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Effect of a compost fertilizer on the productivity and botanical composition of a natural grass stand under mountain conditions

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Abstract: The aim of the study was to determine the impact of compost of bracken (*Pteridium aquilinum* L.) and fresh cattle manure on the yield and the change in the botanical composition of a natural grass stand under mountain conditions. The annual application of compost in a natural meadow of a transitional type with *Chrysopogon gryllus-Agrostis capillaris*, increased significantly ($P < 0.001$) the amount of dry matter in the treated variants from 57.77% (at a fertilizer rate of 3000 kg/dka) to 73.79% (at a fertilizer rate of 2000 kg/dka) compared to the untreated control. Grass stands fertilizerd at a rate of 2000 kg/dka increased to the highest degree the presence of legume components (from 44.7% to 71.2%) in the biomass, which is a prerequisite for the production of fodder with a high crude protein content. The compost application had a positive impact on the grass mass composition and contributed to positive changes in the group of desirable legume and grass meadow species. An increased share of useful legume (*Trifolium pratense*, *T. hybridium*, *T. agrarium* and *Lotus corniculatus*) and grass meadow species (*Agrostis capillaris*, *Festuca rubra*, *Cynosurus cristatus* and *Poa pratensis*) and stimulation of their productive potential was found. In the fertilized variants, the percentage share of weeds participate followed a downward trend compared to the control. Fertilizing with compost of bracken and manure is a highly effective measure and can be recommended to increase hay yields in natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) in the conditions of the Central Balkan Mountain.

Keywords: fertilizing, *Pteridium aquilinum*, manure, yield, floristic composition.

Introduction

Changes related to global climate warming, pollution with harmful substances, reduced biodiversity of natural grass stands, changes in soil composition, landscape, etc. are challenges of particular importance for the development of the agricultural sector (Chettri et al. 2018; Kunwar et al. 2020). Purposeful actions towards an optimal increase in yields, nutritional value, quality parameters of the fodder mass and the realization of the full plant potential are basic principles of sustainable agriculture and include the implementation of new, environmentally friendly, science-based and energy-efficient technologies, through which to ensure the preservation of soil fertility and the environment, and to improve biodiversity (Gomiero et al. 2011; El-Ramady et al. 2014; Rafiee et al. 2016; Alshaal & El-Ramady 2017; Churkova & Churkova 2020; Churkova & Churkova 2021).

In Bulgaria, natural grass stands are the main resource for meeting the food needs of farm animals. Soil erosion and compaction, unregulated grazing and human activity are major factors that could contribute to the low productivity, quality and botanical composition of grass mass (Kebede et al. 2016; Głowacz & Niżnikowski 2018). One way to overcome these problems is to use effective management practices to restore and improve degraded pasture lands (Mekuria et al. 2018; Yalew et al. 2020). Application of organic fertilizers (mainly manure and green compost) is a rational and cheap method to balance soil composition and form dense biomass with high fodder value (Ciepiela et al. 2012; Kitczak et al. 2012; Ociepa-Kubicka & Pachura 2013; Markov 2015).

Unsystematic management of natural and semi-natural grass stands, as well as unregulated human activity lead to the appearance of aggressive and invasive grass species, shrubs and trees, to the loss of valuable species, affecting the yield and quality of the grass mass (Gross et al. 2009; Iliev et al. 2021).

Bracken (*Pteridium aquilinum* L.) is a perennial herbaceous plant that mainly inhabits foot-hill and mountain areas (Gray et al. 2022). The species is an extremely aggressive and dominant weed that suppresses (through shading, release of phenolic compounds, etc.) the development of beneficial vegetation in natural grass stands (Grab & Knight 2018; Fernández & Sierra 2022). In the temperate parts of Northern Europe, bracken fronds emerge from underground rhizomes in mid-May. The fronds reach maturity from late July to early September, which is followed by senescence (Rasmussen et al. 2015). The best time to mow and compost the aboveground mass is late July or early August (Pitman 2000), when the plants have not produced spores and have not accumulated reserve nutrients in the rhizomes (Pitman & Webber 2013). Fertilizing of natural grass stands with compost of bracken and cattle manure improves species composition and increases crude protein concentration in dry matter (Bozhanska et al. 2022). The percentage share of legume components in the treated grass mass increased by 24.15%, and that of grasses by 9.00%. Fertilizing natural grass stands with a peat substrate (of organic origin) is an effective measure

and a good alternative for the production of ecologically clean fodder production because it increases yield and preserves soil biodiversity (Barrett et al. 2016).

