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ROOTING PROPERTIES OF LAWN GRASSES ESTABLISHED ON THE BASIS OF RED FESCUE IN THE ASPECT OF THE APPLIED HYDROGEL

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Abstract. The study was carried out on the basis of two lawn experiments, which were founded in the split-block split-plot with four replications. The experimental unit was a plot with an area of 1 m^2. For investigate purposes was detailed the kind of the lawn and was called it as monoculture (pure sowing) and-mixed. The criterion for the division of mixtures was sharing of red fescue in sowing. In pure sowing were studied four cultivars of red fescue: Adio, Libano, Corail, Simone. In the, monoculture's and mixtures experiment were examined the following factors: the type of subsoil with the addition of hydrogel Aqua-gel P4 (H) and without the addition of the hydrogel Aqua-gel P4 (BH), years of study (2003-2004). In the conducted experiments moderately intensive care (so-called Relax) was used. At the end of each growing period in all plots from selected places chosen in a random way, the samples of turf with the root system were taken. In this study applied the hydrogel (Aqua-gel P4) caused an increase in root biomass in both in the monoculture turf of tested red fescue cultivars and in mixtures. Among the tested cultivars of red fescue the greatest root biomass in years of study produced the Polish cultivar Adio, and from mixtures, only those that had in its composition of 60 and 80% red fescue. The action of the hydrogel to produce turf root biomass was particularly significant, when in the summer 2004 drought occurred. It may indicate its beneficial effects particularly in situations of water shortages in the soil.

Key words: *Festuca rubra*, lawn, lawn mixture, red fescue cultivars, root biomass, rooting

INTRODUCTION

The root zone of grass sites is constantly enriched with mineral and organic components as a result of processes of root growth, their dying and decomposition. The yearly production of underground biomass of grass sites is sometimes 2- to 3 times higher than the aboveground production [Fiala 1997]. The underground root biomass is

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the main source of organic matter and bio-components in grass ecosystems. The mentioned processes, such as biomass production and decomposition, are of particular importance in grass ecosystems and always constitute their most essential characteristic feature [Rychnovská 1983]. The biomass of underground plant organs is also considered as an important component of grass ecosystems – both structural and functional [Fiala 1997]. Grass communities are very sensitive to intensive utilization, such as frequent cutting. This also has an effect on changes in the amount of root biomass (mainly on its reduction) and the distribution of roots in the soil profile [Pielota and Smucker 1995]. Distribution of grass and legume roots in the soil profile shows considerable deviations, but generally, the main root mass is placed in the layer up to 20 cm [Falkowski *et al.* 1994].

Utilization has an essential role in forming the root system. An increase in utilization intensity causes a reduction in the root mass and moving to the upper layer. At grazing, 90% of the root mass can be placed in the layer 0-7 (to 10 cm), and at cutting – on the level 0-15 (to 20 cm) of the profile. According to Pechačkov and Krahulec [1995] the total underground biomass of roots is sometimes almost two times higher on pastures than on regularly cut meadows. In the growing period, a large variability of mass and distribution of roots in the soil profile occurs. Reduction of root mass in the summer – in the period of grass flowering – is a natural phenomenon, independent of the current site factors, and connected with a reduction in growth of new roots and increased dying of the old ones [Rychnovská 1983].

Moreover, the root biomass has a large importance as the most essential element stabilizing sodded grounds. Grasses reduce a negative effect of erosion, since they create the strong root system, they form dense and compact turf [Domański 1995, Kozłowski *et al.* 2000, Frey and Mizianty 2006, Wolski *et al.* 2006, Frey 2007, Karczewska 2008]. In the sod process (which takes place under the influence of grass plants; it is characterized by the predominance of accumulating organic matter in the top layer over the process of mineralization), the proper development of the fibrous root system is the basic element stabilizing the substrate horizontally and vertically. Roots of grasses are usually placed horizontally, buy they also form a strongly developed and deep, orthotropically owo distributed root mass (plant growth, expressed by assuming the vertical position) [Wolski *et al.* 2006, Frey 2007].

