https://doi.org/10.17221/160/2020-HORTSCI

Impact of fertilisers on five turfgrass mixtures for football pitches under natural conditions

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Citation: Zanelli B., Vidrih M, Bohinc T., Trdan S. (2021): Impact of fertilisers on five turfgrass mixtures for football pitches under natural conditions. Hort. Sci. (Prauge), 48: 00–00.

Abstract: For 2 years (2019–2020), a field experiment to test the activities of different fertilisation schemes on the yield, colour and health status of five different grass mixtures for football pitches was conducted. Two grass mixtures were composed of different varieties of perennial ryegrass, one mixture was composed of varieties of perennial ryegrass and Kentucky bluegrass, one mixture consisted of the species *Lolium perenne, Festuca rubra, Festuca arundinacea* and *Poa pratensis*, and the seeds of only one variety of perennial ryegrass were sowed in one plot. Three different fertilisation schemes were included in the experiment. The first scheme (A) contained an inorganic fertiliser with added soil improvers, the second scheme (B) included an organic fertiliser with added soil improvers and the third scheme (C) was composed of an inorganic fertiliser. According to this study, the grass yield largely depends on the soil temperature, amount of precipitation and soil water content, and the occurrence of the fungus *Laetisaria fuciformis* is influenced by the fertilisation scheme, as the % infection with the fungus was highest when organic fertilisers with low % nitrogen was used. The selection of fertilisers is seen as an important factor for the turfgrass colour.

Keywords: sport grass mixtures; abiotic factors; yield; *Laetisaria fuciformis*; fertilization scheme

Lawns have a major impact on human life, adding elegance to environments, such as private or public surfaces. Sport turfgrasses are composed of different grass species that could be found in every lawn (Pooya et al. 2013). Because of the different characteristics of each species, mixtures of two or more grass species that may complement each other to provide functional and aesthetic improvements in turf quality (Pooya et al. 2013) are used for sport turfgrass. The turfgrass quality affects the pitch presentation and playing conditions, which are important for professional football matches. Following the Union of European Football Associations (UEFA) guidelines, every pitch should be well drained, smooth and level, and safe for the players, allow for optimal play and have a good visual appearance (Wilson 2018).

Turfgrasses are classified into two main groups based on their basic biology and climatic adaptation: cool-season grasses (C3) and warm-season grasses (C4). Cool-season grasses are adapted to temperate and subarctic climates. They are active primarily during spring and autumn, when the average daytime temperatures are cool, between 16 °C and 24 °C (Simmons et al. 2011; Romero, Dukes 2016; Wilson 2018). When the temperature reaches 33 °C, the cool-season grasses' growth is impaired (Martiniello, D'Andrea 2006). Seed mixtures of perennial ryegrass (*Lolium perenne* L.), smooth-stalked meadow grass/ Kentucky bluegrass (*Poa pratensis* L.) and red fescue

Supported by the Slovenian Research Agency within the programme Horticulture No. P4-0013-0481.

https://doi.org/10.17221/158/2020-HORTSCI

(*Festuca rubra* L.) are widely used for established football pitches in Central Europe (Barton, Colmer 2006; Martiniello, D'Andrea 2006; Knot et al. 2017).

Cultivars of these species demonstrate large variability in performance and different responses to weather conditions (Martiniello, D'Andrea 2006). Turfgrass selection is sometimes difficult because some cool-season grasses are poorly adapted to summer conditions (high temperatures or poor water availability), and drought or heat stress causes a severe decline in the pitch quality. In addition to other necessary maintenance efforts, well-scheduled irrigation and fertilisation schemes are necessary for an acceptable turfgrass quality (Barton, Colmer 2006). Studies over the last fifty years have focussed on the grass selection that would meet the above requirements (Simmons et al. 2011).

Fertilisers used for maintaining sport turfgrass provide a range of essential nutrients to support growth, help the grass recover from damage and improve the colour, uniformity and density of the grass for the pitch presentation. Nitrogen (N) fertilisation is essential for supporting and maintaining the turf qualities such as the colour, vigour, root growth and disease resistance. The quantity and timing of fertiliser-N applications have a major impact on the occurrence of turfgrass diseases. A balanced fertilisation programme based on frequent light applications of nitrogen during the growing season should discourage disease infections and provide the energy needed for recovery from any disease injuries that occur. An adequately fertilised turfgrass tolerates moisture stress better than a nitrogen-deficient turf, has better resistance to diseases and increases growth (roots and leaves) (Candogan et al. 2015; Głąb et al. 2020).

Interest in the use of natural organic nitrogen sources in turfgrass management (Li et al. 2005) and vegetable growing (Bimova, Pokluda 2009) is increasing because natural organic nitrogen sources provide a number of benefits to soil ecosystems. They improve the soil's physical, chemical and biological properties, as well as reduce the environmental impacts of applied pesticides and provide a certain degree of disease control (Li et al. 2005). Natural organic fertilisers are materials of plant and animal origin, where the nitrogen release requires microbial activity. The nitrogen release from natural organic materials at a rate that is beneficial to turfgrasses depends on degradation by soil microorganisms. Compared with other nitrogen sources, the turf response can be significantly reduced (Peacock, Daniel 1992). Several factors influence the nutrient release from fertilisers: soil pH, soil temperature, microbial activity, moisture content and granular size. In the maintenance of a sport turfgrass, various types of fertilisers are used: quick-release inorganic N, slow-release inorganic N and organic N fertilisers (Bilgili, Açikgöz 2011).

Environmentally friendly fertilisers offer an effective way to improve the nutrient efficiency to minimise the leaching and volatilisation losses of fertilisers and to reduce any environmental hazards. By retarding or even controlling the release of the nutrients into the soil, they reduce the environmental pollution from nutrient losses. Nutrients are coated with environmentally friendly materials that can be degraded in the soil and converted into carbon dioxide, water, methane, inorganic compounds or a microbial biomass (Chen et al. 2018).

The availability of mineral nutrients can affect a plant's susceptibility to pathogens in a variety of ways. Some nutrients, such as nitrogen and sulfur, are constituents of organic compounds that feed, attract or deter pathogens. Other materials, such as calcium and silicon, determine the mechanical properties of the cell walls and influence physical barriers or the palatability (Davis et al. 2018).

Red thread disease is caused by the fungus *Laetisaria fuciformis* (Berk.) Burds. 1979. In recent years, this fungus has become more common and widespread in Europe (Berestetski et al. 2002). The turfgrass species most susceptible to red thread disease are the perennial ryegrass (Cagaš et al. 2010; Curk et al. 2017), Kentucky bluegrass and red fescue (Berestetski et al. 2002). According to known data, the fungus most commonly occurs on older and poorly maintained turfgrass (Cagaš et al. 2010). The development of the disease is favoured by mild temperatures (15–25 °C) and high humidity. The disease severely injures turfgrass leaves, resulting in patches with characteristic symptoms of coral-red mycelium tendrils. Red thread disease can spread over the pitch very quickly with the use of cutting machines and other mechanical actions (Berestetski et al. 2002).

Few studies report the use of different varieties of sport turfgrass species (*Lolium perenne* L. and *Poa pratensis* L.) for the pitch preparation. The aim of this study was to determine the suitability of the varieties included in the tested mixtures for cultivation on football pitches in central Slovenia. Previous studies have not focussed on the study of different

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grass varieties as the main component of each grass mixture intended for a sport turfgrass. Therefore, testing the impact of the fertiliser types on the herbage mass and health of different grass mixtures for sport pitches and how both factors depend on the weather was undertaken.

MATERIAL AND METHODS

Site and experimental design. On September 11, 2018, a field experiment was carried out in the pre-Alpine region of Slovenia on the laboratory field (46°03'N, 14°28'E, 300 m a.s.l.) of the Biotechnical Faculty in Ljubljana. The climate at the site is characterised by a typical temperate continental climate. The response of five different sport grass mixtures to three different fertilisation schemes was studied. The block covered 180 m^2 and was arranged in a split-plot design with three replications. Within each block, five treatments were arranged randomly, and different sport grass mixtures were sown. The seeds of the grasses were sown manually on each block at a rate of 50 g/m^2 and fertilised with DCM Vivifos® 4-30-0 (DCM Ltd. (Grobbendonkmesto, Belgium) at a rate of 25 g/m^2.

