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The Influence Of Pesticides And Albite On The Photosynthetic Activity And Seed Yield Of Eastern Galega (Galega Orientalis)

A. P. Eryashev, P. A. Eryashev
Mordovia State University n.a. N. P. Ogarev, 68 Bolshevitskaya Str., Saransk, 430005, Republic of Mordovia, Russia

Abstract.
The research was aimed at scientific substantiation of the possibility to form high yield in the seeds of Eastern Galega through the use of pesticides and Albite growth regulators. To achieve this goal, the effect of pesticides, time and frequency of using the Albite growth regulator on the foliage, leaf area, photosynthetic potential, net photosynthesis productivity, efficiency of photosynthesis, the coefficient of utilization of photosynthetically active radiation, and the seed yield of Eastern Galega were studied in the field experiments in 2012 – 2014. The studies have shown that the highest foliage of Galega was observed on nonpesticidal background with three introductions of the growth regulator, and on the pesticide background – in the budding phase; the maximum leaf area was formed on nonpesticidal and pesticidal backgrounds with three introductions of Albite, in the phase of germination and budding, and double use of growth regulator on the nonpesticidal background. A similar regularity was observed for the photosynthetic potential. The net photosynthetic productivity did not increase from the studied factors. Photosynthetic productivity (g of seeds per 1,000 PP units) was the highest on nonpesticidal background with double introduction of growth regulator, and in the phase of pod formation, and on the pesticidal background — in the phase of spring regrowth. The coefficient of utilization of the photosynthetically active radiation had an advantage on the nonpesticidal background of double introduction of Albite, and on the pesticidal background — in the phase of spring regrowth and budding. The highest seed yield was observed on the nonpesticidal background with double use of growth regulator (598 kg/ha), and at the beginning of spring regrowth on the pesticidal background (578 kg/ha); this fact was promoted by the density of shoots, the number of beans on them, and the weight of seeds per shoot.
Keywords. Foliage, leaf surface area, photosynthetic potential, photosynthetic productivity, net productivity of photosynthesis, utilization of photosynthetically active radiation, seed yield.

Introduction

The share of grass fodder in the total amount is growing everywhere, and on the average in Russia is 58 %. This is fully justified, since herbs are best adapted to the climatic conditions in most regions, and allow obtaining cheap fodder. One of the main areas of intensifying field fodder production is increasing sowing areas of perennial legume Eastern Galega. This can be done by increasing the seeds' production amounts.

Obtaining crops that are able to use the energy of photosynthetically active radiation (PAR) with high efficiency should be the main goal in improving the yield [1].

In the process of photosynthesis, plants absorb all carbon from the environment (air supply), which forms 42 – 45 % of the dry organic matter weight. The photosynthetic activity of cultivated plants involves a number of important indicators: the size of the photosynthetic apparatus, its development speed, duration, and intensity of leaves' work; the net photosynthetic productivity, the coefficient of PAR utilization. All processes that occur during photosynthesis naturally depend on the environmental conditions. The not fast enough growth of leaf surface area is the factor that most often reduces the yield [2].

The size and the spatial structure of the leaves determine the amount of energy absorbed by the crops. However, the yield does not always grow proportional to the growth of the leaf surface area; upon reaching certain values, the growth stops. For agricultural field crops, the optimum leaf surface area per 1 ha of cultivated plants should be within 2 – 7 m^2/m^2 [3].

The high foliage of Galega was indicated by several researchers [4, 5, 6]. In the experiments of O. P. Rodchenko (1964), treating alfalfa with gibberellic acid increased the number of leaves in the first mowing [7].

The studies of V. A. Gushchina (2003) on leached black soils in the conditions of the Penza region showed that the highest Galega leaf area of 81.1 thousand m^2/ha had been formed after treating the seeds and foliar fertilizing with the ZHUSS (LFTC) Liquid Fertilizing Stimulating Composition. With that, it increased 1.8 times compared to the reference during the first year, and 1.7 times — in the second year [8].

