Waldemar ZIELEWICZ, Barbara GOLIŃSKA
Poznań University of Life Sciences, Department of Grassland and Natural Landscape Sciences
ul. Dojazd 11, 60-632 Poznań, Poland
e-mail: walziel@up.poznan.pl

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USE OF LAWN GRASS MIXTURES WITH IRON SULPHATE FOR THE RENOVATION OF LAWN WITH MOSS

Summary

The experiment was established on the shaded area of the lawn occupied by mosses (Bryophyta sp.) around the Biocentrum building of the University of Life Sciences in Poznań. Lawns with moss were selected for the study, with an average share of at least 55%. Three seed mixtures present on the market in the commercial offer of seed companies were tested in the experiment. Mixture G contained grass seeds coated with a monohydrate form of iron sulphate ($FeSO_4$ H_2O) in the amount of 31.92 mg of Fe, while in the mixture R the heptahydrate form ($FeSO_4$ $7H_2O$) in the amount of 1.5 mg of Fe per 1 gram of kernels was used. The seeds of the H control mixture were not coated with iron sulphate. The best effects of moss control in the lawn, among the tested lawn mixtures whose seeds were coated with iron sulphate were obtained after the use of mixture G. This application led to brisk dying and eradication of mosses yet the germination rate of kernels was slower than in the case of other mixtures and so was the pace of sodding in the areas under renovation.. In the case of the lawn mixture R, no toxic effects on mosses and their permanent control were found. Lack of satisfactory effects in moss control was caused by the use of too low concentration of iron sulphate, which coated the seeds. The most effective moss control and surface coverage with new grass seedlings was obtained using the traditional method based on applying Nawomix fertilizer to control mosses, raking dead moss and sowing seeds with lawn mixture H following seeds covering by soil.
Key words: *moss control, lawn grass mixtures with iron salts, iron sulphate*

WYKORZYSTANIE MIESZANEK NASIENNYCH Z DODATKIEM SOLI ŻELAZA DO RENOWACJI TRAWNIKÓW POROŚNIĘTYCH MCHEM

Streszczenie

Doświadczenie założono na zacienionej powierzchni trawnika opanowanego przez mchy (Bryophyta sp.) wokół budynku Biocentrum Uniwersytetu Przyrodniczego w Poznaniu. Do badań wybrano powierzchnie trawnika porośnięte mchami, których średni udział stanowił co najmniej 55%. W doświadczeniu testowano trzy mieszanki nasienne obecne na rynku w ofercie handlowej firm nasiennych. W mieszance G ziarniaki traw pokryte były jednowodną formą siarczanu żelaza ($FeSO_4$ H_2O) w ilości 31,92 mg Fe, natomiast w mieszance R zastosowano formę siedmiowodną ($FeSO_4$ $7H_2O$) w ilości 1,5 mg Fe w 1 gramie ziarniaków. Ziarniaki mieszanki kontrolnej H nie były pokryte solami żelaza. Najlepsze efekty zwalczania mchów w trawniku, spośród badanych mieszanek gazonowych, których ziarniaki zostały pokryte siarczanem żelaza uzyskano po zastosowaniu mieszanki G. Odznaczała się ona bardzo dobrą szybkością zamierania i skutecznością niszczenia mchów, jednak ustępowała w porównaniu do pozostałych mieszanek pod względem szybkości kiełkowania ziarniaków i zadarniania powierzchni objętych renowacją. W przypadku mieszanki gazonowej R nie stwierdzono toksycznego oddziaływania na mchy oraz ich trwałego zwalczania. Brak zadawalających efektów w niszczeniu mchów spowodowany był zastosowaniem zbyt niskiego stężenia siarczanu żelaza, jakim pokryto powierzchnię ziarniaków. Najbardziej efektywne zwalczenie mchów i pokrycie powierzchni nowymi siewkami traw uzyskano przy wykorzystaniu tradycyjnej metody renowacji trawnika, polegającej na zastosowaniu w pierwszej kolejności nawozu Nawomix zwalczającego mchy, wygrabieniu obumarłego mchu oraz dokonaniu zasiewu mieszanką gazonową H z przykryciem nasion glebą.
Słowa kluczowe*: zwalczanie mchów, mieszanki traw z solami żelaza, siarczan żelaza*