Knowledge about active, live roots and their distribution in the soil profile of various sites provides significant data for comparing different sites from the point of view of their stability. This is also important from the aspect of various events taking place in the given habitat. From the studies by Harkot and Czarnecki [1998] it follows that pratotechnical and weather factors have a large effect on forming the root mass of grasses. One of them may be the application of hydrogel. However, there is no data in the literature concerning the effect of hydrogel placed in the substrate on the amount of root mass of lawn turfs, e.g. established on the basis of red fescue. Hydrogels (also often called agrogels) are the so-called superabsorbents, characterizing by the ability to absorb water, sorption of cations and affecting the improvement of soil physical properties. They are used in various kinds of crops, mainly in horticulture.

The aim of this study was to estimate the effect of hydrogel on the intensity of rooting of lawn turfs, both in monoculture and established on the basis of four varied lawn mixtures.

MATERIAL AND METHODS

The study was carried out based of two lawn experiments, which were established in the split-block split-plot design in four replications. The experiment was conducted at the research station of the University of Natural Sciences and Humanities in Siedlce in 2002-2004 (52°16' N; 22°28' E). The experimental unit was a plot with an area of 1 m^2. Mixtures were planned for research needs, with the composition given in Table 1. The criterion for division of the mixtures was the share of red fescue in sowing. Four cultivars of red fescue were studied in monoculture (pure) sowing: Adio, Libano, Corail, Simone.

Table 1. Species-cultivars composition of lawn mixtures studied in the experiment (own design)
Tabela 1. Skład gatunkowo-odmianowy badanych w doświadczeniu mieszanek trawnikowych (projekt własny)

Name of mixture Nazwa mieszanki	Species – Gatunek	Share Udział %	Cultivar Odmiana
M1	Red fescue – Kostrzewa czerwona *Festuca rubra*	20	Adio
	Perennial ryegrass – Życica trwała *Lolium perenne*	20	Inka
	Sheep's fescue – Kostrzewa owcza *Festuca ovina*	20	Noni
	Heteroleaf fescue – Kostrzewa różnolistna *Festuca heterophylla*	20	Sawa
	Common bent – Mietlica pospolita *Agrostis tenuis*	20	Niwa
M2	Red fescue – Kostrzewa czerwona *Festuca rubra*	40	Adio
	Perennial ryegrass – Życica trwała *Lolium perenne*	15	Inka
	Sheep's fescue – Kostrzewa owcza *Festuca ovina*	15	Noni
	Heteroleaf fescue – Kostrzewa różnolistna *Festuca heterophylla*	15	Sawa
	Common bent – Mietlica pospolita *Agrostis tenuis*	15	Niwa
M3	Red fescue – Kostrzewa czerwona *Festuca rubra*	60	Adio
	Perennial ryegrass – Życica trwała *Lolium perenne*	10	Inka
	Sheep's fescue – Kostrzewa owcza *Festuca ovina*	10	Noni
	Heteroleaf fescue – Kostrzewa różnolistna *Festuca heterophylla*	10	Sawa
	Common bent – Mietlica pospolita *Agrostis tenuis*	10	Niwa
M4	Red fescue – Kostrzewa czerwona *Festuca rubra*	80	Adio
	Perennial ryegrass – Życica trwała *Lolium perenne*	5	Inka
	Sheep's fescue – Kostrzewa owcza *Festuca ovina*	5	Noni
	Heteroleaf fescue – Kostrzewa różnolistna *Festuca heterophylla*	5	Sawa
	Common bent – Mietlica pospolita *Agrostis tenuis*	5	Niwa

The monoculture and mixture experiments were conducted in the culture-earth soil of the hortisole type, using two kinds of substrate: 1) with an addition of hydrogel (H), 2) without hydrogel (BH). Hydrogels are multi-particle, net-like, insoluble polymers.

Moderately intensive cultivation (the so-called Relax) was applied in the experiments, that is without irrigation, with a moderate mineral fertilization. Nutrients necessary for the proper growth and development of grasses, were provided in the form of a mineral slow-release fertilizer. It was applied in accordance with the instruction given on the packaging at a rate of 50 $g \cdot m^{-2}$, mixing it with the top soil layer at a depth of 5-10 cm. At the end of each growing period, turf samples were collected along with the root system with 3 randomly selected places from all the tested plots. In order to do that, a steel sampler was used (a cylinder pointed at the bottom part, with a diameter of

5 cm and a length of 15 cm), which was stuck at a depth of 10 cm, and then the sample of turf (together with the cylinder) was removed from the soil using a special handle at the upper part of the cylinder.

