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# INNOVATIONS ON SCIENTIFIC SUPPORT OF PLANT BREEDING FOR RESISTANCE AGAINST DISEASES AND PESTS

**Goal.** *Database formation of innovations in the scientific support of plant breeding for resistance against pathogens and pests — grounds for creating sustainable varieties.* **Methods.** *Analysis of innovative development of the Institute of Plant Protection of the National Academy of Agrarian Sciences of Ukraine and other institutions of the Scientific and Methodological Center «Protection of Plants» for 2006—2020. Isolation of those relating to the problem of plants' resistance against pests and pathogens.* **Results**. *Methods of plant selection for resistance against the main pathogens and methods of evaluation of resistance of winter wheat, potatoes, clover and alfalfa to pests to create complex resistant varieties have been developed. Donors of potato resistance to canker, alternariosis, phomosis and cyst-forming nematodes were identified. Methods for determining the resistance of cereals to high and low temperatures have been developed. A collection of samples of wild relative of wheat Aegilops biuncilais L. — sources of new genes for plant resistance to diseases and pests. Genes of resistance of soft winter wheat to diseases by DNA markers have been identified. A set of varieties of winter wheat with group and complex resistance against diseases and pests has been formed. Physiological and biochemical mechanisms of resistance of sunflower, soybean, flax oil against pathogens have been established. Collections of sunflower lines based on complex resistance to sunflower broomrape, dry rot, powdery mildew and soybean lines based on complex resistance to white rot and anthracnose have been created. The resistance of forage lupines against the most important pathogens has been studied. Varieties and selection numbers of spring barley, oats, rape, oilseed flax, resistant to major diseases, as well as rice varieties resistant against pathogens and pests were identified. The resistance of modern genotypes of sown hemp, fiber flax and oilseed flax to the main phytophagous insects was evaluated. A method for estimating the selection value of the source material of the main vegetable plants on the basis of disease resistance has been developed. Resistance to viral diseases has been found in cucumber and barley plants.* **Conclusions.** *The established innovations can be widely used by breeding centers and other*

*scientific institutions of the agrarian profile when creating sustainable grain, oilseed, vegetable, fodder and leguminous grain crops. In this case, the timing of the selection process can be accelerated by 40—60%.*

**crops; pests; pathogens; diseases; resistance**

Today in Ukraine the yield of agricultural crops is 2—3 times lower than in developed countries. The main reason for this shortcoming is the non-compliance of manufacturers with technology. After all, the genetic potential of the main varieties and hybrids of plants is used on average only at the level of 30%. An important element of compliance with the technology of growing crops, including cereals, is the implementation of protective measures against pests, diseases and weeds [1].

Over the last 25—30 years, the forms of farming and, at the same time, the technology of growing crops have changed dramatically in Ukraine. The 8- and 10-field crop rotations were replaced by 3—4-field crop rotations, ie the period of crop rotation in crop rotation was halved. The cultivation of vegetables and potatoes moved to the private sector, where compliance with the necessary rotation of crops and spatial isolation became impossible [2].

Of particular importance in this situation is the system of integrated plant protection. The most cost-effective and environmentally friendly in this protection system is the use of damage-resistant varieties and hybrids, taking into account the objects against which these features are directed, as well as the level of resistance. Thus, in highly resistant varieties, the reproduction of pests and the spread of pathogens can be restrained even under conditions that promote their development. Medium-resistant varieties can resist pests only with a weak and medium degree of reproduction. At mass emergence of pests or epiphytic development of diseases on such crops it is necessary to apply in addition means of protection, but thus norms of the expense of pesticides and quantity of processings can be reduced [3].

According to the literature, the use of resistant varieties of winter wheat can simplify the technology of growing crops, reduce the use of pesticides by 30—35%, while increasing yields by 0.4—0.5 t/ha, and gross grain harvest even by 50% sown areas — by 2,5—3 million tons per year. On the protection of potatoes from the Colorado potato beetle under such conditions, savings on pesticide costs can reach UAH 50 million per year [4].

Despite the great achievements of selection, the available pest-resistant varieties of crops are still extremely insufficient. In addition, there are many weaknesses in the strategy of breeding such varieties. One of the reasons for this lies in the lack of comprehensive databases of innovative developments on the issues of scientific support of the selection process.

