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Rodents in Mongolian steppe ecosystem				

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STANDING CROP AND ABOVE-GROUND PRODUCTION OF VEGETATION IN ARID MONGOLIAN STEPPE WITH *CARAGANA* *

In arid steppes of Central eastern Mongolia the steppe vegetation biomass and its rate of production were estimated for a vegetation period. Out of 260 g dry weight, about 160 g d. wt. were two species of *Caragana* (*Caragana pygmaea* (L.) DC. and *C. microphylla* (Pall.) Lam.). Potential digestions rates of sheep and cattle were estimated by detergent method. The highest digestion was found at the beginning of vegetation season. Contents are also estimated of nitrogen, phosphorus, potassium and calcium as well as energy value of plant materials. The impact of small mammals on the steppe vegetation was assessed as augmentation of biomass, energy and nutrients in plants within the area of Brandt vole (*Microtus brandti* Radde, 1861) colonies.

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1. INTRODUCTION

Poor vegetation of arid steppes of Central eastern Mongolia is under strong pressure of grazing cattle and also of mass occurring rodents: bobac marmots (Marmota bobac ssp. sibirica Radde, 1862) and foremostly Brandt voles (Microtus brandti Radde, 1861). The extent of impact of rodent populations on steppe vegetation can be evaluated only by estimating the standing crop storage and primary production of steppe vegetation. At the period of initiation of studies on the role of rodents in steppe ecosystems of Central eastern Mongolia (W e i n e r and G ó r e c k i 1982), the published papers on this topic were lacking. Therefore during the Mongolian-Polish Physical-Geographic Expedition in 1977 within the scope of ecological studies, rough estimates were made of standing crop and primary production in steppe ecosystem, taking into account also the contents of main nutrients and energy value of the plant biomass as well as potential digestion.

2. METHODS

Studies were carried out on a uniform area of the steppe with Caragana microphylla (Pall.) Lam. as a predominant species. This type of vegetation is characteristic for arid steppes of Central eastern Mongolia and covers a considerable area in the region of scientific station Gurwan Turuu, which was the expedition basis.

Besides clumped occurrence of Caragana microphylla dispersed species, Caragana pygmaea (L.) DC. also occurs in the steppe, next are numerous grasses (Stipa krylovii Roshev, Leymus chinensis (Trin.) Tzvel., Lasiagrostis splendens (Trin.) Kunth, Agropyron cristatum (L.)Gaertn., and sedges (e.g. Carex duriuscula C.A.M.). Plants of Artemisia genus are also typical (A. adamsii Bess. A. frigida Willd.), which together with other herbs with a strong odour (e.g. Panzeria lanata (L.) Bge.) occur especially numerously in surfaces with colonies abandoned by voles.

The estimations of biomass were done three times: on 5-10 July, 29 July - 1 August, and 15-20 August 1977. The steppe vegetation biomass was assessed for each of two species of Caragana and for the remaining plants. For estimates of standing crop of Caragana microphylla biomass 10 transects were chosen in the steppe, of a total length of about 10 km. Following these transects records were made of clumps of C. microphylla on this rout. Thus estimated percentage of cover by C. microphylla amounts 25.1 ± ± 1.3.SD. Further, two diameters of each of randomly chosen 170 clumps of Caragana, usually elyptic in shape, were measured and their surfaces were calculated. From the distribution of these values, average size of Caragana clump (95 x 140 cm) and surface (1.044 m^2) were calculated according to which five clumps were chosen as representative during the first and third surveys (in the middle phenophase the biomass standing crop of C. microphylla was not examined). Such chosen clumps were cut off just above the ground, weighed and subsamples of biomass were taken for further analyses.

The biomass of Caragana pygmaea which does not form clumps was determined by cutting off at each sampling date all plants of this species growing on 5 randomly chosen plots, 20 m^2 in area.

The herbs and grasses were examined at 5 permanently chosen sites situated outside the vole colonies, by cutting each time five randomly chosen circular samples, 0.25 m^2 of surface each. In addition, during the middle of vegetation season, (beginning of August) similar samples of vegetation were collected from area of abandoned vole colonies. All plant samples were dried to a constant weight at a temperature of 358 K (85°C), determining their dry weight and water content. In all samples contents of nutrients were analysed: nitrogen (Kiejdahl micromethod), phosphorus (colorimetric method), potassium and calcium (emission flame spectrophotometry). The energetic value was assessed by combustion of samples in adiabatic bomb calorimeter (G ó r e c k i 1965).