On the basis of the collected samples of turf in each research year the assessment of root dry biomass was made based on the method of root system research [Böhm 1985]. Previously washed and cleaned roots were dried in a dryer at 105^{o}C until the time of obtaining the constant root mass, and then the root dry biomass was calculated for individual lawn turfs.

Meteorological data of 2003-2004 was obtained from the Hydrological and Meteorological Station in Siedlce. To estimate the temporal and spacial variability of meteorological elements and assess their impact on the course of plant growing, the Sielianinov hydrothermal coefficient was calculated [Bac *et al.* 1993], dividing the total monthly precipitation by one tenth of the total mean daily temperatures for the given month.

The results obtained were worked out statistically using the analysis of variance suitable for the split-block split-plot design. For significant sources of variability (factors and interaction) a detailed comparison of the means was made with Tukey's test at the significance level $P \leq 0.05$ [Trętowski and Wójcik 1992].

RESULTS AND DISCUSSION

Lawn grasses differ in their resistance to drought, the ability to uruchamiania nutrients from soils and response to fertilization [Falkowski *et al.* 1994], which indicates the fact that roots play an important role in adapting plants to stressful conditions. The root system is one of important factors determining the survival of plants under conditions of drought [Böhm 1985].

Concerning the response of individual cultivars to the used hydrogel (Fig. 1) it was observed that on plots with its addition, a larger dry biomass of roots (on average from the years) was made by the cultivars Adio (276.9 g·m^{-2}) and Corail (271.8 g·m^{-2}). On the treatments without an addition of Aqua-gel P4 a considerably smaller root biomass was recorded for the cultivars Corail, Simone and Libano. Only the Polish culivar Adio formed more root dry biomass, which may indicate its highest resistance to the stress conditions (drought) among the tested cultivars.

Of the analysed lawn grass mixtures (on average from the years) mixtures M4 and M3 were characterized by the largest dry root biomass on the treatments with hydrogel (Fig. 2). It was larger, by 38 and 37%, respectively, than from the treatments without hydrogel.

On the basis of the present study it was found that the amount of the root biomass of mixture lawns was significantly determined by the years of the study, and particularly the current meteorological conditions (Table 2) and the applied hydrogel (Table 3).

It was shown that in 2004 the mean root biomass was significantly higher than in 2003, respectively, for monoculture sowings by 95.6 g·m^{-2}, and for mixtures by 97.3 g·m^{-2}. In 2003 on plots with hydrogel the red fescue cultivars obtained the root biomass significantly higher by 21 g·m^{-2} (11%), and in 2004 by as much as 102.9 g·m^{-2} (31.7%). On average from the years of the study, an addition of Aqua-gel P4 resulted in an increase in the root mass by 62.4 g·m^{-2} (24.3%) for red fescue cultivars, and by 56.1 g·m^{-2} (27.6%) for mixtures.

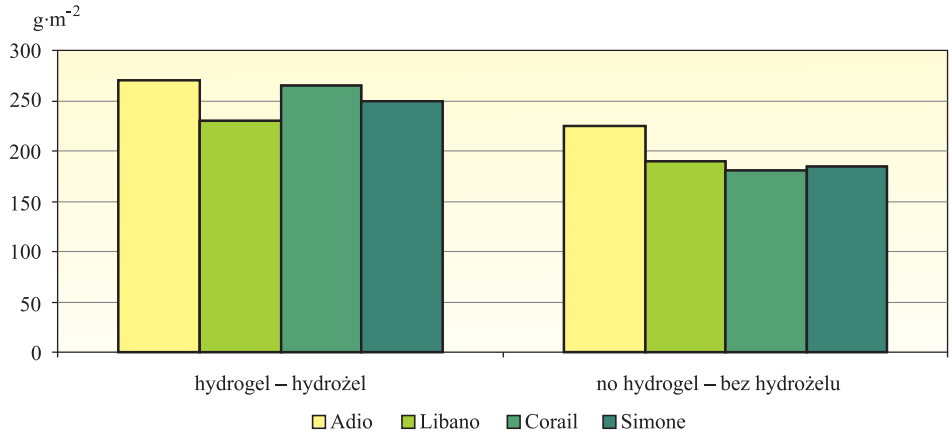
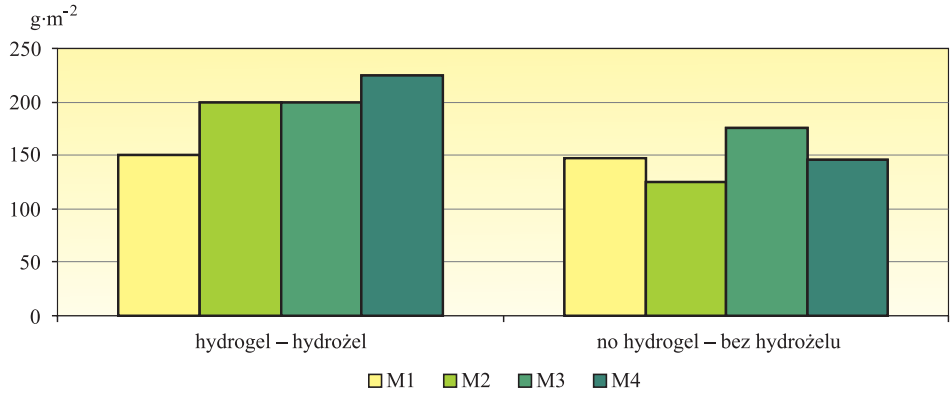