***Goal of the work*** was to form a database of innovations for scientific support of crop selection for resistance to pathogens and pests, which could be the basis for the creation of resistant varieties.

***Research methodology.*** The materials for the study were innovative developments of the Institute of Plant Protection of the National Academy of Agrarian Sciences of Ukraine and other institutions of the Scientific and Methodological Center «Plant Protection» for 2006—2020. Of these, those related to the problem of crops' resistance against pests and pathogens were taken. Subsequently, these innovations were analyzed to determine their role in the selection process.

***Research results.*** Working on the research program «Plant Protection», the Institute of Plant Protection and other institutions of the National Academy of Agrarian Sciences of Ukraine were involved in creating innovations in plant protection. Based on the analysis of the work performed during 2006—2020, a database of innovative developments in plant protection in Ukraine was formed. This database consists of more than 400 innovative developments, of which more than 50 are directly related to scientific support for the selection of agricultural crops for resistance to diseases and pests.

The Institute of Plant Protection of NAAS has developed methods of plant selection for disease resistance, which take into account the availability of a database of species and racial composition of major pathogens of wheat, barley, rape, mustard, tomatoes in different soil and climatic zones of Ukraine, a database of virulence genes of pathogens, a database of known crop resistance genes, methods of creation and application of complex artificial infectious backgrounds for selection of wheat for group resistance. Databases of effective genes for resistance of wheat to the local population of leaf rust pathogen, sources of resistance of winter and spring wheat to leaf rust, *Septoria* disease, powdery mildew, covered smut and spring barley to powdery mildew, covered and black smut were created and transferred to the National Center of Plant Genetic Resources of Ukraine. The use of available databases will create a gene pool of resistant plant forms, reduce the cost of finding sources of resistance by 40% and promptly involve the most effective resistance genes in the selection process, as well as remove inefficient resistance genes.

The juvenile resistance of samples of perspective lines of initial links of selection of winter wheat to pathogens of leaf rust, powdery mildew, *Septoria* disease, *Cercosporella* root rot has been investigated. There are numerous databases: 1 — sources of wheat resistance to local populations of pathogens of leaf rust, powdery mildew and *Septoria* disease in the Northern Forest-Steppe zone of Ukraine; 2 — varieties of winter common wheat of Ukrainian selection by allelic states of genes of resistance to fungal pathogens; 3 — effective genes for resistance of wheat to the pathogen of leaf rust; 4 — the racial composition of the population of the causative agent of leaf rust in wheat; 5 — virulence genes of leaf rust pathogen in wheat. Recommendations for identifying sources of resistance of wheat to local populations of leaf rust, powdery mildew and *Septoria* disease in the Northern

Forest-Steppe zone of Ukraine, as well as determining the epidemiological status of the population of leaf rust (wheat structure and variability) [5, 6].

A lot of attention is focused on the issues of resistance of potatoes against nematode diseases — nematodosises. For this purpose, in 2011—2015, about 1500 variety samples from 6 breeding institutions of Ukraine were tested, of which 1150 were resistant to globoderosis (the pathogen is *Globodera rostochiensis* Woll.) [7]. Out of 22 cultivar samples in field (state) tests, 17 showed resistance to this disease. In relation to ditelenchosis (the pathogen is Ditylenchus destructor Thorne), 1 resistant variety (Povin) and 17 relatively resistant ones were found.

The method of using the mechanisms of resistance of agricultural plants to pests for the creation of complex resistant varieties has been developed. Its components are as follows: field evaluation of resistance of breeding material and varieties of winter wheat, potato, clover and alfalfa against major pests; availability of winter wheat cultivars with group resistance against pests, potato cultivars and hybrids resistant to the Colorado potato beetle and wireworms, clover cultivars of different species resistant to apion weevil and meadow bugs, and alfalfa cultivars of domestic and foreign selection against the main pests of generative organs. There is a database of field evaluation of the level of resistance of winter wheat varieties to the main pests — corn bugs, corn thrips, aphids, cereal flies, cereal leaf beetles, *Anisopia austriaca* beetles, cephids. The purposefulness of wheat selection is indicated: 1) resistance to shedding — resistance to cereal leaf beetles and *Anisopia austriaca* beetles; 2) resistance to lodging — resistance to cephids. According to the results of joint research with the Myronivka Institute of Wheat named after V.M. Remeslo and Institute for Potato Research of NAAS published collective monographs «Metodolohiia otsiniuvannia stiikosti sortiv pshenytsi proty shkidnykiv ta zbudnykiv khvorob [Methodology for evaluating the resistance of wheat varieties against pests and pathogens]» (2010) and «Metodolohiia otsiniuvannia sortozrazkiv kartopli na stiikist proty osnovnykh shkidnykiv ta zbudnykiv khvorob [Methodology for evaluating potato varieties for resistance against major pests and pathogens]» (2013).

