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SPRING BARLEY RESISTANCE TO THE MOST WIDESPREAD DISEASES IN UKRAINE: BREEDING AND GENETICS ASPECTS

To the memory of my teacher, an outstanding breeder and an academician, Procopiy Fomich GARKAVYI is devoted

The problems of barley breeding for resistance to the most widespread diseases in Ukraine are discussed. The results of long-term studies on harmfulness of some diseases, genetics of resistance, the characterization of effective donors, the breeding methods and the results of developing the varieties with complex resistance to the diseases have been discussed.

Key words: *smut diseases, powdery mildew, barleystripe, netblotch, brown rustvirus, scald, barley yellow dwarf virus, yellow mosaic virus, harmfulness, genetics of resistance, plant breeding, grain quality.*

Introduction. The spring barley varieties developed at the Plant Breeding and Genetics Institute (PBGI)are grown almost on 70 % of the area under this crop in Ukraine and Moldova, and about on 14 % in the Russian Federation. The major stability factor of barley grain production is the resistance of commercial varieties to pathogens of infectious diseases; therefore development of such varieties is traditionally the main objective of our breeding work. The old varieties developed at the institute between the thirties and the seventies of the last century were affected by smut, powdery mildew, rust, barley stripe and netblotch, but the varieties developed over the last 40 years are characterized by a genetically controllable resistance to the diseases. The varieties are resistant to lodging, more responsive to fertilizers; under the conditions of insufficient moisture supply in the south of Ukraine they better than other varieties realize high indexes of the potential yield and the quality of grain meant for forage and brewing beer.

Such results were reached by a purposeful systematic breeding work in the following directions: the study of specific and racial structure of the disease pathogens and their harmfulness; the creation of the infectious backgrounds and developing methods of artificial inoculation; the study of the genetics of the resistance as well as searching and developing reliable donors of resistance, development of special breeding methods.

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History and the present. Since the early thirties of the last century Prokofiy Fomich Garkavyi begun his research activity in Odessa at the Ukrainian Plant Breeding and Genetics Institute. He was the pupil of two outstanding scientists of the last century — Andrey Afanasievich Sapegin and Nikolay Ivanovich Vavilov. The stage of scientific plant breeding has begun. For the first time in Ukraine the method of hybridization with the use of ecologically distant genotypes was used. At the same institute A. A. Sapegin for the first time in the world developed and began to apply the method of «variety repairing» [1]. Later on American scientists Harlan H. V. and Pope M. N. called it the method of backcrosses [2]. Such kind of research was offered by A. A. Sapegin to a young scientist P. F. Garkavyi in the preparation of his thesis. At the same time the *radiation*-induced *mutagenesis* began to be used, the important genetic studies on *growth habit*, resistance of plants to covered smut etc. were carried out. Various varieties of spring and winter barley meant for fodder, food and brewing for steppe and forest-steppe regions were developed.

The barley varieties developed by «the barley father of Soviet Union» P. F. Garkavyi over almost the time of half a century gradually occupied the major barley grown areas in Ukraine. Those varieties were also widely grown over the borders of our country: in Moldova, in the North Caucasus, in the Volga region, in the Ural Mountains region, in Kazakhstan, Kyrgyzstan, in the Far East. Over that period of time the yield capacity of barley varieties was more than doubled [3].

The smut diseases were considered as the most widespread and harmful among infectious diseases of cereal crops. To the middle of 19th century scientists considered smut fungi as the diseases of «degeneration» and called them «plague» [4–6]. In the beginning of the last century (1900–1914) in Russia only direct losses of grain from smut diseases were annually of 5682 thousand tons [7].

Thermal disinfection of seeds, sowing of cereal crops in early winter time and other practices were ineffective. Since the beginning of the 60's of the last century chemicals began to be applied. The most popular was Granosan, organic mercury-based preparation that was extremely toxic for people and animals.

In the 70's of the last century despite carrying out large-scale actions on chemical disinfection of seeds only direct losses of barley grain yield from loose smut were on the average of 14 % [8].

Currently, the chemical industry offers a variety of new, already «moderately toxic» preparations: Vitavax 200FF, Maxim Star, Vega, Styrax, Tebuzan Ultra and others.

The modern paleomycologists are of opinion that the pathogenic fungi including the smut ones which belong to the order of Ustilaginales appeared on the Earth 200–250 million years ago [9–11]. By the end of the 19th century in all the classifications the smut fungi were united under the name Ustilago carbo Tul. [12,13]. Later on A. Brefelda and N. I. Vavilov assumed that the smut fungi are *highly specialized species* [13,14]. The mycologists numbered about 900 species of smut fungi in the nature [7], but later on the assumption was disproved [15].

Material and methods. In Ukraine three species of barley smut diseases are spreaded: loose smut — Ustilago nuda (Jens.) Kell. et Sw., covered smut — Ustilago hordei (Pers.) Kell. et Sw., and false loose smut — Ustilago nigra (Tapke). The most widespread was considered loose smut.

