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Productivity of the Herbage Mixtures with *Bromus Inermis Leyss* and *Poterium Polygamum Waldst et Kit*. Treated with Growth Stimulators

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Abstract.

This paper presents the data on the productivity of various perennial herbage mixtures treated with growth stimulators. Under the conditions of Povolzhye grasslands, the maximum productivity, dry matter yield, feed units yield, and digestible protein yield are demonstrated by the four-component herbage mixtures comprising Bromus inermis Leyss, Bromus erectus Huds., Poterium Polygamum Waldst et Kit. and Onobrýchis arenária treated with the growth stimulator Gumi 20M.

Keywords: Bromus erectus Huds., Bromus inermis Leyss, digestible protein, feed unit, Growth Matrix, Gumi 20M, Lótus corniculátus, Medicago sativa hybrid, Onobrýchis arenária, Poterium Polygamum Waldst et Kit.

INTRODUCTION

One of the most pressing agricultural problems is finding ways to increase forage production rate, as well as to improve its quality and energy content. In Russia, only 60 – 70% of the demand for livestock forage is satisfied. Low protein content in the livestock diet remains an issue and a limiting factor for the increase of livestock production [1-4]. Solving this problem requires implementation of adaptive forage production based on high-productivity agrocenoses by means of culture selection, the introduction of new species and development of the agricultural practices that would allow using the available bioclimatic resources in the most efficient way [5-6]. Therefore, plant growth promoting factors and complex fertilizers containing chelated microelements are becoming an essential part of the state-of-the-art agricultural technologies. They are not expensive, but eco-friendly and fit well into the forage cropping technologies [7-8].

One of the promising but not widely used forage crops is *Poterium Polygamum Waldst et Kit*., a perennial herb in the rose family. It contains more protein, carotene, carbohydrates and microelements than grasses or legumes [2, 7-9]. The main advantages of *Poterium Polygamum Waldst et Kit* are perenniality (10 years and more) and high and stable productivity rates: green mass yield of 30 – 33 t/ha, dry matter yield of 6.8 – 7.5 t/ha, feed units yield of 4.0 – 4.5 t/ha, digestible protein content of 0.52 – 0.55 t/ha; available energy amounting to 0.84 – 0.88 GJ/ha, digestible protein content up to 128 g per 1 feed unit [3, 8, 9].

Production of *Poterium Polygamum Waldst et Kit*. seeds is stable and influenced little by weather conditions due to the increased capacity of the crop to be pollinated by honey bees, non-lodging of the stands and a high degree of drought resistance. The seed yield is 1.0 – 1.3 t/ha [1, 4, 7, 9].

Medium-height trimmed herbage allows collection of *Poterium Polygamum Waldst et Kit.* seeds using commercial mechanisms; the herb is early maturing and takes 80 to 85 days from the growth start to seeds ripening. The herb is characterized by morphological uniformity of the plants, isochronic completion of the development phases, high plasticity, the year-to-year stability of the yield despite the changing weather and in different soil and climate [7-9]. It is winter- and cold-hardy, heat- and drought-tolerant; has comprehensive resistance to diseases and pests; its fast growth enables early availability of the cutting mass; it is used in the early spring green forage chain; the nutrition value, palatability and digestibility of all the forage types produced from the herb are good; it is a good early melliferous plant and a perfect component for perennial herbage mixtures. As a pasture plant, it can provide up to 3 grazings. The herb contains hormonal substances that improve the reproductive capacity of the livestock as well as soil structure and fertility [3, 4, 9, 10].

MATERIALS AND METHODS

The field study was set as part of the forage crop rotation performed by Korma research and development laboratory of the Department of Horticulture and Agriculture of Samara State Agricultural Academy. The design of the two-factor study included 5 herbage mixtures (Factor A):

1. *Bromus inermis Leyss + Poterium Polygamum Waldst et Kit.;*
2. *Bromus inermis Leyss + Bromus erectus Huds. + Poterium Polygamum Waldst et Kit.;*
3. *Bromus inermis Leyss + Bromus erectus Huds. + Onobrýchis arenária+ Poterium Polygamum Waldst et Kit.*;
4. *Bromus inermis Leyss + Bromus erectus Huds. + Medicago sativa hybrid + Poterium Polygamum Waldst et Kit.*;
5. *Bromus inermis Leyss + Bromus erectus Huds. + Lótus corniculátus + Poterium Polygamum Waldst et Kit*.;

Factor B tested the effectiveness of treating the specified herbage mixtures with the recommended doses of 3 growth factors: 1. Reference (treatment with water); 2. Growth Matrix; 3. GUMI 20M.

