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YIELDS AND QUALITY OF FORAGE LEGUMES UNDER IMBALANCED YEAR PRECIPITATION CONDITIONS ON SOUTH MORAVIA

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Abstract

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In this paper, yield and quality of forage following species of forage legumes were evaluated with regard to precipitations: lucerne (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.), kura clover (*Trifolium ambiguum* M.), alsike clover (*Trifolium hybridum* L.) and birdsfoot trefoil (*Lotus corniculatus* L.). The trial was sown in the spring of 2008, evaluated in the period 2009–2011. Analysis of samples was performed with the apparatus NIRS 6500. Following parameters were evaluated: production of dry matter, energy concentration (NEL), contents of fibre and crude protein. The highest three year yield average was measured for lucerne (15.01 t.ha^{-1}), followed by red clover group (9.3–11.8 t.ha^{-1}). Kura clover gained the lowest yield (1.97 t.ha^{-1}). The average crude protein contents (g.kg^{-1}) were: lucerne 211.47, red clover group (184.3–194.8), white clover group (229.1–238.7) and birdsfoot trefoil (204.2). The obtained results indicated that lucerne responded at best to periods of drought. Although the production of dry matter decreased in periods of drought, the canopy of stands remained to be complete in contradistinction to white clover, which partly disappeared from the stand. Red clover and alsike clover disappeared from the stand during the trial.

lucerne, clovers, birdsfoot trefoil, drought

Forage legumes represent the main source of plant proteins in the nutrition of ruminants. In forage legumes, the highest concentration of both energy and crude protein can be found out in the stage of flower bud appearance (butonisation); this phenological stage represents and optimum for the crop harvest. Later on, quality of forage legumes decreases, plant tissues quickly lignify, fibre content increases, and the content of energy is reduced (Vorlíček, Dubec, 2006).

Lucerne (*Medicago sativa*) is one of the most frequently grown forage legumes worldwide due to its high nutritional value and its drought tolerance. Lucerne represents a traditional crop in the Czech Republic and at present it is more and more frequently grown also in higher altitudes (Houdek, 2009). Lucerne requires good-quality soils and tolerates also drier conditions. A huge root system of lucerne enables its plants to draw water and nutrients also from deeper soil layers. Results of utility value tests performed within the period of 2007–2010 indicated that yields of dry matter ranged from 17.8 do 22.7 t.ha^{-1} within this three-year time interval under climatic and soil conditions of the Czech Republic (ÚKZÚZ, 2011).

Red clover (*Trifolium pratense*) and white clover (*Trifolium repens*) are other important sources of proteins. In higher altitudes, clovers are typical protein-rich crops that substitute lucerne (which does not give reliable yields there). Clovers tolerate lower temperatures and require a higher content of moisture in soil. As compared with lucerne, clovers contain less crude protein but more water-soluble sugars, which represent an important and easily available source of energy within the process of digestion. A slower lignification is clover's another advantage. This process is characterised by a slower increase in fibre content so that the harvest intervals are extended. From the genetic point of view, red clover has diploid and tetraploid varieties. The process of its breeding and selection is focused above all to yield stability and higher content of sugars in dry matter. Tetraploid varieties contain more water and this may be negatively manifested in the length of wilting period, above all when making silage. A longer period of wilting causes also an undesirable decomposition of sugars and crude proteins.

Diploid varieties of red clover produced in average 17.3 and 13.0 $t.ha^{-1}$ of dry matter in the first and the second production year, respectively (ÚKZÚZ, 2011a [on-line]) while tetraploid ones produced 18.6 and 13.5 $t.ha^{-1}$, respectively (ÚKZÚZ, 2011b [on-line]). In white clover, production of dry matter ranged from 9.8 to 6.8 $t.ha^{-1}$ within the period of three years (ÚKZÚZ, 2006a; ÚKZÚZ, 2009, [on-line]).

