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EFFECT OF MOWING TERM ON BIOMETRICS, YIELD AND NUTRITIONAL PROPERTIES OF HYBRID (*RUMEX PATIENTIA* X *RUMEX TIANSCHANICUS*)

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Abstract

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Expanding the range of food plants enables to balance the ration of animals and organize assembly-line production of feed. Promising in this respect is a hybrid sorrel (*Rumex patientia x Rumex tianschanicus*). According to its biological characteristics it belongs to early crops, which is important for regions with a short frost-free period. The aim of our research was to investigate the effect of mowing term to biometric parameters and productivity of sorrel, the dynamics of green mass and nutrients accumulation during the growing season and identification of the optimum periods of grass harvesting at maximum productivity. Mowing and measurements of biometric indicators of sorrel grass we carried out every 10 days. We have found that the greatest productivity of sorrel hybrid forms is in phases beginning of blooming to - blooming (10–20 June). Under these terms a yield of green mass was 34.7–35.1 t ha^{-1}, crude protein 849–885 kg ha^{-1}, with a maximum daily increase of green mass of 1050 kg ha^{-1} per day.

Key words: hybrid sorrel (*Rumex patientia x Rumex tianschanicus*), mowing term, yield, phase of vegetation

Introduction

With improvement of cropping areas, replacement of energy-intensive and low productivity crops to high-quality and low cost green mass we can solve the problem of feed rations with an imbalance of protein and carbohydrate nutrient. In addition, it is necessary to grow forage grasses which are adapted to the low temperatures, effectively diverges nutrients and water, resistant to disease and salt content in the soil in changing climate conditions (Flachowsky et al., 2013). As a complement to traditional forage crops may be possible to use the new less- spread species. Interesting in this respect can be sorrel hybrid varieties Rumex K–1.

This sorrel was created by professor Yu. Uteush as a result of distant hybridization in the Central Botanical Garden named after N. N. Grishko of the National Academy of Sciences of the Ukraine in 1974–1979.

Hybrid sorrel (*Rumex patientia x Rumex tianschanicus*) belongs to – winter perennials, buckwheat family (*Polygonaceae*). The period of use of its plantations is over seven years, it is a hardy and cold-resistant culture, undemanding for growing conditions, can withstand short-term drought. During prolonged drought it throws leaves and regrows plants in spring, withstand freezing down to – 3–6°C.

In the Siberian weather conditions annually forms seeds and has a high coefficient of reproduction. Its seeds ripen early, 4th–22nd of July, simultaneously, but at full ripeness shed its grain. Sorrel seed picking in Siberia is from 300 to 590 kg ha^{-1}. The seeds have a high germination rate of 90–94% and viability of 96–97% (Stepanov, 1996). The method of regeneration was developed for sorrel plants by direct induction of plumule hypocotyl. Ingrained plants were successfully acclimatized in natural conditions with a survival rate of 90% (Slesaka et al., 2014).

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Surveys, conducted with hybrid sorrel in the Czech Republic, showed that it can reach height 220–260 at the average and yielding capacity 14–16 tons of dry matter of top per hectare. It began to form stable heavy yield from the third year and saved it at this level over a period of several years (Ustak and Ustakova, 1999).

Plants use the maximum amount of solar energy with the big leaf surface, assimilating it for 8 months from March to November. The amount of energy cannot be compared with to the amount obtained in other plant species. Due to the good chemical composition sorrel can be used as raw material for the creation of medical and preventive dietary supplements and dietary food rations. It is known that sorrel improves digestion, serves as an excellent antiscorbutic, is used in disorders of the stomach and liver.

It has the best quality for the production of biofuel: briquettes, pellets, biogas (Masta et al., 2014). On average, this plant gives $50–160·10^9$ J ha^{-1} of energy. For example, the almost same amount of energy can be obtained from the raw material of poplar or willow – about $160–220·10^9$ J ha^{-1}. At the same time the cost of fitofuel from sorrel much lower. Getting biofuels from biomass of different plants is an alternative to replace the solid fossil energy sources (Ivanova et al., 2015; Skorupskaite et al., 2015).

