CHAPTER 3. GENERALIZED SET OF MEASURES TO PROTECT AGROCENOSES OF CRUCIFEROUS CROPS FROM DISEASES

Sergiy Amons
Svitlana Okrushko

DOI: https://doi.org/10.30525/978-9934-26-358-3-3

Important in terms of disease control in cruciferous crops is, first of all, timely monitoring of their agrocenoses, which is recommended to be carried out in accordance with certain terms and phenophases.

Rapeseed requires skillful protection against pests and diseases, and the focus of the entire cultivation technology on loss prevention. This is achieved by following the principles of adaptive or integrated farming [1].

The cultivation of resistant crop varieties is one of the central aspects of integrated crop protection. It is also possible to use varieties that are not fully resistant. The cultivation of relatively non-susceptible varieties in combination with agronomic, sanitary and preventive measures allows to minimize the use of chemicals. Using varieties with different resistance bases and maintaining them is an important element of integrated protection. For the effective use of the resistance factor, information on the composition and dynamics of the pathogen population is required. The results of virulence analysis should be reflected in breeding for resistance and in variety change [2].

The large number of harmful diseases affecting rapeseed plants, the relatively narrow gene pool of the species, the genetic homogeneity of modern "00" type varieties and the rapid increase in sown areas pose a serious threat of epiphytoties. In this regard, in all breeding programs, special attention is paid to the creation of rapeseed varieties resistant to various diseases (phomosis, Alternaria, peronosporosis, sclerotinia, verticillium, fusarium, etc.).

With the emergence of the first low-erucic rapeseed varieties, the problem of resistance to phomosis attracted the most attention from breeders.

The French single-zero winter rape variety Jet Neuf is one of the first sources of resistance to this disease that was widely used. In the case of France, high resistance to phomosis is characterized by winter rape varieties Darmor, Tandem [3] i Ramses [4]. Field resistance found in Rafal, Bienvenu, Sarepta and Quinta varieties [5].

In the UK, varieties with field resistance to phomosis SarNsogpe and Corniche have been identified [6], which, however, are not popular with farmers due to low yields. In Germany, Lirajet, Liberator, and other varieties have field resistance to the disease [7]. and Maxol. According to the results of the immunological evaluation conducted in Poland, the following winter rape varieties were classified as resistant: Libravo, Liradette, LAH 390, MAN 1390 [8]. Breeders have created a large number of spring rape varieties resistant to phomosis: in Australia – Mashka [9], Barossa [10], Yikadee, Eureka і Shiralee [11]; у Канаді – Stellar, Profit [12], Cresor, Legend та Innovator [13], in Poland – Bronowski and Mar; in Ukraine – Kovalevsky.

There is not always a correlation between the resistance of rapeseed to phomosis in the seedling and adult phases [14–15].

In Australia, the main component of field resistance to phomosis is adult plant resistance. The field resistance of adult rapeseed plants to phomosis is polygenic in nature, it is associated with the rate of formation of strong cortical tissue and lignin formation.

In the study of digaploid lines from anthers of F_1 hybrids obtained from crossing varieties Cresor (resistant) and Westar (susceptible), genotypes moderately affected by phomosis in the seedling stage and resistant to this disease in the adult state were identified. High resistance to phomosis was found in field conditions in plants of monosomal rapeseed lines with the added fourth chromosome of *Brassica nigra*. It has been shown that the genes of resistance to phomosis in B. juncea plants are localized in the genome [16]. And when hybridized, they can be easily transferred to the genome of *B. napus* plants [17]. The control of full resistance of *B. juncea* seedlings is carried out by the genome and is determined by one dominant gene. In order to transfer resistance to phomosis to rapeseed plants, somatic hybridization with *Sinapis alba* is being carried out [18]. When transgenic plants were created by integrating a chitinase-producing gene, resistance to phomosis increased slightly, except for one genotype [19].

Under the conditions of Ukraine, increased resistance to phomosis was noted in winter rape varieties Fedorovsky, Fedorovsky improved, Garant, Ivanna, BNV 63, Quinta, Ustinovsky, VRG 109, VDH9002, Galitsky, Horizon, NPP 041, Xaverovsky [20]; in France – in the varieties Jet Neuf, Lembke, Bienvenu. Quite high resistance to Alternaria was found in the Japanese variety Norin44 [21]. Among the spring rape varieties with high field resistance to Alternaria are the following: in Ukraine – Kovalevsky. Yumba, Salut, Ergl, Klytinnyi 8, Nikitinetskyi, Kalynovskyi, Iris, Orion [22].

Various studies have shown that S. alba can be a source of resistance to Alternaria in interspecific crosses. The wild species *Eruca sativa*, *Camelina sativa* and *Capsella bursa-pastoris* are even more interesting in this regard.

In experiments with the introduction of several foreign cytoplasms into the genome of *B. juncea* plants, it was shown that the cytoplasms of *B. campestris* > *B. chinensis*, *B. japonica* species reduce, and *B. napus* and *B. carinata* – increase resistance to Alternaria; the cytoplasm of black mustard does not affect this trait. Resistance to Alternaria leaf spot in Sarepta mustard is caused by one dominant gene. All resistant plants have purple leaves, thick, lobed with protruding veins. All of these traits can be used as gene markers for preliminary evaluation of genotypes for disease resistance in large plant populations [23]. During the selection of embryos from plants of the winter rape variety Primor (susceptible to A. brassicicola) in a selective medium with a filtrate of the pathogen culture, it was possible to isolate resistant samples [24].

As a result of determining the resistance of rapeseed varieties and samples to downy mildew, the spring variety Cresor was isolated, which has race-specific resistance [25], line RES 26 (obtained in Poland by selection from the winter rape variety Janetzkis), which has a dominant monoline (selected from the variety Komet) with resistance due to two independent genes [26].

When evaluating resistance to sporulation on individual cotyledon leaves of winter rape in the laboratory, the following varieties were highly resistant to downy mildew: Cobra, Liporta and Lirabon; medium resistant – Liborius and Arabella; moderately resistant in the field – Envoi and Samourai [22].

The following varieties and cultivars were weakly susceptible to downy mildew: in the UK – winter rape varieties Venvenu, Fiona, Korina and Darmor; in Ukraine – spring rape varieties: Kovalevsky, Vasylkivsky, Maryanivsky and Ukrainsky.

In France, transgenic rapeseed plants based on the Westar variety were developed that produce the enzyme oxalate oxidase, which leads to the degradation of oxalic acid. Some of the resulting plants had increased resistance to sclerotinia. Transgenic plants producing chitinase were also less affected by *S. sclerotiorum*.

In Germany, three lenticular mutants of rapeseed were obtained, whose susceptibility to *S. sclerotiorum*, *L. maculans* and *B. longisporum* fungi according to ELISA test corresponded to 0.21, 0.59 and 1.62 FPE (fungal protein equivalent) against 0.69, 3.98 and 5.54 FPE in conventional varieties, indicating a reduced susceptibility of *Lenticular mutants* [27]. In China, the sterile line 90A was isolated, which is much more resistant to the disease than the fixer with the same genotype; the difference between them is that in the sterile line, the pistils emerge before the flower blooms and the petals fall off later. Plants of six other lines with cytoplasmic male sterility (41A-46A) were less affected than the fixers due to the smaller size of the petals and their later falling off [28].

In France, germplasm with increased resistance to sclerotinia was isolated from the gene pool of rapeseed of Asian origin: Norin9, Norm 16, Genkai, Isuzu, Kogane, Miyuki [29].

In Germany, relatively high resistance was observed in winter rape varieties Doral, Librador, Liroma; in Sweden and Ireland, in spring rape variety Brio. After ethyl methyl sulfonate treatment of spring rape plants of Linetta M2 variety, one highly resistant line was isolated [30]. Winter rape varieties Lirajet, Liberator are relatively resistant to sclerotinia in Poland [31], Vog, VON 1592, VON 1693, MAN 1391, MAN 1592.

A number of cultivars have been selected in the UK for breeding for resistance to light leaf spot: Rochet, Express, Falcon, Libravo, Nickel, Inca, Tomahawk [27]. Dominant genes determining resistance to clubrooted pigeonpea identified in *B. oleracea* representatives polygenic recessive resistance to clubroot pigeonpea was found [32]. Genotypes resistant to this disease were also selected in the *S. nigra* population [33]. Oilseed radish samples, as well as Evvin, Lergo, Salyut and Karat rape varieties, are the most resistant to clubroot [34].

In the experiments to evaluate the source material for resistance to verticillium, it was not possible to identify fully resistant rapeseed genotypes, but there was considerable variability among the samples in the degree of damage to mature plants. Separate cultivars were found to be resistant to this disease: in Poland – VON 1582, in Germany – Korina and Jet Neuf [35].

In most regions of the world, rapeseed is resistant to Albugo sandida (Pers. Et Lev.) Kuntze (white rust), but many varieties in central and eastern China are susceptible to the disease.

Rapeseed is heavily affected by white rust. Therefore, breeders should be careful not to introduce susceptibility with oriental varieties or interspecific crosses with rape.

Absolutely non-susceptible samples of rape to Fusarium wilt have not been found, but as sources of resistance to Fusarium, we can recommend the variety samples of Japanese origin Isuzu, Murasaki, Chisaya. For the purposes of heterotic breeding, it is desirable to use at least one resistant parental form, preferably the maternal one. No resistant samples of white rape and white mustard were found, cabbage samples vary considerably in resistance, and a fairly high level of resistance is observed in samples of oil radish, black radish and mustard, Abyssinian, and Sareptian. Some species can be used to isolate donors of Fusarium resistance and then be included in interspecific crosses with rapeseed.

There are reports that transgenic plants with increased resistance to Fusarium in winter rape have been obtained on the basis of radish defensin RsAfp.

Thus, for such harmful diseases of rapeseed as Alternaria, sclerotinia and verticillium, no sources of resistance within the species have been identified, although differentiation of genotypes by the degree of damage by this disease has been noted. The greatest attention of breeders is attracted to selection for resistance to phomosis. A large number of winter rape varieties resistant to this disease have been developed in France, and spring rape varieties in Australia and Canada. Sources of resistance to cylinderspore are mostly found in the UK. The most significant successes in breeding disease-resistant rape varieties and in creating sources and donors of resistance are currently associated with the transfer of resistance factors by remote hybridization and transgenesis; selection on selective media in tissue culture is promising.

Sprouted seeds and seedlings of rapeseed can be affected by pathogens of various diseases. Therefore, seed treatment is a crucial measure in the fight against diseases. The right place in the crop rotation, spatial separation from areas where rapeseed was grown in the previous year, careful stubble cultivation, optimal nutrient supply, especially boron, and the creation of viable crops are the most important preventive measures to reduce the likelihood of disease infection. Since breeding for resistance has led to positive results in recent years, the selection of resistant, suitable varieties for a particular area of rapeseed cultivation is an important indirect control factor.

Early sowing, high sowing density, wet and mild autumn, as well as damage to plants by rapeseed flea beetle, cryptic borer, cylindersporium and frosts have a stimulating effect on the development of the disease. The use of fungicides does not always pay off. Numerous experiments with fungicides have shown that their effectiveness is higher in the fall than in the spring. By combining both methods, it is possible to increase the effectiveness of the fight against necrosis of the root collar and stems.

Growing healthy rapeseed seed material limits the spread of the most harmful diseases in each zone of the country.

To prevent the accumulation of infection in the soil and dramatically reduce plant disease damage, it is necessary, first of all, to strictly observe crop rotation in crop rotations. Rapeseed should not be returned to its original place until 3–4 years later [36].

In permanent culture, the incidence of *Ph. lingam, S. sclerotiorum, V. longisporium*, and to a lesser extent Alternaria spp. increased.

In Poland, the damage of winter rape by verticillium in permanent sowing was studied (from 1968 to 1994). In monoculture, 8.5% of plants had microsclerotia, and in crop rotation, 2.2%.

A significant increase in the incidence of winter rape with clubroot was observed with an increase in the share of the crop in the crop rotation (when cultivating about 10-12% of the sown area with clubroot, up to 46% of the plantations were affected) and, conversely, in some regions of France, where the crop rotation was grown every other year or in one of three years for 30-40 years, clubroot has never been economically important.

To prevent epiphytosis of Alternaria and Phomosis, it is not recommended to plant rapeseed in low areas with excessive soil moisture [37]. Fields separated from last year's rapeseed crops, and even from this year's cabbage crops, by at least 1 km are optimal. Seed rapeseed should be planted after perennial and annual grasses, and cash crops should be planted after grain crops. This improves the activity of soil microorganisms – antagonists of pathogens of most diseases, which is especially important against clubroot, wilt and phomosis. In addition, the cultivation of garden savory and thyme as an intermediate crop for three years also contributes to the formation of a crop rotation [38] and peppermint [39]. A 60–95% reduction in moth infestation of Chinese cabbage (*Brassicae rapa* ssp. *pekinensis*) and *Brassicae deracea* var. *italika* plants (depending on the inoculum density) was obtained during a four-week period of growing *B. napus* as a bait.

According to V.H. Paul (1992), the main measures to combat downy mildew are the cultivation of disease-resistant varieties and the mandatory observance of crop rotation.

But not only the cultivation of resistant rape varieties, but also the agrotechnical method of plant protection has a fundamental impact on the state of its agroecosystem [40].

According to [41] The choice of a predecessor is primarily determined by the time of harvest. Spring rapeseed can be grown after any grain crop and even potatoes. Since manure is often applied to potatoes in Eastern Europe, spring rape, as the next crop, is always a good utilizer of the remaining nutrients. The accumulation of infection and the harmfulness of diseases increases dramatically if crop rotation is not followed. Thus, when sowing rapeseed after rapeseed, the incidence of Fusarium in the first year after sowing rapeseed was 21.2%; in the second year – 18.5% [42].

A long-term experiment conducted in Germany [43] convincingly proves that long-term cultivation of rapeseed in the same place, with a share of 33% in the crop rotation, has a favorable effect on the development of diseases and a decrease in yields. The more diverse the crop rotation and the smaller the share of rapeseed in the region, the lower the risk of mass reproduction of many pathogens of this crop. Studies have shown that the most favorable conditions for high yields of rapeseed exist in fields that have been vacated after early potatoes, legumes, clover, alfalfa and annual fodder crops. Recommended [44] sowing rapeseed after peas and vetch-oat mixture grown for green fodder.

In addition, it is known that microelements also affect the resistance of rapeseed plants. With a seed yield of 30 centner/ha, rapeseed removes about 200-400 g of boron, 5-16 g of molybdenum, and 300-1800 g of manganese from the soil. Boron plays an important role in increasing the elasticity of tissues, which reduces the cracking of stems and roots during strong growth, and thus reduces the damage to plants by diseases. If the soil lacks boron, rapeseed plants are late to emerge from the rosette phase ("rapeseed sitting"), their growth is slowed down, young leaves are lighter in color, and the edges of the leaf blades are curled. Older leaves show spots of red to red-purple color. Boron deficiency is observed primarily in very light and calcareous soils, and even in drought. Since boron is difficult to move in the plant, small doses of boron in the form of fertilization will have the best effect.

It is necessary to carefully follow the rapeseed cultivation technology developed for each zone of the country. Much attention should be paid to preserving soil moisture, accumulating nutrients, and controlling weeds, especially cruciferous weeds, and pests that are reservoirs and carriers of many diseases. For these purposes, the fields freed from grasses are cultivated using the semi-pair system, and after grain crops, stubble is immediately peeled with disk stubble harrows to a depth of 6–8 cm in a unit with harrows, and after 10–12 days, the field is cultivated using the technology adopted for each zone. The infectious background of sclerotinia can be reduced by a complex of surface tillage with incorporation of plant residues into the lower horizons.

It is necessary to maintain a sufficient amount of humus to increase the biological activity of the soil and the associated antipathogenic potential of the soil. Fertilizers focused on the removal of nutrients based on soil and plant analysis, it is undesirable to apply timely increased doses of potassium fertilizers do not affect the degree of development of downy mildew, however, the introduction of nitrogen in high doses leads to increased damage to rape downy mildew [45].

Increasing the seeding rate of winter rape from 5 to 8 kg/ha leads to a significant increase in the number of affected plants with stem phomosis.

Thus, the rate of disease development with an increase in the seeding rate increased by 1.84 times, and the prevalence of the disease increased by 1.10 times.

In winter rape, increased doses of nitrogen did not have a significant effect on *Ph. lingam*, *B. concentricum*, Alternaria spp. and *S. sclerotiorum*, but with increasing doses of nitrogen, the incidence of *B. cinerea* and Ersyphe spp. increased.

With the increase of sulfur, zinc and boron content in the soil, the resistance of rapeseed to diseases increases [46].

The use of zinc and boron can lead to a reduction or prevention of canola clubroot disease [20].

The optimal soil reaction (pH 6.5–7.5) must be maintained. With an increase in pH from 43 to 54, the severity of winter rape plants increases from 54.1 to 73.9%; at pH 64 it decreases to 50.0%; and at pH 7.3–8.0 it increases again to 72.7%. The author explains these established peculiarities of plant response to *P. brassicae* infection by the specific requirements of winter rape to soil conditions [47].

In soils containing more organic carbon, a decrease in carpogenic germination was observed, while pH did not affect the germination of S. scierotiniorum sclerotia. The percentage of lesions increased with increasing sand content in soil samples, but decreased with increasing silt and clay content [48].

Preparing seeds for sowing is of great importance. After they are brought to a moisture content of 10–12%, they are thoroughly cleaned of weeds, and small, lightweight and defective seeds are removed. After cleaning and drying, the seeds are treated 2–3 days before sowing with 80% of the SP TMTD (5–6 kg/t of seeds) against bacteriosis, phomosis, ascochitosis, blackleg, downy mildew, olive spot? seed mold, black mold or 50% SP Derosal (2–2.5 kg/t of seeds) against root rot, or 70% SP Vitavax 200 (2–3 kg/t of seeds) against seed mold, black spot, downy mildew, helminthosporium root rot.

Applying a thin (several mm) film of biocompatible polymers, including active substances, to the seed surface is a new technique that allows better fixation and distribution of pesticides around the grain, as well as better environmental protection. Coating rapeseed seeds with SEPIRER film treated with the insecticide/fungicide oftanol T. ensured greater efficiency of pesticide treatment at early stages of development (seed or germinating sprout).

The seedbed for rapeseed should have a finely lumpy structure, which is important not only for obtaining friendly germination with a minimum number of seeds, but also for enhancing the effect of herbicides if the rates of their use are reduced for environmental and economic reasons.

Excessive soil crumbling should also be avoided, because with heavy rainfall there is a risk of flooding and crusting, which will negatively affect the field germination of seeds and contribute to the defeat of seedlings by root rot and black leg [49].

Positive results of early sowing to protect winter rape from phomosis were noted: at the time of the onset of climatic conditions favorable for the development of the pathogen (temperature less than 15 °C), the crop is already at the stage of growth, immune to the pathogen [50].

With an increase in plant density from 80 to 240 per 1 m^2, the incidence of B. cinerea, *S. concentricum* and *P. parasitica* increases.

When rapeseed emergence occurs, shallow loosening of row spacings in wide-row crops is recommended to limit blackleg and phomosis, as well as to control weeds, and harrowing across rows in continuous crops when four leaves are formed.