In order to study potential digestion of plant biomass as forage to domestic animals, samples of materials were also analysed by detergent method (G o e r i n g and V a n S o e s t 1970). This method depends on discerning soluble and unsoluble fractions in the material by boiling it in detergent solutions. Later on, these fractions were separated by filtration on Gosh crusible. The whole procedure consists of three phases: 1) separation of the sample on soluble cell content fraction (CC) and unsoluble cell wall content (CWC), 2) separation of unsoluble

T a b l e 1

Dry weight, nutrient content and energetic value of plants in *Caragana* steppe at three phenophases (I - 5-10 July, II - 29 July - 1 August, III - 15-20 August 1977). Values are given in per cent ±SD

Sample		Number of samples analysed	Water	Dry weight	N	P	K	Ca	Energetic value (kJ x g^{-1})
Herbs	I	1[a]	40.9	59.1	1.33	0.149	0.719	0.444	18.175
	II	4	46.9	53.1 ± 8.8	1.17 ± 0.19	0.118 ± 0.018	0.656 ± 0.080	0.490 ± 0.082	14.689 ± 1.234
	III	5	46.7	53.3 ± 4.3	1.37 ± 0.18	0.143 ± 0.02	0.931 ± 0.155	0.647 ± 0.150	15.583 ± 1.095
Herbs in vole colonies	II	4		44.1 ± 14.0	2.09 ± 0.46	0.184 ± 0.04	1.366 ± 0.531	0.620 ± 0.146	16.050 ± 0.728
Caragana pygmaea (L.) DC.	I	1[a]	54.6	45.4	2.10	0.144	0.657	0.869	18.553
	II	1[a]	59.6	40.4	2.21	0.132	0.763	1.052	19.158
	III	1[a]	49.3	50.7	2.55	0.155	0.910	1.228	18.235
C. microphylla (Pall.) Lam.	I	1[a]	46.3	53.7	2.26	0.132	0.683	1.081	17.739

[a]Analysis of nutrient contents was performed on homogenate of 5 samples collected in the field.

Acid Detergent Fiber (ADF), and 3) discerning in it the Acid Detergent Lignin (ADL). The mutual proportions of the above mentioned fractions in the forage sample permit to approximate so-called predicted digestibility of the tested food, basing on appropriate empirical formulas (G o e r i n g and V a n S o e s t 1970). One should remember, however, that quantitative estimate of potential digestibility pertains only to European and North American strains of cattle and sheep, for which these functions were determined empirically.

3. RESULTS

3.1. Chemical composition and energetic values of biomass

In all plant samples a relatively low water content was observed from 41 to 60% (Table 1). Only in abandoned colonies of voles the vegetation contained a little more water. The water content changed inconsiderably during three phenophases (Table 1).

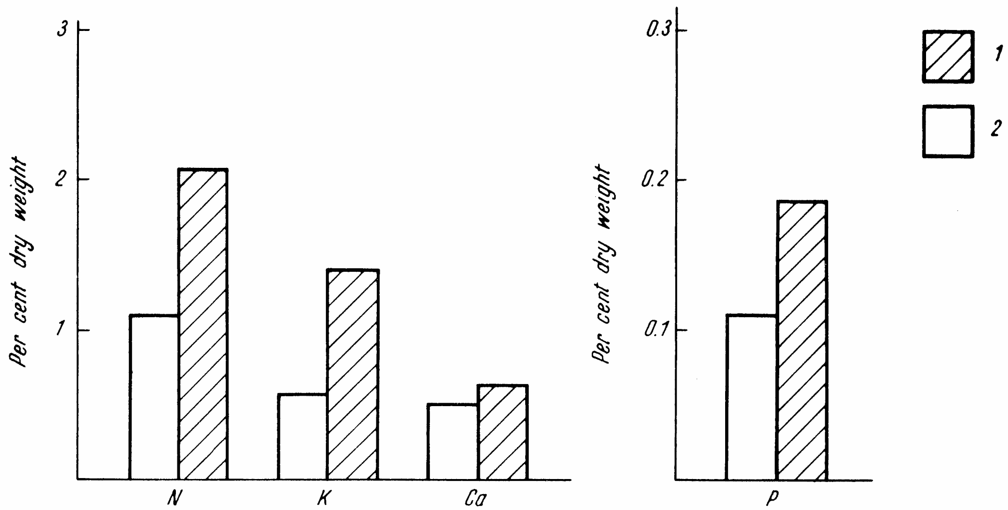

Fig. 1. Nutrient content in steppe vegetation
1 - in vole colonies, 2 - outside colonies

