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IMPACT OF PHYSICAL AND CHEMICAL PARAMETERS OF THE SUBSOIL ON THE BOTANICAL COMPOSITION OF SPORTS FIELD TURF

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Abstract

This paper presents results of a 2-year study on the impact of physical and chemical characteristics of the subsoil on the herbaceous composition of a sports field turf at the Centre for Sport and Recreation in Olsztyn. Samples of soil for physical and chemical analyses as well as samples of plant material for botanical and weight analyses were collected from the top soil (0-15 cm) and drainage layer (15-30 cm) at five sampling points across the sports field. The physical parameters were determined with the methods used in soil science studies. The mass loss during furnace drying was assumed to represent the content of organic matter. The following were analyzed: the hydrolytic acidity of soil, content of organic carbon in soil and concentrations of N, P, K, Ca, Mg, Na, as well as phytoavailable macro- and micronutrients (P, K, Mg, Cu, Mn, Fe and Zn) determined in 0.5 mol HCl dm^{-3}. Detailed botanical and weight analysis of plant material was performed. The results were statistically processed with Statistica 10.0 software. It was shown that the top soil of the sports field had a grain-size composition of poor loamy sand, whereas the drainage layer resembled loose sand and poor loamy sand. The content of floatable parts in excess of the standard value as well as the physical properties such as bulk density, specific density and porosity indicate high compactness and density of the subsoil. It was demonstrated that the top soil had an average-to-high content of phosphorus and magnesium, low-to-average content of potassium, average concentrations of copper, manganese and iron, and a high content of zinc. A high turf share of monocotyledonous and dicotyledonous weeds in the sward, which are resistant to treading, indicates excessive load and high compactness of the sports field as well as worse physical and chemical properties of the subsoil.

Keywords: physical and chemical properties of subsoil, floral composition, sports field.

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WPŁYW WŁAŚCIWOŚCI FIZYKOCHEMICZNYCH PODŁOŻA NA SKŁAD BOTANICZNY MURAWY BOISKA SPORTOWEGO

Abstrakt

Przedstawiono wyniki 2-letnich badań dotyczących wpływu właściwości fizykochemicznych podłoża na skład florystyczny murawy boiska sportowego Ośrodka Sportu i Rekreacji OSIR w Olsztynie. W pięciu reprezentatywnych powierzchniach boiska, z warstwy nośnej (0-15 cm) i warstwy filtrującej (15-30 cm), pobrano próbki glebowe do analiz fizykochemicznych i materiał roślinny do analiz botaniczno-wagowych. W próbkach glebowych oznaczono właściwości fizyczne metodami stosowanymi w gleboznawstwie. Straty masy podczas spalania przyjęto za zawartość materii organicznej. Oznaczono kwasowość hydrolityczną gleby, zawartość węgla organicznego w glebie, N, P, K, Ca, Mg, Na. Makro- i mikroskładniki przyswajalne (P, K, Mg, Cu, Mn, Fe i Zn) oznaczono w 0,5 mol HCl dm^{-3}. Dokonano szczegółowej analizy botaniczno-wagowej materiału roślinnego. Wyniki badań opracowano statystycznie z użyciem programu Statistica 10.0. Wykazano, że warstwę nośną płyty boiska stanowi piasek słabogliniasty, natomiast filtracyjną – piasek luźny i słabogliniasty. Zawartość części spławianych przekraczających przyjętą normę oraz właściwości fizyczne, m. in. gęstość objętościowa, gęstość właściwa i porowatość, świadczą o zagęszczeniu podłoża. Wykazano, że w warstwie nośnej zawartość fosforu i magnezu wynosiła od średniej do wysokiej, potasu – od niskiej do średniej, zawartość miedzi, manganu i żelaza była średnia, cynku – wysoka.

Duży udział chwastów jedno- i dwuliściennych w runi odpornych na udeptywanie świadczy o nadmiernym obciążeniu boiska, zagęszczeniu i pogorszeniu właściwości fizykochemicznych podłoża.

Słowa kluczowe: właściwości fizykochemiczne podłoża, skład florystyczny, boisko sportowe.

INTRODUCTION

Sports field turf should be low, compact, elastic and resistant to treading and damage; it should ensure the safe movement of contestants and create optimal conditions for kicking, rolling and passing a ball (KINDS 1985, TURGEON 2005). In order to meet these requirements, the process of constructing a sports field should include preparation of special subsoil (top soil and drainage layer), selection of proper lawn grass varieties and regular maintenance (KINDS 1985, CANAWAY 1990, THORGOOD 2003, ŁACHACZ et al. 2007, GRABOWSKI et al. 2008). The grass species chosen for sports field turf should withstand intensive use of a field.

