Research on New Technologies and Solutions for Reducing Carbon Emissions

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Abstract. For the first time in the Central Region of the Non-Chernozem zone, the main pathogens affecting soybean varieties of the northern ecotype in this region - downy mildew, fusariosis, and growth retardation virus were studied; the degree of their pathogenicity was established. The species composition of potential soybean pests has been established. The economic threshold of nodule weevil injuriousness has been determined. Studies conducted in soybean crops of the northern ecotype in the conditions of the Kaluga region have established a complex of pests and diseases. The main insect pests of soybeans of the northern ecotype are represented by the orders Coleoptera, Lepidoptera, Heteroptera, Thysanoptera. The arachnid class is represented by the red spider. The main pathogens affecting soybean varieties of the northern ecotype are fungi of the genus Fusarium sp., Peronospora, Ascochyta; viruses – growth retardation virus, Southern Mosaic bean virus, Southern Mosaic Virus, Strawberry wither tip virus.

1 Introduction

In Russia, potential crop losses from pests, diseases, and weeds range from 26 to 50%. The success of plant protection is largely determined by the availability of timely information on the development, distribution, and abundance of harmful objects, as well as on the condition of plants and the general environmental situation. On the basis of such information, it is planned to organize plant protection. The obtained phytosanitary information should be used creatively, based on the specific conditions of the area of crop cultivation. It is important not only to know the most dangerous harmful objects that can negate the labor invested in growing crops, but also to apply effective, economical and environmentally friendly protective methods and means in a timely manner [1, 2].

The main soybean crops in Russia are located in the Far East and in the Central Chernozem region. But recently, information about soybean cultivation in the Volga region and in

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the Non-Chernozem zone of the Russian Federation has been increasingly appearing. Soybean varieties of the northern ecotype differ favorably from soybean varieties of traditional cultivation regions, since they contain more protein [3].

Soybean varieties of the northern ecotype are affected by diseases and damaged by pests. Nevertheless, the species composition of harmful organisms in this region has not been studied before [4].

Soybeans have been sown in the Kaluga region since 1987. By this time, the first soybean variety of the northern ecotype – Mageva, was created, studies were conducted with this variety, and then Okskaya, Svetlaya, and Kasatka soybean varieties were registered in our region.

Soybean plants attract phytophagous insects. Nodule weevils are common in our area, damaging both annual and perennial legumes. In the Orel region, soybean seedlings are harmed not only by Curculionidae weevils, but also by cut worm caterpillars Agrotis and sod webworms Loxostege sticticalis [5].

About 100 species of phytophages are known in the Far East, but only 20 species cause economic harm. One of the specialized pests is the soybean pod borer. Thus, soybean pod borer in the Primorsky Territory, according to research data in 2019-2020, damaged from 4.5 to 10.2% of soybeans of different varieties. The dominant pest species in the Primorsky Territory are the striped soybean leaf beetle Paraluperodes suturalis nigrobilineatus Motsch., soybean aphid Aphis glicines Mats., and soybean pod borer Leguminivora glycinivorella Mats.

According to Titova S.A. and Semenova E. A. (2016) 30 fungal diseases of soybeans have been noted in the Far East. The mild humid climate of the Khabarovsk Territory affects the development of such soybean diseases as septoria, peronosporosis, cercosporosis, fusarium, ascochitosis [6, 7]. Other scientists note that in the Primorsky Territory, 95% of soybean crops were affected by peronosporosis in 2019, with a development degree of 21.6%. The import of infected soybeans with purple cercosporosis from Argentina and Paraguay was noted [8]. Outbreaks of cercosporosis are observed annually in the Primorsky Territory. When soybean plants are affected by cercosporosis, grain quality deteriorates and yield decreases [9].

Diseases of soybean leaves dramatically reduce the assimilation surface of plants, preventing them from realizing the potential yield of the variety.

In the Far East, as noted by R.V. Gnutova, there are seven types of viral diseases of soybeans [10].

