Features of using modern multicomponent liquid fertilizers in white mustard agrocoenosis

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Abstract. This article presents the use of modern multicomponent liquid fertilizers in the white mustard agrocoenosis under the conditions of the Nonchernozem zone of the Russian Federation. A brief review of statistical parameters of oilseed cultivation in Russia is proposed. Under the conditions of field experiments, the features of growth and development of white mustard under the influence of multicomponent liquid fertilizers are investigated and presented. Oilseed production in the region has recently increased significantly. Such promising oilseeds as white mustard, soybean, oilseed flax, rape and others have become common. In 2018, the area under oilseeds in Ryazan region was 121.1 thousand hectares (+25.7 thousand hectares compared to 2017). Oilseeds processing is also gradually developing. The prospects for the use of mustard in the region are analyzed and pointed out. Currently, the production of mustard grain in Ryazan region has decreased from 18.6 to 13.1 thousand hectares, which indicates an underestimation of this crop importance. On the basis of investigations, the necessity of using foliar dressings with multicomponent liquid fertilizers in two phases of vegetation was revealed. A positive impact on the growth and development of white mustard plants in the budding phase and obtaining the greatest yield of white mustard seeds have been noted. The maximum number of seeds was obtained with variety Lucius - 13.9 centners per hectare and with Azotovit + Phosphatovit + RauAktiv it was 16.5 centners / hectare.

1. Introduction
The conditions of the Nonchernozem Zone of Russia, including Ryazan region, are favorable for growing oil plants. There is a positive trend in the regional production of oilseeds such as rapeseed, soybean, and sunflower. Over the past five years, their production has increased and is about 145 thousand tons per year. The growing interest in oilseeds indicates their demand in the market, they are increasingly used in food industry, feed production and bioenergy [1]. Oilseeds far exceed grain crops in terms of profitability, and given that their world market is not limited, there are prospects for further increasing their production.

According to the Ministry of Agriculture and Food of Ryazan region, the area of agricultural land in the region is 2,336.9 thousand hectares, including 1,474.9 thousand hectares of arable land. According to the data of the Territorial Body of the Federal State Statistics Service for Ryazan region,
the sown area in all categories of farms in 2018 [2] was 904.8 thousand hectares, which is 3.3 thousand hectares or 0.4 % less than for the 2017 crop.

Oilseed production in the region has recently increased significantly. Such promising oilseeds as white mustard, soybean, oilseed flax, rapeseed, spring bird rape, spring false flax and others have become common. In 2018, the area under oilseeds was 121.1 thousand hectares (+ 25.7 thousand hectares compared to 2017). Of these, the maximum 50.2 thousand hectares are allocated for rapeseed and 42.2 thousand hectares to sunflower. In 2019, more than 150 thousand hectares were allocated for oilseeds in Ryazan region, Table 1.

| Year | Sunflower | Rape | Soybean | Mustard |
|------|-----------|------|---------|---------|
| 2010 | 6.3       | 8.9  | 0.7     | 1.4     |
| 2011 | 16.9      | 17.9 | 0.3     | 1.6     |
| 2012 | 27.9      | 29.4 | 0.3     | 4.7     |
| 2013 | 32.5      | 44.7 | 3.9     | 5.3     |
| 2014 | 24.7      | 40.9 | 24.3    | 18.6    |
| 2015 | 23.4      | 50.7 | 10.0    | 16.9    |
| 2016 | 22.0      | 51.2 | 11.2    | 15.1    |
| 2017 | 40.2      | 35.6 | 14.9    | 4.7     |
| 2018 | 42.2      | 50.2 | 15.6    | 13.1    |
| 2019 | 55.1      | 48.2 | 31.0    | 8.5     |

Based on the data in Table 1, it can be seen that over the past four years, soybean and sunflower have significant increase in oilseed crops. The maximum increase in white mustard was observed in 2014 - 18.6 thousand hectares. In 2018, these figures decreased to 13.1 thousand hectares and in 2019, mustard crops decreased to 8.5 thousand hectares, which indicates some underestimation of this crop.