Sorrel has good land-reclamation properties, favors the protection from soil pollution by heavy metals. It has a high disinfecting effect: from 14 to 18 times higher than the average effect of traditional crops (Ustak and Vana, 1998). It was found that hybrid sorrel with long-term cultivation has influence on the structure of the soil communities (Hedeneca et al., 2015), also was identified its allelopathic effects on a wide range of organisms. This indicates that the plant has the potential to alter the functioning of ecosystems in places where it is cultivated, which can significantly increase its invasive potential (Hujerova et al., 2013; Hedeneca et al., 2014). Sorrel ability for early vegetation, immediately after the snow melts, allows for the second - third decade of May (stooling, budding) to receive green forage for ensilage with a high content of nutrients. This is topical for regions with a short vegetation season. These advantages make it a promising component of plant and raw material conveyor (Stepanov et al., 2015).

In assessing the fodder crop it is important to evaluate its eatability. Kozhabergenov and Egeubaev (2008), in the South–East of Kazakhstan recommends to use hybrid sorrel for cattle feeding, in the amount of 30–50% of the gross use of green fodder in the form of natural fodder and silage. The level of protein supply Rumex K–1 is an important factor in the growth rate of young animals, the processes of digestion and metabolism.

Researchers conducted in the Altai region, showed that the consistent inclusion granules of sorrel in a dose of 2 g for 1 kg in the diet of sows and piglets during the prenatal process, increased the intensity of the formation of the foetus in the embryonic and postembryonic periods. As a result biostimulation of some facts occurred: increase of metabolism, increase of foetus weight at birth up to 9–11%, improved reproductive qualities of females by 17.6–35.7% and increased growth rate of gilts by 10.5–12.3%. The level of milk of dairy cows production was increased by eating sorrel pellets as well. The highest average of milk yield was 17.6 kg, it was higher than the milk yield of the control group by 10.6%. Also was estimated an increase of dry weight content by 0.73%, fat – by 0.33%, and protein – by 0.23% (Getmanets, 2008).

We must take into consideration the effect of the grass mowing term on herbage production for better use of the biological potential of plants. Systematic mowing of the same herbage areas for several years leads to a gradual reduction in their yields in the following years. It happens in the early stages. Herewith, root system of plants become weak, the reserve of nutrients decreases.

We must take into consideration the dynamics of the growth of green matter and nutrients accumulation during the growing season for determining the optimum term for grass mowing, and collection the maximum of nutrients per hectare.

Materials and Methods

Surveys were conducted during four years (2009–2012) on the experimental field of Omsk Agrarian University. The soil coverage of the experimental area is meadow on black earth. The content of nutrients – $N\text{-}NO_3$ – 12 mg kg^{-1}, P_2O_5 and K_2O – respectively 284 mg kg^{-1} and 225 mg kg^{-1}, humus – 3.4%, pH – 6.7–7.1. We examined herbage sorrel of third year of cultivation. We mowed the sorrel in the first mowing from 20^{th} of May to 10^{th} of July, every 10 days. We conducted the phenological observations of growth and germination of sorrel. During the start phase, we took 10–15% of the plants and during final phase – 75% of the plants of the total in the plot in two non-contiguous duplicates. A height of herbage was measured before the sorrel harvest. Measurements were carried out on the diagonal plots of 10 plants, at the first and third repetitiveness (from the soil surface to the tip of the stem or tip end of inflorescence). We have measured weight of sorrel stems, leaves and inflorescence, then calculated the percentage of each fraction. At the same time we determined the mass of sprouts - (rosettes of leaves) and leaf area. Leaf area is determined by planimetric method using photo-planimeter.

Photosynthetic potential of seeding was determined by the formula (1):

$$\text{Photosynthetic potential} = L * P, \quad (1),$$

where L – daily average leaves area for 1 ha of seeding for the target period (m^2); P – duration of a period (days).

Value of net productivity of photosynthesis was determined by the formula (2):

$$\text{Net productivity of photosynthesis} = \frac{Y}{\text{Photosynthetic potential}}, \quad (2)$$

where Y – dry matter yield ($t\ ha^{-1}$).