Growth Matrix product is a plant growth regulator, a bioorganic, biologically active polymer with pronounced antibacterial and anti-fungal activity. GUMI 20M is a growth stimulator with anti-stress and immunity boosting activity (potassium salts of the brown coal-derived humic acids, contains over 80 macro- and microelements and naturally occurring minerals).

The study design included 4 replications. The plot area was 125 m^2.

The study was conducted with due consideration of the following: the field study method developed by B.A. Dospekhov [11], Procedural Guidelines for Field Studies of Forage Crops developed by National Forage Research Institute n.a. V.V. Viliams [12].

The plough layer of the test plot represented by southern black soil contained 6.9% of organic matter (GOST 26213-91), 62.2 mg/kg of labile phosphorus (GOST 26204-91), 230.0 mg/kg of exchangeable potassium (GOST 26204-91) and 64.0 mg/kg of easily hydrolyzed nitrogen.

RESULTS

The study of the cutting and grazing use of perennial herbage started on 3 May 2015, when the average air temperature over 10 days reached 14.6°C and the soil temperature rose to

9.2°C, which is optimal for seeding perennial herbs. In the third ten-day period of May, when sprouts appeared, the average air temperature was 16.5°C, which enabled sprouting on the 22nd – 23rd day after seeding. Sprout density was 86.1%.

Intensive accumulation of the aboveground biomass by perennial herbs takes place in May and June and that is when they are most susceptible to the influence of stress factors. The average temperature during the spring and summer months of 2015 – 2016 was above the normal values, as well as the precipitation total, which resulted in the accumulation of a large amount of water in the soil that was used during summer and allowed full-fledged growth of the herbage. The weather conditions in 2017 can be described as beneficial since the precipitation received during springtime was 2 times above the normal quantity, and in June there was a 3-fold excess of precipitation as compared to the normal level, which led to the fast development of the plants and green mass gain. Therefore, assessment of the regional weather conditions in 2015 – 2017 shows that in general they were beneficial and met the biological requirements for the forage crops that constituted the mixture.

The use of growth stimulators facilitated stand height increase and green mass accumulation. The highest values of these parameters were characteristic for the herbages that were treated with GUMI M20.

The study results demonstrate that leaf surface area increases gradually with the completion of the phenological phases. The studied products had a positive influence on leaf formation. The greatest degree of influence on the formation of the assimilation system was demonstrated by GUMI 20M (Table 1).

The intensity of leaf growth in herbages increases between the phases of tillering (branching) and fruit formation. In the herbage mixtures that include herbs from different biological groups, there is less competition for resources between the constituent species. Due to even spacing of the leaf mass throughout the levels of the herbage mixture as compared to single-species herbages, the total leaf surface area is larger, which means more intensive photosynthesis and, as a result, higher yield and quality of the final product.

The maximum leaf surface area was observed in the mixture comprising *Bromus inermis Leyss + Bromus erectus Huds. + Onobrýchis arenária + Poterium Polygamum Waldst et Kit*. Good results were also registered for the mixture comprising Bro*mus inermis Leyss + Bromus erectus Huds.+ Poterium Polygamum Waldst et Kit.+ Medicago sativa hybrid + Lótus corniculátus.* At the same time, it was found that the leaf surface area of all the herbages was maximized under treatment with GUMI M20.

An important factor for improvement of the biological yield is photosynthetic potential (PP) that depends on the speed of leaf surface formation and the time of its active functioning. Photosynthesis takes place inside plant leaves, where 90-95% of the dry matter is formed. Treatment of the aerial parts with the studied products was found to improve the photosynthetic potential of the herbage mixtures. As a result of applying reference treatment, the PP value of the mixture with *Poterium Polygamum Waldst et Kit.* amounted to 1575.5-2074.3 thousand m^2/ha*day, while under treatment with Growth Matrix and GUMI 20M the value was in the range of 1709.9-2247.0 and 1718.6-2357.5 thousand m2/ha*day, accordingly. Under treatment with Growth Matrix or GUMI 20M, the maximum PP was registered in the herbage comprising *Onobrýchis arenária* as a legume component (Table 2).

