Promising elements of technologies on cultivating new varieties of leguminous crops in the conditions of central Russia

G A Budarina1*, A S Akulov1 and Z I Glazova1

1Federal Research Center for Legumes and Cereals, 10 Molodezhnaya St., 302502 Orel, Russia

E-mail: budarinagalina61@mail.ru

Abstract. The paper presents the results of two and three years of research on the effectiveness of organic and mineral complex fertilizers and their combination with protectants for pre-sowing treatment of seeds and vegetative plants of new varieties of lentils, chickpeas and soybeans. It is established that the use of the above-mentioned agrochemicals as foliar top dressing is promising and agroeconomically justified. Grain harvest increases depending on the crop: lentils – from 0.22 to 0.39 t/ha, chickpeas – from 0.2 to 0.61 t/ha, soybeans – from 0.18 to 0.24 t/ha providing income from 450 to 15860 thousand rubles/ha with the payback of fertilizers spent by grain, which is significantly higher than at applying complex fertilizers in rows.

It was revealed that promising technique in the cultivation technology of lentil is used for pre-treatment of seeds growth stimulator Alfastim at a dose of 80 ml per 1 ton of seeds, and for the correction of mineral nutrition of lentils during the growing season with the foliar application method we should use agrochemicals LLC “Polydon Agro” the return on which (rubles/rubles) by 3.0–12.2 times more than when applying fertilizers to the soil.

The expediency of pre-sowing treatment of chickpea seeds with a chemical protectant Scarlet, ME in combination with non-root top dressing with multicomponent mineral fertilizers of the Ultramag Combi type in the phase of 6-7 leaves of the crop providing effective protection against seed and soil infection and increasing (by 0.53-0.61 t/ha) grain yield was reliably established.

It is shown that the use of the growth stimulator Alfastim in the processing of soybean seeds at a dose of 50 ml per 1 ton and the microfertilizer Polydon BIO in the budding phase at a dose of 1 l/ha provides a higher productivity of soybean plants with a level of profitability of 228-234% at low costs.

1. Introduction

Sustainable development of crop production in a changing climate is possible only if all technological requirements are met when growing crops, an important place among which belongs to biological and technogenic factors of intensification. A special role is played by energy conservation and environmental safety of high-quality grain production.

With limited moisture reserves and no precipitation during the most vulnerable periods of vegetation, there is a need to increase the acreage under drought-resistant and heat-resistant crops such as chickpeas, soybeans, lentils. However, varietal technologies for the production of these crops for various regions of Russia have not been developed and are not supported by scientific knowledge. In this regard, the purpose of our research was to substantiate promising methods of cultivation of new varieties of lentils, soybeans and chickpeas that contribute to obtaining the maximum yield in the conditions of Central Russia.
2. Materials and methods of research

The research was conducted in 2016-2019 in field and laboratory conditions in the crop rotation of the laboratory of agricultural technologies and plant protection by laying experiments and conducting records and observations according to generally accepted methods. The soil is dark gray forest medium loamy with a high content of mobile elements of mineral nutrition, with a content of humus 4.1-4.5% (according to Tyurin), phosphorus 16.5-18.6 mg/100 g of soil and potassium-10.8-12.5 mg/100 g of soil (according to Kirsanov).

Analysis of seeds for fungal infection and determination of the species composition of pathogens were carried out according to Bilay [1]. Testing of protectants for fungicidal activity is according to the “Guidelines for registration tests of fungicides in agriculture” [2].

In the field experiment, new varieties of soybean Mezenka and Osmon were studied, with seeding rates of 500 and 600 thousand germinating seeds per 1 ha for wide-row sowing, lentils of the Vostochnaya variety – 2 million, chickpeas of the Privo variety – 1-1 million of germinating seeds per 1 ha – for ordinary sowing. The experience is replicated four and five times. The placement of options is randomized. The sown area of the plot is 10 - 15 m². Its predecessor is winter wheat.