The Stagnic Eutric Cambisol (Drainic, Humic, Siltic) (WRB, 2015) at the field experimental site is approximately 110 cm deep with a moderately gleyed layer between 30 cm and 70 cm below the surface. The soil profile consists of a silty loam in the upper 30 cm and a silty clay loam in the lower 80 cm. The parent material is carbonated deposits of sand and gravel. In the upper 6 cm soil layer, the initial pH ($CaCl_2$) and the available P and K contents (extracted in ammonium lactate), % of soil organic matter and % of carbon are given in Table 1. The soil is artificially drained by subsurface drains.

The sport grass (SG) mixtures used in the experiment were as follows: 'SG1' consisting of 50% *Lolium perenne* L. 'Silverdollar', 30% *Lolium perenne* L. 'Vantage', and 30% *Lolium perenne* L. 'Carleve'; 'SG2' consisting of 4% *Lolium perenne* L. 'Fabian', 40% *Lolium perenne* L. 'Tetrastar', and 20% *Lolium perenne* L. 'Mercitwo'; 'SG3' consisting of 25% *Lolium perenne* L. 'Greenway', 20% *Lolium perenne* L. 'Tetragreen', 40% *Lolium perenne* L. 'Greensky', and 15% *Poa pratensis* L. 'SR2100'; 'SG 4' consisting of 100% *Lolium perenne* L. RPR; and 'SG5' consisting of 30% *Lolium perenne* L. 'Barminton', 10% *Poa pratensis* L. "Baron", 25% *Festuca arundinacea* L. 'Barlexas II', 10% *Festuca rubra* L. 'Bardiva', and 25% *Festuca rubra rubra* L. 'Barustic'. The mixture 'SG1' originated from Tempoverde Ltd. (Italy), "SG2' and 'SG3" originated from DLF *Trifolium* Ltd. (Denmark) and 'SG4' and 'SG5' originated from Barenbrug Ltd. (Netherlands).

Table 1. Soil analysis

Depth (cm)	pH in $CaCl_2$	P_2O_5 (mg/100 g)	K_2O (mg/100 g)	Organic matter (%)	C (%)
0–6	6.8	16.1	16.9	5.3	3.1

Turfgrass management. In the field experiment, fertilisers in three different schemes were used. The composition of the first scheme (A) was an inorganic fertiliser with two soil improvers, the second scheme (B) consisted of an organic fertiliser with two soil improvers, and the third scheme (C) was an inorganic fertiliser without soil improvers. The rate of application of each fertiliser and soil improver was 25 g/m^2. Table 2 presents the dates of the fertilisation in the three schemes with the fertiliser and soil improvement descriptions. All the materials for the fertilisation were obtained from Vitalis Crop Care Ltd. (Samobor, Croatia).

The granulated solid inorganic fertilisers NPK NovaTec® Classic 12-8-16(+3+TE), NovaTec® Triplo 15-9-15(+2+TE) and NovaTec® Suprem 21-5-10(+3+TE) are produced by Compo Expert (Münster/Westphalia, Germany). The fertilisers contain potassium sulfate (SOP) and the nitrification inhibitor DMPP (3,4-dimethylpyrazole phosphate), which allow a greater efficiency and prolonged action of nitrogen in the plant nutrition (Vitalis crop care, 2020). DMPP reduces the nitrogen (N) loss and increases the N efficiency (Xu et al. 2019).

The organomineral granular fertilisers NPK, DCM Vital-Green 14-4-8+3MgO+Fe and DCM Grass-Care 6-3-20+3MgO+Fe and the soil improvers DCM Vivisol® Minigran® and DCM Antagon are produced by DCM Ltd. (Grobbendonkmesto, Belgium). DCM Vital-Green 14-4-8+3MgO+Fe with iron chelate (0.05% Fe – EDTA) and magnesium (3% MgO) has a long-lasting effect for good (re)growth of the grass in spring (starter) and growth during the season. DCM Grass-Care 6-3-20+3MgO+Fe contains a high amount of long-lasting potassium, iron chelate (0.1 % Fe – EDTA) and magnesium (3% MgO). This fertiliser is ideal for fall and winter periods and summers with extremely high temperatures (Vitalis crop care, 2020). DCM antagonist contains 50% organic substance, 4% organic N, 3% P_2O_5, 2% K_2O and antagonistic fungi *Trichoderma* spp. DCM Vivisol®

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Table 2. Description of the fertilisation schemes, with specific dates of fertilisation in the experimental years of 2019 and 2020.

Date	Fertilization scheme
28th March, 2019	A: NovaTec® Suprem 21-5-10(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Vital-Green 14-4-8+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Suprem 21-5-10(+3+TE)
17th May, 2019	A: NovaTec® Suprem 21-5-10(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Vital-Green 14-4-8+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Suprem 21-5-10(+3+TE)
20th June, 2019	A: NovaTec® Triplo 15-9-15(+2+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Vital-Green 14-4-8+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Triplo 15-9-15(+2+TE)
23rd July, 2019	A: NovaTec® Classic 12-8-16(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Grass-Care 6-3-20+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Classic 12-8-16(+3+TE)
28th August, 2019	A: NovaTec® Classic 12-8-16(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Grass-Care 6-3-20+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Classic 12-8-16(+3+TE)
3rd October, 2019	A: NovaTec® Classic 12-8-16(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Grass-Care 6-3-20+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Classic 12-8-16(+3+TE)
8th April, 2020	A: NovaTec® Classic 12-8-16(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Vital-Green 14-4-8+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Classic 12-8-16(+3+TE)
25th May, 2020	A: NovaTec® Classic 12-8-16(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Vital-Green 14-4-8+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Classic 12-8-16(+3+TE)
24th June, 2020	A: NovaTec® Classic 12-8-16(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Vital-Green 14-4-8+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Classic 12-8-16(+3+TE)
9th August, 2020	A: NovaTec® Classic 12-8-16(+3+TE) + DCM Vivisol® Minigran® + DCM Antagon B: DCM Vital-Green 14-4-8+3MgO+Fe + DCM Vivisol® Minigran® + DCM Antagon C: NovaTec® Classic 12-8-16(+3+TE)

Minigran® contains 60% organic substances, 85% dry substances and *Bacillus amyloliquefaciens* bacteria, which colonise the soil and take up phosphorus that is unavailable to plants via the roots (Vitalis crop care 2020).

Cutting was performed with a rotary mower (model: Husqvarna LC 153S Push Lawnmower Mulching, Driving Wheels Coupe 53 cm, producer: Husqvarna, Sweden; supplier: Rotar, Slovenia). In 2019, the cutting with herbage mass weighing occurred on the 16th April, 3rd June, 5th July, 19th September and 23rd October, while in 2020, the cutting occurred on the 4th May, 22nd May, 12th June, 13th July, 6th August, 27th August and 16th September. The cutting height was from 2 to 3 cm. The herbage mass was weighed with a JKH-4000 portable scale (producer: Xiamen Jadever Scale Co., Fujian, China).

Colour determination in 2019. The colour visual determination was assessed according to a slightly modified methodology described by the National

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Table 3. Parameters that were measured by the "IoT System for Environmental Parameter Measurements (Slovenian Forestry Institute: Laboratory for Electronic Devices)"

	Soil water content (m^3/m^3)(10^{-2})		Soil temperature (°C)		Air temperature (°C)		RH (50 cm) (%)	Rain (mm)		Precipitation days
	5 cm	10 cm	5 cm	10 cm	50 cm	2 m		average	sum	
In 2019										
27th March–16th April	2.6	2.6	10.5	10.2	8.9	9.6	83.00	2.5	49.7	6
17th May–3rd June	2.9	2.9	17.2	16.6	14.9	15.2	89.00	7.4	133.8	10
20th June–5th July	2.6	2.4	24.7	24.3	22.4	22.7	80.20	4.6	72.9	5
23rd July–12th Aug	2.5	2.3	24.8	24.5	22.7	23.0	85.30	6.0	125.2	6
28th Aug–19th Sept	2.5	2.3	20.3	20.3	17.3	17.6	92.00	3.8	86.7	6
3rd Oct–23rd Oct	2.8	2.6	14.7	14.9	12.6	13.2	92.50	3.0	62.5	5
In 2020										
8th April–4th May	4.2	4.2	13.2	12.9	12.4	13.0	69.24	1.62	43.8	5
25th May–12th June	4.2	4.2	17.28	17.16	15.27	15.53	85.38	6.11	116.2	7
24th June–13th July	4.3	4.3	20.77	20.77	19.86	20.17	81.76	5.66	113.3	6
9th August–27th Sept	4.3	4.4	22.46	22.42	21.42	21.72	85.60	1.65	31.3	2

RH – relative humidity

Turfgrass Evaluation Program (NTEP) (Morris 2019), where a visual scale from 1 (worst/yellow) to 9 (best/dark green) was used (Karcher, Richardson 2003). The evaluation was performed on three different dates: 16th April, 3rd June and 5th July. The determination of the colour was performed an hour before cutting and an hour after cutting.

