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THE YIELD STABILITY AND QUALITY OF LEGUMES DURING TWO CONSECUTIVE, EXTREMELY DRY YEARS

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This study highlights the effect of drought and ambient temperature on performance and herbage quality of legume monocultures and grass–legume mixtures. In a field experiment, the total dry matter yield, seasonal pattern of dry matter yield distribution, content of crude protein and crude fibre of monocultures of red clover and alfalfa and grass–legume mixtures were investigated during two consecutive dry years (2011–2012). Alfalfa cultivars Kamila and Tereza grown as monocultures or as mixtures with *Festulolium braunii* (cultivar Achilles) outperformed the red clover cultivars Fresko and Veles and provided a well-balanced total and seasonal dry matter yield during both years. Across all experimental years, crude protein content was significantly higher at alfalfa monocultures and mixture when compared with clover monocultures ($P < 0.05$). However, considerable lower content of crude fibre at clover monocultures in comparison with alfalfa ones was found. Responses of nutritive parameters of both legume species to weather variables were different. Crude protein content in red clover was independent of rainfall and temperature. In contrast, the crude fibre content correlated with temperature whereby the alfalfa monocultures showed stronger correlations ($P < 0.05$) than red clover monocultures.

Key words: dry matter yield, red clover (*Trifolium pratense* L.), alfalfa (*Medicago sativa* L.), grass–legume mixture, climate change, nutritive value

Forage legumes play an invaluable role in the nitrogen balance and in sustainability grassland agriculture encompassing cold to warm climes (Søegaard *et al*. 2007). In comparison with grasses, forage legumes generally have higher content of protein, pectin, lignin, carotene and vitamins (Frame 2005), and therefore growing grasses and legumes in mixtures can improve herbage nutritive value compared with grass monocultures.

White clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.) and alfalfa (*Medicago sativa* L.) are the most widely cultivated perennial legumes. However, each of these legume species has limitations in terms of its requirements as regards specific soils, climate and management practices, and also in terms of agronomic performance and nutritional features (Sturludóttir *et al.* 2013). Therefore, the choice of forage legume species is based on its adaptation to these factors or to their combination. In the temperate and maritime zones of northern and western Europe, white clover is the most important crop for grazing, while red clover is the most important clover crop of temporary and permanent grasslands on moist, less fertile and acidic soils (Hejduk & Knot 2010). In the continental lowlands of central and eastern Europe and in the northern coastal zone of the Mediterranean basin, alfalfa is widely

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sown, and used for both grazing and as forage. The widespread use of alfalfa in Mediterranean area is particularly due to its high adaptability to arid climate conditions and potential yield and its high nutritional value (Annicchiarico *et al*. 2013).

Forage legumes are considered the backbone of the ley farming in southern regions of Slovakia (Jančovič *et al.* 2005) or in upland and mountain areas with high proportion of natural habitats, where it is necessary to produce high-quality conserved forage for winter. Alfalfa and red clover are the most widespread legume species used in ley farming in Slovakia. Whereas alfalfa has the greatest productive potential in south regions with lower total sum of rainfall, red clover is cultivated mainly in upland and mountain areas with a total annual rainfall of more than 700 mm.

There is increasing evidence that the climate has changed in central Europe during the last several decades. The aridisation trends and shifts in climate zoning during the last decades were also reported in Slovakia (Melo *et al*. 2007; Takáč 2013). The impact of drought events on yields and suitability of grassland and/or forage crop production can be found in a number of studies (e.g. Brázdil *et al*. 2009; Vozár *et al*. 2012; Lang & Vejražka 2012). Increasing variability in seasonal temperature and precipitation patterns influence not only productivity, but also the growing season length and phenology of forage crops in grasslands (Chaplin-Kramer & George 2013). The increased temperature over growing seasons decrease the soluble carbohydrate content of plants, resulting in increased fibre content, decreased nutritive value and digestibility of forage grasses and legumes.

Despite the environmental advantages of legume forage crops (Peeters *et al*. 2006) and their beneficial effects on animal production, there have been only few studies in Slovakia devoted to yield production of forage legumes (Tóth *et al*. 2002; Drobná 2009) or their nutritive value.

The objective of this study was to assess the impact of drought on the yield stability and quality on red clover, alfalfa and their mixtures with *Festulolium braunii* during two consecutive extremely dry years.