The aim of the present study is to determine the impact of a mixture of *Pteridium aquilinum* and fresh cattle manure on the productivity and the change of the floristic composition in a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*), in the region of the Central Balkan Mountain, Bulgaria.

Material and Methods

The experiment was carried out in the Department of Mountain meadow farming and fodder production at the Research Institute on Mountain Stockbreeding and Agriculture, Troyan. It covered a period of four years (2016-2019).

The impact of compost fertilizer was observed (*Pteridium aquilinum* + fresh cattle manure) on the productivity and botanical composition of a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) at an altitude of 460 m, in 4 replications, with 5 m^2 harvest plot size.

The research variants were:

1. Control (not fertilized with compost);
2. Compost application rate of 1000 kg/dka;
3. Compost application rate of 2000 kg/dka;
4. Compost application rate of 3000 kg/dka;
5. Compost application rate of 4000 kg/dka.

Compost fertilizer was applied annually, on the surface (manually by spraying) before the onset of active vegetation of grass species.

The experimental areas were harvested in the phenophase of tasseling-beginning of blossoming-ear formation (for grass species).

Compost of bracken and fresh manure

The compost preparation was according to the method of the English nurseries (Pitmen 1994). Mowed and cut in late spring-early summer (May-June) the grass mass of bracken (*Pteridium aquilinum*) was mixed with fresh cattle manure in a ratio of 50:50 to balance and compensate for the lack of nitrogen in the bracken, and neutralization of some of the toxic alkaloid compounds. The mixture was stirred for 120-140 days (in 15 days). With a mobile pH-meter (model - ZD-06) the reaction of the composted pile was monitored (at a starting value of pH = 5.0-6.0). After six months, the compost acquired a dark brown to black colour with pH = 8.0 (as the final product).

Studied indicators

Dry matter yield (kg/dka) – determined by weight by mowing the harvest plot in replications with subsequent drying of the plant samples (from 0.5 kg) in laboratory conditions at 105°C and recalculation for an area of 1 dka = 1000 m^2 based on the dry matter content.

Botanical composition of the grass stand (%) – determined by weight by analyzing grass samples taken immediately before mowing. The percentage share of the main botanical groups (grasses, legumes and weeds participate) and of the species separately in the composition of the grass mass was determined.

Statistical data processing includes the analysis of variance (ANOVA) and the software product Analysis Toolpak for Microsoft Excel 2010.

Results and Discussion

Productivity of natural grass stand after treatment with a composted mixture with bracken

Agroecological conditions in the experimental area and fertilizing dose affected the productivity of natural grass stands (Iliev et al. 2020).

The dry matter productivity of a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) manured with compost, over the years and average over the period, is presented in Table 1.

In the first experimental year, there was no proven increase in the dry matter yield in the treated variants compared to the control. The variants with compost application rate of 1000 kg/dka (173.52 kg/dka) and 2000 kg/dka (153.13 kg/dka) showed higher dry matter productivity, where the values of the indicator exceeded the untreated control by 31.98% and 16.47%, respectively.

In the year when the experiment was set, the grass stands with compost application rates of 3000 kg/dka and 4000 kg/dka registered lower values regarding dry matter yield compared to the control variant. The reason for the low productivity in these variants was the later compost application (at the beginning of June), when the grass cover was in an advanced vegetation state.

