristics of alfalfa yields in the cropping year

Variety	Cut	Electromagnetical stimulation of seeds				$\overline{X}$
		C	L	F	L+F	
Number of shoots per 1 m^2						
Radius	I	527	680	640	668	629
	II	655	865	715	810	761
	mean	591	772	677	739	695
Ulstar	I	577	798	724	786	721
	II	675	910	825	885	824
	mean	626	854	774	835	772
$\overline{X}$	I	552	739	682	727	675
	II	665	887	770	847	792
	mean	608	813	726	787	–
$LSD_{0.05}$: Electromagnetical stimulation of seeds – 86.4,Variety – 51.2, Cut – 51.2, Electromagnetical stimulation of seeds x Cut – 51.2						
Mass of shoot (g)						
Radius	I	0.57	0.49	0.51	0.48	0.51
	II	0.71	0.58	0.66	0.59	0.63
	mean	0.64	0.53	0.58	0.53	0.57
Ulstar	I	0.50	0.43	0.47	0.45	0.46
	II	0.68	0.53	0.57	0.55	0.58
	mean	0.59	0.48	0.52	0.50	0.52
$\overline{X}$	I	0.53	0.46	0.49	0.46	0.48
	II	0.69	0.55	0.61	0.57	0.60
	mean	0.61	0.50	0.55	0.51	–
$LSD_{0.05}$: Electromagnetical stimulation of seeds – 0.034,Variety – 0.027, Cut – 0.027						
Dry mass yield (kg m^{-2})						
Radius	I	0.30	0.33	0.33	0.32	0.32
	II	0.46	0.50	0.47	0.48	0.48
	total	0.76	0.83	0.80	0.80	0.80
Ulstar	I	0.29	0.34	0.34	0.35	0.33
	II	0.46	0.48	0.47	0.49	0.47
	total	0.75	0.82	0.81	0.84	0.80
$\overline{X}$	I	0.29	0.33	0.33	0.33	0.32
	II	0.49	0.49	0.47	0.48	0.47
	total	0.75	0.82	0.80	0.82	–
$LSD_{0.05}$: Electromagnetical stimulation of seeds – 0.52,Variety – n.s., Cut – 0.032						
Fraction of leaves in dry mass yield (%)						
Radius	I	50.3	55.4	54.6	55.2	53.9
	II	51.7	62.0	58.3	60.6	58.1
	mean	51.0	58.7	56.4	57.9	56.0
Ulstar	I	52.8	58.1	55.0	57.4	55.8
	II	54.0	63.5	62.0	62.8	60.6
	mean	53.4	60.8	58.5	60.1	58.2
$\overline{X}$	I	51.5	56.7	54.8	56.3	54.8
	II	52.8	62.7	60.1	61.7	59.3
	mean	52.1	59.7	57.4	59.0	–
$LSD_{0.05}$: Electromagnetical stimulation of seeds – 5.87, Variety – n.s., Cut – 3.68						

n.s. – not significant. Explanations as in Table 2.

combined with magnetic field as compared to seed stimulation with magnetic field alone. Greater mass of single shoot was characteristic of the shoots of alfalfa *cv*. Radius and of those from the second cut. The yield of dry mass of alfalfa harvested from two cuts in the year of sowing did not vary between the cultivars, while such a variation was observed between the seed stimulation factors and the control treatment. Each variant of seed stimulation caused a significant increase in the yield of alfalfa dry mass in the year of sowing.

Leaves are the most valuable component of the yield of alfalfa and it should be emphasised that in the year of sowing their share in the yield was greater than that of stems in both cuts. In the first cut it was at the level of 54.8%, and in the second it amounted to 59.3%. Seed stimulation had a significant effect on the increase of the share of leaves in the yield of alfalfa. Their share was the highest in treatment L (59.7%) and in treatment L+F (59.0%).

The height of yielding of alfalfa takes place only in the years of full land use, and the most important elements affecting alfalfa yielding in that period are the number of shoots per $1m^2$ and the mass of a single shoot.