Alsike clover (*Trifolium hybridum*) is suitable above all for humid regions with a lower content of nutrients in soil where it can fully replace the red clover. In the stage of flowering, the process of lignification is slow and the quality of forage is not reduced so much as that of lucerne. The average yield (3 varieties, 5 sites) of dry matter in the first and the second year of production was 14.1 $t.ha^{-1}$ (ÚKZÚZ, 2005a [on-line]) and 8.6 $t.ha^{-1}$ (ÚKZÚZ, 2006b [on-line]), respectively. In other trial performed in the same localities, the dry matter yield was only 3.6 $t.ha^{-1}$ in the second production year (2007) (ÚKZÚZ, 2007a [on-line]).

In this experiment, the assortment of clover species involved also Kura clover (*Trifolium ambiguum*), a very rarely grown in central Europe which has not been registered in the Czech Republic yet. In our country, this species was studied in detail only by Vacek (1963) who reported that its height could be as much as 73 cm. As far as the requirements of this species were concerned, it showed a great plasticity and a wide ecological amplitude. Kura clover tolerated a higher level of groundwater, survived in floods (for as much as 7 days) and tolerated also periods of drought (due to the formation of smaller leaves). Its re-growth after individual cuttings was relatively quick and it was also a suitable component of grazing mixtures. In Germany, the Kura clover was experimentally grown in mixtures with Alsike clover. However, as compared with an unfertilized variant of rye grass monoculture, its production of biomass was low. The quality of Kura clover forage was comparable with that of white clover (Gierus, 2012). Riday *et al.* (2012) (Wisconsin; USA) wrote that this was a fodder crop showing a great production potential and recommended it into grazing mixtures because it creates quickly a dense canopy. According to historical sources (Serdyukov, 1930), it is very preferred by sheep.

Birdsfoot trefoil (*Lotus corniculatus*) tolerates wide amplitude of site conditions. *Lotus* species are adapted to many kinds of environmental stress, including flooding conditions, whereas other popular forage legumes, like alfalfa or white clover, cannot thrive (Striker *et al.*, 2005).

For that reason it can be grown above all in those localities where the basic ecological requirements of more demanding species of forage legumes are not satisfied. It requires full sunlight and if shaded by higher canopy, its growth and competitiveness are reduced. As far as yields are concerned, it is comparable with red clover (Regál, Krajčovič, 1963).

Lotus yield levels are even better than lucerne and red clover ones on low fertile soil sites (Klesnil, 1978). The forage quality of birdsfoot trefoil is one of the best among perennial legumes and farm ruminants consume it very well. The process of lignification is slower due to a great amount of leaves and a longer period of flowering. Performance of farm animals fed on this forage species, above all the content of milk protein, is very good (Woodward, 2000). Within the period of three experimental years, production of dry matter of the birdsfoot trefoil stand ranged between 11.0 and 14.0 $t.ha^{-1}$ (ÚKZÚZ, 2007b, ÚKZÚZ, 2006c, ÚKZÚZ, 2005b, [on-line]).

MATERIAL AND METHODS

A small-plot experiment with monocultures of individual forage legumes on arable land was established in the locality Troubsko in the middle of April 2008 in an altitude 277 m a.s.l. Average values of annual and growing-season (April–September) temperatures are 8.6 °C and 14.8 °C. The annual sum of precipitation and growing-season precipitation are 547 and 346 mm, respectively. Temperature average and sum of precipitation are presented in Tab. III for each month of each growing season. The comparison between measured data and climate normal was performed (Tab. III). Soil condition was orthic luvisol order and loam/clay loam soil texture. Agrochemical soil testing was performed before sowing (Tab. I).

The experiment was established in four replications using the method of randomised blocks and the size of each plot (and harvested area) was 10 m^2. A list of selected legumes involved in this experiment is presented in Tab. II. In each year, a dose of 35 kg $P.ha^{-1}$ and 100 kg $K.ha^{-1}$ was applied at the beginning of the growing season. The year 2008 was only the year of crop establishment and for that reason it involved only five weed-killing cuttings. The weeds were regularly controlled by