A. V. Semenchev (2013) noted that the use of Albite in the phases of spring regrowth, budding, spring regrowth + budding in 2011-2013 on cultivated Hungarian Clover (on the background of mineral nutrition with N_{30} P_{60} K_{90} kg of active substance/ha) had contributed to increasing the leaf area by 53.4 %, 18.0 %, and 56.6 %, respectively, compared to the reference (61.6 thousand m^2/ha), and the photosynthetic potential, respectively, by 44.8 %; 11.4 %, and 47.2 %, compared to the reference (2.99 million m^2 • days/ha), and the net photosynthetic productivity (NPP), respectively, by 36.6 %; 5.1 %, and 38.0 %, compared to the reference (4.10 g/m^2 per day) [9].

The effect of chemical methods of weed control on the formation of photosynthetic potential (PP) has been noted by many researchers. For instance, on the leached black soils in the Penza region, the highest PP of Eastern Galega was 2.0, 2.1, 3.1 million m^2 • days/ha with the introduction in the phase of spring regrowth of Basagran 1.5 kg of active substance/ha, compared to the absence of the use. The same regularity (2.5, 2.7, 3.8 g/m^2 per day) was noted for the NPP [10].

Perennial herbs most fully use solar energy during the vegetation season, since they form two or three hay mowings. Photosynthesis consumes only part of it being in the wavelength range between 0.38 and 0.71 µm, which is part of the shortwave radiation. It is called PAR. In the conditions of the Mari El, with the use of only 2 % of incoming PAR, it is possible to obtain up to 16 t/ha of dry matter of Eastern Galega [11].

Thus, one of the technological elements that ensure Eastern Galega high photosynthetic activity and seed yield is the use of plant protection products and Albite. However, in the conditions of the Republic of Mordovia, similar studies were not performed. Therefore, development and improvement of the methods of cultivating seeds of this crop are very urgent and relevant and help increase the production of plant protein in the region.

The purpose of the study is the scientific substantiation of the possibility to obtain high yields of good quality seeds of Eastern Galega based on the use of means of plant protection and Albite in the Republic of Mordovia.

The tasks are as follows:

- determining the influence of the studied factors on the photosynthetic activity and weed infestation of crops; and

- identifying the effect of the means of plant protection and Albite on Eastern Galega seed yield.

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MATERIALS AND METHODS

For achieving these objectives, field experiments were started in 2012 – 2014 at LLC Biosphere in the Ivanovsky region of the Republic of Mordovia in field No. 3 of fodder crop rotation on Eastern Galega 12, 13, 14 years old.

Scheme of the experiment was the following: Factor A. Means of plant protection (Background of plant protection). 1. Without means of plant protection (reference – background w/o pesticides).

2. Means of plant protection (the background of using pesticides was spraying insecticides in the phase of spring regrowth — Break 0.05 l/ha; in the budding phase — Sharpei 0.3 l/ha; treatment with herbicides Basagran (2.0 l/ha) + Miura 1.5 (l/ha) in the phase of spring regrowth; treatment with fungicide Rex Duo 0.4 — 0.6 l/ha in the phase of spring regrowth and budding).

Factor B. The use of Albite growth regulator. 1. Without treatment (reference)

2. Treatment in the phase of spring regrowth 40 ml/ha. 3. Treatment in the phase of spring regrowth and budding (two times). 4. Treatment in the phase of spring regrowth, budding, and pod formation (three times). 5. Treatment in the budding phase. 6. Treatment in the phase of pod formation.

The area of first-order plot was 60 m^2 (12 x 5 m). The area of second order plot was 10 m^2 (2 x 5 m). The experiment was repeated three times, with systematic placement. In accordance with the tasks, the experimental work was based on the method of laboratory and field studies. The object of research was Eastern Galega of the Yalginsky variety.

Field experiments were started; observations and accounting were performed in accordance with the guidelines of B. A. Dospekhov [12]. The leaf area, the PP, the NPP, and the PAR coefficient (C_{PAR}) were determined according to the method of A. A. Nichipirovich [3].

The seed yield was accounted for by mowing plants from 3 m^2 in each plot three times after browning of 100 % of beans, followed by manual threshing. The obtained data were processed by the method of variance analysis of R. A. Fischer with the use of statistical software on personal computers [12].