Weather parameters. The parameters that were measured by the "IoT system for environmental parameter measurements (Slovenian Forestry Institute: Laboratory for Electronic Devices)" are the soil water content, soil temperature, air temperature and relative humidity (RH). Data regarding the average precipitation (mm) of the rain, sum of the rain (mm) and number of precipitation days were collected at the Slovenian Environmental Agency (MeteoSlo 2020).

Average % of infection of red thread (*Laetisaria fuciformis*). The average % infection by red thread (*Laetisaria fuciformis*) was evaluated per specific treatment as the % of infected natural grass area per plot (Berestetski et al. 2002). According to the NTEP recommendation, we used a 1 to 9 rating scale with 1 = 100 % injury and 9 = no injury, resulting in a % (Morris 2019). The occurrence of the disease in the first year of the experiment was noticed on the 17th June and 5th July 2019 and in the second year on the 11th February and 23rd June 2020.

Data analysis. An analysis of variance (ANOVA) was conducted to establish the differences among the sport grass mixtures within the fertilisation schemes. The differences in the average mass of the herbage, colour before/after cutting, and average % of infection by *Laetisaria fuciformis* were analysed via ANOVA. Before the analysis, each variable was tested for homogeneity of variance, and any nonhomogeneous data were log(Y) transformed prior to the ANOVA. Significant differences ($P \leq 0.05$) between the mean values were identified using the Student-Neuman Keuls honestly significant difference multiple range test. All the statistical analyses were performed using Statgraphics Centurion XVI software (Statgraphics Technologies Inc., USA), and the results are presented as the untransformed mean ± the standard error (SE).

RESULTS AND DISCUSSION

Soil and weather conditions. The parameters that were measured in our research are presented in Table 3. The soil parameters were measured at two different depths (5 cm and 10 cm), the air temperature was measured at 50 cm and 2 m, and the RH was measured at 50 cm.

Mass of herbage in the year 2019. According to the general statistical analysis, we confirmed that the herbage mass had a significant impact on the cutting date ($F = 262.32$, $Df = 5$; $P < 0.0001$) and fertilising scheme ($F = 7.86$, $Df = 2$; $P = 0.0005$). We detected no im-

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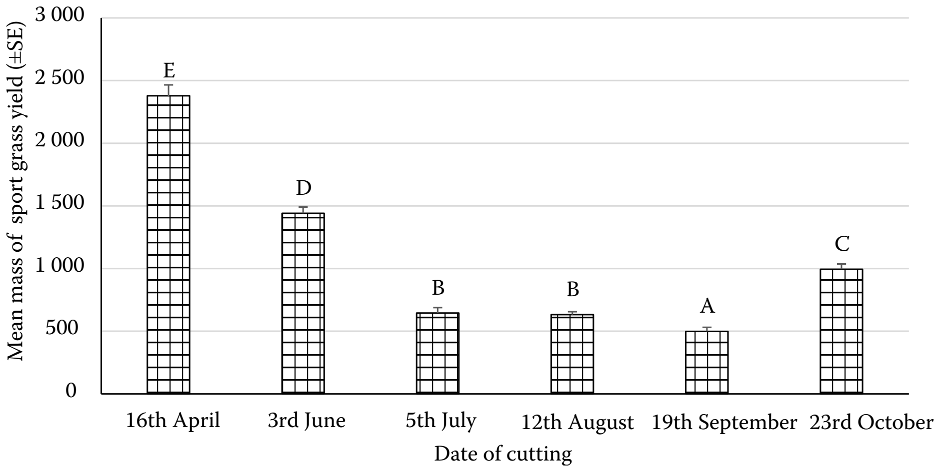

Figure 1. Mean mass (g/m^2) of the grass yield on the day of cutting (±SE) in 2019

Values marked with the same letter do not differ significantly

pact of the sport grass mixture on the herbage mass (*F* = 0.75, *Df* = 4, *P* = 0.55). We determined connections between the cutting date and fertilising scheme (*F* = 6.89, *DF* = 10; *P*<0.0001) and the cutting date and sport grass mixture (*F* = 2.38, *Df* = 20, *P* = 0.0014).

The average herbage mass was significantly higher on the first cut (2 368.88 ± 88.03 g/m^2) and significantly lower on the 19th September (498.93 ± 32.75 g/m^2) (Figure 1). Based on the statistical analysis, the herbage mass of the sport grass mixtures was 1 153.34 ± 100.49 g/m^2 with 'SG1', 1 072.7 ± 89.03 g/m^2 with 'SG2', 989.19 ± 97.41 g/m^2 with 'SG3', 1 097.46 ± 105.55 g/m^2 with 'SG4' and 1 074.71 ± 107.57 g/m^2 with 'SG5', but no significant difference between the sport grass mixtures 'SG1' and 'SG3' was detected (Figure 2).

In the first cutting, we detected the lowest average herbage mass fertilised with scheme C (2 138.0 ± 126.64 g/m^2), but the highest with scheme B (2 705.73 ± 166.22 g/m^2). In all the other cuts, the highest yield was determined where fertilisation scheme C (Figure 3) was used.

The herbage mass was significantly higher in the first cutting term with 'SG1' (2 535.11 ± 181.46 g/m^2). In the second cutting term, the highest yield was with 'SG5' (1 627.56 ± 117.01) (Figure 4).

Regarding the individual treatments, the mean mass of the grass yield after the first cut ranged from 1 849.00 ± 416.29 g/m^2 with 'SG5' (fertilised with scheme A) to 3 041.67 ± 151.94 g/m^2 with 'SG4' (fertilised with scheme B). Based on the mean mass of the grass yield, on the 3rd June 2019, the mixture 'SG5' fertilised with scheme C stands out. On the 5th July 2019, the highest yield was detected again for mixture 'SG5' fertilised with scheme C. At the last cut, the highest yield was detected for all the sport grass mixtures fertilised with scheme C. All the other values are presented in Figure 5.

Mean mass of herbage in 2020. According to the general statistical analysis in 2020, we confirmed the impact on the mass of the grass yield in the fertilising scheme (*F* = 432.24, *Df* = 2, *P* < 0.0001), cutting date (*F* = 428.85, *Df* = 3, *P* < 0.0001) and the interaction between the fertilising scheme and cutting date

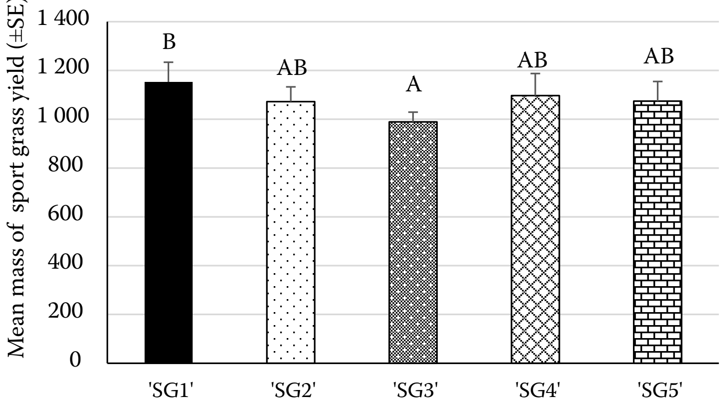

Figure 2. Mean mass (g/m^2) of the grass yield per sport grass mixture (±SE) in 2019