MATERIAL AND METHODS

In 2010, the research trial was established at the site of Grassland and Mountain Agriculture Research Institute in Banská Bystrica (48°74´N, 19°85´E) altitude 369 m a.s.l. The site is located in a moderately warm region (Lapin *et al*. 2002). The climate variables (rainfall, maximum temperatures – T_{max} and minimum temperature – T_{min}) were recorded daily and reported as mean monthly data. For the analysis of drought for 2011 and 2012, Koncek´s moisture index was used, which was calculated by the formula (Konček 1955):

$$I_Z = 0.5\ R + \Delta r - 10T - (30 + v^2)$$

where

R [mm] – total rainfall during the growing season (April–September),

Δr [mm] – positive deviation from 105 mm of total rainfall for winter months (December–February),

T [°C] – mean temperature during the growing season (April–September),

v [m/s] – mean wind speed measured at 14 h during the growing season (April–September).

The value $I_z > 120$ indicates very moist region, I_z ranging from 60 to 120 characterises moist region, I_z from 0 to 60 is typical for moderately moist region, I_z from –20 to 0 was set for moderately dry region, I_z from –40 to –20 to dry region and I_z less than –40 corresponds to very dry region.

The trial was arranged in a randomised complete block design with two replications on the *Leptic Cambisol Skeletic* (IUSS Working Group WRB 2006). The trial comprised the following six treatments: Treatment 1 – monoculture of red clover cultivar Fresko, Treatment 2 – monoculture of red clover cultivar Veles, Treatment 3 – red clover–grass mixture cultivar Fresko with *Festulolium braunii* cultivar Achilles, Treatment 4 – monoculture of alfalfa cultivar Kamila, Treatment 5 – monoculture of alfalfa cutivar Tereza and Treatment 6 – alfalfa–grass mixture alfalfa cultivar Tereza with *Festulolium braunii* cultivar Achilles (Table 1). Each plot was 7 m long and 1.5 m wide. The trial was established in spring 2010 without crop cover. Irrigation and weed/pest/diseases protection were not applied after sowing. The seeding rates of the monoculture were 20 kg/ha for red clover and 15 kg/ha for alfalfa, and the seeding rates of the mixtures were 26 kg/ha, where 16 kg/ha was for *Festulolium braunii* and 10 kg/ha for red clover or alfalfa, respectively. The fertiliser application included 30 kg N/ha, 30 kg P/ha and 60 kg K/ha applied before seeding in spring 2010; 30 kg P/ha and 60 kg K/ha were applied in spring 2011 and 2012. The stands were cut three times a year: the **1st cut** was at the early budding stage for red clover monocultures or at the early flowering stage for alfalfa monocultures; the **2nd** cut approximately 6–7 weeks later; and the **3rd** cut at the beginning of September. The cover of plant functional groups and plant species was visually estimated directly in percentages in each plot before each cut. The dry matter (DM) yield was determined by drying to a constant weight at 60°C in an oven. The crude protein (CP) was determined by the Kjeldahl method (N × 6.25). The crude fibre (CF) was determined by the Hennenberg–Stohmann method (1860). DM yield, CP and CF were subjected to a multifactor analysis of variance. The Pearson correlation was used to determine the relationship between two variables. Statistical analyses were performed using Statgraphics software version 5.0.

RESULTS AND DISCUSSION

Climatic conditions

At the Banská Bystrica site, the long-term mean annual rainfall is 795.5 mm, the sum of rainfall over growing season 431.5 mm, mean annual temperature 8.1°C and mean temperature over growing season 14.6°C (data recorded by the Department of Meteorological Service in Banská Bystrica). Compared with long-term averages, the sum of rainfall over growing season in 2011 (158.8 mm) and 2012 (117 mm) were lower by 63% and 73%, respectively (Figure 1). To the contrary, mean temperatures over growing seasons 2011 and 2012 increased by 1.9°C and 1.7°C, respectively. Very low total rainfall and increased mean temperature over growing seasons in 2011 and 2012 resulted in I_z values of –111.20 and –71.82, respectively. According to Koncek´s moisture index classification, both the years could be classified as very dry.