A balanced fertilization system has a positive impact on controlling the prevalence of cruciferous crops. Mineral fertilizers increase the plant's resistance to environmental stressors, increase disease resistance, and accelerate seed development and maturation.

For example, here are the results of studying the effectiveness of microfertilizers on the development of Fusarium and Alternaria in spring rape (Table 3.1).

On average, over 3 years, a decrease in the development of diseases was observed with the use of foliar fertilizers. The lowest damage by Fusarium was noted in the variant with the introduction of Intermag Profi Oilseeds (1 l/ha) + Ultramag Boron (1 l/ha) + Biostim Oilseeds (in 2 phases) (0.5 l/ha), the development of the disease was 10.7% (9.2% lower than in the control). The effect of fertilizers on the development of late blight was not significant, depending on the variant, the reduction of the disease varied from 3.2% (Biostim Oilseed (1 l/ha) + Ultramag Boron (1 l/ha), Intermag Professional Oilseeds (1 l/ha) + Ultramag Boron (1 l/ha) + Biostim Oilseeds

(2 phases) (0.5 l/ha)) to 2.0% (Intermag Professional Oleaginous (1 l/ha) + Ultramag Boron (1 l/ha)).

Table 3.1

Impact of liquid mineral fertilizer treatment on the disease incidence of spring rape, 2015–2017, % [53; 56]

Variant	Fusarium				Pod alternaria			
	2015	2016	2017	Average	2015	2016	2017	Average
Control (without processing)	18.1	19.1	21.7	19.6	19.3	26.3	23.1	22.9
Intermag Profi Oil (1 l/ha) + Ultramag Boron (1 l/ha)	36.0	10.5	19.2	21.9	13.0	26.0	23.8	20.9
Biostim Oil (1 l/ha) + Ultramag Boron (1 l/ha)	20.9	15.7	10.6	15.7	10.8	25.8	22.4	19.7
Intermag Profi Oil (1 l/ha) + Ultramag Boron (1 l/ha) + Biostim Oil (1 liter/ha)	15.3	14.6	17.3	15.7	14.8	25.4	21.9	20.7
Intermag Profi Oil (1 l/ha) + Ultramag Boron (1 l/ha) + Biostim Oil (2 phases) (0.5 l/ha)	8.7	12.2	11.2	10.7	11.8	25.3	22.1	19.7
SSD_{05}	8.1	2.1	4.1		1.8	0.7	0.9	

Similar studies were conducted by Y. Savchuk [52]. The winter rape varieties used in the research were Snow Queen, Andromeda, and Vesuvius, which are undergoing state testing. Sowing dates were studied: early (August 11); optimal (August 21); late (August 31). Before sowing, the seeds were treated with microfertilizers such as Vuxal microplant, Terios and Askofol. Vuxal microplant is a highly concentrated suspension of micronutrients intended for late fertilization of intensive crops. Vuxal Terris is a public fertilizer for seed treatment with nitrogen, phosphorus, copper, manganese, molybdenum and zinc. Vuxal ascophol is a highly concentrated suspension extracted from the brown water of Ascophyllum nodosum. The research was conducted at the Agronomic Experimental Station of the National University of Life Sciences of Ukraine in 2014–2017.

It was found that microfertilizers had no significant effect on the development of diseases. The disease susceptibility of winter rape varieties overwhelmingly depended on the sowing time and the properties of the variety. According to the tables, the winter rape variety Vesuvius was relatively resistant to downy mildew, the damage of which in the early and optimal sowing dates was 0%; late – 3.1% (control). The damage to the variety Snow Queen by this disease at the optimal sowing date was 0%, in the early and late sowing dates the damage by downy mildew was 3.5 and 2.1%, respectively. The winter rape variety Andromeda proved to be resistant to downy mildew. In the early sowing period, the damage to the varieties by phomosis amounted to 18.6 – 22.5% (Tables 3.2–3.3).

Table 3.2

Disease incidence in winter rape varieties (early sowing) [53; 56]

Variety	Microfertilizer	Disease, %		
		downy mildew	phomosis	alternariosis
Snow Queen	Control	3.5	20.8	5.8
Andromeda		0.5	18.6	25.0
Vesuvius		0.0	22.5	20.4
Snow Queen	Microplants	1.5	10.2	6.6
Andromeda		0.1	10.0	16.6
Vesuvius		0.0	8.0	10.0
Snow Queen	Ascophol	2.0	15.1	5.8
Andromeda		0.0	5.6	10.0
Vesuvius		0.0	10.0	12.0
Snow Queen	Therios	2.8	10.0	6.5
Andromeda		0.0	10.0	15.0
Vesuvius		0.0	20.0	15.4

In the optimal and late sowing periods, the damage was 45 times less, which is associated with the biological properties of the pathogen and the developmental stage of the variety (Table 3.4).

The damage to the winter rape variety Snow Queen by phomosis at all sowing dates was stable. In the early sowing period, the maximum damage by Alternaria in Vesuvius and Andromeda varieties was 20.4 and 25.0%, respectively (control variant) (Table 3.4).

Table 3.3

Disease incidence in winter rape varieties (optimal sowing time) [53; 56]

Variety	Microfertilizer	Disease, %		
		downy mildew	phomosis	alternariosis
Snow Queen	Microplants	0.5	2.4	3.1
Andromeda		0.1	0.8	1.1
Vesuvius		2.2	3.1	2.8
Snow Queen	Control	0.0	5.2	6.4
Andromeda		0.0	2.0	3.6
Vesuvius		0.0	0.8	3.0
Snow Queen	Therios	1.2	1.2	1.2
Andromeda		0.5	2.2	4.1
Vesuvius		0.0	0.4	1.0
Snow Queen	Ascophol	1.2	0.8	0.8
Andromeda		0.8	1.3	2.8
Vesuvius		2.1	3.3	3.8

Table 3.4

Disease incidence in winter rape varieties (late sowing) [53; 56]

Variety	Microfertilizer	Disease, %		
		downy mildew	phomosis	alternariosis
Snow Queen	Ascophol	1.0	0.3	2.2
Andromeda		0.6	0.5	1.1
Vesuvius		1.1	0.9	0.6
Snow Queen	Therios	0.0	0.3	0.5
Andromeda		0.0	0.3	1.3
Vesuvius		0.1	0.5	0.5
Snow Queen	Control	1.2	5.1	3.3
Andromeda		0.5	1.1	2.3
Vesuvius		3.1	2.2	3.0
Snow Queen	Microplants	0.8	0.0	1.2
Andromeda		0.0	0.3	0.1
Vesuvius		2.0	1.8	2.6

The use of micronutrient fertilizers depending on the sowing time limits the development of diseases in winter rape varieties. Thus, with the use of Vuxal Microplant, Ascophol and Terios in the optimal and late sowing periods, the damage to varieties by phomosis and alternaria was 1.5–2 times lower compared to the control. In the early sowing period, the use of micronutrient fertilizers reduced the damage by downy mildew by 1.0–1.5 times.

Microfertilizers Vuksal Microplant were highly effective against diseases of winter rape in the early sowing period, and Terios and Askofol in the optimal and late periods.

To reduce seed losses due to black spotting, rapeseed is harvested in a short time. In the case of separate harvesting, mowing into swaths begins when the seeds are brown on the central stem. Swaths are threshed at a seed moisture content of no more than 12%. For direct harvesting, seed moisture content is allowed up to 10% [53].

It is noted that a rational fertilizer system can regulate the prevalence of diseases of winter rape [53–54]. The system of mineral nutrition of plants is of particular importance in the fight against rapeseed diseases. Thus, the introduction of nitrogen in the form of ammonium nitrate (N_{60}), without phosphorus and potassium, into the main fertilizer contributed to better seed germination compared to the control (by 2.9%), reduced the number of affected plants by blackleg by 25%, but increased the disease of alternaria and root bacteriosis by 16.6% and 27.3%, respectively. The introduction of phosphorus-potassium fertilizers ($P_{90}K_{150}$) into the main fertilizer had a more positive effect on all processes of growth and development of winter rape, in particular, seed germination was higher by 5.9% and 2.8% compared to the control than in the variant with nitrogen (N_{60}). In the autumn period, rapeseed plants on the background of phosphorus-potassium fertilizers developed a better root system and better tolerated frosts, respectively, by 83.3% and 22.2%, 36.1% and 28.9%. Phosphorus-potassium fertilizers increased the resistance of winter rape plants to blackleg, alternaria and root bacteriosis by 2.7, 1.5 and 1.8 times compared to the control, respectively, and by 2.0, 1.8 and 2.3 times compared to the variant where N_{60} was used. The application of the main mineral fertilizer at a dose of $N_{15}P_{35}K_{90}$ increased the density of seedlings by 5.9% compared to the control, the length of lateral branches of the main root by 18 cm or 2.5 times, the number of leaves of the autumn rosette and better wintering of plants. Symptoms of mineral nutrition deficiency were detected in 15% of plants, which is 4.5 times less than in the control. This dose of fertilizer contributed to a sharp decrease in the number of plants affected by diseases compared to the control: black leg by 4 times, Alternaria by 10 times, and root bacteriosis by 1.8 times. The main fertilizer $N_{30}P_{70}K_{120}$ had a positive effect on all processes of winter rape development in the autumn, in particular, field germination of seeds was higher by 14.7% compared to the control and by 8,3% compared to the variant with $N_{15}P_{35}K_{90}$. Increasing the dose of phosphorus and potassium fertilizers contributed to better root system formation. The length of lateral branches of the main root exceeded the control variant by 3 times, and by 1.5 times – the variant with the introduction of $N_{15}P_{35}K_{90}$. The structure of the rosette of rapeseed leaves in the autumn period of rapeseed vegetation corresponded to the optimal amount, which contributed to an increase in the preservation of the number of plants after wintering, compared to other variants of the experiment. Increasing the dose of the main mineral fertilizer to $N_{60}P_{90}K_{150}$ had a positive effect on the growth and development of winter rape, the density of seedlings exceeded the previously indicated variants by 16.2, 9.7 and 1.3%, respectively; the length of lateral branches of the main root increased by 4 and 1.6 times, and by 6.7%, respectively. After the restoration of spring vegetation, the density of plants in the variant exceeded the previous variants by 1.9 times, 25.0 and 2.9 points, respectively. The development of diseases in the fall was observed on single plants. Mineral fertilizers applied during critical phases of rapeseed growth and development increase the resistance of winter rape plants to diseases. Thus, the introduction of nitrogen in the main fertilizer and feeding plants with it reduces the spread of phomosis and the intensity of the disease development, compared to the control, by 6,7 and 0,9 points, respectively; alternaria, by 2.8 and 8.1 points, respectively. The application of phosphorus-potassium fertilizers is more effective in increasing plant resistance to diseases. Compared to the control and nitrogen application, the introduction of $P_{90}K_{150}$ contributed to a decrease in the spread and intensity of phomosis development by 12.5 and 1.1, 5.8 and 0.2 points, respectively; Alternaria by 18.8 and 13.7, 16.0 and 5.6 points, respectively; Cylindrosporium by 8.0 and 5.1, 4.1 and 0.4 points, respectively. The application of balanced mineral fertilizers in low doses ($N_{100}P_{35}K_{90}$) dramatically reduces the spread and intensity of disease development compared to the control, one-sided nitrogen application and phosphorus-potassium fertilizers: Phomosis, respectively, by 16.6 and

1.7, 9.9 and 0.8, 4.1 and 0.6 points; Alternaria, respectively, by 28.5 and 18.0, 25.7 and 8.9, 9.7 and 3.3 points; Cylindrosporium, respectively, by 12.7 and 5.7, 8.6 and 0.6, 4.5 and 0.4 points. Further increase in balanced mineral fertilizers $N_{200}P_{70}K_{120}$ and $N_{230}P_{90}K_{150}$ does not significantly reduce the disease of winter rape with phomosis compared to the minimum dose of fertilizer $N_{100}P_{35}K_{90}$. The experiment showed a significant decrease in the spread and intensity of Alternaria and Cylindrosporium development.

The influence of soil cultivation systems on the development of some diseases of rapeseed was also investigated [55]. Thus, the experiment showed that the most common and harmful disease of winter rape is Alternaria brassicae. The development of the disease depends on weather conditions. In 2018, the air temperature was high for April (13,4°C), which was almost twice as high as the long-term average (7,7°C), and only 10.1 mm of rain fell (40 mm); such weather conditions did not favor the development of the disease and its first manifestations were recorded on June 20–22. In 2017, on the contrary, sufficient precipitation (III decade of April – 19.5 mm, I decade of May – 5.6 mm) and optimal air temperature in the first decade of May (13.8°C) were favorable for the development of Alternaria and the first signs of the disease were detected on May 13–15.

7 days after spraying the crops with Kolosal Pro fungicide (propiconazole + tebuconazole), the development of Alternaria varied within 1.0–1.2% with a spread of 10-15%, while in variants without fungicide protection, the development of the disease was 4.3–5.7% with a spread of 68% under different methods of soil cultivation (Table 3.5). It should be noted that the development of the disease under shelf tillage during the growing season was 1.5 times lower than under surface tillage. According to Table 5, 20 days after spraying, an increase in the development of the disease was observed. That is, the toxic effect of the preparation restrained the development of Alternaria for 18–20 days.

The technical effectiveness of the fungicide Kolosal Pro against Alternaria is the highest 14 days after spraying and is 84.0–88.0%.

The influence of soil cultivation system on the development of diseases of winter rape is also noted in another study [56] – under conditions of sufficient moisture of the Ivano-Frankivsk Institute of Agricultural Production, the use of plowing by 20–22 cm and shallow tillage by 5–6 cm allows to obtain friendly shoots of winter rape. Plowing the soil by 20–22 cm contributes to better wintering of winter rape, which is 13.4% higher than the result obtained in the variant with shallow tillage by 5–6 cm. The damage to plants by downy mildew depends more on climatic conditions than on the tillage system.

The average long-term rate of winter rape damage by Alternaria and the intensity of the disease development in the variant with plowing at 20–22 cm was, respectively, 14.2 and 7.0%, which is lower than in the variant with shallow tillage at 5–6 cm, respectively, by 2.0 and 2.0 points.

On average, over 4 years of research, the number of winter rape plants affected by phomosis in the variant with shallow tillage by 5–6 cm was 3.2 points higher than in the variant with plowing by 20–22 cm.

An important part of the system of controlling the development of the cruciferous disease reserve is an established system of primary and secondary seed preparation and treatment. It has been established that rapeseed seeds with high moisture content are often subject to mold, which leads to loss of germination and deterioration of the quality of the oil and meal produced. To avoid this, immediately after threshing, the seeds are separated from the heap and spread out for drying with a layer of slightly more than 1 cm with frequent turning [55].

Table 3.5

Alternaria development on pods of winter rape (Institute of Agriculture of Western Polissya NAAS, 2017–2018) [55]

Experiment variant		Disease development (days) after spraying, %.			
		before spraying	after 7	after 14	after 20
Shelf by 20–22 cm (control)	Without pesticides (control)	1.0	4.3	7.5	17.0
	Integrated security system	1.0	1.0	1.2	3.8
Shallow by 10–12 cm	Without pesticides (control)	1.0	5.0	12.5	19.0
	Integrated security system	1.0	1.2	1.5	5.3
Superficial by 6–8 cm	Without pesticides (control)	1.0	5.7	11.7	20.0
	Integrated security system	1.0	1.2	1.5	5.0

Diseases, as noted in the previous sections, affect the quality and chemical composition of cruciferous seeds. Thus, in some studies it is noted [55] that according to I.L. Markov, the greatest changes in the fatty acid composition of oil are observed when winter and spring rape seeds are damaged by pathogens of Alternaria, white and gray rot. At the same time, the proportion of saturated fatty acids, palmitic and stearic acids, monounsaturated fatty acids – erucic, eicosenic and polyunsaturated fatty acid – linoleic acid increases in the oil, but the proportion of monounsaturated fatty acid – oleic and polyunsaturated fatty acid – linoleic acid decreases. Many years of research have established [56] that abiotic factors are one of the main regulating factors of disease in rapeseed. Disease development intensifies when the optimal temperature and humidity coincide in certain periods of time. These optimal conditions are usually different for different pathogens or even for the same disease in regions with different climatic conditions and different agricultural practices. For example, under conditions of moderate temperatures and intense precipitation, the development of Alternaria in rapeseed is enhanced. Over the years of observation (1999–2006), in 6 cases out of 8, winter rape plants were affected by 45 to 100%, pods – 42%, with an average disease intensity of 18%. Spring rape was less affected by Alternaria than winter rape. Thus, in 2002, 46–90% of winter rape plants were affected, with a disease severity of 10–83%, and 26–42% and 3–13% of spring rape, respectively. In 2005, in the northwestern regions, 23–46%, or a maximum of 70%, of winter rape plants were affected, with a disease intensity of 2–10%, and spring rape, respectively, G1-26 and 0.1–5%, and 8–29% of winter rape pods, and 2–7% of spring rape pods. In 2006, 36–100% of winter rapeseed plants were affected in the northwestern regions, 18–56% in the central and southern regions, and 12–36% of spring rapeseed plants. In the northwestern and some central regions of Ukraine, winter rape root bacteriosis is annually observed on 12–64% of the surveyed areas, with 1 to 19% of diseased plants. The spread of rapeseed bacteriosis depends on the climatic conditions in September, when moisture deficit alternates with excessive precipitation, which can lead to the formation of a cavity (hollow) inside the roots, near the root collar, which is inhabited by bacteria. The second critical period for winter rape plants is snowless, frosty winters, as well as frequent thaws, when most of the affected roots become slimy and soaked, leading to plant death. One of the leading places in limiting the development of diseases belongs to the correct soil cultivation system that would meet the most optimal requirements of rapeseed for this agricultural measure.

Biological control of cruciferous crops is actively developing. Thus, against Fusarium and white rot of rapeseed, the staff of the Laboratory of Biological Plant Protection Products of the Oilseeds Research Institute tested the biological product Vermiculen – 0.2 kg/ha of paste based on a strain of fungus antagonist Penicilliitm vermiculatum. The biological effectiveness was 60-90%, and the biological product was not inferior to the effectiveness of foundationol [57]. The introduction of the bacterial strain MaBI Bacillus sp. into the soil as a suspension reduced the number of *S. sclerotiorum* apothecia to 18.8–36.5 % compared to the control, which resulted in a significant reduction in yield losses.

In the experiments, among 217 bacterial isolates isolated from rapeseed plants and related species, isolates inhibiting the growth of *P. sclerotiorum* were selected. Among them were *Pseudomonas fluorescens*, *P. chlororaphis*, *P. agglomerans*, *Stenotro-phomas*.Thirty isolates inhibited the growth of the pathogen due to volatile components, five isolates produced oxalate oxidase [58].

Inoculation of soils with the fungus *Coniotkyrium minitans* (IMI 134523), isolated from the sclerotia of *S. sclerotiorum* of rapeseed, led to a decrease in their survival and reduced the production of apothecia. The effectiveness was especially high when inoculating *S. minitans* in the fall (during sowing of winter rape). S. minitans survives for two years and was able to spread to neighboring areas and infect sclerotia there. However, *S. sclerotiorum* could not be completely eradicated [59].