Values marked with the same letter do not differ significantly

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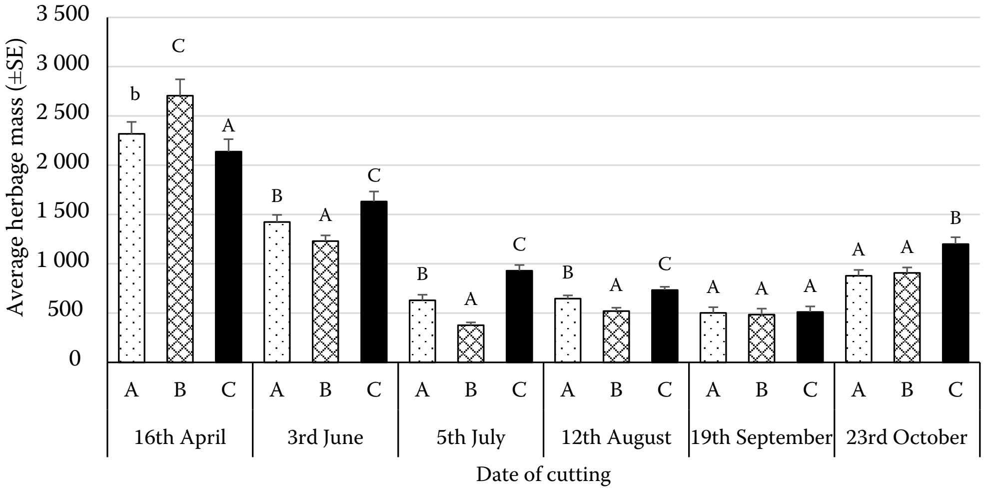

Figure 3. Mean mass (g/m^2) of the herbage per fertilisation scheme according to the different dates in 2019

Letters represent the differences between the schemes within cutting dates

($F = 89.51$, $Df = 12$, $P < 0.0001$). We detected no impact of the grass mixture ($F = 1.34$, $Df = 4$, $P = 0.51480.3790$) on the yield. If we consider seven cutting terms in 2020 (Figure 6), significantly higher grass yields were at the third (1 031.53 ± 26.97 g/m^2), fourth (983.83 ± 47.0 g/m^2) and sixth (1 024.42 ± 19.97 g/m2) cuts. Significantly higher grass yields were obtained with fertilising scheme C (963.67 ± 27.39 g/m^2). Based on the general statistics (Figure 7) in 2020, we did not notice any differences in the yield between the individual grass mixtures.

In five of the seven cuts in 2020, a significantly higher grass yield for fertilising scheme C was detected. In scheme C, the mean mass of the grass yield was 699.73 ± 14.49 g/m^2 at the first cut, 1 031.00 ± 26.78 g/m^2 at the second cut, 1 242.27 ± 13.53 g/m^2 at the third cut, 1 415.47 ± 20.67 g/m^2 at the fourth cut, 1 179.67 ± 21.40 g/m^2 at the sixth cut and 800.40 ± 5.95 g/m^2 at the seventh cut. All the values are presented in Figure 8.

During the first cut in 2020, the highest grass yield was detected with mixture 'SG1' fertilised with scheme C (730.68 ± 19.37 g/m^2). The mean mass of the grass yield was the highest between the second and third cuts, and the yield for all the SG mixtures was the highest when we fertilised with scheme C. All the values are presented in Figure 9.

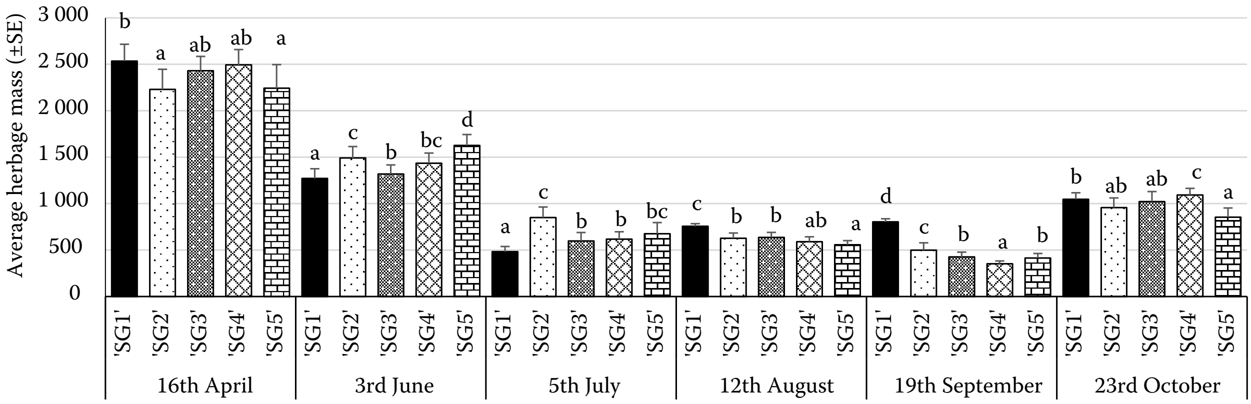

Figure 4. Mean mass (g/m^2) of the herbage per sport grass mixture according to the different dates of cutting in 2019

Letters represent the differences between the turf mixtures within cutting dates

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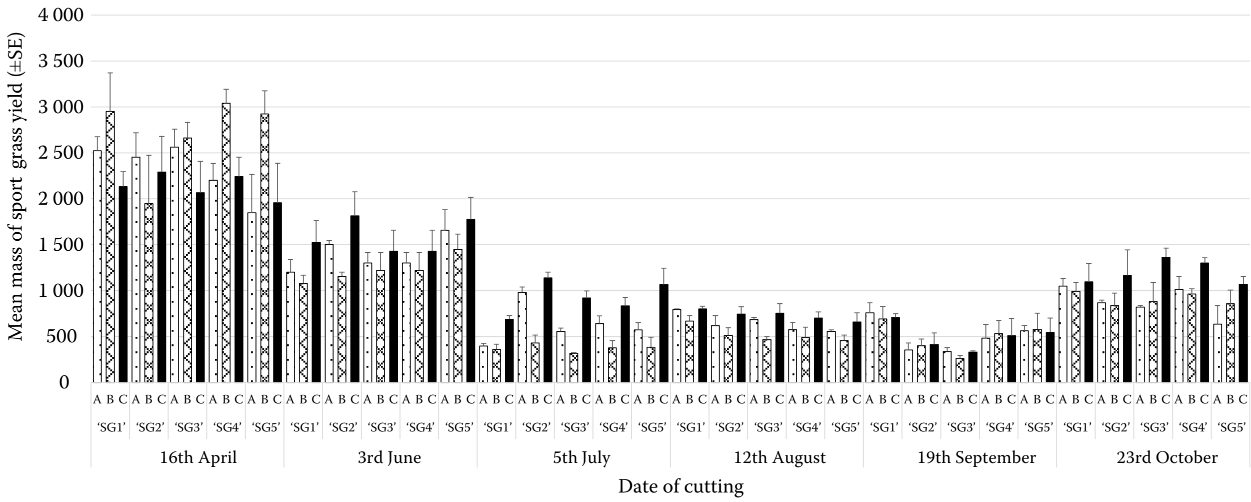

Figure 5. Mean mass (g/m²) of the sport grass yield per fertilisation scheme according to the different natural grass mixtures in 2019

Colour determination in 2019. According to the general statistical analysis, the turfgrass colour before cutting was significantly influenced by the fertilisation scheme ($F = 42.46$, $Df = 2$, $P < 0.0001$), sport grass mixture ($F = 5.20$, $Df = 4$, $P = 0.0007$), date of evaluation ($F = 63.40$, $Df = 2$, $P < 0.0001$) and interaction between the fertilisation scheme and date of evaluation ($F = 16.88$, $Df = 63.40$, $P < 0.0001$). Additionally, after cutting, the colour of the turfgrass was significantly influenced by the fertilisation scheme ($F = 34.65$, $Df = 2$, $P < 0.0001$), turfgrass mixture ($F = 5.56$, $Df = 4$, $P = 0.0004$), date of evaluation ($F = 54.20$, $Df = 2$, $P < 0.0001$), and interaction between the fertilisation scheme and date of evaluation ($F = 14.35$, $Df = 4$, $P < 0.0001$). On the 16th April, the average colour index before cutting was the highest in schemes A and B (a significant difference), while on two other evaluation dates, the colour index was the highest in scheme C. All the values are presented in Figure 10. The lowest colour index was detected at the beginning of June.

According to Figure 11, when the turfgrass was evaluated on the 3rd June and 5th July, the lowest colour indices were detected when the turfgrass was fertilised with schemes A and B. On the first evaluation date, there was no difference detected between the different fertilisation schemes.