DM yield

The mean total DM production of cultivars of red clover ranged from 3.87 t/ha (cv. Veles) to 5.13 t/ha (cv. Fresko). In general, the DM yield of the red clover was below the range typically reported for this crop. A study conducted with several populations and cultivars of red clover under natural conditions without irrigation, fertilisation and pest/disease protection in Croatia showed that the average DM yield ranged from 13.6 to 24.4 t/ha, respectively (Tucak *et al*. 2013). Low DM and green matter yield of cultivars of red clover in this study are consistent with the findings of Drobná (2009) who observed that green matter yield of three Slovak cultivars of red clover was 12.69, 13.8 and 13.5 t/ha. The comparisons of DM yield at the treatments with red clover showed differences between monocultures and grass–clover mixture. Table 2 provides evidence of the positive effects of grass–clover mixtures for DM yield particularly in 2011. On average, the mixture of red clover with *Festulolium braunii* overyielded monocultures of red clover cv. Fresko and cv. Ve-

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Composition and seeding rates of legume monocultures and grass–legume mixtures

Treatment	Species	Seeding rate [kg/ha]		
		Legume	Grass	Total
1	Red clover cv. Fresko	20	–	20
2	Red clover cv. Veles	20	–	20
3	Red clover cv. Fresko + *Festulolium braunii* cv. Achilles	10	16	26
4	Alfalfa cv. Kamila	15	–	15
5	Alfalfa cv. Tereza	15	–	15
6	Alfalfa cv. Tereza + *Festulolium braunii* cv. Achilles	10	16	26

les by 25% and 45%, respectively. Similar studies conducted with 15 different monocultures and binary mixtures, consisting of *Phleum pratense* L., *Poa pratensis* L., *Trifolium pratense* L. and *Trifolium repens* L., showed that the mixtures were 9%, 15% and 7% more productive in the first, second and third years, respectively (Sturludóttir *et al.* 2013).

Both cultivars of red clover and its mixture with *Festulolium braunii* showed higher total DM yield in 2011 (Table 2). In 2012 (the second harvest year), the highest decrease (67%) in DM production was observed at red clover cv. Veles. Similar to our study, Lang and Vejražka (2012) reported decrease in DM production at red clover cv. Vesna by 25% and 62% in 2010 (the second harvest year) and 2011 (the third harvest year), respectively. Frankow-Lindberg *et al*. (2009) observed a decrease of DM yield of red clover with time at two sites in Sweden. However, a decline was more rapid at the Rådde site with silty soils compared with Uppsala site where the soils were dominated by clay. The low DM yield at red clover observed in our study was associated with decline of its proportion in the stands (Table 3). Both cultivars of red clover showed a remarkably higher cover in 2011 than in 2012 ($P < 0.05$). These results are consistent with findings of Frame (2005) who reported that progressive decline in annual DM production with age is typical of clover swards due to a natural decline in plant population.

Contrary to treatments with red clover, alfalfa plots showed significant increase in the DM yield in 2012 (Table 2) when compared with 2011. Gherbin *et al*. (2007) observed that alfalfa grown under Mediterranean environments with high temperatures and low rainfall provided similar DM yields over a 4-year experimental period. Monocultures of alfalfa outperformed the mixture of alfalfa with *Festulolium braunii* in both years. Nevertheless, the differences were not significant. On average, the total DM yield ranged from 8.4 t/ha for the mixture of alfalfa cv. Tereza with *Festulolium braunii* to 9.8 t/ha for the alfalfa cv. Kamila.

Seasonal pattern of DM yield distribution

Seasonal pattern of DM production is determined by several factors related to weather, plant biological properties, soil characteristics and ley management. In 2011, all of the treatments had the highest DM yields in the 2nd cut (Table 4). In 2012, the monocultures of red clover demonstrated the same pattern with the highest DM yields in the 2nd cut. To the contrary, Skinner *et al*. (2004) reported that