The study of loose smut harmfulness which we carried out in the Steppe (Odessa, PBGI) and Forest-Steppe region (the experimental farm «Novoselovskoe» in Kotovsk district of Odessa region) revealed that the yield shortfall was due to the direct as well as the hidden losses. The hidden losses of two row barley varieties were 5–6 times more than direct ones, and six row varieties having maximum level of the direct losses of 3,2 % had the actual decrease in yield of 30 % and more comparing with the check variety. According to our observation such a high level of the hidden losses was caused by several factors: an increase in the rate of small seeds, a decrease in the field germination and tillring, a partial death of the plants during the growing season, a serious affect by some diseases [16].

An extensive study of a species and racial composition of the smut diseases began for the first time at the All-Union Research *Institute* of Plant Industry (VIR) in the beginning of 1960's by Prof. V. I. Krivchenko. Using the empirical testing sets the species and racial composition as well as the area of distribution of the smut diseases were determined; the methods of artificial inoculation were improved, the world collection was evaluated using an artificial inoculation; some entries resistant to smut were recommended to use in breeding [17].

A characteristic feature of biological reproduction of the smut fungi is their intraspecific and interspecific hybridization. Each new generation of the fungi is a complex heterogeneous population. As some species and physiological races of the smut fungi often parasitize in the tissue of the same plant the probability of the contact between them increases significantly, and therefore it plays a crucial role in the processes of race formation. It was proved that the virulence genes of the smut fungi hybrids were often identical and were inherited independently of other traits. It was assumed that false loose smut, which was described by V. E. Tapke in Canada in 1932, was the product of hybridization between loose and covered smut [15, 18–21].

False loose smut of barley is the pathogen with a dust-forming sorus therefore it is often confused with loose smut. In the stage of barley flowering the spores of the fungi fall on the ovary of the flower and then penetrates through the hull. The spores remain viable on the grain surface and even in the soil within 3–5 years. During this time a diploid parasitic mycelium is formed. This species considerably progresses and occurs in the populations of «dust-forming smut» in many regions of Ukraine, the Central Russia, Siberia and Kazakhstan [15, 21, 23–25].

According to our observations false loose smut on winter barley in Ukraine practically was completely replaced in the fungi population by covered and loose smut [20]. False loose smut affects 35 species of cultivated plants [15, 23]. In our studies (1981–1990) when 25 the most widespread barley varieties in Ukraine and Russia were inoculated with different smuts it was found that under the identical infectious load the infection rate of false loose smut was much higher than that of loose or covered smut [26].

Taking into account afore-mentioned as well as a high energy of reproduction and the migration ways of smut pathogens, it is necessary to acknowledge that a strategic direction of breeding for resistance to the smut diseases should be a complex resistance to all three smut species [27, 28].

The evaluation of the world collection of VIR revealed that the most number of entries resistant to the smut fungi was found among the local varieties from Ethiopia [17]. More detailed studies revealed that their resistance as a result of the associated evolution of a host plant and the pathogen is race specific and is inherited polygenicaly. Therefore, their use in the breeding program is quite problematic. In order to overcome the low productivity of the genotypes involved in the hybridization backcrosses and composite crosses should be used. But in this case there is always a jeopardy that the complex heterogeneous system of resistance will be «disintegrated» in the hybrid progeny into some weak genes and the resistance will be lost.

The universal representative of this group is a local variety from Ethiopia — Jet (k-18703, c. i. 967) which was introduced to Canada from the world collection of VIR in the early 1930's. In the beginning, in this variety one dominant gene of resistance designated as Un6 was identified. Later on, almost in 10 years, in the variety Jet one more gene — Un3 was revealed, and then some more genes of resistance to loose and covered smut were identified. D. L. Mumford and D. C. Rasmusson found out at Jet variety the reaction of «supersensitivity» that meant the following: when the first sprout with fungusmycelium in an apical cone perished completely from the node tillering a new tillers ratoon, however without parasitic mycelium [29].

Soon in Canada the first commercial varieties with resistance to loose smut were developed: Keystone (Un6), Paragon, Befarb, Kitchin, Bonanza, Conquest, Trent (Un3, Un6). Some similar varieties were also developed in the Western Europe: Harar (Italy), Djeddah, Emir (Netherlands), Edelmut (Germany) [30, 31].

The intensive searches of new sources of the resistance genes did not give positive results over many years. The resistance in the examined entries of the collection was identical to Jet variety or it was characterized by a weak immunological effect. Over 30 years the only donor of resistance was the barley variety Jet. Only in the end of 1960s in Canada in the entry of winter barley introduced from the Northern Caucasus (it was probably the variety Krasnodarskiy 2929), a dominant gene was identified which suppressed the infection of all loose smut races in America. At first, this entry was named «Russian», and later on «Milton». The gene was designated as Un8 [32].

