

Use of different crop rotation models as a factor of agriculture biologization

*Natalia Velkova, Julia Bobkova**, and *Vladimir Naumkin*

Federal State Budgetary Establishment of Higher Education "Oryol State Agrarian University named after N.V. Parakhin", 302019 Eagle, Russian Federation

Abstract. In recent years, more attention has been paid to the biologization of agriculture in the cultivation of agricultural crops. Despite the large variety of entomophilic plants in Russia, their distribution area is uneven. Their significant areas are concentrated in the European part, in intensive agriculture zone. At the same time, over 90% of wild honey plants, with a huge honey reserve, are located beyond the Urals, in Siberia, in the Far East. In such conditions, beekeepers in Central Russia must achieve high honey flows, mainly from agricultural entomophilic crops. The article discusses the issues of organizing a full-fledged feed base for beekeeping and provides various options for specialized crop rotations for beekeeping farmers' households. The organization of a full-fledged honey base for bees, through the rational use of different crop rotation models, in modern conditions will contribute to the sustainable development of beekeeping and crop production. The use in crop rotations of perennial grasses, good nectariferous plants, such as melilot, alfalfa, sainfoin, Eastern galega, is possible only in farms with animal husbandry. Such grasses are the best precursors in crop rotation and allow solving a complex of problems in the field of forage production, soil protection from erosion, and nitrogen enrichment.

1 Introduction

In crop products manufacture, it is necessary to use such farming systems that make it possible to maximize the use of biological factors to reduce the openness of substances and energy cycle. An important role is played by the maximum use of agroecological productivity resources [1].

In Russia, there are more than 1000 species of entomophilic plants located in different geographical and soil-climatic zones [2]. They grow on the territory of the country extremely unevenly. A significant part of the field entomophilic plants is concentrated in the European part of Russia, mostly in intensive agriculture zone [3,4]. At the same time, over 90 percent of wild nectariferous plants, with a huge honey reserve, are located beyond the Urals, in Siberia, in the Far East. This honey resource is still very poorly used. About 90% of the existing honeybee colonies are concentrated in the most populated European part of Russia. In such conditions, beekeepers must achieve high honey flows, mainly from

* Corresponding author: bobkovaj75@mail.ru

agricultural entomophilic crops. It is possible that in the future they will be able to travel long distances to different regions of the country, but at the moment, due to the huge territories, poorly developed road network, lack of established infrastructure for beekeepers, it is extremely problematic and costly.

A significant part of the beekeepers-farmers, based on the above, is guided by the organization of a stable honey base for bees due to the competent use of land areas for cross-pollinating crops sowing. Quite often, beekeepers-farmers have 200-250 bee colonies and large areas of arable land (200-500 hectares). Peasant farm enterprises "Sosnovskoe" (Tambov region), "Volya" (Kirov region), "Anastasia" (Ivanovo region), M.Yu. Churilkina i A.I. Gnilova (Tula region), "Somovo" (Ryazan region), "Medunitsa" (Krasnoyarsk Krai), "Vasilevo" (Oryol region) along with the use of natural honey-bearing lands, sow mustard, melilot, phacelia, echium, buckwheat, and motherwort on large areas to improve the honey base. They are interested in obtaining not only stable honey flows, but also seeds of nectariferous crops, in some cases grain, livestock feed, and other products (medicinal raw materials) to meet their own needs and for the purpose of their implementation. In such farms, crop rotation should be the main condition for maintaining a rational system of agriculture, where it is possible to produce planned crops and correctly allocate agricultural crops, introduce the best technologies for cultivating nectariferous plants, apply the entire range of agrotechnical measures, and ensure weed control.

In peasant farm enterprises with developed beekeeping, which have arable land, it is necessary to master specialized crop rotations with the maximum saturation of their most valuable and technological for cultivation (mechanized sowing, harvesting) crops of honey-bearing value [6].

In some peasant farms and enterprises of other forms of ownership of the Orel region that have apiaries, such field honey plants as buckwheat, rapeseed, clover, melilot, mustard, phacelia, sunflower and others are actively used. An impressive set of these nectariferous crops is regularly grown in the fields of the Shatilovskaya agricultural experimental station for ecological variety testing and demonstration to regional agronomists and scientists. For many years, large collections of buckwheat, vetch, clover, rapeseed, vetchling, deervetch, and other varieties have been studied at the FSBSI FSC for Legumes and Cereals. For a long time, various types of nectariferous plants were cultivated in the crop rotations of the former Orel experimental station of the Research Institute of Beekeeping (buckwheat, phacelia, melilot, clover, echium). Several nectariferous crops were grown at the Novosilskaya forest improvement station, the Orlovskaya biofactory and other enterprises of the region.