A database on the resistance of maize hybrids against major pests has been created. It presents 9 hybrids of Ukrainian selection and 2 foreign hybrids for all types of resistance — antixenosis, antibiosis, tolerance and evasion.

A collection of samples of the wild relative of wheat *Aegilops biuncilais* L., which are sources of new genes for plant resistance to diseases and pests, has been compiled. The directions of optimized use of the gene pool of pathogens resistant to pathogens and pests of soft wheat in breeding programs are developed: 1) molecular-genetic labeling of the characteristic collection of the gene pool represented by varieties — donors and sources of resistance to pathogens; 2) the presence of genetic diversity by loci of reserve

proteins of varieties from the world collection of wheat and identified genes for resistance to pathogens of certain diseases; 3) entry in the information database of the gene pool of wheat varieties of domestic selection of genetic formulas of 90 newly created varieties by loci of spare proteins. There is also information on genotypes by molecular markers of potato resistance genes to the golden potato cyst-forming nematode. It allows to increase the efficiency of plant breeding for resistance to pests and diseases by 60%.

Scientists of the Ukrainian Scientific-Research Quarantine on Plants Station of the Institute of Plant Protection of the NAAS have developed effective laboratory and field methods for assessing the resistance of potato breeding material to *Alternaria* and *Phoma*. Potato varieties of domestic selection resistant to alternariosis (Skarbnytsia, Fantaziya, Luhivska, Slovianka, Yavir) and relatively resistant to phomosis (Bernina, Madison, Myroslava, Solita) were identified.

A system for improving the health of potato plants has also been developed, and a bank of differentiating varieties of potato canker pathotypes and species and races of cyst-forming nematodes has been created. Donors of potato resistance to the pathogen of canker (Bozhedar, Santarka, Shchedryk, Slovianka, Zabava, Serpanok, Bazis, Fantaziya, Chervona Ruta varieties) and to nematodes (Slovianka, Vodogray, Partner, Chervona ruta) were identified.

Inheritance of potato resistance to canker can be carried out by PCR-analysis of DNA. Thus, real-time PCR-diagnosis of potato canker DNA allows: 1) detection and quantitative determination of potato canker DNA in susceptible potato samples; 2) determine the relative fluorescence from 25 to 350; 3) identify the pathogen of cancer in the early stages of the disease. At the same time, it is possible to obtain real results about the presence or absence of potato canker DNA in the studied samples during a short period of time and to determine the inheritance of potato canker resistance within 2 days.

Methodological recommendations for determining the resistance of cereals to high and low temperatures have been issued. They indicate the optimal temperatures and incubation times to determine the frost resistance of winter barley and wheat and heat resistance of barley; the method of determining the leakage of electrolytes is cited. It is indicated that the use of biological preparation Reglalg for pre-sowing seed treatment and subsequent treatment of plants during the growing season helps to increase the level of plant resistance to the negative effects of abiotic factors and pathogens of fungal diseases and at the same time — increase yields.

According to the results of numerous studies conducted by scientists of the Myronivka Institute of Wheat named after V.M. Remeslo NAAS during 2016—2020, stable samples were selected among 203 collection numbers of winter wheat on separate artificial infectious backgrounds of pathogens,

group resistance to diseases was revealed among 86 numbers of MIW selection, separated among varieties of Ukraine from different varieties from Ukraine 164 samples on resistance to the main pathogens, 2239 lines of initial selection links were investigated on artificial infectious backgrounds of pathogens and stable ones were selected among them. A set of varieties of winter wheat with group and complex resistance to diseases and pests has been formed. 220 constant disease-resistant lines of the breeding nursery of the plant protection department were transferred to the laboratory of winter wheat breeding for further research and 20 lines — to the National Center for Plant Genetic Resources of Ukraine.