I: *Agrochemical soil testing on locality Troubsko*

pH (KCl)	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)	Mg ($mg.kg^{-1}$)	N (%)	Humus (%)
7.15	39	177	191	0.160	1.78

hand extraction during production years. During three following production years (i.e. in 2009–2011), fodder was harvested with a Hege 212 forage plot harvester; harvested fresh matter was weighed and samples for analyses were taken after each cutting. In the first and the third experimental year, the date of the first cutting was determined on the base of phenological stages (i.e. at the beginning of butonisation). In the first and the third year of production, the dates of the first cutting were on 6 and 26 May, respectively. The following three cuttings were performed in time intervals of 45 days. In the second production year (2010), the first cutting was performed, due to frequent and continuous rains in May, as late as on 11 June. To this date, nearly all species of forage legumes were at the end of the flowering stage. In this year it was possible to perform only three cuttings and the time intervals between them could not be exactly 45 days. In the third production year, the occurrence of root nodules with symbiotic bacteria was evaluated in the stand of Kura clover. Harvested samples were dried at 60 °C for 48 hours. Homogenised samples were analysed at Crop Research Institute – VSTE Jevíčko (CRI) using the NIRS 6500 apparatus (reflectance 400–2500 nm, band width 2 nm) under WinISI II (v. 1.50) program environment. The following parameters were estimated: yield per plot in dry matter (d.m.), dry matter (105 °C), and contents of fibre, crude proteins, NEL (net energy lactation). Statistic evaluation was performed at CRI using the method of multi factorial analysis of variance (ANOVA P>0.05) followed by post-hoc Tukey's test.

RESULTS AND DISCUSSION

In the year of crop establishment (2008), seeds of all forage legumes germinated well and stands on experimental plots were fully developed and nearly free of weeds to the end of growing season. In the first production year (2009), distribution of precipitations in spring period was in normal but interval between the second and the third cuts the rainfalls were substantially higher than long term average (Tab. III). A higher supply of water in this period was utilized at best by red clover. Its varieties

II: *Species and varieties of forage legumes involved in this experiment, their sowing rates and ploidy levels (2n = diploid 4n = tetraploid)*

Variant	Crop/variety	MGS (ks.ha^{-1})	Sowing rate [kg.ha^{-1}]
1	*Medicago sativa* 'MORAVA'	8	17.7
2	*Trifolium pratense* 'SUEZ' (2n)	8	17.3
3	*Trifolium pratense* 'VLTAVÍN (2n)	8	18.5
4	*Trifolium pratense* 'AMOS' (4n)	8	27.6
5	*Trifolium pratense* 'VESNA' (4n)	8	23.7
6	*Trifolium repens* 'HÁJEK'	15	12.4
7	*Trifolium repens* 'JURA'	15	10.7
8	*Trifolium repens* 'KRÁL'	15	11.6
9	*Trifolium hybridum* 'POODERSKÝ'	15	11.6
10	*Lotus corniculatus* 'LOTAR'	15	17.6
11	*Trifolium ambiguum* 'ENDURA'	15	17.3

MGS – millions of germinative seeds

III: *Monthly sums of precipitation and temperature average in the experimental site in the growing season*

Year	April		May		June	
	Precipitation [mm]	Temperature [°C]	Precipitation [mm]	Temperature [°C]	Precipitation [mm]	Temperature [°C]
2008	34.2 ^{0}	9.90 ^{0}	53.0 ^{0}	15.30 ^{0}	49.7 ^{0}	19.50 ^{3}
2009	3.5 $^{-2}$	13.80 ^{3}	44.4 ^{0}	15.10 ^{0}	98.5 ^{1}	17.10 ^{0}
2010	44.8 ^{0}	10.00 ^{0}	106.2 ^{2}	13.60 ^{0}	120.8 ^{2}	18.60 ^{1}
2011	35.2 ^{0}	11.50 ^{2}	42.3 ^{0}	14.20 ^{0}	46.3 $^{-1}$	18.70 ^{1}
Year	July		August		September	
	Precipitation [mm]	Temperature [°C]	Precipitation [mm]	Temperature [°C]	Precipitation [mm]	Temperature [°C]
2008	43.4 $^{-1}$	20.20 ^{2}	47.4 ^{0}	19.60 ^{2}	52.1 ^{0}	13.90 ^{0}
2009	141.0 ^{2}	20.30 ^{2}	28.4 $^{-1}$	20.10 ^{3}	14.8 $^{-1}$	16.60 ^{2}
2010	113.7 ^{1}	21.90 ^{3}	80.2 ^{0}	18.20 ^{0}	74.5 ^{1}	12.70 ^{0}
2011	58.1 ^{0}	18.30 ^{0}	33.6 $^{-1}$	19.60 ^{2}	44.5 ^{0}	16.10 ^{2}