The number of shoots per unit of area was significantly differentiated by the stimulation of seeds, the cuts, and the years of use (Table 4). The mean number of shoots per $1m^2$ in a cut was significantly higher in all treatments with seed stimulation than in the control treatment. The highest density of plants was obtained after seed stimulation with laser light in conjunction with variable magnetic field, and with laser light alone. It was significantly different from that obtained after seed stimulation with variable magnetic field only. The density of alfalfa shoots in the first and second regrowth was similar and significantly higher than in the third. The interaction of stimulation x cuts displayed a positive effect of the stimulation factors on the area density of alfalfa shoots in each of the cuts. Significant differentiation in the number of shoots per a unit of area was observed also between the years of use. The highest density of plants was noted in the first year of full land use, and significantly lower and comparable to each other in the second and third. The interaction of stimulation x years of use revealed a significant increase in the density of alfalfa shots in two successive years of full land use under the effect of all stimulation factors studied, whereas in the third year no such increase was noted in the treatment with magnetic field.

The factors under study affected also the height of shoots of alfalfa at the time of harvest. Compared with the control, significantly the highest shoots grew from seed irradiated with laser light. Apart from that, the shoots were the highest in the first regrowth and different significantly from shots from the 3rd cut. Taking into account the years, a significant decrease of shoot height was noted in the successive years of full land use.

The mass of a shoot is an important element affecting the yield. The values of that trait, in terms of fresh and dry mass of a shoot, are given in Table 5. The mean mass of a fresh shoot (at time of harvest) varied from 4.82 to 8.07 g and was significantly differentiated by all of the experimental factors and by their interactions. Significantly greater mass was characteristic of shots of *cv*. Radius, from the 1st cut and in the years 2011 and 2010. The factors of seed stimulation caused a significant decrease in the unit mass of a shoot, with relation to the control treatment. Significantly the lowest mass was recorded for shoots grown from seeds stimulated with L+F. The dry mass of a shoot, apart from the factors studied, was also affected by the weather conditions which caused that, compared to the fresh mass, greater dry mass was noted for shoots from the 3rd cut and in the year 2011. Otherwise, similar relations were observed as for the fresh mass of shoots.

The annual yield of fresh and dry mass of alfalfa is presented in Table 6. Significantly greater amounts of mass were obtained for *cv*. Radius and in the years 2009 and 2010. Seed stimulation caused a significant increase in the yield of fresh mass as compared to the control treatment. The highest yield was obtained for alfalfa treated with laser light and with the laser and magnetic field stimulation combined. It differed significantly from the yield obtained from seeds stimulated with the magnetic field alone.

The true comparative effect against the background of the experimental factors are the yields of dry mass which displayed significant relationships between the cultivars, seed stimulation factors and the years. Higher yields were noted for the hybrid alfalfa *cv*. Radius and in the first year of full land use. In the second and third year the yields were lower, but did not differ significantly, as opposed to the yields of fresh mass. The effect of the stimulation factors on dry mass yield was similar as in the case of fresh mass. The highest yields were obtained in the treatments with laser light – (L) and (L+F).

A significant issue in alfalfa cultivation for fodder is the distribution of yield productivity from the particular cuts and the share of leaves in the yield. The values of those parameters as related to the factors studied are presented in Figs 1-3. In the case of fresh and dry mass yields of alfalfa the seed stimulation factors did not cause any significant differences in yield productivity from the particular regrowths. Also, no significant differences between the cultivars were observed. Greater variation was noted with relation to the years. In the yield of fresh mass the first cut had the greatest share in 2011 and the lowest in 2009. In 2010, in turn, the share of the 3rd cut was higher than that of the 2nd. Dry mass productivity from the particular cuts was different than that of fresh mass. On average, the share of the 1st cut decreased, that of the 3rd cut increased, while that of the 2nd cut remained unchanged.

The share of leaves in dry mass yield increased in the successive cuts for both cultivars. In the case of *cv*. Ulstar their content was *ca*. 2% greater than for *cv*. Radius. Seed stimulation with the physical factors caused a slight increasing tendency in the participation of leaves in the yield of

T a b l e 4. Number and height shoots (mean in cut)