The analysis of references and our own results of the long-term study of an array of resistant genotypes (tabl.) enabled us to draw the following conclusions:

– the racial composition of smut fungi in different regions is not identical; a considerable quantity of the identified genes of resistance appeared to be not effective to a «local» smut in Ukraine;

– the resistance of the variety Jet to the populations of different smut species is controlled by the complex polygene system. The resistance to «local» loose, false loose and covered smuts, unlike the Canadian species, is inherited conjointly;

– the resistance of c. i.13664 (the spring genotype, a derivative of the variety Milton) to all the smut species is controlled by one independent dominant gene Un8;

– the linkage of the identified genes with any marker morphological traits was not found, except Un1 gene on chromosome 7HS of the variety Trebi [33] and Un8 gene on chromosome 1HL of the variety Milton [29]. The chromosomal localization of other genes remains still unclear;

– the resistance reaction of the entries from the VIR collection, namely k-3282, к-8682, k-8855, k-8686, k-8692, k-8695, k-8709, k-8710, k-8721, k-8731, k-8761, k-20141, is identical to the reaction of the variety Jet. These entries cannot be considered as donors of new genes of resistance, but undoubtedly they need to be examined [25, 26, 30–32];

– we identified some new genes of resistance in the entries k-8728 (Ethiopia) and I-6823 (Turkey).

Testing these sources in other regions of Russia (some European locations, Siberia) confirmed the results of our studies. Prof. V. I. Krivchenko recognized these entries as the donors which are of «extremely high immunologic type». The lysis of mycelium begins already in an embryo stage, in the first stage of pathogenesis. The new dominant genes are not allelic to the gene Un8, and are inherited independently. These genes were designated as Un11 and Un12 [17, 31].

The use in plant breeding the resistance of embryonic type has big prospects because it is beyond the theory of «*associated* evolution». In this case we probably deal with a product of «divergent evolution». Such resistance is race specific and monogenicaly inherited; it is simply controlled, and that allows using in breeding backcrosses and composite crosses. The varieties developed with involvement of Un8 and Un12 genes keep resistance to the smut diseases over 40 years.

In the breeding program, which we began in 1972 under the guidance of P. F. Garkavyi, the variety Jet and the entry c. i. 13664 were used as donors of the resistance.

Table

The efficiency of barley resistance genes to loose smut (PBGI, 1974–1987)

Source of resistance genes	Author	Gene symbol	Susceptibility level and reaction type on artificial inoculation, %	
			Plants	Germs
Trebi	Livingston J. E., 1942	Un1	S до 80	60–70
Missuri	Livingston J. E., 1942	Un2	S до 80	50–70
Ogalitsu	Schaller C. W., 1949	**Un3**	R(S) 0–40*	20–50
Dorsset	Schaller C. W., 1949	Un4	S до 100	50–60
X173–10–5-6–1	Schaller C. W., 1949	Un5	S до 70	40–50
Keystone	Scoropad W. P., Johnson L. P., 1952	**Un6**	R(S) 0–30*	30–40
Conquest	Moseman J. G., Metcalfe D. R., 1969	**Un3, Un6**	R	30–50
Anoidium	Andrevs J. E., 1956	un7	S до 90	80–90
c. i. 13664	Metcalfe D. R., 1966	**Un8**	R	0
OAC-21–1	Kozera W., 1979	Un9	S до 70	50–60
OAC-21–2	Kozera W., 1979	Un10	S до 70	50–60
L-8728 (nutans)	Garkavyi P. F., Kirdoglo E. K., 1980	**Un11**	R(M) 0–10*	0–10
L-6823 (nutans)	Garkavyi P. F., Kirdoglo E. K., 1985	**Un12**	R	0

A note: R — absolute resistance, M — incomplete resistance, S-susceptibility.
* The degree of infestation changes depending on the race of the fungus.

Due to the fact that these primitive genotypes was characterized by low grain productivity and other negative traits to develop the breeding material resistant to smut and possessing a complex of other economically valuable traits using simple crosses was impossible. Therefore, we developed the method of discontinuous backcrosses [27, 28].

We controlled the transfer of the resistance genes in the hybrid progeny after each cycle of crosses by inoculation the seeds of F2 generation with the suspension of false loose smut spores and F2 plants with loose smut spores during flowering using the vacuum method. The discontinuous backcross allowed to obtain the desirable results. Within F2 plants a selection on morphological (approbation) traits of the recurrent variety was made; one ear from a plant was used for making a cross (backcross), and other two-three ears were inoculated by V. I. Krivchenko's methods. Then, by the resistance of F3 «female» lines only those plants of F1 BC^n were selected which were absolutely not affected by loose and false loose smut. Later on this method was approved and applied in other breeding institutions [17, 34].

