

FORAGE QUALITY OF NATURALLY RESTORED LEGUME SPECIES FROM BURNT GRASSLANDS

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Abstract

The aim of the present study is to analyze the chemical composition of legume meadow species participating in post-fire successions in view of their importance for restoring the forage value of grasslands after burning. The object of observation are burnt pasture and meadow grasslands in four locations on the territory of Bulgaria, located in three different floristic regions. The legume species with the highest frequency during the first vegetation period after burning are determined. The content of crude protein, crude fibre, crude fat, ash, nitrogen-free extractive substance, calcium, phosphorus, and nitrogen in the dry forage biomass was measured. Significant differences were found in the values and ratios of the analyzed quality parameters. The *Vicia* species are characterized by the highest content of crude protein (average 16.35%) in dry matter. The biomass of *Medicago falcata* is distinguished by the highest concentration of crude fibre, total minerals, calcium and phosphorus, and by a significantly lower content of nitrogen-free extractive substances. The dry matter of *Astragalus onobrychis* contains the highest amount of crude protein (21.16%) and nitrogen (3.02%), and a low content of crude fibre (26.80%) – an indicator for good quality of the realized forage mass. In contrast, the lowest

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average values of crude protein (13.61%) and nitrogen (1.94%) are recorded for *Trifolium* species. The potential of the studied wild legume grasses for restoring the forage value of burnt meadows in relation to specific ecological and geographical conditions is discussed.

Key words: crude protein, crude fibre, ash, macrominerals, burnt legume meadow grasses

Introduction. Global climate change, associated with higher extreme air temperatures and prolonged droughts, is a prerequisite for the emergence of local or spatially more extensive fires with varying degrees of intensity [1]. Fire is an important ecological factor that causes significant changes in habitat conditions, affects the structure of the floristic composition of plant communities (certain functional groups of plants are selected, with increased adaptability and ability to fast/quickly recover), as well as the relationships between species [2].

According to WÓJCIK et al. [3] the increased concentration of mineral substances (in exchangeable form) in the ash leads to rapid growth and development of hemicryptophyte species, which cover a vast area in the burnt regions. A large part of the legume grass species distributed in natural meadows and pastures belong to this life form with a significant impact on the recovery processes in the burnt habitats, and with a high soil cover coefficient [4]. Their ability to fix atmospheric nitrogen leads to organic soil matter enrichment and stabilization of ecosystem functions.

The species composition of legume grasses is an important ecological indicator for the direction and dynamics of post-fire succession processes. According to studies conducted in Northern Bulgaria, the species *Bituminaria bituminosa*, *Vicia striata*, *Medicago minima*, *Lathyrus pratensis*, and *Trifolium medium* predominate in the initial phases of succession, demonstrating a high degree of adaptability and distribution in burnt habitats [5]. Changes in the chemical profile of the plant mass formed before and after the fire correlate with the regenerative and competitive ability of the dominant species [6, 7]. According to NAYDENOVA and BOZHANSKA [8] an experiment involving undersown, self-seeded and self-recovered legume grasses in burnt areas shows that the undersown species *Melilotus albus* and the self-recovered rhizome *Coronilla varia* produced biomass with superior levels of crude protein, fibre, and essential macronutrients like nitrogen, phosphorus, and calcium. The monitored quality indicators of the populations of self-seeded species *Bituminaria bituminosa* and *Vicia grandiflora* highlights their potential as adapted genotypes in burnt grasslands [8].

While there is extensive research on how fire affects main soil and plant parameters, there is still very limited data on how it changes the chemical composition of the dry matter of individual vegetation groups and especially legume grasses (one of the pioneer grasses after fire).

The aim of the present study is comparative assessment of legume meadow species from burnt grasslands in terms of crude protein content, crude fibre, crude

fat, ash, nitrogen-free extractive substance, calcium, phosphorus and nitrogen in the dry matter, to demonstrate their role in the processes of restoring the forage value of grasslands after burning.