Table 2

Standing crop of biomass and of nutrients in *Caragana* steppe at three phenophases
Explanations see Table 1

Sample		Biomass	Dry weight	N	P	K	Ca	Energetic value
		(g x m^{-2})						(kJ x m^{-2})
Herbs	I	116.8	69.0	0.919	0.103	0.496	0.306	1253.9
	II	243.7	129.4	1.518	0.153	0.849	0.634	1901.1
	III	243.7	129.9	1.774	0.186	1.209	0.841	2024.3
Herbs in vole colonies	II	317.5	140.0	2.926	0.258	1.912	0.868	2247.1
Caragana pygmaea (L.) DC.	I	6.2	2.8	0.059	0.004	0.019	0.025	52.3
	II	5.0	2.0	0.045	0.003	0.015	0.021	38.5
	III	14.1	7.1	0.182	0.011	0.065	0.088	130.2
C. microphylla (Pall.) Lam.	I	295.5	158.5	3.582	0.209	1.083	1.713	3015.3
	III	282.9	151.9	3.433	0.201	1.038	1.642	2889.7

The nitrogen content was also constant (about 1.2% d. wt. in herbs and about 2.2% d. wt. in Caragana sp.). With the elapse of vegetation period gradual mineralization of biomass followed (increase in content of P, K, Ca) (Table 1).

The samples of plants collected from vole colonies were characterized by a higher contents of all nutrients examined (Fig. 1).

3.2. Storage of biomass, nutrients and energy

In Table 2, data on biomass storage of the two species of Caragana as well as of herbs in three phenophases are presented. The total biomass standing crop ranged from 230 to 289 g d. wt. x $\times$ m^{-2}, out of which Caragana microphylla formed majority (Fig. 2).

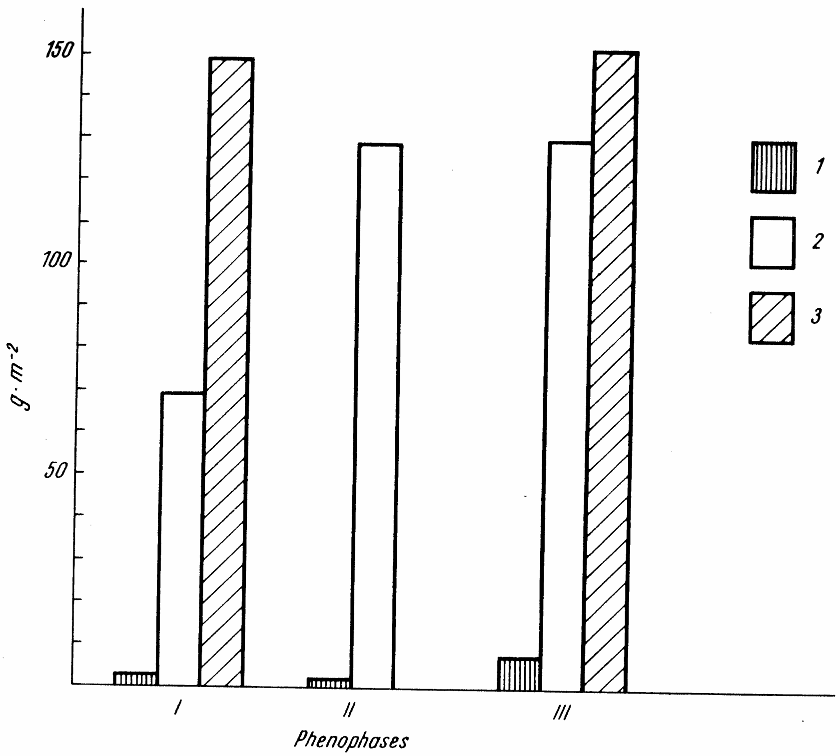

Fig. 2. Standing crop of steppe vegetation in growing period Phenophases: I - 5-10 July, II - 29 July - 1 August, III - 15-20 August 1977; 1 - Caragana pygmaea (L.) DC., 2 - herbs, 3 - Caragana microphylla (Pall.) Lam.