Specification		Electromagnetical stimulation of seeds				$\overline{X}$
		C	L	F	L+F	
Number of shoots per 1 m^2						
Variety	Radius	443	553	511	559	516
	Ultras	434	538	495	547	503
$LSD_{0.05}$:			–			n.s.
Electromagnetical stimulation of seeds x Variety			n.s.			–
Cut	I	484	571	532	588	544
	II	477	590	556	617	560
	III	352	475	419	453	425
$LSD_{0.05}$:			–			19.3
Electromagnetical stimulation of seeds x Cut			59.7			–
Year	2009	490	593	578	658	580
	2010	412	535	481	519	487
	2011	411	508	448	481	462
$LSD_{0.05}$:			–			19.3
Electromagnetical stimulation of seeds x Year			59.7			–
$\overline{X}$		438	545	502	553	–
$LSD_{0.05}$			23.2			–
Shoot height (cm)						
Variety	Radius	74	78	76	78	76
	Ultras	71	75	73	74	73
$LSD_{0.05}$:			–			n.s.
Electromagnetical stimulation of seeds x Variety			n.s.			–
Cut	I	76	79	77	77	77
	II	72	76	74	74	74
	III	68	74	71	74	72
$LSD_{0.05}$:			–			3.12
Electromagnetical stimulation of seeds x Cut			8.74			–
Year	2009	82	87	84	83	84
	2010	73	75	73	75	74
	2011	61	68	64	66	65
$LSD_{0.05}$:			–			3.12
Electromagnetical stimulation of seeds x Year			8.74			–
$\overline{X}$		72	76	74	75	–
$LSD_{0.05}$			3.46			–

Explanations as in Table 2.

T a b l e 5. Fresh and dry mass of single shoot

Specification		Electromagnetical stimulation of seeds				$\overline{X}$
		C	L	F	L+F	
		Fresh mass of single shoot (g)				
Variety	Radius	6.94	6.24	6.31	6.08	6.39
	Ultras	6.45	5.93	6.03	5.69	6.03
$LSD_{0.05}$:			–			0.17
Electromagnetical stimulation of seeds x Variety			0.45			–
Cut	I	8.07	7.63	7.77	7.54	7.78
	II	5.49	5.33	5.16	4.82	5.24
	III	6.25	5.30	5.57	5.29	5.61
$LSD_{0.05}$:			–			0.23
Electromagnetical stimulation of seeds x Cut			0.74			–
Year	2009	5.87	5.55	5.48	5.07	5.48
	2010	7.27	6.29	6.44	6.22	6.55
	2011	6.96	6.41	6.57	6.47	6.59
$LSD_{0.05}$:			–			0.23
Electromagnetical stimulation of seeds x Year			0.74			–
$\overline{X}$		6.70	6.08	6.17	5.88	–
$LSD_{0.05}$			0.29			–
		Dry mass of single shoot (g)				
Variety	Radius	1.52	1.39	1.40	1.33	1.43
	Ultras	1.40	1.33	1.32	1.23	1.32
$LSD_{0.05}$:			–			0.04
Electromagnetical stimulation of seeds x Variety			0.11			–
Cut	I	1.56	1.49	1.50	1.45	1.50
	II	1.22	1.17	1.15	1.03	1.14
	III	1.60	1.40	1.44	1.36	1.45
$LSD_{0.05}$:			–			0.05
Electromagnetical stimulation of seeds x Cut			0.16			–
Year	2009	1.48	1.44	1.40	1.28	1.40
	2010	1.42	1.25	1.26	1.22	1.29
	2011	1.47	1.38	1.42	1.34	1.40
$LSD_{0.05}$:			–			0.05
Electromagnetical stimulation of seeds x Year			0.16			–
$\overline{X}$		1.46	1.36	1.36	1.28	–
$LSD_{0.05}$			0.06			–

Explanations as in Table 2.

T a b l e 6. One-year fresh and dry mass yield

Specification		Electromagnetical stimulation of seeds				$\overline{X}$
		C	L	F	L+F	
		Fresh mass yield (kg m^{-2})				
Variety	Radius	9.12	10.38	9.66	10.20	9.84
	Ultras	8.35	9.57	8.91	9.21	9.01
$LSD_{0.05}$:			–			0.26
Electromagnetical stimulation of seeds x Variety			0.68			–
Year	2009	8.64	9.93	9.57	10.02	9.54
	2010	8.97	10.17	9.36	9.72	9.56
	2011	8.58	9.81	8.91	9.36	9.16
$LSD_{0.05}$:			–			0.39
Electromagnetical stimulation of seeds x Year			1.21			–
$\overline{X}$		8.73	9.97	9.28	9.70	–
$LSD_{0.05}$			0.47			–
		Dry mass yield (kg m^{-2})				
Variety	Radius	1.95	2.28	2.10	2.22	2.14
	Ultras	1.77	2.10	1.92	1.98	1.94
$LSD_{0.05}$:			–			0.05
Electromagnetical stimulation of seeds x Cut			0.15			–
Year	2009	2.13	2.52	2.40	2.50	2.39
	2010	1.71	1.98	1.80	1.90	1.85
	2011	1.74	2.04	1.83	1.89	1.87
$LSD_{0.05}$:			–			0.09
Electromagnetical stimulation of seeds x Year			0.27			–
$\overline{X}$		1.86	2.17	2.01	2.10	–
$LSD_{0.05}$			0.06			–

