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PRODUCTIVITY OF SELECTED GRASSES IN MIXTURES WITH *TRIFOLIUM REPENS* L. AT TWO LEVELS OF NITROGEN FERTILIZATION

BEATA GRYGIERZEC

Department of Grassland Management, Institute of Plant Production
University of Agriculture in Krakow

rrgolab@cyf-kr.edu.pl

Abstract. The paper contains a compilation of results of field research conducted in 2007–2009 at the Plant Breeding Station-HBP in Skrzeszowice near Krakow (220 m a.s.l.). The investigations compared two grasses: hybrid ryegrass (Gala, c.v.) and perennial ryegrass (Solen c.v.) cultivated in mixtures with white clover (Romena c.v.) sown 50% each. Grasses in mixtures were evaluated against the background of diversified nitrogen fertilization rates of 50 and 100 kg N·ha^{-1}. The aim of the investigations was comparison of hybrid ryegrass and perennial ryegrass in view of gas exchange, chlorophyll level in leaves and yielding of two-species mixtures at two levels of mineral nitrogen fertilization. During the three-year period of investigations the hybrid ryegrass revealed greater intensiveness of photosynthesis and transpiration, as well as higher average number of chlorophyll pigments than perennial ryegrass. Both grasses assimilated best in the second and third re-growths at the rate of 50 kg N·ha^{-1}. Increasing the rate to 100 kg N·ha^{-1} caused a decline in photosynthesis. The lowest SPAD values were noted in plants fertilized with nitrogen dosed 50 kg N·ha^{-1} and in the second place in plants from the control treatments. Higher values of this index were assessed in plants fertilized with a higher nitrogen dose. A mixture of white clover with hybrid ryegrass yielded better than the mixture with perennial ryegrass. Nitrogen fertilization had a significant effect on mixture yielding during the vegetation season only when applied at the rate of 100 kg N·ha^{-1}.

Key words: *Lolium x boucheanum*, *Lolium perenne*, *Trifolium repens, mixtures, fertilization, productivity*

INTRODUCTION

Field cultivation of grasses is one of cheaper sources of forage acquisition, constituting an important element of crop rotation in sustainable agriculture. It is also justified on farms with inadequate share of permanent grasslands in forage balance for ruminants. Grasses leave a good site for many consecutive crops, abundant in organic matter which remains from harvest residue [Kryszak 2003, Peoples 2001]. Species properly matched to the site conditions are able to secure high yields of green fodder, which may be fed directly or destined for production of hay, ensilaged hay or dehydrated forage, depending on the farm fodder needs. Perennial ryegrass and hybrid ryegrass belong to the best productive grass species, most often used in field mixtures. In order to improve the fodder quality and at the same time decrease the high costs of nitrogen fertilization, it is recommended to cultivate grasses in mixtures with legumes [Høgh-Jensen et al. 2004, Søegaard et al. 2007, Staniak 2008]. In comparison with monocropping such mixtures are characterized by a higher and more stabile level of yielding, higher concentration of energy and more balanced protein to energy components ratio [Borowiecki 2008, Gaweł 2011, Kessler and Lehmann 1998]. So far perennial ryegrass with white clover mixture was the subject of

numerous papers [Olszewska 2007]. However, there is much less information about cultivation of hybrid ryegrass with white clover.

Therefore, the investigations were conducted to compare hybrid ryegrass and perennial ryegrass cultivated in mixtures with white clover, considering gas exchange, chlorophyll level in leaves and yielding at two levels of mineral nitrogen fertilization.

MATERIALS AND METHODS

The investigations were conducted in 2007–2009 at the farm of Plant Breeding Station – HBP located in Skrzeszowice (50°20′ N, 20°15′ E) village about 30 km north-east from Krakow (220 m a.s.l.), on degraded chernozem formed from loess. The soil chemical properties were as follows: pH_{KCl} – 6.9; available P – 51.0, K – 86.0 and Mg – 24.0 mg·kg^{-1} of soil; organic N – 1.5 and total carbon – 12.4 g·kg^{-1} of soil.

The experiment was set up by means of randomised block method in four replications, the area of each plot was 12 m^2 (3 x 4).

Analyzed were two grasses: hybrid ryegrass (tertaploid Gala cultivar) and perennial ryegrass (tetraploid Solen cultivar) grown in mixtures with white clover (Romena c.v.) sown 50% of each. Grasses in mixtures were evaluated against the background of diversified nitrogen fertilization at the rates of 50 and 100 kg N·ha^{-1} applied twice: early in spring and after first cut, each dose was applied in equal parts, as 34% ammonium nitrate. Also 35 kg P g·ha^{-1} of phosphorus was used for fertilization in the form of triple superphosphate (46% P_2O_5). It was applied once in spring. Potassium was applied at the rate of 83 kg K g·ha^{-1} in the form of high percentage potassium salt (60% K_2O), in two equal doses early in spring and after the first cut.