For qiute a short time (1972–1976) using a greenhouse (that allowed to grow up three generations per year) the analogues of varieties Yuzhnyi, Chernomorets, Odesskiy 36, Odesskiy 69, Odesskiy 70, Nutans 244 resistant to smut were developed. In the sequel these lines were used as the secondary donors of the resistance. Simultaneously promising breeding lines with complex resistance to other diseases were developed.

Powdery mildew (Erysiphegraminis f.sp. hordei = Blumeria graminis f. sp. hordei). It is widespread and quite harmful disease. In the regions with sufficient moisture supply the yield losses can reach 30 % and more. In the Western Europe, with more wet climate than in the Steppe region of Ukraine, powdery mildew is the most harmful disease of this crop. If the affection of the plants in the field by the disease reaches 20 % the plants should surely be treated with fungicide by spraying it on the plants.

In the European countries the big attention to the problem of barley resistance to powdery mildew has been paid over 100 years. The result of the first genetic experiments on the character of barley resistance to powdery mildew inheritance was published by F. Biffen in 1905 [35]. In many countries the study of the racial composition of the pathogen and identification of the resistance genes began. With the development of genetic research methods it became possible to ascertain their chromosomal localization. All this contributed to the development of resistant varieties.

The relationship between the host-plant and the pathogen are usually based on the race specific relations according to Harold Henry Flor *gene-for-gene theory* [36]. During the plant vegetation powdery mildew passes a few generations. The pathogen evolves much faster than new varieties are developed.

Therefore, the resistance of pure line varieties in 3–5 years often changed into considerable susceptibility of the varieties. If the distribution of varieties with identical genes of resistance was wider they faster lost the resistance, and the race of the fungus virulent for the varieties became more widespread. It was proved that the genes of virulence are kept and constantly accumulated in the fungus population. On the European continent over two hundred races of powdery mildew have already been registered. In the south of Ukraine the powdery mildew population numbers a hundred races. The ratio of races in the population changes over the years, but the overall virulence always remains at a high level [37, 38]. To resist against epiphytotic distribution of powdery mildew we should just have a lot of different resistant varieties.

For barley over 150 genes of resistance have already been described [39]. By means of molecular markers chromosomal localization was found for many of them. Resistance genes are almost in the whole genome: 1H, 2H, 4H, 5H, 6H, 7H linkage groups [40–44].

Our long-term experience in the breeding work convinced us that sufficiently reliable protection against powdery mildew can be obtained by a combination of several efficient genes in one genotype. It is not difficult to obtain such a combination in practical breeding since the resistance genes are in different linkage groups.

Therefore, the problem of barley breeding for the resistance to powdery mildew can be reduced to the following measures:

– the control over the changes of the pathogen racial composition, timely registration and study of new virulent races;

– the involvement in breeding different genetic sources of the resistance;

– hybridization for the purpose of combining several resistance genes in one genotype taking into account their chromosomal localization;

– the improvement of methods of an infectious background creation and the artificial inoculation.

The evaluation of the breeding material for resistance to powdery mildew in the field infectious background should be done twice: at the tillering and the earing stage. If the infection remains in small amounts only on the leaves of the lower layer such breeding lines should not be discarded. The experience of cultivation of such varieties by *agricultural producers* has shown that heterogeneous varieties with the low degree of the disease affection remain to be resistant for much longer time than homogeneous varieties. It happens due to the fact that the population of many races survives on the plants of the varieties which are heterogeneous by resistance, and for that reason the epiphytoty is not occurred for a longer period of time.

Barley stripe (Helminthosporium gramineum = Pyrenophora graminea) affects barley practically in the whole territory of Ukraine. However, the mass affection by the disease more often occurs in the central and the north-western regions. Barley stripe is especially dangerous when seedlings are affected: the roots blacken and rot (root rot), on the leaves the olive-red spots emerge, the tissue bursts lengthways into two or three parts and then dries up, the plants wither and perish. In the years with a cold, wet and long spring harmfulness of barley stripe reaches a considerably high level. However, according to our observations in the south of Ukraine the degree of the disease affection of spring barley is of 5–10 % and 30–35 % of winter barley.

The genetics of barley resistance to the pathogen is less studied than that to powdery mildew, nevertheless we have quite a wide choice of donors of the resistance. Among the old domestic varieties a high resistance to the disease possess the following varieties: Nutans 244, Nutans 518, Odesskiy 36, Pervenets', Visnyk, Nutans 778, Donetskiy 4, Zernogradskiy 73; among the new varieties — Hetman, Halaktyk, Halateia, Enei; among the European varieties — Mishka (France), Katarina, Thuringen (Germany), Ingrid (Denmark).

Resistance gene Rdg1 was identified in the variety Vada; Rdg2 gene — in the variety Perga and Express, and it was localized on the chromosome 7HS; Rdg3 gene was also identified [45, 46].