The most characteristic reaction of soybean plants to the disease is a change in the enzymatic activity that controls the host metabolism.

2 Materials and Methods

From 2015-2020, vegetation and field experiments, records and observations of the development of harmful organisms were carried out. The research was conducted on the territory of the Kaluga region.

The purpose of our research is to determine the species composition of pests and diseases of soybean varieties of the northern ecotype in the conditions of the Kaluga region.

Research tasks:

1. To establish the species composition of pathogens and pests by soybean development phases in the Kaluga region;
2. To determine the effect of damage to soybean plants by various pests and diseases on the seed yield.

The experiments were laid in fourfold repetition. The placement of plots is randomized. Plants that were not damaged by pests and not affected by phytopathogens served as controls.

The objects of research were soybean varieties of the northern ecotype, zoned in the Kaluga region: Mageva, Okskaya, Svetlaya, and Kasatka.

The accounting of pests and diseases of soybeans was carried out in accordance with the methodology for accounting for the number of major pests and diseases of legumes presented in the reference manual "Methods of agrotechnical research in experiments with major field crops" [11]. Accounting for the number of nodules was determined by the method of studying the biological fixation of air nitrogen. The plants were dug to the depth of the arable layer. The roots were freed from the soil by dry disassembly followed by washing on sieves with a hole diameter of 0.5 mm. The roots were separated from the stems at the level of the root neck. The number and mass of nodules in the sample, the mass and humidity of plant organs were determined, and samples were taken for chemical analysis. The leaf area was determined by the die-cutting method. Accounting and diagnosis of diseases were carried out during a route survey of experimental plots, 10 plants were selected in 10 places, a total of 100 plants. The degree of disease spread and the degree of plant damage were considered according to phytopathological scales [12].

During the accounting, not only the number of pests was determined, but also the degree of damage to plants. Pest accounting was determined at stationary sites, by the method of "mowing" with a net (10 samples of 10 strokes), followed by the determination of insects in laboratory conditions, during a route examination by examining 100 plants – 10 samples of 10 plants and when analyzing soybeans.

The harvest by plot was led to standard humidity.

3 Results

In the first years of research (from 2015 to 2020), sitona weevils (*Sitona crenitus, Sitona lineatus*) were found on soybeans in the conditions of the Kaluga region among pests. It has been noted that weevils cause particular harm to soybean plants. Both beetles and larvae are dangerous. As a result of the research, the economic threshold of harmfulness of sitona weevils of the genus *Sitona* on soybeans was determined – 30 pcs/m^2.

Weather conditions, especially air temperature, are known to have a significant impact on the development of phytophagan insects. Thus, the growing season of 2015 was characterized by high temperatures and lack of precipitation. The air temperature in all decades was higher than the average annual values by 2.6-3.2°C, which negatively affected the development of cultivated plants. During this period, the following pests were identified on soybean crops during route surveys: sitona weevil and blue flea beetles, pea thrips, tarnished plant bugs, dusky stink bugs, and spider mite. The calculations carried out during the phase of intensive soybean growth showed that the number of spider mites – the average number of larvae, nymphs, and imagos per leaf, increased from 22.3 to 33 pieces within two weeks.

Sitona weevils *(Sitona crenitus, Sitona lineatus)* and blue flea (*Phyllotreta undulate)* caused the greatest harm at the beginning of the growing season – during the soybean germination phase. The percentage of leaf damage by sitona weevil in soybean varieties ranged from 15.4-16.0% in Okskaya and Svetlaya varieties, and up to 19.4% in Mageva variety. The highest percentage of leaf damage by cruciferous flea was observed in soybeans of the Svetlaya variety. To a lesser extent, the Okskaya variety was damaged by beetles during the germination phase.

Pea thrips (*Kakothrips robustus*) in crops was found during soybean flowering phase.

It was found that damage to plants by pea thrips reduces the assimilation surface of leaves by half, and seeds are not formed on damaged plants. The damaged leaves had an uneven yellowish-white color, dark discharge of thrips was observed on the leaf underside, the leaves quickly dried up and fell off.