The compost in the second experimental year had a significant impact on the productivity of the fertilized variants. The variant with a fertilizer rate of 2000 kg/dka (418.61 kg/dka) had the proven and highest distinction in the dry matter amount. The values of the indicator exceeded the control by 64.07% ($P < 0.01$). Higher rates of fertilizing (3000 kg/dka and 4000 kg/dka) also had a reliable positive effect on the grass stand productivity. The relative dry matter yield (392.46 kg/dka and 389.52 kg/dka) exceeded the unfertilized variant by 53.83% and 52.67%, respectively ($P < 0.05$). The annual fertilizing with 1000 kg/dka increased the dry matter yield insignificantly by 32.28% compared to the unfertilized variant.

In the third experimental year, the impact of the after-effect of fertilizing with compost of bracken and cattle manure increased the productivity of the treated grass stands. The highest dry matter yield was found in the variant fertilized with 2000 kg/dka (522.41 kg/dka), where the excess compared to the control was by 83.47% ($P < 0.01$). In the variants fertilized with rates of 1000 kg/dka and 3000 kg/dka, the excess was respectively 67.71% and 69.68% ($P < 0.05$).

Tab. 1 Dry matter yield (kg/da) of a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) fertilized with compost, over the years year and average over the period. Abbreviation: comp. = compared.

Variants	2016		2017		2018		2019		Average for the period	
	yield	comp. to C	yield	comp. to C	yield	comp. to C	yield	comp. to C	yield	comp. to C
Control	131.47	100.00	255.13	100.00	284.74	100.00	219.66	100.00	222.75	100.00
1000	173.52	131.98	337.50	132.28	477.55	167.71	427.20	194.48	353.94	158.90
2000	153.13	116.47	418.61	164.07	522.41	183.47	454.31	206.82	387.11	173.79
3000	111.82	85.06	392.46	153.83	483.15	169.68	418.32	190.44	351.44	157.77
4000	129.71	98.66	389.52	152.67	445.95	156.62	451.03	205.33	354.05	158.94
$LSD_{0.05}$	***66.89***	***50.87***	***110.85***	***43.56***	***165.72***	***58.15***	***115.72***	***52.72***	***54.85***	***24.60***
$LSD_{0.01}$	***93.89***	***71.40***	***155.60***	***61.14***	***232.62***	***81.62***	***162.43***	***74.00***	***76.99***	***34.52***
$LSD_{0.001}$	***132.55***	***100.80***	***219.68***	***86.32***	***328.41***	***115.23***	***229.31***	***104.47***	***108.69***	***48.74***

Tab. 2 Botanical composition (%) of a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) fertilized with compost (for every group – grasses, legumes and weeds participate). Abbreviation: g - grasses, l - legumes, wp - weeds participate.

Variants	2016			2017			2018			2019		
	g	l	wp	g	l	wp	g	l	wp	g	l	wp
Control	5.8	31.4	62.8	8.2	36.2	55.6	37.1	16.2	46.7	14.5	36.1	49.4
1000	12.5	44.2	50.0	6.8	65.5	27.7	21.7	49.5	28.8	45.8	29.5	24.7
2000	20.0	44.7	32.9	7.6	71.2	21.2	19.4	47.8	32.8	28.8	52.8	18.4
3000	16.8	40.0	43.2	12.6	50.6	36.9	19.0	51.7	29.3	30.3	48.7	21.0
4000	10.8	33.3	55.9	18.7	62.6	18.7	16.5	48.4	35.1	55.6	21.8	22.6

The most significant effect of annual compost application (a result of the accumulation of organic matter) was in the fourth experimental year, when the highest dry matter yield was found in the grass stands fertilized with 2000 kg/dka (454.31 kg/dka) and 4000 kg/dka (451.03 kg/dka). The excess compared to the untreated control was respectively 106.82% and 105.33% at a high level of significance ($P < 0.001$). In the variants fertilized with rates of 1000 and 3000 kg/dka, the increase in dry matter yield was respectively 94.48% and 90.44% ($P < 0.01$) compared to the control.