Soybean production is a great potential for successful agribusiness. Entrepreneurs who understand this are increasing the number of soybean processing companies. However, there are small nuances and disadvantages. Cultivation of soybeans is a rather expensive and complicated matter. One of the nuances is the presence of suitable climatic conditions. It is important to note that soy is an important protein-oilseed crop for the region with developed animal husbandry.

The obtained analysis allows us to conclude that the volume of sown areas of oil plants should be increased from year to year.

To meet domestic needs and make the cultivation of these crops cost-effective, it is also important to increase yields. Achieving these goals presupposes cultivation of modern zoned varieties and observance of the time of planting crops, the effective use of mineral fertilizers that can improve plant nutrition through a set of trace elements, which is considered extremely important, the use of modern plant protection products against pests [3], diseases and weeds and application of advanced technologies and modern agricultural equipment in the soil treatment system. Various techniques will keep the topsoil fertile for a longer time [4].

The sunflower seeds yield in Ryazan region in 2018 amounted to 95.0 thousand tons, which was 25.9 thousand tons more than that of the previous year (the size of the acreage was 42.2 thousand hectares). This was a historical record of the sunflower. In 2019, the increase in acreage expanded to 55.1 thousand hectares.
In terms of the yield obtained, spring rape oilseeds are equal. In 2017, the gross yield of rapeseed was 65.5 thousand tons, and 2018 was characterized by a slight decline to 62.3 thousand tons.

In 2018, the yield of mustard seeds in Ryazan region increased to 6.2 thousand tons, compared with previous years. Climatic conditions had some positive effect on crop formation.

In 2014, soybean had significant indicators, the gross yield was 20.4 thousand tons. The volume of soybeans production in Ryazan region in 2018 decreased to 19.1 thousand tons. And the cultivated areas in 2019 increased significantly, to 31.0 thousand hectares.

The leading agricultural municipal districts of Ryazan region, which are engaged in growing oilseeds, are Sarayevskiy district with the sown area of 23.6 thousand hectares, Miloslavskiy district with 15.4 thousand hectares, Skopinskiy district with 14.3 thousand hectares and Mikhailovskiy District with 12.0 thousand hectares (of the total area under crops of the region). In total, there are about 23 municipal districts in Ryazan region, which in one way or another provide themselves with oilseeds.

In our opinion, it is important to complete the study of oilseeds, above all, cabbage (cruciferous), the study of their adaptive and productive potential at the population, species and ecotypic levels in the Non-Black-Earth Region of Russia [5]. Such a crop is white and gray mustard (tendergreen).

Mustard (Sinapis) is an annual plant belonging to the cruciferous family. It has a great many-sided significance and in terms of food and feed advantages, it substantially exceeds many agrarian crops. The length of the growing period is 65-90 days. In addition, it is an excellent precursor for cereals: it increases soil fertility and helps to reduce weed infestation.

For example, the yield of white mustard gives high levels of herbage, 100 kg contains 12 feed units and 1.3 digestible protein. The yield of mustard seeds is, on average, 12–15 t / ha, and that of herbage is 20 t / ha. The resulting green fertilizer is used for feeding the livestock, as strip plantation on fallow lands and for snow retention.

An alternative crop of sunflower could be white mustard, which makes it possible to increase the production of vegetable oil without degrading the soil. In addition, the dynamics of the mustard market indicates an increase in demand for it over the past years. This crop is not picky to the environmental conditions. It grows on almost all types of soil, with the exception of light sandy. The crop is cold resistant and the seeds germinate at a temperature of 1 ... 3 °C.

The main goal of this work is to determine the effectiveness of foliar fertilizing with multicomponent liquid fertilizers in the conditions of Ryazan region.

2. Target setting
Crop producers face a number of problems, one of which is the sowing of high-quality varieties that are approved for use and are listed in the state register of breeding achievements. Currently, seventeen pieces of mustard are listed in the state register: Passion, Ruslana, Lucius, Snow White, Rhapsody, Fairy, Rainbow, Tango, Semenovskaya, Profi, Elena, Aurora, etc. [6].

Agricultural organizations face another problem when growing oilseeds. Seeds during harvesting often have a moisture content of 15–20 % or more, and there is a violation of storage and, subsequently, the loss of seed quality. Therefore, they require drying and refinement. Most businesses do not have the possibility to do this. That is why it is so important, when growing oilseeds, to develop a plan for receiving seed material, taking into account the capacity of the cleaning and drying plants, to obtain high-quality seeds.