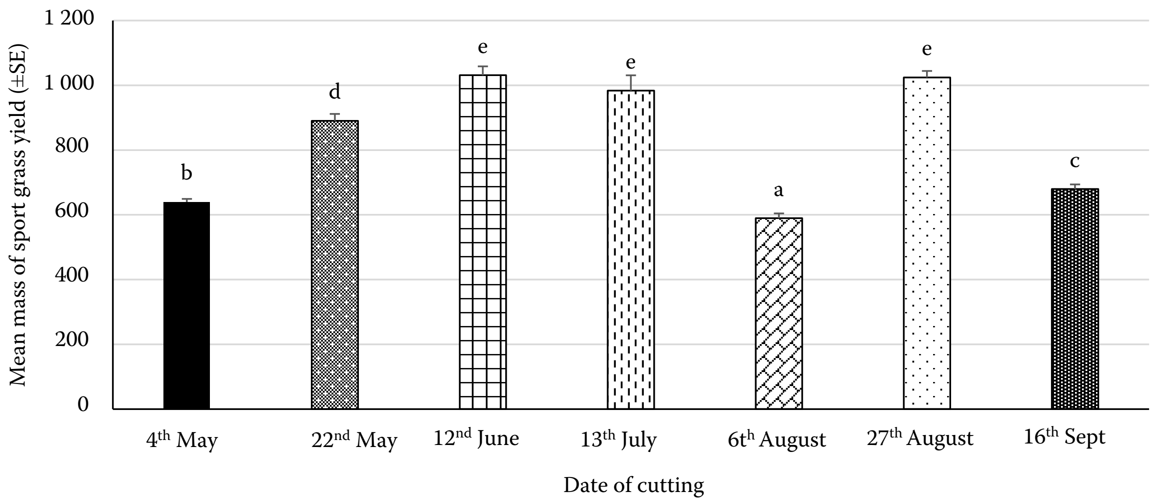

Figure 6. Mean (g/m²) mass of the grass yield per the cutting date in 2020

Letters represent the differences between the cutting dates

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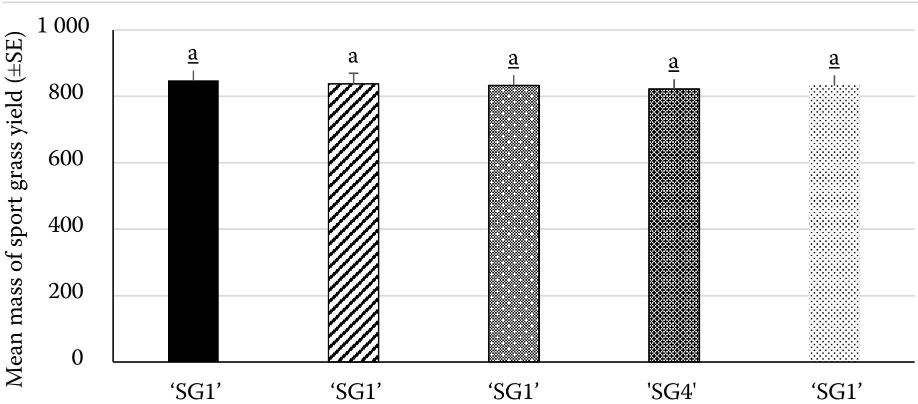

Figure 7. Mean mass (g/m^2) of the grass yield per the sport grass mixture (±SE) in 2020

Letters represent the differences between the grass varieties) in 2020

Average % of infection caused by red thread (*Laetisaria fuciformis*). According to the general statistical analysis, the average infection by the red thread was significantly influenced by the sport grass mixture (F = 6.29, Df = 4, P< 0.0001), fertilisation scheme (F = 52.00, Df = 2, P < 0.0001) and year of assessment (F = 15.47, Df = 3, P < 0.0001). In general, a 32.47 ± 3.88% infection was detected when fertilisation scheme B was used. However, an 11% infection by the red thread was detected with fertilisation scheme A, and a 4% infection was recorded with the turfgrass fertilised with scheme C. On the turfgrass, noticeable patches of dead plants with symptoms of coral-red mycelium tendrils were observed.

In the first year of the experiment, the average % of infection was influenced by the evaluation date (F = 4.29, Df = 1, P = 0.04), ranging from 23.22 ± 2.49% on the 17th June to 16.00 ± 2.43% on the 5th July. In the second year of the experiment, the average % of the infection was also influenced by the evaluation day (F = 15.76, Df = 1, P < 0.0001), ranging from 2.68 ± 1.33% on the 11th February to 21.62 ± 4.57% on the 23rd June 2020.

Regarding 2019, the highest (F = 47.54, Df = 2, P < 0.0001) average % of infection was recorded where fertilisation scheme B was used (38.67 ± 2.95%). Where fertilisation scheme C was implemented, an average infection rate of 5.83 ± 1.81% was detected, and where fertilisation scheme A was used,

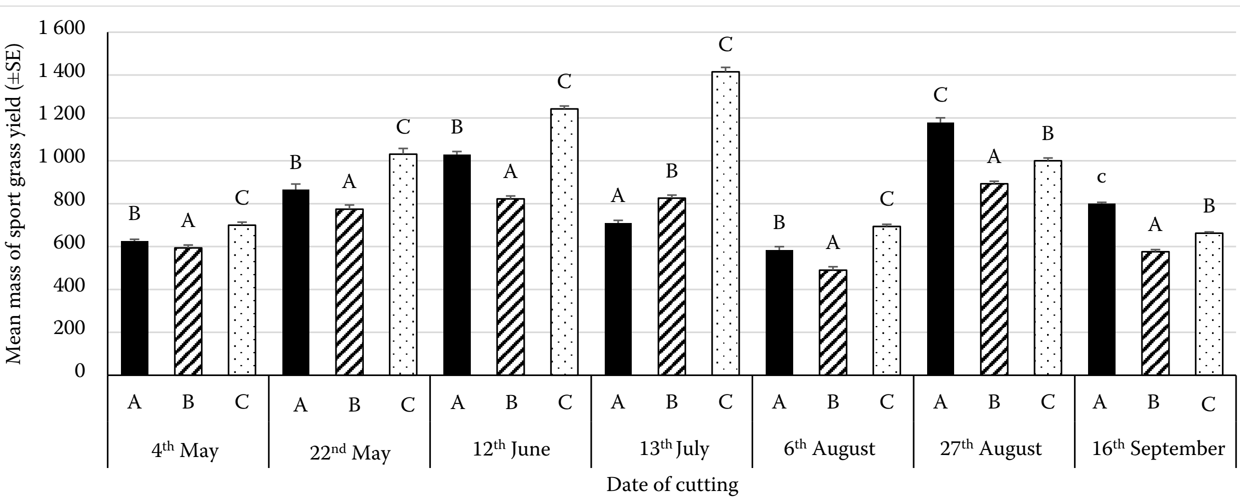

Figure 8. Mean mass (g/m^2) of the sport grass yield between the fertilisation schemes within the cutting dates in 2020

Letters represent the differences between the fertilisation schemes within the cutting dates

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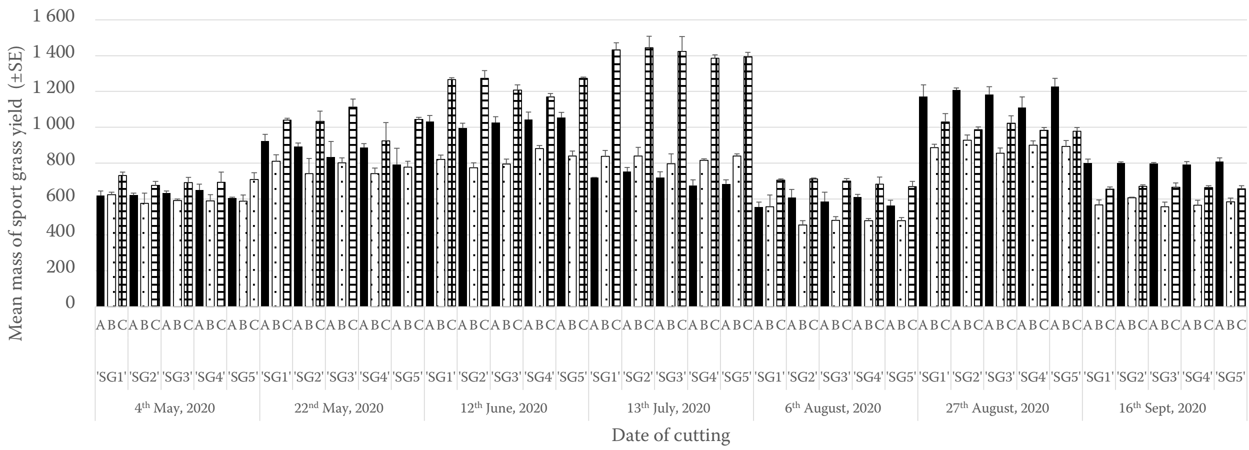

Figure 9. Mean mass (g/m^2) of the turf grass yield per fertilisation scheme according to the different sport grass mixtures in 2020

an average infection rate of 14.33 ± 2.51% was detected (Figure 12). There was also a difference detected between the sport grass mixtures (*F* = 2.93, *Df* = 4, *P* = 0.0223). In 2020, the average % of infection was also influenced by fertilisation scheme B (*F* = 9.46, *Df* = 2, *P* = 0.0002)

In both experimental years, statistically significant differences between the average % of infection between the sport grass mixtures in 2019 (*F* = 2.93, *Df* = 4, *P* = 0.0223) and 2020 (*F* = 1.68, *DF* = 4, *P* = 0.0424) was confirmed. The lowest % of infection was detected where 'SG2" (4.33±2.56%) and 'SG5' (4.05±2.29%) were used (Figure 13).

