ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Agricultura 8(2) 2009, 31-41*

EFFECT OF METHOD AND TIME OF SOWING ON THE GROWTH, DEVELOPMENT, CHLOROPHYLL CONTENT AND PHOTOSYNTHESIS RATE OF *Festuca rubra* L. SSP. *commutata, trichophylla, rubra* GROWN FOR SEEDS IN THE YEAR OF ESTABLISHMENT AND IN THE FIRST PRODUCTION YEAR

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Abstract. The experiment was carried out at the Variety Testing Station in Chrząstowo (53°09' N; 17°35' E). The aim of the study was to estimate the effect of a cover crop (spring barley) and sowing times (spring and summer) on the growth and development, chlorophyll content and photosynthesis rate of three subspecies of red fescue (ssp. *rubra*, *trichophylla* and *commutata*) in the first and second year of growth. Spring barley had a negative effect on leaf greenness index and development of the red fescue undersown crop in the year of establishment. Red fescue sown at the end of July developed as that sown at the beginning of the month. Delay of sowing until the middle of August resulted in reduction in plant tillering and height and in the photosynthesis rate of the youngest leaves in the year of establishment and of the flag leaf in the first production year. Fast growth rate of the creeping cultivar Nista may indicate a higher usefulness of this cultivar for sowing with a cover crop as compared with chewing cultivar Mirena and short creeping Womira.

Keywords: chlorophyll, chewing-, creeping-, short creeping red fescue, photosynthesis

INTRODUCTION

Seed plantations of red fescue are established in pure sowing from spring to the end of July or as undersown crops. In spring sowings, the cover crop is most often spring barley [Ramenda 1999]. Chastain and Grabe [1988] indicated that it provides a higher inflow of photosynthetically active light and uses less water and ripens earlier than

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wheat. In Denmark, sowing into winter barley, wheat or oilseed rape is also applied [Boelt 1997]. The plant development state at the end of growth, determined by a number of leaves, has an effect on the amount of seed yield in the following year [Boelt 1999]. The amount of assimilates formed and plant growth depend on site and genetic factors. A study of perennial ryegrass [Olszewska 2002] showed that soil moisture had a decisive effect on the photosynthesis rate. In red fescue (*Festuca rubra* L.) photosynthesis and growth rates were different in the subspecies *rubra*, *trichophylla* and *commutata* [Huylenbroeck and Bockstaele 1999].

Photosynthesis takes place mostly due to pigments contained in chloroplasts, among which chlorophyll *a* and *b* occurs in higher plants [Strzałka 2005]. Goliński and Xi [2000] point out the relation between chlorophyll content and the cultivar or red fescue regrowth and its limitation under conditions of low moisture. Olszewska [2002] in turn reported an increase in SPAD value as a gauge of chlorophyll content in leaves of perennial ryegrass under conditions of water stress. Gaborcik [2003] did not find a difference in SPAD values even between species from the genera *Lolium*, *Festuca* and their hybrids.

The aim of the study was to estimate the effect of the cover crop and delaying sowing on the growth and development, chlorophyll content and photosynthesis rate of red fescue in the year of establishment and the first production year.

The research hypothesis assumed that cultivars belonging to subspecies: *commutata*, *trichophylla* and *rubra* have different contents of chlorophyll and photosynthesis activity, determining the growth rate, thus they will respond differently to the presence of the cover crop or a delay of the sowing time.