Thanks to the improved ratio of fatty acids in new varieties of white and gray mustard, these crops have become new high-quality raw materials for the food industry.

Vegetable mustard oil is a popular product. It is a dark-yellow liquid with a peculiar bitter taste and pleasant smell. High concentration is in essential polysaturated acids (8-12 % linolenic (Omega-3), 14-32 % linoleic (Omega-6) and monounsaturated Omega-9 fatty acids (22-30 % oleic and up to 5-42 % erucic). Omega-3 and Omega-6 in the composition of the product put it on a par with flaxseed, hemp and olive oils. In addition, mustard oil contains vitamins of group B (B9, B6, B4, B3, B2, B1), D, K, A, P, E; essential oils; phytosterols; chlorophyll and phytoncides.
In general, the introduction of plants is one of the real ways for the development of crop production, the expansion of biodiversity, allowing revealing all the potential possibilities of species. The great scientist N.I. Vavilov emphasized the historical role of the proper introduction of new cultivated plants in the development of world agriculture.

Plant introduction is the introduction of cultivated varieties or plants to places where they have not previously grown, or the introduction of wild plants into the culture. There are two forms of introduction: naturalization and acclimatization.

In the structure of oilseed crops in the southern part of the Nonchernozem zone, a significant proportion is occupied by such crops as spring rapeseed and sunflower, but, however, this subsector, in general, has not yet been changed according to the principle of high adaptability and productivity, obtaining biologically valuable products. In this regard, the introduction, expansion of the range of oilseed plants and the selection of new highly productive crops are the decisive factors in optimizing production systems.

One of the advantages of non-traditional and less common crops is the increased genetically determined resistance to environmental stress factors. Therefore, such crops have great potential and high economic significance. In our opinion, a comprehensive study of oilseeds, crucifers first, the study of their adaptive and productive potential at the population, species and ecotypic levels in the Non-Black Earth Region is relevant.

As an alternative to spring rapeseed and sunflower, such promising oilseeds as oil flax, spring bird rape, winter rapeseed, white and gray mustard, oil radish and some others can be considered.

Therefore, the introduction of new types of oilseeds into agricultural production is of great importance and great prospect.

3. Materials and methods
The studies were conducted in the educational and scientific innovation center (ESIC) "Agrotechnopark" of Ryazan region in 2017-18 on dark gray forest soils. Gray forest soils are typical of the Nonchernozem zone of Russia.

The aim of investigations was to increase the volume of production of oilseed raw materials on the basis of the introduction of new varieties of white mustard into the agricultural production of Ryazan region using multicomponent liquid fertilizers in crops.

The experiments took place on dark gray forest soils, the humus content in the soil was 3.4–4.5 %, the phosphorus content was 16.2–18.0 mg / 100 g soil and the potassium content was 12.9–14.1 mg / 100 g, pH 5.7–5.9.

The main investigation method was field experiment, which was accompanied by phenological observations, records and laboratory analyses. The records and observations during the growing season were carried out on the basis of the “Methodology of state variety testing of agricultural crops” [7] and methods of the All-Russian Institute of Feed [8]. The repetition was fourfold. Mathematical processing of investigation results was done by B.A. Dospekhov (1985) and with the help of computer programs [10]. Qualitative analysis of oilseeds was carried out in laboratories of FSBEI HE RSATU and Agrochemical Service Station "Ryazanskaya".

The object of investigations was Lucius variety of white mustard.

Seed cultivation of Lucius variety has been conducted in the federal scientific institution "Penza Research Institute of Agriculture" since 2016. The vegetation period is 95–96 days. The variety is characterized by early ripening (it ripens 6–8 days earlier than the Rainbow standard), large seeds, the weight of 1000 seeds is 7.0–7.1 g, that is 3.9 g higher than the standard and stable seed yield (average 1.94 t / ha). The fat content in seeds is 20.5-20.7 %. The content of erucic acid in oil is 23.6-24.2 %. The content of allyl oil is 0.59-0.68 %. The variety is approved for use in all regions.