Material and method. The study focuses on burnt pastures and meadow grasslands in four specific Bulgarian sites: Krapets, Suhindol, Ponor, and Karavelovo (Table 1). The locations were selected from the database of fires registered in the European Forest Fire Information System (EFFIS). Fire-affected areas burnt in 2024, mainly located within Natura 2000, and mostly grasslands, were chosen. Additionally, sites across different regions of our country were included to capture a wider range of conditions. A key criterion was to cover an area of at least 100 m². The sample plots were plotted in QGIS (version 3.40.9) to ensure they were at least 10 m from other vegetation types (e.g., forest, crop cultivation, etc.). The studied locations fall into the three floristic regions or subregions [9,10].

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Description of the studied locations

Locations	Floristic region	Coordinates	Fire date
South Bulgaria Karavelovo, burnt area	Thracian Lowland floristic region	42°63'90.9"N/24°66'18.5"E	16.07.2024
North Bulgaria Krapets, burnt area	Forebalkan, Eastern floristic subregion	43°07'47.2"N/24°92'82.2"E	09.2024
Suhindol, burnt area	Forebalkan, Eastern floristic subregion	43°18'17.3"N/25°18'38.2"E	08. 2024
West Bulgaria Ponor, burnt area	Western Balkan Mts. floristic subregion	42°56'48.2"N/23°08'43.4"E	06.09.2024

The botanical composition of the grasslands was studied during the first post-fire growing season, and the constancy of legume species (S) was assessed using Uranov's 5-point scale [11]. Depending on the plant diversity, 5 to 10 samples of fresh biomass were collected from randomly selected spots of 0.25 m² from each location. Based on the percentage of the representatives of each species identified in the samples, the following stability classes were established: V – 81–100%; IV – 61–80%; III – 41–60%; II – 21–40% and I – 1–20%.

The species *Trifolium campestre* and *Vicia cracca* demonstrated the highest ecological plasticity and belong to IIIrd class of stability degree, followed by *T. montanum*, *T. striatum*, *V. hirsuta*, *V. grandiflora*, *V. tenuifolia* and *Lotus corniculatus* – all belonging to the IIInd class of stability. The species *T. incarnatum*, *T. alpestre*, *T. arvense*, *T. hybridum*, *T. hirtum*, *T. medium*, *V. pannonica* subsp. *striata*, *V. narbonensis*, *Lotus angustissimus*, *Genista sagittalis*, *Astragalus onobrychis*, *Coronilla varia*, and *Medicago falcata*, present low level of distribution

and belong to the Ist level of stability in the studied grasslands.

The chemical composition of dry fodder from 22 legume species (with a high significant presence in the indicated locations, was analyzed according to the Weende analysis [8], and included the main nutritional indicators: Crude protein (CP, %) by Keldahl (according to BDS/ISO-5983); Crude fibre (CFr, %); Crude fat (CF, %) (according to BDS/ISO-6492); Crude ash (Ash, %) (according to BDS/ISO-5984); Nitrogen-free extractable substances (NFE, %) = $100 - (\text{CP, \%} + \text{CFr, \%} + \text{CF, \%} + \text{Ash, \%} + \text{Moisture, \%})$; calcium (Ca, %) – complexometric and phosphorus (P, %) – with vanadate-molybdate reagent according to the method of GERICKE and KURMIES [12], spectrophotometer (Agilent 8453 UV - visible Spectroscopy System), measuring in the area of 425 nm.

The data were analyzed using descriptive statistical methods. The Analysis ToolPak add-in in Microsoft Excel 2010 was used for the statistical analysis.