Fig. 1. Dry roots biomass for individual monoculture lawns depending on the used hydrogel (mean for 2003-2004)
Rys. 1. Sucha biomasa korzeni na poszczególnych trawnikach monokulturowych w zależności od zastosowanego hydrożelu (średnia z lat 2003-2004)



M1-M4 – for explanations see Table 1 – objaśnienia w tabeli 1

Fig. 2. Dry roots biomass for individual mixture lawns depending on the used hydrogel (mean for 2003-2004)
Rys. 2. Sucha biomasa korzeni na poszczególnych trawnikach mieszankowych w zależności od zastosowanego hydrożelu (średnia z lat 2003-2004)

A favorable effect of the application of superabsorbents on a growth in the root mass of different plants was found also in other studies [Hetman 1993, Hetman and Szot 1994, Hetman *et al.* 1998, Kościk and Kowalczyk-Juśko 1998].

Table 2. Hydrometrical Sielianinow indexes in individual months of growing seasons of 2003--2004

Tabela 2. Współczynnik hydrometryczny Sielianinowa w poszczególnych miesiącach okresów wegetacyjnych w latach 2003-2004

Month – Miesiąc						
April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	September wrzesień	October październik
2003						
1.30	0.67	1.22	0.72	1.10	0.92	2.78
2004						
1.58	2.29	0.96	0.99	1.20	0.44	1.05

to 0.5 – high drought – do 0,5 – silna posucha, 0.51-0.69 – drought – posucha, 0.70-0.99 – week drought – słaba posucha, over 1 – no drought – powyżej 1 – brak posuchy

Table 3. Dry root biomass on average for the tested lawns depending on the used hydrogel and years of study, $g \cdot m^{-2}$

Tabela 3. Sucha biomasa korzeni średnio dla badanych trawników w zależności od zastosowanego hydrożelu i lat badań, $g \cdot m^{-2}$

Year Rok	Kind of lawn – Rodzaj trawnika					
	monoculture – monokultura			mixture – mieszanka		
	BH	H	mean for years średnia dla lat	BH	H	mean for years średnia dla lat
2003	167.1	188.9	178.0	95.4	158.0	126.7
2004	222.1	325.0	273.6	199.3	248.8	224.0
Mean for hydrogel Średnia dla sorbentu	194.6	257.0	225.8	147.3	203.4	175.4
$LSD_{0.05} – NIR_{0,05}$ for – dla:						
	years – lat		12.9	years – lat		16.6
	hydrogel – hydrożelu		10.3	hydrogel – hydrożelu		13.2
	interaction – interakcji:					
	years × hydrogel – lata × hydrożel		14.6			

BH – without the addition of the hydrogel Aqua-gel P4 – bez dodatku hydrożelu
H – with the addition of hydrogel Aqua-gel P4 – z dodatkiem hydrożelu

Root biomass (Table 4) changed in the years of the study and depended significantly also on the cultivar of red fescue and the species composition of the mixture. The significantly highest root biomass was obtained by the Polish cultivar Adio (253.7 $g \cdot m^{-2}$). It dominated in the root biomass amount over the other cultivars both in the first and second year of the study. It belongs to cultivars forming the compact and strong root system. [List of cultivars... 1997]. In the case of mixtures of lawn grasses it was proved that a higher percentage share of seeds of the red fescue cultivar Adio guaranteed obtaining a higher root biomass. On average from the years of the study (Table 4) the significantly highest root biomass was found on the plots sown with the mixture with 60% of red fescue. The same tendency concerning the formation of root biomass occurred in 2003, whereas in 2004 the significantly highest root dry biomass was observed in the mixture with 80% of seeds of the red fescue cultivar Adio. Therefore, it can be concluded that under stress conditions (heavy drought which occurred in September 2004 – Table 2) a large proportion of this cultivar in mixture M4 affected its

better resistance, at the same time contributing to a more intensive development of the root system.