Plants damaged by thrips were found in foci. No foci of pea thrips were found on the plots

of the Okskaya soybean variety (Table 1).

The economic threshold for the harmfulness of pea thrips is 1 imago per 2 flowers or 2 larvae per 1 flower.

Table 1. The effect of pea thrips on the development of soybean plants, 2020.

Indicator / Option	Control	Pea thrips
Mageva variety		
1. Leaf area, cm^2/plant	471	239.5
2. Leaf damage, %	0	100
3. Seed damage	0	No seeds
Okskaya variety		
1. Leaf area, cm^2/plant	567	0
2. Leaf damage, %	0	0
3. Seed damage	0	0
Svetlaya variety		
1. Leaf area, cm^2/plant	560	389.7
2. Leaf damage, %	0	100
3. Seed damage	0	No seeds

According to our observations, the number of larvae exceeded the economic threshold of harmfulness and amounted to 5 larvae per 1 flower.

During the seed filling phase, a survey of crops was conducted, as a result of which damage to soybean seeds by tarnished plant bug (*Lygus pratensis L.*) was revealed.

Damage to seeds by the tarnished plant bug was observed in plants of all soybean varieties, but plants of the Mageva variety were more damaged – 32.0%. The tarnished plant bug carries viral diseases.

The following pests were identified in soybean crops during the growing season of 2015 during accounting and route surveys: beetles of the sitona weevil of the genus *Sitona*, steelworm caterpillars (*Pyrrhia umbra L.*), willow Semiothisa notata caterpillars (*Semiothisa alternate Hb.*), nymphs of the pentatomid rape bug (*Eurydema oleraceae L.*), of the berry dusky stink bug (*Dolicoris baccarum L.*), of the sorrel bug (*Coreus magrinatus L.*) (Table 2).

During the bean formation phase, the crops were examined, as a result of which damage to soybean seeds was revealed by alfalfa worm. Older caterpillars gnaw out large holes in the beans, through which they eat the seeds.

Table 2. Species composition of soybean pests in the Kaluga region.

Insect Class, Order	Representatives
1. Coleoptera	Bristly sitona weevil – *Sitona crenitus Hrbst.;* Pea leaf weevil – *Sitona lineatus Hrbst.;* Blue flea – *Phyllotreta undulate Kutsch.;* Light chafer – *Anomala luculenta Erichson;* Garden chafer – *Phyllopertha horticola L.*
2. Hemiptera	Tarnished plant bug – *Lygus pratensis L.;* Sorrel bug – *Coreus magrinatus L.;* Berry dusky stink bug – *Dolicoris baccarum L.;* Pentatomid rape bug – *Eurydema oleraceae L.*
3. Thysanoptera	Pea thrips – *Kakothrips robustus Uzel.*
4. Lepidoptera	Antique tussock moth – *Orgyia antique L.;* Willow Semiothisa notata – *Semiothisa alternate Hb.;* Alfalfa worm – *Heliothis viriplaca Hufn.;* FIeld moth – *Mesapamea secalis L.;*

	Steelworm – *Pyrrhia umbra L.*; Ehistle lady –*Vanessa cardui L.;* Pod borer (lima-bean) – *Etiella zinckenella Tr.*
Class Arachnids, Order Mites	Spider mite – *Tetranychus urticae C.L.Koch.*

Source: Compiled by the authors.

During the harvest, it was revealed that one fifth of all beans were damaged by alfalfa worm – *Heliothis viriplaca Hufn*. The prevalence of alfalfa worms in the experiment was 80%. Crop losses amounted to 20% (Figure 1).

