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MINERALS MANAGEMENT IN SILVOPASTORAL SYSTEM OF KARST PASTURE

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Minerals management in silvopastoral system of karst pasture

A survey of mountain pasture topsoil was undertaken first to set up field experiment in karst region on effects of applied P on minerals concentration in herbage. Content of SOM, C, N, CEC of soil and its base saturation are presented in the article. Great variability in depth, pH value and K level was found in soil. Low base saturation and high deficit of P was more common for all soil samples. Six different plant species presenting a great portion of herbage available for grazing and browsing at different occasions during grazing season were sampled and analysed for macro- and some microminerals. Concentration of P was very low in perennial grasses (1.1 g P kg^{-1} of DM). In leaves of common hazel (*Corylus avellana* L.) and common beech (*Fagus silvatica* L.) the concentration of P was identical as in white clover (*Trifolium repens* L.) and the level was high enough to cover animal needs when intake of herbage was sufficient. Leaves of woody plants were high in Mn concentration, but still below the levels that reduced growth rate in lambs. Application of P fertilizer had only small effect on increase of P in herbage, but large one on decrease on concentration of Ca in herbage. There was not clear effect of added P on concentration of Zn, Mn, Fe and Cu. Higher yield of DM induced with added fertilizer had not have any dilution effect on concentration of those minor elements in herbage.

Key words: animal husbandry / animal nutrition / pasturing / karst pastures / soil / herbage / minerals / superphosphates

Drevesno pašna raba in rudnine na kraškem pašniku

Na območju planinskega pašnika je bil napravljen pregled rodovitnosti zemlje in nato izveden poljski poskus o vplivu gnojenja s P na vsebnost rudnin v zelinju kraške vegetacije. V prispevku so predstavljeni podatki o vsebnosti organske snovi v tleh, C in N, kapacitete sorpcije ter zasičenost z bazami sorptivnega dela tal. Ugotovljena je bila velika variabilnost v debelini vrhnje plasti zemlje, pH vrednosti in oskrbljenosti tal s K. Značilna je tudi nizka zasičenost z bazami sorptivnega dela tal in veliko pomanjkanje rastlinam dostopnega P v zemlji. Za določanje vsebnosti rudnin v zelinju razpoložljivem za pašo in smukanje, je bilo vzorčeno šest različnih vrst rastlin, ki predstavljajo znaten delež krme v različnih delih pašne sezone. V travah, ki predstavljajo ob koncu pomladi znaten delež razpoložljive krme je bila ugotovljena zelo nizka vsebnost P (1,1 g kg^{-1} SS). V listju navadne leske (*Corylus avellana* L.) in navadne bukve (*Fagus sylvatica* L.) je bila vsebnost P enaka kot v zelinju plazeče detelje (*Trifolium repens* L.) in je bila dovolj visoka za pokritje potreb pašnih živali po P, če je v obroku dovolj zaužitega zelinja. V listih lesnatih rastlin je bila ugotovljena visoka vsebnost Mn, toda še vedno pod vrednostjo, ki vpliva na zmanjšanje dnevnih prirastov pri jagnjetih. Gnojenje s fosfati ni imelo značilnega vpliva na povečanje vsebnosti P v zelinju, toda močno je vplivalo na zmanjšanje vsebnosti Ca v zelinju rastlin ruše. Uporabljena fosfatna gnojila niso značilno vplivala na spremembo vsebnosti Zn, Mn, Fe in Cu v zelinju razpoložljivem za pašo. Višji pridelek zelinja dosežen z uporabo fosfatnih gnojil ni učinkoval razredčitveno na vsebnost mikroelementov v zelinju kraškega pašnika.

Ključne besede: živinoreja / prehrana živali / paša / kraški pašniki / tla / zelinje / minerali / superfosfati