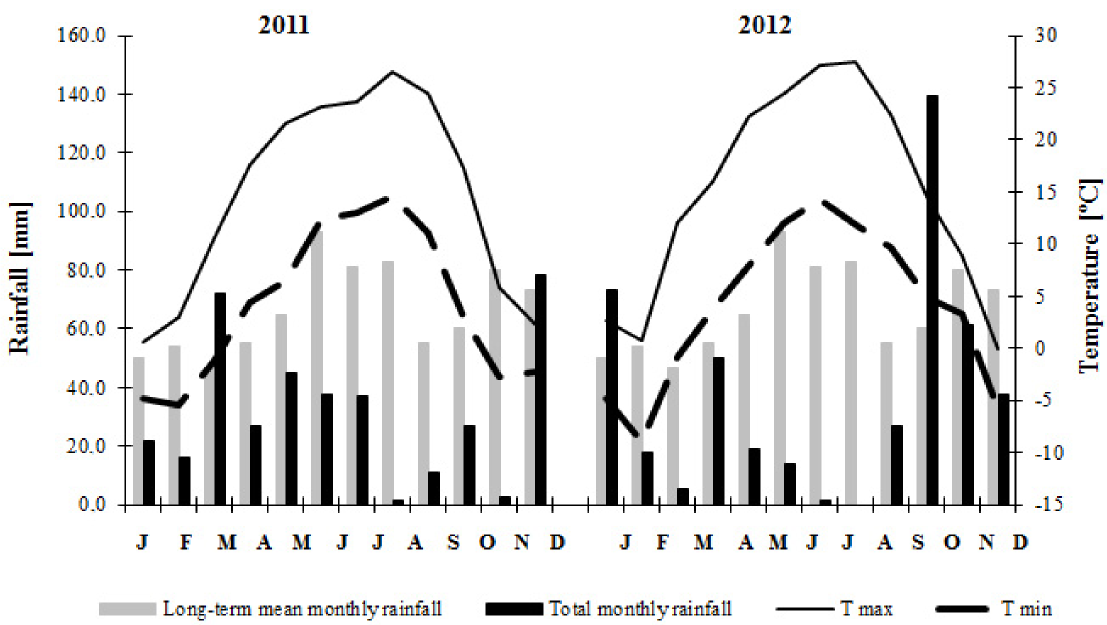

Figure 1. Monthly mean of maximum and minimum temperatures [°C], total monthly rainfall [mm] for 2011 and 2012, along with the long-term mean rainfall at Banská Bystrica, Slovakia

long-term period of drought had no effect on growth rate of grass–clover mixtures in the 1st cut but reduced growth by 33% and 43% in the 2nd and the 3rd ones. The low values of correlation coefficients indicated that neither rainfall quantity nor T_{max} during regrowth period directly affected the DM yield at monocultures of red clover. The lack of correlations between rainfall and DM yield of red clover may be attributed to soil moisture retention. Queen *et al.* (2009) argue that red clover DM yield was positively correlated with soil moisture, where variation in soil moisture was largely determined by location and year. Contrary to monocultures of red clover, its mixture with *Festulolium braunii* was found to be positively correlated with rainfall (r = 0.67, P < 0.05). Higher correlation with rainfall may be related to higher proportion of *Festulolium braunii* in mixtures (not shown), which as a shallow-rooted plant is more sensitive to water availability during growing season than legumes. Similarly, Gutmane and Adamovich (2008) reported that DM yield of *Festulolium* hybrids was strongly dependent on the climatic conditions in the year of yield and particular period of regrowth.

In alfalfa treatments, seasonal pattern of DM yield distribution in 2012 differed from red clover treatments with the highest yield in the 1st cut and the lowest in the 3rd one (Table 4). On average, monocultures of alfalfa overyielded monocultures of red clover by 4-, 3- and 6-fold in the 1st, 2nd and 3rd cuts in 2012, respectively. The positive influence of alfalfa on DM yield and its annual distribution in our study are consistent with the findings of Albayrak and Türk (2013) who noted that alfalfa grown in monoculture had the least yield decrease over the course of growing season compared with the red clover and the alfalfa–orchardgrass mixture. High DM production of alfalfa monocultures was likely caused by its remarkably higher cover in stands (from 82% to 98%) during the whole growing season in 2012. Similar to monocultures of red clover, no relation between DM yield and rainfall was found at alfalfa monocultures (Table 4). By contrast, cover of alfalfa in monocultures showed negative correlation with rainfall (r = –0.43, P < 0.05) though not significant. Our findings agree with the view that alfalfa has a reputation of being a drought-enduring species due to its ability to extract water from depth in the soil if available (Annicchiarico *et al*. 2013).