The introduction of Trichoderma harzianum into the soil inhibited the mycelial stage of *S. sclerotiorum* by 94%, but did not affect the carpogenic germination. The latter was inhibited by 100% when flour from Dwarf, Essex rape seeds with a high glucosinolate content was added to the soil, with a 33% reduction in myceliogenic germination. Flour of the low-glucosinolate rapeseed variety Stonewall, introduced into the soil, reduced carpogenic germination by 44% and did not affect myceliogenic germination. Flour of both varieties inhibited colonization of T. harzianum sclerotia in the soil from 100% to 0 and 8%, respectively, which is why the biocontrol activity of *T. harzianum* decreased in the presence of rice flour [60].

A scheme has been developed to effectively protect winter rapeseed crops from weeds, pests and diseases under intensive cultivation technology. Thus, if 10–15% of leaf blades show symptoms of phomosis or cylindrosporosis, the crops are immediately treated with fungicides. The most effective suppression of gray rot development on winter rape crops is achieved by treating with appropriate preparations at the optimum time – when 10–12% of affected plants appear. The minimum harmfulness of verticillium is observed when treating crops immediately after the first symptoms of plant wilting appear.

The high susceptibility of yellow-seeded samples of spring rape to Fusarium wilt, as well as the high harmfulness and widespread spread of this disease makes it necessary to use chemical control measures.

One of the most effective methods of chemical plant protection is seed treatment.

Seed treatment allows to:

– disinfect seeds from plant pathogens that are transmitted through seed material;

– protect seeds and seedlings from mold in soil conditions;

– to reduce damage to seedlings by root rot and soil-borne pests when treating seeds with combined preparations with the addition of insecticide;

– to reduce the negative impact of traumatic injuries on seed quality by activating its protective properties and preventing the development of microorganisms;

– to stimulate plant growth and development due to the effect of the products on some physiological processes in seeds and germinating plants;

The most effective way to disinfect seeds is to apply the pesticide in film-forming formulations, the so-called inlay and hydrophobization of seeds.

As film formers, you can use a 5% aqueous solution of polyvinyl alcohol, 2–2.5% aqueous solution of sodium salt of carboxymethyl cellulose (for encrustation) and a solution of polystyrene in chloroform (for hydrophobization).

An important advantage of inlaying is that the active substances on the seed surface are not fixed in a continuous film, but in discrete spots. Therefore, with the same protective effect, less active material is required than with classical methods of treatment.

Recommendations for the use of fungicides to prevent damage to spring rape plants by these diseases are ambiguous [61]. In the scientific literature, it is proposed to use the fungicide Forsazh, hp (0.6 l/ha) [62], Aliet, s.p. (1.2–1.8 kg/ha) and Rovral 50 VP, (1.5 kg/ha) [63], Caramba and

Folicur (0.3 l/ha) [64], Ridomil Gold (2.5 l/ha), Derosal 50 (10 kg/ha) and Sarfun 500 (0.6 l/ha) [65–66].

Chemical measures against diseases in rapeseed are also used only when absolutely necessary and reasonable. However, a mandatory measure against seed-borne diseases of rapeseed is disinfection of seeds against external and internal infection with fungicide-protectants approved for use in Ukraine. In order to detect the initial stage of disease development on rapeseed plants in a timely manner and to take effective protective measures to limit their harmfulness, it is necessary to systematically monitor diseases in rapeseed crops. Since most diseases develop simultaneously, rapeseed fields should be inspected at the appropriate time of the plant's growing season. Against the diseases that develop on rapeseed plants during the growing season, in each specific case, on each specific field, an informed decision should be made based on its phytosanitary condition, the expediency of preventive spraying of rapeseed crops with fungicides.

Table 3.6

In vitro evaluation of fungicide efficacy against *Fusarium wilt* pathogen of spring rape [67]

Варіант	**Overgrowth area of the Petri dish surface, cm^2 per day of accounting**			
	3th	**5th**	**10th**	**20th**
1	2	3	4	5
Control (without fungicide)	46.5***	63.6****	63.6****	63.6****
TMTD, SP (800 g/kg of thiram) etalon	0.0	2.5*	10.6*	63.6****
TMTD, VSK (400 g/l tyramine)	0.4*	3.1*	15.5*	63.6****
Maxim, CS (25 g/l fludioxonil)	1.2*	23.2**	31.2**	32.5**
Vincit, SC (25 g/l thiabendazole + 25 g/l flugriafol)	1.3*	3.3*	8.4*	45.1***
Corbel, KE (750 g/l phenropimorph)	1.1*	7.3*	11.7*	54.0****
Panoktin, BP (350 g/l guazatin)	0.1*	0.1*	0.8*	16.6**
Sportak, KE (450 g/l prochlorazole)	0.1*	0.1*	3.8*	17.9**
Raxil T, CS (500g/kg of thiram + 15g/kg of tebuconazole)	The mycelium grows upward only on agar cuttings without transferring to medium			
Raxil, CS (60 g/l tebuconazole)				

(End of Table 3.6)

<table>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>Raxil T, CS (500g/kg of thiram + 15g/kg of tebuconazole)</td><td colspan="4" rowspan="2">The mycelium grows upward only on agar cuttings without transferring to medium</td></tr>
<tr><td>Raxil, CS (60 g/l tebuconazole)</td></tr>
<tr><td>Dividend, CS (30 g/l of difenoconazole)</td><td colspan="4" rowspan="3">Complete inhibition of F. oxysporum growth</td></tr>
<tr><td>Premium, CS (25 g/l triticonazole)</td></tr>
<tr><td>Folicur BT, CE; (125 g/l tebuconazole + 100 g/l bayleton)</td></tr>
</table>

Note: * – very weak fungal growth (1-25 %); ** – weak growth (26-50 %);
*** – medium growth (51-75 %); *** – strong growth (75-100 %).

Until now, the search for fungicides against any particular pathogen has been conducted empirically. To isolate one fungicide suitable for practical use, it is sometimes necessary to test up to 50 thousand chemical compounds [67], Therefore, for the initial selection of fungicidal compounds, methods that require a minimum amount of test substances and low labor costs are used.

For the primary screening of fungicides, a modification of the widely used diffusion method was used [67-68]. The essence of the test is that the test substance is applied to a sterile paper disk, placed in a Petri dish, poured with agar medium, and inoculated with a fungus. The sterile zone is used to judge the activity of the compounds. In laboratory conditions, the primary evaluation of the fungicidal activity of the drugs was carried out on a pure culture of Fusarium oxysporum: TMTD, TSK, maxim, vincit, corbel, panactin, sportak, raksil T, raksil, dividend, premis and follicle. TMTD, SP (800 g/kg of tyramine) was used as a standard (Table 3.7).

The studied fungicides Dividend, Premis, Raxyl and Folicur completely suppressed the development of pathogen mycelium within 20 days, which indicates their high efficiency. Subsequently, all the preparations were tested for disinfection of seeds from pathogens and molds.

Study [68] showed that rape seeds are a source of primary infection with Fusarium pathogens and molds.

The percentage of Fusarium spp. infection of seeds in the control (untreated) varied over the years and averaged 5% over 3 years, which is 2.2–10 times higher than in the inlaid variants. Throughout the entire period, *F. oxysporum* did not develop on seeds treated with systemic preparations: Premis, Follicle, Raxyl T and Raxyl and contact panactin. In all other variants, with the exception of vincit, dividend and sportak, the beginning of the pathogen development coincided with the beginning of its development on untreated seeds (control). All the tested preparations also showed biological effectiveness, reducing the stock of infectious inoculum of such pathogens on seeds as Alternaria spp.

Table 3.7

Frequency of occurrence of Fusarium and mold pathogens on inlaid spring rape seeds [67]

Variant	Consumption rate, kg/t, l/t	Seeds with viable mycelium, % on the 10th day of recording		
		Fusarium spp	*Alternaria spp*	others
Control (without processing)	–	5.0	15.3	8.7
TMTD, SP (800 g/kg), benchmark	5.0	2.3	6.7	1.0
TMTD, VSC (400 g/l)	3.0	2.0 >	6.7	3.7
Maxim, CS (25 g/l)	2.0	2.3	2.7	2.0
Maxim, CS (25 g/l)	5.0	1.7	2.7	0.7
Vincite, SC (25+25 g/l)	2.0	1.3	8.3	1.7
Korbel, KE (750 g/l) + NaCMC	1.0	1.3	2.3	2.0
Sportac, KE (450g/l) + NaCMC:	2.0	0.7	0.7	0.3
Dividend, CS (30 g/l)	2.0	0.7	5.7	2.0
Panoktin, BP (350 g/l)	2.0	0.0	5.0	3.7
Premium, CS* (25 g/l)	2.0	0.0	11.5	2.0
Folicur BT, KE* (125+100 g/l) + NaCMC	1.0	0.0	7.0	0.0
Raxyl T, CS* (500+15 g/kg)	2.0	0.5	0.0	3.5
Raxyl, CS* (60 g/l)	0.5	0.0	1.0	1.0

Note: * – two-year data.

The inlay of spring rape seeds with all fungicides, in general, contributes to a decrease in germination energy and, in some variants, laboratory and field germination. These indicators varied over the years. The greatest negative impact of the preparations on the processes of seed germination is explained by the initial low quality of the seed material. Against the background of all fungicides, the greatest phytotoxic effect on seedlings in the laboratory and young plants in the field was observed in Premis and Folicur BT, which on average over 2 years of testing reduced the energy of seed germination by 20.4–33.5%, laboratory germination by 9.2–18.4% and field germination by 7.4–11.3%. In seedlings under laboratory conditions in variants with Folicur, the root system was represented only by a central root with very weak pubescence, the length of which was 37.5–43.1% of the control, which had well-developed central and lateral roots with dense pubescence. As for Premium, with normal development of the root system of seedlings, their length was 53.1–58.5% of the length of seedlings from untreated seeds. Sportak significantly reduced the energy of seed germination in the first year of testing, but germination rates both in the laboratory and in the field were of the same order, from year 3 it was 5%, which is 2.2–10 times higher than in the variants with inlay. Throughout the entire period, the germination rate on seeds treated with systemic preparations: Premium, Folicur, Raxil T and Raxil and contact panactin, F. oxysporum did not develop. In all other variants, with the exception of Vincite, Dividend and Sportak, the beginning of pathogen development coincided with the beginning of its development on untreated seeds (control). All the tested preparations also showed biological effectiveness, reducing the stock of infectious inoculum of such pathogens on seeds as Alternaria spp.

During the three years of field experiments, the meteorological conditions for the growth and development of spring rape were not the same. However, the common factor is that during the flowering period of yellow-seeded rape, droughts were observed under the dominance of easterly winds. At high temperatures, yellow-seeded rape showed such phenomena as heterostylia, deformation of pistils, reduced pollen productivity, etc. This caused a low degree of realization of the potential productivity of yellow-seeded rape (Tables 3.8–3.9) and, apparently, low biological efficiency of seed treatment with fungicides. These results are consistent with the data obtained during the study of the influence of the level and mode of moisture supply to wheat plants on the effectiveness of pre-sowing seed treatment with contact and systemic fungicides. It has been shown that dry conditions at any stage of wheat organogenesis before filling reduce the biological effectiveness of treatment, and sowing treated seeds in insufficiently moist soil can lead to a decrease in yield and grain quality compared to the untreated control.

Thus, in breeding for resistance to Fusarium wilt of spring rape, an infectious background should be widely used, which makes it impossible to make mistakes when evaluating the source material. When creating such a background, it is possible to use complex compositions of pathogen populations that are as close as possible to the natural one existing in a given soil and climatic zone. The introduction of materials into the soil of the infectious nursery should be carried out simultaneously with sowing seeds.

Table 3.8

Effect of fungicide treatment of spring rape seeds (type "000") on Fusarium infection [61]

Variant	Consumption rate, l/t, kg/t	Plants affected by Fusarium, %				Average biological efficiency, %
		2001	2002	2003	average	
Control (without processing)	–	77.2	99.6	57.9	78.2	–
TMTD, SP (800 g/kg), etalon	5.0	27.6	95.3	59.6	60.8	22.8
Korbel, KE (750 g/l)+NaCMC	1.0	34.4	94.5	39.9	56.3	30.3
Vincite, SC (25+25 g/l)	2.0	25.9	92.4	46.2	54.8	31.7
Dividend, CS (300 g/l)	2.0	27.4	93.1	44.0	54.8	32.0
Sportac, CE (450 g/l) + NaKMC	2.0	32.9	92.7	30.0	51.9	38.6

The temperature optimum for infection of yellow-seeded spring rape with F. oxysporum is within 14–16 °C, which is 6–10 °C lower than for infection of blue-seeded rape. At early terms of spring sowing of "000" type rape, conditions more favorable for infection are created (Table 3.10).

As a criterion for the feasibility of using fungicides, it is proposed to take into account the excess of the cost of a possible crop shortfall over the cost of applying the fungicide twice. If the cost of a lost harvest is less than the cost of two treatments, it is not advisable to use chemical protection on rapeseed.

Table 3.9

Seed quality of spring rape seeds (type *'000") after treatment with different fungicides, 2001–2003 [61]

Variant	Consumption rate of preparative, l/t, kg/t	Germination energy of the seed, %				Seed germination, %							
						laboratorial				fieldwork			
		2001	2002	2003	Xavr	2001	2002	2003	Xavr	2001	2002	2003	Xavr
Control	–	66.0	95.0	92.0	84.0	72.0	96.0	94.0	87.0	51.0	69.0	76.0	65.0
TMTD, SP (800 g/kg), benchmark	5.0	70.0	91.0	91.0	84.0	77.0	95.0	93.0	88.0	53.0	72.0	74.0	66.0
Korbel, KE (750 g/l) +NaKMC	1.0	49.0	96.0	92.0	79.0	75.0	98.0	94.0	89.0	53.0	74.0	75.0	67.0
Vincite, SC (25+25 g/l)	2.0	57.0	93.0	91.0	80.0	74.0	95.0	91.0	87.0	52.0	67.0	79.0	66.0
Dividend, CS (300 g/l)	2.0	67.0	93.0	90.0	83.0	75.0	94.0	91.0	87.0	53.0	73.0	73.0	66.0
Sportak, CE (450 g/l) + NaKMC	2.0	32.0	96.0	89.0	72.0	69.0	96.0	93.0	83.0	48.0	74.0	76.0	66.0
Premium, CS (25 g/l)	2.0	35.0	86.0	–	60.0	64.0	86.0	–	75.0	41.0	64.0	–	53.0
Folicur BT, KE (125+100 g/l) + NaKMC	1.0	20.0	74.0	–	47.0	53.0	78.0		66.0	39.0	58.0	–	49.0

Seed of varieties unstable to phomosis should be treated with a mixture of bitertanol and tebuconazole (12 g and 0.2 g of d.v./g of seed, respectively). If necessary, it is also advisable to treat the plants in the fall (in some cases twice). Spring treatments are also possible, but in general they are much less effective than autumn treatments. Fungicide treatment should be combined with insecticide treatment, as mechanical damage by insects contributes to the development of phomosis.

In the UK, the fungicides Prochloraz and Sportak provided satisfactory results against canker when applied in late fall or spring at recommended rates.

Table 3.10

Efficiency of fungicide application in the treatment of spring rape seeds (type "000") against Fusarium head blight [61]

Variant	Consumption rate, l/t, kg/t	Yields, t/ha	Oil content in seeds, %.	Oil yield, t/ha	Content of glucosinolates, µmol/g	Weight of 1000 seeds, g
Control	–	0.22	42.7	0.083	22.2	2.3
TMTD, SP (800 g/kg), benchmark	5.0	0.23	42.8	0.087	22.7	2.4
Korbel, KE (750 g/l) +NaKMC	1.0	0.28	42.7	0.105	22.7	2.4
Vincite, SC (25+25 g/l)	2.0	0.27	42.9	0.102	22.1	2.3
Dividend, CS (300 g/l)	2.0	0.28	42.8	0.105	20.3	2.4
Sportak, CE (450 g/l) + NaKMC	2.0	0.29	42.8	0.109	21.8	2.5

There was no increase in the effectiveness of prochloraz when the recommended rate was applied in several terms. However, this disease did not significantly affect the seed yield, which may be due to its relatively weak development [68–69].

Sopra (France) is building protection of rapeseed crops on the use of fungicides with flutriafol and procyamidone as active ingredients, which belong to different groups of chemical compounds, have different modes of action, and an additional spectrum of activity. Both substances can be mixed with other drugs (e.g., Deroprene FL, Deroprene 80 WC). Flutriafol is highly effective against *Ps. capsellae*, *C. concentrium, A. brassicae*. Procyamidone is a highly effective agent against A. brassicae and S. sclerotiorum. In the developed strategy, the concentrations of flutriafol and procimidone were reduced by 20 and 25% (94 g of flutriafol and 375 g of procimidone). The use of flutriafol and procimidone allows to protect rapeseed crops during the entire growing season [70].

Folicur (tebuconazole) effectively inhibited the development of *S. sclerotiorum, L. maculans*, *Pyrenopeziza brassicae*, Alternaria spp., Verticillium spp., *Mycosphaerella brassicicola*, *B. cinerea, B. concentricum* when the fungicide was applied in the flowering and early seed ripening phases [71].

Application of Folicur before flowering of rapeseed reduced lodging of the crop regardless of the presence of the disease, and the retardant effect of the drug increased with increasing dose. The effectiveness of tebuconazole against stem diseases and its ability to prevent lodging of rapeseed significantly decreased during treatment after flowering. Double application of tebuconazole before and after flowering not only provided complete protection of the crop from diseases and delayed lodging, but also led to a significant increase in yield. It is believed that the reduction of lodging in oilseed rape by tebuconazole may be due to both the suppression of stem disease development and the ability of the fungicide to inhibit the aging of green tissues [72].

With a high infection background of Alternaria spp. and *B. cinerea*, the best results can be obtained with early treatments (at the beginning of flowering) with the following fungicides: fluzilazole + carbendazim, procyamidone, tebuconazole, metconazole and azoxystrobin [73].

Ronilan (1.5 l/ha), Torak (0.6 l/ha), Sumislex (0.7–1.0 l/ha), Verizan (2–3 kg/ha), Rovral (1.0–1.5 l/ha) are recommended for controlling Phoma, Verticillium and S. sclerotiorum fungi.

In the protection of rapeseed from *S. sclerotiorum*, *A. brassicae, B. cinerea*, which affect plants at the beginning of flowering, a mixture of prochloraz (133 g/l) and iprodione (133 g/l) at a dose of 3 l/ha is effective [74].

Sportak PF (1 and 1.5 l/ha) and bavistin (0.5 l/ha) with double treatment, carbendazim and rovral were effective fungicides against white leaf spot on winter rape crops.

At the recommended doses, the dinitroaniline herbicides Sytoxidium and Cyclosidium, which are most often used on rapeseed in Iran, have the highest antifungal activity against S. sclerotiorum in vitro on toxic CAA media [75].

In Schleswig-Holstein, the area under rapeseed reached 90 thousand hectares. One of the problems of the industry is the fight against fungal diseases, among which the first place is occupied by *S. sclerotiorum* stem damage. The fungicides Ronilan, Sumilex, Verizan, and Rovral were used to combat sclerotinia. The optimal time for using fungicides is in the phase of full flowering (5–10 days after the beginning of flowering). These drugs are effective against Botrytis, Alternaria, *C, concentricum* fungi. In 1983–1986, aerial fungicide treatment in the Lübeck region was carried out on 5.6–20 thousand hectares of rapeseed crops. On average, up to 100–150 marks/ha is spent in the area to combat fungal diseases of rapeseed.