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1 INTRODUCTION

The grazing animals will play very important role in the process of farming restoration on hill and karst grassland of Slovenia. The land under consideration was mainly used as cut meadows (hand cut) in the past. The plant minerals such as phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na) and sulphur (S) were drained out from the grassland soils because the hay produced there was fed to animals in confinement to get large volume of yard manure, which was used then on arable land to keep their fertility at the level high enough for good crop production (Gruden, 1910). Seminatural grasslands have longer history than is often realized (Walter, 1973), and karst grassland was a subject to depletion of plant available minerals most of the time (Vidrih A, 2005). An additional reason for depletion of plant minerals from karst hay grassland is strong wind bora (Mihevc, 1997). Most of nutrients in plants are organic and recycled to grassland soils through the decomposition of herbage. That is why this material must come in good contact with the soil, and mineralized by soil microorganisms. This way dead leaves and tillers can not be blown away by wind. Trampling of grazing animals is most efficient method for to incorporate organic matter into top layer of soil. But this trampling was absent from hay grassland, and wind erosion took its share of minerals from karst grassland. Occasional burning (accidentally or purposely) of vegetation over abandoned karst grassland was an additional drawn out of minerals from karst soil. As a consequence of all this a large area of karst grassland has been abandoned and converted to woody plant types of ecosystem. It has become increasingly evident that region is loosing its typical landscape, and that important habitat of very large proportion of wild fauna and flora is decreasing in size very much (Grove and Rackham, 2001; Kaligarič *et al.*, 2006).

Very variable soil profile, stoniness as well as topography are serious limitations for levels of production and potential for improvement of karst pasture vegetation. Whilst it is recognised that these limitations exist, it is also clear that they are of a kind which cannot readily be changed by improvement measures used under more favourable conditions for farming. Thus greater attention must be given to the nature of chemical limitation of soil fertility and the methods for their correction (Vidrih M *et al.*, 2007). Sima *et al.* (2004) is suggesting that this soil factors are probably more important in limiting production of grazing animals on potentially improvable soils than are climatic factors. Concentration of minerals in both soil and plant, influences the mineral status of grazing animals, and considering all these facts, the soil and herbage available for grazing on karst pasture were analysed for concentration of minerals, and the effect of P fertilization on mineral status of herbage is reported.

2 MATERIAL AND METHODS

A study was conducted on a herbaceous community of the Festuco-Brometea Br.-Bl. (Kaligarič, 1997) in the Dinaric karst site of Slovenia (lat. 45.41 °N, long. 14.12 °E, alt. 820 m) with 1500 mm rainfall. The experimental site was part of the mountain pasture Vremščica for milking sheep. Field experiment was set in the farmlet that has North exposition, with moderate slope and was subdivided into 6 paddocks and lasted from 2002 to 2005. The herbage was utilized by grazing only in a 6 week rotation during 100 to 120 day-long grazing season. Soil samples were collected in spring before onset of the grazing season from sites appropriate to locate the planned field experiment. To determine the concentration of minerals in herbage available for grazing and browsing, samples were collected from formerly not fertilized area. The grass species: sheep's fescue (*Festuca ovina* L.), chalk false brome (*Brachypodium pinnatum* L.) and erect brome (*Bromus erectus* L.) were collected in spring, because of their high abundance for grazing during that period. Young branches and leaves of common hazel (*Corylus avellana* L.) and common beech (*Fagus sylvatica* L.) were sampled during summer grass dormant period, as leaves of shrubs represented supplemental feed at that time. Legume white clover (*Trifolium repens* L.) was sampled at beginning of second rotation from grazed but not fertilized area. As very valuable feed white clover is grazed soon after the sheep enter the paddock. All together six different plant species were collected separately (three grass species, two shrub species and a legume species). Within a paddock where lambs (sheep replacement) were grazed under regular rotation, an experiment of latin square design consisting of four treatments with four replicates was set. Four levels of P (0, 30, 90, 270 kg P_2O_5 ha^{-1}) were under investigation in the first year. Next year superphosphate was applied again only at treatment 30 and 90 kg P_2O_5 ha^{-1}. In spring of the third year the superphosphate was applied equally as in a first year; all three fertilized treatments received superphosphate at the same rate as the first year. Total amount of applied P during four years of investigation was 0, 90, 270 and 540 kg P_2O_5 ha^{-1} respectively for treatment 1, 2, 3 and 4.