1. Introduction and aim of the study

Development of mosses is a popular issue on lawns launched on acidic soils and in shaded places. Negligence of regular fertilization with calcium, overwatering and constant shadowing of green enclaves lead to a successive spread of mosses and regression of grass [2]. Mosses are non-vascular plants with no vascular tissue. They may absorb water and mineral components via the whole surface of a plant. They do not develop typical leaves, stems or roots – instead, they have microphiles (small leaves), small stems and rhizoids which attach them to the ground [1]. Mosses are more expansive than most of the grass species, especially in cool and shaded areas of lawns with little drainage of the soils and compact soils. In order to stop the development of mosses on lawns, it is advised to get rid of all the trees and bushes in the areas which are exposed to sunlight for less than 3-4 hours daily or to dispersed light for less than 6-8 hours daily, i.e. to less light than is required for the development of grass species [6]. In order to limit the development of mosses in garden and golf courses, [7] it is recommended to water the grass only when it is necessary and to resign from automatic systems of watering in the shaded parts of a lawn. Also, regular sanding of lower and shaded areas allows for fast drying of a top of soil layer [3].

Due to their availability and simplicity, substances which contain iron salts are widely used in order to limit the development of mosses in lawns. Such substances cause fast blackening and dying of mosses. Other substances

which control mosses in lawns and stony elements in gardens are: potassium salts, pelargonic acid, coper sulphate, ammonium sulphate, fatty acids, quinoclamine [8, 10]. Glyphosate salts (e.g. Roundup 360 SL) is one of the most popular active substances for the mosses control from the areas which have been totally covered with them. There are, however, opinions that this substance is ineffective against mosses when applied in the advisable doses [13, 9]. Conditions under which glyphosate is toxic to mosses have not been fully discovered yet. As there are numerous moss species, it is possible that some of them have become insensitive to this active substance. In the individual research [14] claimed that the lack of vascular system in mosses impairs transportation of active substances of system herbicides in a plant, which makes these substances ineffective. Svenson et al. [11] find that regular aeration and verticutting eradicate dead felt together with sheets of mosses which cover lawns. Methods for mechanical control of mosses are often combined with fertilizers containing ferrous salts which are toxic to mosses and therefore lead to their dieback. This method is often supplemented with under-sowing of a lawn with a regenerating grass in the areas where mosses were eradicated, which makes the development of mosses less probably for a longer period of time. Currently, there are grass mixtures available which are designed to fast renovation of lawns covered with mosses and whose kernels are additionally coated with iron salts which control mosses and prevent lawns from their further expansion. Due to little research and literature available in this subject area, experimental works were launched in order to verify usefulness of the concept of lawns' renovation based on seed mixtures supplemented with iron salts.

The aim of the research was to assess the effectiveness of various methods for the renovation of lawns with moss using seed mixtures different in terms of kernels coating with iron sulphate.

2. Material and methods

An experiment was carried out in a shaded part of a lawn covered with mosses (*Bryophyta sp.)* where their average share was at least 55% around a building of Biocentrum at Poznań University of Life Sciences. Other species in the lawn were: red fescue (*Festuca rubra*) – 33%, annual meadow grass (*Poa annua*) – 7%, common dandelion (*Taraxacum officinale*) – 3% and white clover (*Trifolium repens*) – 2%.

Three seed mixtures available in domestic market were tested. G-mixture contained: red fescue (*Festuca rubra*) – 50%, perennial ryegrass (*Lolium perenne*) – 45%, westerworld ryegrass (*Lolium westerwoldicum*) – 5%. Another mixture – marked with "R"- contained: red fescue (*Festuca rubra*) – 20%, perennial ryegrass (*Lolium perenne*) – 40% and tall fescue (*Festuca arundinacea*) – 40%. A control mixture H (with kernels not coated with iron salts) was composed of: perennial ryegrass (*Lolium perenne*) – 15%, red fescue (*Festuca rubra*) – 60%, sheep's fescue (*Festuca ovina*) – 15% and smooth-stalked meadow grass (*Poa pratensis*) – 10%.

