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EFFECT OF LASER STIMULATION ON CROP YIELD OF ALFALFA AND HYBRID ALFALFA STUDIED IN YEARS OF FULL LAND USE*

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A b s t r a c t. The seeds of alfalfa cv. Legend as well as hybrid alfalfa cv. Radius were irradiated with divergent He-Ne laser bundle directly prior to sowing. The field experiments were carried out in the years 2003-2004 by using the method of the land random square (20 m^2) and four repetitions. Lucerne variety and six doses and repetitions of irradiation were taken as independent variables. The following parameters were estimated from field experiments: number of shoots of Lucerne, dry matter of single shoot, cropping yields of green and dry matter, percentage of cut in one-year crop yield and percentage of leaves in dry matter. Laser stimulation resulted in growth of the number of shoots per 1 m^2 and the yields of green and dry matter.

K e y w o r d s: lucerne, laser stimulation of seeds, yield

INTRODUCTION

Sowing and hybrid alfalfa are classified among perennial small-seed papilionaceous plants. They are characterized by multi-cut harvest, high protein content, and ability of binding atmospheric nitrogen through symbiosis with nodule bacteria [8,12,13]. Alfalfa has an ability of self-regulation of the growing density within certain ranges of sowing density, which leads to the generation of similar numbers of shoots per unit of surface area from different sowing densities [14].

Alfalfa producers tend to improve the quality and quantity of crop yield through, among other things, various methods of improvement of sowing material. Methods usually applied include chemical (seed dressing, growth regulators,

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etc.), biological (seed vaccination with *Rhizobium meliloti* bacteria), and physical (magnetic fields, laser irradiation, and others). The physical methods are safer for the environment than the chemical methods, as they only modify the physiological and biochemical processes in seeds [2,3,7,12].

Laser stimulation is a physical phenomenon consisting in the ability of absorbing and storing radiant energy by plant cells and tissues. The same phenomenon can be observed in the case of seeds: they first absorb the energy of light, and then transform it into chemical energy and use it for subsequent growth [2,3,6].

The objective of this work was the determination of the effect of irradiation of seeds of sowing and hybrid alfalfa with He-Ne laser on their crop yield and its structure in years of full land use.

MATERIAL AND METHOD

In the years 2003-2004 a field experiment with alfalfa was conducted at Kolonia Spiczyn, in the district of Łęczna. Two species of alfalfa were used in the experiment: sowing alfalfa (*Medicago sativa* L. *ssp. sativa*) cultivar Legend, and hybrid (*Medicago sativa* L. *ssp. sativa* x *ssp. falcata*) cultivar Radius. Legend is an American cultivar, entered in the COBORU register in 1999 [1]. It is characterized by a greater number of pinnules in the leaf (from three to seven), and greater content of protein and lower content of fibre in dry mass. It is a medium-early cultivar, high yielding and resistant to decay diseases [8,13]. Radius is a Polish cultivar, entered in the COBORU register in 1988 [1]. It is a medium-early cultivar, high yielding and re-growing after cutting. In terms of crop yield it is superior to all other Polish cultivars.

At the Department of Physics, University of Agriculture, Lublin, alfalfa seeds were stimulated with He-Ne laser light, using the Koper and Dygdała [9] apparatus for pre-sowing laser stimulation of seeds.

The field experiment was conducted on a soil of the good wheat complex (quality class IIIa), with the random blocks method in four replications. Each plot had a surface area of 20 m^2. The factors studied were alfalfa species: (sowing and hybrid) and doses of surface power of divergent beam laser light of 0 (control), 3 and 6 mW cm^{-2} (referred to as R0, R3 and R6), with 1-, 3- and 5-times of exposure (referred to as x1, x3, x5). The duration of a single exposure was 0.1s.

In the field experiment, for every cut the following were determined: number of alfalfa shots per 1 m^2, dry mass of single shots and crop yield of green and dry mass, and percentage share of leaves in the dry mass yield.

In each year of the experiment three cuts were taken. The first and third cut were mowed during the budding of plants, and the second at the beginning of the blooming phase.

The results obtained were processed statistically using analysis of variance and the least significant difference ($NIR_{0.05}$), according to the Tukey test [11].

Data concerning the atmospheric conditions during the period of the study were compiled on the basis of information from the Agrometeorological Station at Felin. The distribution of mean monthly temperatures and sums of precipitations are presented in Table 1 in comparison to the multi-year data. Apart from that, meteorological conditions are presented for the vegetation periods of alfalfa in years of full land use (Tab. 2).