Major soil physical and chemical properties were analysed in soil samples (Egner *et al.*, 1960; Janitzky, 1986; SIST ISO 13878, 1998; Soil Survey Staff, 2009). The concentration of minerals in herbage samples was determined by standard procedures for plant tissue (Ca, Mg, Na, Mn, Zn, Fe and Cu were determined by atomic

***Table 1:** Chemical properties of soil (n=30) on mountain pasture Vremščica (SD – standard deviation, SE – standard error of average)*
***Preglednica 1:** Fizikalne in kemijske lastnosti tal (n = 30) planinskega pašnika Vremščica (SD – standardna deviacija, SE – standardna napaka povprečja)*

	Soil depth cm	pH in KCl	Clay %	P_2O_5 mg 100 g^{-1} of soil	K_2O mg 100 g^{-1} of soil	SOM %	C %	C:N ratio
Average	12.6	4.5	21.1	2.7	14.4	9.9	5.7	13.2
SE	0.8	0.1	1.3	0.4	1.6	0.7	0.4	0.7

absorption spectrometry [Varian Model AA240, Palo Alto, CA], P by spectrophotometric determination [Fias, Perkin Elmer, USA], K by flame photometry [FP6410, Unicom Optics, PRC]). To determine concentration of minerals in herbage from fertilized experiment, samples were obtained immediately before grazing (pre-grazing). To represent the herbage grazed by the animals, samples were obtained by hand plucking at the end of the spring. Sampling units (n = 25) were randomly selected out of the population from each plot, and combined in one sample for each treatment. Herbage samples were oven dried for approximately 12h at 100 °C and ground in a hammer mill to pass a 1-mm sieve. These samples were chemically analysed and the results are assumed to relate closely to the composition of the herbage eaten. The data obtained from our study were subjected to analysis of variance for random block and latin square design with GenStat Release v7.1 (Genstat 7 Committee, 2003) and Duncan's post hoc test at $P < 0.05$ probability level to determine significant differences between the treatments.

3 RESULTS AND DISCUSSION

3.1 MINERALS IN SOIL

Most frequent type of soil found over pasture Vremščica is typically brown rendzina. This is less productive soil, where nutrient concentration and water holding capacity are low. Reasons for this are slow process of soil formation and very long history of utilisation of vegetation that existed there in the past (Lovrenčak, 1993). The top layer of soil – A1 horizon, where most roots of herbal vegetation can be found is in average 12.6 cm tick, has low pH, and is deficient in P available to plants (2.7 mg P_2O_5 100 g^{-1} of soil). Level of K in soil is low to moderate (Table 1). Content of soil organic matter (SOM) in top layer is high (10%). This and substantial content of clay in soil (> 20%), is the reason for the high cation exchange capacity (CEC) of the soils of karst pasture. Clay in rendzina is not only a source of nutrients, its also determine the degree to which organically bound P can accumulate in the soil (Table 2). Because of very high CEC the base saturation of this soil is low (32.3%). Ca and Mg together present most of this base saturation, which should be round 80% to assure balanced soil for good growth of white clover and efficient fixation on N by symbiotic bacteria. C to N ratio is too high (13.2 :1) for to accomplish efficient transformation of dead organic matter into humus. The very high saturation of soil with hydrogen ion (67.8% H^+) is in accordance with soil acidity (4.5 pH). The rank of saturation of exchange capacity with hydrogen ion should be 10 to 15% H^+ as stated by Kinsey and Walters (2006).

3.2 MINERALS IN HERBAGE

From results obtained in current research it is evident that great differences exist in concentration of minerals between three kinds of available herbage for animals grazing or browsing within vegetation of karst pasture. Native perennial grasses which are adapted to grow on P deficient soil with a pronounced dry season spell have very low concentration of minerals in total (49.4 g ash kg^{-1} of DM on average). In leaves of shrubs the concen-

***Table 2:** Cation exchange capacity (CEC), base saturation and mineral composition in the soil (n = 30) on mountain pasture Vremščica (SD – standard deviation, SE – standard error of average)*
***Preglednica 2:** Kapaciteta sorpcije, zasičenost z bazami in koncentracija mineralov v tleh (n = 30) planinskega pašnika Vremščica (SD – standardna deviacija, SE – standardna napaka povprečja)*

	Base	CEC	Base saturation	Ca	Mg	K	Na	H
	eq mmol H 100 g^{-1} soil		%					
Average	9.7	30.0	32.2	24.6	6.3	1.2	0.2	67.8
SE	1.2	1.3	3.4	2.9	0.8	0.1	0.07	3.4

Table 3: *Concentration of minerals (g kg^{-1} or mg kg^{-1} of DM) in six different plant species of sward available for grazing and browsing from vegetation most abundant on karst pasture. Means followed by the same letter in a row are not significantly different based on Duncan's test (P < 0.05)*