Spraying with one of the fungicides carbendazim (0.55 kg d.in./ha), iprodione (0.5 kg d.in./ha), vinclozalin (0.5 kg d.in./ha) or mixtures of iprodione with thiophanate-methyl (0.5+0.5 kg d.in./ha) significantly reduces the infection of S. sclerotiorum. Fungicide treatment did not affect the weight of 1000 seeds. The treatment is optimal in late April and early May before the humidity increases [76].

Against downy mildew, during the growing season, crops are sprayed twice with Aliet, SP (800 g/kg) at the rate of 1.2–1.8 kg/ha. The first – 12–15 days after germination, the second – during the budding period, mainly on crops for seed production. It is recommended to apply these sprays in combination with insecticides to kill pests. No second chemical treatment is applied to crops intended for green mass production. When powdery mildew appears, the crops are treated with 1% colloidal sulphur at the rate of 2.5–3.5 kg of the product per 1 ha. This work is completed later, 6–7 days before harvesting.

Since the primary source of infection can be infected rapeseed, it must be cleaned, calibrated and treated. For this purpose, the same treatments mentioned above are used: TMTD, 80% NPK 5–6 kg/t and Vitavax 200, 75% NPK 2–3 kg/t, which contribute to the long-lasting protection of rapeseed against Fusarium and Alternaria [77]. It is also recommended to use a complex preparation – Rapkol, TK – 25 kg/t. According to [78]. This product not only protects rapeseed seedlings from diseases, but also prevents damage by cruciferous fleas. In addition to the above-mentioned products, other fungicides have been tested in the fight against Fusarium. The biological effectiveness in the fight against seed infection of Fusarium and Alternaria was 97.4% for Vincit, 96.2% for Baytan-Universal, 98.7% for Vitavax + boric acid, and 96.2% for boric acid + $MnSO_4$ [79–80]. Trace elements, being nutrients, increase plant productivity and resistance [81–83]

In addition, there are recommendations to use such preparations as Rovral, 3 kg/ha and Folicur, 1 kg/ha for the treatment of plants during the growing season, which prevents damage from Alternaria [84]. With a high degree of spread of this disease, the best results were obtained with early treatment of plants (at the beginning of flowering) with solutions of the following fungicides: procyamidone, tebu conazole, metconazole and azoxystrobin or a tank mixture – flusilazole + carbendazim.

To protect crops from rot, it is recommended to use products from the carboxamide class, boscalid, 200 g/l. The use of chemicals from the class of benzimidazoles, carbendazim, 500 g/l, is almost universal. This is a systemic preparation recommended against a complex of diseases. The fungicide is aimed at inhibiting the process of nucleation in fungal cells. It is most effective against diseases of vegetative organs, as well as a complex of seed-borne phytopathogens, and is often used for pre-sowing seed treatment. Also effective in this class are fungicides with benomyl-based formulations, 500 g/kg, with combined action.

High efficiency is characterised by systemic triazole preparations: triadimefon, 250 g/l; metconazole, 60 g/l; propiconazole, 250 g/l; tebuconazole, 250 g/l, which are effective against peronosporosis, alternaria, phomosis, powdery mildew, and suppress root rot, smut fungi and seed mould.

Variants of fungicide combinations on winter rape and different seeding rates were also studied [85]. Thus, the use of fungicides in autumn had a pronounced positive impact on reducing the development of stem blight. Thus, against the background of a sowing rate of 1 million germinating seeds/ha, the level of biological efficiency of fungicides against stem blight was 33–92%, and against the background of 1.8 million germinating seeds/ha – 40–93%.

Among the fungicides studied, against the background of a seeding rate of 5 kg/ha, the maximum value of biological effectiveness against stem blight was on the variants Rex C and Impact, and in thickened crops – when using Zenon Aero and Impact.With an increase in the seeding rate, the damage to the leaves by fomites also increased slightly. The difference was especially significant in the rosette phase in spring (immediately after the resumption of vegetation) [86].

In the phase of 6 leaves (3 pairs of true leaves), such preparations as Zenon Aero and Impact stood out among the fungicides studied in the first background. At the increased seeding rate, the lowest development of the disease was observed when treating crops with Zenon Aero, Impact and Falcon. The maximum biological effectiveness of fungicides was in the rosette phase in spring. By the flowering stage, the effect of autumn fungicide treatment ceased. There were no significant differences in the value of biological efficiency, depending on the seeding rate. On the backgrounds with different seeding rates, the maximum value of biological efficiency was observed when using Zenon Aero and Impact.

Autumn application of fungicides on winter rape did not give a positive result in controlling Alternaria leaf blight of winter rape. Seeding rate had the greatest impact on this disease. In particular, with an increase in the seeding rate, the prevalence of Alternaria increased by 1.36 times (Table 3.11).

With the increase in sowing density, the phytosanitary condition of the seeds of the new crop deteriorated. This effect was especially significant for Alternaria. All the fungicides studied did not affect the infection of seeds with Alternaria, but somewhat reduced the infection of seeds with Phomosis. Here, too, Impact had a slight advantage. The use of fungicides helped to increase the safety of plants in the autumn and winter period. At the increased seeding rate, the highest plant survival was observed when using Rex Duo, while Zenon Aero stood out against the background of the seeding rate. At the same time, there were no significant differences in plant density in spring between the variants of experiments with fungicides.

To assess the mechanisms of fungicides influence on winter hardiness in autumn before going to wintering, the main indicators affecting the winter hardiness of rape were determined (Table 3.12). Spraying winter rape plants with fungicides in most cases led to a decrease in the height of the growth point from the surface. At higher seeding rates, this effect was most intense in the cases of Falcon and Zenon Aero, and at lower seeding rates –

Alto Super and Zenon Aero. In general, the results obtained indicate the pronounced growth-regulating properties of triazole fungicides on winter rape. Data on seed yields (Table 3.12) show that increasing the seeding rate of winter rape from 1 to 1.8 million Germinating seeds per 1 ha leads to a significant decrease in crop yield.

Table 3.11

Values of biometric parameters affecting winter hardiness of winter rape [86]

Variant	Number of leaves, pcs/plant	Root collar diameter, mm	Height of the growth point, mm
Seeding rate 1 million germinating seeds/ha			
Control	8.3	5.30	19.6
Alto super	8.6	5.49	17.5*
Rex S	8.4	5.51	18.3*
Rex Duo	8.5	5.42	18.0*
Zenon Aero	8.9	5.60*	17.7*
Impact	8.3	5.09	18.8
Falcon	8.7	5.50	18.4*
Seeding rate of 1.8 million germinating seeds/ha			
Control	7.6	4.00	18.2
Alto super	8.0	4.00	18.0
Rex S	7.6	4.82*	17.6*
Rex Duo	8.1	4.45*	17.3*
Zenon Aero	8.3	4.00	16.9*
Impact	8.6	6.18*	18.5
Falcon	8.1	4.91*	16.0*

Note: * – not significant before controlling for P = 0.05.

Thus, in the control variant, at a seeding rate of 8 kg/ha, the yield of winter rape decreased by 1.87 t/ha. Treatment with fungicides slightly increased the yield of rape against this background, but in this case it was 1.61–1.82 t/ha less than when sown at a seeding rate of 5 kg/ha.

Among the studied variants of fungicide treatment, the most effective in terms of plant productivity was Zenon Aero against the background of a seeding rate of 5 kg/ha. In this variant, the biological yield for two years reached 4.43 t/ha, and the increase from the treatment was 0.73 t/ha. The return on treatment was slightly lower when Falcon was used (+0.65 t/ha compared to the control). The positive effect of autumn fungicide treatment of plants is primarily manifested in an increase in the number of pods per plant and the weight of 1000 seeds.

Table 3.12

Biological yield of winter oilseed rape under different fungicide treatments, t/ha [86]

Variant	Year		Average	Growth from fungicide	Deviations in seeding rate
	2007	2008			
Seeding rate 1 million germinating seeds/ha					
Control	3.98	3.41	3.7	–	–
Alto super	4.85	3.68	4.27	0.57	–
Rex S	4.41	3.52	3.97	0.27	–
Rex Duo	4.46	3.84	4.15	0.45	–
Zenon Aero	4.84	4.01	4.43	0.73	–
Impact	4.37	3.59	3.98	0.28	–
Falcon	4.48	4.21	4.35	0.65	–
Seeding rate of 1.8 million germinating seeds/ha					
Control	1.92	1.74	1.83	–	–1.87
Alto super	2.61	2.71	2.66	0.83	–1.61
Rex S	2.45	2.12	2.29	0.46	–1.68
Rex Duo	2.19	2.46	2.33	0.5	–1.82
Zenon Aero	2.44	2.74	2.59	0.76	–1.84
Impact	2.46	2.12	2.29	0.46	–1.69
Falcon	2.8	2.54	2.67	0.84	–1.68
$SSD_{05}A$	0.75	0.65			
$SSD_{05}B$	0.26	0.17			

Fungicides based on aluminium fosetyl (800 g/kg), which are organophosphate compounds, are also used against downy mildew.

Interesting results were obtained in the following studies [86] to study the impact of diseases (downy mildew and phomosis) on the development and productivity of winter rape plants depending on sowing dates, row spacing and density, and mineral fertiliser application. Three sowing dates were studied: early – 7–10.08; optimal – 19–22.08 and late – 28–31.08. The data on the effect of sowing dates on the damage of winter rape of the Xaverivskyi variety and its productivity are presented in Table. The analysis of the table data shows that downy mildew and phomosis affect rape plants differently depending on the sowing date. The maximum damage by downy mildew was observed at an early sowing date. The disease spread was 65%, and its development was 11.4%. When using the late sowing date, the spread of downy mildew was lower and amounted to 38%, and the development – 8.5%. The phomosis incidence increased from 32% to 41% when switching from early to late sowing, and the disease development increased by 1.3 times. The yield of rapeseed seeds at late sowing dates was 6.2 centner/ha higher than at early sowing dates. The difference in seed yields between early and late sowing dates can be explained by optimal weather conditions in autumn, as well as the influence of diseases, as downy mildew affects young rapeseed plants, and phomosis affects plants of later vegetation.

The data on the impact of seeding rates in the wide-row sowing method on the disease incidence and productivity of winter rape are presented in Tables 9.13–9.14. The analysis of these tables shows that the lowest efficiency was found in the variant with a seeding rate of 2.5 million seeds per 1 ha. The incidence of downy mildew in this variant was 80%, phomosis – 69%, and the development of diseases was 12.1 and 4.7%, respectively. The seed yield of this variant was the lowest – 16.4 centner/ha. Excellent results were obtained in the variant with the optimal rate of 1.5 million seeds per 1 ha. The disease incidence and development of this variant was within the optimal range compared to other variants. The seed yield was maximum and amounted to 18.4 centner/ha.

Table 3.13

Influence of sowing dates on disease infection of winter rape of Xaverivskyi variety and its productivity (NUBiP agricultural station) [87]

Sowing dates	Downy mildew		Phomosis		Productivity seeds, centners / ha
	affected plants, %	disease progression, %	affected plants, %	disease progression, %	
Early	65	11.4	32	2.6	17.5
Optimal	52	10.0	28	2.5	18.3
Late	38	8.5	41	3.5	23.7
SSD_{05}	1.5	2.2	1.7	0.9	4.5

Similar studies have shown the dependence of spring oilseed rape on the timing of sowing.

Table 3.14

Effect of sowing dates of spring oilseed rape of Vasylkivskyi variety on the severity of downy mildew [87]

Sowing dates	Phase 2–3 leaves		The budding phase	
	affected plants, %	disease progression, %	affected plants, %	disease progression, %
5th April	15.0–30.0	0.5–7.8	30.0–43.5	0.7–10.5
25th April	30.0–43.6	0.6–10.2	44.0–59.2	1.7–15.4

The data in the table shows that the development of downy mildew in spring rape increases at late sowing dates. Thus, at the early sowing date (5 April) compared to the late sowing date (25 April), the number of affected plants was 13.5–15% less in the 2–3 leaf stage and 11.0–15.7% less in the budding stage, respectively, and the development of the disease was 0,1% and 2,4% less in the 2–3 leaf stage and 1,5–4.9% less in the budding stage.

Table 3.15 shows the results of studies of seeding rates of narrow-row sowing method and their influence on disease severity and productivity of winter rape seeds of Xaverivskyi variety. The data in the table indicate that the severity of downy mildew and phomosis differed only slightly compared to the wide-row sowing method. The maximum seed yield was observed in the variant with a seeding rate of 1 million seeds per 1 ha, which is optimal.

Table 3.15

Influence of seeding rates on disease incidence and productivity of winter rape variety Xaverivskyi under wide-row sowing method (NUBiP agricultural station) [87]

Seeding rates (million seeds/ha)	Downy mildew		Phomosis		Seed yield, centners / ha
	affected plants, %	disease progression, %	affected plants, %	disease progression, %	
0,5	33	6.1	44	3.5	16.1
1,0	41	7.0	40	3.4	17.3
1,5	50	7.8	52	3.7	18.4
2,0	72	11.8	68	4.5	18.1
2,5	80	12.1	69	4.7	16.0
SSD_{05}	1.2	2.0	4.5	0.8	3.3

Table 3.17 shows the results of studies of the effect of mineral fertiliser doses on disease incidence in winter rape of the Xaverivskyi variety and its productivity. Analysis of the data shows that the incidence of downy mildew and phomosis increases with an increase in the dose of nitrogen fertiliser. Thus, when applying the optimal rate of mineral fertilisers $N_{60}P_{60}K_{60}$, the damage and development of downy mildew and phomosis was at the level of control (without fertilisers).

Table 3.16

Influence of seeding rates on disease incidence and productivity of winter rape variety Xaverivskyi at narrow-row sowing [87]

Seeding rates (million seeds/ha)	Downy mildew		Phomosis		Seed yield, centners/ha
	affected plants, %	disease progression, %	affected plants, %	disease progression, %	
0,5	50	8.9	53	2.8	18.9
1,0	55	9.5	50	2.8	21.1
1,5	66	10.0	60	3.6	20.1
2,0	70	11.5	66	3.9	19.1
2,5	76	12.6	72	4.1	18.9
HIP_{05}	5.4	1.8	4.3	1.2	1.9

The seed yield in this variant exceeded the control by 1.6 centners /ha. In the variant where the same doses were applied, only nitrogen was applied half under the main cultivation and the other half in the spring, the disease incidence was also at the level of the previous variant. And the seed yield of this variant exceeded the control by 3.9 centners /ha. And in the variant with an increased dose of potash fertiliser $N_{60}P_{60}K_{90}$, the disease incidence, on the contrary, decreased by 18% compared to the control, and phomosis – by 12%. The development of diseases was also lower by 2.3 and 1,7%, respectively. Seed yields exceeded the control by 3.2 centner/ha. Further increase in nitrogen fertiliser doses in the $N_{90}P_{90}K_{90}$ variant showed that the incidence of downy mildew increased by 8% compared to the control, and phomosis by 15%. The development of diseases was respectively 3.8 and 1.8% higher.

Similar studies were conducted on spring rape in relation to downy mildew (Tables 3.17–3.18).

Table 3.17

The role of fertilisation of spring rape of Vasylkivskyi variety on the damage by downy mildew [87]

Fertiliser rates	Phase 2-3 leaves		The budding phase	
	affected plants, %	disease progression, %	affected plants, %	disease progression, %
Control	20.5–46.0	0.7–10.5	35.2–61.0	2.4–18.3
$N_{60}P_{60}K_{90}$	15.4–34.0	0.5–8.2	25.0–50.0	0.9–14.2
$N_{120}P_{120}K_{120}$	12.8–35.0	0.3–7.1	23.3–43.0	0.8–13.5
SSD_{05}	2.2–7.2	0.3–0.5	0.6–4.1	0.4–0.8

The results of the records of plant damage by the pathogen downy mildew indicate that the disease developed less in the experimental variants where fertilisers were applied. It was noted that the highest resistance of rapeseed plants to the disease was in the areas where a double dose of mineral fertilisers was applied. At the same time, the results showed that the use of a double dose of mineral fertilisers has no effect, i.e. the threshold for applying mineral fertilisers $N_{60}P_{60}K_{90}$ in spring rape was found, given the limited spread of downy mildew.

Thus, in order to increase plant disease resistance, the correct use of mineral fertilisers is an integral part of the developed system of disease control measures.

By the author [87] the following generalisations have been made:

1. Disease development in winter rape of the Xaverivsky variety depends on the sowing date. The pathogen of downy mildew developed more intensively at early sowing. The phomosis pathogen, on the contrary, developed more intensively at a later sowing date. This phenomenon can be explained by the biological characteristics of pathogens. For example, downy mildew develops more intensively on young rapeseed plants (budding phase), while phomosis, on the contrary, develops more intensively on rapeseed plants in later stages of development (flowering and podding phase). The advantage of rapeseed yields at late sowing compared to early sowing is explained by the climatic conditions prevailing during the autumn growing season. Plants of early sowing of winter rape are overgrown, poorly adapted to wintering, and are more severely affected by root bacteriosis, which is one of the factors of yield loss.

Table 3.18

Effect of mineral fertiliser doses on disease incidence in winter rape of Xaverivskyi variety and its productivity [87]

Variants with fertilisers	Downy mildew		Phomosis		Seed yield, centners/ha
	affected plants, %	disease progression, %	affected plants, %	disease progression, %	
Control (no fertiliser)	70	11.5	48	3.8	17.5
$N_{60}P_{60}K_{60}$	68	11.0	45	3.5	19.1
$N_{30}P_{60}K_{60}+N_{30}$	72	11.2	43	3.2	21.4
$N_{60}P_{60}K_{90}$	52	9.2	36	2.1	20.7
$N_{90}P_{90}K_{90}$	78	15.3	63	5.6	21.6
SSD_{05}	4.0	1.9	5.1	2.2	2.25

2. In experiments to study the effect of sowing rates in wide-row and narrow-row sowing, it was found that the most intense damage and development of diseases was observed in the variant with a sowing rate of 2.5 million seeds per 1 ha. Excellent results in terms of both disease resistance and seed yield were obtained in the variant with a sowing rate of 1.5 million seeds per 1 ha in a wide-row sowing method with a row spacing of 0.45 m.

The development of pathogens was similar in the narrow-row sowing method. The optimum seeding rate of winter rape was established at 1 million seeds per 1 ha with a row spacing of 0.15 m (narrow-row sowing method), in which the development of diseases was moderate and the seed yield was 21.1 centners /ha.

3. In an experiment to study the effect of mineral fertiliser doses on the development of diseases of winter rape of the Xaverivskyi variety and its productivity, the optimal rate of mineral fertiliser application $N_{30}P_{60}K_{60}$+ N_{30} in spring was established. At this dose, a moderate development of downy mildew and phomosis pathogens was recorded. The seed yield under this variant was 21.4 centners /ha. In the control variant without fertilisers – 17.5 centners /ha. The dose of mineral fertiliser $N_{60}P_{60}K_{90}$ is also worthy of note. This rate helped to reduce the development of diseases, and the seed yield was 20.7 centners /ha.