The research was performed in the second agropedological area in the third natural-economic zone. The soil of experimental plots was dark gray forest with argilliferous particle size distribution. The content of humus was 5.1 %; pH_{KCl} — 5.0; hydrolytic acidity — 5.2 mg • eq to 100 g of soil; phosphorus — 97 mg/kg of soil; and exchangeable potassium — 144 mg/kg of soil. The content of microelements, mg/kg was the following: Mo — 0.12 (low), B — 1.4 (high), Mg — 41, Cu — 7.9 (high), and Co — 1.0 (low) mg/kg.

Agrometeorological conditions during the years of the studies differed by year. In 2012, the periods from the beginning of vegetation until budding, and until flowering were very arid (hydrothermal index = 0.44 and 0.57). The periods from budding to flowering and from flowering to pod formation were waterlogged (hydrothermal index = 1.88 to 1.54); from pod formation to seed ripening (hydrothermal index = 0.94) and from the beginning of spring vegetation until seeds ripening — slightly arid (hydrothermal index = 0.89).

In 2013, the periods from the beginning of the spring vegetation until budding and until flowering were arid (hydrothermal index = 0.72 and 0.75). From budding until flowering, the periods were normally humid (hydrothermal index = 1.04); from flowering to pod formation — strongly arid (hydrothermal index = 0.15). The period from flowering to seed ripening was slightly arid (hydrothermal index = 0.89), and from pod formation to ripening – normally humid (hydrothermal index = 1.09), from the beginning of spring vegetation to seeds ripening – slightly arid (hydrothermal index = 0.84)

In 2014, the periods from the beginning of spring regrowth until budding and flowering of Galega were severely arid (hydrothermal index = 0.69 and 0.57). Significant lack of moisture was observed in the interphase periods of budding and flowering (hydrothermal index = 0.32) and flowering and pod formation (hydrothermal index = 0.33). The period from pod formation to seed ripening was mildly arid (hydrothermal index = 0.80). The generative period of Galega was very arid (HTI = 0.63). The same was the period from the beginning of spring regrowth until seed ripening (HTI = 0.61).

The methods of farming were the ones adopted in the Republic, except for the studied variants. In the autumn, mineral fertilizers were introduced at the rate of $P_{60}K_{60}$ (double granular superphosphate — 1.3 kg/ha, potassium chloride — 1.0 kg/ha); in the spring, harrowing was performed. Crops were treated with pesticides and Albite with the use of a manual backpack sprayer, according to the scheme of the experiment.

RESULTS

The research has shown that on the average for 2012 – 2014, means of plant protection did not affect the foliage of Galega (Table 1).

The use of Albite contributed to its increase; it was the maximum after three introductions and in the budding phase. In considering individual differences, this indicator was dominant, compared to the reference, on the nonpesticidal background after three introductions of the growth regulator, and on the pesticidal background — in the budding phase. No interaction between the factors was noted. The maximum foliage of Galega (62.6 %) was noted in 2013, 45.6 % — in 2012, and 42.5 % — in 2014. It was weakly correlated to the seed yield (r = 0.22), with the average leaf surface area (r = 0.58), PP (r = 0.67), PAR coefficient (r = 0.39); similar to the reversed — with photosynthetic productivity (r = – 0.32), and net photosynthesis productivity (r = – 0.39).

On the average over the three years, means of plant protection did not contribute to increasing the leaf surface area (Table 2).

It was the highest in the case of three introductions of Albite in the phase of spring regrowth and budding, compared to the reference. In the same variants on the nonpesticidal and pesticidal backgrounds, and with two introductions of the growth regulator on the nonpesticidal background, this value dominated with individual differences considered. No interaction between the factors was noted. The maximum leaf surface area was (160.7 thousand m^2/ha) in 2013, 43.7 thousand m^2/ha — in 2012, and 34.9 thousand m^2/ha — in 2014. Moderate correlation was found between the leaf surface area and the seed yield (r = 0.66), the PAR coefficient (r = 0.54); and strong with the PP (r = 0.93), weak reverse — with the NPP (r = -0.33). The linear regression equation between leaf surface area and the seed yield has the form: $y = 11.74 + 5.46\ x$, significant at x = 67.1 to 95.0.

The use of means of plant protection on the average over 2012 – 2014 did not contribute to increased PP (Table 3).