Preglednica 3: *Koncentracija mineralov (g kg^{-1} ali mg kg^{-1} SS) v šestih različnih vrstah rastlin ruše, ki so bile na razpolago za pašo in smukanje iz najbolj obilne vegetacije na kraškem pašniku. Povprečja z enako črko v vrstici se ne razlikujejo statistično značilno (p < 0,05)*

Herbage content	Sheep's fescue	Chalk false brome	Upright brome	Common hazel	Common beech	White clover
Ash (g kg^{-1})	42.8 a	55.8 c	49.7 b	60.0 c	46.4 b	104.8 d
Phosphorus (g kg^{-1})	0.98 a	0.97 a	1.25 b	2.65 c	2.63 c	2.64 d
Calcium (g kg^{-1})	2.74 a	5.33 b	4.11 b	13.2 d	8.1 c	15.9 d
Magnesium (g kg^{-1})	1.30 a	1.19 a	1.48 a	3.58 c	2.82 b	3.74 c
Potassium (g kg^{-1})	9.1 a	11.3 b	14.1 b	10.9 a	10.9 a	29.6c
Sodium (g kg^{-1})	0.04 a	0.16 b	0.24 b	0.17 b	0.15 b	0.89 c
Zink (mg kg^{-1})	15.8 a	22.6 b	21.2 b	32.9 c	26.7 b	27.9 b
Manganese (mg kg^{-1})	42.2 a	49.9 a	94.1 b	310.9 d	199.6 c	107.5 c
Iron (mg kg^{-1})	84.1 b	98.6 c	91.4 c	75.0 a	89.8 b	112.9 d
Copper (mg kg^{-1})	3.7 a	8.0 c	7.1 b	11.9 d	14.7 d	7.4 b

tration of minerals is similar (53.2 g ash kg^{-1} of DM) as in grasses. In the herbage of white clover was found 104.8 g ash kg^{-1} of DM, which is twice as much ash as have the formers (Table 3).

The average concentration of P in grasses under investigation was 1.1 g P kg^{-1} of DM. This is half of what is requirement for sheep and cattle in their diet. Only herbage containing at least 2.5 g P kg^{-1} of DM will ensure that the P requirement for all classes of sheep will be met if their DM intakes are adequate (Whitehead, 2000). For rapidly growing animals the herbage on offer should contain at least 3.0 g P kg^{-1} of DM (Ozanne and Howes, 1971).

Leaves of common hazel and common beech were much better source of P for animals grazing karst pasture vegetation than perennial grasses. On average the concentration of P in leaves of shrubs was 2.6 g P kg^{-1} of DM. This is very important to know, because during dry summer period when grasses are seed set and such a herbage has very low concentration of P, animals must have possibility to browse leaves of woody plants. Herbage of white clover had enough P (2.6 g kg^{-1} of DM) for the need of grazing animals. The problem is that white clover is very sparsely found and less abundant over karst pasture. During the period of improvement of karst pasture (control grazing, fertilizer or lime application) legumes are distributed as patches over area and their proportion in total in the sward is still very low. Only for a short period of time after entering the new paddock, the intake of legumes may be sufficient high by grazing animals.

Concentration of Ca was lowest in herbage of sheep's fescue (2.7 g Ca kg^{-1} of DM) and highest in white clover (15.9 g Ca kg^{-1} of DM). Leaves of common hazel had more Ca than leaves of common beech. Values for Ca in herbage of white clover were adequate for maintenance, growth and pregnancy of grazing animals. But when diet as a whole is deficient in P, as this is the case when perennial grasses present bulk of diet, than the concentration of Ca must be higher, because its absorption in animals is decreased due to P deficiency in herbage.

A K level in herbage under investigation was high and exceeded the requirements of grazing animals (Whitehead, 2000). High concentration of K in herbage of white clover (29.6 g K kg^{-1} of DM was indication that samples of this herbage were collected from the patches where animal dung was left formerly. Animal diet low in Na level, but high in K level could further reduce the Na intake of the grazing animals (Aspinall *et al.*, 2004). This was the case with grasses and leaves of shrubs in present research. Only herbage of white clover had adequate concentration of Na (0.89 g Na kg^{-1} of DM) to maintain full Na status of lactating ewes with lambs (Gillespie *et al.*, 2006).