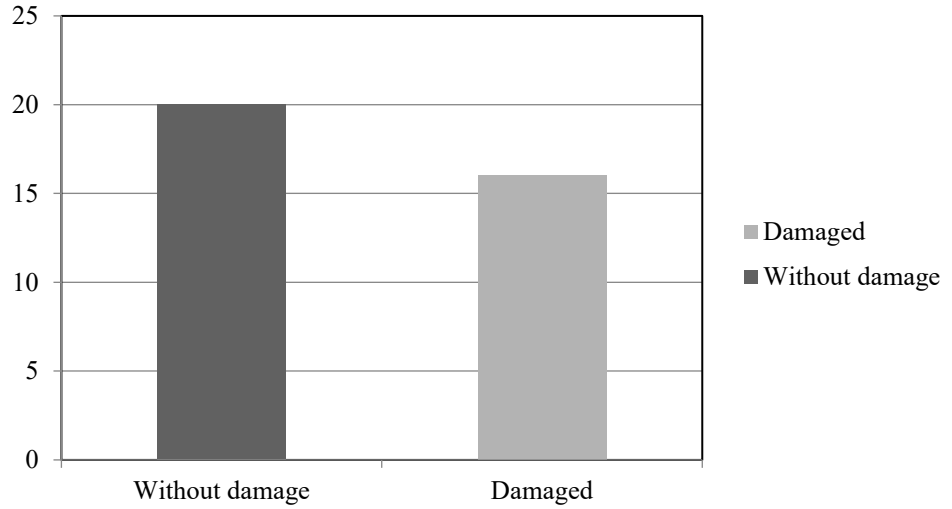

Fig. 1. Soybean seed yield depending on alfalfa worm damage, kg/ha. LSD_{05} – 3.4 kg/ha.

The harmfulness of pathogens is well known. Crop losses from fungal diseases in some years can reach 50-60%. Losses from viral pathogens reach 100%.

During the research in the Kaluga region, diseases such as fusariosis *(Fusarium sp).*, downy mildew (*Peronospora manshurica),* ascochytosis (*Ascochyta sojacola)*, growth retardation virus (*Soybean stunt virus),* strawberry wither tip virus – (*Strawberry virus 2),* southern bean mosaic virus (***SBMV)*** were identified. Some of the research was conducted on an artificial background. It was noted that in a small number of fungi of the genus *Fusarium sp.* they are able to stimulate the development of soy nodules. But, if the infectious load is increased, the number and mass of nodules decreases by 1.5-7 times.

During the research, we noted that soybean plants are strongly affected by peronosporosis on a fusarium background. There were no affected plants in the control variant.

The peronosporosis causative agent – *Peronospora manshurica* reduces the yield of soybean seeds by 2.5 times (Figure 2).

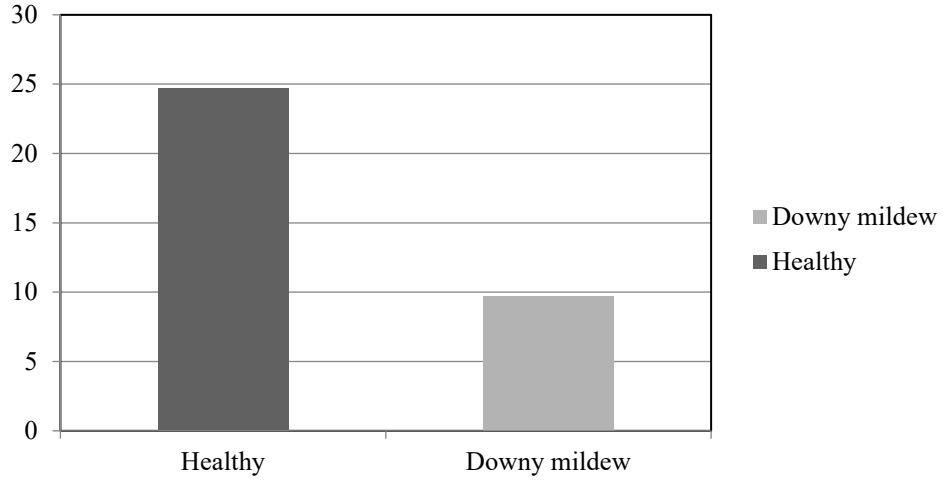

Fig. 2. Yield of soybean seeds depending on the peronosporosis lesion, kg/ha. LSD_{05} – 2.7 c/ha.