It prevailed after triple spraying with Albite in the phase of spring regrowth and budding, the excess over the reference amounted to 30.0; 31.0, and 23.1 %. In the same variants on the pesticidal and nonpesticidal background, and without means of plant protection after the double introduction of growth regulator, this indicator had the highest value with individual differences considered. No interaction between the factors was noted. The maximum PP of Galega (6.90 million m^2 • days/ha) was noted in 2013, 1.94 million m^2 • days/ha — in 2012, and 1.36 million m^2 • days/ha — in 2014. This index had the medium correlation with the seed yield (r = 0.55) and the PAR coefficient (r = 0.45), a similar reverse one with NPP (r = -0.53).

On the average for 2012-2014, means of plant protection and Albite did not significantly increase the NPP (Table 4).

In consideration of individual differences, it can be noted that this indicator did not exceed the studied factors. Negative interaction of factors was determined. The minimum NPP of Galega (0.78 g/m^2 a day) was observed in 2013, 3.61 g/m^2 a day — in 2014, and 2.70 g/m^2 a day — in 2012.

The use of pesticides resulted in the reduced productivity of photosynthesis in 1 g of seeds per 1,000 PP units by 15.6 % (Table 5).

Table 1 – Foliage of Galega, % (average for 2012 – 2014)

Background of plant protection (A)	Variants of Albite application (B)						On the average for factor A, LSD_{05}= 1.5
	1st	2d	3d	4th	5th	6th	
Without pesticides (reference)	49.9	50.3	51.4	54.6	52.7	48.3	51.2
The use of pesticides	47.8	50.7	50.7	52.3	55.0	52.3	51.5
On the average for factor B, LSD_{05}= 2.7	48.9	50.5	51.0	53.4	53.9	50.3	51.3
LSD_{05} for particular differences = 3.8							

Table 2 – Leaf surface area, thousand m^2/ha (average for 2012 – 2014)

Background of plant protection (A)	Variants of Albite application (B)						On the average for factor A, LSD_{05} = 5.1
	1st	2d	3d	4th	5th	6th	
Without pesticides (reference)	67.7	93.9	85.9	90.6	81.5	62.2	80.2
The use of pesticides	71.4	83.0	73.4	87.7	87.0	73.4	79.3
On the average for factor B, LSD_{05}= 8.8	69.2	88.5	79.6	89.1	84.3	67.8	79.7
LSD_{05} for particular differences = 12.4							

Table 3 – Photosynthetic potential, million m^2 • days/ha (average for 2012 – 2014)

Background of plant protection (A)	Variants of Albite application (B)						On the average for factor A, LSD_{05} = 0.28
	1st	2d	3d	4th	5th	6th	
Without pesticides (reference)	2.80	4.03	3.63	3.87	3.43	2.63	3.40
The use of pesticides	3.00	3.57	3.07	3.67	3.70	3.43	3.41
On the average for factor B, LSD_{05}= 0.49	2.90	3.80	3.35	3.77	3.57	3.03	3.40
LSD_{05} for particular differences = 0.68							

Table 4 – Net photosynthetic productivity, g/m^2 a day (on the average for 2012 – 2014)

Background of plant protection (A)	Variants of Albite application (B)						On the average for factor A, LSD_{05} = 0.2
	1st	2d	3d	4th	5th	6th	
Without pesticides (reference)	2.43	1.87	2.63	2.97	2.10	2.70	2.28
Use of pesticides	2.53	2.63	2.47	2.43	2.47	1.97	2.42
On the average for factor B, LSD_{05}= 0.36	2.48	2.25	2.55	2.20	2.28	2.33	2.35
LSD_{05} for particular differences = 0.51							

Table 5 – Productivity of Galega photosynthesis, g of seeds per 1.000 PP units (average for 2012 – 2014)

Background of plant protection (A)	Variants of Albite application (B)						On the average for factor A, LSD_{05} = -7
	1st	2d	3d	4th	5th	6th	
Without pesticides (reference)	142	140	164	120	138	179	147
Use of pesticides	90	166	146	122	103	119	124
On the average for factor B, LSD_{05} = -12	116	153	155	121	121	149	136
LSD_{05} for particular differences = 17							