Accounting for the harvest of green mass was continuous on the entire plot. The contents of absolutely dry matter were determined on the day of harvest. 10 plants were cut, milled (length less than 1 cm), then the sample was thoroughly mixed and 1 kg of sample was collected three 100 g, after that drying in an oven at 105°C to constant weight. Content of feed units and metabolic energy was determined for evaluation of fodder food-value from the sorrel grass for cattle. 1 feed unit is conditionally equal to food-value of 1kg of oat, measurable by adipopexis and equal to 150 g of fat, which is equivalent to $5.92 \cdot 10^6$ J (1414 kkal) of net energy. 1 oat feed unit is equal to 0.6 starch equivalents on energy value.

The most significant effect on plant growth and development of hybrid sorrel provided the meteorological conditions of the growing season, especially heat and water supply. Vegetation period of 2009 is distinguished by relatively warm and rainy weather. Sorrel growing was observed on 18–20th April. In May the plenty of shower rains was fixed – 142% of long-time average annual value at average monthly temperature 12.5°C. Also it was noticed low air humidity – 54% for this period, aridity of air led to premature aging of stand. Vegetation period of 2010 was characterized by the high air temperature and shortage of precipitations. Vegetation renewal of sorrel was noticed on April 14–16 after snow cover melting. In 2011 the weather conditions were at the level of long-term values, the spring was warm with precipitations. Sorrel growing was observed on April 8-12. In April, 2012 the weather was warm with shortage of precipitations (81% of standard) as a result of which the sorrel growing in spring was noticed from April 4. Average monthly temperature exceeded the standard on 5.7°C.

Statistical data processing is carried out with usage of Microsoft Excel 2007. Table data is represented as average values for four years of surveys (2009–2012). Pearson correlation coefficients, mistakes and criteria of essentiality of correlation coefficient for evaluation of connection between yield capacity of sorrel and valuable practical indicators of crop (not all results are presented) were calculated. The differences were statistically significant at the level $P < 0.05$.

Results and Discussion

The studies showed that the phase of stem sorrel reached after 30–40 days after the regrowth in the spring (Table 1). Sorrel reached bud-formation period in the third ten days of May in 40–50 days from the beginning of vegetation renewal of crop at the height of 70 cm and shoot weight of 59 g.

Table 1

The flowering began on the 50–60th day, in the first decade of June. Hybrid sorrel is a short-season crop, so the stage of blooming and fruiting takes short period. Full blooming of plants was observed on the 60–70th day after the renewal of the vegetation and continued for 9–12 days (Figure 1). The largest biometrics of sorrel stand was observed on the 30th of June on the stage of fruiting, on the 70–80th day from spring after growing.

Table 1
Characteristics of stand of hybrid sorrel depending on term of the first mowing (for the period of 2009–2012 at average)

Term of the first grass mowing		Plant height, cm		Leaf area, $m^2\ m^{-2}$		Photosynthetic potential, $m^2\ m^{-2}$ per day		Net productivity of photosynthesis, g m^{-2} per day		The mass of sprout (rosette of leaves), g	
		mowing									
date	stage of vegetation [1]	1	2	1	2	1	2	1	2	1	2
20.05	stooling	49	44	3.2	3.5	31.0	36.0	4.5	1.6	36	38
30.05	budding	70	38	5.1	3.2	41.5	33.5	4.6	1.6	59	29
10.06	beginning of blooming	105	34	4.6	2.9	48.5	30.5	8.5	1.6	84	26
20.06	blooming	111	31	4.1	2.4	43.5	26.5	10.7	1.5	91	21
30.06	fruiting	113	28	3.8	2.1	39.5	22.5	12.0	1.5	92	18
10.07	ripening seed (wax ripeness)	91	19	2.9	1.6	33.5	18.5	11.9	1.3	70	13

[1] Stage of hybrid sorrel in the second mowing - rosette of leaves

Fig. 1. Herbage of fodder sorrel under various conditions of mowing: *A* – phase of stooling; *B* – phase of blossoming

We determined photosynthetic potential and net productivity of photosynthesis to describe photosynthetic work of seedlings. The photosynthetic potential characterizes the ability to use solar radiation by agricultural crops for photosynthesis during the vegetation. Net productivity of photosynthesis indicates the amount of organic matter accumulated by a unit of leaf surface per time unit (Tretyakov, 2005).