During the growing season, a complex of agrotechnical (two treatments of soybean row spacing with a mounted cultivator equipped with pointed legs (270 mm) and protective measures for crop care was carried out: in the phase 1-2 of this soybean leaf, the herbicide Hermes was implemented at a dose of 0.9 – 1.0 l/ha to control annual weeds, to control lentil pests, the plants were treated during the period of germination—budding with the insecticide Kinfos – 0.4 l/ha and flowering period—formation of beans with a fungicide Titul Duo – 0.4 l/ha.

The experiments included promising organic and mineral complexes Alfastim, Polydon Bio, Polydon Boron, Polydon PK, Ultramag Combi and protectant Scarlet, ME, used in the treatment of seeds and vegetative plants. Seeding of experimental plots was carried out with a selection seeder SKS-6-10. The yield was taken into account by continuous threshing of plots with a Sampo – 130 harvester. Experimental data were processed by the method of dispersion analysis according to B.A. Dospekhov, 1985 [3].

3. Results

3.1. Lentils

Lentils are one of the most valuable food legumes. Lentil grains contain up to 32% protein, up to 2% fat, and up to 62% nitrogen-free compounds. The Research Institute of Nutrition of the Russian Academy of Medical Sciences recommends that the population consume 2.5–3.0 kg of lentils per year [4]. However, the acreage and yield of this crop in Russia remain at a low level: in 2018, they amounted to 271.4 thousand hectares with an average yield of 7.9 C/ha.

One of the reasons limiting the productivity of this crop is the optimization of mineral nutrition. Even on fertile soils with a high content of nutrients, lentils can experience starvation due to various weather conditions that negatively affect their mobility and digestibility. Without providing a complete set of macro- and microelements in the necessary quantities and ratios for the periods of growth and development of plants, the costs of other elements of the technology become ineffective. Therefore, the improvement of modern systems of additional mineral nutrition is becoming one of the available and effective agricultural methods to increase productivity.

The most popular in recent years are quite simple and relatively low-cost methods of using agrochemicals: pre-sowing seed treatment and corrective leaf feeding with multicomponent organic and mineral complexes containing, in addition to macro- and microelements, growth substances of natural origin, amino acids and polysaccharides [5, 6].

Polydon Agro is also engaged in the production and implementation of such complex fertilizers [7].

Since 2010, research has been carried out in the Federal Research Center of LC to study the effectiveness of leaf fertilization with complex mineral fertilizers from the series TerraFlex (Belgium), Rexolin (Netherlands), Speedfol (South Africa) on buckwheat [8,9]. However, similar studies on lentils have not been conducted and there is no information about the use of non-root top dressing in the scientific literature. Therefore, in connection with the appearance of national highly effective
agrochemicals-correctors of mineral nutrition, namely, produced by Polydon Agro, we have conducted field tests of them on lentil crops since 2016.

The study of the influence of organic and mineral agrochemicals in the treatment of seeds and vegetative plants showed a significant dependence of lentil yield on the meteorological conditions of the year, characterized by different quality indicators.

Lentils were sown in different years at a soil temperature of 13.2 – 16.8°C at a depth of 0-10 cm with a difference of 4 – 7 days. However, the field germination of lentils averaged 83-84% of the sown seeds over three years and was almost equal in terms of experimental options.

Analysis of the effect of non-root fertilizing with organic and mineral fertilizers on lentil yield showed that their use reliably (HCP = 0.11 t/ha) provides an increase in grain yield (on average for three years) from 0.24 to 0.39 t/ha, which is almost equivalent to adding a complex fertilizer N19P19K19 (0.23-0.24 t/ha). The most effective option was pre-sowing treatment of seeds with Alfastim and subsequent double feeding of vegetative plants during the period of germination – budding with Polydon BIO and during flowering – the formation of Polydon N + Polydon RK beans. The average increase in lentil grain yield over three years was 0.39 t/ha. Single treatment of crops gave approximately the same yield increase of 0.20–0.23 t/ha. The share of the influence of the “non-root top dressing” factor on lentil yield, depending on the year, ranged from 12.8 to 25.5%.