The share of herbs ranged only from 69 to almost 130 g x m^{-2}, showing a clear increase in the first part of vegetation season (Table 2). The storage of herbs in the area of vole colonies was clearly higher than in the remaining area of the steppe (Fig. 3)

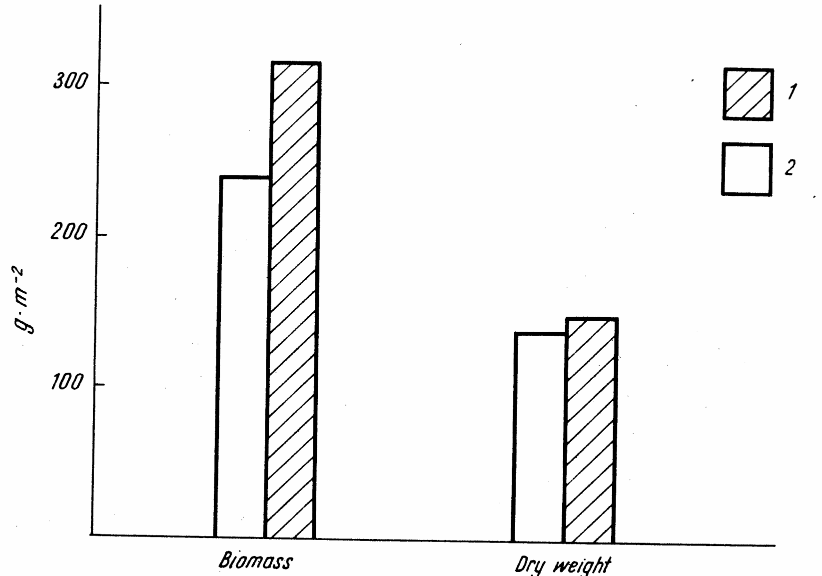

Fig. 3. Comparison of standing crop of steppe vegetation
1 - in vole colonies, 2 - outside vole colonies

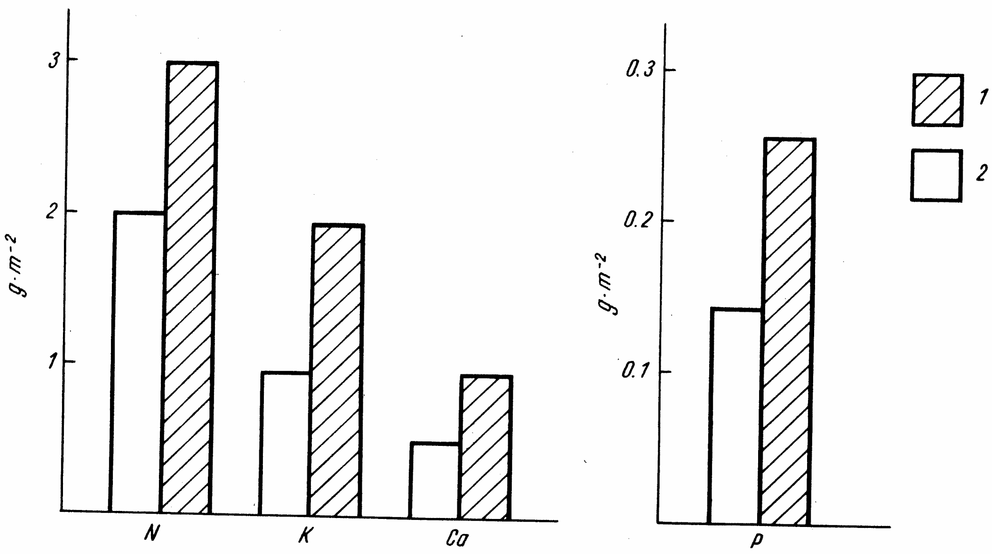

Fig. 4. Nutrient storage in steppe vegetation
1 - in vole colonies, 2 - outside vole colonies