Excessive compactness of the upper layer of subsoil, a common cause of turf degradation, leads to a change in the soil physical properties, reduced porosity and worse subsoil permeability (DIN 18035, GIBBS et al. 1993, HUFF 2003). Compaction of the subsoil results in the elimination of grasses and expansion of other, unwanted plants.

The objective of the study was to determine the impact of physical and chemical properties of soil on the botanical composition of sports field turf at the Centre for Sport and Recreation (CSR) in Olsztyn.

MATERIAL AND METHODS

In 2009-2010, a study was carried out at the main sports field located at the Centre for Sports and Recreation in Olsztyn, which was constructed in the late 1970s.

The field turf was rolled with a drum roller in early spring each year. It was fertilized twice with phosphorus and potassium: in early spring (45 kg P_2O_5 and 70 kg K_2O ha^{-1}) and in autumn (35 kg P_2O_5 and 80 kg K_2O ha^{-1}), and several times with nitrogen: at the onset of the plant growing season and then every 2-3 cuts (20-30 kg N ha^{-1}). The grass sward was mowed at least once a week in May and June, and then every two weeks in late summer and autumn. Irrigation was done during spells of dry weather.

Each year in the spring, the herbicide Starane 250 EC at 1.0-1.2 l ha^{-1} was applied for selective weed control. During a break in the sporting season (in June 2010), the grass layer was rejuvenated by direct grass seeding into the sward. The turf was mowed low (at app. 2 cm), dragbrushed and groomed. These treatments were followed by sand application, pulverization by harrowing and direct seeding into the sward (four times on crossing lines and on diagonals) of a lawn grass mixture (made by the SHR Sport Nieznanice) at 250 kg ha^{-1} (4 times at 62.5 kg ha^{-1}). A Vredo disc seeder and a light drum roller were employed. Under-sowing was performed with a mixture of lawn grasses composed of *Lolium perenne* cultivars Niga (44.5%), Nira (3.6%) and Inka (11.9%); *Poa pratensis* culivars Amason (19.6%) and Ani (0.4%); *Festuca rubra* cultivars Adio (9.97%), Nimba (10.0%) and Leo (0.03%). On five representative sub-fields set out in the middle of a field (points 1, 2, 4 and 5) and in its centre (point 3), soil samples for physical and chemical analyses and plant samples for botanical and weight analyses were taken from the top soil (0-15 cm) and drainage (15-30 cm) layers. The ash content was determined in soil samples after combustion in a muffle furnace at 550°C. The mass loss in the furnace was assumed to represent the content of organic matter (Sapek, Sapek 1997). The following determinations were made: total porosity from the formula: $fc = 1 - (gc : gw) \cdot 100$ (% vol.); real-time moisture of the subsoil with the drying method; bulk density (gc) measured in small, 100 cm^3 cylinders by drying the samples at 105°C; specific density (gw) calculated from a regression equation (Okruszko 1971); hydrolytic acidity with the Kappen's method; total nitrogen with the Kiejdahl's method; potassium and sodium with flame photometry; total phosphorus with the colorimetric method after mineralization of soil samples in sulphuric acid; total calcium with complex titration, and total magnesium by measuring the absorption of radiation of magnesium ions on an ASA apparatus. The content of organic carbon was measured by colorimetry with oxidant mixture of 0.2 M potassium dichromate solution in sulphuric acid and the detection of absorption on a spectrophotometer. The available forms of macro- and microelements (P, K, Mg, Cu, Mn, Fe and Zn) were measured in

0.5 mol HCl dm^{-3}. In the autumn of 2009 and 2010, 100 g plant samples were randomly collected from each sub-area of the field. A detailed botanical and weight analysis was performed on green material. Lawn grasses, other grasses, legumes, herbs and weeds were identified and their per cent shares in the sward were determined after drying.

The results were statistically processed with Statistica 10.0 software (Data Analysis Software System, Statsoft Inc. 2011). Correlation analysis between the examined factors was performed with the Pearson's linear correlation. The values of correlation coefficients were calculated between the basic physical and chemical parameters of the top soil layer and the share of lawn grasses and other types of plants in the sward.

RESULTS AND DISCUSSION

The surface layer of soil under a sports field, called the top soil (0-15 cm), in our study was sampled to the right of the penalty area, where it was composed of grains representing the texture of light loamy sand and loamy sand (*Classification of soil granulation…* 2009). The content of skeletal particles in the top soil ranged from 18 to 25%, sand fractions (with the predominance of coarse and medium sand) varied from 71 to 88%, dust fraction constituted from 8 to 22% and silt fraction made up from 4 to 7% (Table 1). The percentage of floatable fraction (<0.02 mm) ranged between 7 and 18%, which was above the required minimum set for a sports field, except for points 2 and 3 (DIN 18035).