The leaf area increased from 3.2 m^2 m^{-2} in the stooling stage to 5.1 m^2 m^{-2} in the bud-formation stage during the sorrel development stages, and photosynthetic potential increased reaching the maximum value to the initial blossom stage (10.06) – 48.5 m^2 m^{-2} per day. After this stage, the reduction of photosynthetic potential was observed caused by the desiccation of root and lower stem leaves.

During after-grass the leaves area and photosynthetic potential were maximal in the first period of mowing (20.05–30.05) and minimal later (30.06–10.07) – 3.2–3.5 m^2 m^{-2}, 33.5–36.0 m^2 m^{-2} per day and 1.6–2.1 m^2 m^{-2}, 18.5–22.5 m^2 m^{-2} respectively. The values of sorrel leaves area corresponds to the optimal value for agricultural plants and varies in the range of 2–7 m^2 m^{-2} (Alexeyenko, 1967). Net productivity of photosynthesis was increased according to the growth and development of crop from 4.5 g m^{-2} per day in stooling stage to 12 g m^{-2} per day in the fruiting stage. According to the information of Uteush (1991) net productivity of photosynthesis of hybrid sorrel is 12–13 g m^{-2} per day in spring period under conditions of the Ukraine.

Daily average gain of sorrel plants at the height on the vegetation stages changed. Plants growth in the initial period of vegetation was delayed and was only 1.2–1.6 cm per day. In the period of bud-formation stage the growth rate of plants increased (2.1 cm per day), reaching maximum (up to 3.5 cm per day) to the initial blossom stage. In the period of full blossom the height gain decreased (to 0.6 cm per day) and stopped in the fruiting stage in fact. In the beginning of vegetation the root leaves grew at an intensive rate and in the period of flower bearing axis their growth slowed down.

In the period of after-grass the sorrel development stage in the all variants was rosette with 5–8 leaves. It was found that between plant biometric indicators at after-grass and term of the first mowing was the inverse dependence. If the first mowing were earlier so sorrel would have stouter and higher rosette of leaves. The largest indicators of height and leaves weight of aftermath were noticed at the first mowing in the early terms (May, 20–30) in the stage of stooling and bud-formation. During the first mowing the height of aftermath and leaves weight was decreased in June.

According to the sorrel growth and development its stand structure was changed in the period of the first mowing. The reduction of leaves content in the yield and increase of proportion of stems and raceme was observed with increase of period of crop vegetation. The stems content in the yield was 45–46%, leaves content – 51–56%, racemes – 3% (bud-formation stage) during sorrel mowing in May and racemes content (June, 10–20) 46–47%, 36–39%, 15–17% respectively during the mowing at blooming stage. At this the proportion of leaves in stand from the early stages to late stages of sorrel development decreased: from 55% in the stooling stage to 30% in the fruiting stage, and proportion of racemes increased from the bud-formation stage (3%) till the fruiting stage – 21%.

Surveys showed that the first mowing term had influence on weed infestation of crops. High content of weeds in stand was observed at the period of its mowing in the early stages (stooling and bud-formation): 3.2–3.9% for the first mowing (low infestation), 10.8–12.6% – average infestation (Milaschenko, 1978).

During the stand mowing in the late terms (beginning of blooming and beginning of fruiting) the reduction of weeds proportion in top is observed at the first mowing as well as after-grass. At the after-grass the infestation of crop was bigger than at the first mowing and it is connected with that aftermath consists of rosettes of leaves at the height of 17–47 cm and is overtopped by weed plants. The establishment of correlational relationship showed that the yield capacity of herbage of hybrid sorrel in the first mowing has close direct connection with the term of its mowing r = 0.98 ± 0.10. The yield capacity of sorrel in the first mowing is determined by the height of plants (r = 0.99 ± 0.08) and the shoot weight (r = 0.98 ± 0.09). At the after-grass the close connection of yield capacity of herbage was found with the height of plant (r = 0.98 ± 0.10), the shoot weight (r = 0.95 ± 0.16) and leaf area (r = 0.89 ± 0.23). Values of correlation coefficients are quite high, so it confirms about close connection between yield capacity of sorrel and biometrical indicators of crop at two mowings. These correlation connections are statistically significant ($P < 0.05$), since criteria of essentiality of correlation coefficients are exceeded the value of Student's t-test.