Table 1. Mean monthly air temperatures and total rainfall during vegetation period as compared to corresponding perennial values

Month	Mean monthly temperatures (°C)			Total rainfall (mm)		
	Period 1951-2000	2003	2004	Period 1951-2000	2003	2004
IV	7.4	6.5	7.9	40.6	40.7	38.1
V	13.0	16.3	11.9	58.3	71.4	38.0
VI	17.9	17.4	15.8	65.8	39.6	49.9
VII	17.3	19.8	18.1	78.0	98.1	90.5
VIII	17.2	18.7	18.3	69.7	27.0	48.5
IX	7.9	13.5	12.8	52.1	29.0	14.2
Mean Total	13.5	15.4	14.1	364.5	305.8	279.2

Table 2. Meteorological profile for one-year of full land use versus vegetation periods of three cuts

Specification	Year	Years of full land use (2003-2004)			
		First cut	Second cut	Third cut	Σ / $\overline{x}$
Dates	2003	15.04-27.05	28.05-07.07	08.07-30.08	15.04-30.08
	2004	02.04-31.05	01.06-15.07	16.07-10.09	02.04-10.09
Vegetation period (days)	2003	43	41	54	138
	2004	60	45	57	162
Mean twenty-four hour temperature (°C)	2003	12.1	17.5	18.9	16.2
	2004	9.9	15.7	15.0	13.5
Total rainfall (mm)	2003	91.6	60.2	102.9	254.7
	2004	71.6	77.1	120.7	269.4
Number of rainy days	2003	12	14	13	39
	2004	10	12	15	37

RESULTS AND DISCUSSION

The years 2003 and 2004 were characterized by higher mean air temperature and lower precipitation as compared to the multi-year data (Tab. 1). In 2003, July and August proved to be especially warm months. The most favourable amount of rainfall, on the other hand, occurred in July. June, August and September were characterized by rainfall levels below the 50-year average. Especially low levels of precipitation were recorded in September. High temperature and good rainfall distribution in 2003 caused that the vegetation period lasted only 138 days (Tab. 2). Especially during the vegetation of the third re-growth that year the weather conditions were favourable. 2004 was a cooler year with a similar level of rainfall. Lower temperatures during vegetation of all the re-growths caused an extension of the total vegetation period to 162 days. The greatest difference – 17 days – in the duration of vegetation in 2003 and 2004 was recorded for the first re-growth, when in the latter year the mean air temperature was 9.9ºC. Overall, the distribution of meteorological conditions during alfalfa vegetation should be estimated as favourable [14]. The density of alfalfa shoots per 1 m^2 was significantly differentiated by the cuts, doses of laser irradiation, and interaction between those two factors (Tab. 3). The best results were obtained for the second cut under the following conditions of laser irradiation: R3x3, R6x3, R6x5. All the results, with all the irradiation variants except for R3x1, were significantly higher than those for the control object. Similar relations were obtained by Wilczek, Ćwintal *et al*. [18] in the case of red clover.

Table 3. Number of lucerne shoots (arts m^{-2})

Specification	R0	R3x1	R3x3	R3x5	R6x1	R6x3	R6x5	$\overline{x}$
Varieties:								
Legend	514	575	632	626	594	654	639	605
Radius	534	589	676	630	642	675	675	631
Years:								
2003	538	599	668	634	640	650	643	624
2004	510	565	640	622	596	680	672	612
Cuts								
I	563	611	611	597	654	630	622	612
II	566	679	807	764	698	837	809	737
III	443	456	543	522	501	525	540	504
$\overline{x}$	524	582	654	628	618	664	657	–
$NIR_{0.05}$*	Between:							
	cuts						58.2	
	doses of irradiation						64.1	
	at interaction dose of irradiation x cuts						102.6	

* Least significant difference.

Dry mass of a single shoot was only significantly differentiated by the cuts (Tab. 4). The highest value of that feature was recorded for the first cut, and the lowest for the third. Laser stimulation of seeds caused an insignificant decreasing tendency in the mass of single shoot, while in the case of red clover there was a significant drop in the values of that feature under the effect of irradiation [18].