The use of different varieties of grass species in the seed mixtures for sport turfgrasses has already been studied by Pooya et al. (2013), who established that a mixture of several grass species and varieties is more resistant to weather conditions and diseases than a monoculture. In our study, we also wanted to test the suitability of different cultivars of grass species to extend their use to larger sports areas covered with turf. In the first two cutting terms, the grass yield was significantly the highest. The average air temperatures in the periods before the first two cuts did not exceed 16 °C, which enabled the ideal grass development that thrived better in the colder part of the year (Simmons et al. 2011). The grass yield then increased again in October, when the average daily temperatures fell again.

In the period between the fertilisation and cutting from 17th May to 3rd June 2019, the highest number of precipitation days, also the highest sum of the rain (mm), was detected. The high sum of rain during this period had an impact on the largest grass yield in the season. According to Bastug and Buyuktas (2003) and Kim et al. (2016), the grass growth and yield can be influenced by the water

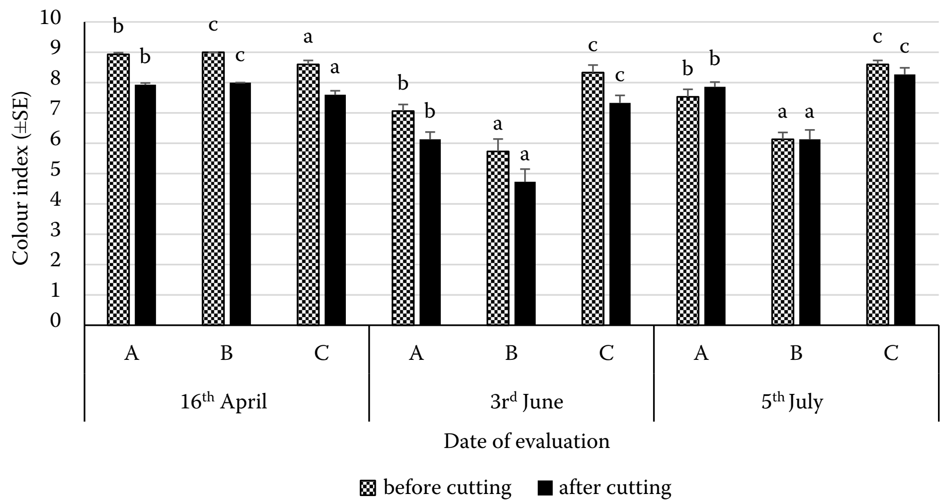

Figure 10. Average colour index according to the different fertilisation schemes in 2019

Letters represent the differences within the fertilisation schemes within one date

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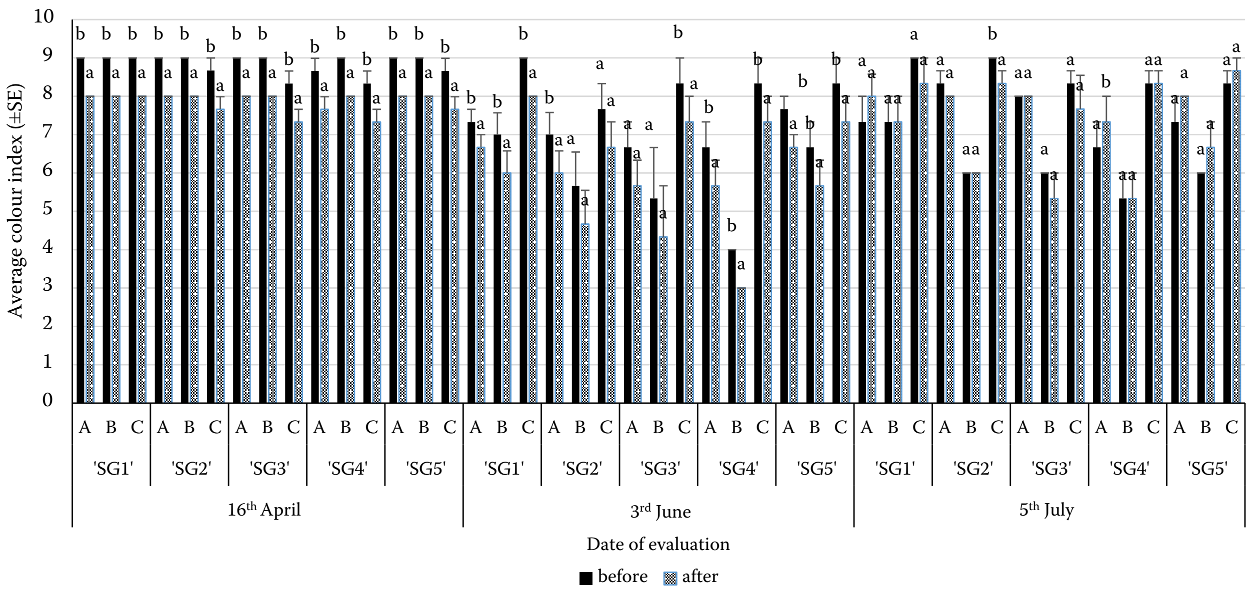

Figure 11. Average colour index according to the different fertilisation schemes within the sport grass mixtures

Letters represent the differences within the fertilisation schemes between the evaluations before/after cutting

from regular irrigation, while the water typically came from precipitation in this study. The soil temperature was also an important factor in the growth of the grass species. Regarding the data in our research, similar to that established by Pote et al. (2006), at 23 °C, the growth of cool-season grasses (C3) stopped, and the high temperatures affected the lower physiological activity of the plants. In the second year of the experiment (2020), the water content in the soil was significantly higher than the water content of the soil in the first year of the experiment (2019), which affected the yield of all the grass mixtures, independent of the fertilisation. The soil water content and root growth are known to be negatively related (Sainju et al. 2017).

With the combination of more different turfgrass species in mixtures for the sport pitch in this study, it has been determined that plants complement/combine with each other with their properties (Pooya et al. 2013). The lowest grass yield was detected for mixture 'SG3" consisting of 25% *Lolium perenne* L. 'Greenway', 20% *Lolium perenne* L. 'Tetragreen', 40% *Lolium perenne* L. 'Greensky', and 15% *Poa pratensis* L. 'SR2100', which can relate to the sensitivity of the sport grass mixture to the occurrence of disease and the slow recovery of damaged plants.

The composition of the 'Greensky' variety in the mixture is the highest, and 'Greensky' is a variety with low secondary growth and slow regrowth.