The drainage layer (15-30 cm) represented the grain-size composition of loose sand and poor loamy sand (point 5). The content of skeletal parts ranged from 13 to 21%, sand fraction varied from 87 to 93% (with the predominance of coarse and medium sand), dust fraction constituted from 4 to 9%, and silt fraction made up from 2 to 4%. The percentage of floatable fraction (<0.02 mm) ranged from 5 to 9% and did not exceed the norm, except point 5 (DIN 18035).

Based on the grain-size composition of the subsoil, this layer was categorized as light and medium skeletal formation (*Classification of soil granulation* … 2009). The physical properties of the subsoil (the top soil and drainage layers) are typical of poor loamy sands and loose sands. In the examined soil formations, the ash content was significant, ranging from 66.0 to 89.1% in the top soil and from 67.8 to 91.7% in the drainage layer (Table 2).

The bulk density of the tested subsoil layers was high and ranged, on average, from 1.55 to 1.67 Mg m^{-3}, with the higher values determined for the top soil (Table 2). The recorded bulk density values indicate high compactness of the subsoil, especially in the top soil layer.

On average, the specific density was 2.45 Mg m^{-3} in the top soil and

Table 1

Grain-size composition of the subsoil under a sport field turf

Research point number	Layer type	Layer depth (cm)	Fraction content (%)							Definition of soil formation acc. PTG*
			skeletal parts	granular parts						
			gravel fraction	sand fraction			dust fraction		silt fraction	
				coarse sand	medium sand	fine and very fine sand	coarse dust	fine dust		
			particle diameter (mm)							
			>2.0	2.0-0.5	0.5-0.25	0.25-0.05	0.05-0.02	0.02-0.002	<0.002	
1	top soil	0-15	21	11	39	37	4	5	4	ps
2			24	18	32	36	5	3	4	ps
3			18	26	33	29	4	4	4	ps
4			18	38	30	20	3	5	4	ps
5			25	31	29	11	11	11	7	pg
Mean			21	25	33	26	5	6	5	
1	drainage	15-30	20	39	42	12	2	2	3	pl
2			16	55	25	12	3	3	2	pl
3			16	44	31	17	3	3	2	pl
4			13	32	31	30	2	2	3	pl
5			21	34	23	30	4	5	4	ps
Mean			17	41	30	20	3	3	3	

* Classification of soil granulation and mineral formations (Rocz. Glebozn. 2009)

Table 2

Physical properties of the subsoil

Sampling point	Layer type	Layer depth (cm)	Ash content (%)	Bulk density (Mg m-3)	Specific density (Mg m-3)	Total porosity (%)	Sandle - time moisture content layers (%)
1	top soil	0-15	81.0	1.67	2.43	31.3	29.4
2			76.0	1.64	2.36	30.1	27.2
3			66.0	1.67	2.43	31.3	25.8
4			86.1	1.69	2.48	31.9	27.9
5			89.1	1.66	2.54	34.6	27.3
Mean			79,6	1,67	2.45	31.8	27.5
1	drainage	15-30	83.1	1.57	2.38	34.0	26.9
2			78.3	1.55	2.28	32.0	23.7
3			67.8	1.58	2.39	34.0	20.3
4			89.3	1.56	2.37	35.0	17.5
5			91.7	1.57	2.48	36.7	26.4
Mean			82.0	1.57	2.38	34.3	23.0

2.38 Mg m^{-3} in the drainage layer. The recorded values approximate the density of mineral soil, which ranges from 2.50 to 2.80 Mg m^{-3} (OKRUSZKO 1971).

The total porosity of the top soil ranged between 30.1 and 34.5%, being close to the upper values of poor loamy sands. In the drainage layer, it was higher (32.0-36.7%) and similar to the total porosity of loose sands. Soil porosity depends on a variety of factors, such as the grain-size composition, humus content, mesofauna and plant root activity, soil tillage, fertilization and the weather (KONSTANKIEWICZ 1985). An optimal total porosity of the surface layer of a sports field ranges from 35 to 40% (DIN18035, ŁACHACZ et al. 2007).