Table 4. Dry root biomass of individual cultivars of red fescue and its lawn mixtures in 2003--2004, $g \cdot m^{-2}$

Tabela 4. Sucha biomasa korzeni poszczególnych odmian kostrzewy czerwonej oraz jej mieszanek trawnikowych w latach 2003-2004, $g \cdot m^{-2}$

Year Rok	Kind of lawn – Rodzaj trawnika							
	monoculture – monokultura				mixture – mieszanka			
	Adio	Libano	Corail	Simone	M1	M2	M3	M4
2003	206.3	144.8	182.9	178.1	105.3	133.4	147.2	121.0
2004	301.0	274.2	267.8	251.3	217.6	199.2	234.7	244.6
Mean Średnia	253.7	209.5	225.3	214.7	161.4	166.3	190.9	182.8
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:								
varietes – odmian	32.2				mixtures – mieszanek			27.9
					interaction – interakcji:			
					years × mixtures – lata × mieszanki			39.5

The analysis of variance (Fig. 3) indicated the significance of interaction years × hydrogel × the red fescue cultivar. An addition of Aqua-gel P4 to the substrate contributed to an improvement in moisture conditions, which significantly affected an increase in root biomass only in the cultivars Corail and Simone. In 2004 all the cultivars grown on the plots with hydrogel demonstrated a significant growth in root biomass, but the Adio cultivar was characterized by the highest root biomass.

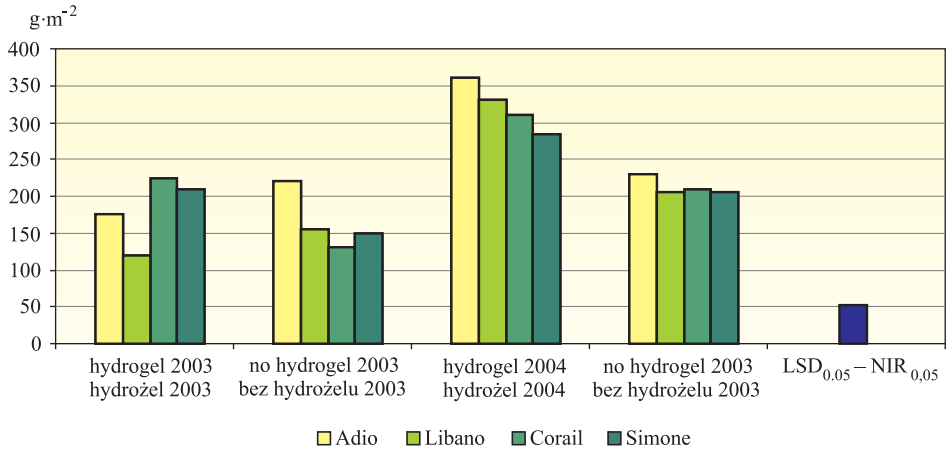


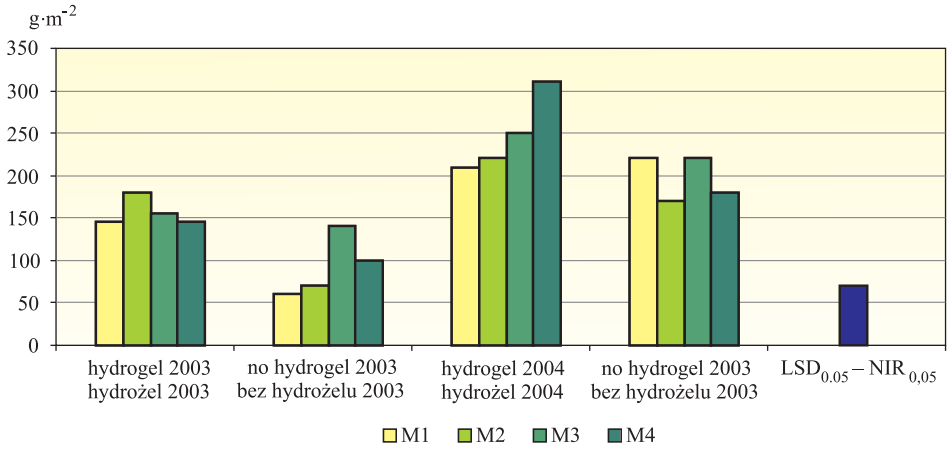
Fig. 3. Root biomass of individual red fescue cultivars depending on the used hydrogel in the years 2003-2004