Mixture G contained grass kernels coated with a monohydrate form of iron sulphate ($FeSO_4$ H_2O) and in mixture R – with a heptahydrate form of it ($FeSO_4$ $7H_2O$). What was also different, was the intensity of coating of kernels with a protective green pigment and iron salts. After rinsing kernels in a 5-mole HCl, on the surface of 1 g of G mixture kernels, 31.92 mg of Fe was determined, whereas on R mixture kernels – only 1.5 mg of Fe. Determination of Fe in water solutions rinsed out of seeds and in 5-mole HCl was conducted with a method of atom absorption spectrophotometry (AAS).

In order to assess the effectiveness of various methods of renovation of lawns covered with mosses with the application of seed mixtures G, R and H, a two-factorial experiment was carried out in the plots of 2.0 m^2 each in randomized block design, in three replications in the years 2014-2015. A factor of the first stage included a method for lawn's renovation, and a factor of the second stage – seed mixture. In the first year (2014), the experiment was launched on August 29th. An analogical scheme was repeated in a different part of a lawn in another year (2015) by sowing each mixtures in pre-prepared plots on July 5th.

Among these two methods for the renovation of a lawn, the first one consisted of mowing a lawn, raking a predominant above-ground biomass of mosses, sowing the mixtures and covering seeds with a 0.5-1.0 cm soil layer. In the second variant, raking mosses was omitted and seed mixture were sown directly on the lawn area, without the seeds being covered with soil. In plots there were sown 40 g of each mixtures i.e. a sowing norm of 200 kg ha^{-1} was applied. An experimental plots was watered regularly. In case of a renovation method with H mixture, sowing was preceded with an application of a fertilizer in a form of powder with 12% of Fe which eradicated mosses (produced by Nawomix).
It was applied two days before sowing.

The effectiveness of the destruction of mosses, the speed of mosses dying, the rate of germination of grasses and the density of surface coverage with new seedlings of grasses with various methods for the renovation of lawns covered with mosses were scored on a 1-9 scale, also applied in COBORU. On the scale, 1 stands for the lack or little effectiveness of an investigated trait and 9 stands for the best effect. Effects of mosses eradication and sodding a lawn with new seedlings were assessed after 30 days whereas the speed of mosses dying and rate of seed germination after the renovation were monitored on a daily basis.

Statistical analysis of the results was completed with Statistica, Analwar 5.2 FR and MS Excel. The significance of differences between the means were verified with Tukey's test at the level of significance of p=0.05.

3. Results and discussion

Mixture G used in the renovation of a lawn was effective in the control of mosses and the effect of their blackening and dying was observed even in 3-4 hours after application. In the first year of the experiment, combined with raking and covering grass seeds with soil, the effectiveness of mosses eradication was scored at 7.6, whereas in the second year – at 7.3 (Table 1). A slightly better result of mosses destruction observed in both years, was obtained when sowing G mixture without kernels being covered with soil. An effect of mosses control with R mixture was very poor. In the first year of the research, after an application of the method with raking mosses and coating kernels with iron salt, mixture R was scored as few as 2.0. The result was even lower in the next year (only 1.6). A variant without coating kernels with iron salt after sowing this mixture of grasses also did not result in

the increase of a toxic impact of iron salts on mosses. The most effective and long-lasting destruction of mosses in the lawn was observed after an introduction of a traditional three-stage method with application of anti-mosses fertilizer with 12% of Fe, raking dead mosses and sowing H mixture which did not contain iron sulphate. Both eradication and speed of mosses dying after application of this method were scored on 9.0 in every variant: with raking mosses and covering seeds with soil and without covering seeds with soil in both research years (Table 1).

A statistical analysis shows that a method of renovation did not have a significant impact on the effectiveness of mosses' eradication. When combined with H mixture, implementation of G mixture with a higher content of iron salt and Nawomix fertilizer, which is toxic to mosses in grass, was much more effective than R mixture. An interaction of a method of renovation and a seed mixtures did not have significant impact on the destruction of mosses in a lawn.