Explanations as in Table 2.

alfalfa, greater differences being observed for the 2nd and 3rd cuts, primarily under the effect of laser light – treatments (L) and (L+F). A factor that also had a modifying effect on the parameter in question were the weather conditions during the vegetation of the particular regrowths in the successive years of cultivation.

DISCUSSION

Perennial papilionaceous plants are known for their irregular emergence and problems with seed germination (Zając *et al.,* 2007). Field emergence rates of alfalfa obtained in this experiment varied from 33.1 to 51.2% and were comparable with literature data (Zając *et al.,* 2007). The seed stimulation factors under study caused a significant increase of the field emergence capacity of both alfalfa cultivars. Such an effect was obtained for stimulation with laser light (on average by 8.5%), magnetic field (by 12.8%), and when both stimulation factors were applied in combination (by 11.7%). Positive effects of seed stimulation in terms of increased rates of alfalfa emergence have been obtained with laser light (Dziwulska *et al.,* 2006), and also in the case of other crop plants (Aladjadjiyan, 2007; Hernandez *et al.,* 2010; Vasilevski, 2003). In turn, a positive effect of magnetic field treatment on the emergence rates of cereal plants was noted by Pietruszewski and Gruszecka (2003) and by Pietruszewski and Kania (2010).

The applied combinations of electromagnetic stimulation caused a significant increase in the number of shoots per 1 m^2 in the year of sowing and in the years of full land use with relation to the control treatment. In the year of sowing the largest number of shots was recorded in treatment L (813 shoots m^{-2}), and in the years of full land use in treatment L+F

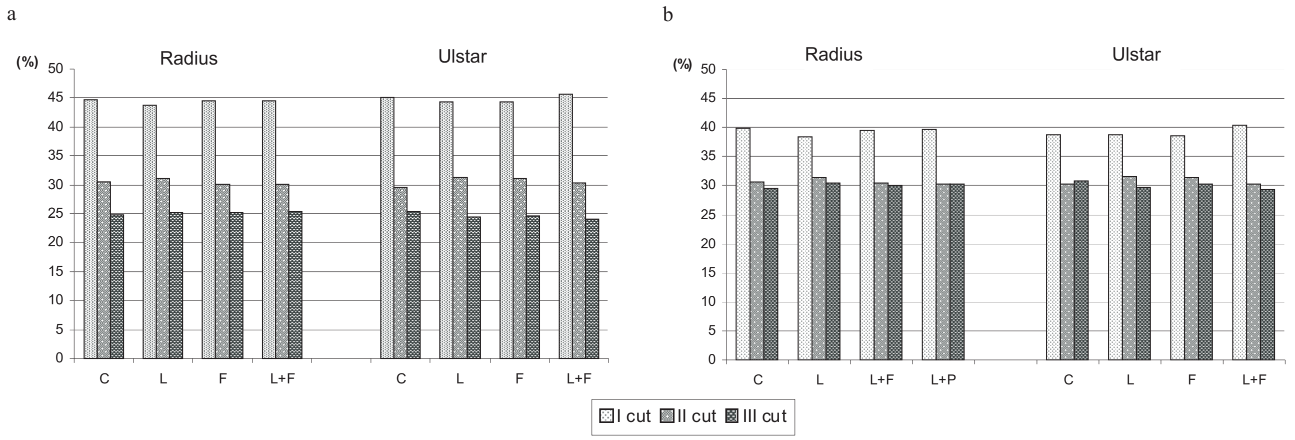

Fig. 1. Percentage of cuts in one-year: a – fresh and b – dry mass yield in dependence of the method of electromagnetic stimulation of seeds applied.