The use of the maximum dose of mineral fertiliser $N_{90}P_{90}K_{90}$ was not effective, as it contributed to an increase in the damage to rapeseed plants by pathogens of downy mildew and phomosis.

In Slovakia, Hungary, and the Czech Republic, the biological preparation AZOTER SC® is recommended to reduce the infectious pressure of the sclerotinia pathogen, which, along with nitrogen-fixing and phosphorus-mobilising bacteria, contains the fungus *Coniothyrium minita*ns. The fungus parasitises sclerotia and thus reduces the infection load during the initial infection of rapeseed with ascospores. Regular use of the biological product can significantly reduce the infectious potential in the soil, which leads to a decrease in the degree of damage to the roots and stems of plants. At the same time, the top layer of soil is cleared of sclerotia and root infection is prevented, which is not achieved by applying fungicides. However, in the case of strong infectious pressure of the pathogen, the use of this product is not enough (Table 3.19).

It should not be forgotten that the use of chemical methods of protecting cruciferous plant species from diseases is mostly of preventive value, since the treatment of plants with chemicals is carried out on the assumption that the pathogen will be destroyed before it penetrates the tissue. Therefore, chemicals are used to treat the outer surface of plants, which provides external protection against pathogens.

Table 3.19

Effect of fungicide on sclerotinia infection and yield of winter oilseed rape [28]

Experimental conditions	Degree of damage		Seed yield, centners / ha	
	Control	Application of the fungicide	Control	Application of the fungicide
4 years with low damage	16	3	33.4	36.5
6 years with medium damage	42	11	31.6	36.4
2 years with severe damage	74	20	23.8	30.0

In addition to external protection, the chemical method can be used for plant immunisation, as a result of which plants are able to actively prevent pathogens from entering the body. Chemicals are injected into the interior of plants (or seeds). The treated plants become resistant to parasitic organisms. Chemicals are used to kill pathogens on the surface of plants or seeds, so the chemical method is active, unlike the passive agronomic method. The chemical method is particularly effective in case of massive disease manifestation, its epiphytosis, when by spraying the affected fields the pathogen is destroyed over large areas and thus the harvest is preserved.

Over the past 40 years, a number of active ingredients have been studied to determine the effectiveness of fungicides for their integrated use. Thus, in 1995–2000, a study was conducted to investigate the effectiveness of their individual formulations in Ukraine. such preparations as sportak 45% c.e., alliette 80% w.p. were studied, and polycarbacin 80% w.p. was used as a control.

The first treatment of winter rape plants was carried out in autumn at the stage of 3–5 leaves. The second one was in spring, before budding. The application was based on the consumption of the working solution – 400 l/ha. Table 3.20 shows the results of treatment of winter rape plants with chemicals to limit the development of downy mildew and phomosis diseases. High effectiveness against downy mildew and phomosis of such fungicides as Aliette 80% w.p. at the rate of 1б5 kg/ha and Sportak 45% w.p. – 1 l/ha was established. The reduction in disease incidence was 1б8 and 2 times compared to the control, respectively.

The data of the yield results obtained in the variants of winter rape treatment with different fungicides are presented. Aliette exceeded the standard by 2б6 centner/ha; Sportak – by 2б7 centner/ha. Thus, the above research data indicate the need to use fungicides against cruciferous diseases as a preventive measure of plant protection.

Depending on the number of apothecia formed and the local and annual weather conditions, fungicides should be applied during flowering. The effectiveness of chemical control of sclerotinia is shown in Table 3.21, which summarises the results of an 11-year trial.

Treatment of Alternaria in rapeseed is based on timely application of fungicides. To do this, use products with active ingredients [85]:

– Tebuconazole. Preparations with this active ingredient from the triazole class protect the crop from Alternaria and Phomosis. In plant cell membranes, tebuconazole inhibits ergosterol biosynthesis of phytopathogens by inhibiting demethylation at the C-14 position. The difference from other triazoles is the effect on metabolism. Growth-regulating effect is an additional effect of the use of drugs with this active ingredient.

– Propiconazole. Propiconazole also acts as an inhibitor of ergosterol biosynthesis in the membranes of phytopathogen cells. After application, the cell walls of pathogens are destroyed, mycelium growth stops, and then it dies. Movement occurs acropetally.

– Azoxystrobin, a fungicide from the strobilurin class, inhibits mitochondrial respiration in pathogen cells. Drugs based on this active ingredient are contact-based and have a therapeutic effect, as well as a partially systemic effect. It will be especially effective in the early stages of infection development – azoxystrobin fights the growth of conidia, the initial growth of fungal mycelium and prevents spore formation.

Table 3.20

Influence of different chemicals on the development of winter rape diseases (Agronomic Research Station NUBiP) [87]

Experimental variants	Disease incidence, %	
	Downy mildew	Phomosis
Control (no treatment)	10.2	6.4
Polycarbacin 80% w/w 2.4 kg/ha	6.0	3.8
Aliette, 80% w.p. 1.5 kg/ha	5.6	3.7
Sportak, 45% c.e. 1 litre/ha	5.1	3.1
SSD_{05}	2.2	1.8

Table 3.21

Effect of different chemicals on the yield of winter oilseed rape seeds (Agronomic Experimental Station of NUBiP) [87]

Experimental variants	Seed yield, centners / ha
Control (no treatment)	20.2
Polycarbacin, 80% w/w, 2.4 kg/ha	22.6
Aliette, 80% w.p., 1.5 kg/ha	22.8
Sportak, 45% c.e., 1 litre/ha	22.9
SSD_{05}	2.7

To limit the development of pathogens of this disease and the spread of Alternaria itself, it is recommended to use the following fungicides:

– Bukat, CS – 0.5 l/ha (tebuconazole) from IFAGRI;

– Veto, CE – 0.5 l/ha (propiconazole) from IFAGRI;
– Azociper Neo, CS – 0.75–1 l/ha (azoxytrobin + ciproconazole);
– Clark, WG – 0.25-0.4 kg/ha (azoxytrobin);
– Confirm, SE – 1–1.4 l/ha (thiophanate-methyl + tebuconazole + cyflufenamide) from Sumi Agro;

To improve the wetting of the working solution and increase its effectiveness, we recommend the following adjuvants/SAS:
– MultiMaster (0.08 – 0.16 l/ha);
– Silixan 106 (0.05 – 0.1 l/ha).

It is also worth noting the experience of Ukrainian producers in protecting spring and winter rape from major diseases.

Thus, it is noted [88-151], that among a number of factors that limit the potential productivity of winter rape varieties and hybrids is a violation of cultivation technology, in particular the crop protection system, which leads to a shortfall of 30–40% of the seed yield. Diseases and pests cause great damage to crops, causing significant losses and reducing product quality. The damage caused by the intensive development of diseases and massive pest infestation is the early and premature death of leaves, buds, and pods, which significantly reduces the quantity and quality of the crop. The introduction of a highly effective system of plant protection against a complex of pests is the most important stage of modern technology for growing winter rape.

It is noted that during 2005–2022 in Ukraine, the most common and harmful diseases of spring and winter rape are snow mould (typhoid), black leg (rhizoctonia), downy mildew (peronosporosis), black spot (alternaria), stem cancer or root neck necrosis (phomosis), white rot or sclerotinia (white stem) grey rot (botrytis), light spot (cylindrosporium), verticillium wilt (verticillium blight), fusarium wilt (fusarium), winter rape root bacteriosis, and spring rape mucilage bacteriosis. Less common are white spotting (ring spotting, or grey stem), powdery mildew, clubroot, common mosaic, wrinkled mosaic, black ring spotting, turnip yellow virus, and greening of flowers.

The shortfall in seed yields due to diseases, depending on the hybrid and its cultivation technology, ranges from 15 to 70% or more, and the sowing and technological qualities of rapeseed are significantly affected. Scientists have found that white rot and phomosis cause the greatest yield losses – 20–60%.

Alternaria and cylindrosporium can cause yield losses of 15-30%, peronosporium – 15–25%, and grey rot – 10–20%.

Diseases also significantly affect the biochemical composition of rapeseed plants and seeds. For example, peronosporosis, Alternaria, Phomosis, and Cylindrosporium significantly reduce the content of vitamin C, protein, fat, sugar, essential amino acids, and oil in rapeseed.

Recent long-term studies have shown that the spread and development of most diseases depends on the weather conditions of the growing season and the technology of growing winter and spring rapeseed. Under conditions of high humidity, heavy dewfall at night and an average daily air temperature of 8...15°C, plants are likely to be affected by downy mildew, and with frequent light rains – by cylindrosporium. High air humidity, frequent rains with wind at air temperatures of 15...24°C during the day and 12...18°C at night contribute to the development of Alternaria and Phomosis. In warm and humid weather (temperature 17...26°C, relative humidity – 80–100%, frequent rains, thickened crops), rapeseed plants are most often affected by white and grey rot, bacteriosis.

For timely detection of rapeseed diseases, it is necessary to systematically monitor crops throughout the growing season. This will facilitate decision-making on the use of fungicides.

It is advisable to carry out preventive chemical measures on winter rape in autumn: in the stages of plant development ES 17 (2nd true leaf) – ES 23 (6th true leaf) against downy mildew with plant damage of more than 5% in conditions of high air humidity (90–100%) and average daily temperature of 8. ...12°C; against Alternaria and Phomosis in warm, long autumn, with air humidity of 80% and above, plant damage intensity of up to 2% and disease spread of more than 10%; against Cylindrosporium – with plant damage of up to 10% in conditions of high humidity, frequent light rains with wind. Chemical protection of winter oilseed rape in spring against diseases is advisable in the plant development stages ES 33 (beginning of budding) – ES 57 (elongation of the pedicel, end of budding): 30 – against downy mildew with plant damage of more than 10% and development above 1%, under conditions of high humidity and average daily air temperature of 8...15°C; – against Alternaria, Phomosis – with plant damage up to 30% and development above 5%, under conditions of high humidity, frequent precipitation and air temperature during the day

15...24°C and at night – 12... 18°C; – against cylindrosporiosis – in case of plant damage of more than 30% and development above 1%, high humidity or prolonged stay of water droplets on plants, frequent rains with wind, heavy dew at night and average daily air temperature of 10...15°C; – against white and grey rot – in years with warm and humid weather (temperature 17...26°C, relative humidity – 80-100%, frequent rains, thickened crops). In order to increase the technical efficiency of fungicides and seed productivity of plants, one of the biostimulants is added to the working suspensions or emulsions: Biotransformer, (300–400 granules/ha); Biosil (Emistim C), v.p., (5–10 ml/ha); Vermistim K, v.p., (5-8 l/ha); Redostim, v.p., (50 ml/ha); Stabilan 750 SL, v.p., (1.5–2.0 l/ha).

An effective measure on winter rape in autumn, in the phase of 4-6 rosette leaves, against root bacteriosis, snow mould, Alternaria, Phoma, Cylindrospora, grey and white rot, against overgrowth of plants before they enter winter, suspension of vegetative mass growth and increase of their winter hardiness is spraying rape with one of the fungicides – inhibitors of rape leaves growth based on active substances: metconazole, 60 g/l (Karamba, in. p.); tebuconazole, 250 g/l (Mystic, c.e.; Orius 250, c.e.; Folicur 250 EW, c.e.; Fortress ES, c.e.; Unique, c.s., Amulet, c.e.; Alpha-Tebuzol, c.e.; Berkut, c.e.; Kolosal, c.e.; Polygard, c.e.; Cerfun, m.v.e.); propiconazole, 250 g/l (Tilt 250 ES, c.e.; Tinazole, c.e.) and a mixture of active ingredients – protioconazole, 80 g/l + tebuconazole, 160 g/l (Tilmor 240 ES, c.e.). It is advisable to combine these treatments with foliar feeding of plants with microelements, especially boron (0.5 kg/ha). The deficiency of this trace element in the soil reduces plant resistance to infectious diseases and low temperatures, intensive leaf and plant growth point death, slows down the development of generative organs, and reduces seed productivity.

An effective measure against mould, white and grey rot is timely harvesting, desiccation of crops, thorough cleaning and drying of seeds, if necessary. To prevent seed spoilage as a result of diseases (mould, blackleg, white and grey rot), the moisture content of commercial seeds is brought to 7–8% before storage, and that of seed seeds to 8–10% and stored at a temperature not exceeding 10...15°C. Ploughing or ploughing up post-harvest crop residues significantly reduces the infection stock in the soil. Timely and high-quality implementation of these measures significantly limits the spread and development of diseases and minimises the use of chemical protection products on rapeseed.

By spraying spring rape crops with fungicides together with growth stimulants, we reduce pest and disease damage and increase seed yields. With the combined use of the fungicide Ridomil Gold and the growth stimulator Emistim, the damage by Alteriosis is reduced by 6.3%; peronosporosis – by 5,2%; phomosis – by 6.1%, grey rot – by 6.5% [152]. The growth-regulating fungicide Karamba Turbo with a consumption rate of 1.0 l/ha and 1.2 l/ha ensures the absence of diseases on plants throughout the growing season. Rapeseed lateral shoots develop evenly, flowering occurs simultaneously, which leads to uniform pods setting and their filling with seeds [153].

According to Basf research, the use of Pictor fungicide on crops reliably protects the crop from major fungal diseases, promotes uniform pod maturation, and reduces seed losses during the pre-harvest and harvest periods [154].

The ideal time to treat crops with Piktor systemic fungicide at a rate of 0,5 l/ha is the full flowering stage. Due to the innovative active ingredient boscalid (200 g/l) in combination with dimoxystrobin (200 l/ha), this product perfectly controls the spread of Alternaria, Phoma and Sclerotinia. In addition to protecting crops from diseases, this product provides a "physiological effect" that slows down plant aging (less ethylene accumulates), activates photosynthesis, nitrogenase activity (conversion of nitrate nitrogen into protein nitrogen), optimises gas exchange and moisture transfer in plants, and thus prolongs the period of generative development. As a result, plants lay more seeds per pod, increase the weight of 1000 seeds, and accumulate more fatty acids. In his research, V.P. Savenkov found that the use of a mixture of Piktor fungicide and Karamba growth regulator (during the flowering phase) affects plant height and stem diameter, as well as pod preservation. The mixture of products increases the number of lateral branches and the weight of 1000 seeds [155]. Scientists of the breeding and genetics institute [156] confidently state that the combined use of Alterno and Pictor fungicides has proven to have an unsurpassed destructive effect on a wide range of pathogens. Also, these products make it possible to obtain healthy rapeseed plants of ideal shape with a strong structure and no lodging. In their own research, the authors of the monograph [157–158]

It is noted that in order to realise the productivity potential of rapeseed, it is important to form optimal structural organs in disease-free plants as the basis of the photosynthetic biological system. This is achieved through effective chemical protection in compliance with all agronomic practices. Fungicides have a positive effect on limiting the development of winter rape diseases (Table 3.22).

Thus, the use of fungicides after the vegetation recovery allows to increase the yield of winter rape by 4.6–5.6 centner/ha. In this regard, the best results were shown by the use of the fungicide Architect SE, where the yield exceeded the control variant by 5.6 centner/ha (Table 3.23).

Table 3.22

Influence of fungicides on diseases of winter rape plants, % (average for 2018–2020) [160]

Variant	Disease development, %					
	Alternariosis		Pho-mosis	White rot	Grey rot	Cylindro sporiosis
	leaves	pods				
Control (without processing)	24	78	30	12	26	8
Pictor KS, 0,5 l/ha	14	32	18	10	18	3
Architect CE, 2,0 l/ha	8.1	12	8	6	14	2
Alterno KE, 1,0 l/ha	15	36	19	12	20	3

Other preparations had a less significant effect on the above parameters, exceeding the yield of the control variant by 4.6–5.1 centner/ha. The weight of 1000 seeds varied depending on the fungicide used and was the highest when using Architect SE, where it was 5.1 g, and the lowest when using Alterno CE, where it was 4.1 g. Ensuring high economic efficiency of winter rape production can be achieved through the use of aggregate factors, among which the introduction of intensive crop cultivation technologies is important.

Based on the data obtained, it was concluded that to control the spread of diseases in the rapeseed agrophytocenosis, it is advisable to use the preparation Architect SE (pyraclostrobin 100 g/l + calcium prohexadione 25 g/l + mepiquat chloride 150 g/l) at a rate of 2.0 l/ha, which significantly reduced the damage to winter rape by major diseases and had a therapeutic effect, while ensuring a yield of 25.1 centner/ha. Compliance with technological measures of rape cultivation in combination with the correct application of an integrated system of protection against pests can significantly increase the efficiency of cultivation technology and minimise crop losses.

Table 3.23

Effect of fungicides on seed yield, weight of 1000 seeds and biometric parameters of rapeseed (average for 2018–2020) [160]

Variants	Plant density, pcs/m^2	Plant height, cm	Pods formed per plant, pcs.	Length of pods, mm	Seeds per pod, pcs.	Weight of 1000 seeds, g	Yield, centners/ha
Control (without processing)	43.9	180	95	69	20	2.1	19.5
Pictor KS, 0.5 l/ha	48.0	175	220	91	26	4.5	24.6
Architect CE, 2.0 l/ha	49.2	168	276	106	31	5.1	25.1
Alterno KE, 1.0 l/ha	48.4	170	234	87	25	4.1	24.1
SSD_{05}							1.49

Some variants of these schemes have been actively researched recently. Thus, according to the results of a study by a master's student of Vinnytsia Agrarian University [159] the effectiveness of a certain combination of fungicides on winter rape crops was investigated. According to the scheme of these studies, in autumn, when winter rape plants developed in the phase of 4–6 leaves, they were treated with Folicur 250 EW, EV and 42 Karamba, c. When analysing the development of winter rape plants of the Artus variety in the experimental variants, it was found that the fungicides used in comparison with the control variant inhibited the development of the crop. Thus, the number of leaves before entering the winter increased on average per 1 plant: in the control variant to 10–12 pcs, and in the variants with fungicide treatment – only to 8–9 pcs (Table 3.24). After overwintering, the number of leaves per plant decreased in all experimental variants, which is due to the critical conditions that occurred during overwintering.

The analysis of wintering of winter rape plants showed that the use of fungicides had a positive effect on the preservation of plants during wintering. Thus, in the variant without fungicides, up to 14.5% of rape plants did not survive the winter, and in the variants with Karamba, v. and Folicur 250 EW, EV about 7%. The explanation for this may be not only the fungicidal effect of the preparation, but also the inhibitory effect of the preparations, thus preventing the rape plants from outgrowing (Table 3.25).

Table 3.24

Development of plants of winter rape variety Artus depending on the use of fungicides, average for 2021–2022 [160]

№	Experimental variant	Number of leaves of winter rape, on average per 1 plant, pcs.			
		before processing	14 days after treatment	before entering winter	after the resumption of vegetation
1	Control (without processing)	4–6	8–9	10–12	8–10
2	Caramba, v., 1.25 g/l	4–6	6–7	8–9	7–8
3	Folicur 250 EW, EW, 1 l/ha	4–6	6–7	8–9	7–8

Table 3.25

Overwintering of winter rape plants of the Artus variety depending on the use of fungicides, average for 2021–2022 [160]

№	Experimental variant	Density of winter rape plants, pcs./m^2	
		before entering winter	after the resumption of vegetation
1	Control (without processing)	48	41
2	Caramba, v., 1.25 g/l	48	45
3	Folicur 250 EW, EW, 1 l/ha	48	45

The analysis of the data showed that the disease incidence of winter rape plants before entering the winter in the control was: downy mildew – 11.5% and Alternaria – 16.7% and Fusarium – 8.0%. Spraying of winter wheat crops with Karamba fungicide reduces the development of downy mildew by 10.1%, alternaria by 14.9% and phomosis by 6.8% compared to the control. The use of Folicur 250 EW, EV fungicide reduces the damage to winter rape plants by 10.4%, downy mildew by 15.3% and phomosis by 7.1% compared to the control. After the resumption of winter rape vegetation in spring, repeated surveys revealed that the number of affected plants slightly increased.