Table 1. Effect of renovation methods of lawn with mosses on the moss destruction (scale 1-9)
Tab. 1. Wpływ metod renowacji trawników porośniętych mchami na skuteczność zniszczenia mchów (skala 1-9)

Lawn renovation methods	Lawn grass mixtures	2014	2015
Moss raking, sowing and covering seeds with a soil layer	G	7.6	7.3
	R	2.0	1.6
	H	9.0	9.0
$LSD_{0.05}$		0.970	1.680
No moos raking, sowing without covering seeds with a soil layer	G	8.6	7.6
	R	1.3	1.6
	H	9.0	9.0
$LSD_{0.05}$		1.188	1.534

Significance of experimental factors:
$LSD_{0.05}$ for the renovation method = not significant
$LSD_{0.05}$ for the lawn grass mixture = 0.787
$LSD_{0.05}$ for years of research = 0.210
Interaction method x lawn grass mixture = not significant
Source: own study / Źródło: opracowanie własne

The fastest effect of mosses dying (Table 2) was observed after an application of a traditional method with Nawomix fertilizer and sowing of H mixture (8.6 scores in the first year and 8.3 in the second year – with the coverage of seeds with soil, and 8.6 scores in both years – without soil coverage). Comparatively positive effects in terms of the speed of mosses dying were observed in the case of G mixture. In this situation, also fast blackening of a green mass of mosses, dying and drying were observed. On the plots under renovation with raking mosses and covering of soil kernels with G mixture, the speed of mosses dying was marked as 7.3 scores in the first year and as slightly higher (7.6) in the second year. In the variant with no coverage soil of kernels, the speed of mosses dying was even better (8.6 in the first year and 7.6 in the second year). In the case of R mixture, no effects were observed in all the years. A statistical analysis confirmed that a method of renovation and a year of the research did not have significant effect on the speed of mosses dying. What had a strong impact on this process, was a type of seed mixture of grasses. An interaction of an applied method for renovation and a grass seed mixture did not have much influence on the speed of mosses dying.

Table 2. Effect of renovation methods of lawn with mosses on the speed of mosses dying (scale 1-9)
Tab. 2. Wpływ metod renowacji trawników porośniętych mchem na szybkość zamierania mchów (skala 1-9)

Lawn renovation methods	Lawn grass mixtures	2014	2015
Moss raking, sowing and covering seeds with a soil layer	G	7.3	7.6
	R	1.0	1.3
	H	8.6	8.3
$LSD_{0.05}$		1.680	2.566
No moos raking, sowing without covering seeds with a soil layer	G	8.3	7.6
	R	1.6	1.6
	H	8.6	8.6
$LSD_{0.05}$		1.940	2.656

Significance of experimental factors:
$LSD_{0.05}$ for the renovation method = not significant
$LSD_{0.05}$ for the lawn grass mixture = 0.855
$LSD_{0.05}$ for years of research = not significant
Interaction method x lawn grass mixture = not significant
Source: own study / Źródło: opracowanie własne

Kernels germinated fastest when a traditional method of renovation with Nawomix fertilizer, H mixture, and soil coverage of 0.5 cm was applied. In both years, at the same method of renovation, the rate of germination was scored 9.0 (Table 3). In a variant of this method with no seeds covered, this characteristic was scored 7.6 in the first year and 7.0 in the second research year. Slightly lower evaluations in terms of these traits were observed in mixture R (when compared to mixture H). In the renovation variant with raking mosses and covering seeds with soil, a germination rate was scored 8.6 and 8.3 in the following years. In a renovation method of sowing kernels without soil cover, mixture R turned out to be the best in terms of a rate of germination. A slightly higher score might have been obtained by thick coating of kernels with a green pigment which prevented them from an unfavorable activity of iron sulphate which, on the other hand, might have positively influenced longer maintaining moisture in kernels and lowered their pace of drying with a method of sowing directly on mosses.