The weather conditions had influence on dynamics of herbage growth, in the vegetation periods of 2010 and 2012, identifiable by shortage of precipitation and the high air temperature, the herbage gain was lower by almost 1.5–3 times than in 2009 and 2011 years, which were more favorable on moistness. Consequently, the reduction in yields of herbage and yield of crop of dry matter were noticed in these periods.

The highest rate of gain of vegetative weight in the first mowing was observed in the period from May 30 to June 10. This period corresponds to the transition of plants from bud-formation stage to the blooming stage (Table 2). In the period of bud-formation of stand (May 30) increase of gain of herbage was noticed for this period – 473 kg per day. The yield capacity of herbage reached 28.7 t ha^{-1} with the maximal yield capacity during the day – 1050 kg to the blooming stage. The gain of herbage decreased to 130 kg per day with yield capacity 29.7 t ha^{-1} (full blooming stage) and the gain of herbage was not observed in the future. It was found that the reduction of after growth and yield capacity of crop at the after-grass is observed together with growth of herbage in the first mowing on the calendar terms (Stepanov et al., 2015).

The optimal period of harvest for fodder was mowing from June 10–20 – the initial blooming stage and the next 10 days for mass blooming of sorrel. The food-value of herbage depends on content of dry matter so the content of dry matter in top is one of the most important indicators at the evaluation of fodder plant and for determination of optimal term of crop harvest.

The maximal amount of dry matter harvest for two sorrel mowing (5.06–5.10 t ha^{-1}) was observed during the first mowing in the blooming and fruiting stage –June 20–30 (Table 3). The highest productivity of sorrel for two mowings was received in the first mowing at initial blooming and full blooming stages.

According to the surveys, conducted with sorrel in different climate and environmental conditions, the sorrel has high food-value. In our surveys, the sorrel has the high content of protein 21.7–23.8% in the early development stages (stooling, bud-formation), so it gives ability to use widely for balancing rations for animals on the protein.

The value of crude protein concludes in content of non-replaceable proteins, consisting the most valuable food-value part, and also non-protein nitrogen compounds.

Table 2

Dynamics of growth of the green mass of sorrel hybrid depending on the length of the first period of mowing (for the period of 2009–2012 at average)

Term of the first grass mowing		Green mass						The growth of green mass in the first mowing of the day kg ha^{-1}
Date	Stage of vegetation	Total, t ha^{-1}	The first mowing, t ha^{-1}	Increase				
				The first mowing to the stooling phase		The sum of the two mowing		
				t ha^{-1}	%	t ha^{-1}	%	
20.05	stooling	20.4	13.5	-	-	-	-	383
30.05	budding	24.6	18.2	4.7	135	4.2	121	473
10.06	beginning of blooming	34.7	28.7	15.2	213	14.3	170	1050
20.06	blooming	35.1	29.7	16.2	220	14.7	172	130
30.06	fruiting	32.7	28.3	14.8	210	12.3	160	-
10.07	ripening seed (wax ripeness)	25.6	22.4	8.9	166	5.2	125	-

Table 3
Productivity sorrel hybrid depending on the length of the first grass mowing (for the period of 2009–2012 at average)

Term of the first grass mowing		Totally dry substance, t ha^{-1}	Feed units			Crude protein			Metabolic energy, 10^9 J $\cdot ha^{-1}$
Date	Stage of vegetation		Total		The first mowing, t ha^{-1}	Total		The first mowing, kg ha^{-1}	
			t ha^{-1}	%		kg ha^{-1}	%		
20.05	stooling	1.73	1.01	-	0.68	402	-	276	16.8
30.05	budding	2.37	1.36	135	1.06	517	129	401	22.7
10.06	beginning of blooming	4.58	2.47	245	2.19	849	211	740	43.1
20.06	blooming	5.06	2.56	253	2.32	885	220	791	45.9
30.06	fruiting	5.10	2.18	216	1.98	672	167	595	39.5
10.07	ripening seed (wax ripeness)	4.26	1.50	148	1.36	466	116	410	31.1