The porosity of the examined soil, except at sampling point 5, was less than the standard DIN 18035, thus being responsible for worse aerial and hydrous soil properties. Another consequence was a more difficult access of the turf rhizosphere to oxygen, causing poor root growth, especially at high irrigation doses. The results showed a significant correlation coefficient between the specific density and porosity of the top soil of the examined sports field versus the proportion of common meadow grass, red fescue and legumes (Table 3). The physical properties of the top soil under the sports field decided about the shares of particular plants in the sward: common meadow grass (from 47.6 to 66.6%), red fescue (54.8 to 86.5%) and legumes (79.2 to 90.2%).

The fertility of the top soil of the sports field is specified in Table 4. The reaction of this layer was only weakly varied, ranging from neutral to alkaline, and being above the required pH (pH from 5.5 to 6.5). An increase in pH to 7.5 reduces the amount of absorbable iron, manganese and zinc. In comparison with the content of macronutrients (P, K, Mg, Ca, Mg, Na and N, in total) in cultivated soils, the top soil was rich in nitrogen (1.18-2.40 N g kg^{-1}) and calcium (11.70-20.70 Ca g kg^{-1}), moderate in phosphorus (0.90-1.00 P g kg^{-1}), and poor in potassium (1.00-1.30 K g kg^{-1}), magnesium (1.90-3.90 Mg g kg^{-1}) and sodium (0.04-0.12 Na g kg^{-1}). The statistical analyses demonstrated that potassium in the top soil was the only analysed macronutrient which affected significantly the share of grasses, herbs and weeds in the sward in the individual years of the research. In 2009 and 2010, respectively, the values of correlation coefficients reported for perennial ryegrass (R = 0.62, 0.84), common meadow grass (R = 0.68, 0.65), herbs and weeds (R = -0.57, -0.96) and other grasses (R = -0.84, -0.83) indicate the beneficial effect of potassium on the share of perennial ryegrass and common meadow grass in the sward, limiting the contribution of other grasses and herbs and weeds (Table 3).

In the top soil, total nitrogen was strongly connected with organic carbon (Table 4). The C : N ratio in the surface layer was on average 11.76 : 1.0, which implies good microbiological activity in this soil layer. According to the content of organic matter (up to 3.0%), the subsoil is classified as mineral formation at sampling points 1, 3 and 4 (up to 3.0% organic substance) and humus mineral formation at points 2 and 5 (4.62% to 4.72% of organic matter) – Table 4.

Table 3

The Pearson's linear correlation coefficients (R) for species and groups of plants in the sports field turf, content of potassium and physical properties of the top soil

Year	Species and groups of plants	K	Specific density	Total porosity
2009	*Lolium perenne* L.	0.62*	0.25	0.26
	Poa pratensis L.	0.68*	-0.81*	-0.74*
	Festuca rubra L.	-0.19	0.82*	0.93**
	Other grasses	-0.84*	-0.21	-0.30
	Legumes	0.11	0.95**	0.90**
	Herbs and weeds	-0.57	-0.51	-0.64
2010	*Lolium perenne* L.	0.84*	-0.04	-0.02
	Poa pratensis L.	0.65*	-0.70*	-0.69*
	Festuca rubra L.	0.41	0.74*	0.83*
	Other grasses	-0.83*	-0.21	-0.30
	Legumes	-0.39	0.89**	0.92**
	Herbs and weeds	-0.96*	0.35	0.28

* significant for α = 0.05, ** significant for α = 0.01

The content of organic matter in the top soil under a sports field should be within 2 to 4.0% (DIN 18035, ŁACHACZ et al. 2007). The study demonstrated that the content of organic matter, except for points 2 and 5, did not exceed these parameters.

Apart from the humus content, the fertility of the subsoil also depends on the abundance of macronutrients available to plants (KALISZ, ŁACHACZ 2009, GRZEGORCZYK et al. 2011, 2013) – Table 4. According to the norms proposed by the IUNG Puływay (1990) for evaluation of concentrations of macro- and micronutrients in soil, the content of phosphorus was moderate at point 1 and high at points 2, 3, 4 and 5 (ranging from 62.3 to 87.2 mg P kg^{-1}). The content of potassium ranged from 74.7 to 107.9 mg K kg^{-1} of soil, whereas the content of magnesium (45.0-62 Mg mg kg^{-1}) was within the moderate-to-high range. The content of most microelements (Cu, Mn and Fe) was average but high for zinc (Table 4).