The Institute of Oilseed Crops of NAAS has established physiological and biochemical mechanisms of sunflower, soybean, flax oil resistance to pathogens of major diseases. The basics of creating sunflower varieties and hybrids with complex resistance to sunflower broomrape and powdery mildew are scientifically substantiated — this is a fundamentally new method of evaluating sunflower resistance to sunflower broomrape in laboratory conditions, analysis of the immunological variability of the collection and selection of variety samples with signs of complex resistance to powdery mildew of all forms of manifestation and sunflower broomrape, detection of aggressive races of sunflower broomrape, application of modernized infectious artificial background to the main pathogens. Collections were created: 1) sunflower lines based on complex resistance to sunflower broomrape, dry rot, powdery mildew; 2) soybean lines based on complex resistance to white rot and anthracnose. Methodological recommendations have been developed for the creation of effective methods for selecting sunflower and soybean lines with a high level of resistance to a complex of major diseases.

Genes of resistance of common winter wheat to diseases by DNA markers have been identified at the Institute of Plant Production named after V.Ya. Yuryev of NAAS. Thus, 10 culture samples were identified by the IB—267 marker for the leaf rust resistance gene Lr26, wheat-rye translocations (1RS of rye chromosome) were detected in 9 wheat samples, and a catalog of genetic value of common winter wheat varieties with identified DNA markers was formed. It can be successfully used in breeding work.

The National Science Center «Institute of Agriculture NAAS» studied the resistance of forage lupines and soybean to the main pathogens. At the same time, a gene pool of resistant forms was created by the method of assessing the damage of collection samples and selection material on infectious backgrounds, selection numbers of lupine resistant to fusarium wilt and viral narrow-leaf disease and sources of soybean resistance to a complex of diseases (bacteriosis, viruses, mycosis) were identified, and the racial composition of the main pathogens was established.

The Institute of Agriculture of the Carpathian Region of NAAS identified sources of resistance of agricultural crops to major diseases, namely:

1) the least affected potato varieties to pathogens of late blight and dry rot; 2) the least affected varieties of fiber flax to the pathogens of anthracnose, fusarium wilt and fusarium browning; 3) breeding numbers of oats with increased resistance to crown rust and helminthosporiosis; 4) highly resistant to powdery mildew, leaf spot, dwarf and covered smut varieties of oats; 5) winter wheat varieties are relatively resistant to *Septoria* disease and fusariose head blight; 6) cultivars of spring barley with high resistance to powdery mildew, striped spot, brown, reticulate, dwarf rust, covered smut, crown rust and helminthosporiosis; 7) spring rape varieties resistant to downy mildew and phomosis.

At the Carpathian State Agricultural Research Station of the Institute of Agriculture of the Carpathian Region of the NAAS the resistance of oilseed cruciferous crops to pathogens of major diseases was evaluated. The strains of fungi that cause diseases were isolated in pure culture and identified: 1) alternariosis on leaves, stems and pods of winter rape and mustard plants; 2) phomosis on leaves and stems of winter rape; 3) sclerotiniosis on the stems of winter rape. This should be taken into account when carrying out selection work on the resistance of oilseed cruciferous crops to local populations of pathogens.

The Institute of Rice of NAAS studied the immunological properties of varieties and varieties of rice. At the same time, varieties and cultivars resistant to pathogens and major pests were identified [8].

At the Institute of Agriculture of the North-East of the NAAS research was conducted on the resistance of modern genotypes of hemp seed, fiber flax and oilseed flax to the main phytophagous insects. Thus, it was noted that the Globa hemp seed variety is significantly less damaged by hemp flea beetles, and also has the highest level of resistance to the main pests. On the other hand, oilseed flax varieties were damaged 1,3 times more than fiber flax varieties due to the larger area of the leaf apparatus and plant foliage and high juiciness.

The Institute of Vegetables and Melons of the NAAS has developed a methodology for evaluating the breeding value of the raw material of the main vegetable plants based on disease resistance. At the same time, the following possibilities are pointed out: 1) the use of various mathematical and statistical methods for more effective evaluation and selection of resistant source material under the conditions of various infectious backgrounds; 2) creation of a package of computer programs for the expert evaluation of the results of phytoimmunological studies in vegetable production, which includes the following modules: «Analysis of a small number of variation series», «Analysis of the results of a one-factor experiment by the method of dispersion analysis», «Analysis of the results of the experiment by the method of correlation analysis», «Analysis results of the experiment by the method of regression analysis».