Rys. 3. Biomasa korzeni poszczególnych odmian kostrzewy czerwonej w zależności od zastosowanego hydrożelu w latach 2003-2004

Statistical analysis showed the significance of interaction years × hydrogel × type of mixture also in relation to the root biomass formed by mixtures (Fig. 4).

On the basis of this data it can be concluded that the action of hydrogel became apparent particularly in 2004, causing a significant increase in root biomass in the case of the mixture with 80% of red fescue seeds.

In the literature on lawn turfs there is very few studies concerning the assessment of their root system. On account of this, the discussion of the results obtained refers to the literature determining explicitly this quality value.



M1-M4 – for explanations see Table 1 – objaśnienia w tabeli 1

Fig. 4. Root biomass of individual mixtures depending on the used hydrogel in the years 2003--2004

Rys. 4. Biomasa korzeni poszczególnych mieszanek w zależności od zastosowanego hydrożelu w latach 2003-2004

CONCLUSIONS

1. The applied hydrogel (Aqua-gel P4) caused an increase in root biomass both in monoculture turfs and in mixtures.

2. Of the tested red fescue cultivars, the largest root biomass was formed by the Polish cultivar Adio, and of mixtures, only those which contained 60 and 80% of red fescue.

3. The impact of hydrogel on forming the root biomass of lawn turfs was particularly visible in dry months in 2004, which can indicate its favorable effect, particularly in case of water deficit in the soil.

REFERENCES

Bac S., Koźmiński C., Rojek M., 1993. Agrometeorologia [Agrometeorology]. PWN Warszawa [in Polish].

Böhm W., 1985. Metody badań systemów korzeniowych [Methods of root system research]. PWRiL Warszawa [in Polish].

Domański P., 1995. Poradnik dla użytkownika trawników oraz firm zakładających i pielęgnujących tereny zieleni [Guide for the lawn user and firms establishing and managing green areas]. COBORU Słupia Wielka [in Polish].

Falkowski M,. Kukułka I., Kozłowski S., 1994. Właściwości biologiczne roślin łąkowych [Biological properties of meadow plants]. Wyd. AR Poznań [in Polish].

Fiala K., 1997. Underground plant biomass of grassland communities in relation to mowing intensity. Acta Sc. Nat. Brno 31(6), 54.

Frey L., 2007. Księga polskich traw [Book of Polish grasses]. Instytut Botaniki im. Szafera PAN Kraków [in Polish].

Frey L., Mizianty M., 2006. Psammofilne gatunki traw zapobiegające erozji wydm nadmorskich [Psammophilic grass species preventing erosion of maritime dunes]. Zesz. Nauk. UP we Wrocławiu, Rolnictwo LXXXVIII, 71-78 [in Polish].

Harkot W., Czarnecki Z., 1998. Dynamika wydłużania systemu korzeniowego siewek polskich odmian traw gazonowych na glebie o zniszczonej i ulepszonej wierzchniej warstwie [Dynamics of elongation of the root system of seedlings Polish cultivars of grass lawn on the soil and improved the damaged surface layer]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura LIII, 177-184 [in Polish].

Hetman J., 1993. Nowe komponenty podłoża do ukorzeniania sadzonek goździka [New components of substrate for rooting of carnation seedlings]. Mat. Konf. Postęp w uprawie goździków, Łódź, 16-22 [in Polish].

Hetman J., Martyn W., Szot P., 1998. Możliwości wykorzystania hydrożeli w produkcji ogrodniczej pod osłonami [Possibilities for using hydrogels in horticulture production under screens]. Zesz. Probl. Post. Nauk Rol. 461, 31-45 [in Polish].