Yield increase is ensured not only through the facilitation of the photosynthetic activity of the agrophytocenosis but also by means of improving its working elements: leaf surface units and chloroplasts, which is expressed through net photosynthesis rate (NPR). This parameter increases together with PP up to a certain value and then starts to decrease. This is due to the less active use of solar radiation in dense herbages where little light reaches the middle and bottom layers. Thus, the herbage mixtures had the following net photosynthesis rates: 2.48 – 8.11 g/m^2*day with *Bromus inermis Leyss*, 6.07 g/m^2*day with *Bromus inermis Leyss + Bromus erectus Huds.*, 10.96 g/m^2 with *Bromus inermis Leyss + Bromus erectus Huds. + Onobrýchis arenária*, 9.64 g/m^2*day with *Bromus inermis Leyss + Bromus erectus Huds. + Medicago sativa*; 6.24 g/m^2*day with *Bromus inermis Leyss + Bromus erectus Huds. + Lótus corniculátus*.

With passing through phenological phases, green mass production rate increases in all the herbage mixtures until Poaceae and Leguminosae enter the heading and blossoming phase accordingly. During the heading (blossoming) stage, augmentation of the green mass slows down due to the fact that Poaceae reach the peak of their development and enter the phase of fruit formation, while Leguminosae start or continue their blossoming phase. Application of the studied products to the aerial parts of the plants provided them with an additional supply of microelements, which had a positive effect on the yield. The most beneficial influence on the green mass production was exerted by GUMI 20M product (Table 3).

Table 1. Leaf surface area of the herbage comprising *Bromus inermis Leyss* and *Poterium Polygamum Waldst et Kit.* treated with growth stimulators, the mean for 2016 – 2017 in thousand m^2/ha.

Treatment	Mixtures with *Poterium Polygamum Waldst et Kit.*	Tillering (branching)	Stooling (budding)	Heading (blossoming)	Fruit formation
Reference	*Bromus i. L.*	27.04	47.32	52.43	56.75
	Bromus i. L.+ Bromus e. H.	24.67	39.5	48.49	59.17
	Bromus i. L. + Bromus e. H.+ Onobrýchis a.	36.52	52.24	69.92	73.79
	Bromus i. L. + Bromus e. H.+ Medicago s.h.	35.4	50.12	67.45	71.81
	Bromus i. L. + Bromus e. H. + Lótus c.	35.93	48.59	65.42	69.71
Growth Matrix	*Bromus i. L.*	29.53	51.62	57.18	61.91
	Bromus i. L.+ Bromus e. H.	26.84	42.87	52.65	64.35
	Bromus i. L. + Bromus e. H. + Onobrýchis a.	39.69	56.72	75.98	80.11
	Bromus i. L.+ Bromus e. H. + Medicago s.h.	38.46	54.39	73.24	77.91
	Bromus i. L.+ Bromus e. H. + Lótus c.	39.08	52.88	71.03	75.73
Gumi 20M	*Bromus i. L.*	31.62	55.64	61.1	66.18
	Bromus i. L.+ Bromus e. H.	28.27	45.76	55.41	67.77
	Bromus i. L. + Bromus e. H. + Onobrýchis a.	41.58	59.95	79.55	83.96
	Bromus i. L. + Bromus e. H. + Medicago s.h.	40.31	57.12	76.72	81.7
	Bromus i. L. + Bromus e. H. + Lótus c.	41.03	55.31	74.39	79.25

Table 2. Photosynthetic potential of the cutting and grazing herbage mixture comprising *Bromus inermis Leyss* and *Poterium Polygamum Waldst et Kit.* under treatment with growth stimulators, the mean for 2016-2017 in thousand m^2/ha*days.

Treatment	Mixtures with *Poterium Polygamum Waldst et Kit.*	PP over the period with *Poterium Polygamum Waldst et Kit.*
Reference (water)	*Bromus i. L.*	1575.5
	Bromus i. L.+ Bromus e. H.	1503.3
	Bromus i. L. + Bromus e. H.+ Onobrýchis a.	2074.3
	Bromus i. L. + Bromus e. H.+ Medicago s.h.	2011.5
	Bromus i. L. + Bromus e. H. + Lótus c.	1983.0
Growth Matrix	*Bromus i. L.*	1709.9
	Bromus i. L.+ Bromus e. H.	1628.3
	Bromus i. L. + Bromus e. H. + Onobrýchis a.	2247.0
	Bromus i. L.+ Bromus e. H. + Medicago s.h.	2177.7
	Bromus i. L.+ Bromus e. H. + Lótus c.	2149.0
Gumi 20M	*Bromus i. L.*	1833.3
	Bromus i. L.+ Bromus e. H.	1718.6
	Bromus i. L. + Bromus e. H. + Onobrýchis a.	2357.5
	Bromus i. L. + Bromus e. H. + Medicago s.h.	2285.6
	Bromus i. L. + Bromus e. H. + Lótus c.	2254.4

Table 3. The productivity of the herbage mixtures comprising *Bromus inermis Leyss* and *Poterium Polygamum Waldst et Kit* under treatment with growth stimulators, the data for 2016 – 2017, t/ha.