Since the micronutrients in soils are derived almost entirely from the parent material, the soils on limestone are normally low in all micronutrients except Mn. Concentration of Zn, Mn, Fe and Cu elements in herbage were within the lower part of values reported elsewhere (Spears, 1994; Grace, 1983). There was less Zn in grasses and more in leaves of woody plants. Symptoms of Zn deficiency in sheep and cattle may occur when animals graze herbage with less than about 20 mg Zn kg^{-1} of DM.

Herbage of sheep's fescue had less than this and the values for Zn of other herbage was little above this.

Very high was the concentration of Mn (311 mg Mn kg^{-1} of DM) in leaves of common hazel and similar high was for common beech leaves. The average value for three grasses under survey was 62.1 mg Mn kg^{-1} of DM, and for herbage of white clover was 107.5 mg Mn kg^{-1} of DM. Limestone as a parent material where rendzina soil is formed has high content of Mn. With increasing acidity of top soil, leaching of Mn occurs and this element accumulates on clay particles in lower soil horizons. Because the roots of woody plants search for minerals deeper in the soil, the higher absorption of Mn is achieved by the roots of woody plants. Mn content was high in white clover too, because this valuable plant can be very easy introduced on places where woody plants were growing. When shrubs are thinned and open space with enough light is formed, white clover has an opportunity for fast establishment. Decomposing shrub leaves are additional source of Mn for white clover grown on shrub cleared areas.

Several studies, in which Mn cycling was researched, have indicated that 20 to 25 mg Mn kg^{-1} of DM is adequate for growth and reproduction (Grace, 1983). Concentration of Mn in leaves of shrubs exceeded 10 to 14 times the values required in animal diet for optimum skeletal development and to prevent reproductive problems. Variability of Mn concentration in different grass species grown at the same location can be very high as reported by Orešnik *et al.* (1999). But all these concentrations of Mn in herbage are still well below the levels that reduced growth rate observed in lambs grazing pastures which contained 400 mg Mn kg^{-1} of DM (Grace, 1983). Sheep may be somewhat more susceptible than cattle to excessive Mn intake.

As reported by Grace (1983) the animal growth rates were only significantly reduced where concentrations of Mn were above 1200 mg kg^{-1} of DM for the full 2 week grazing period. The soil pH strongly influences the Mn level in plants with the Mn uptake being greatest in acid soil. Liming tends to decrease herbage concentration of Mn through its effect on soil pH. Change from pH 5.2 to 6.2 reduced the concentration of Mn in the herbage of mixed sward from an average of 290 to 130 mg Mn kg^{-1} of DM. To lessen the amount of lime required to lower herbage Mn concentration, the improved grazing management which limits the dead material content appear to be effective as was found by Smith *et al.* (2006). Variability in concentrations of iron (Fe) between kinds of herbage under investigation is very small. In leaves of common hazel is the lowest concentration of Fe (75.0 mg Fe kg^{-1} of DM) and in white clover herbage is the highest (112.9 mg Fe kg^{-1} of DM). These concentrations in herbage are adequate to cover animal requirements upon Fe, and are not to high to interfere with the Cu metabolism in animals.

Leaves of common beech have highest concentration of Cu (14.7 mg Cu kg^{-1} of DM), lesser is in common hazel and much lower in white clover (7.4 mg Cu kg^{-1} of DM). Provided that the availability of the Cu is not greatly influenced by the presence of high S supply and the DM intakes are adequate, then herbage containing 5 to 6 mg Cu kg^{-1} of DM for sheep and 7 to 10 mg Cu kg^{-1} of DM for cattle requirements of Cu should meet (Spears, 1994).

3.3 P FERTILIZATION AND CONCENTRATION OF MINERALS IN HERBAGE

The regular application of different rate of superphosphate did not have any pronounced effect on ash content. It is normal with soils in the pH range from 4.5 to 5.5 which are deficient in P, that the application of P produces positive yield response. This is the reason that content of ash in herbage is not much increased because of dilution effect. But the application of superphosphate increased the concentration of P in herbage. On control treatment there was 3.4 g P kg^{-1} of DM of herbage. An increase of 23% for concentration of P in herbage was achieved in average on treatments where superphosphate was applied at the rates of 90 to 540 kg ha^{-1} P_2O_5 during three year time.