Agrotechnical measures for the cultivation of mustard were taken in accordance with the existing zonal recommendations [9]. The forecrop was winter wheat. Preparation of the soil before experimental sowing included primary tillage to a depth of 12-14 cm, fall tillage to a depth of the arable layer of 20-22 cm.
There was early spring harrowing, then 10–12 cm cultivation and 2-4 cm presowing cultivation immediately before the sowing. The seeding rate was 2.0 million of germinated seeds / ha and the actual seed weight was 12 kg / ha. The seeding depth was 1.5–2 cm. The method of sowing was a row one with the help of a hinged pneumatic selection seeder SSNT-16.

There was herbicidal treatment with preparation Galion, BP - 0.3 l / ha and insecticidal treatment with Fastak, EC, 0.1 l / ha. The treatments were carried out with an OPSh-15-01 sprayer in an aggregate with MTZ-1221. The working fluid consumption was 200 l / ha.

Multicomponent liquid fertilizers Intermag profi, Azotovit, Phosphatovit and RauAktiv were used in the studies according to the prescribed scheme. Characteristics of the preparations used are the following ones:

Intermag Profi is a concentrated complex liquid micro fertilizer, designed with the nutritional requirements of oilseeds. It contains a well-balanced set of macro-microelements that fully meet the nutritional requirements of oilseeds. The microelements included in the composition are in a chelate form good for the plant, which guarantees their complete, high-quality and effective assimilation by the surface of the plants. The registrant is Intermag LLC. The state registration number is 1658-09-204-366-0-0-0-1.

Azotovit is a microbiological liquid fertilizer. The number of viable Azotobacter chroococcum cells in its composition is at least 5 billion / cm$^3$. It provides plants with nitrogen nutrition, increases yields, suppresses phytopathogenic microflora, increases the efficiency of application of nitrogen mineral fertilizers, reduces the toxic effect of fungicides on plant seedlings and restores soil fertility. The state registration number is 1085-08-208-106-0-0-0-1.

Phosphatovit is a liquid fertilizer. It contains spores and living cells of Paenibacillus mucilaginosus bacteria with a concentration of not less than 0.12 x 10$^9$. It provides plants with phosphorus, potash and nitrogen nutrition, increases the efficiency of application of complex mineral fertilizers. It possesses phosphate-mobilizing properties of soil bacteria, i.e. promotes the dissolution of silicate minerals and the release of phosphorus and potassium from complex compounds with their conversion into forms available to the plant. The state registration number is 1086-08-208-106-0-0-0-1.

The rate of preparations application is 1 l / ha. The working fluid consumption is 200 l / ha.

The pilot plot scheme:
1) Control - without treatment.
2) Foliar dressing with Intermag Profi (phase of 2-4 true leaves + phase of budding + insecticide).
3) Foliar dressing with Nitrogen + Phosphatovite (phase of 2-4 true leaves).
4) Foliar dressing with Intermag Profi + Azotovit + Phosphatovit (phase of 2-4 true leaves).
5) Foliar dressing with Nitrogen + Phosphatovite 2-4 true leaves + RauAktiv (phase of budding - flowering (30 % of the maximum leaf surface, before flowering).

4. Results and discussion
The period of emergence of white mustard in studies is 6-10 days. Under favourable conditions, seedlings appear earlier, germination is accompanied by the absorption of 65 % and 60 % moisture, respectively, on an absolutely dry mass. Initial germination temperature is + 1 + 2˚C.

Agroecological conditions influenced the field germination in the experiment: soil temperature at the depth of sowing, air temperature, soil moisture, presence of soil pests and soil crust. Varietal parameters had high germination energy and viability, which ensured friendly seedlings and significant yield increases. On average, the greatest field viability was obtained by variety Lucius - 189.4 pcs. / m$^2$ with laboratory viability of 97 % and the germination energy of 92 %.