Month Temperature: 0 normal, 1 warm, 2 very warm
Month Precipitation: –2 very dry, –1 dry, 0 normal, 1 wet, 2 very wet

produced in the third cutting (8.62 t.ha^{-1} in d.m.) by nearly 132% more dry matter than in the first one (3.71 t.ha^{-1} in d.m.). Within the same time interval, dry matter production of Kura clover and lucerne was only slightly increased and white clover, alsike clover and birdsfoot trefoil produced the same amounts of dry matter as in the first cut. As far as the qualitative parameters of fodder were concerned, no differences in qualitative parameters were observed between the first three and the fourth cut.

The varietal description of 'AMOS' states higher resistance to drought and more forage production in drier regions (DLF, [on-line]). Red clover varieties 'AMOS' and 'VESNA' became dry in our trial more than 50% of plot acreage. After the third cut, alsike clover 'POODERSKÝ' completely disappeared from experimental plots. These results may be caused by dry period on site. In the second year of production (2010), the precipitations during the growing season were higher than the average. Wet soil surface did not allow harvest experimental plots in time and for that reason the quality of the first cut was impaired. Also the subsequent cutting could not be performed in time due to a wet weather. Delayed harvest in 2010 resulted in higher contents of fibre in all species of forage legumes (Tab. V); the highest increase was recorded in white clover varieties. Delayed harvest in 2010 resulted in lower concentrations of crude protein. Variety AMOS was statistically significant different in protein content than other ones in 2010 (Tab. VI). The concentration of energy (NEL) statistical significantly decreased in almost all species (except birdsfoot trefoil) in 2010. Other years were almost similar in NEL values for each variant and we have no find statistical significant difference. Lucerne gained higher NEL (approx. 0.2–0.55 MJ) value compared with all red clovers in all years (Tab. VII). Zeman *et al.* (1995) published similar NEL values for 'lucerne hay 15% crude protein' (5.07 MJ) and 'red clover hay very good quality' (5.03 MJ). High lucerne NEL values in our trial could be caused by high level of crude protein content (Tab. VI), which is important parameter for NEL value.

Pozdíšek *et al.* (2002) reported an average weekly decrease of energy concentration in dry matter of red clover by 0.28 MJ.kg^{-1} within the period starting at the beginning of May and ending in the half of June. In 2010 some species of forage legumes produced in general less forage that in the preceding year. Concretely, this concerned all varieties of white clover, both diploid varieties of red clover, tetraploid red clover variety 'VESNA', and birdsfoot trefoil. No decrease in dry matter production was observed in lucerne, tetraploid red clover variety 'AMOS', and Kura clover. As far as Kura clover was concerned, Vacek (1963) appreciated positively its quick re-growth after individual cuts. In an experiment with monitoring the rate of growth and re-growth after cutting of 22 species of forage crops, this author classified it as one of the best. In our experiment, Kura clover produced nearly six-times and three-point-five-times less dry matter in the first and the second year of production than varieties of red clover (Tab. IV); in the first year, the yield of fresh matter was 1.8 t.ha^{-1}. In the first year of production, Vacek (1963) mentioned that the yield after the first cut was 7.8 t.ha^{-1} and Ljubskaya (1951) reported 4 to 6 t.ha^{-1}.

Low yield of fresh matter and bad visual appearance of kura clover plots could be caused by insufficient nitrogen supply. We did not find any nodules of *Rhizobium* sp. on roots from 20 plants. The same situation was published by a number of authors (e.g. Seguin *et al.*, 2001; Bettler and Thomet, 2007).