MATERIAL AND METHODS

The research concerning red fescue grown for seeds (*Festuca rubra* L.) was carried out at the Experiment Variety Testing Station in Chrząstowo (53°09' N; 17°35' E) in two series, including the establishment year and the first production year (the first series – 2004 and 2005, the other – 2005 and 2006 respectively). Three lawn cultivars: chewing (ssp. *commutata*) Mirena, with short runners – short creeping (ssp. *trichophylla*) Womira and creeping (ssp. *rubra*) Nista were sown in spring in pure sowing, with barley, and in summer, in the middle and at the end of July and in the middle of August. A split-plot design in four replications was used, and the area of plots was 15 m^2. The soil on which the field experiment was located is categorized as a medium-heavy soil of defective wheat complex, quality class IVa. It was characterized by a very high content of phosphorus and potassium and the neutral pH value. The seeding rate of spring barley cultivar Justina was reduced by 20% in relation to the recommendations and amounted to 120 $kg \cdot ha^{-1}$. Fescue was sown in an amount of 8 $kg \cdot ha^{-1}$, at a depth of 1 cm, with a row spacing of 24 cm. Red fescue in spring pure sowing and with barley was fertilized with rates: N – 60 kg, P – 4 kg and K – 29 $kg \cdot ha^{-1}$. The rates applied after the harvesting of barley or the first cut of red fescue in the year of establishment were N – 40 kg, P – 26 kg and K – 66 $kg \cdot ha^{-1}$. In the case of second cut harvesting, additional amounts of pure components N, P and K were: 40, 4 and 29 $kg \cdot ha^{-1}$ respectively. A rate of mineral nitrogen prior to the beginning of growth in the first production year was 60 $kg \cdot ha^{-1}$ in all treatments.

Spring barley was harvested in the first decade of August. Two cuts of red fescue green crop were gathered in the year of establishment (2004) in spring pure sowing, (15th August and 5th October), and one in 2005 (6th October).

Leaf greenness index (chlorophyll content) was measured using the N-Tester SPAD 502. The apparatus measures a difference between the absorption of light with a wavelength of 650 nm (the maximal absorption of light by chlorophyll *a* and *b*) and that of 940 nm (light absorbed by leaf tissues). Quotients of these differences are displayed in the form of the so called SPAD units [Fotyma 2000]. The measurements were made on 30 youngest, randomly selected leaves of each plot. Photosynthesis rate was determined using the portable gas analyser Li-Cor 6400. Several readings were made on the youngest leaves in three replications for each treatment. The program „Variance Analysis of Sustainable Experiments" was used for statistical calculations. The significance of differences was determined according to the Tukey test, at the level of significance $\alpha = 0{,}05$. Measurements from two series, for the year of establishment and the first production year, were used for making a synthesis. In 2005, the fall measurement of SPAD and photosynthesis values in the fescue from sowing in the middle of August appeared technically impossible, therefore, the synthesis was not made and the results are presented separately for each establishment year.

The weather conditions in the area of research are usually favorable for plant growth and development. The average long-term total precipitation is 511 mm, of which nearly 40% falls in the period from June to August. The weather conditions in the establishment year (2004) favored the development of red fescue (Fig. 1). Rainfall was not heavy (an annual total of 443 mm), but quite evenly distributed throughout the growing season. Short periods of drought occurred in June and September. In 2005, the amount of rainfall from April to the beginning of June was sufficient for the newly sown red fescue. A drought period begun in the second decade of June, and a dry period in September, which had a negative effect on the development of red fescue from summer sowings, particularly in the case of their delay until the middle of August.

In 2005 and 2006 the total rainfall in April and May was sufficient for the proper growth and development of red fescue in the first production year. Water deficit in June, repeated in both years, occurred several days earlier and was more severe in 2006. Moderate rainfall in the first and second decades of July made plant harvesting easier.

RESULTS AND DISCUSSION

In the establishment years, red fescue undersown into spring barley at the time of germination and emergence developed as the plants in pure sowing. At the beginning of tillering stage, the development of undersown crop was inhibited. Until the harvest of the cover crop (in the first decade of August) only a slow growth of shoots and leaves was observed. Until this time, fescue in pure sowing was fully tillered and reached a height of 13 (Mirena), 15 (Womira) or 20 cm (Nista). Earlier a similar, negative effect of a cover crop on the growth and development of the aboveground part and on photosynthesis rate was shown in a study of perennial ryegrass [Szczepanek et al. 2004].