On average over the experimental period, the compost application of bracken and cattle manure had a proven effect on the productivity of a natural grass stand of a transitional type with *Chrysopogon gryllus-Agrostis capillaris*. Organic fertilizing recorded a significant increase in the values of the indicator in all treated variants by 73.79% (at a rate of 2000 kg/dka), 58.94% (at a rate of 4000 kg/dka), 58.90% (at a rate of 1000 kg/dka) and 57.77% respectively (with a norm of 3000 kg/dka) at $P < 0.001$.

Botanical composition of natural grass stand treated with compost of bracken and cattle manure

Fertilizing natural grass stands with organic fertilizers creates conditions for the development of valuable and high-quality species (Bozhanska et al. 2021). As a result, there is a degradation in the percentage of low-quality plant species and an advantage of grass and legume meadow species in the biomass, which provide

fodder with a balanced composition and high digestibility (Naydenova & Vasileva 2019; Vasileva & Enchev 2018).

During the experimental years, fertilizing the natural grass stand with compost (bracken and cattle manure) caused significant changes in the plant species composition in the different biological groups (Tab. 2).

In the first experimental year (2016), grasses occupied a share of 12.5%, whereas legumes - 44.2%, in the grass stands with compost application rate of 1000 kg/da. *Lotus corniculatus* (13.6%) and *Trifolium pratense* (28.4%) were dominant legume species, and *Cynosurus cristatus* (4.5%) and *Agrostis capillaris* (3.4%) were more common among the grasses (Fig. 1). The edificator in the grass stand (*Chrysopogon gryllus*) registered a low share in the composition of the formed biomass (2.3%). At a fertilizing rate of 2000 kg/dka, the total share of grasses was 20.0%, and of legumes was 44.7%. The presence of *Agrostis capillaris* and *Cynosurus cristatus* was respectively 9.4% and 3.2% compared to 2.3% and 3.5% in the control variant. *Lotus corniculatus* (11.8%) and *Trifolium pratense* (32.9%) prevailed again among the legumes, which also had a dominant presence in the other experimental variants. In the grass stands fertilized with 3000 kg/dka of compost, a lower presence of grasses was reported. Their relative share was 16.8% with the predominant participation of *Agrostis capillaris* (5.0%) and *Cynosurus cristatus* (6.7%). Legumes (*Trifolium pratense* and *Lotus corniculatus*) had a high percentage in the grass stands with a total share of 40.0%. The subsequent highest rate of fertilizing (4000 kg/dka) increased to a higher degree the share of motley grasses and legumes, and decreased that of grasses. The following grass species had the highest percentage: *Agrostis capillaris* (4.8%), *Cynosurus cristatus* (3.6%) and *Lolium perenne* (2.4%), whereas among legumes *Lotus corniculatus* (9.5%) and *Trifolium pratense* (23.8%) were dominant again.

The weeds participate group occupied 62.8% of the composition of the untreated grass stand. In the fertilized variants, the values were lower and varied from 32.9% (2000 kg/dka) to 55.9% (4000 kg/dka).

In the second experimental year (2017), fertilizing with compost significantly increased the amount of legume component in the grass stand. In the variants with fertilizing rates of 1000 kg/dka, 2000 kg/dka and 4000 kg/dka, legumes had a share of 65.5%, 71.2% and 62.6%, respectively. Dominant species were *Trifolium agrarium*, *T.* pratense and *Lotus corniculatus* (Fig. 2). The highest share of *Trifolium agrarium* was registered in the variants fertilized with 4000 kg/dka (33.3%), whereas the lowest was found in the control variant (12.5%). The share of *Lotus corniculatus* in the grass stand ranged from 4.2% (in the unfertilized control) to 20.0% (in the variant fertilized with 4000 kg/dka). The group of grasses during the year was mainly represented by the species, such as *Agrostis capillaris*, *Anthoxanthum odoratum* and *Cynosurus cristatus*. The applied fertilizing caused changes in the percentage share of the main edificators in the grass stand. *Chrysopogon gryllus* decreased its share in the volume of the plant mass to 6.7% in the variants fertilized with a rate of 4000 kg/dka. The share of *Agrostis capillaris* also followed a downward trend to 2.5%

respectively in the variants fertilized with a rate of 1000 kg/dka; up to 7.6% at a rate of 2000 kg/dka; up to 6.9% at a rate of 3000 kg/dka and up to 4.0% at rate of 4000 kg/dka.