Intensiveness of photosynthesis and grass leaves transpiration were measured using a portable gas analyzer Li-Cor 5400. The indices were assessed at constant CO_2 concentration (400 ppm) at lighting 1000 µmol·m^{-2}·s^{-1}. Moreover, chlorophyll content in leaves was measured using chlorophyll meter SPAD-502. The measurements were made on the youngest but fully developed leaves, which were selected at random from each plot. Four measurements were conducted in each re-growth at one-week intervals. The plants were cut thrice during the vegetation season. Harvested biomass was weighted in order to determine dry mass yield, then 1 kg sample was dried at the temperature of 105°C to constant weight. Obtained results were verified statistically by means of ANOVA using Statistica 6.0 application. Significance of differences was verified by means of Tukey's test on the confidence level p=0.05.

Annual precipitation total during the period of investigations ranged from 608.8 and 856.4 mm, whereas precipitation total for the six months (April–September) fell within the range from 387.1 to 539.9 mm. Average annual temperature reached the values of 8.8–9.8°C and between 15.2–16.1°C during the vegetation season.

The paper presents a compilation of average results from the field experiment lasting for three vegetation periods in 2007–2009.

RESULTS AND DISCUSSION

Average share of white clover cultivated in mixtures with hybrid ryegrass and perennial ryegrass was mainly dependant of the applied nitrogen fertilization rate and the year of cultivation (Fig. 1). The lowest amount of white clover was noted in the objects receiving the maximum nitrogen rate in every year of the investigations, whereas the highest on the control objects in the

second year of the experiment. Clover quantity in the sward was also affected by the grass used in the mixture. Both hybrid and perennial ryegrass revealed a high competitiveness in displacing other sward components.

Intensiveness of photosynthesis in leaves of the analysed grass species was diversified and depended on fertilization level (Tab. 1). Perennial ryegrass cultivated in the mixture with white

Table 1. Mean intensity of photosynthesis of the grasses (μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$)

Mixture	N fertilization ($kg \cdot ha^{-1}$)	1st regrowth	2st regrowth	3st regrowth	Mean
Lolium x boucheanum + *Trifolium repens*	0	16.4	17.2	14.7	16.1
	50	14.8	20.1	18.5	17.8
	100	14.1	18.6	15.0	15.9
Lolium perenne + *Trifolium repens*	0	15.3	11.5	10.7	12.5
	50	13.5	17.3	15.5	15.5
	100	12.8	12.1	11.6	12.2
$LSD_{0.05}$		2.8	2.6	2.4	3.4

clover revealed a lesser intensity of photosynthesis than hybrid ryegrass in all re-growths. Average intensity of photosynthesis in perennial ryegrass leaves was 13.4 μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$, while in hybrid ryegrass leaves it was 20% higher, i.e. 16.6 μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$. On average for three years of the investigations, the highest intensity of photosynthesis characterized hybrid ryegrass on all objects in the second cut and perennial ryegrass in the first cut on the control and the object receiving maximum nitrogen fertilization. Moreover the highest photosynthesis intensity was registered in leaves of perennial ryegrass fertilized with a lower nitrogen dose in the second cut. Research conducted by Olszewska [2003, 2009] showed that photosynthesis process was the most intensive in grasses of the second re-growth, which has been partially confirmed by the Author's own research.

Application of lower nitrogen fertilization rate in case of the analyzed grass species, significantly influenced photosynthesis process in the second and third re-growth. Both hybrid and perennial ryegrass in the second and third re-growth were most intensively assimilating at the rate of 50 kg $N \cdot ha^{-1}$. Increasing the dose to 100 kg $N \cdot ha^{-1}$ caused a decline in photosynthesis. However, no significant differences were noticed between the plants originating from the control and objects fertilized with nitrogen at the rate of 100 kg $N \cdot ha^{-1}$.

During the three-year period of investigations hybrid ryegrass cultivated in the mixture with white clover revealed a higher average intensity of transpiration than perennial ryegrass (Tab. 2). During the period of presented research, grasses on the control objects evaporated the greatest amounts of water per leaf area unit in the first and third re-growth, and then the plants fertilized with a lower nitrogen dose. Increase in nitrogen fertilization to 100 kg $N \cdot ha^{-1}$ reduced water evaporation in case of both analyzed grass species in each re-growth. Under the influence of higher nitrogen dose, grasses of the second re-growth were characterised by a higher intensity of transpiration than plants from the control objects. Limiting water evaporation from leaf area unit

Table 2. Mean intensity of transpiration of the grasses (m mol $H_2O \cdot m^{-2} \cdot s^{-1}$)

Mixture	N fertilization ($kg \cdot ha^{-1}$)	1st regrowth	2st regrowth	3st regrowth	Mean
Lolium x boucheanum + *Trifolium repens*	0	5.12	3.59	8.14	5.62
	50	2.43	7.15	7.65	5.74
	100	1.97	6.42	4.08	4.16
Lolium perenne + *Trifolium repens*	0	4.35	3.16	4.69	4.07
	50	3.69	6.38	4.17	4.75
	100	3.24	5.49	3.52	4.08
$LSD_{0.05}$		1.33	2.35	2.54	3.05

under the influence of nitrogen fertilization was also demonstrated by Olszewska [2005, 2007]. On the other hand Piotrowska et al. [2003] did not confirm any significant effect of nitrogen fertilization on the intensity of grass transpiration.