Thus, in the variant without the use of fungicides, the incidence of downy mildew was 15.5%, alternaria – 19.8% and fusarium – 10.1%. Spraying of winter wheat crops with Karamba, v. fungicide reduces the development of downy mildew by 12%, alternaria by 17.1% and phomosis by 7.3% compared to the control. The use of Folikur 250 EW, EV fungicide reduces the damage to winter rape plants by 12.4%, downy mildew by 17.6% and phomosis by 7.1% compared to the control.

Table 3.26

Disease incidence of winter rape plants depending on the use of fungicides in the conditions of the farm "Havest", Chudniv district, Zhytomyr region, average for 2021-2022 [160]

Experimental variant	Disease development, %		
	downy mildew	alternariosis	phomosis
before entering winter			
Control (without processing)	11.5	16.7	8.0
Caramba, v., 1.25 g/l	1.4	1.8	1.2
Folicur 250 EW,EW, 1 l/ha	1.1	1.4	0.9
after the resumption of vegetation			
Control (without processing)	15.5	19.8	10.1
Caramba, v., 1.25 g/l	3.5	2.7	2.8
Folicur 250 EW,EW, 1 l/ha	3.1	2.2	2.5

The technical efficiency of the use of growth-regulating fungicides on winter rape crops is shown in Table 9.26. The highest efficiency before entering the winter – 92% among the studied fungicides was provided by Folicur 250 EW, EV in protection against Alternaria, which is 3% more than Karamba.

After the restoration of winter rape vegetation in spring, it was found that the technical efficiency of Folikur 250 EW, EV against diseases was 75-89%. The technical efficiency of Karamba, v. against downy mildew was 77%, alternaria – 86%, phomosis – 72%.

Figure 3.1 – Growth point height of rapeseed plants treated with Karamba Turbo 1.0 l/ha (right) compared to control (left) [160]

Table 3.27

Technical efficiency of fungicide application in winter rape agrophytocenosis, average for 2021–2022 [160]

Experimental variant	Technical efficiency, %		
	downy mildew	alternariosis	phomosis
before entering winter			
Control (without processing)	–	–	–
Caramba, v., 1.25 g/l	88	89	85
Folicur 250 EW,EW, 1 l/ha	90	92	89
after the resumption of vegetation			
Control (without processing)	–	–	–
Caramba, v., 1.25 g/l	77	86	72
Folicur 250 EW,EW, 1 l/ha	80	89	75

To ensure high and sustainable yields of winter rape seeds, it is necessary to minimise plant stress during critical periods of growth, which will allow to preserve a larger number of pods per plant and, as a result, increase crop productivity. The analysis of the data obtained shows that depending on the spraying of winter rape crops with fungicides, the number of pods per plant varies from 125.5 to 138.3 pcs, the number of seeds per pod from 17.6 to 18.5 pcs, the weight of 1000 seeds from 7.9 to 9.5 g, the weight of seeds per plant from 7.9 to 9.5 g (Tables 3.28–3.29).

The use of Folikur 250 EW, EV fungicide increases the number of pods per plant by 12.8 pcs, the number of seeds per pod by 0.9 g, the weight of 1000 seeds by 0.4 g, and the weight of seeds per plant by 1.6 g.

Reducing the incidence of powdery mildew had a positive effect on improving the yield structure.

The use of fungicide Karamba, v., 1.25 g/l increased the yield of winter rape seeds by 0.46 t/ha or 18.5% compared to the control. The treatment of winter rape crops of the Artus variety with the fungicide Folicur 250 EW, EV provides an increase in seed yield by 0.53 t/ha or 21.4% compared to the control.

Table 3.28

Formation of elements of winter rape yield structure depending on fungicide application in the conditions of the farm 'Havest', Chudnivskyi district, Zhytomyr region, average for 2021–2022 [160]

Experimental variant	Number of pods per plant, pcs.	Number of seeds per pod, pcs.	Weight of 1000 seeds, g	Seed weight per plant, g
Control (without processing)	125.5	17.6	3.5	7.9
Caramba, v., 1.25 g/l	135.8	18.1	3.7	9.2
Folicur 250 EW, EW, 1 l/ha	138.3	18.5	3.9	9.5

Thus, the use of fungicides in autumn, which have a protective and growth-stimulating effect on winter rape plants, allows to effectively protect plants from pathogens of the crop (Alternaria, Phoma, downy mildew) and improve the wintering of the crop. This allows us to increase the productivity of winter rape and solve the issue of providing producers with raw materials for oil production.

Another study conducted in another region of Ukraine also confirms the effectiveness of the above options for using fungicides.

As an example of studying the effectiveness of different variants of fungicide use in protecting cruciferous crops from diseases, we present the results of a study of the effectiveness of fungicides on winter rape in the Ivano-Frankivsk branch of the agricultural company Continental Farmers Group.

Table 3.29

Yield of winter rape depending on the use of fungicides in the conditions of the farm "Havest", Chudniv district, Zhytomyr region, average for 2021–2022 [160]

Experimental variant	Seed yield, t/ha				
	2021	2022	average	± to control	in % to control
Control (without processing)	2.31	2.65	2.48	–	–
Caramba, v., 1.25 g/l	2.78	3.1	2.94	+ 0.46	18.5
Folicur 250 EW,EW, 1 l/ha	2.86	3.16	3.01	+ 0.53	21.4

For this purpose, an experiment with fungicidal preparations belonging to the new generation of drugs was conducted in the field. The first spraying was carried out with fungicides Taler, 25% c.e. – 1.0 l/ha, Kamzol, 6% p.c. – 1.25 l/ha, Architect, 37.5% c.e. – 1.5 l/ha in autumn at the stage of 3–5 true leaves to protect plants from diseases and to prevent overgrowth of plants. The second spraying in the spring at a crop height of 20–25 cm was carried out with Taler, 25% e.e. – 1.0 l/ha, Kamzol, 6% p.c. – 1.25 l/ha, Architect, 37.5% e.e. – 1.0 l/ha. During the flowering period in the experimental variants, the plants were sprayed with Amistar Extra fungicide, 28% c.e. – 1.0 l/ha.

Taler, 25% c.e., which has the active ingredient tebuconazole 250 g/l, is a systemic fungicide from the triazole group, the mechanism of action of which is to block the biosynthesis of ergosterol, which is an important structural component of fungal cell membranes. The product is moderately toxic and belongs to the third hazard class. The maximum number of treatments is two. In Ukraine, it is registered and authorised for use on winter rape at a consumption rate of 1.0 l/ha.

Camzol 6% r.c. contains the active ingredient metconazole 80 g/l, also from the triazole group, and is characterised by a systemic therapeutic effect. The mechanism of action of metconazole is also to block ergosterol biosynthesis. The drug is moderately toxic, hazard class III. It has a systemic therapeutic effect. In Ukraine, it is registered and authorised for use on winter rape at a consumption rate of 1.25 l/ha.

Architect, 37.5% w/w, which contains three active ingredients, namely pyraclostrobin 100 g/l + mepiquat chloride 150 g/l + calcium prohexadione

25 g/l, is a combined fungicide. It has systemic and translaminar action. Pyraclostrobin belongs to the group of strobilurins, the mechanism of action of which is to block the cellular mitochondrial respiration of fungi. It is moderately toxic, belongs to the third hazard class. In Ukraine, it is registered and approved for use on winter rape at a consumption rate of 1.0–1.5 litres/ha.

Amistar Extra, 28% h.p., is also a combined action fungicide, as it contains two active ingredients: ciproconazole 80 g/l from the triazole group and azoxystrobin 200 g/l from the storobilurin group. It is moderately toxic, belongs to hazard class III. The drug is characterised by systemic and translaminar action. In Ukraine, it is registered and approved for use on winter rape at a consumption rate of 1.0 l/ha.

In autumn, winter rape plants showed signs of phomosis and downy mildew, and symptoms of diseases such as powdery mildew, Alternaria and sclerotinia appeared in spring.

In autumn, after the application of Taler, 25% c.e. – 1.0 l/ha, Kamzol, 6% c.e. – 1.25 l/ha and Architect, 37.5% c.e. – 1.5 l/ha, on the experimental variants, a low degree of damage to winter rape plants by phomosis and downy mildew was noted compared to the control. Thus, the development of these diseases in the variants after spraying with the studied fungicides was: phomosis was within 1.0-1.1%, and in the control – 6.7%, peronosporosis – 1.2–1.3%, and in the control – 6.1%. The application of fungicidal preparations with morphoregulatory properties in autumn effectively restrained plant growth: the height of plants on the preparations was 11.5–11.9 cm less than on the control. In addition, the sprayed plants formed a 1.9–2.3 mm thicker root collar in autumn, which contributed to their better wintering. In the spring, during the period of plant vegetation recovery, this difference persisted: the thickness of the root collar in the variants with the preparations was 4.1–3.4 mm thicker (Table 3.30).

The effectiveness of autumn application of fungicidal preparations was: against phomosis was in the range of 83.6-85.1%, against downy mildew – in the range of 78.7¬80.3% (Table 3.31).

Thus, the application of fungicidal preparations Taler, 25% c.e. – 1.0 l/ha, Kamzol, 6% p.c. – 1.25 l/ha and Architect, 37.5% c.e. – 1.5 l/ha in autumn on winter rape prevented plant damage by diseases, as well as contributed to their enhanced root formation and improved wintering.

Table 3.30

Effect of autumn fungicide application on biometric parameters and disease development of winter rape plants [160]

Experimental variant	Product consumption rate, l/ha	Plant height, cm	Root neck thickness, mm		Disease development, %	
			on the 15th day	vege-tation recovery	phomosis	perono-sporosis
Control (spraying with with water)	–	37.8	5.1	11.7	6.7	6.1
Thaler, 25% c.e.	1.0	26.0	7.0	15.1	1.0	1.2
Camisole, 6% p.a.	1.25	25.9	7.4	15.8	1.0	1.2
Architecture, 37.5% c.e.	1.5	26.3	7.2	15.7	1.1	1.3

Table 3.31

Effectiveness of autumn fungicide application against diseases of winter rape [160]

Experimental variant	Product consum-ption rate, l/ha	Efficiency of the drug action, %	
		phomosis	peronosporosis
Control (spraying with with water)	–	–	–
Thaler, 25% c.e.	1.0	85.1	80.3
Camisole, 6% p.a.	1.25	85.1	80.3
Architecture, 37.5% c.e.	1.5	83.6	78.7

In the research [162] also determined the effectiveness of application in spring at a plant height of 20-25 cm of fungicidal preparations Thaler, 25% c.e. – 1.0 l/ha, Kamzol, 6% p.c. – 1.25 l/ha, Architect, 37.5% c.e. – 1.0 l/ha and during flowering of Amistar Extra, 28% c.e.s. – 1.0 l/ha against diseases such as phomosis, peronosporosis, sclerotinia, powdery mildew and alternaria, as the damage to plants by the pathogens of these diseases increased in spring.

After spraying with pesticides, the damage to plants by the main diseases was recorded at the beginning of flowering after the second spraying and during the formation of pods after the third spraying.

The results of the records of phomosis development in the experimental variants are presented in Table 3.32.

Table 3.32

Technical effectiveness of fungicides against phomosis [160]

Experimental variant	Disease progression, %		Effectiveness of the drug, %	
	beginning of flowering	pod formation	beginning of flowering	pod formation
Control (spraying with with water)	15.0	21.6	–	–
Taler, 25% hp – 1,0 l/ha, Taler, 25% hp – 1,0 l/ha, Amistar Extra, 28% hp – 1,0 l/ha	1.7	3.3	88.7	84.7
Camzol, 6% p.c. – 1,25 l/ha,, Camzol, 6% p.c. – 1,25 l/ha, Amistar Extra, 28% h.p. – 1,0 l/ha	1.4	3.1	90.7	85.6
Architect, 37.5% e.m. – 1,5 l/ha, Architect, 37.5% e.m. – 1,0 l/ha, Amistar Extra, 28% hp – 1,0 l/ha	2.1	4.4	86.0	79.6

The development of phomosis in the experimental variants where fungicidal preparations were used at the beginning of flowering was in the range of 1.4–2.1%, in the phase of pod formation – 3.1–4.4%, while in the control there was a significant damage to plants of 15.0% and 21.6%, respectively. The technical efficiency of the preparations at the beginning of flowering was in the range of 86.0–90.7%, during pod formation – 79.6–85.6%.

The results of the records of peronosporosis development on the experimental variants are presented in Table 3.33.

The development of downy mildew in the experimental variants where fungicidal preparations were used at the beginning of flowering was in the range of 1.3–1.6%, in the phase of pod formation – 2.2–3.0%, while in the control there was a significant damage to plants of 11.4% and 17.4%, respectively. The technical efficiency of the preparations at the beginning of flowering was in the range of 86.0–88.6%, during the formation of pods – 82.8–87.4%.

Table 3.33

Technical efficacy of fungicides against downy mildew [160]

Experimental variant	Disease progression, %		Effectiveness of the drug, %	
	beginning of flowering	pod formation	beginning of flowering	pod formation
Control (spraying with with water)	11.4	17.4	–	–
Taler, 25% hp – 1,0 l/ha, Taler, 25% hp – 1,0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	1.6	3.0	86.0	82.8
Camzol, 6% p.c. – 1.25 l/ha, Camzol, 6% p.c. – 1.25 l/ha, Amistar Extra, 28% h.p. – 1.0 l/ha	1.3	2.2	88.6	87.4
Architect, 37.5% e.m. – 1.5 l/ha, Architect, 37.5% e.m. – 1.0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	1.4	2.3	87.7	86.8

The results of the accounting of Alternaria development on the experimental variants are presented in Table 3.34.

The development of Alternaria in the experimental variants where fungicidal preparations were used at the beginning of flowering was in the range of 2.3–3.7%, in the phase of pod formation – 4.5–5.1, while in the control there was a significant damage to plants of 25.9% and 35.5%, respectively. The technical efficiency of the preparations at the beginning of flowering was in the range of 80.3–85.7%, during pod formation – 85.6–87.3%.

The results of powdery mildew development on the experimental variants are presented in Table 3.35.

The development of powdery mildew in the experimental variants where fungicidal preparations were used at the beginning of flowering was in the range of 1.3–2.7%, in the phase of pod formation – 2.5-4.1%, while in the control there was a significant damage to plants of 22.5% and 30.1%, respectively. The technical efficiency of the preparations at the beginning of flowering was in the range of 88.0–94.2%, during pod formation – 86.4–91.7%.

Sclerotinia is the most harmful disease of winter rape plants, as it causes significant losses in seed yield even at a relatively low level of its development. The highest development of sclerotinia was observed at the beginning of pod formation.

Table 3.34

Technical effectiveness of fungicides against Alternaria [160]

Experimental variant	Disease progression, %		Effectiveness of the drug, %	
	beginning of flowering	pod formation	beginning of flowering	pod formation
Control (spraying with water)	25.9	35.5	–	–
Taler, 25% hp – 1,0 l/ha, Taler, 25% hp – 1,0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	3.7	5.1	85.7	85.6
Camzol, 6% p.c. – 1.25 l/ha, Camzol, 6% p.c. – 1.25 l/ha, Amistar Extra, 28% h.p. – 1.0 l/ha	2.3	4.5	91.1	87.3
Architect, 37.5% e.m. – 1.5 l/ha, Architect, 37.5% e.m. – 1.0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	2.7	4.6	80.3	87.0

The results of the records of the development of sclerotinia in the experimental variants are presented in Table 3.36.

The development of sclerotinia in the experimental variants where fungicidal preparations were used at the beginning of flowering was in the range of 1,1–2,1%, in the phase of pod formation – 135–3.2%, while in the control there was a significant damage to plants of 7.8% and 10.0%, respectively.The technical efficiency of the preparations at the beginning of flowering was in the range of 73.1–85.9%, during pod formation – 68.0–85.0%.

A fairly low level of damage compared to the control was also observed in the variant where we applied Architect, 37.5% s.e. in autumn at a rate of 1.5 l/ha, Architect, 37.5% s.e. in spring at a rate of 1.0 l/ha, and Amistar Extra, 28% h.p. – 1.0 l/ha during flowering. In this variant, the development of phomosis was 4.4%, downy mildew – 2.3%, alternaria – 4.6%, powdery mildew – 2.9%, sclerotinia – 3.2%.

A low level of development of the main diseases on winter rape plants compared to the control was also recorded in the variant where we applied Taler, 25% h.e. – 1.0 l/ha in autumn and spring, and Amistar Extra, 28% h.p. – 1.0 l/ha during flowering. The development of phomosis on this variant was 3.3%, downy mildew – 3.0%, Alternaria – 5.1%, powdery mildew – 4.1%, sclerotinia – 2.1%.

Table 3.35

Technical efficiency of fungicidal preparations against powdery mildew [160]

Experimental variant	Disease progression, %		Effectiveness of the drug, %	
	beginning of flowering	pod formation	beginning of flowering	pod formation
Control (spraying with with water)	22.5	30.1	–	–
Taler, 25% hp – 1,0 l/ha, Taler, 25% hp – 1,0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	2.7	4.1	88.0	86.4
Camzol, 6% p.c. – 1.25 l/ha, , Camzol, 6% p.c. – 1.25 l/ha, Amistar Extra, 28% h.p. – 1.0 l/ha	1.3	2.5	94.2	91.7
Architect, 37.5% e.m. – 1.5 l/ha, Architect, 37.5% e.m. – 1.0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	1.7	2.9	92.4	90.4

As a result of the surveys, we found that the best results in reducing the level of development of the main diseases on winter rape plants were recorded in the experimental variant, where in autumn in the phase of 3–5 true leaves and in spring at a plant height of 20–25 cm we applied the drug Kamzol, 6% p.c. – 1.25 l/ha, and during flowering – Amistar Extra, 28% h.p. – 1.0 l/ha. Thus, in this variant of the experiment, the degree of plant damage was as follows: phomosis – 3.1%, downy mildew – 2.2%, alternaria – 4.5%, powdery mildew – 2.5%, sclerotinia – 1.5%.

The use of the scheme, which provided for the application in autumn in the phase of 3–5 true leaves and in spring at a plant height of 20-25 cm of the fungicide Kamzol, 6% p.c. – 1.25 l/ha and during flowering – Amistar Extra, 28% h.p. – 1.0 l/ha, provided for the highest technical efficiency of the preparations, which exceeded 85%. The effectiveness of this scheme of fungicide application against phomosis was 85.6%, downy mildew – 87,4%, Alternaria – 87.3%, powdery mildew – 91.7%, sclerotinia – 85%.