Beekeepers-farmers have recently shown considerable interest in the cultivation of medicinal and essential oil crops of nectariferous value (mustard, motherwort, peppermint, leuzea, sage, hyssop, dragonhead, calendula). Beekeeping farm "Anastasia" (Ivanovo region) with our assistance purchased 108 kg of motherwort and 80 kg of phacelia. These seeds, together with the available melilot, were sown to improve honey base, production of seeds and medicinal raw materials. Scientific and medical farm enterprise "Venets" (Tatarstan) sows calendula, valerian and other nectariferous plants, sold in its own pharmacy.

The National Park "Orlovskoye Polesie" (Orel region), which has a good apiary, grows buckwheat, rapeseed, clover, as well as seven types of medicinal nectariferous herbs, for their subsequent delivery to the pharmacy network of the city of Orel and the region, improving the beekeeping forage base in the National Park.

At the request of beekeepers-farmers, the FSC of Beekeeping planned original models of crop rotations, the use of which makes it possible to consider the direction of each farm and the prospects for its development. For example, the subsidiary beekeeping farm of the Oryol Collection Department (Oryol region), in addition to sowing of nectariferous crops,

provided for wheat sowing in the crop rotation (to supply its employees with grain) and one field for hemp, in order to ensure mutually beneficial business relations with a nearby hemp plant. In crop rotations, the greatest preference is given to entomophilic crops, from which from which one can get not only honey, but also seeds, as well as medicinal raw materials [7].

2 Work objective (Goalwork)

To analyze long-term experience of beekeeping peasant-farm enterprises and scientific research in the field of agriculture and beekeeping of the Orel region, and on their basis to make recommendations for the design of crop rotations, taking into account the needs of beekeeping industry for farms of various categories and specializations.

3 Results and discussion

Several variants of specialized crop rotations have been developed for farms of beekeepers-farmers who have arable land, in which nectariferous crops occupy 60-80% of the arable land. Crop rotations are given according to Burmistrov [7].

Option one (for beekeeping and seed farms):

1. Barley + perennial legumes (melilot, red and rose clover, alfalfa, galega, sainfoin), echium
2. Melilot, clover, etc., echium
3. Mustard (or rapeseed, oil radish), other annual nectariferous plant
4. Buckwheat (in the south - coriander, sunflower)
5. Phacelia
6. Green-manured fallow (or complete)

Considering the zonal characteristics, interest and capabilities of the farm, in this crop rotation, if necessary, the specific set of nectariferous crops and the areas allocated for them are specified. Such an adjustment can be carried out even after the development of the crop rotation, since this is not accompanied by a change in the number of fields and a violation of the accepted rotation (alternation) of perennial and annual crops.

Option two (for beekeeping and seed farms with additional livestock industries):

1. Barley (for green fodder, grain) + perennial legumes (clover, galega, alfalfa, sainfoin)
2. Perennial herbs of the 1st year of use (for seeds)
3. Perennial grasses of the 2nd year of use (for hay and haylage)
4. Buckwheat (in the south - coriander, sunflower)
5. Peas, vetch, and oats mix (with the addition of phacelia or mustard)
6. Phacelia
7. Barley (or oats) + melilot, echium
8. Melilot (for haylage, silage, seeds), echium
9. Annual nectariferous plants (rapeseed, mustard, radish, coriander)
10. Fallow (green-manured or complete)

In the proposed crop rotation, the area of forage crops (legumes, barley, oats, peas, vetch and oats mix) has been increased. Part of the seed-growing nectariferous crops plantings, if necessary, can also be harvested for fodder purposes (melilot, radish, rapeseed).

Option three (specialized crop rotation with the inclusion of nectariferous, medicinal and essential oil crops):

1. Complete fallow (dead)

2. Nectariferous, medicinal and essential oil crops: motherwort, hyssop, sage, leuzea, peppermint, lavender (for the south), blueberry, etc. (crops setting up)
3. 3-4-5. Medicinal and essential oil crops of the 1st-3rd year of use
4. Phacelia + melilot, pink clover, sainfoin, echium
5. Melilot and other legumes, echium
6. Annual medicinal and essential oil crops: calendula, ammi visnaga (for the south), coriander, common borage, dragonhead, etc.