Measurements of chlorophyll content in leaves index revealed that hybrid ryegrass had a higher average amount of chlorophyll pigments than perennial ryegrass (Tab. 3). Chlorophyll level in leaves during vegetation period was variable but the changes did not have any uniform character. Moreover, considerable diversification of chlorophyll content in grass leaves of the individual re-growth was also demonstrated by Gáborčik [1997], Kozłowski et al. [2001] and Goliński and Xi [2000].

Table 3. Leaf greenness index of the grasses (SPAD) in 2007–2009

Mixture	N fertilization ($kg \cdot ha^{-1}$)	1st regrowth	2st regrowth	3st regrowth	Mean
Lolium x oucheanum + *Trifolium repens*	0	32.9	31.5	37.8	34.1
	50	34.3	30.9	35.7	33.6
	100	37.4	35.7	38.2	37.1
Lolium perenne + *Trifolium repens*	0	34.3	33.5	36.2	34.6
	50	31.5	27.9	35.8	31.7
	100	36.7	30.6	38.7	35.3
$LSD_{0.05}$		4.7	3.4	6.2	2.5

On average, during the Author's own three-year investigations, the lowest values of SPAD were registered in grasses fertilized with nitrogen dosed 50 kg $N \cdot ha^{-1}$, in the next place in grasses from the control. Generally higher values of this index were assessed in plants fertilized with a higher nitrogen dose.

The first re-growth had the highest total share in sward dry mass yield in the individual re-growths for the three years of the experiment, between 54 and 58% in the hybrid ryegrass and white clover mixture, and between 53 and 56% in the perennial ryegrass with white clover mixture (Fig. 2). Average total dry mass yield from individual objects was higher for the mixture of hybrid ryegrass with white clover, constituting between 7.47 and 17.6 $t \cdot ha^{-1}$, whereas for the mixture of perennial ryegrass with white clover from 6.53 to 14.5 $t \cdot ha^{-1}$.

CONCLUSIONS

1. During the period of three-year investigations hybrid ryegrass revealed a higher intensity of photosynthesis and transpiration and higher average quantity of chlorophyll pigments than perennial ryegrass.
2. In the second and third re-growth both hybrid and perennial ryegrass were assimilating best at the fertilization rate of 50 $N \cdot ha^{-1}$. Increasing the dose to 100 $kg \cdot ha^{-1}$ caused a decline in photosynthesis.
3. The lowest SPAD values were registered in plants fertilized with nitrogen at the rate of 50 $kg \cdot ha^{-1}$ and in the second place in plants from the control. Higher values of this index were assessed in plants fertilized with a higher nitrogen dose.
4. A mixture of white clover with hybrid ryegrass produced larger yields than its mixture with perennial ryegrass. Nitrogen fertilization only at the rate of 100 $kg \cdot ha^{-1}$ significantly affected the mixture yields in the vegetation season.

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B. Grygierzec

PRODUKCYJNOŚĆ WYBRANYCH TRAW W MIESZANKACH Z *TRIFOLIUM REPENS* L. PRZY DWÓCH POZIOMACH NAWOŻENIA AZOTEM

Synopsis. Praca zawiera zestawienie wyników badań polowych przeprowadzonych w latach 2007–2009 w Stacji Małopolskiej Hodowli Roślin-HBP w Skrzeszowicach koło Krakowa (220 m n.p.m.). W badaniach porównywano dwie trawy życicę mieszańcową (odmianę Gala) oraz życicę trwałą (odmianę Solen) uprawiane w mieszankach z koniczyną białą (odmianą Romena) w zasiewie po 50%. Trawy w mieszankach oceniano na tle zróżnicowanego nawożenia azotem w dawkach 50 i 100 kg N·ha^{-1}. Celem podjętych badań było porównanie życicy mieszańcowej i życicy trwałej pod względem wymiany gazowej, poziomu chlorofilu w liściach oraz plonowania dwugatunkowych mieszanek przy dwóch poziomach nawożenia azotem mineralnym. W okresie trzechletnich badań życica mieszańcowa wykazywała większą intensywność fotosyntezy i transpiracji oraz wyższą średnią ilością barwników chlorofilowych niż życica trwała. Obie badane trawy w odrostach drugim i trzecim najlepiej asymilowały przy dawce 50 kg N·ha^{-1}. Zwiększenie dawki do 100 kg N·ha^{-1} spowodowało spadek fotosyntezy. Najmniejsze wartości SPAD stwierdzono w roślinach nawożonych azotem w dawce 50 kg N·ha^{-1}, następnie w roślinach z obiektów kontrolnych. Większe wartości tego wskaźnika oznaczono w roślinach nawożonych wyższą dawką azotu. Mieszanka koniczyny białej z życicą mieszańcową plonowała wyżej niż mieszanka z życicą trwałą. Istotny wpływ na plonowanie mieszanek w sezonie wegetacyjnym wywierało nawożenie azotem tylko w dawce 100 kg N·ha^{-1}.

Słowa kluczowe: *Lolium x boucheanum*, *Lolium perenne*, *Trifolium repens,* mieszanki, nawożenie, produkcyjność