There were no affected plants in the control variant. But peronosporosis affects soybean plants not only on an infectious background. In the humid summer of 2017, the prevalence of peronosporosis in soybean crops was 33%. The yield of soybean seeds in crops infected with peronosporosis reached 9.7 c/ha – 39.3% of the yield of unaffected plants.

In the 2015 field experiment and in the 2015-2020 vegetation experiments, a growth retardation virus (GRV) was detected on a fusarium background on soybeans. The death rate of soybean plants affected by the virus was 100% [4].

Viral diseases such as wild strawberry wither tip and growth inhibition were detected in soybean crops of the Mageva variety. Plants infected with the southern bean mosaic virus have been identified in soybean crops of the Svetlaya variety.

Soybean plants of the Mageva and Svetlaya varieties affected by viral infection significantly reduce biometric indicators – plant height by 5-6 cm, leaf area by 1.4-2 times (Table 3).

Table 3. Effect of viral infection on soybean leaf area, 2015.

Option / Indicator	Mageva		Svetlaya	
	Healthy	Damaged	Healthy	Damaged
1. Plant height, cm	27	22	29	23
2. Leaf S, cm^2/plant	471	239.5	560	389.7

The number and mass of nodules when infected with viruses decreases – the number – by 1.6–1.7 times, the mass – by 1.3-1.5 times.

The yield of seeds affected by soybean plant viruses decreases in both the Mageva variety and the Svetlaya variety by 1.8 times [4] (Figure 3). Such indicators as plant height are also decreasing: in the Mageva variety – by 44%, in the Svetlaya variety – by 29%. The number of beans per plant is reduced by 1.8 times.

The number of seeds decreases by varieties by 1.7-1.8 times.

Table 4. Number and weight of nodules depending on the lesion by viruses.

Option / Indicator	Mageva		Svetlaya	
	Virus	Healthy	Virus	Healthy
1. Number of nodules, pcs/plant	32.7	53.7	35.5	61.0
2. Nodule weight, g/plant	1.48	2.2	1.95	2.6

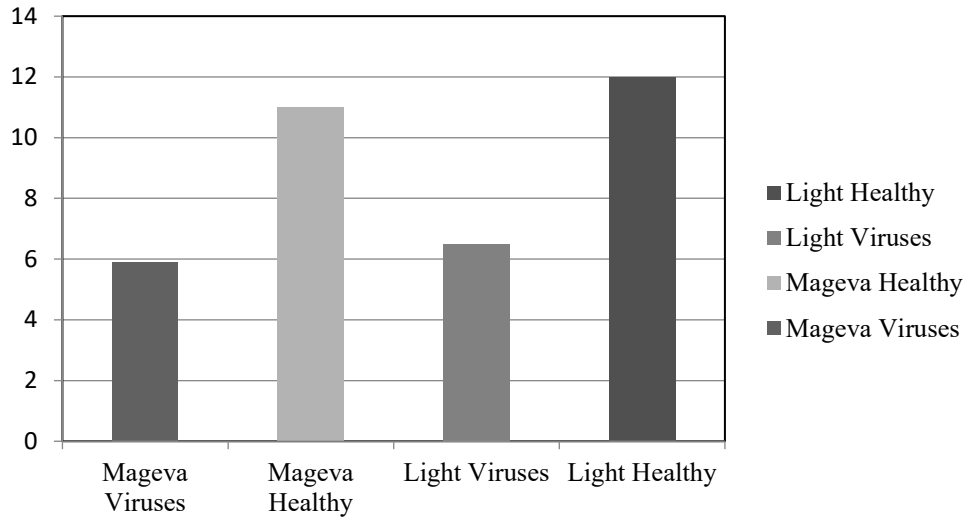

Fig. 3. Soybean yield depending on viral infection, c/ha.