At the ear formation stage of barley (in June) the undersown fescue was characterized by a significantly smaller leaf greenness index than the plants in pure sowing. The difference still remained 7-10 days after barley harvesting (Table 1). In the middle of June, in pure sowing, Mirena had a significantly smaller chlorophyll content

index than the other cultivars. Similar results were obtained in crops undersown in barley, while the difference in relation to the cultivar Nista was not significant. No relation of the variety and the method and time of sowing with changes in this feature of leaves in summer (July) (Table 1) and in fall (October) (Table 2) was shown. In the relatively humid 2004, the development of undersown crops after harvesting of the cover crop was rather intensive. However, self-sown barley appeared too, which could be the cause of low SPAD value readings at the beginning of October (Table 2). In the dry 2005, the growth and development of red fescue in the year of establishment in all the treatments was strongly limited. Under these conditions, chlorophyll content was similar in spring and summer sowings. Prior to the end of growth, the fescue sown with cover crop achieved the similar height as in spring pure sowing. However, it formed remarkably fewer vegetative shoots.

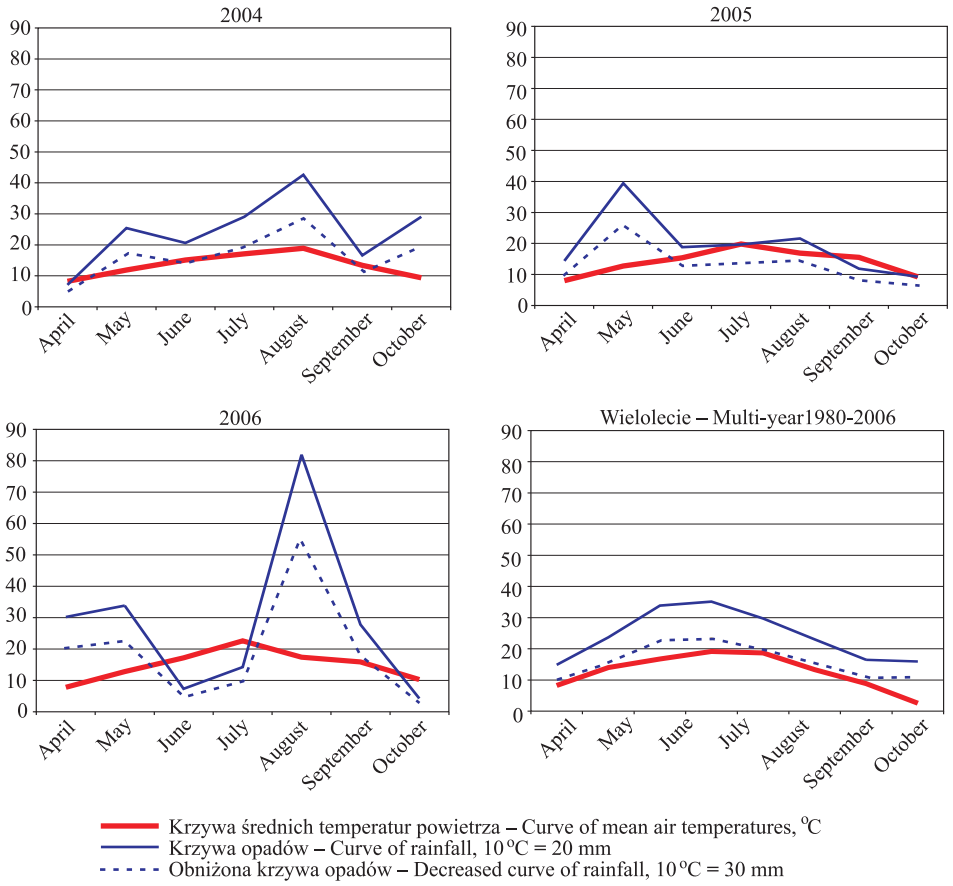

Fig. 1. Hydrothermal conditions in 2004-2006 in relation to the long-term means of 1980-2006
Rys. 1. Warunki hydrotermiczne w latach 2004-2006 na tle średnich z wielolecia 1980-2006