Results and discussion. The results obtained allow comparative analysis both between different legume genera and species collected in the burnt areas during the first vegetation one year after fire event. In the burnt grasslands, species from the *Trifolium* genus were the most frequent, with *Vicia* and *Lotus* (trefoil) being the next most common representatives (Table 2). Significant differences were found in the average values of the indicators for the main chemical composition of the dry matter. The lowest content of crude protein (13.61%) and nitrogen (1.94%) was measured for the *Trifolium* species. In contrast, for the genus *Astragalus* maximum values of crude protein (21.16%) and nitrogen (3.02%), as well as relatively low concentrations of crude fibre (26.80%) were measured, which suggests the formation of biomass with good digestibility and nutritional value. The dry matter of the genus *Medicago* show the highest content of crude fibre (42.36%), total minerals (8.31%), calcium (6.78%), and phosphorus (0.53%).

A key indicator of the the palatability of grass forage are nitrogen-free extractable substances. In this context, the plant biomass of the genus *Medicago* contained the significantly lowest content of easily digestible carbohydrates (19.62%), while the biomass of both genus *Trifolium* and *Genista* recorded the highest content, 38.41% and 38.61%, respectively.

Among the species in the genus *Trifolium* significant variation in the values of the monitored forage quality indicators were measured. The crude protein content of the species *T. campestre* differ depending on the location with values from 12.74% (Krapets) to 16.97% (Karavelovo); crude fibre – from 26.13% (Ponor) to 34.85% (Krapets); crude fat – from 0.61% (Krapets) to 2.61% (Ponor); nitrogen-free extractable substances – from 34.82% (Karavelovo) to 44.95% (Ponor); calcium – from 0.78% (Ponor) to 3.18% (Karavelovo), and phosphorus – from 0.17 (Karavelovo) to 0.36% (Ponor), (Table 2). Similar results were obtained for the species *T. montanum* where the values of crude protein and crude fibre varied, respectively, from 11.75% (Ponor) to 15.43% (Krapets), and from 27.04% (Krapets) to 40.91% (Ponor). The ratio between the two parameters is an important in-

indicator of the quality and nutritional value of the forage. The closest values to the optimal ratio (1/1.2–1.3) were observed in the species of the genus *Vicia*, *V. hirsuta*, and *V. grandiflora*, collected from the region of Suhindol. These species are among the most frequent legume grasses to appear during the initial stage of vegetation recovery following a grassland fire.

The high crude protein content (average 16.35%) found in the species of the genus *Vicia* confirms their role as an important source for increasing the amount of protein fraction in the dry matter of forage. Therefore, the species *V. hirsuta*, *V. narbonensis*, *V. tenuifolia*, *V. grandiflora*, and *V. pannonica* subsp. *striata* established in the Suhindol location are of particular interest. The values of crude protein and calcium in these grass stands are high, 17.68–20.00% and 2.52–2.86%, respectively, and those of crude fibre are relatively low (24.36–28.42%), which suggests good digestibility of plant biomass from burnt grass stands when used as pasture. The potential of the species *V. hirsuta*, *V. sativa*, and *V. tenuifolia* for increasing the economic value of grassland, erosion control and alternative fodder for animal husbandry were described by the research of TÎȚEI and COZARI [13].

On the post-fire successions three species of *Lotus* were found and their biomass was notable for having relatively the highest average level of crude fibre (36.92%), crude fat (2.70%), and calcium (2.55%) among the legume grasses studied. The values of these indicators negatively affect the digestibility of the feed, but favour the normal function of the digestive system and energy metabolism in ruminants [14]. Across the observed habitats, the species *L. corniculatus* showed significant differences in the amount of the main chemical parameters of the dry matter (Table 2). In Krapets (subregion Eastern Forebalkan), it produced biomass with higher content of crude protein (17.07%), crude fibre (46.02%), mineral substances (7.26%), and calcium (4.13%).