4 Discussion

Soybean varieties of the northern ecotype have been zoned in the Kaluga region since 1987. Soybean can be quite a competitive leguminous crop in the Kaluga region. Soy plants – rich in protein are quite attractive for various harmful objects not only in areas of traditional soybean cultivation, but also in the Non-Chernozem zone. The species composition of organisms harmful for soybean is strongly influenced by biotic and abiotic environmental factors.

Kovalenko T.K., Lukashenko A.V. [13] note that in the conditions of the Primorsky Territory, the main damage to soybean crops from the group of omnivorous pests is caused by the steelworm – *Pyrrhia umbra L.,* alfalfa worm – *Heliothis viriplaca Hufn.,* lima-bean pod borer – *Etiella zinckenella* with 2-4 caterpillars per 10 strokes of the net [13]. The same work species were identified in soybean crops of the northern ecotype in the Kaluga region. The prevalence of alfalfa worms in our experiment was 80%, and crop losses were 20%. Types of specialized soybean pests, such as soybean pod borer – *Leguminivora glycinivorella Mats.*, striped soybean leaf beetle – *Paraluperodes suturalis nigrobilineatus Motsch.*, soybean aphid *Aphis glicines Mats*., were not found in the Kaluga region.

In the Orel region, soybean seedlings are harmed by weevils, caterpillars of cut worms and meadow moths, and in the conditions of the Kaluga region, according to our observations, these pests have not been noted. In the Kaluga region, nodule weevils *(Sitona crenitus, Sitona lineatus)* and blue flea (*Phyllotreta undulate) cause the greatest harm during the germination phase.* The percentage of leaf damage by sitona weevil in soybean varieties was 15...16% in Okskaya and Svetlaya varieties and up to 19% in Mageva variety. As a result of

the research, the economic threshold of harmfulness of sitona weevils of the genus Sitona on soybeans was determined – 30 pcs/m^2. The highest percentage of leaf damage by cruciferous flea was observed in soybeans of the Svetlaya variety. To a lesser extent, the Okskaya variety was damaged by beetles during the germination phase.

When conducting research in conditions of elevated temperatures of the growing season in 2002, we identified pea thrips (*Kakothrips robustus UzeL.*), the number of larvae of which exceeded the economic threshold of harmfulness and amounted to 5 larvae per 1 flower. In the same year, severe damage to soybean seeds by tarnished plant bug (*Lygus pratensis L.*) was observed in the Mageva variety – 32.0%. In the conditions of the Kaluga region, the sorrel bug – *Coreus magrinatus L.,* the dusky stink bug - *Dolicoris baccarum L.,* the pentatomid rape bug - *Eurydema oleraceae L. were also identified.* In the conditions of the Primorsky Territory, according to Kovalenko T.K., Lukashenko A.V. [7, 208-211], in soybean agrocenoses, 2 species of dusky stink bugs (Hemiptera, Pentatomidae) were noted in single specimens: sloe bug *Dolycoris baccarum* L., bright green shield bug *Palomena viridissima* Poda, and tarnished plant bug *Lygus pratensis* L. (Miridae)

5 Conclusion

Studies conducted in soybean crops of the northern ecotype in the conditions of the Kaluga region have established a complex of pests and diseases, which is somewhat different from the complex of harmful objects of traditional cultivation areas of this crop. The species diversity of harmful objects is determined by climatic, environmental, and anthropogenic factors. The main insect pests of soybeans of the northern ecotype are represented by orders of Coleoptera, Lepidoptera, Hemiptera, Thysanoptera. The arachnid class is represented by the spider mite (Tetranychus urticae).

The main pathogens affecting soybean varieties of the northern ecotype are fungi of the genus Fusarium sp., Peronospora, Ascochyta; viruses – growth retardation virus, southern bean mosaic virus, strawberry wither tip virus.

The conducted studies allow to conclude that in the conditions of the Kaluga region at this stage a certain complex of harmful organisms has been formed that reduce the productivity of soybean plants.

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