Net blotch (Helminthosporium teres = Pyrenophora teres) is not so dangerous as barley stripe is. It affects barley mainly during the stage of earing and grain filling. The degree of the affection in the south of Ukraine frequently does not exceed 10–15 %. The susceptible varieties sometimes can be affected up to 40–50 %. In the genetic studies the resistance of barley to the pathogen was determined in the following linkage groups: 3H (Rpt1 gene), 1H (Rpt2 gene), 2H (Rpt3 gene), 7HL (Rpt4 gene), 6HS (Rtd gene) [47–49].

The following European varieties are highly resistant to the pathogen: Galleon (Rpt4 gene), km-1192, km-123, Zenith (Slovakia), NAD-685 (Poland), Atos (France). A high resistance to the pathogen passess our new varieties Prestyzh, Hetman, Halateia, Romantyk, Komandor, Enei and Sviatohor.

Scald (Rhynchosporium secalis) over the last 25 years became widespread in Ukraine. The disease affects barley, rye and a lot of cereal grass species. Just at the tillering stage watery spots of 0,5–2,0 cm size emerges on barley leaves, then the spots gradually dries up, darkens, surrounded by a yellowish or dark-red and often crenated border. When the disease affection is strong the leaves are completely dried up. Under favorable weather conditions for the disease the affection of barley plants in the field by the pathogen can be even stronger than by barley stripe or powdery mildew. A lot of commercial varieties from Europe, Belarus and Russia are highly susceptible to the disease. Resistant to the disease are the following varieties: Pervenets', Ityl', Odesskiy 111, Visnyk, Stalker, Halateia, Ekzotyk, Kharkovskiy 112, Donetskiy 14, Larissa (Germany), Sladko, Amulet, Tolar (Czechia), Dolly, Morrison (Canada), Roland (Sweden).

In the genetic researches the resistance to this pathogen has already been studied quite well. 14 genes have already been located almost in all the chromosomes of barley genome [46, 51, 52]. On the chromosome 1H — Rrs14 gene; on the chromosome 3HS — Rrs1, Rrs3, Rrs4 genes; on the chromosome 4H — rrs6, rrs7, rrs8, Rrs9, Rrs10, rrs11, and Rrs12 genes; on the chromosome 6H — Rrs13 gene; on the chromosome 7HS — Rrs2 gene [45, 50, 51].

Leaf rust (Puccinia hordei) is the most harmful among the rust species. It is a specialized pathogen affecting spring barley in the temperate climate regions. After a warm winter and in cool weather in the spring as well as in the beginning of summer during the booting stage on leaves small, up to 1–2 mm, lightreddish-brown and later on black andreddish-brown pustules emerge, firstly at the top and then on underside of the leaf. The pustules are often arranged linearly. In susceptible varieties up to 70 % of the leaf area can be covered with pustules. In 2001 in the course of epiphytoty of the disease in the collection nurseries, where almost all the varieties of Ukraine and the most popular varieties of the Western Europe were studied, there was no resistant variety. Only some of our new varieties were resistant: Ityl', Halaktyk, Hetman.

By means of molecular markers 14 dominant genes of resistance to leaf rust have recently been localized. They are located almost on all the chromosomes of the genome [53–59]. In the variety Gull on the chromosome 1HS — Rph4 gene; in the variety Oderbrucker on the chromosome 2H — Rph1 gene; in the variety PI 355447 on the chromosome 2HL — Rph15 gene; in the variety

Magnif 102 on the chromosome 3HS — Rph5 gene; Rph6 gene was found in the variety Bolivia; Rph7 gene — in the variety Cebada Capa; on the chromosome 3HL — Rph10 gene in the variety Clipper C8; on the chromosome 5HL — Rph9 gene in the variety HOR 2596; on the chromosome 5HS — RphTR gene in the variety TR-306; Rph19 gene — in the variety Reka 1; on the chromosome 6HL — Rph11 gene in the variety Clipper C-67; on the chromosome 7HL — Rph3 gene in the variety Estate.

Virus diseases in the northwest and southwest regions of Ukraine also often cause significant damage to the crop in the field. Barley is susceptible to all the phytoviruses (there are over 40 of them), but the most harmful is **barley yellow dwarf virus** (BYDV) and **barley yellow mosaic virus** (BYMV). They have similar external characters: yellowing of leaves, chlorosis, spotting, dwarfism, plant withering, but each virus species is strictly specific. For breeding first of all the degree of harmfulness, the way of migration and the development conditions matters. Viral diseases in Ukraine are primarily dangerous for winter barley. In some years the affection by the disease reached 70 %. For spring barley in the south of Ukraine the virus diseases are less harmful. The carriers of BYDV are different species of insects: aphids, leafhoppers, gout flies, barley leaf beetles. When mass reproduction of the insect-carriers takes place in warm wet autumn there is often a stronger affection of barley plants by BYDV. The barley plants of early sowing are affected by the virus disease several times stronger than the plants of early October sowing. In autumn the obvious damage of plants usually does not occur. Nevertheless, it is still important in due time to treat the plants (even before the seedlings emerge) against the insect-carriers with the insecticide of system action. If it is not done, with the beginning of the spring the plants of winter barley would suffer and can perish completely.