Treatment	Mixtures with *Poterium Polygamum Waldst et Kit.*	Tillering (branching)		Stooling (budding)		Heading (blossoming)		Fruit formation	
		Green mass, t/ha	Dry matter, t/ha	Green mass, t/ha	Dry matter, t/ha	Green mass, t/ha	Dry matter, t/ha	Green mass, t/ha	Dry matter, t/ha
Reference	*Bromus i. L.*	7.14	1.38	10.86	2.65	15.57	3.90	17.52	6.66
	Bromus i. L. + Bromus e. H.	5.94	1.33	9.27	2.36	12.76	3.34	18.89	5.89
	Bromus i. L. + Bromus e. H.+ Onobrýchis a.	5.94	1.33	16.14	3.34	25.51	5.58	29.52	10.63
	Bromus i. L. + Bromus e. H.+ Medicago s. hybrid	7.02	1.42	10.93	2.66	17.54	5.99	19.44	8.37
	Bromus i. L. + Bromus e. H. + Lótus c.	7.91	1.62	11.37	2.84	14.56	4.77	18.84	7.04
Growth matrix	*Bromus i. L.*	8.26	1.75	16.35	2.64	15.63	4.46	18.26	8.19
	Bromus i. L.+ Bromus e. H.	7.22	1.61	14.04	2.62	15.13	4.23	19.5	7.16
	Bromus i. L. + Bromus e. H. + Onobrýchis a.	7.22	1.61	15.01	3.95	24.37	6.04	29.54	11.13
	Bromus i. L.+ Bromus e. H. + Medicago s. hybrid	8.51	1.75	21.03	2.73	18.52	5.76	28.61	10.48
	Bromus i. L.+ Bromus e. H. + Lótus c.	10.94	2.48	16.51	2.99	15.84	4.72	19.34	6.83
Gumi 20M	*Bromus i. L.*	9.27	2.10	15.30	3.53	17.2	5.71	19.76	7.27
	Bromus i. L.+ Bromus e. H.	10.69	2.08	16.10	3.72	17.52	5.45	19.32	7.54
	Bromus i. L. + Bromus e. H. + Onobrýchis a.	10.69	2.08	22.34	5.45	28.07	8.34	32.77	14.45
	Bromus i. L. + Bromus e. H. + Medicago s. hybrid	12.89	1.85	17.83	4.67	24.02	7.35	29.65	14.11
	Bromus i. L. + Bromus e. H. + Lótus c.	14.27	3.14	17.46	4.82	18.07	6.02	21.29	7.03

As the crops in the herbage mixture comprising *Bromus inermis Leyss, Bromus erectus Huds., Onobrýchis arenária* and *Poterium Polygamum Waldst et Kit.* went through their phenological phases, the maximum yield increment increased as compared to the reference, and the yield reached 13.19 t/ha during the tillering (branching) phase, 22.34 t/ha during the stooling (budding) phase, 28.07 t/ha during the heading (blossoming) phase and 32.77 t/ha during the fruit formation stage.

The Growth Matrix product had a beneficial effect on the mixtures of *Bromus inermis Leyss, Bromus erectus Huds., Onobrýchis arenária* and *Poterium Polygamum Waldst et Kit.* during the fruit formation stage with the yield of 29.54 t/ha.

As regards the dry matter yield, the mixture of *Bromus inermis Leyss + Bromus erectus Huds. + Onobrýchis arenária* showed better results than any other option. The best result of 14.45 t/ha was obtained under treatment with Gumi 20M during the fruit formation phase. The mixture of *Bromus inermis Leyss + Bromus erectus Huds. + Medicago sativa hybrid* shall be emphasized as well for its high yield of the dry matter.

In the process of analyzing the forage value of the obtained harvest, it was found that the older the herbage, the more feed units it yields, with the maximum during the fruit formation phase (Table 4).