Table 4. Dry matter of single shoot (g)

Specification	R0	R3x1	R3x3	R3x5	R6x1	R6x3	R6x5	$\overline{x}$
Varieties:								
Legend	1.00	0.96	0.95	0.94	0.98	0.92	0.92	0.95
Radius	1.03	0.98	0.91	0.93	0.90	0.88	0.90	0.93
Years:								
2003	1.02	0.98	0.99	0.97	0.94	0.94	0.96	0.97
2004	1.01	0.96	0.87	0.90	0.94	0.86	0.86	0.91
Cuts								
I	1.33	1.31	1.40	1.33	1.26	1.32	1.32	1.32
II	0.98	0.85	0.72	0.79	0.83	0.71	0.74	0.80
III	0.72	0.75	0.66	0.68	0.71	0.67	0.66	0.69
$\overline{x}$	1.01	0.97	0.93	0.93	0.93	0.90	0.91	–
$NIR_{0.05}^{*}$	between: cuts							0.16

* Least significant difference.

Significantly higher yields of green mass were obtained in 2004, a year characterized by longer vegetation (Tab. 5). The yields obtained, on the level of 68.5-73.4 t ha^{-1}, should be estimated as high in the light of literature data. Laser stimulation of seeds resulted in a slight increase in green mass yield which, however, was not statistically proven.

Table 5. Green matter yield (t ha^{-1})

Specification	R0	R3x1	R3x3	R3x5	R6x1	R6x3	R6x5	$\overline{x}$
Varieties:								
Legend	68.1	70.7	70.7	72.2	73.7	72.9	72.7	71.6
Radius	68.9	73.1	75.9	72.6	73.2	73.8	74.2	73.1
Years:								
2003	63.6	68.7	70.1	68.3	69.1	68.8	68.7	68.2
2004	73.4	75.1	76.5	76.5	77.8	77.9	78.2	76.5
$\overline{x}$	68.5	71.9	73.3	72.4	73.4	73.3	73.4	–
$NIR_{0.05}^{*}$	between: years							6.8

* – Least significant difference.

Statistically confirmed variability in green mass yields were only caused by doses of laser irradiation (Tab. 6). All the irradiation variants gave results significantly better than those for the control, with the exception of R3x1. Similar yields of green mass were recorded in both years, for both cultivars – Legend and Radius, which indicates higher water content in green mass in 2004 in comparison with 2003.

Table 6. Dry matter yield (t ha^{-1})

Specification	R0	R3x1	R3x3	R3x5	R6x1	R6x3	R6x5	$\overline{x}$
Varieties:								
Legend	15.7	16.7	17.1	17.3	17.6	17.5	17.3	17.0
Radius	16.4	17.6	18.0	17.3	17.1	17.4	17.8	17.4
Years:								
2003	16.1	17.5	18.1	17.5	17.7	17.4	17.5	17.4
2004	16.0	16.7	17.0	17.1	17.1	17.4	17.5	17.0
$\overline{x}$	16.0	17.0	17.5	17.3	17.4	17.4	17.5	–
$NIR_{0.05}$*	between: doses of irradiation							1.2

* Least significant difference

The obtained yields of dry mass, at the level of 16.0-17.5 t ha^{-1}, should be estimated as very high in the light of the literature data [14,16]. Factors that contributed to the obtaining of such results included also good weather conditions during alfalfa vegetation and the good soil conditions.

Distribution of cuts in the annual field of dry mass, with relation to cultivars and laser irradiation of seeds, is presented in Figure 1. A somewhat higher share of the second and third re-growths was characteristic of the Legend cultivar. Laser irradiation doses R3x1, R3x3, R6x1 and R6x3 caused an increase in the participation of the first cut in the annual crop yield. Overall, such factors as cultivars grown and laser stimulation of seeds had a weak effect on the share of particular cuts in the annual crop yield.

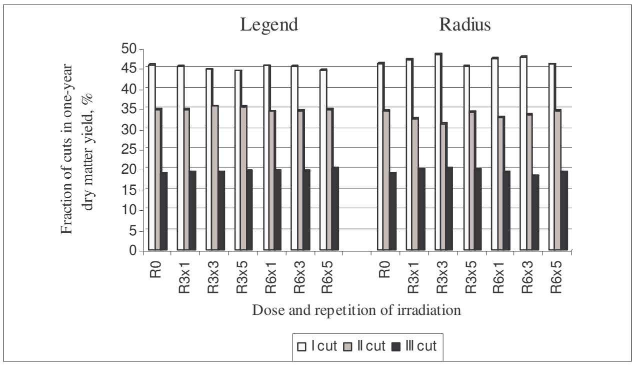

Fig. 1. Percentage of cuts in one-year dry matter yield versus doses and repetitions of irradiation for varieties as indicated

Figure 2 presents the share of particular cuts in the annual crop yield against the years and the laser stimulation. A notably better distribution of yields from cuts in the annual crop yield was recorded in 2003, when the share of the first cut decreased in favour of the second, while in 2004 the share of the first cut increased and that of the second decreased. The distribution of yields per cut was more balanced in 2003, which should be rated as favourable from the viewpoint of fodder supply [5,14].