Table 6 – PAR coefficient (average for 2012 – 2014)

Background of plant protection (A)	Variants of Albite application (B)						On the average for factor A, LSD_{05} = 0.08
	1st	2d	3d	4th	5th	6th	
Without pesticides (reference)	1.30	1.54	1.93	1.57	1.70	1.45	1.58
Use of pesticides	1.62	2.02	1.70	1.68	2.01	1.39	1.75
On the average for factor B, LSD_{05} = 0.15	1.46	1.78	1.82	1.63	1.86	1.42	1.67
LSD_{05} for particular differences = 0.21							

Table 7 – The yield rate of Galega, kg/ha (average for 2012 – 2014)

Background of plant protection (A)	Variants of Albite application (B)						On the average for factor A, LSD_{05} = 17
	1st	2d	3d	4th	5th	6th	
Without pesticides (reference)	385	540	598	469	441	441	479
The use of pesticides	264	578	424	473	412	396	425
On the average for factor B,LSD_{05} = 30	324	559	511	471	426	419	452
LSD_{05} =17; LSD_{05} for particular differences = 42							

It was the maximum after the double treatment with Albite and in the phase of spring regrowth. In terms of particular differences, this indicator had the maximum value on the nonpesticidal background after the double introduction of the growth regulator and in the phase of pod formation, while on the pesticidal background — in the phase of spring regrowth. Positive interaction between the factors was observed. The maximum photosynthetic productivity of Galega (238 g per 1,000 PP units) was observed in 2012, 134 g per 1,000 PP units — in 2014, and 103 g per 1,000 PP units — in 2013. Between this index and the seed yield, a moderate correlation (r = 0.66) was determined, which was expressed by a linear regression equation: Y = 126.4 + 2.4x valid for x = 90.0 – 166.0.

On the average over the years of research, means of plant protection increased the PAR coefficient (C_{PAR}) to 1.75 (Table 6).

The use of Albite contributed to its increase (1.63 – 1.90), except for the phase of pod formation. When considering individual differences, it had an advantage on the nonpesticidal background after the double introduction of Albite, and on the pesticide background — in the phase of spring regrowth and budding. Positive interaction between the factors was observed. The maximum C_{PAR} of Galega was noted in 2013, and in 2012 and 2013 — 59.4 and 88.6 % of this level. Between this index and the seed yield, a moderate correlation (r = 0.42) was determined.

On the average for 2012 – 2014, the use of means of plant protection decreased the seed yield by 11.3 %; apparently, this was due to plants' inhibition with herbicides, and to a reduction in the number of pollinators in old-grown plantings of Galega from the use of insecticides (Table 7).

It was the highest after spraying the plants with Albite in the phase of spring regrowth. By private differences, this indicator dominated on the nonpesticidal background after the double use of growth regulator, and at the beginning of spring regrowth on the pesticide background, the excess over the reference was 55.3 and 50.1 %. Positive interaction between the factors was observed. The maximum Galega seed yield (714 kg/ha) was noted in 2013, 462 kg/ha — in 2012, and 182 kg/ha — in 2014.

Conclusion

Thus, the highest foliage of Galega was observed on nonpesticidal background with three introductions of the growth regulator, and on the pesticide background – in the budding phase; the maximum leaf area was formed on nonpesticidal and pesticidal backgrounds with three introductions of Albite; in the phase of germination and budding, and the double use of growth regulator on the nonpesticidal background. A similar regularity was observed for the PP. The NPP did not increase from the studied factors. Photosynthetic productivity (g of seeds per 1,000 PP units) was the highest on nonpesticidal background with the double introduction of growth regulator, and in the phase of pod formation, and on the pesticidal background — in the phase of spring regrowth. The coefficient of PAR utilization of the photosynthetically active radiation had an advantage on the nonpesticidal background by double introduction of Albite, and on the pesticidal background — in the phase of spring regrowth and budding. The highest seed yield was observed on the nonpesticidal background with the double use of growth regulator (598 kg/ha), and at the beginning of spring regrowth on the pesticidal background (578 kg/ha); this fact was contributed to by the density of shoots, the number of beans on them, and the weight of seeds per shoot.

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