Table 3. Effect of renovation methods of lawn with mosses on the germination rate of grass seeds (scale 1-9)
Tab. 3. Wpływ metod renowacji trawników porośniętych mchem na szybkość kiełkowania ziarniaków traw (skala 1-9)

Lawn renovation methods	Lawn grass mixtures	2014	2015
Moss raking, sowing and covering seeds with a soil layer	G	6.6	6.3
	R	8.6	8.3
	H	9.0	9.0
$LSD_{0.05}$		0.970	1.530
No moos raking, sowing without covering seeds with a soil layer	G	5.3	4.6
	R	8.0	7.3
	H	7.6	7.0
$LSD_{0.05}$		1.188	1.680

Significance of experimental factors:
$LSD_{0.05}$ for the renovation method = 0.734
$LSD_{0.05}$ for the lawn grass mixture = 0.250
$LSD_{0.05}$ for years of research = not significant
Interaction method x lawn grass mixture = not significant
Source: own study / Źródło: opracowanie własne

In the first year, the rate of germination of grass seeds from mixture R seeded directly on mosses was scored 8.0,

and 7.3 in the second one. In terms of this trait, the worst score was granted to a renovation method with mixture G. A method of renovation and an applied mixture of grasses was statistically significant for the germination rate of kernels. A high content of iron sulphate marked in mixture G, which had strong impact on the dying of mosses and maintaining the effect for 30 days, had a negative impact on the germination of seeds from this mixture.

According to the research results, the germination rate of kernels is connected with the density of surface coverage with new seedlings of grasses in a lawn i.e. sodding after a renovation. The method with raking mosses and covering seeds with soil was much better and statistically significant in terms of this characteristic (Table 4). When analyzing an effect of a mixture type, the largest density of new grass seedlings on lawns was visible after an application of H mixture. An estimate of mixture R was a bit lower: from 8.6 scores in the first research year up to 8.3 in the second year. The weakest, yet satisfying coverage of grasses with these seedlings in the area which was previously exposed to renovation was completed with mixture G. The effect of a grass mixture used in renovation turned out to be statistically significant. An interaction between covering seeds with soil and a type of mixture turned out to be not-significant in terms of an influence on the density of seedlings in the renovated areas.

Table 4. Effect of renovation methods of lawn with mosses on the density of surface coverage with new seedlings of grasses (scale 1-9)

Tab. 4. Wpływ metod renowacji trawników porośniętych mchem na gęstość pokrycia powierzchni nowymi siewkami traw (skala 1-9)

Lawn renovation methods	Lawn grass mixtures	2014	2015
Moss raking, sowing and covering seeds with a soil layer	G	7.0	6.3
	R	8.6	8.3
	H	9.0	8.6
$LSD_{0.05}$		ns	0.970
No moos raking, sowing without covering seeds with a soil layer	G	4.6	5.0
	R	7.3	6.3
	H	7.6	7.3
$LSD_{0.05}$		1.940	1.534

Significance of experimental factors:
$LSD_{0.05}$ for the renovation method = 0.361
$LSD_{0.05}$ for the lawn grass mixture = 0.925
$LSD_{0.05}$ for years of research = 0.271
Interaction method x lawn grass mixture = not significant

Source: own study / Źródło: opracowanie własne

Unfavorable impact of various substances which control mosses on plants became a subject of study [12]. When implementing iron salts, copper salts, fungicides and detergents, it was also observed by [5] and [1], that apart from satisfying effects e.g. limitations to the development of mosses, some substances give harmful side effects to the physiology of sod grasses. [3] proved that copper sulphate and zinc sulphate were especially phytotoxic for creeping bentgrass and velvet bentgrass in golf courses. In one of the investigations by [4], it turned out spot application of a dishwashing detergent limited the development of mosses but also caused phytosociological impact on grasses and therefore visibly impaired their state through weakening, sod thinning and reducing grass' quality. A toxic impact of too high concentration of iron sulphate which coated grass kernels, used in lawn renovation mixtures on the ability of germination of kernels coated with iron salts, was already observed in the previous research [15]. In individual research, an application of iron sulphate from Nowamix with 12% of Fe, caused only short discoloration of leaf blades of grasses into dark green. In practice, mosses are also eradicated by active substances fungicides registered for the control of diseases in cereal plants. In the research by [7] on the use of combination of two active substances – mancozeb and copper hydroxide, which had previously been used for the eradication of bacteria and fungi diseases – it was observed that the substance also affects mosses. Application of this mixture every two weeks in a vegetation season, led to a total destruction of mosses in the green growth of creeping bentgrass in a golf course. [3] draw attention to the fact that an excessive use of this substance may result in higher concentration of cooper in a golf course, which is antagonistic to iron ions. Too high concentration of copper may lead to the deficiency of iron in plants. In such a case, alternating such substances as Nawomix, which contains iron salts, or seed mixtures G and R, whose kernels are coated with iron sulphate, would minimize such hazard and limit the development of mosses for a longer period of time.