In the third year of production (2011), Kura clover was present on experimental plots but its stand was not harvested because it was too low for harvester. In the third harvest year, annual yields of dry matter decreased in all varieties of red and white clover. Besides a natural decrease in production that occurred in individual years, this decrease was caused also by a zero production of biomass after the

IV: *Dry matter production [t.ha^{-1}] and post hoc Tukey's test for differences between years for each variant*

Variant	Species/variety	Dry matter forage yield					
		2009		2010		2011	
1	*Medicago sativa* 'MORAVA'	16.35	ab	16.71	ab	11.96	c
2	*Trifolium pratense* 'SUEZ' (2n)	15.31	a	10.71	b	4.61	c
3	*Trifolium pratense* 'VLTAVÍN' (2n)	15.10	a	10.08	b	2.75	c
4	*Trifolium pratense* 'AMOS' (4n)	14.57	ab	11.16	ab	4.80	c
5	*Trifolium pratense* 'VESNA' (4n)	16.42	a	12.42	b	4.70	c
6	*Trifolium repens* 'HÁJEK'	8.35	a	4.85	b	1.82	c
7	*Trifolium repens* 'JURA'	8.17	a	5.27	b	1.99	c
8	*Trifolium repens* 'KRÁL'	8.20	a	4.65	b	2.21	c
9	*Trifolium hybridum* 'POODERSKÝ'	9.19	a	*		*	
10	*Lotus corniculatus* 'LOTAR'	12.23	a	8.33	bc	6.60	bc
11	*Trifolium ambiguum* 'ENDURA'	2.73	a	3.17	a	*	

* Not evaluated

V: *Weighted averages of fibre concentration in dry matter [g.kg⁻¹] and post hoc Tukey's test for differences between years for each variant*

Variant	Species/variety	Fibre					
		2009		2010		2011	
1	*Medicago sativa* 'MORAVA'	228.40	bc	297.50	a	237.70	bc
2	*Trifolium pratense* 'SUEZ' (2n)	219.00	c	289.40	a	248.60	b
3	*Trifolium pratense* 'VLTAVÍN (2n)	219.60	bc	295.30	a	233.70	bc
4	*Trifolium pratense* 'AMOS' (4n)	212.50	bc	287.80	a	236.50	bc
5	*Trifolium pratense* 'VESNA' (4n)	219.30	c	290.10	a	252.10	b
6	*Trifolium repens* 'HÁJEK'	192.40	bc	264.80	a	209.40	bc
7	*Trifolium repens* 'JURA'	191.00	a	255.10	a	197.70	a
8	*Trifolium repens* 'KRÁL'	197.70	bc	256.20	a	198.30	bc
9	*Trifolium hybridum* 'POODERSKÝ'	199.50	a	*		*	
10	*Lotus corniculatus* 'LOTAR'	218.20	bc	273.50	a	202.00	bc
11	*Trifolium ambiguum* 'ENDURA'	217.80	b	278.80	a	*	

* Not evaluated

VI: *Weighed averages of crude protein concentration in dry matter [g.kg⁻¹] and post hoc Tukey's test for differences between years for each variant*

Variant	Species/variety	Crude proteins					
		2009		2010		2011	
1	*Medicago sativa* 'MORAVA'	218.00	a	204.40	a	212.00	a
2	*Trifolium pratense* 'SUEZ' (2n)	201.00	ab	187.10	ab	173.50	c
3	*Trifolium pratense* 'VLTAVÍN (2n)	199.20	a	185.80	a	185.50	a
4	*Trifolium pratense* 'AMOS' (4n)	212.60	a	188.50	bc	183.30	bc
5	*Trifolium pratense* 'VESNA' (4n)	203.50	a	180.30	ab	169.20	bc
6	*Trifolium repens* 'HÁJEK'	236.50	a	223.70	a	227.20	a
7	*Trifolium repens* 'JURA'	234.90	a	243.00	a	238.70	a
8	*Trifolium repens* 'KRÁL'	234.90	a	240.60	a	240.50	a
9	*Trifolium hybridum* 'POODERSKÝ'	218.00	a	*		*	
10	*Lotus corniculatus* 'LOTAR'	198.00	a	198.30	a	216.20	a
11	*Trifolium ambiguum* 'ENDURA'	183.80	a	172.80	a	*	