Weeds participate again prevailed in the unfertilized variants with a share of 55.6%, whereas the species of the group participated in the range from 18.7% (4000 kg/dka) to 27.7% (1000 kg/dka) in the fertilized variants.

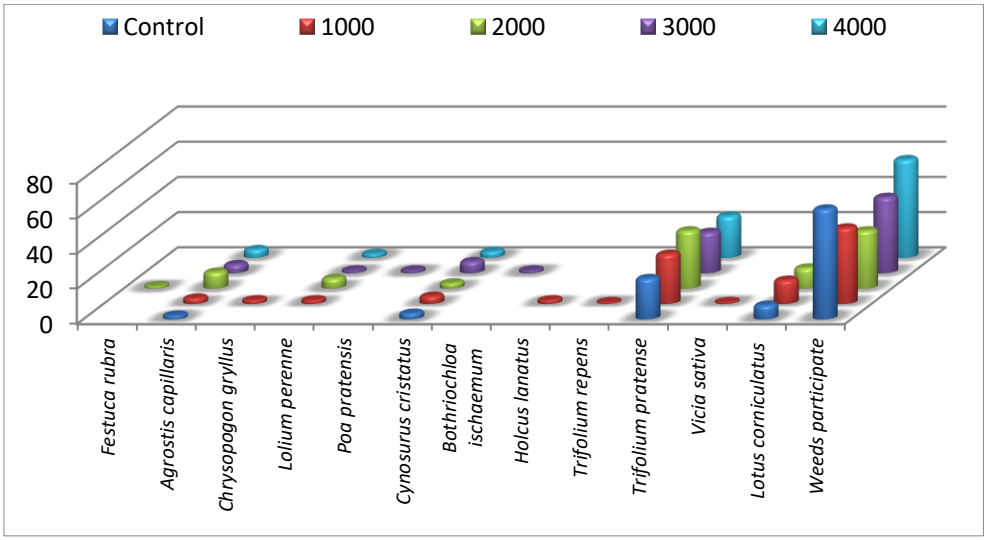

Fig. 1 Botanical composition (%) of a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) fertilized with compost for every species (first experimental year - 2016).

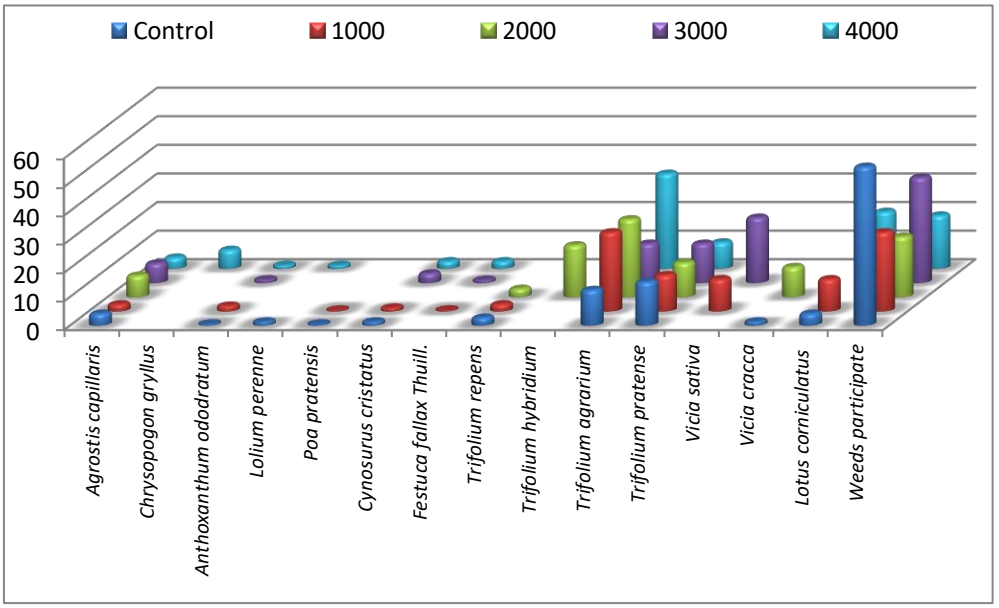

Fig. 2 Botanical composition (%) of a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) fertilized with compost for every species (second experimental year - 2017).