Analysis of the influence of the studied fertilizers produced by Polydon Agro on the main characteristics that characterize the formation of lentil plant productivity (plant length, productivity of one plant and weight of 1000 grains) showed that all the studied fertilizers when spraying vegetative plants have a stimulating effect on the productivity of an individual plant (table 1).

It is important to note that the cost of mineral fertilizers added to the rows to increase the yield of lentil grain is 16-28 times more than fertilizing vegetative plants. Payback of 1 kg of complex fertilizers by crop increase (rubles/rubles) it ranged from 15.8 to 176.0, which significantly exceeds the payback rate (5.2 rubles/rubles) of mineral fertilizers. In addition, the use of the studied organic and mineral fertilizers allows getting additionally an average of 2.2–3.9 C/ha of grain per hectare, which in value terms is from 8.8 to 15.6 thousand rubles/ha. Taking into account the low consumption and low cost of the studied agrochemicals, their use for leaf dressing of lentils is agroeconomically justified in obtaining an additional crop.

For the first time, studies on the effect of foliar top dressing with complex organic and mineral fertilizers have shown their high agro-economic efficiency. The use of these fertilizers for leaf fertilizing lentils is advisable as a “reserve” to eliminate the lack of nutrients during the growing season of plants and get an additional crop increase.

### Table 1. Yield and economic efficiency of fertilizer application under the lentils (average over 2016-2018).

| Variant of experiment | Yield t/ha | The yield increase from fertilizer, t/ha | The cost of yield increase rubles/ha | The cost of fertilizers rubles/ha | Payback of fertilizers by crop increase, rubles/rubles |
|-----------------------|------------|----------------------------------------|-------------------------------------|-------------------------------|-----------------------------------------------|
| 1. Control (without fertilizers); | 1.88 | – | – | – | – |
| 2. N19P19K19 (in rows) | 2.11 | 0.23 | 9200 | 1770 | 5.2 |
| 3. Alfastim (80 ml/t) + Benazol (2 kg/t) – seed treatment; | 2.10 | 0.22 | 8800 | 50 | 176.0 |
| 4. Var. 3 + Polydon Boron (0.6 l/t) top dressing during the period of germination – budding; | 2.11 | 0.23 | 9200 | 145 | 63.5 |
| 5. Var. 3 + Polidon BIO (1.0 l/ha) top dressing during the | 2.12 | 0.24 | 9600 | 359 | 26.7 |
3.2. Chickpeas

Chickpeas can be considered the most heat-resistant crop of all legumes. However, the acreage of this crop in the conditions of Central Russia is not large enough due to the limited assortment of chickpeas and the long growing season of zoned varieties. In addition, the high contamination of seed material with mold and pathogenic fungi and bacteria, relatively weak resistance to root and leaf-stem diseases, and the lack of scientific data on the use of fertilizers dictate the feasibility of studying complexes of fungicides and organic and mineral fertilizers for processing seeds and crops.

In 2018 – 2019, the effect of the combined use of the Scarlet, ME disinfectant with microfertilizer Ultramag Combi on reducing the harmfulness of root rot of chickpeas of the Privo-1 variety and increasing crop yield was studied.

Analysis of the data of the phyto examination of seeds showed a high (62.4%) infection of chickpea seeds with mold fungi and bacteriosis, which led to a significant decrease in their sowing qualities. In this regard, field germination and stem density of chickpeas without treatment with disinfectants decreased by an average of 52.0% (table 2). Therefore, the treatment of seeds of modern chickpea varieties is a mandatory technique that allows not only to improve their sowing qualities, but also to preserve the plants for harvesting as much as possible. According to research data from previous years (2015 – 2016), the highest number (97.6 – 99.3%) of plants preserved for harvesting and the highest yield were on variants with seed treatment.