In the stooling stage of sorrel 1 kg of dry matter had 0.58 fodder units (metabolic energy $9.7 \cdot 10^6$ J), in the bud-formation it had 0.56 fodder units (metabolic energy $9.5 \cdot 10^6$ J) and 0.50 fodder units in the blooming stage (metabolic energy $9.4 \cdot 10^6$ J). In compliance to the data of A. Stepanov (1996) the sorrel has the high concentration of metabolic energy ($9.3 \cdot 10^6$ J kg^{-1}) and provision of 1 fodder unit of digestible protein (293 g). Besides, the content of digestible protein in $1 \cdot 10^6$ J of metabolic energy is 17.4 g at the standard 8–12 g for dairy cows.

According to the further growth and development of crop the reduction of protein, fat, ash, vitamins and energy content is noticed, but the cellulose content is increased from 25.1% in the stooling stage to 39.0% in the fruiting stage. According to the surveys, conducted in Altay region, the rate of crude protein from the stage of leaves rosette to the bud-formation of sorrel decreased by 10.4%, the metabolic energy was reduced by $1.8 \cdot 10^6$ J, ash decreased by – 2.7%, sugar reduction – 6.2 g kg^{-1} and carotene decreased by 49 mg kg^{-1} (Evtefeev and Zykovich, 2011)

Biological usefulness of fodder is determined by qualitative composition and quantitative content of amino acids. The lack or absence in the feed ration of at least one essential acids leads to metabolic disorder, restricts the use of the other amino acids and nutrients. The hybrid sorrel contains up to 73 g kg^{-1} of essential amino acids in absolutely dry matter, it is about 48% of the total amount, the role of some of them in the metabolism process is important.

Mineral substances play an important role in the plant nutrition – especially phosphorous and calcium contained in ash. Mineral substances are necessary for the synthesis of vital compounds, are involved in the regulation of the osmotic pressure of the tissue fluid, processes of digestion, absorption and intake of fodder nutrients in the animal organism. According to M. Usova (1999) sorrel ash content varies from 14.8 to 22.6%, which exceeds the ash content in corn and alfalfa 1.5 times. The content of potassium (31.6 g kg^{-1}) and calcium (11.3 g kg^{-1}) is within zootechnical standards; however, there is a deficiency of phosphorus – 4.4 g kg^{-1}.

Microelements play an important role in the regulation of fundamental physiological processes in the animal organism (growth, development, reproduction, respiration, etc.). Within the standards of cattle feeding in the sorrel blooming stage it contains zinc – 29.7 mg kg^{-1}, manganese – 55.9 mg kg^{-1}, ferrum – 110.8 mg kg^{-1} and deficiency of copper – 0.9 mg kg^{-1} while the standard is 5–10 mg kg^{-1}. At the after-grass the content of microelement is higher than at the first mowing (blooming): zinc by 21%, ferrum – 29%, manganese – 22%, at the same time there is a deficiency of copper. With further sorrel development the content of microelements is reduced due to the desiccation and abscission the lower part of the stems of the leaves, which contain much more of these elements than stems (Kukusheva and Stepanov, 2012).

The animals need vitamins to support the normal activity of the organism and the growth. They have a high biological activity; act as catalysts in the metabolic processes. According to Abramova (2012) sorrel contains 49.9 mg of thiamine (vitamin B_1) per 1 kg of herbage, 149.8 mg kg^{-1} of riboflavin (vitamin B_2), 48.1 mg kg^{-1} of ascorbic acid (vitamin C).

Conclusions

Herbage of hybrid sorrel can be used during the vegetation as a source of valuable green fodder and raw material for the preparation of different types of fodder.

Even at the early terms of sorrel mowing it is possible to obtain yielding capacity of herbage in the range: at the first mowing – 7.8–22.8 t ha^{-1}, after-grass – 4.3–12.0 t ha^{-1}. The optimal harvest time of fodder sorrel is mowing it from the 10^{th} to the 20^{th} of June (beginning of blooming stage and next 10 days of the most crops blooming) with the yielding capacity of herbage at 34.7–35.1 t ha^{-1}, feed units 2.47–2.56 t ha^{-1} and 849–885 kg ha^{-1} of crude protein for two mowings.

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