4. Conclusions

1. Among the examined grass mixtures whose kernels were coated with iron sulphate, the best effects of mosses destruction in lawns were observed after an application of G mixture. This application led to brisk dying and eradication of mosses but the germination rate of kernels was slower than in the case of other mixtures and so was the pace of sodding in the areas under renovation.
2. In the case of R mixture, no toxic impact on mosses and their eradication was observed. The lack of satisfying effects was caused by top low concentration of iron sulphate which coated kernels. This, however, had no negative impact on the germination rate and sodding in the renovated areas.
3. The most effective mosses destruction and covering the areas with new seedlings was observed when using a traditional method of lawns' renovation i.e. by applying Nowamix, raking dead mosses and sowing with H mixture (without iron sulphate) following seeds covering by soil.

5. References

[1] Boesch B.P., Mitkowski N.A.: Chemical methods of moss control on golf course putting greens. Applied Turf Science, 2005, 9: 1-8.
[2] Cook T.W., Whisler J.: Controlling Mosses in Lawns. Extension Service Publication, Oregon State University, Corvallis, 1994.
[3] Cook T., McDonald B., Merrifield K.: Controlling moss in putting greens. Golf Course Management, 2002, 70(9): 103-106.
[4] Gelernter W., Stowell L.J.: Chemical and cultural controls for moss, *Bryum argenteum*, on putting greens. Super Journal: PACE Turfgrass Research Institute, 1999: 1-6.
[5] Happ K.A.: Moss eradication in putting green turf. USGA Green Section Record, 1998, 6(5): 1-5.
[6] Hummel N.W.: Methods for moss control. Golf Course Management, 1994, 64: 106-110.
[7] Landschoot P., Cook J., Park B.: Moss control - new products and strategies. USGA Green Section Record, 2004, 42(4): 7-9.
[8] Newmaster S.G., Bell F.W., Vitt D.H.: The effects of glyphosate and triclopyr on common bryophytes and lichens in

northwestern Ontario. Canadian Journal of Forest Research, 1999, 29: 1101-1111.
[9] Roberts K., Ziegenhagen L.: The effects of Roundup on Kindbergia. Class report, Botany 465, Oregon State University, Corvallis, 1999.
[10] Settle D.M., Kane R.T., Miller G.C.: Evaluation of newer products for selective control of moss on creeping bentgrass greens. USGA Turf and Environ, 2006, 6(5): 1-6.
[11] Svenson S.E., Smith B., Briggs B.: Controlling liverworts and moss in nursery production. Combined Proceedings International Plant Propagators Society, 1997, 47: 414-422.
[12] Turgeon A.J., Vargas J.M.: The turf problem solver. New Jersey: John Wiley and Sons, 2006: 162-163.
[13] Woodfill D.: Resistance of common mosses to glyphosate. Class report, Botany 465, Oregon State University, Corvallis, 1999.
[14] Yelverton F.H.: Managing silvery thread moss in creeping bentgrass greens. Golf Course Management, 2005, 3: 103-107.
[15] Zielewicz W., Golińska B.: Ocena kiełkowania ziarniaków mieszanek traw gazonowych pokrytych siarczanem żelaza w celu zwalczania mchów. Łąkarstwo w Polsce, 2017, 20: 199-207.

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