The breeding of barley genotypes resistant to BYDV is quite feasible. The dominant and recessive genes of resistance to BYDV are known, already identified and located [60–62]. Yd1 and Yd2 genes were identified in the Great Britain and Germany. The genes were transferred by backcrosses from the Ethiopian entries to the following varieties of winter barley: Asorbia, Brunhild, Banjo, Frances, Franca, Ganois Venus and spring barley: Corris, Shannon and Sutter. In France the varieties with Yd2 gene were also developed: Vixen, Naturel, Clarine.

The carrier of barley yellow mosaic virus is a soil fungus Polymyxa graminis which infects the roots of cereals. Fighting the virus using agricultural practices is almost ineffective, resistant varieties are needed.

In Japan and Germany the results on the study of the genes of resistance to BYMV have recently been published. In Germany a set of allelic recessive genes has been localized: on the chromosome 4HL — rym8 and rym9 genes; on the chromosome 4HS — rym11 gene; on the chromosome 3HL — rym4 and rym5 genes; on the chromosome 5HS — rym3 gene; on the chromosome 7HL — dominant Rym2 gene [63, 64].

Discussion of the results. The breeding program we developed which meant a stage-by-stage combination in one genotype of complex resistance to the pathogens of infectious diseases, tolerance to abiotic factors, high indexes of grain productivity and quality began quite quickly to give the desirable results (fig.).

The breeding work was carried out in quite a large volume, annually about 1000 cross combinations were made, about 8 thousand genotypes were studied in the breeding nurseries on the infectious background of powdery mildew and an artificial inoculation with loose, covered and false loose smuts. The hothouses covered with a polyethylene film and phytothrone greenhouses were used to grow up to three plant generations per year.

Our first variety of the steppe ecology **Pervenets'** that possessed the resistance to smut (Un8 gene), powdery mildew (Mla_1 and Ml_{at} genes), barley stripe and leaf rust, was registered in 1983 for growing in Rostov, Volgograd, Saratov, Oriol as well as in Bashkortostan and Tatarstan, in Khabarovsk, Primorskiy, Kamchatka and Amur regions. The variety was developed from the crosses (c.i. 13664 x Donetskiy 4) x Odessky 36^2. The variety Pervenets' is characterized by high heat tolerance and produces a large smooth grain with increased protein (up to 18 %) and lysine (up to 5 %) content. In 1982 the USSR State Commission for Plant Variety Testingrecognised thevariety Pervenets'as the best variety by grain quality and it was the first to be included in the group of «extra valuable» varieties [65]. The grown area of the variety was over 800 thousand hectares and until recently it was grown in many regions of the Russian Federation.

In 1987 the variety **Visnyk** was registered for growing in Lipetsk region as «extra valuable» variety by grain quality. It was obtained from the similar cross combination and possessed the similar indexes of resistance to diseases, but it was more productive. In the late eighties it was grown on the area over 60 thousand hectares.

In developing the variety **Romantyk** the task was set to develop for Forest-Steppe region and Polesie a short stem variety resistant to diseases and lodging, meant for brewing and growing under farming practices of high-intensity, possessing yield potential not less than 8,0 t/ha. The variety Romantyk was developed using step by step hybridization (Pervenets'x Trumpf) x Sundence. In 1988 it was registered for growing in Vinnitsa, Khmelnitskiy and Belgorod regions. In the early nineties it was grown on the area about 100 thousand hectares and was notable for resistance to smut and to the diseases that affect the stem and leaves.

The variety **Ityl'** is adapted to the conditions of Tatarstan and was developed from the cross Pervenets'x Donetskiy 8. The variety has a large grain, it is heat tolerant and resistant to smut and other diseases. The variety considerably exceeded check varieties by its grain productivity which was over 7.2 t/ha. The USSR State Commission for Plant Variety Testing included the variety in the group of «extra valuable» by grain quality. In 1991 it was registered for growing in Tatarstan, Chuvashiya, Mordovia and Mari republic.

On the basis of the resistance gene **Un12,** which we identified, as a result of composite backcrosses a short stem variety of intensive type **Prestyzh** resistant to smut diseases was developed. It was officially registered in Ukraine and Moldova in 1995. Its grown area in 2000 was over 200 thousand hectares.