Nutritive value

On average, the monocultures of red clover and alfalfa exhibited significantly higher CP values (P < 0.05) than their mixtures with *Festulolium braunii* (Table 6). Our findings are in agreement with Albayrak and Türk (2013) who noted that alfalfa and clover monocultures had higher CP contents than legume binary mixtures. For red clover

T a b l e 2

Total dry mater yield [t/ha] in monocultures of red clover, alfalfa and their mixtures with *Festulolium braunii*

Treatment		Year		Mean
		2011	2012	
1	Red clover cv. Fresko	6.48	3.78	**5.13B**
2	Red clover cv. Veles	5.62	2.12	**3.87A**
3	Red clover cv. Fresko + *Festulolium braunii* cv. Achilles	9.03	4.58	**6.81C**
Mean		7.04^b	3.49^a	–
4	Alfalfa cv. Kamila	7.63	12.02	**9.83A**
5	Alfalfa cv. Tereza	7.85	11.27	**9.56A**
6	Alfalfa cv. Tereza + *Festulolium braunii* cv. Achilles	5.83	11.31	**8.47A**
Mean		7.10^a	11.53^b	–

Treatments means in the same rows with different lower-case letters, and treatment means with different upper-case (in bold face) in the same columns are significantly different at P < 0.05 level according to *LSD* multiple range test treatments, the CP concentration ranged from 112.5 g/kg at the 1st cut to 150.3 g/kg at the 2nd cut. Alfalfa treatments similar to red clover showed the highest CP content in the 2nd cut. Significantly higher CP concentration in the 2nd cut compared with the 1st and the 3rd ones in our study was connected with the highest proportion of legumes in stands in the 2nd cuts. For red clover, monocultures and monoculture of alfalfa cv. Tereza, CP content did not decline significantly with time in the 3rd cut, and followed typical patterns described by Whitehead (2000) who reported that the CP concentration in herbage of legumes declines with increasing maturity less markedly than in herbage of grasses. For grass–legume mixtures, the lowest CP content occurred in the 1st cut (94.10 g/kg, 106.82 g/kg) and the highest in the 3rd cut (147.61 g/kg, 146.83 g/kg). Similarly, Eriksen *et al*. (2013) found that CP concentration significantly

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Legume proportion [%] in monocultures of red clover, alfalfa and their mixtures with *Festulolium braunii*

Treatment		Year	
		2011	2012
1	Red clover cv. Fresko	79.0	27.0
2	Red clover cv. Veles	82.0	26.3
3	Red clover cv. Fresko + *Festulolium braunii* cv. Achilles	39.7	29.0
Mean		66.9^{b}	27.4^{a}
4	Alfalfa cv. Kamila	77.7	97.7
5	Alfalfa cv. Tereza	72.3	97.3
6	Alfalfa cv. Tereza + *Festulolium braunii* cv. Achilles	39.0	81.0
Mean		63.1^{a}	91.6^{b}

Treatments means in the same rows with different lower-case letters are significantly different at $P < 0.05$ level according to *LSD* multiple range test

T a b l e 4

Dry mater (DM) yield [t/ha] at the monocultures of red clover, alfalfa and their mixtures with *Festulolium braunii* in the 1st, 2nd and 3rd cuts [t/ha]

Year	Cut number	T_{max}[°C]	R [mm]	Treatment					
				1	2	3	4	5	6
2011	1st	19.1	59.0	1.22	0.73	2.38	1.09	1.41	1.00
	2nd	23.4	51.4	3.65	3.71	4.12	3.58	3.13	3.18
	3rd	25.1	48.2	1.61	1.18	2.53	3.02	3.31	1.45
2012	1st	18.4	69.4	1.34	0.82	2.32	4.51	4.89	4.43
	2nd	25.5	33.6	1.74	1.00	1.68	4.14	3.29	3.37
	3rd	26.4	0.0	0.70	0.30	0.59	3.38	3.09	3.51
r_{Tmax}				0.05	0.05	–0.32	0.23	0.04	0.03
r_{R}				0.33	0.29	0.67^{+}	–0.09	0.14	–0.15

T_{max} – mean of maximum temperatures per cut, R – sum of rainfall per cut 1, 2, 3, 4, 5, 6 – treatments, r_{Tmax} – Pearson correlation coefficient for relationship between the DM yield and T_{max}, r_{R} – Pearson correlation coefficient for relationship between the DM yield and sum of rainfall per cut, $^{+}$ – significantly different at 95% level increased from 121 g/kg in the 1st cut to 223 g/kg in the 3rd cut. The patterns of CP content in the herbage of red clover–grass mixture revealed that herbage cut in May contained less CP than the 110 g/kg required for dairy cows (NRC 2001). The correlation coefficients for the relationship among CP concentrations and weather variables, legume proportion and cutting time are presented in Table 8. For red clover mixture, there was a positive relationship between CP and cut number, between CP and T_{max}, and negative correlation between CP content and sum of rainfall. Jensen *et al*. (2003) observed increased CP concentration with water stress at the late-season harvest for ryegrass and orchardgrass cultivars. They explained an increase in CP content by shorter and cooler days during the late-season. However,