Contrary to the statement for P was found for the concentration of Ca in herbage. At the control treatment, there was 9.0 g Ca kg^{-1} of DM. Application of P fertilizer decreased the Ca concentration in herbage. With highest rate (540 kg ha^{-1} P_2O_5) of fertilizer use, the content of Ca in herbage was 6.1 g P kg^{-1} of DM. Changes in concentration of Mg in herbage through applied superphosphate are smaller than for Ca, but are in same direction; higher yield of DM, less Mg in herbage on weight basis.

Concentration of K is within the range found in grasses collected from grazed sward only (12.2 g K kg^{-1} of DM). Increased concentration of K in herbage from plots with higher rate of superphosphate fertilization can only be explained through effect of deposited sheep urine; more of it was left on plots with higher amount of herbage available for grazing and longer stay of animals on those plots.

Concentration of Na in the herbage, was in average 1.2 g Na kg^{-1} of DM. At low rate of applied P fertilizer the dilution effect through higher yield is more distinct. At heavier fertilization and higher yield the animals interfere with their excreta on concentration of Na in herbage. Sheep were all the time supplemented with common salt

Table 4: *Effect of superphosphate application on concentration of minerals (g kg^{-1} or mg kg^{-1} of DM) in herbage available for grazing (pre-grazing) on the karst pasture. Means followed by the same letter in a row are not significantly different based on Duncan's test ($P < 0.05$)*
Preglednica 4: *Vpliv gnojenja z superfosfatom na koncentracijo mineralov (g kg^{-1} ali mg kg^{-1} SS) v razpoložljivem zelinju za pašo na kraškem pašniku. Povprečja z enako črko v vrstici se ne razlikujejo statistično značilno ($p < 0,05$)*

	Fertilizer treatments – total applied kg P_2O_5 ha^{-1} in three years			
Herbage content	not fertilized	90 kg ha^{-1}	270 kg ha^{-1}	540 kg ha^{-1}
Ash (g kg^{-1})	87.2 a	84.2 a	85.4 a	84.9 a
Phosphorus (g kg^{-1})	3.40 a	3.38 a	4.93 b	4.18 b
Calcium (g kg^{-1})	8.97 b	6.84 a	6.03 a	6.08 a
Potassium (g kg^{-1})	12.22 b	9.85 a	10.53 a	12.53 b
Magnesium (g kg^{-1})	1.96 b	1.93 b	1.80 a	1.85 a
Sodium (g kg^{-1})	1.21 a	1.06 a	1.13 a	1.24 a
Zink (mg kg^{-1})	22.60 a	22.82 a	21.52 a	22.85 a
Manganese (mg kg^{-1})	60.2 b	60.4 b	50.1 a	62.6 b
Iron (mg kg^{-1})	371.8 b	503.7 c	274.4 a	379.1 b
Copper (mg kg^{-1})	13.06 b	10.18 a	10.93 a	10.90 a

and this might have an effect on concentration of Na in herbage.

There is not clear effect of added P on concentration of Zn, Mn, Fe and Cu (Table 4). Higher yield of DM induced with added fertilizer didn't have any dilution effect on concentration of those minor elements in herbage. Concentration of Fe is higher than found in different plant species at the onset of experiment. The reason for this might be the sampling of herbage closer to ground and possible contamination of sward with trampling of grazing animals.

The soils of karst grassland as such are very unsuitable for to improve their fertility and to increase the abundance of legumes in the sward on the short time. Slow decomposition of soil organic matter (SOM) is the limiting factor to the cycling nutrients in the soil-plant-animal system. As reported by Clark and Woodmansee (1992) the microorganisms have a substantial requirement for P. Net mineralization of SOM conducted by them, occurs only when their need on P has been met. The critical ratio of C to P for mineralization to occur must be less than 100:1 (Tate, 1985). In the soil of karst grassland dead SOM has the C to P ratio well above this. On addition the high content of SOM of karst grassland acts as big sink for P added with fertilization. As dead plant material of karst vegetation, largely present in the rooting zone, is insufficient in P, initially immobilisation of this element occurs when added to the soil, even in a large amount of P fertilizer.