In the third experimental year (2018), the impact of compost on the botanical and species composition of the grass stand was similar to that of the second experimental year. The share of legumes increased. There was an increase in grass species to a lesser extent.

The share of legumes in the treated variants is as follows: 49.5% (1000 kg/dka), 47.8% (2000 kg/dka), 51.7% (3000 kg/dka) and 48.4% (4000 kg/dka) with dominant species, such as *Lotus corniculatus* and *Trifolium pratense*. Their percentage share in the grass stand ranged from 26.9% (2000 kg/dka) to 35.3% (4000 kg/dka) (Fig. 3). The presence of the edificator *Agrostis capillaris* remained relatively stable in the group

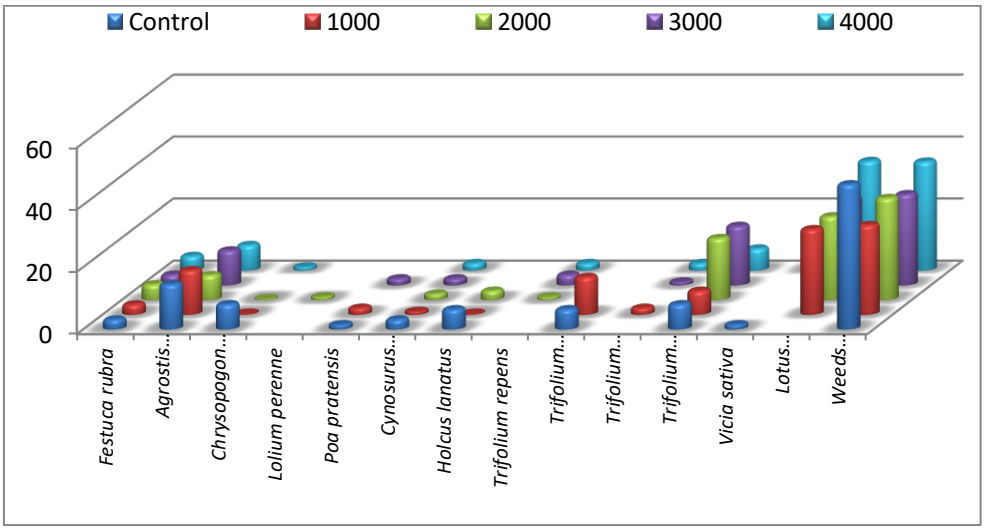

Fig. 3 Botanical composition (%) of a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) fertilized with compost for every species (third experimental year - 2018).