As a result of accounting for damage to chickpeas by root rot, a significant decrease in their development in the budding phase was noted under the influence of seed treatment with Scarlet, ME at a dose of 0.4 l/t. The biological efficiency of this method for all variants was almost the same and averaged 63.4%, which made it possible to increase grain yield by 29.0% without the use of fertilizers.

Table 2. Effect of complex application of Scarlet, ME with microfertilizer Ultramag Combi on seed quality and yield of chickpeas of Privo - 1 variety (Av. for 2018-2019).

| Variant/Drug | Germination, % | Seed germination, % | Contamination of seeds, % | Stem density, PCs/m² | Livability of seeds, % | Yield, t/ha | % to control |
|--------------|----------------|---------------------|--------------------------|----------------------|------------------------|------------|-------------|
| 1. Control (without treatment) | 75.5 | 73.5 | 35.8 | 62.4 | 35.8 | 35.0 | 97.7 | 0.69 | - |
| 2. Treatment of chickpea seed with a disinfectant Scarlet, ME, 0.4 l/t (standard) | 83.0 | 78.5 | 74.8 | 21.5 | 74.8 | 73.0 | 97.6 | 0.89 | +29.0 |
Structural analysis of the sheaf material and yield confirmed the positive effect of the complex application of the multi-component mineral fertilizer Ultramag Combi with Scarlet, ME disinfectant in the treatment of seeds and vegetative plants on increasing chickpea yield. A significant increase in grain yield by 0.53 – 0.61 t/ha or 88.4 – 76.8% was due to an increase in the number of seeds (by 16.0 - 46.2%) and their weight (by 39.5 – 51.3%) from 1 plant. At the same time, two-time and one-time treatment of crops did not significantly differ in their impact on yield and exceeded the same indicator for the variant with seed treatment with Scarlet, ME at a dose of 0.4 l/t by 46.1 and 37.1%.

From the above, it follows that pickling before sowing is a mandatory technique in the technology of growing chickpeas for grain in the conditions of Central Russia, and to increase productivity, seed treatment should be combined with non-root top dressing of plants with multi-component mineral fertilizers of the Ultramag Combi type.

### Soybean

Among legumes and oil crops, soybean takes the first place in world agriculture as a highly profitable commercial crop, with a yield close to sunflower. With a yield of 1.5 t/ha, the profitability of soybean production is 100% [10].

The implementation of the breeding process in the arid conditions of recent years have enabled breeders FRC of leguminous and cereal crops to select adaptive to drought conditions breeding material on the basis of which new varieties Mezenka and Osmon. However, standard technologies do not provide stable yields of high-quality soy grain and require improvement and development of new elements in its cultivation.

Studies of promising technologies was conducted against the background of effective plant nutrition by soil application of calculated doses of mineral fertilizers (N 63 – 150 P 75 – 149 K 150 - 164), processing of seeds with growth stimulant Alfastim and crops during the growing season with organic fertilizer the Polydon Bio, when seeding 500 and 600 thousand germinating seeds per 1 ha and in wide row method of sowing.

It should be noted that when applying the calculated dose of mineral fertilizers to the yield of 3.0 t/ha (N 63 – 150 P 75 – 150 K 149 - 164), the reaction of the studied varieties was equivalent to the seeding rate of 500 thousand units of germinating seeds per 1 ha (table 3). The yield increase was 0.09 t/ha. In addition, both varieties used the natural fertility of the soil quite effectively, forming a yield of 2.7 t/ha on a non-fertilized background.