The species of the genus *Genista*, *Astragalus*, *Coronilla*, and *Medicago* were less prevalent and occupied more limited distribution area within the grasslands composition of in post-fire areas. The species *A. onobrychis* and *M. falcata* possess the highest content of crude protein (21.16%) and calcium (6.78%) compared to the other self-recovered legume grasses after fire has occurred. The content of total nitrogen and crude protein, in addition to fodder value, is also indicative for the primary ecological function of legume grasses, the efficiency of nitrogen absorption from the air and its gradual release into the soil. Due to symbiotic nitrogen fixation, legumes contribute to increasing the nitrogen content in the soil and stabilizing meadow ecosystems in the early stages of secondary succession [15]. Consistent with this, the data collected from the analysis indicate a high nitrogen content in the dry biomass of *A. onobrychis*, *V. hirsuta*, *V. tenuifolia*, *V. grandiflora*, *M. falcata* and *T. campestre*, suggesting faster rates of mineralization and recovery of grassland communities involving these species.

The biomass chemical composition of individual grass species can also be linked to the flammability and fire resistance of grasslands. The biomass of some

T a b l e 2

Chemical composition (%) of wild legume species with a higher distribution range (from class III to I) collected from studied burnt areas

Plant species	Location	CP	CFr	CP / CFr	CF	Ash	NFE	N	Ca	P
<i>Trifolium incarnatum</i>	Ponor	12.22	38.67	1/3.16	1.50	6.34	33.39	1.75	1.87	0.35
<i>Trifolium montanum</i>	Ponor	11.75	40.91	1/3.48	1.02	4.59	34.19	1.68	1.43	0.19
<i>Trifolium montanum</i>	Krapets	15.43	27.04	1/1.75	2.79	6.64	39.91	2.20	3.18	0.11
<i>Trifolium striatum</i>	Ponor	13.09	32.47	1/2.48	1.29	5.32	39.91	1.87	2.09	0.26
<i>Trifolium striatum</i>	Karavelovo	14.09	30.71	1/2.18	1.35	4.87	40.10	1.99	2.33	0.12
<i>Trifolium campestre</i>	Ponor	13.61	26.13	1/1.92	2.61	5.02	44.95	1.95	0.78	0.36
<i>Trifolium campestre</i>	Karavelovo	16.97	32.34	1/1.91	2.26	5.51	34.82	2.42	3.18	0.17
<i>Trifolium campestre</i>	Krapets	12.74	34.85	1/2.74	0.61	5.93	37.64	1.83	2.36	0.28
<i>Trifolium alpestre</i>	Ponor	14.56	33.88	1/2.33	1.52	6.75	35.85	2.09	1.21	0.34
<i>Trifolium arvense</i>	Karavelovo	13.37	29.84	1/2.23	3.06	5.15	40.19	1.90	3.84	0.24
<i>Trifolium hybridum</i>	Karavelovo	13.36	36.41	1/2.72	1.89	7.11	32.99	1.90	1.48	0.19
<i>Trifolium hirtum</i>	Karavelovo	12.36	30.98	1/2.51	1.90	5.98	40.80	1.76	1.67	0.35
<i>Trifolium medium</i>	Krapets	13.37	33.62	1/2.51	1.29	7.94	36.28	1.92	4.59	0.26
Mean		13.61	32.91	1/2.42	1.78	5.93	37.77	1.94	2.31	0.25
CV, %		10.37	12.82		40.90	16.64	9.38	10.31	47.95	34.92
<i>Vicia grandiflora</i>	Ponor	15.04	34.04	1/2.26	1.78	4.75	36.61	2.15	1.21	0.48
<i>Vicia grandiflora</i>	Subindol	18.16	24.36	1/1.34	1.94	7.70	40.07	2.60	1.87	0.21
<i>Vicia cracca</i>	Ponor	12.89	37.10	1/2.88	1.23	5.83	35.05	1.84	2.74	0.22