The scheme of spraying plants, which included the use of Thaler, 25% c.e. – 1.0 l/ha in autumn and spring and Amistar Extra, 28% c.e. – 1.0 l/ha during flowering, provided efficiency against phomosis at the level of 84.7%, peronosporosis – 82.8%, alternaria – 85.6%, powdery mildew – 86.4%, sclerotinia – 79.0%.

Table 3.36

Technical efficacy of fungicides against sclerotinia [160]

Experimental variant	Disease progression, %		Effectiveness of the drug, %	
	beginning of flowering	pod formation	beginning of flowering	pod formation
Control (spraying with with water)	7.8	10.0	–	–
Taler, 25% hp – 1,0 l/ha, Taler, 25% hp – 1,0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	1.5	2.1	80.8	79.0
Camzol, 6% p.c. – 1.25 l/ha, Camzol, 6% p.c. – 1.25 l/ha, Amistar Extra, 28% h.p. – 1.0 l/ha	1.1	1.5	85.9	85.0
Architect, 37.5% e.m. – 1.5 l/ha, Architect, 37.5% e.m. – 1.0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	2.1	3.2	73.1	68.0

The spraying scheme, which included the application of Architect, 37,5% s.e. – 1.5 l/ha in autumn, and Architect, 37.5% s.e. – 1.0 l/ha in spring and Amistar Extra, 28% h.p. during flowering. – 1.0 l/ha also provided a relatively sufficient level of protection: against phomosis –

79.6%, downy mildew – 86.8%, alternaria – 87.0%, powdery mildew – 90.4%, sclerotinia – 68.0%. The obtained research results and their analysis indicate the expediency of introducing into the system of protection of winter rape crops from the main diseases, preparations of systemic protective and therapeutic action Taler, 25% c.e., Kamzol, 6% p.c, Architect, 37.5% c.e. and Amistar Extra, 28% c.e. The first spraying of plants should be carried out in autumn in the phase of 3-5 true leaves with fungicides Taler, 25% c.e. – 1.0 l/ha, or Kamzol, 6% p.c. k. – 1.25 l/ha, or Architect, 37.5% s.e. – 1.5 l/ha, not only to protect plants from diseases such as phomosis and downy mildew, but also to prevent their overgrowth. The second spraying against further development of phomosis, downy mildew, as well as against diseases such as powdery mildew, Alternaria and sclerotinia should be carried out in spring at a crop height of 20–25 cm also with Taler, 25% e.p. – 1.0 l/ha, Kamzol, 6% p.c. – 1.25 l/ha, Architect, 37.5% e.p. – 1.0 l/ha. During the flowering period, plants should be sprayed with Amistar Extra fungicide, 28% h.p. – 1.0 l/ha, mainly against Alternaria and Sclerotinia.

According to the scheme of the experiment, the first spraying of plants was carried out in autumn in the phase of 3-5 true leaves with fungicides Taler, 25% c.e. – 1,0 l/ha, Kamzol, 6% p.c. – 1.25 l/ha, Architect, 37.5% c.e. – 1.5 l/ha. The second spraying was also carried out with Taler, 25% c.e. – 1,0 l/ha, Kamzol, 6% p.c. – 1.25 l/ha, Architect, 37.5% c.e. – 1.0 l/ha in spring at a crop height of 20–25 cm. And during the flowering period, the plants were sprayed with Amistar Extra fungicide, 28% c.p. – 1.0 l/ha.

As a result of the studies, it was found that the yield of the Athora hybrid in 2021 was higher than in 2020. The yield of winter rape seeds in variants with fungicide plant protection systems was significantly higher than in the control. The application of Taler, 25% c.e., Kamzol, 6% p.c., Architect, 37.5% c.e. in the phase of 3–5 true leaves and at a plant height of 20–25 cm and Amistar Extra, 28% c.e. in the flowering phase had a positive effect on plant productivity. The yield of the control without fungicides was significantly lower and amounted to only 27.6 centner/ha.

The economic efficiency of the studied systems of protection of winter rape against diseases is presented in Table 3.37.

Table 3.37

Economic efficiency of different fungicide application schemes on winter oilseed rape, hybrid Athora [160]

Experimental variant	Weight of 1000 seeds, g	Yield, centner/ha			± to control centner/ha
		2020	2021	сер.	
Control (spraying with with water)	3.7	24.9	30.2	27.6	–
Taler, 25% hp – 1,0 l/ha, Taler, 25% hp – 1,0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	4.5	36.5	38.3	37.4	9.8
Camzol, 6% p.c. – 1.25 l/ha, Camzol, 6% p.c. – 1.25 l/ha, Amistar Extra, 28% h.p. – 1.0 l/ha	4.7	39.4	40.1	39.8	12.2
Architect, 37.5% e.m. – 1.5 l/ha, Architect, 37.5% e.m. – 1.0 l/ha, Amistar Extra, 28% hp – 1.0 l/ha	4.6	37.8	39.8	38.9	11.3
SSD_{05}	0.31	1.8	2.8	2.8	

The highest yield of the hybrid Athora in the amount of 39.8 centner/ha was obtained in the experimental variant, where in autumn and spring we applied Kamzol, 6% p.c. – 1.25 l/ha, and in flowering Amistar Extra, 28% p.c. – 1.0 l/ha, which was 12.2 centner/ha higher than in the control.

On the variant of the experiment, which was applied in autumn and spring Thaler, 25% hp – 1.0 l/ha and during flowering Amistar Extra, 28% hp – 1.0 l/ha, the yield was slightly lower and amounted to 37.4 centner/ha, which was 11.3 centner/ha higher than in the control.

On the variant of the experiment, where in autumn the Architect, 37.5% e.s. was applied at a rate of 1.5 l/ha, and in spring the Architect, 37.5% e.s. at a rate of 1.0 l/ha, the yield was also high compared to the control, but lower compared to the other two variants and amounted to 37.4 centner/ha, which was 9.8 centner/ha higher than the control.

The increase in the yield of winter rape hybrid Athora with the use of fungicides in the system of plant protection against diseases provided better indicators of 1000 seeds weight compared to the control. The weight of 1000 seeds in the variants with fungicidal preparations was 1.0–0.8 g higher than in the control.

Between the variants of the experiment with fungicides, the actual difference in yield and weight of 1000 seeds did not go beyond the smallest significant difference, that is, it was not reliable and was within the error.

Thus, the results of the presented studies indicate that the use of plant protection systems for winter rape against diseases, which include the application of Taler, 25% c.e., Kamzol, 6% p.c., Architect, 37.5% c.e. and in the flowering phase – Amistar Extra, 28% c.e. – 1.0 l/ha in autumn and spring, allows to reliably preserve the seed yield. The best results in terms of the impact of fungicide application on winter rape were provided by the experimental variant: Kamzol, 6% p.c. – 1.25 l/ha in autumn in the phase of 3–5 true leaves + Kamzol, 6% p.c. – 1.25 l/ha in spring at a plant height of 20–25 cm + Amistar Extra, 28% h.p. – 1.0 l/ha during flowering.

In general, for the control of major diseases in cruciferous crops agrocenoses, different variants of disinfectants and fungicides can be used in accordance with the recommended list of those approved for use in Ukraine (Figure 3.2).

It is worth noting the specifics of the oil radish disease protection system. The first element of the disease protection system is the use of resistant varieties and the cultivation of healthy seed material. The second point is to observe the correct crop rotation with a return to the previous place no earlier than three to four years later and spatial isolation between cruciferous crops (at least 1 km). This is especially important against Fusarium wilt and phomosis. After stubble harvesting, the fields are peeled with disc harrows to a depth of 6–8 cm in a unit with harrows, and ten to twelve days later they are cultivated using the technology recommended for each zone. Another important element is the use of treated seeds. This prevents the development of many diseases of seedlings and seedlings. The optimal timing and seeding rates are also of phytopathological importance. In addition, rolling the field before and immediately after sowing with heavy rollers reduces the development of root diseases. Adherence to the optimal seeding rate and sowing technology (row, wide-row) reduces losses from phomosis, Alternaria, white and grey rot, and white spot, which are typical for thickened crops. When seedlings appear, shallow loosening of row spacings in wide-row crops or harrowing across rows in continuous crops is recommended to limit the development of blackleg and phomosis, as well as to control weeds.

Name of active substance (dosage form)	Norms consumption rates l.kg/ha,	What diseases are treated against	Method, processing time, limitations	Duration of the last treatment (days) and maximum number of treatments (times)
Duration of the last treatment (days) and maximum number of treatments (times)	0,75-1,0	Alternaria, phomosis, downy mildew, white and grey rot	Spraying during the growing season	30(2)
Becocil, 500 g/kg (w/w)	0,5-0,6	Powdery mildew, phomosis	Spraying during the growing season	20(2)
Dimoxystrobin, 200 g/l + Boscalid 200 g/l (h.p.)	OS	Alternaria, phomosis, sclerotinia	Spraying during the growing season	30(1)
Diphenoconol, 2S0, g/l + paclobutrazol, 125 g/l (q.s.)	0,3-0,5	Alternaria, downy mildew, phomosis	Spraying during the growing season. Inhibition of growth of the suckers, increased resistance to extreme weather conditions, simultaneous flowering	50(1-2)
Carbendazim, 500 g/l {hp)	0,6	Alternaria, phomosis	Spraying during the growing season	(2)
Metelaxle – M,40 g/kg mancoceb, 640 g/kg (&g.)	2¿	Alternaria, peronosporium	Spraying during the growing season	30(3)
Munkotseb, 800 g/kg (w/w)	23-3,0	Alternaria	Spraying during the growing season	30(2)
Metcocazole, 60 g/l (b.p.)	0,75-1,25	Alternaria, phomosis, white rot	Spraying during the growing season, as well as in the phase of 4-6 leaves of the crop to prevent overgrowth and improve wintering	55(2)
Picoxistrobin, 200 g/l ciproconazole, 80 g/l (c.s.)	0,5-1,0	Alternaria, phomosis, downy mildew, cylindrosporium, white and grey rot	Spraying during the growing season	-(2)
Propiconazole, 250 g/l (c.e.)	0,5	Inhibition of plant growth, increased resistance to extreme weather conditions	Spraying in the phase of 4-5 litres/stock	30(2)
Propiconazole, 300 g/l + tebuconazole 200 g/l (m.e.)	0,4-0,6	Alternatively, phomosis, powdery mildew, sclerotinia	Spraying during the growing season	50(2)

Figure 3.2 – List of fungicides recommended in Ukraine for the control of cruciferous crops [161–164]

On the 12–15th day after germination, it is important to treat the crops with one of the recommended fungicides against downy mildew and phomosis. The second treatment (preferably with preparations based on a different active ingredient) is carried out on the crops during the budding period to obtain full-fledged healthy seeds. It reduces the development of Alternaria, white spot, grey and white rot. Whenever possible, both sprays are combined with insecticides, taking into account the timing of the likely occurrence of diseases and the forecast of pest populations. Crops intended for growing green mass are not treated a second time.

Leaf desiccation is also important, as it not only accelerates seed ripening but also reduces the degree of infection with pathogens such as Alternaria, Phoma and, especially, white and grey rot. This measure is carried out 7 to 10 days before harvesting with one of the recommended products. Another point is the short harvesting time for oil radish (reducing losses from Alternaria, phomosis, white and grey rot). Crops are mowed when the seeds are ripe, and the swaths are threshed at a moisture content of no more than 12%. For direct combining, the moisture content limit is up to 15%.

The last step is to care for the seeds after threshing, as they have high moisture content and can become covered with mould, which in turn will lead to a loss of germination and a decrease in the quality of oil and meal. To prevent this, the seeds are dried immediately after harvesting in a layer no thicker than 1 cm with frequent stirring. It is recommended to dry the seeds to a moisture content of no more than 7–8%. During drying, it is important to adjust the temperature of the heat carrier correctly. It should be 35°C if the seed moisture content is 35–40%, and 40°C if the moisture content is 25%. The system of measures to protect rapeseed from pests and diseases is presented in Table 3.38–3.39.

The recommendations of C. Hablak [165] on the model example of winter rape. The following are the recommendations of these studies in the author's version. The choice of fungicide is based on information about the sources of primary and secondary infection, the time of infection and the rate of infection growth. When justifying the choice of fungicide, the species composition of pathogens should be carefully analysed and the choice should be made on the product that suppresses the pathogen that causes the greatest losses and yield.

Table 3.38

System of measures to protect rapeseed from pests and diseases [165]

Terms of carrying out, phase of develop-ment	**Pests, diseases, Economic threshold of harm-fulness**	**Activities**	**Preparation, norm of vitrates, l, kg/ha, kg, l/t**
1	2	3	4
Annually	Different pathogens	Organisational, economic and agrotechnical measures	Growing disease-resistant varieties and hybrids of rapeseed; saturation of crop rotation with beetroot and cabbage crops no more than 25%, growing rapeseed after these and other crops in 4-5 years, the best predecessors are annual and perennial legumes, cereal grains, clean and busy fallow, distance from last year's cabbage fields 1 km, preparing the field for sowing using a soil cultivation system typical for the area, applying fertilisers and herbicides. Control of the phytosanitary condition of the crops
July (winter (winter rape). January-February (spring rape)	Diseases (mould, black foot, phomosis, alternaria, bacteriosis, downy mildew, rot)	Mordanting cleaned and calibrated conditioned seeds, use of regulators growth	InSet, VG, 2.5-3.5 l/t; Kaiser, TN, 4 l/t; Comanche WG, VG, 5 kg/t; Contador Maxi, TN, 3-6 l/t; Cruiser 350 FS, TN, 4 l/t; Cruiser 600 FS, TN, 2 l/t; Cruiser OSR 322 FS, TN, 15 l/t; Lumiposa, TN, 17 l/t; Lord, VG, 2. 5-3.5 kg/t; Meeder Pro, TN, 3 /t; Modesto Plus 510 FS, TN, 16.7 l/t; Nuprid 600, TN, 3-6 l/t; Sidoprid 600, TN, 4 l/t; Tabu, KS, 6-8 l/t; Masterpiece, KS, 4 l/t; Acrobat, ZP, 2 kg/t; Vaxa, CS, 2-3 kg/t; Vispar, CS, 2-3 kg/t; TMTD, CS, 3 l/t; Fire, TN, 2.5-3 kg/t
The end of August and early September. Seedlings winter rape	Black leg	Loosening row spacing, harrowing	–

(End of Table 3.38)

1	2	3	4
4-6 leaves of the culture	Alternaria, cylindros-poriosis, phomosis, white spotting, sclerotinia	Spraying with with fungicides upon presence of infection and for restraining leaf growth preventing overgrowth of plants, increasing resistance to extreme weather conditions and improving overwintering	Alterno, KE, 0.5-1 l/ha; Aperol, KE, 05-1 l/ha; Berkut, KE, 1 l/ha; Ekhnaton, KE, 1 l/ha; Ikarus 250, EW, 1 l/ha; Karamba, KE, 0.75-1.25 l/ha; Lekar BT, KS, 0.5-1 l/ha; Ludik 250, EW, 1 l/ha; Orbit, EW, 1 l/ha; Pegasus, EF, 0.5-0.75 l/ha; Polygard, EF, 0.5-0.75 l/ha; Retardin EW, EF, 0-0.75 l/ha; Setar 375, SO, CS, 0.3-0.5 l/ha; Tebukur 250, EF, 0.75-1 l/ha; Tebufor, EF, 1 l/ha; 1 l/ha; Tilmor 240 ES, EF, 0.75-0.9 l/ha; Tilt 250 ES, CE, 0.5 l/ha, Furil, KS, 1 l/ha; Fortress Total ES, KE, 1 l/ha; etc.
September-October 2-4 leaves – rosette formation of winter rape	Downy mildew, Alternaria, phomosis, cylindros-porium, white spot, etc. etc.	Treatment with fungicides (in case of signs of disease and favourable weather conditions for their development)	Acanto plus 28, CS, 0.5-1 l/ha; Aliette 80 WP, WP, 1.2-1.8 kg/ha; Amistar Extra 280 SC, CS, 0.75-1 l/ha; Alterno, CE, 0.5-1 l/ha; Evito T, CS, 0.5-1 l/ha; Impact T, CS, 1 l/ha; Kolosal, CE, 0.75-1 l/ha; Kustodia, CS, 1-1.2 l/ha; Pictor, CS, 0.5 l/ha; Propuls 250 SE, SE, 0.8-0.9 l/ha; Retardin EW, EF, 0.5-0.75 kg/ha; Simetra 325 SC, CS, 0.5-1 l/ha; Starpro, CS, 0.45-0.6 l/ha; Suprem, EF, 1-1.5 l/ha; Title Duo, KKR, 0.25-0.3 l/ha; Universal, WP, 0.25-0.35 kg/ha; Faraday, VG, 0.4-0.5 kg/ha; Fital, RK, 2-3 l/ha; Fast and Furious, CS, 0.6 l/ha; Fungicur, VG, 0.25-0.5 kg/ha; Hilton, CS, 0.6 l/ha; Healer, WP, 1.8-2.5 kg/ha; Yutaka, SE, 1.0-1.4 l/ha, etc. Use of growth regulators during the growing season
n the spring, winter crops resume vegetation and spring rape sprouts appear. Seedlings – 2-4 leaves of spring rape	Blackleg, bacteriosis, snow mould mould. Cruciferous fleas, 3-5 specimens per square metre	Loosening of the of row spacing. Harrowing, fertilising with nitrogen fertilisers (winter). Spraying with with insecticides	Alfagard 100, CE, 0.15 l/ha; Atrix, CE, 0.1-0.15 l/ha; Bestseller Turbo 200, KC, 0.05-0.08 l/ha; Biskaia 240 OD, MD, 0.3-0.4 l/ha; Break, ME, 0.05-0.07 l/ha; Versar, KE, 0.6 l/ha; Destroy, KC, 0.1 l/ha; KAIZO, VG, 0.15-0.2 kg/ha; Karate Zeon 050 CS, SC, 0.15 l/ha; Corsair, VG, 0.05-0.07 kg/ha; Lamdex, SC, 0.15 l/ha; Lord, VG, 0.05-0.07 kg/ha; Mavrik, EV, 0.2-0.3/ha; Mospilan, VP, 0.1-0.12 kg/ha; Sirocco, KE, 0.7-1.2 l/ha; Tom, KE, 0.1-0.15 l/ha; Fisheka, TB, 2 tab. /ha; Fury, BE, 0.1 l/ha; Caesar, CE, 0.125-0.15 l/ha; Shaman, CE, 0.6 l/ha or others.