| 3. Scarlet, ME, 0.4 l/t т + spraying plants in phase 6 of real leaves with microfertilizer Ultramag Combi, 0.5l/ha | 84.0 | 80.0 | 74.0 | 21.0 | 74.0 | 72.5 | 98.0 | 1.30 | +88.4 |
|---|---|---|---|---|---|---|---|---|---|
| 4. Scarlet, ME, 0.4 l/t т + seed treatment + 2 - fold spraying of plants with microfertilizer Ultramag Combi ((in phase of 6 real leaves and again in the budding phas) | 84.0 | 79.0 | 74.9 | 20.5 | 74.9 | 74.4 | 99.3 | 1.22 | +76.8 |
| HCP 05 | | | | | | | | 0.20 |
Soybean varieties reacted differently to the pre-sowing use of the growth stimulator Alfastim and to the microfertilizer Polydon Bio used during the growing season. Thus, the Mezenka variety practically did not react to seed treatment with a growth stimulator and foliar top dressing, while the Osmon variety with a seeding rate of 500 thousand germinating seeds per 1 ha provided the maximum yield growth on an unfertilized background. When seeds were treated with Alfastim at a dose of 0.5 l/ha, the increase in soybean yield was 0.18 t/ha, and when plants were sprayed with Polydon Bio, it was 0.24 t/ha.

As a result of three year research (2016-2018), high technological efficiency of both varieties was established, which allows harvesting by direct combining with minimal losses. The height of attachment of the lower bean in the Mezenka variety averaged 16.4 cm, in the Osmon variety – 17.8 cm. It should be noted the tendency to increase the attachment height of the lower bean in the Mezenka variety when using an increased seeding rate (600 thousand units/ha) and on a fertilized background. The seeding rate of 500 thousand units of germinating seeds per 1 ha was set for the Osmon variety in 2016-2018.

Table 3. Productivity of new varieties of soybeans using various elements of cultivation technology.

| Factor A | Factor B | Factor C | Yield, t/ha | Factor increase |
|----------|----------|----------|-------------|----------------|
| variety  | Seedin   | Feed     | Treatment of seeds and crops with microfertilizer | A  | B  | C  |
|          | g rate   | backgr   | 2016 2017 2018 aver |            |
| Mezenka  | 500      | not treated | 2.77 2.96 2.47 2.73 | - | - | -0.01 |
|          | thousand | seed treatment | 2.66 2.74 2.76 2.72 | 0.02 |
|          | germini   | treatment of seeds and crops | 2.58 2.77 2.89 2.75 | |
|          | ngs seeds | treatment by vegetation | 2.64 2.81 2.74 2.73 | |
|          | /ha       | not treated | 2.94 2.83 2.71 2.83 | 0.09 |
|          |           | seed treatment | 3.00 2.89 2.68 2.86 | |
|          |           | treatment of seeds and crops | 2.96 2.87 2.61 2.81 | -0.02 |
|          |           | treatment by vegetation | 2.79 2.78 2.84 2.80 | -0.03 |
| Osmon   | 500      | not treated | 2.58 2.64 2.53 2.58 | 0.10 |
|          | thousand | seed treatment | 3.04 2.54 2.70 2.76 | -0.18 |
|          | germini   | treatment of seeds and crops | 2.69 2.36 2.59 2.55 | -0.03 |
|          | ngs seeds | treatment by vegetation | 2.76 2.59 2.65 2.67 | 0.09 |
|          | /ha       | not treated | 2.85 2.65 2.37 2.62 | 0.09 |
|          |           | seed treatment | 2.61 2.64 2.70 2.65 | 0.03 |
|          |           | treatment of seeds and crops | 2.98 2.53 2.87 2.79 | 0.17 |
|          |           | treatment by vegetation | 2.94 2.84 2.79 2.86 | 0.24 |
| Osmon   | 600      | not treated | 3.29 2.54 2.66 2.83 | -0.04 |
|          | thousand | seed treatment | 2.73 2.60 2.65 2.66 | -0.17 |
|          | germini   | treatment of seeds and crops | 2.92 2.34 2.72 2.66 | -0.09 |
|          | ngs seeds | treatment by vegetation | 2.87 2.63 2.65 2.72 | 0.04 |
| NPK      | not treated | 2.76 2.84 2.51 2.70 | - |
| NPK      | seed treatment | 2.93 2.62 2.66 2.74 | 0.04 |
4. Summary