T a b l e 3

Contents of cell fractions and potential digestibility of plant biomass

Sample		N	Per cent			Estimated dry matter digestibility (per cent)	
			CWC	ADF	ADL	cattle	sheep
			$\bar{x} \pm SD$				
Grass	I	1	62	35	8	55.1	58.9
Grass	II	3	67.7 ± 9.3	38.3 ± 3.5	23.0 ± 5.2	10.7 ± 6.5	24.2 ± 5.2
Grass	III	5	58.8 ± 4.3	35.2 ± 2.3	13.2 ± 1.3	32.2 ± 6.7	41.0 ± 5.2
Plants in vole colonies	II	3	57.7 ± 9.5	38.0 ± 7.9	18.2 ± 7.5	27.5 ± 15.0	37.4 ± 11.8
Caragana microphylla (Pall.) Lam. (green parts)	I	1	59	37	14	31.8	40.7
C. microphylla (lignified parts)	I	1	65	37	22	13.2	26.1
C. pygmaea (L.) DC. (whole plants)	I	1	70	38	20	11.2	24.5
	II	1	73	50	27	7.0	21.3
	III	1	50	36	18	34.4	42.7

and this was connected with differences in species composition of vegetation.

The storage of nutrients and energy present in plant biomass increased during the vegetation season, however, a considerable part of these nutrients was found in *Caragana microphylla*, the species avoided by homoeothermic consumers (Table 2). The total storage of nutrients in vegetation modified by the impact of rodents in their colonies is clearly higher than outside the colonies (Fig. 4).

3.3. Analysis of potential forage quality

Detergent analysis of plant samples in *Caragana* steppe shows an increase in unsoluble cell wall contents (CWC) and Acid Detergent Lignin (ADL) during the vegetation season. This brings about a considerable lowering of the potential digestibility at the peak of vegetation season (Table 3). The highest nutritional values was observed in plants collected in an early stage of growth (digestibility for the cattle and sheep was 55 and 59% of dry weight, respectively - Table 3). Potential digestibility of plants overgrowing vole colonies is higher than that of remaining samples (Table 3). The results of detergent analyses showed, however, a considerable dispersion.

High contents of Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) leads to the fact that potential nutritional value of the two species of *Caragana* for ruminants is lower than that of herbs in the same vegetation periods.

4. DISCUSSION

The estimated standing crop of plant biomass in the steppe of Central eastern Mongolia corresponds to biomass and production of arid continental grasslands (Whittaker 1970, Breymeyer and Van Dyne 1980). In terms of dry above-ground biomass it surpasses a little the dry steppes of Altai region in the USSR (40-140 g d. wt. $\times$ m^{-2}) (Rodin and Basilevič 1967). The nutrient contents (N, P, K, Ca) and their standing crop in plants are also close to those reported by Soviet authors for Central Asia including Altai region (Rodin and Basilevič 1967).

4.1. The biomass production rate

The herbs showed the fastest increase in biomass of above-ground parts between I and II collection (or within about 23 days: since 5-10 July to 29 July-1 August). In the further period (until about 22 August) neither the biomass accumulation nor dry matter content undergo changes, hence one can assume that since the end of July the rate of growth and that of dying out of herbs comes to equilibrium. In the initial period of vegetation the production rate of herbs reached, on the average, 2.6 g d. wt. $\times$ m^{-2} $\times$ day^{-1}, and energy accumulation rate was 28.18 kJ $\times$ m^{-2} $\times$ day^{-1}. In the later period (about 17 days) the production rate as expressed by dry weight decreased almost by a factor of hundred. Simultaneously the energy accumulation rate decreased only by factor of four (Table 4).

In spite of this decrease in dry matter growth rate of herbs in August, the accumulation of nutrients was still observed (Table 4). The rate of accumulation of examined elements decreased inconsiderably and in the case of potassium it even increased as compared with the highest biomass increase.

The increase in biomass of *Caragana pygmaea* occurred not earlier than in August because of different phenology of this species (inconsiderable decrease in biomass of *C. pygmaea* during the first period can be attributed to dying and grazing of the previous year shoots but it can also result from the error of the estimate).

4.2. Forage value of steppe vegetation

The data on biomass storage, nutrient content and potential digestibility permit to develop some speculations on predicted nutritional value of the steppe vegetation for domestic ruminants. All data show that, the highest contents of water, nutrients and energy are found in mass-occurring *Caragana microphylla*. This species is characterized also by a relatively high potential digestibility. One should, however, mention that this plant is avoided both by wild and domesticated mammals although it does not reveal, neither strong aroma or protective spines. *Caragana microphylla* is strongly exploited by heterothermic consumers (in-

T a b l e 4

Average daily accumulation rate of biomass and nutrients in plants. All values in $g \times m^{-2}$