The highest feed unit yield was demonstrated by the four-component herbages comprising *Bromus inermis Leyss, Bromus erectus Huds., Poterium Polygamum Waldst et Kit.* and *Onobrýchis arenária* or *Medicago sativa hybrid*. The maximum productivity of these herbages is reached under treatment with growth stimulators.

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Table 4. Forage value of the harvest yielded by the mixture comprising *Bromus inermis Leyss and Poterium Polygamum Waldst et Kit*, the mean for 2016 – 2017.

Treatment	Mixtures with Poterium Polygamum Waldst et Kit.	Stooling (budding)		Heading (florification)		Fruit formation	
		Feed units t/ha	DP t/ha	Feed units t/ha	DP t/ha	Feed units t/ha	DP t/ha
Reference	*Bromus i. L.*	2.37	0.15	3.81	0.30	5.65	0.47
	Bromus i. L.+ Bromus e. H.	2.55	0.15	4.19	0.31	4.33	0.41
	Bromus i. L. + Bromus e. H.+ Onobrýchis a.	3.15	0.28	6.00	0.57	7.58	0.90
	Bromus i. L. + Bromus e. H.+ Medicago s.h.	4.07	0.34	6.16	0.62	5.88	0.83
	Bromus i. L. + Bromus e. H. + Lótus c.	2.32	0.18	4.10	0.39	4.99	0.61
Growth Matrix	*Bromus i. L.*	2.52	0.20	4.44	0.33	4.65	0.42
	Bromus i. L.+ Bromus e. H.	2.39	0.18	3.57	0.37	4.61	0.51
	Bromus i. L. + Bromus e. H. + Onobrýchis a.	4.45	0.37	7.84	0.85	8.81	1.07
	Bromus i. L.+ Bromus e. H. + Medicago s.h.	3.21	0.26	4.34	0.55	5.73	0.80
	Bromus i. L.+ Bromus e. H. + Lótus c.	2.53	0.21	3.51	0.36	4.82	0.59
Gumi 20M	*Bromus i. L.*	2.79	0.22	4.71	0.39	6.99	0.55
	Bromus i. L.+ Bromus e. H.	3.67	0.31	4.35	0.50	5.63	0.56
	Bromus i. L. + Bromus e. H. + Onobrýchis a.	4.22	0.33	8.39	0.97	8.31	1.14
	Bromus i. L. + Bromus e. H. + Medicago s.	4.95	0.38	4.83	0.59	6.92	1.01
	Bromus i. L. + Bromus e. H. + Lótus c.	4.56	0.32	4.76	0.50	5.79	0.74

For example, when treated with Growth Matrix the herbage with *Onobrýchis arenária* yields 7.84 t/ha and 8.81 t/ha of feed units during the blossoming and fruit formation stages accordingly. Use of Gumi 20M ensures a good yield of feed units by the herbages with *Onobrýchis arenária* accumulating 8.39 t/ha during the blossoming stage and 8.31 t/ha during the fruit formation stage, and by the herbages with *Medicago sativa hybrid* accumulating 4.83 t/ha and 6.92 t/ha accordingly.

In regard to the digestible protein yield, the herbages with legume components had better results. The best options were the herbages comprising *Poterium Polygamum Waldst et Kit.* and *Bromus inermis Leyss*, *Bromus erectus Huds.*, *Onobrýchis arenária* or *Medicago sativa hybrid*, which yielded the largest amount of digestible protein equal to 1.01 – 1.14 t/ha

DISCUSSION

Cultivation of perennial forage crops is essential for ensuring stable forage production in the grasslands of Povolzhye. The study showed that the greatest forage production stability is characteristic for the four-component herbages comprising *Poterium Polygamum Waldst et Kit.* and *Bromus inermis Leyss*, *Bromus erectus Huds.*, *Onobrýchis arenária* or *Medicago sativa hybrid*, which are better adapted to the conditions of semiarid grassland zone. Treatment of the forage crops with growth stimulators effectively facilitates leaf formation and photosynthetic activity of the plants, which has a significant positive effect on the quantity and quality of the harvest.

CONCLUSIONS

According to the study results, the best productivity parameters are demonstrated by the herbage mixture comprising *Poterium Polygamum Waldst et Kit.*, *Bromus inermis Leyss*, *Bromus erectus Huds.* and *Onobrýchis arenária* under treatment with the growth stimulator Gumi 20M, with the yield of green mass – 32.77 t/ha, dry matter – 14.45 t/ha, feed units – 8.31 t/ha, digestible protein – 1.14 t/ha.

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