* Not evaluated

VII: *Weighed averages of energy concentration NEL in dry matter [MJ.kg⁻¹] and post hoc Tukey's test for differences between years for each variant*

Variant	Species/variety	NEL					
		2009		2010		2011	
1	*Medicago sativa* 'MORAVA'	6.44	ab	5.78	c	6.32	ab
2	*Trifolium pratense* 'SUEZ' (2n)	6.14	ab	5.59	c	5.76	bc
3	*Trifolium pratense* 'VLTAVÍN (2n)	6.10	ab	5.51	c	5.94	ab
4	*Trifolium pratense* 'AMOS' (4n)	6.07	a	5.61	c	5.83	ab
5	*Trifolium pratense* 'VESNA' (4n)	5.99	a	5.58	bc	5.61	ab
6	*Trifolium repens* 'HÁJEK'	6.45	a	5.99	bc	6.37	ab
7	*Trifolium repens* 'JURA'	6.56	a	6.08	c	6.49	ab
8	*Trifolium repens* 'KRÁL'	6.36	ab	5.91	c	6.58	a
9	*Trifolium hybridum* 'POODERSKÝ'	6.65	a	*		*	
10	*Lotus corniculatus* 'LOTAR'	6.51	ac	6.27	c	6.83	ab
11	*Trifolium ambiguum* 'ENDURA'	6.38	a	5.85	b	*	

* Not evaluated

second cut. In this period, the re-growth of clover stands did not take place due to a precipitation deficit occurring in summer months. A decrease in biomass production was observed also in lucerne and birdsfoot trefoil but it was not so intensive as in clovers. However, there were marked differences between individual cuts. So, for example, the stand of lucerne produced more than 4.5 t.ha^{-1} (in d.m., data not shown) of forage in the first and the second cut but the harvest in fourth one was only 0.5 t.ha^{-1} (in d.m., data not shown); in birdsfoot trefoil, the corresponding yields of fresh biomass were approximately 2.5 t.ha^{-1} and 0.3 t.ha^{-1} (in d.m., data not shown), respectively. Also in this year (2012), it was possible to observe a similarly low production of dry matter in other experiments with lucerne due to extraordinary drought.

CONCLUSIONS

The aim of this study was to evaluate effects of a precipitation deficit on yields and quality of some selected varieties of forage legumes. For this purpose, experiments with various species of forage legumes (i.e. lucerne, red clover, whiter clover, Kura clover, alsike clover and birdsfoot trefoil) were established in the locality Troubsko (277 m above sea level). In the first and the third year of production, four harvests were performed while in the second one only three (due to heavy rains). The obtained results indicated that red clover responded to low soil moisture content more sensitively than white clover. Under conditions of water deficit, yields of red clover quickly decreased but if there was enough moisture, its yields were comparable with those of lucerne. After the harvest, i.e. within the period of re-growth, red clovers were very sensitive to moisture deficit in soil. Under conditions of moisture deficit in soil, the re-growth of this species was slow and plants got dry. This was manifested above all in tetraploid varieties that required an increased supply of water. White clover stands were a little more tolerant to periods of dryness than red clovers and especially the young stands were able to adapt themselves better to the lack of water. In older stands however, fluctuating rainfalls caused a gradual disappearance of this species from stands. Alsike clover was unsuitable for growing in regions with a water deficit.

In regions with frequent water deficit in deep soils with neutral ph reaction it is recommended to grow either lucerne or birdsfoot trefoil. Although these two species decrease their yields due to the lack of rainfalls, their stands are closed, they do not suffer from weed infestation, and individual plants do not die off.

Imbalanced rainfall pattern delayed harvests due to continual rainfalls, contents of fibre were increased in all forage legumes under study and concentration of energy (NEL) was decreased. Birdsfoot trefoil was the only exception because it produced, in spite of a delayed harvest, the same energy concentration as at the moment of an optimum harvest. The delayed harvests caused a decrease in the content of crude protein only in the red clover variety 'AMOS' and in alsike clover. Periods of dryness did not influence quality of forage harvested on optimum terms. Kura clover stayed on plots only for 2 production years.

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