Sample		Period of growth (days)	Biomass	Dry weight	N	P	K	Ca	Plants in vole colonies
Herbs	I-II	23	5.52	2.63	0.0260	0.0022	0.0153	0.0143	6.73
	II-III	17	0.00	0.029	0.0151	0.0019	0.0212	0.0122	1.72
Caragana pygmaea (L.) DC.	I-II	23	-0.0521	-0.035	-0.0006	-0.00004	-0.0002	-0.0002	-0.143
	II-III	17	0.5353	0.300	0.0081	0.0005	0.0029	0.0039	1.288

[in]sects). On the other hand, C. pygmaea is claerly preferred by small mammals. The later species also contains more nutrients than the herbs, high energy value and in the period of maximum biomass standing crop (end of August) it is characterized by a high potential digestibility. It seems, however, that domestic animals do not exploit this species, either (perhaps because of spines).

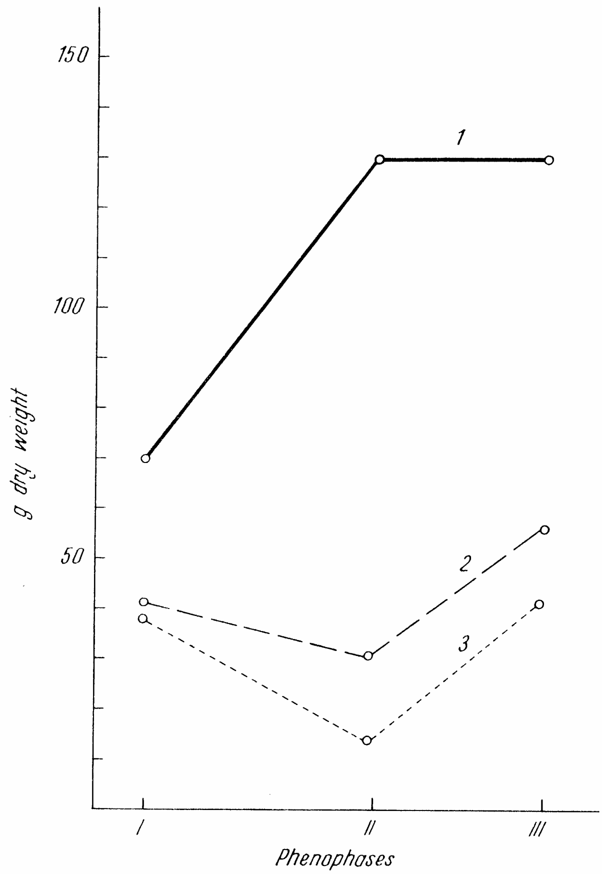

Fig. 5. Storage of dry matter of vegetation in growing period 1 - total storage, 2 - storage digestible to sheep, 3 - storage digestible for cattle

The perennial vegetation consisting mostly of grasses and sedges shows the best properties as potential forage at the beginning and end of the vegetation season. Its best quality results both from the high content of nutrients and high potential digestibility. It is stricking that although total storage of dry matter is increasing rapidly in the first period of vegetation season and later on it maintains a constant level, the storage of digestible dry matter (as calculated from predicted coefficients of digestibility for cattle and sheep) decreases in the first period and then increases considerably (Fig. 5). Absolute values of estimated coefficients of digestibility should be considered with certain caution since one cannot be sure to what degree the applied empirical formulas fit for the animals inhabiting Mongolia. The acceptance of different values for these coefficients would not, however, alter the general pattern of changes. Conspicuous decrease in digestibility of grasses and sedges in the period of second sample collection can be related with lack of rainfall in this period.

4.3. The effect of vole colonies on primary production, nutrient storage and nutritional value of forage

Analyses of chemical composition of vegetation and the rate of biomass production in the *Caragana* steppe within and outside of colony area show significant differences. The herb biomass within the colony area differs in chemical composition from the remaining vegetation, namely, it contains more nutrient and energy; all differences tested by t-test are statistically significant ($p < 0.02$) or highly significant ($p < 0.001$: N, P, K). The plants overgrowing the colony area hold more water but this difference is not significant statistically. The total biomass of plants in colonies is also higher than outside of them. Such effect was also reported by K u č e r u k (1963) and Z i m i n a and Z l o t i n (1980) in similar steppe ecosystems.

Taking into account the fact that the colonies of voles in the year of studies covered 12% of the steppe surface, it means that the activity of voles caused an increase of total biomass of steppe vegetation by 3.6% whereas amount of nutrients accumulated in the biomass increased as much as by 11.1% in the case of nitrogen and 8.2, 15.0, 4.4 and 2.2% for phosphorus, potassium, calcium and energy, respectively.