Table 5

Legume proportion [%] in monocultures of red clover, alfalfa and their mixtures with *Festulolium braunii* in the 1st, 2nd and 3rd cuts [%]

Year	Cut number	T_{max} [°C]	R [mm]	Treatment					
				1	2	3	4	5	6
2011	1st	19.1	59.0	78	86	28	60	50	36
	2nd	23.4	51.4	94	92	48	89	85	44
	3rd	25.1	48.2	65	68	43	84	82	37
2012	1st	18.4	69.4	30	26	24	95	96	70
	2nd	25.5	33.6	32	28	33	98	98	88
	3rd	26.4	0.0	19	25	30	97	98	85
r_{Tmax}				−0.23	−0.24	0.49	0.51	0.50	0.36
r_R				0.50	0.45	−0.01	−0.43	−0.43	-0.58^{+}

T_{max} – mean of maximum temperatures per cut, R – sum of rainfall per cut, 1, 2, 3, 4, 5, 6 – treatments, r_{Tmax} – Pearson correlation coefficient for relationship between the legume proportion and T_{max}, r_R – Pearson correlation coefficient for relationship between the legume proportion and sum of rainfall per cut, $^{+}$ – significantly different at 95% level

Table 6

Content of crude protein [g/kg] in monocultures of red clover, alfalfa and their mixtures with *Festulolium braunii*

Treatment		Cut number			Mean
		1st	2nd	3rd	
1	Red clover cv. Fresko	122.5	169.5	144.0	**145.3B**
2	Red clover cv. Veles	121.1	149.9	138.5	**136.5B**
3	Red clover cv. Fresko + *Festulolium braunii* cv. Achilles	94.1	131.6	147.6	**124.4A**
Mean		112.5[a]	150.3[b]	143.4[b]	–
4	Alfalfa cv. Kamila	191.5	170.2	143.9	**168.5C**
5	Alfalfa cv. Tereza	118.1	163.6	141.7	**141.1B**
6	Alfalfa cv. Tereza + *Festulolium braunii* cv. Achilles	106.8	117.6	146.8	**123.7A**
Mean		138.8[a]	150.5[b]	144.1[a]	–

Treatments means in the same rows with different lower-case letters, and treatment means with different upper-case (in bold face) in the same columns are significantly different at $P < 0.05$ level according to *LSD* multiple range test the mean of maximum temperatures in our study did not significantly differ from the 2nd cut to the end of September. For alfalfa mixture, there were similar correlations between CP content and weather variables and cutting time. Contrary to red clover–grass mixture, there was a significant positive correlation between alfalfa proportion in stand and CP concentration (r = 0.69, P < 0.05). This situation was due to the fact that alfalfa proportion was significantly higher (not shown) in comparison with proportion of red clover in grass–clover mixture.

As would be expected, the monocultures of red clover had lower concentration of CF than monocultures of alfalfa and mixtures (Table 7). In our study, there was a strong negative relationship for the CF concentration and clover proportion in monoculture of cv. Fresko (r = –0.74, P < 0.05) and monoculture cv. Veles (r = –0.78, P < 0.05). To the con-

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Content of crude fibre [g/kg] in monocultures of red clover, alfalfa and their mixtures with *Festulolium braunii*

Treatment		Cut number			Mean
		1st	2nd	3rd	
1	Red clover cv. Fresko	198.4	256.2	268.7	**241.1A**
2	Red clover cv. Veles	222.2	254.5	255.2	**243.1A**
3	Red clover cv. Fresko + *Festulolium braunii* cv. Achilles	251.3	267.9	325.4	**281.6B**
Mean		224.0^a	259.6^b	283.1^c	–
4	Alfalfa cv. Kamila	186.3	295.4	328.5	**270.0A**
5	Alfalfa cv. Tereza	248.0	284.9	365.9	**299.6C**
6	Alfalfa cv. Tereza + *Festulolium braunii* cv. Achilles	249.2	305.9	290.8	**281.9B**
Mean		227.8^a	295.4^b	328.4^c	–

Treatments means in the same rows with different lower-case letters, and treatment means with different upper-case (in bold face) in the same columns are significantly different at P < 0.05 level according to *LSD* multiple range test