Many different plant species can be found within the indigenous karst sward (Kaligarič, 1997; Vidrih M, 2003). Unfortunately, most of the grasses are of low feeding quality (Brachypodium spp., *Festuca ovina* L., Koeleria pyramidata L., *Bromus erectus* L., Carex spp.). Further obstacle for higher stocking rate or better production is low portion of legumes in existing sward. It almost never exceeds 6% (Vidrih and Kotnik, 1995; Batič *et al.*, 1999). Among different species of herbs 41 of them are medicinal plants, which can have distinct effect on animal health due to their higher concentration of minerals or any of secondary substances (Kotnik and Vidrih A, 1995).

As reported by Jones and Thomas (1987) there are several abiotic and biotic mechanisms that redistribute clay and nutrients in the landscape, similar to karst pastures, resulting in nutrient rich and nutrient poor patches which are differentially exploited by herbivores. Much of the spatial pattern of plant communities in karst pasture is similarly linked to variations in soil nutrient supply, which is in addition affected by deposition of excreta by grazing animals.

When a nutrient is extremely deficient, as a P in karst soil, the addition of a small amount of nutrient will increase the yield but actually cause a small decrease in concentration of minerals. Due to high Ca level, consumed leaves of woody plants may result in a diet with an excessively Ca to P ratio compared to grasses. Intake of leaves of woody plants would be advantageous and would balance a selected diet on pasture dominated by grasses, is a statement made by Garmo (1999). A large amount of forage for animals in former times comprised leaves of shrubs and trees. Thus herbivores are adapted to utilize the foliage of woody plants in amount not harmful to them. Patchy pattern of grazing even on ideal ryegrass -

white clover pasture is clear evidence that animals needs more than just an abundance of most palatable herbage for to satisfy their physiological requirements.

Mineral concentration in both soil and plant influences the mineral status of grazing animals and many other factors, such as selective grazing, interaction between minerals and production level. The important concept is that it is the concentration of the P in soil solution and not the total potentially available P that determines the rate at which the plant will grow (Mouat, 1984). A large amount of added P on small scale is achieved through the dung patch and at the site where the animals are camping or have drinking facilities. Since most nutrients ingested by grazing animals are returned to the soil in excreta, it is very important to achieve even distribution of it and to prevent nutrients transfer or accumulation on camp sites (Rigueiro-Rodríguez *et al.*, 2007). Nutrients in urine and dung patches within the main grazing area cause a mosaic of nutrient levels and may lead to nutrient losses, even from unfertilized soils. Leaching losses may be smaller when woody plants are present on pasture. Trees and shrubs can further sequester nutrients from deeper soil layers as reported by Lehmann *et al.* (1997).

Increased nutrient availability often causes or accelerates grass encroachment and a decrease in species diversity. However, grazing has been found to decrease grass encroachment and increase species diversity (Batič *et al.*, 1999), a finding attributed to improved light access to plant species of low growing habit. Such conditions favoured a number of plant species which had otherwise low competitive ability under conditions of higher nutrient availability and denser vegetation like the white clover has.

4 CONCLUSIONS

The mineral composition of plants collected from karst pasture vegetation vary widely, so any changes in botanical composition of the vegetation can lead to major changes in mineral intake of grazing animals. In karst environment seldom all necessary growth factors are adequate to meet the needs of all plants within a sward. The large amount of P needs to be applied to achieve better plants growth on karst pastures. This is often uneconomic in term of cost of input and value of current return. But the beneficial effect of P fertilization will still be felt in later years and if this residual effect is used as a base for continued application, more and more efficient systems may be developed. Even with higher rates of applied P initially there will be no much increase in the concentration of minerals in herbage available for grazing. To improve the efficiency of the system in shorter time, there is a need to exploit more efficiently all different groups of plants presented in vegetation of karst pasture and to enhance the speed of mineralisation of large amount of SOM.

Since most nutrients ingested by grazing animals are returned to the soil in excreta it is very important to know the content of the minerals in different plants the animals have on offer. And at the same time managing animal grazing the way to exploit most efficiently the available minerals in dung and urine and to increase the activity of soil microorganisms to achieve more efficient decomposition of dead organic matter. It is likely that the creation and maintenance of such patches is necessary for the survival of grazers in nutrient poor environment as the karst pasture is. The importance of nutrient return through dung and urine of grazing and browsing animals will have great value when feeding animals during the winter on grazing land.

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