One should remember, however, that this augmentation of total dry biomass and nutrient storage occurred due to the increase in biomass of a number of unedible plant species whereas grazed by animals grasses, sedges and probably Caragana pygmaea became less abundant. For this reason the observed increase in potential digestibility of herbs in vole colonies has no practical meaning for consumers.

The authors wish to express their sincere gratitude to Dr. A. Pacyna (Institute of Botany, Jagiellonian University) for kind identification of the steppe plant species.

5. STRESZCZENIE

Stan biomasy i produkcja nadziemnych części roślin suchego stepu karaganowego w Mongolii

1. Stan biomasy roślinności w suchym stepie środkowo-wschodniej Mongolii oceniono na 230-289 g suchej masy na m^2, z tego około 160 g s. m. x m^{-2} przypadało na dwa gatunki Caragana sp., a resztę stanowiły rośliny zielne. Stwierdzono znacznie wyższy stan biomasy roślinności zielnej na koloniach norników.

2. Tempo produkcji biomasy było najwyższe na początku okresu wegetacyjnego i wynosiło wówczas dla roślin zielnych 2,3 g s. m. x x m^{-2} dziennie.

3. Metodą detergentową oceniono w materiałach roślinnych zawartość ścian komórkowych, kwaśnego włókna oraz lignin i na tej podstawie obliczono przewidywaną strawność roślinności stepowej dla owiec i bydła. Najwyższą strawność (odpowiednio 55,1 i 58,9% s. m.) posiadają rośliny zielne na początku okresu wegetacyjnego.

4. W próbkach roślinności stepowej dokonano również analizy zawartości azotu, fosforu, potasu i wapnia. Określono także ich wartość energetyczną.

5. Najwyższą zawartość wody, biogenów i energii posiada Caragana microphylla (Pall.) Lam. Jest ona jednak unikana przez wszystkie ssaki. Najlepsze właściwości, jako potencjalna pasza, wykazują rośliny zielne.

6. Oszacowano wpływ drobnych ssaków na roślinność stepu. Stan biomasy, oraz ilość energii i biogenów na koloniach norników są istotnie wyższe niż na pozostałej powierzchni stepu. Zwiększyło to ogólną biomasę roślinności o 3,6%, energii o 2,2% a biogenów o 4,4 do nawet 15%. Wzrost ten nastąpił na skutek przyrostu nie jedzonych gatunków, podczas gdy ubywały wyjadane trawy i turzyce.

6. РЕЗЮМЕ

Я. Вайнэр, В. Гродзиньски, А. Гурэцки, К. Пэжановски

Продуктивность назсмной части растений сухой монгольской степи

I. Авторы оценили биомассу степной растительности на 230-289 г. сухой массы на м^2. Из общего количества - I60 г. с. м. на м^2 приходится на 2 вида рода *Caragana* остальное количество составляют все (за исключением кустарников) однодольные и двудольные зелёные растения. Констатировали более высокое участие этих растений на колониях полёвок.

2. Максимальный темп продукции приходится на начало вегетационного периода, для зелёных растений он равняется 2,3 г. с. м. на м^2 в день.

3. При помощи детергентового метода в растительном материале определили количество клеточных стенок, кислых волокон и лигнина и на основании этого подсчитали предполагаемую перевариваемость степной растительности для овец и рогатого скота. Максимальной поверхностью (соответственно 55,I и 58,9%) обладают зелёные растения в начале вегетационного периода.

4. Анализировали образцы степной растительности, определяя количество азота, фосфора, калия и кальция. Определяли также их энергетический баланс.

5. Максимальным количеством воды, биогенов и энергии обладает *Caragana microphylla* (Pall.)Lam., однако этого растения избегают все млекопитающие. Однодольные и двудольные зелёные растения обладают самыми высокими потенциальными кормовыми свойствами.

6. Определили влияние мелких млекопитающих на растительность степи. Состояние биомассы, энергии и биогенов на колониях полёвок значительно выше, чем на остальной поверхности степи, в связи с чем увеличивается количество общей биомассы растительности на 3,6% энергии на 2,2%, а биогенов от 4,4 до I5%. Такое увеличение явля-

ется результатом прироста не съедаемых животными видов, а также результатом исчезновения съедаемых трав и осоки.

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