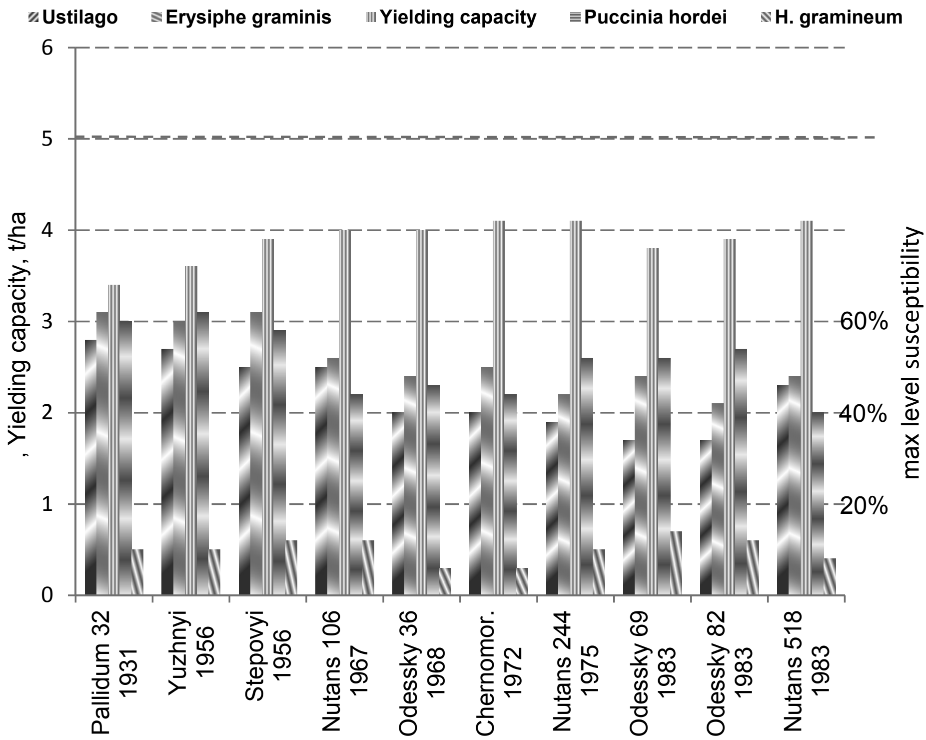
Under the program of breeding varieties for the intensive farming practices in the regions with insufficient moisture supply from the cross (Druzhba x NAD-360) xPrestyzh a short stem variety **Hetman** meant for brewing was developed (in the Register of Ukraine and Moldova since 2001, in the Register of Russia since 2005) as well as the variety **Khadzhibei**, a sister line of the variety Het'man, (in the Register of Russia since 2003). High tillering combined with high cold and heat tolerance, resistance to lodging, and a complex resistance to diseases enable these varieties to produce up to 8,0 t/ha of smooth grain with thin hull.

Under the program of breeding varieties resistant to the changes of growing conditions from the cross Itil' x Odesskiy 115 the variety **Halaktyk** was developed. It has been in the Registers of Plant Varieties since 1999 for all the regions of Ukraine and Moldova, and meant for brewing. Since 2002 the variety has been the National check variety of Ukraine. The variety is characterised by high resistance to smuts, leaf and stem diseases (8–9 points), it is also resistant to lodging. Under favorable conditions in farming crop production the variety yieldsup to 8,0 t/ha. According to the State Statistics Service of Ukraine the grown area of the varietyHalaktyk in 1995 was 131.3 thousand hectares.

A valuable by grain quality, an early maturing, having large grain variety **Halateia** was developed by the method of step by stephybridization of the steppe ecology varieties resistant to smut and other diseases. In the Register of Plant Varieties of Ukraine the varietyHalateia has been since 1998 for growing in the Forest-Steppe region and Polesie, and since 2002 — for the Steppe region. Its productivity under farming conditions in the experimental farm «Bogunovskaya elita» (Ivanivka district of Odessa region) in 2001 was 8.9 t/ ha (!). The variety is resistant to all smut species, barley stripe, net blotch,leaf rust, powdery mildew and scald (8–9 points).

For the conditions of insufficient moisture supply as a result of step by step hybridization with the involvement of the most heat tolerant domestic varieties of the steppe ecology the variety **Yuzhnyi** was developed. In the Register of Plant Varieties of Ukraine the variety has been since 2001. It is a m*id maturing variety* of medium high, resistant to diseases and having large grain.

Later on for Polesie and the Forest-Steppe regions of Ukraine the short stem varieties resistant to diseases and lodging were developed: **Selenit** (Ros' x Odesskiy 164) x Edem, in the Register since 2004; **Vodohrai** (Halaktykx Mishka), in the Register since 2005; **Komandor** (Het'manx Mishka), in the Register since 2007; **Sviatohor** (Hetmanx Tselinka), in the Register