The main crop purpose in this crop rotation: organization of honey flow, production of seeds or planting material, medicinal and essential oil raw materials.

Thus, in different variants of crop rotations, wide opportunities for the cultivation of many nectariferous crops are allowed.

It is very important to use the new most productive and nectar-producing varieties in crop rotations, which are well visited by bees and provide honey flow [8].

Due to the fact that nectariferous crops diverse crop rotations provide bees with abundant honey flow in diverse crop rotations, mainly from the middle of June and in July (mustard, echium, Jacob's-ladder, phacelia, clover), bee colonies for the spring must be placed so that they were provided with good early support honey flow from natural nectariferous plants (willow, maple, blackthorn, lungwort, etc.) and cultural fruit and berry plants [9,10]. This will contribute not only to the better development of colonies for the main honey flow, but also to an increase in the nectar resources used by bees [7,8].

An important role in the implementation of this task is played by the study and development of plant resources, which equally applies to the Orel region. There are 525 species of valuable nectariferous, medicinal, forage and other plants belonging to 63 families and 130 genera. The increase in ploughing and agricultural development of the region territory, the destruction of weeds in fields and ribs lead to a decrease in the area occupied by wild nectariferous plants and an increase in the role of cultivated nectariferous plants [11].

In current conditions, it is necessary to saturate the existing crop rotations of agricultural enterprises with cultivated nectariferous plants. The crop rotation system, for example, in the Orel region, has undergone significant changes over the past 30 years. Changes in the forms of ownership and management, the reorganization of the agro-industrial complex management led to the collapse of the existing system of agriculture in the farms of the region [12].

The decrease in the number of cattle inevitably led to a decrease in the importance of forage crop rotations, and, as a result, a decrease in the diversity of forage crops, including nectariferous plants. In this way, according to the regional statistics service, the annual grasses area from 2015 to 2019 decreased almost by half and in 2019 amounted only 16.7 thousand hectares in the region [13].

Similar changes occurred with the perennial grasses wedge. Small farm enterprises abandoned animal husbandry, which led to changes in the structure of sown areas in favor of grain crops. For example, educational-experimental enterprise "Lavrovsky" of the Orel district, Orel region at the end of the 70-80-ies of the last century had a large milking herd of about 270 heads, fur farm and more productive apiary for 120 bee colonies. Buckwheat, melilot, phacelia and 220-250 hectares of clover were sown in the fields. Since the end of the 90s, the number of animals began to decline. The fur farm, the livestock of cows and the apiary were liquidated. Only buckwheat with a yield of 6-10 c/ha is sown among nectariferous plants.

In the context of agriculture intensification, certain changes are also taking place in the structure of crop rotations of large holdings. Crop rotations are taking on more pronounced specialization, the need for which is caused by many objective reasons. Crop rotations include the minimum number of crops with the maximum allowable saturation of the

leading crop: grain, technical, forage [12]. The set of cultivated crops is also changing. In this way, the area under buckwheat in the region decreased from 106.2 thousand hectares in 2017 to 52.2 thousand hectares in 2019. This is due to the yield instability over the years and the low purchase price of this crop. Nevertheless, such crops as sunflower and rapeseed, which are also important as nectariferous plants, have increased their area in the region over the past 5 years, respectively, rapeseed - 1.5 times, sunflower - almost twice [13].

Currently, crop rotations with a short rotation are accepted: four-five-field rotations, and in small farms there are no rotations at all. In such conditions, it is impossible to properly build a system of tillage, fertilization, weed control, pests and agricultural crops diseases control, to protect against soil erosion, that is, all the tasks that crop rotation solves. This isn't about creating a full-fledged honey base in such conditions.

On the other hand, the inclusion of specific nectariferous crops in the crop rotations of peasant (farmer) farm and agricultural enterprises is determined by the planned structure of the sown areas and the natural and climatic conditions of the region. Of course, their choice should be in favor of those crops that are also used for other economic purposes. At the same time, they should be selected so that certain groups of honey plants have the same flowering time, because some of them may poorly distil nectar for some reason [8].