Hetman J., Szot P., 1994. Superabsorbenty – nowe, cenne składniki podłoży do ukorzeniania sadzonek chryzantemy [Superabsorbents – new, valuable components of substrates for rooting of chrisantemum seedlings]. Mat. Konf. Nowości w uprawie chryzantem, Poznań, 34--38 [in Polish].

Karczewska A., 2008. Ochrona gleb i rekultywacja terenów zdegradowanych [Soil protection and reclamation of degraded areas]. Wyd. UP Wrocław [in Polish].

Kościk B., Kowalczyk-Juśko A., 1998. Zastosowanie żelu Aqua – Terra jako dodatku do podłoża w uprawie tytoniu papierosowego jasnego [Application of Aqua – Terra gel as an addition for substrate in cultivation of light cigarette tobacco]. Zesz. Probl. Post. Nauk Rol. 461, 227-238 [in Polish].

Kozłowski S., Goliński P., Golińska B., 2000. Pozapaszowa funkcja traw [Function of grasses besides fodder utilization]. Łąkarstwo w Polsce 3, 79-94 [in Polish].

Lista odmian roślin rolniczych 1997 [List of agricultural crops cultivars]. COBORU Słupia Wielka [in Polish].

Pechačkova S., Krahulec F., 1995. Efficient nitrogen economy: Key to the succes of Polygonum bistorta in an abandoned mountain meadow. Folia Geobot. Phytotax. 30, 211-222.

Pielota L.M., Smucker J.M., 1995. Fine root dynamics of alfalfa after multipe cuttings and during a late invasion by weeds. Agron. J. 87, 1161-1169.

Rychnovská M., 1983. Grasslands: a multifunctional link between natural and man – made ecosystems. Ekologia 2, 337-345.

Trętowski J., Wójcik A.R., 1992. Metody doświadczeń rolniczych [Methods of agricultural experiments]. WSRP Siedlce [in Polish].

Wolski K., Kotecki A., Spiak Z., Chodak T., Bujak H., 2006. Ocena wstępna możliwości wykorzystania kilkunastu gatunków traw w stabilizacji skarp obwałowań składowiska „Żelazny Most" w Rudnej [Initial assessment of several grass species utilization in stabilization of scarp embankments of the landfil „Iron Most" in Rudna]. Zesz. Nauk. UP we Wrocławiu, Rolnictwo LXXXVIII, 293-299 [in Polish].

WPŁYW STOSOWANIA HYDROŻELU NA MASĘ SYSTEMU KORZENIOWEGO MURAW TRAWNIKOWYCH ZAŁOŻONYCH NA BAZIE KOSTRZEWY CZERWONEJ

Streszczenie. Badania realizowano na podstawie dwóch doświadczeń trawnikowych, które założono w układzie split-blok split-plot w czterech powtórzeniach. Jednostką doświadczalną było poletko o powierzchni 1 m^2. Dla potrzeb badawczych zaprojektowano mieszanki trawnikowe. Kryterium podziału mieszanek stanowił udział kostrzewy czerwonej w siewie. W siewie czystym badano cztery odmiany kostrzewy czerwonej: Adio, Libano, Corail, Simone. W doświadczeniach – zarówno jednogatunkowym, jak i mieszankowym – badano następujące czynniki: rodzaj podłoża z dodatkiem hydrożelu (H) i bez dodatku hydrożelu (BH), lata badań (2003-2004). W doświadczeniach stosowano umiarkowanie intensywną pielęgnację. Pod koniec każdego okresu wegetacji ze wszystkich badanych poletek z miejsc wybranych w sposób losowy pobierano próbki darni wraz z systemem korzeniowym. Hydrożel powodował zwiększenie biomasy korzeniowej zarówno w murawach jednogatunkowych badanych odmian kostrzewy czerwonej, jak i w mieszankach. Spośród odmian kostrzewy czerwonej największą biomasę korzeniową wytwarzała polska odmiana Adio, a z mieszanek tylko te, które zawierały w swoim składzie 60 i 80% kostrzewy czerwonej. Działanie hydrożelu na wytworzenie biomasy korzeniowej muraw trawnikowych było szczególnie wyraźne, gdy w okresie letnim 2004 r. występowały posuchy. Może to świadczyć o jego korzystnym oddziaływaniu szczególnie w sytuacji niedoboru wody w glebie.

Słowa kluczowe: biomasa korzeni, *Festuca rubra*, korzenienie, mieszanka trawnikowa, odmiany kostrzewy czerwonej, trawnik

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