The Institute of Agroecology and Environmental Management and Myronivka Institute of Wheat named after V.M. Remeslo of NAAS also carried out a significant amount of research work on the detection of resistance to viral diseases in agricultural plants and the creation of resistant and tolerant varieties. At the same time, the presence of cucumber green mottle mosaic virus (CGMMV) in cucumber plants of greenhouse farms in different regions of Ukraine, and the presence of viral antigens in tomato and pepper plants were indicated. The tolerance of winter wheat cultivars was evaluated based on the analysis of plant productivity under the influence of the barley yellow dwarf virus. According to the results of the diallel analysis of the inheritance of tolerance to CGMMV, wheat genotypes with high general and specific combining ability for this trait were found, but a different nature of the inheritance of tolerance was noted depending on the characteristics of the genotypes of the variety samples.

## CONCLUSIONS

A significant part of the innovative developments of the Scientific and Methodological Center «Plant Protection» headed by the Institute of Plant Protection of NAAS concerns the issues of scientific support of selection for resistance of agricultural crops to pests and pathogens. They can be widely used by breeding centers and other scientific institutions of an agrarian profile in the creation of stable varieties of grain, oilseed, vegetable, fodder crops, potatoes, fiber flax. In this case, the timing of the selection process can be accelerated by 40—60%.

The introduction of resistant varieties in the production will significantly solve the problems of plant protection from pest organisms and at the same time increase the yield of crops. This will further strengthen the agricultural sector of Ukraine's economy and improve the welfare of the population.

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**Інновації з наукового забезпечення селекції рослин на стійкість проти хвороб та шкідників**

**Мета**. *Сформувати базу даних інновацій з наукового забезпечення селекції рослин на стійкість проти збудників хвороб та шкідників — підстави для створення стійких сортів.* **Методи**. *Аналіз інноваційних розробок Інституту захисту рослин Національної академії аграрних наук України та інших установ Науково-методичного центру «Захист рослин» за 2006—2020 рр. Виділення тих із них, що стосуються проблеми стійкості рослин проти шкідників та збудників хвороб.* **Результати.** *Розроблено методи селекції рослин на стійкість проти основних збудників хвороб та методику оцінювання стійкості пшениці озимої, картоплі, конюшини й люцерни проти шкідників для створення комплексно стійких сортів. Виявлено донори стійкості картоплі щодо збудників раку, альтернаріозу, фомозу та цистоутворюючих нематод. Розроблено методики визначення стійкості зернових до високих та низьких температур. Складено колекцію зразків дикого родича пшениці Aegilops biuncilais L. — джерел нових генів стійкості рослин проти хвороб та шкідників. Ідентифіковано гени стійкості пшениці м'якої озимої проти хвороб за ДНК-маркерами. Сформовано набір сортозразків пшениці озимої з груповою та комплексною стійкістю проти хвороб та шкідників. Встановлено фізіологічні та біохімічні механізми стійкості соняшнику, сої, льону олійного проти збудників хвороб. Створено колекції ліній соняшнику за ознакою комплексної стійкості проти вовчка, сухої гнилі, несправжньої борошнистої роси та ліній сої за ознакою комплексної стійкості проти білої гнилі та антракнозу. Досліджено стійкість кормових люпинів проти найголовніших патогенів. Виявлено сорти та селекційні номери ячменю ярого, вівса, ріпаку, льону-довгунця, стійкі проти основних хвороб, а також сортозразки рису, стійкі проти збудників хвороб та шкідників. Оцінено стійкість сучасних генотипів конопель посівних, льону-довгунця та льону олійного проти основних комах-фітофагів. Розроблено методику оцінювання селекційної цінності вихідного матеріалу основних овочевих рослин за ознакою стійкості проти хвороб. У рослин огірка й ячменю виявлено стійкість проти вірусних хвороб.* **Висновки.** *Створені інновації можуть широко використовуватись селекційними центрами й іншими науковими установами аграрного профілю при створенні стійких сортів зернових, олійних, овочевих, кормових культур, картоплі, льону-довгунця. При цьому терміни здійснення селекційного процесу можуть бути прискорені на 40—60%.*

**сільськогосподарські культури; шкідники; збудники хвороб; стійкість**

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