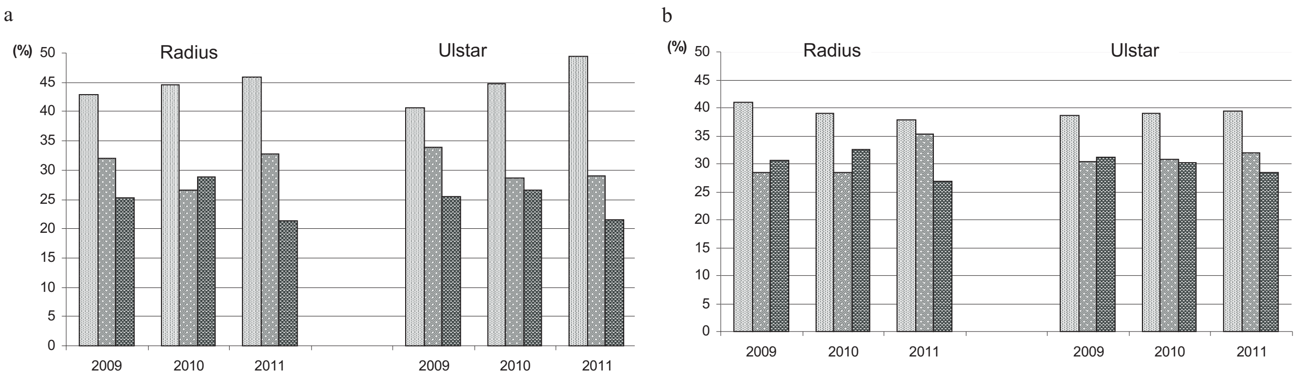

Fig. 2. Percentage of cuts in one-year: a – fresh and b – dry mass yield in dependence on years. Legend as in Fig. 1.

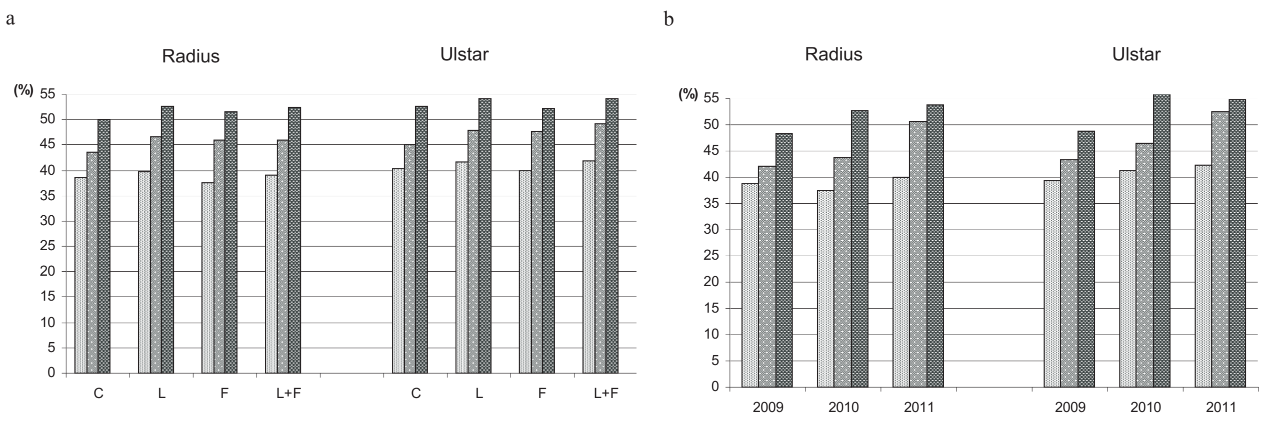

Fig. 3. Fraction of leaves in dry mass yield in dependence on the electromagnetic stimulation method: a – of seeds and b – on the years. Legend as in Fig. 1.

(553 shoots m^{-2}). That increase, in relation to the control treatment, amounted to 33.7% in the year of sowing and to 26.2% in the years of full land use. Studies by Azharonok *et al.* (2009), concerned with the effect of magnetic field on the numbers of pulse plants before harvest, indicate that the numbers varied with relation to plant species and to the time of stimulation of their seeds.