Table 1. Leaf greenness index of red fescue from spring sowing in the establishment year, SPAD (mean from 2004-2005)

Tabela 1. Indeks zieloności liścia kostrzewy czerwonej z zasiewu wiosennego w roku siewu, SPAD (średnia z lat 2004-2005)

Cultivar Odmiana (O)	Date of measurement – Termin pomiaru					
	middle of June – połowa czerwca			middle of August – połowa sierpnia		
	sowing method – sposób siewu (S)					
	pure czysty	undersown crop wsiewka	mean średnia	pure czysty	undersown crop wsiewka	mean średnia
Mirena	7.93	2.93	5.43	5.67	4.63	5.15
Womira	12.97	4.58	8.77	6.14	4.43	5.28
Nista	13.77	3.13	8.45	7.51	5.23	6.37
Mean – Średnia	11.56	3.54	7.55	6.44	4.76	–
$LSD_{0.05}$ – $NIR_{0.05}$ for – dla:						
middle of June – połowy czerwca	S 0,493	O 0,794	S x O 0,803	O x S 1,123		
middle of August – połowy sierpnia	S 1,446	O 1,017	S x O 1,582	O x S 1,439		

In the establishment years, the red fescue sown in the middle of July developed faster than that from sowing at the end of this month. At the beginning of October the plants from the earliest summer sowing time reached a height of 6-8 cm and formed 6-8 lateral shoots. A two-week delay of sowing resulted in a reduction in height by 1-2 cm, and in tillering by 2-3 shoots. The fescue sown in the middle of August showed the weakest development. In 2004, at the end of growth, it formed only 2-3 lateral shoots and reached a height of 3-4 cm. Additionally, a smaller chlorophyll content index (Table 2) and photosynthesis rate (Table 3) were observed than those in plants from July sowings. In 2005, at the end of growth, the fescue sown at the most delayed time formed only 1-2 leaves and had a height of 1-3 cm, which made the measurement of SPAD and photosynthesis impossible. In both establishment years, the fescue sown at the end of July was characterized by intensive photosynthesis.

The study by Olszewska [2002] indicates that a decrease in field water capacity from 80 to 40% resulted in a reduction in photosynthesis rate in perennial ryegrass by 42-44%. A similar effect of water deficit was observed in the present study in the establishment year 2005, when photosynthesis rate was nearly three times lower than in the relatively humid 2004 (Table 3). A particularly low photosynthesis rate and even wilting of leaf parts was observed in the variant of spring pure sowing. This was probably caused by water deficit, resulting from a high transpiration of dense sward in this treatment. Kacperska [2005] reports that growth stunting is one of the first plant responses to water deficit. Long-term water stress can result in leaf shedding, which enables assimilation area to be reduced. According to Strzałka [2005], as the water deficit progresses, the process of photosynthesis undergoes inhibition, and then is totally stunted.

In the cultivar Nista at the end of vegetation in establishment years, young plants grown from runners appeared in inter-rows. Moreover, this cultivar was higher by 1-3 cm than the short creeping Womira, and Womira in turn, higher than the chewing Mirena. Differentiation in the growth rate of red fescue subspecies was also indicated by Huylenbroeck and Bockstaele [1999], who classify *Festuca rubra* L. ssp. *rubra* as a fast growing form, *commutata* – slowly growing, a *trichophylla* – an intermediate form.

Table 2. Leaf greenness index of red fescue at the beginning of October in the establishment year, SPAD
Tabela 2. Indeks zieloności liścia kostrzewy czerwonej na początku października w roku siewu, SPAD