Table 4

Chemical properties of the subsoil

Specification	Sampling point number					Mean
	1	2	3	4	5	
pH KCl	7.09	7.17	7.45	7.22	7.22	7.23
pH H_2O	7.68	7.82	7.98	7.76	7.78	7.80
Total content (g kg^{-1})						
N	1.18	2.40	1.53	1.35	2.16	1.72
P	1.00	0.90	1.00	0.90	0.90	0.90
K	1.30	1.30	1.00	1.00	1.00	1.00
Ca	11.70	20.70	20.10	15.14	17.50	17.10
Mg	2.40	2.40	1.90	2.00	3.90	2.52
Na	0.09	0.12	0.08	0.06	0.04	0.08
C-org.	13.7	27.4	17.4	16.2	26.80	20.30
Organic matter (%)	2.36	4.72	3.00	2.79	4.62	3.50
C:N	11.61	11.42	11.37	12.00	12.41	11.76
Content of available (g kg^{-1})						
P	6.23	8.72	7.19	8.11	7.63	7.58
K	8.30	9.13	10.79	7.47	8.30	8.80
Mg	4.50	6.20	5.00	5.10	6.00	5.40
Content of available (mg kg^{-1})						
Cu	1.7	2.2	3.6	2.2	3.8	3.5
Mn	206	143	181	177	178	177
Fe	1900	2000	2100	1700	2700	2080
Zn	10.2	22.4	15.6	15.9	17.3	16.3

Table 5

Share of grasses and other plants in the sward (% d.m.)

Species and groups of plants	Sampling point number									
	1		2		3		4		5	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Lolium perenne L.	22.5	28.6	26.3	31.0	20.7	25.7	27.0	30.5	26.2	29.4
Poa pratensis L.	25.0	33.0	27.0	35.9	21.4	31.0	22.8	33.6	21.1	31.0
Festuca rubra L.	13.1	18.1	11.0	15.0	13.5	14.4	12.0	16.0	17.4	20.5
Other grasses	27.9	17.8	25.8	15.7	31.8	21.5	26.8	16.6	25.5	15.4
Legumes	1.0	0.3	0.6	0.1	0.8	0.4	1.8	0.3	2.2	0.6
Herbs and weeds	10.5	2.2	9.3	2.3	11.8	4.0	9.6	3.0	7.6	3.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The botanical composition of the sports field sward is presented in Table 5. The results of our detailed botanical and weight analyses show that apart from grass species sown spontaneously, the sward included some other species of monocotyledons and dicotyledons. In total, 16 plant species were identified in the sward, including 5 grass, 2 legume, 1 sedge and 8 herb and weed species. The under-sown species (*Lolium perenne* L.*, Poa pratensis* L., *Festuca rubra* L.*)*, regardless of the sub-area, increased their proportion in the sward (from 55.6 to 81.9% d.m.). *Poa pratensis* L. was the predominant species, with only slightly less abundant *Lolium perenne* L.*,* in contrast to *Festuca rubra* L.*,* which was the least numerous (Thorogood 2003, Łachacz et al. 2007, Grabowski et al. 2008). Of the other grasses, *Poa annua* L. was identified most often, especially in the centre of the sports field (Table 5). Legumes such as *Trifolium repens* L. and *Medicago lupulina* L. were rare in the sward. Herbs and weeds were represented by the following species: *Plantago media* L., *Plantago lanceolata* L., *Bellis perennis* L., *Taraxacum officinale* F.H. Wigg, *Achillea millefolium* L.*, Ranunculus repens* L. and *Carex hirta* L. The presence of undesired species in the sward indicates excessive load (utilization) of the sports field, compactness of the top soil as well as worse physical properties of the subsoil, the findings consistent with the reports in literature (Beard et al. 1978, Gibbs et al. 1993, Huff 2003, Turgeon 2005, Grzegorczyk et al. 2011, 2013).

CONCLUSIONS

1. The subsoil under the examined sports field presented the grain-size composition of poor loamy sand and loose sand. Medium sand (0.25-0.50 mm) and coarse sand (0.50-1.00 mm) sub-fractions were predominant in the sand fraction.

2. Substantial amounts of floatable parts (<0.02 mm), slightly exceeding the standard value, high bulk and specific density as well as low porosity indicate high compactness and density of the subsoil.

3. The reaction of the subsoil ranges from neutral to alkaline, and exceeds the optimal value for grasses (pH_{HCl} 5.6-6.5).

4. The top soil layer had an average-to-high content of phosphorus and magnesium, low-to-average content of potassium, average content of copper, manganese and iron and a high concentration of zinc.

5. A substantial proportion of monocotyledonous and dicotyledonous weeds in the sward, which are more resistant to treading, suggest excessive load, high compactness and worse physical and chemical properties of the subsoil.

6. The low-to-average content of potassium in the top soil under the sports field significantly contributed to an increase in the proportion of under-sown grass species, such as *Lolium perenne* L., *Poa pratensis* L., *Festuca rubra* L., and to a smaller share of undesired plants in the sward.

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