T a b l e 8

Pearson correlation coefficients between nutritive parameters (content of CP [g/kg], CF [g/kg]) and legume proportion [%], cut number, sum of rainfall per cut [mm] and mean of maximum temperature [°C]

Parameter	Variable	Treatment					
		1	2	3	4	5	6
CP [g/kg]	Legume proportion [%]	0.11	0.34	0.28	0.74$^+$	0.72$^+$	0.69$^+$
	Cut number	0.28	0.29	0.79$^+$	0.77$^+$	0.40	0.55
	R [mm]	0.07	0.08	−0.59$^+$	0.55	−0.31	−0.49
	T_{max} [°C]	0.29	0.31	0.81$^+$	0.72$^+$	0.52	0.51
CF [g/kg]	Legume proportion [%]	−0.74$^+$	−0.78$^+$	0.11	0.88$^+$	0.69$^+$	0.74$^+$
	Cut number	0.45	0.27	0.75$^+$	0.64$^+$	0.70$^+$	0.39
	R [mm]	−0.41	−0.35	−0.43	−0.53	−0.56	−0.38
	T_{max} [°C]	0.56	0.33	0.61$^+$	0.70$^+$	0.67$^+$	0.57

CP – crude protein, CF – crude fibre, T_{max} – mean of maximum temperatures per cut, R – sum of rainfall per cut
$^+$ – significantly different at 95% level

trary, the CF content in forage from alfalfa–grass mixtures was positively affected by alfalfa proportion in stand. The explanation for this was that clovers have generally lower fibre content than grasses (Sturludóttir *et al.* 2013) and alfalfa as well. For monocultures of alfalfa, the fibre concentration also displayed a strong positive correlation with cutting time (Table 8). Our findings agree with Frame (2005) who reported that fibre content at alfalfa decreased with increasing number of cuts in a season by cutting at earlier stages of growth. This situation can be explained by alfalfa morphology mainly by greater leaf-to-stem ratio in comparison with clover and by different intensities of cell wall lignification of stems and leaves. Marković *et al*. (2012) noted that proportion of lignified tissue continues to increase over time as the stem of alfalfa develops in size while leaf lignification and digestibility change only a little. Schönbach *et al*. (2012) observed that drought caused by water stress results in rapid plant maturation, fibrous and less digestible herbage. Similarly, Ge *et al*. (2011) showed that elevated ambient temperature induced earlier plant senescence. Moreover, Sanz-Sáez *et al*. (2012) reported that elevated CO_2 in combination with high temperature reduced CP content and enhanced fibre content. In a study performed by Thornwaldsson *et al*. (2007), it has been shown that temperature is the climate factor with the strongest influence on the grass digestibility. In our study, there was a non-significant negative correlation between CF concentration and sum of rainfall available to the cut. The CF content was positively correlated with T_{max} whereby alfalfa monocultures showed stronger correlations with T_{max} than clover monocultures. This difference can be explained by higher proportion of more fibrous alfalfa stems in DM yield in comparison with clover stands.

Within the context of impact of climate change on grassland management and animal nutrition, red clover monocultures under 3–cut system provided herbage of higher quality than alfalfa monocultures and grass–legume mixtures. However, water stress in combination with higher ambient temperature negatively affected persistency of red clover in stands. In contrast, alfalfa performed significantly better, nevertheless with lower herbage quality. This study agrees with Sobocká *et al*. (2005) who noted that changes in plant species productivity induced by climate change will lead to marked shifts in agro-climatic zoning, cropping patterns and introduction of new crop varieties in Slovakia.

CONCLUSIONS

Our results showed the negative impact of water stress on red clover persistence in stands and consequently on DM production and seasonal pattern of DM yield. To the contrary, alfalfa displayed high yield potential and stability during two consecutive dry years. As would be expected, the monocultures of red clover and alfalfa exhibited significantly higher CP content than mixtures with *Festulolium braunii*. Nevertheless, alfalfa monocultures and alfalfa–grass mixture had higher CF concentration in comparison with red clover monocultures. Out of the weather variables, ambient temperature was the factor that predominantly affected concentration of CP and CF, especially in alfalfa monocultures. This study has shown the advantages of including alfalfa in the temporary grassland in moderately warm regions. Nevertheless, the adaptation of a more suitable cutting management to increase the nutritive value of alfalfa herbage must be employed.

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