Cultivar Odmiana (O)	2004						2005					
	Method/time of sowing – Sposób/termin siewu (S)											
	spring – wiosenny		summer – letni			mean średnia	spring – wiosenny		summer – letni			mean średnia
	pure czysty	undersown crop wsiewka	middle of July połowa lipca	end of July koniec lipca	middle of August połowa sierpnia		pure czysty	undersown crop wsiewka	middle of July połowa lipca	end of July koniec lipca	middle of August połowa sierpnia	
Mirena	12.2	8.5	16.3	12.9	9.4	11.8	16.6	13.9	11.2	12.5	–	13.5
Womira	13.2	6.3	17.2	13.9	13.5	12.8	16.0	15.7	11.6	11.4	–	13.7
Nista	13.6	8.1	18.7	17.5	13.7	14.3	15.5	18.2	17.7	14.6	–	16.5
Mean – Średnia	13.0	7.6	17.4	14.7	12.2	13.0	16.0	15.9	13.5	12.8	–	–
LSD – NIR for – dla:												
year – roku 2004	S 4,11	O 2,39	S x O 6,16	O x S 5,35								
year – roku 2005	S 5,81	O 3,71	S x O 8,20	O x S 7,41								

Table 3. Photosynthesis rate in leaves of red fescue at the beginning of October in the establishment year, µmol $CO_2 \cdot m^{-2} \cdot s^{-1}$
Tabela 3. Intensywność fotosyntezy w liściach kostrzewy czerwonej na początku października w roku siewu, µmol $CO_2 \cdot m^{-2} \cdot s^{-1}$

Cultivar Odmiana (O)	2004						2005					
	Method/time of sowing – Sposób/termin siewu (S)											
	spring – wiosenny		summer – letni			mean średnia	spring – wiosenny		summer – letni			mean średnia
	pure czysty	undersown crop wsiewka	middle of July połowa lipca	end of July koniec lipca	middle of August połowa sierpnia		pure czysty	undersown crop wsiewka	middle of July połowa lipca	end of July koniec lipca	middle of August połowa sierpnia	
Mirena	23.0	17.4	24.4	31.5	24.5	24.2	2.5	11.9	8.1	12.3	–	8.7
Womira	22.9	21.6	24.7	27.8	18.3	23.1	2.7	10.9	8.7	15.6	–	9.5
Nista	23.5	24.3	23.1	22.3	18.9	22.4	3.5	5.1	5.2	10.9	–	6.2
Średnia – Mean	23.1	21.1	24.1	27.2	20.6	23.2	2.9	9.3	7.3	12.9	–	–
LSD – NIR for – dla:												
year – roku 2004	S 6,47	O 4,08	S x O 10,23	O x S 9,12								
year – roku 2005	S 5,02	O 2,89	S x O 6,44	O x S 5,79								

In the first production year, on the basis of sward height measurement at the beginning of vegetation it was indicated that on average for all the times and ways of sowing, Nista was higher than Womira, and the chewing cultivar Mirena was the lowest (Table 4). In pure stand in spring and summer the differences in height between cultivars were non-significant, while with barley as a cover crop, the cultivar Nista was higher than Mirena and Womira. This may indicate a higher usefulness of *Festuca rubra* L. ssp. *rubra* for sowing with a cover crop as compared with ssp. *trichophylla* or ssp. *commutata*. Huylenbroeck and Bockstaele [1999] claim that creeping cultivars of red fescue have a low light compensation point (LCP). Therefore, their growth can be intensive also under conditions of a lower photosynthetically active light intensity.

Table 4. Sward height at the beginning of growth in the first production year, cm (mean from 2005-2006)

Tabela 4. Wysokość runi w czasie ruszenia wegetacji w pierwszym roku pełnego użytkowania, cm (średnia z lat 2005-2006)

Cultivar Odmiana (O)	Method/time of sowing – Sposób/termin siewu (S)					Mean Średnia
	spring – wiosenny		summer – letni			
	pure czysty	undersown crop wsiewka	middle of July połowa lipca	end of July koniec lipca	middle of August połowa sierpnia	
Mirena	10.0	12.7	7.0	7.0	3.3	8.0
Womira	11.0	14.3	7.8	6.7	4.3	8.8
Nista	12.0	18.0	9.0	7.3	3.7	10.0
Mean – Średnia	11.0	15.0	7.9	7.0	3.8	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: S 1,53 O 0,75 S x O 2,03 O x S 1,68						