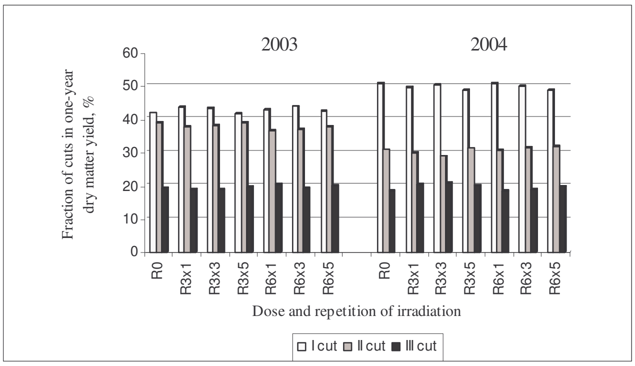

Fig. 2. Percentage of cuts in one-year dry matter yield versus doses and repetitions of irradiation for years as indicated

The share of leaves in dry mass yield is an important indicator of fodder quality, as leaves have the highest content of proteins, phosphorus, calcium, magnesium and most microelements [5,16,17]. As follows from Figure 3, the cultivars Legend and Radius were characterized by similar distributions of that feature. Irradiation with laser light did not cause any greater differentiation in the mass of leaves.

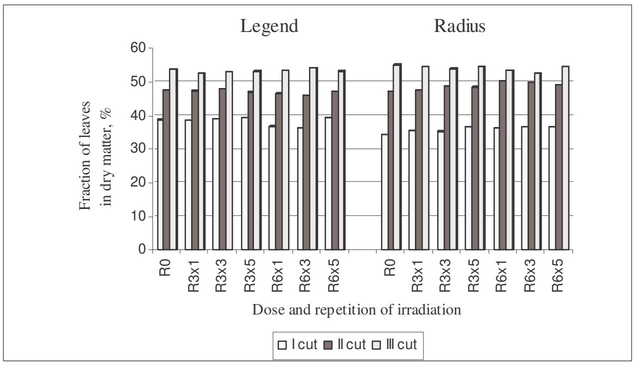

Fig. 3. Percentage of leaves in dry matter versus doses and repetitions of irradiation for varieties as indicated

The years of experiment, on the other hand, had a slight differentiating effect on the share of leaves in the dry mass yield (Fig. 4). In 2003 a somewhat greater share of leaves from the second cut was recorded in comparison to 2004. The factors under study had only a weak effect on the variability of that feature.

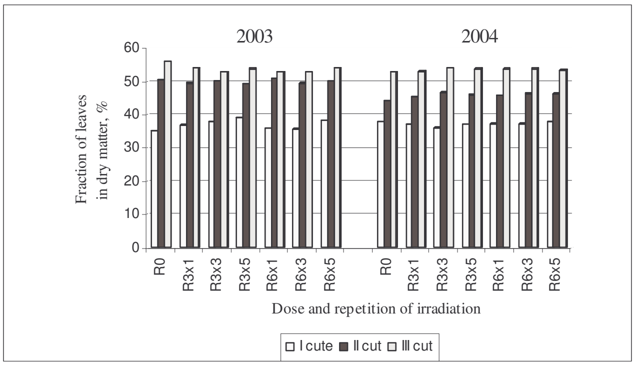

Fig. 4. Percentage of leaves in dry matter versus doses and repetitions of irradiation for years as indicated

CONCLUSIONS

1. The density of alfalfa shoots per 1 m^2 was significantly differentiated by the cuts, doses of laser irradiation, and interactions between those factors. The best results were obtained in the second cut and objects R3x3, R6x3, R6x5.

2. Dry mass of single shoot was significantly differentiated only by the cuts. The highest values of that feature were recorded in the first cut, and the lowest in the third.

3. The field experiment produced high yields of green mass (68.5-73.4 t ha^{-1}) which were significantly differentiated only by the weather conditions in the particular years.

4. In the experiment very high yields of dry mass were obtained (16.0-17.5 t ha^{-1}). Those were significantly differentiated only by the doses of laser irradiation. All the crop yields from irradiated objects were significantly higher than those from the control object, with the exception of variant R3x1.

5. Alfalfa cultivars, doses of laser irradiation, and years of experiment had only a weak effect on changes in the share of individual cuts in the annual yield of dry mass and on the participation of leaves in the yield.