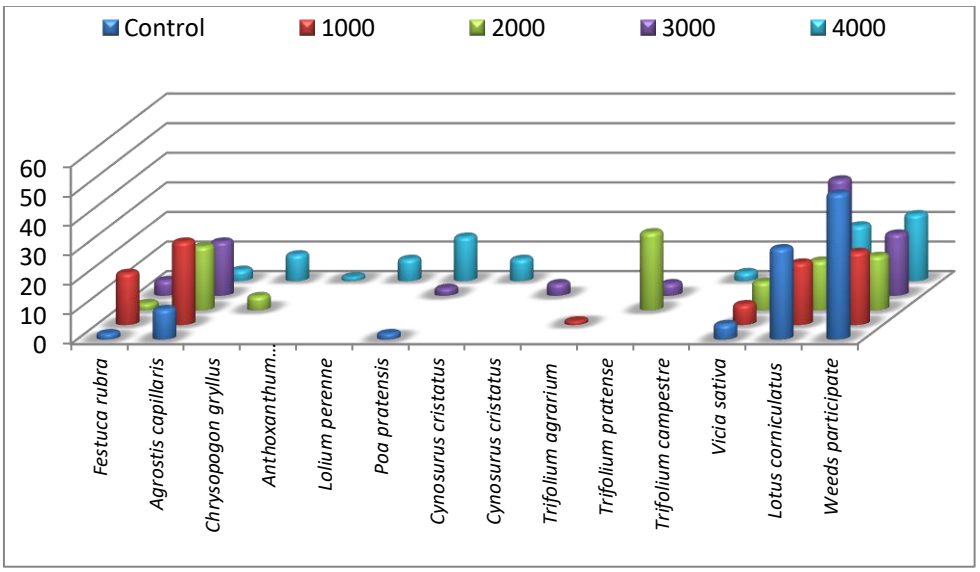

Fig. 4 Botanical composition (%) of a natural grass stand (a transitional type with *Chrysopogon gryllus-Agrostis capillaris*) fertilized with compost for every species (fourth experimental year - 2019).

of grasses. Its share in the grass stand of the fertilized variants was respectively: 14.3% (1000 kg/dka), 8.0% (2000 kg/dka), 11.2% (3000 kg/dka) and 8.2% (4000 kg/dka). The compositions of the compost suppressed the development of *Chrysopogon gryllus* (edificator) and reduced its share in the grass stand to 0.4% (in the variants fertilized with 1000 and 2000 kg/dka).

During the year, weeds participate had the largest share in the unfertilized grasslands (46.7%). In the fertilized variants, their amount was reduced from 28.8% (1000 kg/dka) to 35.1% (4000 kg/dka).

During the subsequent fertilizing in the fourth experimental year (2019), the changes in the botanical composition of the natural grass stand were characterized by an increase in the share of grasses in variants with fertilizing rates of 1000 kg/dka (up to 45.8%) and 4000 kg/dka (up to 55.6%) (Tab. 2). The dominant grass species in the grass stand were *Festuca rubra*, *Agrostis capillaris*, *Poa pratensis* and *Cynosurus cristatus* (Fig. 4). *Agrostis capillaris* occupied the largest share (as separate species) in the variants with fertilizing rates of 1000 kg/dka (28.2%) and 2000 kg/dka (21.6%). Legumes predominated mainly in the grass stands with compost rates of 2000 kg/dka (52.8%) and 3000 kg/dka (48.7%). Highly productive legumes, such as *Lotus corniculatus*, *Trifolium pratense* and *Vicia sativa* remained as dominant.

In the last experimental year, the weeds participate group again had the highest quantitative presence in the unfertilized control (49.4%). In the variants treated with compost, their percentage decreased from 18.4% (1000 kg/dka) to 22.6% (4000 kg/dka).

Conclusion

On average over the experimental period, the treatment with compost of bracken and fresh manure stimulated the productive potential of plants in the natural grass stands. Dry matter yield in all variants with fertilizing increased significantly ($P < 0.001$) from 57.77% (3000 kg/dka) to 73.79% (2000 kg/dka).

It was established that annual fertilizing with a composted mixture positively affected the grass composition in a natural meadow of a transitional type with *Chrysopogon gryllus-Agrostis capillaris* and contributed to desirable changes in the groups of legume and grass meadow species. All fertilizing rates reduced the percentage amount of weeds participate from 38.32% (4000 kg/dka) to 50.91% (2000 kg/dka) and increased the participation of legume and useful meadow grasses from 38.53% (4000 kg/dka) to 80.57% (2000 kg/dka) and with from 15.55% (2000 kg/dka) to 54.88% (4000 kg/dka).

Fertilizing with a compost rate of 2000 kg/da increased to the highest degree the legume component (from 44.7% to 71.2%) in the total volume of the grass mass, which suggests the formation of fodder with a higher concentration of crude protein.

Over the years of experiment, the dominant species in the fertilized variants from the group of grasses were *Agrostis capillaris*, *Festuca rubra*, *Cynosurus cristatus* and *Poa pratensis*, and for legumes: *Trifolium pratense*, *T. hybridium*, *Lotus corniculatus* and *Trifolium agrarium*.

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