In the present study, the creeping cultivar Nista, in contrast to the chewing Mirena, had slightly darker leaves and was characterized by a higher chlorophyll content index (CCI), although the differences were not always proved statistically (Tables 1, 2, 5, 6). The opposite results were presented by Goliński and Xi [2000], who found the highest chlorophyll content in the cultivar Bargreen, which belongs to *Festuca rubra* L. ssp. *commutata.* Also Martiniello and D'Andrea [2006] reported that this subspecies had a darker color in spring and autumn as compared with ssp. *rubra* and *trichophylla*. Domański [2006 and 2007] points to a high varietal differentiation of leaf color among subspecies of *Festuca rubra* L. In creeping red fescue (ssp. *commutata*) the leaf color determined in 9^o scale ranged from 2 to 7. In short creeping forms (ssp. *trichophylla*) this was from 1 to 4, and in those creeping (ssp. *rubra*) from 3 to 5. The color of the creeping cultivar Nista in moderately intensive utilization was determined as vivid green (5^o).

Table 5. Leaf greenness index of red fescue at the beginning of growth in the first production year, SPAD (mean from 2005-2006)
Tabela 5. Indeks zieloności liścia kostrzewy czerwonej w czasie ruszenia wegetacji w pierwszym roku pełnego użytkowania, SPAD (średnia z lat 2005-2006)

Cultivar Odmiana (O)	Method/time of sowing – Sposób/termin siewu (S)					Mean Średnia
	spring – wiosenny		summer – letni			
	pure czysty	undersown crop wsiewka	middle of July połowa lipca	end of July koniec lipca	middle of August połowa sierpnia	
Mirena	9.58	8.18	9.28	6.69	6.37	8.02
Womira	7.46	8.45	9.64	12.32	10.35	9.64
Nista	6.64	10.28	10.77	11.40	9.73	9.76
Mean – Średnia	7.90	8.97	9.90	10.14	8.82	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: S 3,048 O 1,272 S x O 3,885 O x S 2,845						

In the first production year at the beginning of growth and at flowering of red fescue (in the middle of June) no effect of the method and time of sowing on the SPAD value was found (Tables 5 and 6). In early spring, the leaf greenness index of the cultivar Mirena in August sowing and at the end of July was significantly lower than those of Womira and Nista (Table 5). Similar differences, although statistically non-significant, occurred in the variant of spring sowing with barley and that from the middle of July. In this period, in spring pure sowing, Mirena had a significantly higher chlorophyll content index than Nista, and in June, also as compared with the cultivar Womira (Tables 5 and 6).

Table 6. Greenness index of red fescue flag leaf in the middle of June in the first production year, SPAD (mean from 2005-2006)
Tabela 6. Indeks zieloności liścia flagowego kostrzewy czerwonej w połowie czerwca w pierwszym roku pełnego użytkowania, SPAD (średnia z lat 2005-2006)

Cultivar Odmiana (O)	Method/time of sowing – Sposób/termin siewu (S)					Mean Średnia
	spring – wiosenny		summer – letni			
	pure czysty	undersown crop wsiewka	middle of July połowa lipca	end of July koniec lipca	middle of August połowa sierpnia	
Mirena	25.4	22.3	23.4	25.8	21.9	23.7
Womira	21.6	19.2	23.9	23.4	23.6	22.4
Nista	22.8	26.5	24.5	25.2	24.4	24.7
Mean – Średnia	23.2	22.7	23.9	24.8	23.3	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: S 4,87 O 1,04 S x O 4,98 O x S 2,32						

The photosynthesis rate of the flag leaf of red fescue was relatively small (Table 7), which may indicate the essential role of the panicle as a source of assimilates for developing grains. The measurement of photosynthesis, on average for methods and times of sowing, showed the lowest intensity of this process in Womira. The creeping cultivar Nista showed a high activity of CO_2 assimilation in sowings which were delayed until the end of July and the middle of August, while in Mirena – this value was high in spring sowing. Photosynthesis rate, on average for cultivars, was the highest in

fescue sown at the end of July. The fescue from spring pure sowing was characterized by a very low intensity. There was also the largest number of generative shoots in this sowing variant (unpublished data), but a high chlorophyll content (Table 6) indicates the sufficient light intensity. The reason for photosynthesis limitation was presumably a water deficit in conditions of June drought in both research years, which was higher than in the other sowing variants.