Apart from the physical factors, the numbers of shoots per 1 m^2 were differentiated by the cuts and by the weather conditions, which is in conformance with literature data (Zając *et al.,* 2007).

In the years of full land use the height of shoots during harvest was the greatest in the treatment with laser light stimulation (76 cm) and differed significantly from the control treatment (72 cm).

Studies on shoot length of plants of species *Medicago radiata* and *Medicago polymorpha* revealed significantly greater shoot length after the application of magnetic field with induction of 88 and 128 μT for 10 min with relation to the control (Balouchi and Modarres Sanavy, 2009). In turn, studies concerned with the effect of high-frequency magnetic field applied for 5, 10, 15, 20 min on the height of plants revealed a variation among pulse plants. The best effect was achieved for the exposure time of 15 min (Azharonok *et al.,* 2009). Martninez *et al.* (2009) conducted studies on peas and lentils, in which a constant magnetic field with induction of 125 and 250 mT was applied for periods of 1, 10, 20, 60 min, 24 h, and as a permanent treatment. Those authors observed a positive effect of the treatments on the trait under study. In this study on alfalfa, magnetic field caused a significant decrease in the mass of a shoot, but did not cause any significant differentiation in shoot height.

In a study by Kordas (2002), on the other hand, it was found that magnetic field caused a reduction in the height of plants of spring wheat.

The seed stimulation factors applied in the experiment presented here caused a significant decrease in the mass of an alfalfa shoot during the year of sowing and in the years of full land use.

As follows from studies on wheat, seed stimulation with magnetic field caused an increase of yield (Pietruszewski and Kania, 2010), studies by Kordas (2002) showed a decrease of that parameter, and in an experiment by Pietruszewski and Gruszecka (2003) a varied effect of variable magnetic field on the yields of cereal plants was observed.

The yields of dry mass of alfalfa under analysis increased in the year of sowing under the effect of laser light and of laser light and magnetic field combined, while in the years of full land use they increased under the effect of all stimulation treatments. The highest yield of fresh and dry mass was obtained from seeds irradiated with He-Ne laser light. An increase of alfalfa yielding under the effect of laser light stimulation was observed by Ćwintal and Olszewski (2007) and by Dziwulska *et al.* (2006). The above effect results from the increase of the number of shoots per 1 m^2.

In turn, in the case of magnetic field stimulation, positive effects on pulse plants and clover were achieved by Azharonok *et al*. (2009).

The yields of alfalfa obtained in this study should be considered as high in the light of literature data (Petkova and Panayotona, 2007; Radović *et al.,* 2009; Stanisavijević *et al.,* 2006 and 2011). A modifying effect of the weather on alfalfa yielding is emphasised by Radović *et al*. (2009) and by Stanisavijević *et al*. (2006). That opinion is supported also by the results of this study, in which the higher yields of dry mater were obtained in 2009.

According to Radović *et al.* (2009), alfalfa yields in the third year of use were lower than in the second. Whereas, in our study similar levels of alfalfa yielding were obtained in the second and third year of full land use, which was, however, primarily determined by the weather conditions.

The participation of leaves in the yield of dry mass of alfalfa increased in the successive cuts for both cultivars. Moreover, a growing tendency of the participation of leaves was noted in the 2nd and 3rd regrowth in the treatments with laser light and with laser light combined with magnetic field. Alfalfa leaves are the most valuable as fodder, therefore it is desirable that their share relative to that of stems is as high as possible (Pembleton *et al.,* 2010; Petkova and Panayotova, 2007).

CONCLUSIONS

1. In the sowing year, significantly higher field emergence and number of alfalfa plants and shoots per 1 m^2 were registered for *cv*. Ulstar as compared to *cv*. Radius. In the following years of exploitation the higher yields were observed for *cv.* Radius.

2. Electromagnetic stimulation of seeds caused a significant increase in alfalfa emergence rate, number of shoots per 1 m^2 and their height at time of harvest, and a decrease in the fresh and dry mass of a shoot.

3. The seed stimulation factors under study caused a significant increase in the mean annual yield of alfalfa as compared to the control. The highest yields of fresh and dry mass were obtained from seeds irradiated with laser light.

4. The percentage share of leaves in the dry mater yield of alfalfa increased in the successive cuts and was higher for *cv*. Ulstar and under the effect of seed stimulation with laser light and with laser light in combination with magnetic field.

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