Even I.N. Klingen, an outstanding Russian agronomist, the founder of the bee-field system of agriculture, was clear about the dependence of the yield in field cultivation on bees. Herefrom, he put forward a proposal for the organization of "bee field cultivation". As a result of the experiments, he came to the conclusion that it was necessary to select both the bee and the clover flower. Klingen proposed to adapt the structure of clover flowers to the convenient sucking of nectar by bees, provided that the flower is successfully fertilized. In his opinion, it is necessary to sectionalize the bee itself, lengthening its proboscis, giving it more weight, making it more energetic, hardier in the winter. Then it will be possible to achieve "such a large honey flow in the Non-Chernozem zone, and maybe in Siberia, that honey will be produced no less than refined sugar and sand from sugar beet." In the works of I.N. Klingen, the idea of the connection of field farming with beekeeping was carried out – about raising the soil fertility and grandiose yield of field crops, about the same honey flow by bees: clover, buckwheat, mustard. To ensure honey flow, he proposed "to distribute the plants in descending order according to the time of flowering from spring to autumn, with their allocation in homogeneous groups and with the elimination of competition with each other during the flush of flowering." In thus way, he was at the origin of the flower-nectar conveyor development and the organization of the bee field farming. The data obtained by him were confirmed for various cultures by many researchers [14].

In the mid-80s, the Orel Experimental Station of the FSC for Beekeeping signed an agreement on cooperation with the Buckwheat Breeding Laboratory of the FSBSI FSC for Legumes and Cereals. The employees of the institute had to introduce new varieties of buckwheat and technologies of their cultivation in station fields, provide the team of station field breeders with seed material of a new buckwheat variety, provide regular assistance in the preparation of crop rotations and exercise strict control of all agrotechnical methods of crop cultivation. For many years, the average yield of buckwheat crops at the Orel experimental beekeeping station did not exceed 7 c/ha, although there were sufficient bee colonies for its pollination. Scientists of the FSBSI FSC for Legumes and Cereals, Candidates of Agricultural Sciences S.Yu. Koblev, G.E. Martynenko, senior researcher V.V. Antonov regularly visited station fields. As a result of strict compliance with all agricultural techniques from soil preparation to harvesting, the yield of the new variety Snezhet in the first year was 12 c/ha, the second year - 16 c/ha, the third year – 21 c/ha. The apiary of the beekeeping station received honey. This example once again clearly

demonstrates that the observance of crop rotation and all agrotechnical methods of crop cultivation is an important condition for obtaining its high yield.

Based on the prevailing natural and economic conditions in the region and taking into account the needs of beekeeping, at the moment, we can recommend the following crop rotation structures for small farms:

1. Peas - Winter wheat - Buckwheat - Barley
2. Seed fallow - Winter wheat - Buckwheat - Spring wheat.
3. Peas - Winter wheat – Winter rapeseed - Barley
4. Dead fallow - Winter wheat - Soy - Buckwheat - Barley

Considering the specialization of farms in the production of sugar beet, potatoes, rapeseed, we can recommend the following crop rotation structures:

1. Peas - Winter wheat - Sugar beet - Buckwheat - Spring wheat
2. Lupine - Winter wheat - Sugar beet - Buckwheat - Barley
3. Dead fallow – Winter rape – Winter wheat - Potato – Buckwheat – Barley
4. Lupine - Winter wheat – Winter rape - Potato - Buckwheat - Barley

Large farms specializing in sunflower production are characterized by crop rotations with a large set of crops, since sunflower is very demanding to observe the crop rotation. This is due to both the reserves of residual moisture in the soil, and the presence of infection and broomrape seeds in it. Sunflower can be returned to its former place in 6-7 years. Taking into account this feature of the crop, the following crop rotation structures can be recommended for these farms, with their possible saturation with cultivated nectariferous plants:

1. Dead fallow - Winter wheat - Buckwheat - Barley - Lupine - Winter wheat - Sunflower
2. Dead fallow - Winter wheat - Rapeseed - Barley - Peas - Winter wheat – Buckwheat - Sunflower
3. Dead fallow - Winter wheat - Sugar beet - Buckwheat – Barley - Soy - Winter wheat - Sunflower

In some cases, if it is appropriate, it is possible to replace rapeseed with mustard, provided that the next fallow field is not rapeseed, replacing dead fallow with green-manured one using one of the types of mustard as a green-manured crop.