Table 7. Photosynthesis rate in the flag leaf of red fescue in the middle of June in the first production year, μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$ (mean from 2005-2006)

Tabela 7. Intensywność fotosyntezy w liściu flagowym kostrzewy czerwonej w połowie czerwca w pierwszym roku pełnego użytkowania, μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$ (średnia z lat 2005-2006)

Cultivar Odmiana (O)	Method/time of sowing – Sposób/termin siewu (S)					Mean Średnia
	spring – wiosenny		summer – letni			
	pure czysty	undersown crop wsiewka	middle of July połowa lipca	end of July koniec lipca	middle of August połowa sierpnia	
Mirena	8.7	12.3	14.9	12.5	9.7	11.6
Womira	7.1	8.2	7.3	13.0	9.8	9.1
Nista	7.9	12.2	10.1	16.2	12.4	11.7
Mean – Średnia	7.9	10.9	10.8	13.9	10.6	–
$NIR_{0,05}$ – $LSD_{0.05}$ dla – for: S 1,51 O 0,996 S x O 2,46 O x S 2,28						

CONCLUSION

Spring barley applied as a cover plant reduced the chlorophyll content and development of red fescue in the year of establishment. The red fescue sown at the end of July developed as that from sowing at the beginning of that month. A delay of sowing until the middle of August resulted in a reduction of tillering, plant height and photosynthesis rate in the year of establishment, and also of the flag leaf in the first production year. The creeping cultivar Nista was characterized by a high chlorophyll content index and a fast growth rate. The turf of this cultivar at the beginning of vegetation in the first production year with barley as a cover crop was higher than that of the chewing Mirena and short creeping Womira, which may indicate a higher usefulness of this cultivar for sowing with a cover crop.

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WPŁYW SPOSOBU I TERMINU SIEWU NA WZROST, ROZWÓJ, ZAWARTOŚĆ CHLOROFILU ORAZ INTENSYWNOŚĆ FOTOSYNTEZY *Festuca rubra* L. SSP. *commutata*, *trichophylla*, *rubra* W ROKU SIEWU I PIERWSZYM ROKU UŻYTKOWANIA W UPRAWIE NA NASIONA

Streszczenie. Badania wykonano w Stacji Oceny Odmian w Chrząstowie (53°09' N; 17°35' E). Ich celem była ocena wpływu rośliny ochronnej oraz terminów siewu (wiosennego i letniego) na wzrost i rozwój, zawartość chlorofilu oraz intensywność fotosyntezy trzech podgatunków kostrzewy czerwonej (ssp. *rubra*, *trichophylla* i *commutata*) w pierwszym i drugim roku wegetacji. Jęczmień jary miał negatywny wpływ na indeks zieloności liścia i rozwój wsiewki kostrzewy czerwonej w roku siewu. Kostrzewa czerwona wysiewana w końcu lipca rozwijała się podobnie jak z zasiewu na początku

tego miesiąca. Opóźnienie siewu do połowy sierpnia spowodowało ograniczenie krzewistości i wysokości roślin oraz intensywności fotosyntezy najmłodszych liści w roku siewu i liścia flagowego w pierwszym roku pełnego użytkowania. Szybkie tempo wzrostu rozłogowej odmiany Nista może wskazywać na jej większą przydatność do zasiewu z rośliną ochronną niż kępowej odmiany Mirena i krótkorozłogowej Womiry.

Słowa kluczowe: chlorofil, fotosynteza, kępowa, rozłogowa, krótkorozłogowa kostrzewa czerwona

Accepted for print – Zaakceptowano do druku: 27.02.2009