As a result of studying the effectiveness of using organic and mineral fertilizers as non-root top dressing of leguminous crops, their feasibility and prospects for use on lentils, chickpeas and soybeans were established:

- it was found that non-root fertilizing with fertilizers Alfastim, Polydon Boron, Polydon BIO, Polydon N, Polydon RK in two terms provide an average increase in the yield of lentil grain – 0.22-0.39 t/ha and have an advantage over the row method of applying mineral fertilizers, as their costs for increasing the grain yield are 16-28 times less, and the profit in value terms is 1.04 - 1.70 times more. The share of this factor influence on lentil yield was 12.8 – 25.5% depending on vegetation conditions;

- it was found that the combined use of the multi-component mineral fertilizer Ultramag Combi with the Scarlet, ME disinfectant in the treatment of seeds and vegetative plants of the chickpea Privo - 1 variety provides an average yield increase of 0.53 – 0.61 t/ha. Treatment of chickpea seeds with Scarlet, ME, 0.4 l/t without foliar top dressing protects chickpea from root rot by 62.2%, increases grain yield by 29.0%;

- differences in the reaction of new soybean varieties to microfertilizers Alfastim and Polydon Bio used for seed treatment and vegetation depending on the background of mineral nutrition were revealed. The Mezenka variety practically did not react to seed treatment with a growth stimulator and foliar top dressing, while the Osmon variety, when treated with Alfastim at a dose of 0.5 l/ha, provided the maximum (0.18 t/ha) yield growth on a non-fertilized background, and the yield increase when spraying plants with Polydon Bio was 0.24 t/ha.

5. References

[1] Bilay V I, Gvozdyak R I, Skripal I G 1988 Microorganisms – pathogens of plant diseases 552
[2] Guidelines for registration tests of fungicides in agriculture 2009 378
[3] Dospekhov B A 1985 Methodology of field experiment (with bases of statistical processing of research results) 351
[4] Special fertilizers 2012 35
[5] Catalog of biologic drugs and bioactivated fertilizers 2016 29
[6] Innovative experience in lentil production 2013 44
[7] Adaptive technologies of leaf feeding 2012 30
[8] Glazova Z I Assessment of the effect of non–root top dressing on buckwheat yield in the system variety – top dressing – weather conditions (Agriculture) 2014 (4) 40–42
[9] Glazova Z I Yield of new varieties of buckwheat depending on weather conditions and fertilizers (Agriculture) 2014 (4) 40–42
[10] Shirinyan O M 2014 Soybean. New varieties and technologies 23
[11] Polukhin A A, Panarina V I 2020 Main problems of selection and seed production of agricultural crops and ways to solve them (Zernobobovye i krupyanye kul’tury) 3(35) 5-11
[12] Grudkina M, Polukhin A, Grudkina T 2019 Factors increasing the effectiveness of state support in agriculture (IOP Conference Series: Earth and Environmental Science) 274 012113
[13] Hamitowa S M, Glinushkin A P, Avdeev Y M, Naliukhin A N, Kostin A E, Kozlov A V, Uromova I P, Rudakov V O, Tesalovskiy A A, Protopopova E V, Pigorev I Y, Polukhin A A, Sycheva I I 2017 Condition Assessment Of Tree Plantations and Phytosanitary Properties of Soils in Cedar Groves (International Journal of Pharmaceutical Research & Allied Sciences) 6(4) 1-7
[14] Medvedev A V 2020 *Improving the innovative and entrepreneurial potential of irrigated agriculture in the South of Russia* (Russian Economic Bulletin) 3 (3) 149-153

[15] Bayanova O V 2020 *Mechanism for ensuring the growth of feed crop production* (Russian Economic Bulletin) 3 (1) 124-127