Meteorological conditions in the years of investigations were favorable for the development of weeds and the average degree of contamination was noted. The dominant weeds were field oat grass (Avena fatua), knotweed species (Polygonum spp.), lambs quarter goosefoot (Chenopodium album), green amaranth (Amarantus retroflexus), common orache (Atriplex patula) and barnyard (Echinochloa crusgalli). Weed infestation by perennial weeds was represented by rhizomatous - couch grass
(Elytrigia repens), meadow pine (Equisetum arvense) and soboliferous - cursed thistle (Cirsium arvense), field milk thistle (Sonchus arvensis), field bindweed (Convolvulus arvensis). The number of weeds in the agrotechnological experimental station conditions was about 55.3 - 60.5 pcs / m². The effect of the systemic post-emergent herbicide Galion, VR, based on clopyralid and piclorama, on such weed families as Asteraceae, Labiatae, Solanaceae, some species of Polygonaceae and Chenopodiaceae was noted.

It should be noted that the used variety Lucius is practically not affected by diseases in the conditions of the region and fungicidal treatments were not carried out.

Since pods of white mustard do not crack, it can be harvested by direct combining with full ripeness of seeds, when the pods become brown - yellow. It is cost-effective to have own seed fund. However, the process of storage is important, mustard seeds can be invaded by pests that eat and litter them, reducing germination. Therefore, it is important to clean the storage thoroughly and decontaminate it before receiving a new crop.

The results of the harvest and yield of white mustard plants are presented in Table 2.

Table 2. Crop structure elements and the yield of white mustard, depending on the action of organic fertilizers

| Variant                              | Crop structure elements | Yield, centners per hectare |
|--------------------------------------|-------------------------|-----------------------------|
|                                      | Density of planting before harvesting, pcs / m² | Number of seeds in pods, pcs | Weight of 1,000 seeds, g |
| Control (without treatment)          | 184.0                   | 4.0                         | 4.0                        | 12.6                      |
| Intermag Profi                       | 186.2                   | 6.0                         | 4.4                        | 14.1                      |
| Azotovit + Phosphatovit              | 182.4                   | 6.0                         | 4.2                        | 13.2                      |
| Intermag Profi + Azotovit + Phosphatovit | 180.0                   | 5.0                         | 4.2                        | 13.3                      |
| Azotovit + Phosphatovit + RauAktiv    | 185.8                   | 6.6                         | 4.6                        | 16.5                      |

SSD₀₅ centners per hectare (yield) 2017 – 2.23; 2018 – 1.43

Analysis of the data in Table 2 leads to the following conclusions: the impact of the biological preparations used had some positive effect on growth and development of white mustard plants. The variants with biological fertilizers treatment had higher photosynthetic and crop structure parameters.

It should be noted that variety Lucius was characterized by resistance to diseases and pests. As a result, it contributed to better preservation of plants to harvest. The use of multicomponent liquid fertilizers has led to an increase in yield and obtaining high-quality seeds, compared with the control variant.

The maximum number of seeds was obtained on the variant with the use of preparation Azotovit + Phosphatovit + RauAktiv - 16.5 centners / hectare. It is important to note that the positive dynamics of increasing the yield was traced in other variants as well, compared with the control. The variant with the use of preparation Intermag Profi showed no less worthy results, compared to the control variant.

The achieved level of yield is far from exhausting the potential of the studied variety Lucius in the region, including the technology of using biological fertilizers.

5. Conclusion

Thus, increasing the profitability of agricultural production is an urgent and important task that can be solved by expanding the area of oilseed crops and using new, high-quality varieties and hybrids in the
region. The main task of the production is to increase the white mustard oilseed crops using Intermag Profi, Azotovit and Phosphatovit organic fertilizers.

The foliar application in experiments in the phase of 2-4 true leaves have contributed to the improvement of vegetative growth and development of plants, which is expressed in an increase in the height of plants, the number of pods and the mass of 1,000 seeds due to the balance of macro-microelements. In turn, foliar dressing in the budding phase has made it possible to increase the yield of the resulting product in a good manner.

It is important to note that the Lucius variety used in investigations has a high mass index of 1,000 seeds, up to 7 grams or more. It is slightly affected by cruciferous fleas and practically not affected by diseases in the region. Variety Lucius in studies is characterized by early flowering that is very important in the conditions of the region.

The results obtained indicate that foliar applications with multicomponent fertilizers have given the highest yields, on the variant with the use of preparations Azotovit + Phosphatovit + RauAktiv (16.5 centners / ha). Based on the above data of the applied technology, liquid multicomponent fertilizers can be recommended as foliar applications.

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