REFERENCES

1. COBORU: Index of cultivated plant and vegetable varieties registered in Poland (in Polish). Słupia Wielka, 2004.
2. **Dziwulska A.:** Effect of pre-sowing laser biostimulation on germination, growing pattern, crop yield and quality of drops of lucerne. Doctoral dissertation (in Polish). AR, Lublin, 2005.
3. **Dziwulska A.**, **Koper R.:** Effects of pre-sowing laser biostimulation on germination of lucerne seeds (in Polish). Acta Agrophysica, 82, 33-39, 2003.

4. **Dziwulska A., Koper R., Wilczek M.:** Estimation of effect of He-Ne laser beam on germination capacity of white clover variety of Anda cultivar (in Polish). Acta Agrophysica, 3(3), 435-441, 2004.
5. **Falkowski M., Kukułka I., Kozłowski S.:** Chemical properties of meadow plants (in Polish). Wyd. AR, Poznań, 2000.
6. **Gładyszewska B., Koper R., Kornarzyński K.:** Technology and effects of the pre-sowing laser biostimulation of cucumber seeds (in Polish). Zesz. Probl. Post. Nauk Roln., 454, 213-219, 1998.
7. **Injuszin W.:** Laser Light and Crop (in Russian). Kainar Ałma-Ata, 1981.
8. **Jelinowska A.**, **Skrzyniarz H.:** Plant cultivation technology – lucerne (in Polish). Wyd. IUNG, Puławy, 1994.
9. **Koper R.**, **Dygdała Z.:** System used in pre-sowing laser light biostimulation of seeds (in Polish). Patent UPRP, nr 162598, 1993.
10. **Koper R., Mikos-Bielak M., Próchniak T., Podleśny J.:** Effect of pre-sowing laser biostimulation of white lupine seeds on chemical properties of crop yields (in Polish). Inżynieria Rolnicza, 4 (15), 43-52, 2000.
11. **Oktaba W.**: Calculus of probability and mathematical statistics (in Polish). Wyd. AR, Lublin, 1994.
12. **Podleśny J.**, **Koper R.:** Effectivity of application of pre-sowing laser light treatment on white lupine seeds (in Polish). Zesz. Prob. Post. Nauk Roln., 454, 255-262, 1998.
13. **Staszewski Z.:** Lucernes (in Polish). Państ. Wyd. Rol. i Leśn., Warszawa, 1975.
14. **Wilczek M.:** Hybrid alfalfa and alfalfa. Specific plant breeding (ed. Z. Jasińska and A. Kotecki) (in Polish). Wyd. AR Wrocław, 2, 197-214, 2003.
15. **Wilczek M., Ćwintal M.:** Effect of quantity of seeds of lucerne sown in summer term on growing pattern and cropping yield (in Polish). Fragmenta Agronomica, 2(34), 5-11, 1992.
16. **Wilczek M., Ćwintal M.:** Cropping yield of hybrid alfalfa versus sowing terms and number of sown seeds. II part. Cropping (in Polish). Biul. IHAR, 185, 71-78, 1993.
17. **Wilczek M., Ćwintal M.:** Effect of fertilization on the contents of basic organic and mineral compounds. I part. Basic of organic (in Polish). Biul. IHAR, 197, 187-194, 1996.
18. **Wilczek M., Ćwintal M., Kornas-Czuczwar B., Koper R.:** Effects of pre-sowing laser biostimulation on yield of di- and tetraploid red clover in years of full usage (in Polish). Acta Agrophysica (in press).

WPŁYW LASEROWEJ STYMULACJI NASION NA PLONOWANIE LUCERNY SIEWNEJ I MIESZAŃCOWEJ W LATACH PEŁNEGO UŻYTKOWANIA

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S t r e s z c z e n i e. Nasiona lucerny siewnej odmiany Legend i mieszańcowej Radius naświetlono światłem lasera He-Ne, bezpośrednio przed siewem. W latach 2003-2004 przeprowadzono eksperyment polowy, metodą bloków losowanych w czterech powtórzeniach, na poletkach 20 m^2. W badaniach polowych uwzględniono dwa czynniki: odmiany oraz sześć dawek mocy wiązki rozbieżnej światła lasera i kontrolę. Określono: liczbę pędów lucerny na 1 m^2, suchą masę pojedynczego pędu, plon zielonej i suchej masy, procentowy udział pokosów w rocznym plonie suchej masy oraz procentowy udział liści w plonie suchej masy. Stymulacja laserowa spowodowała istotny wzrost liczby pędów na 1 m^2 oraz plonu zielonej i suchej masy.

S ł o w a k l u c z o w e: lucerna, stymulacja laserowa nasion, plon