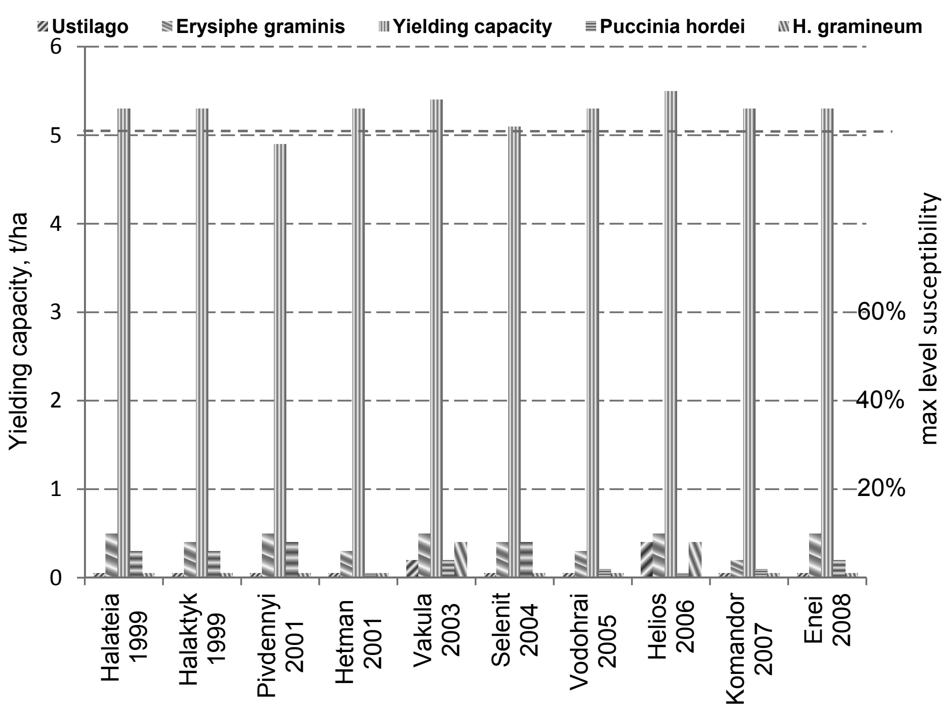


Fig. The average grain productivity (competitive trial, collection nursery, t/ha) and the degree of the affection by the pathogens of the infectious diseases of spring barley varieties on the infectious background (PBGI, 1999–2011) since 2010; **Voievoda** (Hetmanx Linus), in the Register since 2012 for all the regions of Ukraine. If the recommended farming practices for growing these varieties are strictly adhered then without application of fungicides the varieties are capable to yield up to 8,5 t/ha.

For the arid Steppe regions of Ukraine from the cross Yuzhnyi x Slavianskiy-91 the «valuable by grain quality» variety **Enei** of steppe ecology was developed. In the Register of Plant Varieties of Ukraine the variety has been since 2008. It is heat tolerant, m*id maturing,* having large grain *variety*. The *variety* is resistant to smut, powdery mildew, leaf rust, barley stripe and net blotch.

The spring barley varieties developed at institute over the last 15 years are the best in Ukraine and Moldova, they are grown in many regions of Russia. Under the farming conditions the variety Halaktyk is noted for the yield stability. The variety Komandor is the national check variety for Forest-Steppe region and Polesie. By the results of the studies carried out by the laboratory of the technological evaluation of brewing properties (Khmelnitskiy town) of the «Obolon'» company the variety Sviatohor was recognised as the best brewing variety of Ukraine.

The breeding work continues. The modern European varieties, donors of new genes of resistance to diseases, are involved in hybridization.

The co-authors of above mentioned varieties in different years were P. F. Garkavyi, A. A. Linchevskiy, E. P. Shevchenko, L. A. Dubinina, O. P. Garkavyi, V. A. Perekhrest, V. P. Tarasiuk.

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СТІЙКІСТЬ ЯРОГО ЯЧМЕНЮ ДО НАЙБІЛЬШ ПОШИРЕНИХ В УКРАЇНІ ХВОРОБ ЦІЄЇ КУЛЬТУРИ: СЕЛЕКЦІЙНІ ТА ГЕНЕТИЧНІ АСПЕКТИ

Обговорюються проблеми селекції ячменю на стійкість до найбільш поширених в Україні хвороб. Наводяться результати багаторічних досліджень шкодочинності ряду захворювань та генетики стійкості, характеристика ефективних донорів, методи і результати створення сортів з груповою стійкістю до хвороб.

Таблиця — 1. Рисунки — 2. Бібліографія — 65.

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Кирдогло Е. К. Сборник научных трудов СГІ–НЦНС. 2013. Вып. 22 (62).

УСТОЙЧИВОСТЬ ЯРОВОГО ЯЧМЕНЯ К НАИБОЛЕЕ РАСПРОСТРАНЕННЫМ БОЛЕЗНЯМ ЭТОЙ КУЛЬТУРЫ В УКРАИНЕ: СЕЛЕКЦИОННЫЕ И ГЕНЕТИЧЕСКИЕ АСПЕКТЫ

Обсуждаются проблемы селекции ячменя на устойчивость к наиболее распространенным в Украине болезням. Приводятся результаты многолетних исследований вредоносности ряда заболеваний и генетики устойчивости, характеристика эффективных доноров, методы и результаты создания сортов с групповой устойчивостью к болезням.

Таблица — 1. Рисунок — 1. Библиография — 65.