The use in crop rotations of perennial grasses, good nectariferous plants, such as melilot, alfalfa, sainfoin, Eastern galega, is possible only in farms that have animal husbandry. Such grasses are the best precursors in crop rotation and allow solving a complex of problems in the field of forage production, soil protection from erosion, and nitrogen enrichment.

For the first time in Russia, A.P. Savin developed the melilot system of agriculture – a system-forming factor for optimizing agricultural production. The introduction of this system allows to increase grain production by 20-30%, and honey and feed - by 200-300%, while reducing costs by 50-70%. The melilot system of agriculture allows the rational use of arable land by 100%. This is environmentally friendly agriculture: rejection of pesticides in crop rotation; preservation and improvement of soil fertility, increasing the quantity and quality of agricultural products. The productive stability of agriculture increases with each rotation. In addition, the melilot system of agriculture is a factor in the biological intensification of the leading branches of agriculture: feed production, crop production, animal husbandry and beekeeping. In particular, the research of Professor A.P. Savin confirms the relationship of yellow and white melilot to entomophilic cultures, which are characterized by high nectar productivity. Thus, on average, the nectar productivity of yellow melilot at the end of flowering was from 345.5 to 405.8 kg/ha, white melilot - from 404.7 to 488.4 kg/ha. The melilot system of agriculture for a long time has successfully

proved itself in many farms of our country, especially in farms with bee-breeding specialization [15].

In several small region farm enterprises that have bees, such crops as phacelia and common echium are sown in pure form or in a mix. As a rule, such crops are grown on special field plots due to biological features – uneven maturation and field clogging [16].

5 Conclusion

The organization of a full-fledged honey base for bees, through the rational use of different crop rotation models, in modern conditions will contribute to the sustainable development of beekeeping and crop production.

Cultivated nectariferous plants, on the one hand, increase biodiversity in agroecosystems, which is already a powerful biological factor in agriculture. On the other hand, nectariferous plants - perennial grasses reduce the rate of soil degradation, contributing to its protection from water and wind erosion. The increase of nectariferous legumes in the structure of sown areas also leads to the replenishment of soil nitrogen reserves.

References

1. V.T. Lobkov, N.I. Abakumov, Yu.A. Bobkova, A.I. Zolotukhin, N.K. Kruzhkov, V.V. Polov, S.A. Plygun, M.F. Tsoi *Fertility without "chemistry": fundamentals of biologization of agriculture in Central Russia on the example of the Orel region*, 160 (2016)
2. F.D. Likhonos, A.S. Tuz, A.Y. Lobachev, *Apple tree. Cultural flora of the USSR*, 125 (1983)
3. N.G. Krasova, A.M. Galasheva, Z.E. Ozherelieva, *Breeding and variety culture of fruit and berry crops*, **4(1-2)**, 66 (2017)
4. M.A. Vishnyakova, A.V. Kushnareva, T.V. Shelenga, G.P. Egorova Vavilovsky, *Journal of Genetics and Breeding*, **24(6)**, 625 (2020)
5. A.Yu. Korolyuk, M.P. Tishchenko, *Bulletin of Tomsk State University. Biology*, **49**, 50 (2020)
6. N.I. Velkova, V.P. Naumkin, *Cultivation of white mustard in the conditions of the CChR*, 380 (2018)
7. A.N. Burmistrov, *Organization of honey-bearing base of farms*, 22 (2002)
8. V.P. Naumkin, Yu.A. Shashkin, A.N. Burmistrov, *Technological recommendations for effective pollination of buckwheat by honeybees*, 24 (1993)
9. L.J. Friesen, S.C. Stushnoff, *Hortscience*, **20**, 744 (1985)
10. M.R. Salazar-Gutiérrez, B. Chaves, G. Hoogenboom, *Sci. Hort.*, **198**, 344 (2016)
11. I.Yu. Bogatishcheva, *Resources of melliferous plants of the Central forest-steppe*, 19 (2004)
12. A.P. Isaev, *Crop rotations in zonal systems of agriculture*, 34 (2000)
13. Website of the Territorial Body of the Federal State Statistics Service for the Orel region (2021)
14. I.N. Klingen, *On the practical significance of fertilization of red clover by Caucasian bees*, 48 (1910)
15. A.P. Savin, *Sweet clover farming system*, **10**, 18 (2020)

16. A. A. Gordeev, L. G. Gordeeva, Main directions of Beekeeping Development in the region, **1**, 58 (2019)