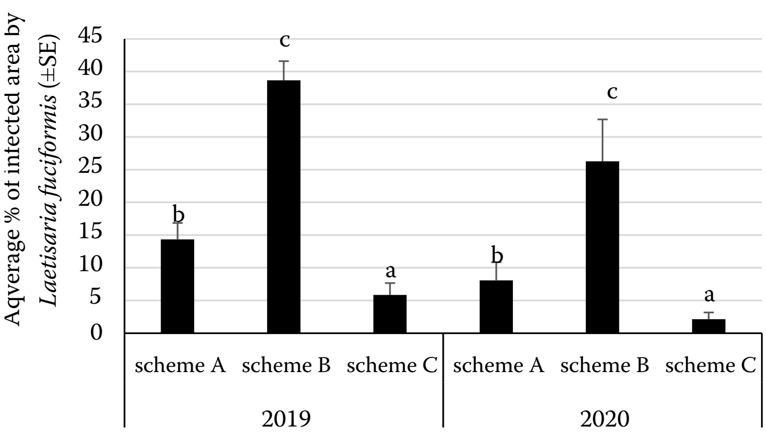

Figure 12. Average % of area infected by *Laetisaria fuciformis*

Letters represent the differences between the fertilisation schemes within the evaluation year

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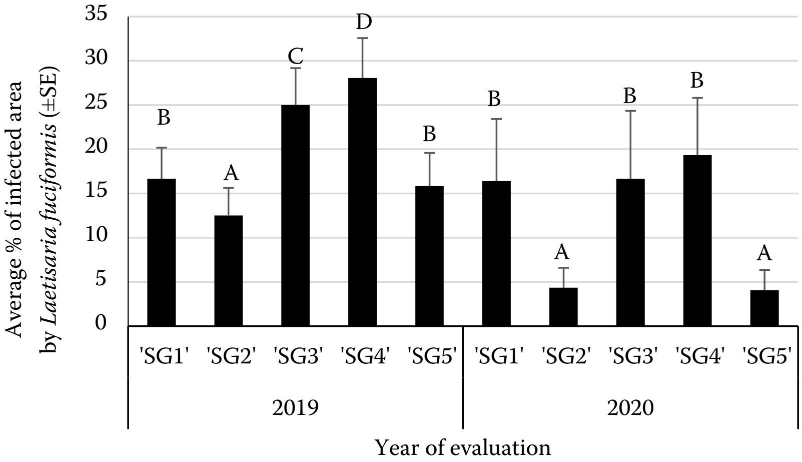

Figure 13. Average % of area infected by *Laetisaria fuciformis*

Letters represent the differences between the sport grass mixtures within the evaluation year

'Tetragreen' is a tetraploid variety with the main benefits of quicker germination, establishment under cool conditions and increased seedling vigour. 'Tetragreen' tends to maintain growth longer than diploid cultivars as temperatures fall in the winter and then it replaces the lost grass cover during the winter wear. 'SR2100' has aggressive growth and wear tolerance, but the mixture contains the lowest amount of "SR2100'. 'Greenway' also has slow recovery and high summer wear tolerance. Regarding reports about cultivar testing of all the major turfgrass species, all the varieties mentioned in mixture 'SG3' have low scores for resistance to red thread (Turfgrass seed 2018; Morris 2019; DLF 2020). The results confirm that mixture 'SG3' is not suitable for use in sport pitches with these climate conditions.

Plant growth is an important factor that regulates the seasonal biomass fluctuations and soil activity. In June, July and August 2019, the highest grass yield was in scheme C (inorganic fertiliser), and the lowest was in scheme B (organic fertiliser). For that period, warm conditions without precipitation, but high humidity, were characteristic. The air temperature and humidity are important environmental factors that affect the microbial activity and activity in the soil. There is an optimal level at which the growth and activity of microbes is greatest, and below that level, the growth and activity decline. Seasonal changes in the soil temperature and moisture directly control the time fluctuations of the soil microbial biomass and activity in some ecosystems (Yao et al. 2011). Therefore, organic fertilisers are slowly released and work better when there is more precipitation or regular irrigation. The inorganic fertilisers that we used were influenced by the weather conditions; at high humidity, the inorganic fertilisers released nutrients. The content of the new nitrification inhibitor DMPP in the mentioned fertilisers, which is effective at much lower doses and less harmful to yield growth, improves the efficiency of N fertilisers or reduces the loss of N in the environment (Xu et al. 2019), which results in faster growth and higher grass yields.

Nitrogen, phosphorus and potassium belong to the group of important elements for turfgrass growth (Vargas et al. 2005). Nitrogen fertilisers are used to maintain the growth and visual quality of turfgrass sports. The fertilisation programme of the N fertiliser application coincides with the demand for cool-season turfgrass growth in early spring and autumn (Yao et al. 2011). Radhakrishnan et al. (2017) reported positive effects of the bacteria of the genus *Bacillus* spp. that make it easier for plants to adapt to stressful conditions (higher temperatures, drought, etc.). In our research, with the combination of natural fertilisers (biobased) and additional soil improvers (DCM Vivisol® Minigran®/DCM Antagon), we proved that high grass yields can be achieved even without mineral fertilisers. Regarding the usage of mineral fertilisers on sports turfgrasses, past studies have shown that turfgrasses with the smallest possible labour input are more appreciated. The problem also arises when the source of excavation of mineral fertilisers becomes limited, and it is necessary to look for alternative sources (Chojnacka et al. 2020) or fertilisers. The soil improvers used in scheme B with the content of *Trichoderma* spp. allows plants to make more use of phosphorus from the soil. The secondary metabolites secreted by *Trichoderma* spp. have proven their role in suppressing the growth of pathogenic microorganisms and stimulating plant growth (Vinci et al. 2018).

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Acikgoz et al. (2016) reported that fertilisation with organic fertilisers with the addition of *Bacillus subtilis* and *Bacillus megaterium* has a positive impact on the sport grass yield and produces a darker colour. In our study, we detected a higher grass yield in treatments where we used supplements based on *Bacillus* spp. and *Trichoderma* spp., but no darker colour was established. The use of turfgrass mixtures for sport pitches is also important for its health and care, and this was also confirmed in our study. Red thread disease caused by the fungus *Laetisaria fuciformis* occurs on turfgrasses under favourable conditions of mild temperatures (15–25 °C) and high humidity (Berestetski et al. 2002). During the period of occurrence in our experiment in both years, the weather conditions (air temperature of 24 °C and RH 85%) were favourable for the spread of red thread disease.

Turfgrass fertilisers can be "good" or "bad" in connection with the spread of the disease. Vargas et al. (2005) reported that nitrogen fertilisation inhibits the infection extent with the fungus *Laetisaria fuciformis*. As confirmed in this study, the fungus was more pronounced when the turfgrass was fertilised with organic fertilisers (scheme B). By using scheme B, replacement of conventional fertilisation was studied, but unfortunately, the appropriate conditions for the operation of organic fertilisers were not achieved. The organic fertilisers used in our research contained microorganisms characterised that needed the soil moisture to function (Melentev et al. 2000). During the period of occurrence of the disease, a dry period with low precipitation and higher humidity was recorded. According to this study, high humidity is not effective in the action of organic fertilisers, which has already been established by Wei et al. (2011). Under controlled conditions, organic fertilisers have a more efficient action because, with regular irrigation, they release nutrients accessible to the plants, and microorganisms have more activity (Yao et al. 2011). Fertilisers containing *Bacillus* spp. need more nitrogen in the soil to function (Sun et al. 2020), so, in our experiment, a higher impact on the grass yield when we added fertilisers with high nitrogen or used fertilisation scheme A was confirmed.

A turfgrass composed of only one variety of grass species is more susceptible to disease occurrence (Vargas et al. 2005); in our example, that mixture was 'SG4' (100% *Lolium perenne* L. RPR). Vargas et al. (2005) established that grasses from the genus *Festuca* L. have good resistance to the fungus *Laetisaria fuciformis*, which we detected in our research for the mixture "SG5", with *Festuca* spp. (30% *Lolium perenne* L. 'Barminton', 10% *Poa pratensis* L. 'Baron', 25% *Festuca arundinacea* L. 'Barlexas II", 10% *Festuca rubra* L. 'Bardiva', 25% *Festuca rubra rubra* L. "Barustic'). Mixture 'SG2", composed of the new tetraploid perennial ryegrass varieties "Fabian', "Tetrastar" and 'Mercitwo', which have high resistance to the mentioned disease, had the lowest sensitivity to the fungus *Laetisaria fuciformis* (Turfgrass seed 2018; DLF 2020).

CONCLUSIONS

Comparing the same time period in both years of the experiment, we found that the average % of the fungal infection was higher in the second year of the experiment. This is evidence that the fungus occurs more extensively on an older turfgrass. We also established that the choice of cultivar is an important factor for the aesthetics and functionality of a sports lawn. We proved that the appropriate (visual) condition of the lawn can be achieved by being careful in choosing the grass composition of the mixture and the type of fertiliser.

Acknowledgment

We would like to thank Boštjan Medved Karničar for providing technical assistance. Study was performed at Development and Research Centre for Studying the Growth and Development of Agricultural Crops in Ljubljana (IC RRC-AG [IO-0022-0481-001].