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Continued

Plant species	Location	CP	CPr	CP / CPr	CF	Ash	NFE	N	Ca	P
<i>Vicia cracca</i>	Karavelovo	14.14	33.18	1/2.35	1.91	6.56	35.96	2.01	1.46	0.12
<i>Vicia cracca</i>	Suhindol	14.28	32.14	1/2.25	3.22	6.73	35.88	2.04	1.65	0.19
<i>Vicia hirsuta</i>	Karavelovo	12.67	33.09	1/2.61	2.33	7.06	37.30	1.82	1.21	0.11
<i>Vicia hirsuta</i>	Suhindol	20.00	27.22	1/1.36	2.67	6.64	35.60	2.86	1.00	0.28
<i>Vicia tenuifolia</i>	Suhindol	19.07	26.32	1/1.38	2.57	8.29	35.67	2.72	1.87	0.45
<i>Vicia narbonensis</i>	Suhindol	19.55	26.52	1/1.35	2.43	6.86	36.15	2.77	2.10	0.31
<i>Vicia pannonica</i> subsp. <i>striata</i>	Suhindol	17.68	28.42	1/1.61	1.65	8.58	35.68	2.52	1.65	0.18
Mean		16.35	30.24	1/1.85	2.17	6.90	36.40	2.33	1.68	0.25
CV. %		17.35	13.86		26.75	16.31	3.92	17.25	30.26	50.71
<i>Lotus corniculatus</i>	Karavelovo	12.38	30.98	1/2.50	3.68	5.45	39.45	1.77	1.39	0.12
<i>Lotus corniculatus</i>	Krapets	17.07	46.02	1/2.69	1.38	7.26	21.26	2.46	4.13	0.22
<i>Lotus angustissimus</i>	Karavelovo	12.02	33.77	1/2.81	3.05	5.32	37.44	1.71	2.12	0.22
Mean		13.82	36.92	1/2.67	2.70	6.01	32.72	1.98	2.55	0.19
CV. %		20.39	21.67		44.02	18.04	30.48	21.05	55.65	30.39
<i>Genista sagittalis</i>	Ponor	13.80	34.12	1/2.47	1.01	4.89	38.61	1.98	1.86	0.36
<i>Astragalus onobrychis</i>	Krapets	21.16	26.80	1/2.27	2.60	7.19	34.40	3.02	3.17	0.24
<i>Coronilla varia</i>	Krapets	17.16	33.94	1/1.98	0.94	7.38	32.57	2.46	3.26	0.34
<i>Medicago falcata</i>	Krapets	18.82	42.36	1/2.25	1.15	8.31	19.62	2.72	6.78	0.53

Abbreviations: CP – crude protein (% DM); CPr – crude fibre (% DM); CF/CPr – crude protein to crude fibre ratio; CF – crude fat (% DM); Ash – crude ash (% DM); NFE – nitrogen-free extractive substances (% DM); N – total nitrogen (% DM); Ca – calcium (% DM); P – phosphorus (% DM); DM – dry matter.

of the perennial species (*M. falcata*, *A. onobrychis*, *C. varia*, *L. Corniculatus*, *V. tenuifolia*, and *V. pannonica* subsp. *striata*), superficially affected by the fire is characterized by higher content of mineral substances as ash. According to DRACH et al. [16] this is associated with higher fire resistance and can be considered an ecological adaptation of the local plant species for Suhindol and Krapets. For the Ponor location, such a species was *T. medium* with 7.94% ash, while for Karavelovo – *V. grandiflora* and *T. hybridum* with 7.70% and 7.11% ash, respectively.

Conclusions. The presented data demonstrate the chemical profiles and quality of different legume species capable of self-seeding and restoration of burnt pastures and meadows in the studied areas. *Trifolium* is the most frequent species to reappear after fires, followed by the genus *Vicia* and *Lotus*.

Astragalus onobrychis yielded the highest concentrations of crude protein and nitrogen in the biomass, whereas *Medicago falcata* was characterized by peak levels of crude fibre and minerals in the dry matter. Conversely, the *Trifolium* genus exhibited the lowest protein and nitrogen content. *Vicia* species were characterized by optimal crude protein-to-fibre ratio, which indicates good digestibility and overall nutritional quality of the feed.

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