REFERENCES

Acikgoz E., Bilgili U., Sahin F., Guillard K. (2016): Effect of plant growth promoting *Bacillus* sp. on color and clipping yield of three turfgrass species. Journal of Plant Nutrition, 39: 1404–1411.

Barton L., Colmer T.D. (2006): Irrigation and fertiliser strategies for minimizing nitrogen leaching from turfgrass. Agricultural Water Management, 80: 160–175.

Bastug R., Buyuktas D. (2003): The effects of different irrigation levels applied in golf courses on some quality characteristics of turfgrass. Irrigation Science, 22: 87–93.

Berestetski A., Ehrig F., Kastirr U. (2002): Preliminary evaluation of turfgrass (perennial ryegrass and red fescue) cultivars for resistance to red thread disease using artificial infection. Plant Breeding, 121: 493–500.

Bilgili U., Açikgöz E. (2011): Effects of slow-release fertilizers on turf quality in a turf mixture. Turkish Journal of Field Crops, 16: 130–136.

https://doi.org/10.17221/158/2020-HORTSCI

Bimova P., Pokluda R. (2009): Impact of organic fertilizers on toal antioxidant capacity in head cabbage. Hoticultural Science, 36:21–25.

Cagaš B., Ševčíková M., Macháč R. (2010): Field resistance of *Festuca rubra* varieties to red thread (*Laetisaria fuciformis*). In: Huyghe, C. Sustainable use of genetic diversity in forage and turf breeding. Springer Science + Business Media B.V: 289–293.

Candogan B.N., Bilgili U., Yazgan S., Acikgoz E. (2015): Irrigation level and nitrogen rate affect evapotranspiration and quality of perennial ryegrass (*Lolium perenne*). International Journal of Agriculture & Biology, 17: 431–439.

Chen J., Lu S., Zhang Z., Zhao X., Li X., Ning P., Liu M. (2018): Environmentally friendly fertilizers: A review of materials used and their effects on the environment. Science of the Total Environment, 613–614: 829–839.

Chojnacka K., Moustakas K., Witek-Krowiak A. (2020): Bio-based fertilizers: a practical approach towards circular economy. Bioresource Technology. Availabe at https://doi.org/10.1016/j.biortech.2019.122223

Curk M., Vidrih M., Laznik Ž., Trdan S. (2017): Turfgrass maintenance and management in soccer fields in Slovenia. Urban Forestry & Urban Greening, 26: 191–197.

Davis J.L., Armengaud P., Larson T.R., Graham I.A, White P.J., Newton A.C., Amtmann A (2018): Contrasting nutrient–disease relationships: Potassium gradients in barley leaves have opposite effects on two fungal pathogens with different sensitivities to jasmonic acid. Plant, Cell and Environment, 41: 2357–2372.

DLF (2020): https://www.dlf.com/professional-turf/species-varieties (accessed July 9, 2020).

Głąb T., Szewczyk W., Gondek K., Mierzwa-Hersztek M., Palmowska J., Nęcka K. (2020): Optimization of turfgrass fertigation rate and frequency. Agricultural Water Management: 234. Availabe at https://doi.org/10.1016/j.agwat.2020.106107

Karcher D.E., Richardson M.D. (2003): Quantifying turfgrass color using digital image analysis. Crop Science, 43: 943–951.

Kim S., Williams A., Kiniry J.R., Hawkes C.V. (2016): Simulating diverse native C4 perennial grasses with varying rainfall. Journal of Arid Environment, 134: 97–103.

Knot P., Hrabe F., Hejduk, S., Skladanka J., Kvasnovsky, M., Hodulikova, L., Caslavova, I., Horky, P. (2017): The impact of different management practices on botanical composition, quality, colour and growth of urban lawns. Urban Forestry & Urban Greening, 26: 178–183.

Li K., Xing B., Torello W. A. 2005. Effect of organic fertilizers derived dissolved organic matter on pesticide sorption and leaching. Environmental Pollution, 134: 187–194.

Martiniello P., D'Andrea E. (2006): Cool-season turf grass species adaptability in Mediterranean environments and quality traits of varieties. European Journal of Agronomy, 25: 234–242.

Melentev A.I., Kuzmina L.Y., Galimzyanova N.F. (2000): Effect of temperature and soil moisture content on colonization of the wheat rhizosphere by antiphytopathogenic Bacilii. Microbiology, 69: 426–432.

MeteoSLO. (2020): National Meteorological Service of Slovenia. Available at http://www.meteo.si (accessed Sept 1, 2020)

Morris K.N. (2019): A guide to NTEP turfgrass ratings. The national turfgrass evaluation program: 1–5. Available at https://www.ntep.org/pdf/ratings.pdf

Peacock C.H., Daniel P.F. (1992): A Comparison of turfgrass response to biologically amended fertilizers. Hortscience, 27: 883–884.

Pooya E.S., Tehranifar A., Shoor M., Selahvarzi Y., Ansari H. (2013): The use of native turf mixtures to approach sustainable lawn in urban landscapes. Urban Forestry & Urban Greening, 12: 532–536.

Pote J., Wang Z., Huang B. (2006): Timing and temperature of physiological decline for creeping bentgrass. Journal of American Soccer and Horticultural Science, 131: 608–615.

Radhakrishnan R., Hashem A., Abd Allah E.F. (2017): Bacillus: A Biological tool for crop improvement through bio-molecular changes in adverse environments. Frontiers Physiology, 8: 667.

Romero C.C., Dukes M.D. (2016): Review of Turfgrass Evapotranspiration and Crop Coefficients. Transactions of the ASABE, 59: 207–223.

Sainju U.M., Allen B.L., Lenssen A.W., Ghuimire R.P. (2017): Root biomass, root/shoot ration, and soil water content under perennial grasses with different nitrogen rates. Field Crop Research, 210: 183–191.

Simmons M., Bertelsen M., Windhager S., Zafian H. (2011): The performance of native and non-native turfgrass monocultures and native turfgrass polycultures: An ecological approach to sustainable lawns. Ecological Engineering. 37: 1095–1103. Available at https://www.bspb.co.uk/sg_userfiles/2891_BSPB_Turfgrass_2018_MED.pdf (accessed Sept 1, 2020).

Sun B., Bai Z., Bao L., Xue L., Zhang S., Wei Y., Zhang Z., Zhuang G., Zhuang X. (2020): *Bacillus subtilis* biofertilizer mitigating agricultural ammonia emission and shifting soil nitrogen cycling microbiomes. Environment International: 144.

Turfgrass Seed (2018): Available at https://www.collier-turfcare.co.uk/FTP-Images/Technical/Barenbrug/2891%20BSPB%20Turfgrass%202018_LO.PDF

Vargas J.M. Jr. (2005): Management of turfgrass diseases. 3rd Ed. John Wiley & Sons. Inc.: 322.

Vinci G., Cozzolino V., Mazzei P., Monda H., Spaccini R., Piccolo A. (2018): An alternative to mineral phosphorus fertilizers: The combined effects of *Trichoderma harzianum* and compost on *Zea mays*, as revealed by 1H NMR and GC-MS metabolomics. Plos One 13(12): e0209664.

Vitalis crop care (2020): Available at https://www.vitaliscropcare.hr/index.php?main=prof&cat=program&program=travnjaci (in Croatian).

https://doi.org/10.17221/160/2020-HORTSCI

Wei Z., Yang X., Yin S., Shen Q., Ran W., Xu Y. (2011): Efficacy of *Bacillus*-fortified organic fertiliser in controlling bacterial wilt of tomato in the field. Applied Soil Ecology, 48: 152–159.

Wilson C. (2018): UEFA Pitch Quality Guidelines: Natural Turf Pitch Management. 2018 Ed. Switzerland, UEFA: 56.

Xu J., Zhu T., Xue W., Ni D., Sun Y., Yang J., Xu L., Chen X., Li H., Liu M. (2019): Influences of nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP) and application method on nitrogen dynamics at the centimeter-scale. European Journal of Soil Biology, 90: 44–50.

Yao H., Bowman D., Shi W. (2011): Seasonal variations of soil microbial biomass and activity in warm- and cool-season turfgrass systems. Soil Biology & Biochemistry, 43:1536–1543.

Received: November 9, 2020
Accepted: March 24, 2021
Published online: November 22, 2021