(End of Table 3.38)

1	2	3	4
Seedlings – rosette of spring rape; stalking – budding of winter rape	Phomosis, downy mildew, cylindros-porium, white spot, alternaria, etc.	Fungicide treatment (in case of disease manifestation and favourable weather conditions for their development)	Acanto plus 28, CS, 0.5-1.0 l/ha; Aliette 80* WP, WP, 1.2-1.8 kg/ha; Amistar Extra 280 SC, CS, 0.75-1 l/ha; Alterno, CE, 0.5-1 l/ha; Evito T, CS, 0.5-1 l/ha; Impact T, CS, 1 l/ha; Kolosal, CE, 0.75-1 l/ha; Kustodia, CS, 1-1.2 l/ha; Pictor, CS, 0.5 l/ha; Propuls 250 SE, CE, 0.8¬0.9 l/ha; Retardin, VG, 0.4-0.5 kg/ha; Simetra 325 SC, CS, 0.5-1 l/ha; Starpro, CS, 0.3-0.6 l/ha; Suprem, EV, 1-1.5 l/ha; Tebaz Pro, CS, 0.5-1 l/ha; Title Duo, LF, 0.25-0.3 l/ha; Topazio, LF, 3-4 kg/ha; Universal, LF, 0.25-0.35 kg/ha; Faraday, LF, 0.4-0.5 kg/ha; Fitial, RK, 2.0-3.0 l/ha; Fast. KC, 0.6 l/ha; Fungicur, VG, 0.25-0.5 kg/ha; Hilton, KC, 0.6 l/ha; Healer, WP, 1.8-2.5 kg/ha; Yutaka, SE, 1-1.4 l/ha, etc.
Stemming phase – budding of plants (at a height of 10-15 cm) of spring rape	Alternaria, phomosis, etc. diseases	Spraying with fungicides with retardant properties, which promotes branching of lateral shoots, simultaneous of flowering, formation	Karamba, CE, 0.75-1.25 l/ha; Setar 375 SC, CS, 0.3-0.5 l/ha; Tebufor, CE, 0.5-1; Triafer T 300, CS, 0.6-1.0 l/ha; Tilmore 240 ES, CE, 0.75-0.9 l/ha; Fital, RK, 2.0-3.0 l/ha and analogues
Before harvesting	Alternaria, phomosis, grey rot	Desiccation for 70% browning of pods and wet weather	6-7 days before harvesting harvest – Diquat, RK, 1.5-3 l/ha; Zhar BT, RK, 2-3 l/ha; Reglon Super 150 SL, RK, 2-3 l/ha; Retro 150 SL, RK, 2-3 l/ha; Squar, RK, 2-3 l/ha;; Ra, PK, 2-3 l/ha; Desikash, PK, 3 l/ha; Reglon Air 200 SL, PK, 1-2 l/ha; Reglon Forte 200 SL, PK, 1.5-2.25 l/ha; Sukhoviy Next, PK, 1.3-2.0 l/ha; 10 days before harvesting harvest – Basta 150 SL, RK, 2-2.5 l/ha; 14 days before harvesting Glyphogan, RK, 3 l/ha; Volcano Plus, RK, 3 l/ha; Extraclin 607, RK, 2.4 l/ha; Clinic, RK, 3 l/ha; Clinic Extreme, RK, 2-3 l/ha; Richard, RK, 3 l/ha; Roundup Extra, RK, 2.6 l/ha; Roundup Max, RK, 2.4 l/ha; Tornado 500, RK, 2 l/ha; Roundup Power, RG, 1,5 kg/ha.

*It is forbidden to use straw for animal feed and oil for food purposes.

The diseases of rapeseed are ranked in the following order by their damage potential:
- Alternaria;
- phomosis;
- cylindrosporium;
- root bacteriosis;
- snow mould;
- downy mildew;
- black leg;
- white rot;
- grey rot;
- white spotting;
- Fusarium wilt;
- Verticillium wilt.

Table 3.39

System of protection of classical winter rape against weeds, diseases and pests for the Forest-Steppe, Polissya with a yield of 4–5 t/ha [161–165]

Phase	Product	Active ingredient	Rate, l (kg)/ha	Analogue products	Range of action
1	2	3	4	5	6
After sowing	Butisan Star	metazachlor 333 g/l, quinmerac 83 g/l	2	Tranche Super	
Autumn protection	Kropex	clomazone 480 g/l	0,2	Kalif	
2-4 leaves / BBCH 12-14 to 8 leaves / BBCH 18 (either in autumn or spring)	Galley Super	clopyralid 267 g/l, picloram 80 g/l, aminopyralid 17 g/l	0,3	Trier	Annual dicotyledons and perennials, including root and sprouting weeds
2-4 leaves / BBCH 12-14 to 6 leaves / BBCH 16. Appearance of carrion (2 leaves in cereals)	Fusilade Forte	Fluazifop-p-butyl, 150 g/l	1,5	Miura, Gramidin, Agil	Perennial, annual cereal weeds

(End of Table 3.39)

1	2	3	4	5	6
(either in autumn or spring)	Caramba Turbo	methconazole 30 g/l, mepiquat chloride 210 g/l	0,7–1,4	Folikur	Rastregulation
4-6 leaves / BBCH 14-16 T_o	Acro's opercular	lambda-cyhalothrin 300 g/l imidacloprid iodine g/l	0,25	Contador Duo	Cruciferous flea beetle, rapeseed sawfly
	Boric acid		1,0		Boron-containing fertiliser
6-8 leaves / BBCH 16-18, T_1	Folikur	tebuconazole, 250 g/l	1,0		Rastregulation
	Boric acid		1,0		Boron-containing fertiliser
Spring protection	Dr Krop	carbendazim, 500 g/l	1,0	Derosal	Alternaria, septoria, phomosis
Restoration of vegetation / BBCH 20-29 – BBCH 30-39, T_3	Fastak	Alpha-cypermethrin, 100 g/litre	0,15	Karatezone	Rapeseed flower beetle, cruciferous fleas
	Boric acid		1,0		Boron fertiliser
Restoration of vegetation (either in autumn or spring) / BBCH 20¬29	Galley Super	clopyralid 267 g/l, picloram 80 g/l, aminopyralid 17 g/l	0,3	Trier	Annual dicotyledons and perennials, including root and sprouting weeds
Restoration of vegetation (either in autumn or spring) BBCH 20-29	Fusilade Forte	fluazifop-p-butyl, 150 g/l	1,5	Flora	Perennial, annual cereal weeds
	Folikur	tebuconazole, 250 g/l	1,0		Resistance to lodging and better formation of side shoots
	Magnesium sulphate		0,003		Fertiliser

(End of Table 3.39)

1	2	3	4	5	6
Stemming – green bud / BBCH 40-49 – BBCH 50-59, T_4	Razit	imidacloprid, 140 g/l + acetamiprid, ibo g/l + alpha-cypermethrin, 100 g/l	0,1		Insects, mites and soil pests
	Bortrak			Humi-friend (0.5 l/ha)	Boron fertiliser
	Humifield BP18		0,4	Ligno-gumat BM (0.3 l/ha), Ukrainian humates (0.2 l/ha)	Microfertiliser
	Alterno	methconazole, 80 g/l, pyraclos-trobin, 130 g/l			Grey rot, phomosis, sclerotinia, cylindrical sporulation
Beginning and end of flowering BBCH 60-69, T_5	Biscay	thiacloprid, 240 g/l	0,4		Seed beetle, rapeseed gall midge, aphids, rapeseed borer, fleas
Green pod (in the presence of pests) / BBCH 70-79	Acro opercular Urea	lambda-cyhalothrin, 300 g/l, imidacloprid, 100 g/l	0,1 0,02	Contador Duo	Aphids, cereal flies Fertiliser
Desiccation / BBCH 85-87,70% of browned pods (seed moisture content not more than 25-30%)	Reglon Super	diquat, 150 g/l	2,5	Diquat, Reglon Spectrum	Desiccant

In recent years, crop rotation disturbances have contributed to the spread of grey and white rot, Fusarium and Verticillium wilt, snow mould, blackleg, clubroot, viral and mycoplasma diseases.

The disease control system may include fungicide treatments during the growing season and seed treatment with seed dressing during the following phases [165]:

T_{00} – pre-sowing seed treatment;

T_0 – the first treatment with a fungicide-retardant (4–6 leaves (development of leaf rosette) / BBCH 14–16);

T_1 – second treatment with a fungicide-retardant (6–8 leaves (BBCH 16–18);

T_2 – the third treatment with a fungicide-retardant (8–10 leaves / BBCH 18–20);

T_3 – the first fungicide treatment (development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39);

T_4 – the second fungicide treatment (growth in length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59);

T_5 – the third fungicide treatment (beginning to end of flowering / BBCH 60–69).

The second treatment with T_4 fungicide, which is carried out in the phase 40–49 to 50–59, and the third spraying with T5 in the period 60–69, which reduces pod damage and increases oil content by 1.3–3.4 times, play an important role.

The first treatment with T_3 fungicide in the period 20–29 to 30–39 is recommended in case of rainy summers and a high infection load with diseases that damage young plants, or in the absence of high-clearance sprayers, as well as with no-till and strip-till technologies.

It is important to note that crops should be treated against phomosis, downy mildew, Alternaria, and cylindrosporium in T_0 – the first treatment with a retardant fungicide (4–6 leaves (development of a leaf rosette) / BBCH 14–16) and T_3 – the first treatment with a fungicide (development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39).

Schemes for protecting winter rape from downy mildew [165]:

It would like to note that triazoles with retardant effect do not protect against secondary (local) leaf damage by downy mildew. Instead, fungicides with the active ingredients dimethomorph, metalaxyl, cymoxanil, aluminium fosetyl, azoxystrobin, picoxystrobin, dimoxystrobin, and propamocarb hydrochloride provide preventive protection. These are the following drugs: azoxystrobin, 250 g/l (Taser, 0,5–1 l/ha), dimethomorph, 180 g/l + cymoxanil, 125 g/l (Fregat 0.6–1.0 l/ha), carbendazim, 200 g/l + metalaxyl, 100 g/l (Metacarb 1–1.2 l/ha), metalaxyl, 80 g/kg + mancoceb, 640 g/kg (Healer 2.5 kg/ha), picoxystrobin, 200 g/kg + ciproconazole, 80 g/kg (Acanto Plus 0.5–1 l/ha). Only aluminium fosetyl, 800 g/kg (Aliette 1.2–1.8 kg/ha) can move basipetally from the shoot to the root system, where the primary infection with the peronospora pathogen occurs through root hairs.

Primary infection of winter rape with downy mildew occurs latently in the soil through root hairs of the root system. Then the pathogen freely penetrates the roots, stems, leaves, spreads in the intercellular space, and out through the stomatal openings on the underside of the leaves, sporulation (zoosporangia with zoospores), which we see as a light coating. Such diseased plants cannot be treated and will not produce a crop. From plants affected by primary infection, the infection spreads by rain, wind, insects and water over long distances (up to 500 m), causing secondary (local) leaf damage at very high humidity, penetrating healthy plants through leaf stomata.

The main protection against seed and soil infection of downy mildew is provided by effective treatments made of active ingredients or their combinations (metalaxyl-m, fluopicolide, fluoxastrobin, thiram): fluopicolide, 120 g/l + fluoxastrobin, 90 g/l + clothianidin, 300 g/l (Modesto Plus 8 l/t), metalaxyl-m, 350 g/l (Metalax 2 l/t), metalaxyl-m, 116 g/l + thiabendazole, 20 g/l + thiram, 400 g/l (Faer 2.5 l/1t).

The next protection against downy mildew is to protect crops with fungicides against secondary infection from the 4–6 leaf stage.

Treatment of winter rape crops against phomosis, grey rot, powdery mildew should be carried out in T_4 – the second fungicide treatment (growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59). Against grey rot, powdery mildew, sclerotinia (white rot), Alternaria, cylindrosporium, the treatment should be carried out in T_5 – the third fungicide treatment (beginning to end of flowering / BBCH 60–69). Moreover, against sclerotinia, fungicides can be applied at the beginning of flowering of the main tassel, and against Alternaria, it can be carried out at a later date – at the end of flowering, when the tops of the inflorescences are ripe.

Depending on the fungicide disease control programme, the following fungicide application schemes are possible for winter oilseed rape [165]:

– 1-time application (variant A) – growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59 (T_4);

– 1-time application (variant B) – beginning to end of flowering / BBCH 60–69 (T_5);

– 1-time application (variant B) – development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39 (T_3);

– 2-fold (variant A) – development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39 (T_3) + growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59 (T_4);

– 2-fold (variant B) – development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39 (T_3) + beginning-end of flowering / BBCH 60–69 (T_5);

– 2-fold (variant B) – growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59 (T_4) + beginning-end of flowering / BBCH 60–69 (T_5);

– 3 times – development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39 (T_3) + growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59 (T_4) + beginning-end of flowering / BBCH 60–69 (T_5).

Types of active ingredients of fungicides by the nature of their action [165]:

According to the nature of their action (not to be confused with the mechanism of action and mobility in the plant), fungicides are divided into: preventive action, also known as "protective action", curative, eradicating and immunising. All contact fungicides with protective action (mancoceb, copper hydroxide, thiram) and fungicides with low systemicity (translaminar or local-systemic) from the group of strobilurins, benzamidazoles (benomyl), dicarboximides (iprodione), phenylpyrroles (fludioxonil) are used prophylactically in the initial stages of the disease (spore germination on the leaf), the beginning of penetration into the leaf (germ tube elongation, apsorium formation).

Curative (curative, therapeutic) systemic fungicides (xylem-mobile and phloem-mobile) act on the pathogen from inside the plant, from the moment of penetration. The greatest effectiveness is approximately until the middle of the latent (hidden) period of disease development and germination, when no visible signs have yet appeared in the leaf. These include triazoles, imidazoles, phenylamines (mefenoxam), some strobilurins (azoxystrobin, fluaxostrobin), etc. The activity of triazoles against diseases decreases in descending order: rust – septoria – powdery mildew. Imidazoles: Septoria – Fusarium. Morpholins: powdery mildew – rust.

The most effective powdery mildew products are fungicides from the morpholin group (spiroxamine, fenpropidin, fenpropimorph). A distinctive feature of morpholines is their high volatility (vapour pressure at 20 ºC), and in spiroxamine it is 500 times higher than in the most volatile strobilurin. The biology of powdery mildew development is such that the mycelium is located on the leaf surface, not inside, and to effectively combat this surface pathogen, either contact fungicides or systemic fungicides with high volatility are used. This is the so-called "vapour phase" effect, when the active ingredient of the fungicide is active not only at the point of direct application, but also beyond it. Picoxystrobin and trifloxystrobin also have vapour phase activity, but it is much less.

Eradicating fungicides (antisporulants) inhibit the formation of spores. They include strobilurins and some contact fungicides.

Immunising fungicides activate defence mechanisms in the plant itself, also known as elicitors. They include some contact fungicides (copper-based), phosphonic acid fungicides (aluminium fosetyl).

Many combined fungicides mostly combine active ingredients with preventive and curative effects with different mechanisms of action on the pathogen: strobilurins with triazoles, carboxamides with triazoles, triazoles with benzimidazoles. This allows us to expand the spectrum of fungicide activity and gives us more flexibility in the timing of treatment.

Features of application [165]:

Often, questions arise about the strategy of using two-component products from different classes with preventive and curative properties or one-component fungicides with preventive (carboxamides, strobilurins) or curative action (triazoles). A fungicide with a broad spectrum and long-lasting protective effect (strobilurins + triazoles, carbendazim + triazoles) is preferable for treatment during the period of growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59 (T_4), as such a fungicide will smooth out the aftereffects of errors in the selection and application of the first fungicide in the spring during the development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39 (T_3), and will give time to analyse the phytosanitary situation.

Strobilurins and carboxamides are usually used prophylactically in T_3 or T_4 against foliar diseases. Triazoles are used in T_4 or T_5, usually curatively when the EMP of foliar diseases is reached. In the absence of disease, triazoles are usually not effective.

Strobilurins are used prophylactically, they prevent germination of pathogen spores, but do not cure when the fungus has already penetrated. Triazoles, on the contrary, treat, but do not affect spore germination. Strobilurins can work prophylactically for up to 6 weeks, while triazoles are much less effective (2–3 weeks). At the same time, the use of one-component strobilurins or two-component fungicides with protective and curative effects (strobilurins + triazoles, carbendazim + triazoles) on winter rape in T_4 is the second fungicide treatment (growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59), T_5 – the third fungicide treatment (beginning to end of flowering / BBCH 60–69) often at high temperatures lead to the closure of leaf stomata by the contact components of the preparation and disruption of their transpiration, wilting of leaves.

Temperature minimums at which fungicides can be used [165]:

– 5 °C – morpholines (fenpropidin, fenpropimorph); dithiocarbamates (mancoceb); imidazoles (prochloraz); quinazolines (proquinazid);

– 10 °C – strobilurins (generic azoxystrobin, picoxystrobin, etc.);

– 10–12 °C – triazoles (propiconazole, tebuconazole, ciproconazole, protioconazole, metconazole, etc.).

The indicated temperatures are the limit within which they are effective. Ideally, they should be applied at 18–20 °C in cloudy weather without rain.

Triazoles are more soluble in water, so they have a higher systemicity than strobilurins and morpholins. Strobilurins have a higher lipophilicity, which means they provide better protection at the point of fungal penetration into the plant. Morpholins are more volatile, which means that protection is provided not only at the point where the fungicide has been applied, but also around it, which is important for controlling surface pathogens.

There are also questions about the effectiveness of combining triazoles with strobilurins in two-component formulations, as well as triazoles with carboxamides with reduced doses of active ingredients compared to single-component triazoles, strobilurins, carboxamides in full doses. For example, a single-component fungicide with a higher dosage of Azoxin 0.6–0.8 l/ha (azoxystrobin, 250 g/l) is more effective compared to a multi-component fungicide with lower doses of active ingredients Kapital 1–1.2 l/ha (azoxystrobin 150 g/l + ciproconazole, 60 g/l + epoxiconazole, 50 g/l). When used prophylactically in T_3, T_4 in the absence of disease, triazoles in two-component formulations will be useless, as triazoles are used in the presence of disease. Only the second component of the product (strobilurins or carboxamides) will act prophylactically, and it will be in a reduced dosage compared to a one-component fungicide. It is believed that one-component fungicides are more effective because they contain higher doses of active ingredients than half the doses of active ingredients in two-component products.

In addition, we should not forget about the resistance of the disease to the fungicide. Disease resistance to the active ingredient, and then to all active ingredients of this chemical class through one site of action in the cell, occurs most rapidly when two-component fungicides from different classes are used at lower half doses compared to a single-component product with a full dose of the active ingredient. For example, if a disease has developed resistance to azoxystrobin from the strobilurin class, then it will also develop resistance to other members of the strobilurin class (dimoxystrobin, picoxystrobin, etc.). At the same time, fungal organisms also adapt very quickly to single-site, single-component drugs. As a result, resistant forms of diseases to pure strobilurin fungicides have emerged. After that, strobilurins were used only in combination with other chemical classes, but at half the rates to save money. In my opinion, two-component fungicides from different classes with full rates, as in one-component fungicides, are not profitable from a cost perspective.

It is advisable to purchase fungicides in advance for the new season for combined active ingredients (strobilurins with triazoles, carboxamides with triazole), which can be used universally for pre-infection and post-infection treatment. Usually, purchasing triazoles in advance to save money and for preventive use is not an effective measure.

Wet weather during the ripening period requires at least two applications of the fungicide on winter rape. In dry weather, one treatment may be sufficient. Thus, in the regions of Ukraine that are characterised by 400 millimetres of precipitation or more per year, it is better to apply the fungicide twice: T_3 – the first fungicide treatment (development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30-39), T_4 – the second fungicide treatment (growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59).

For winter rape in the western region of Ukraine, 2–3 fungicide treatments during the growing season are the norm, although 3 treatments are more common: T_3 – the first fungicide treatment (development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30-39), T_4 – the second fungicide treatment (growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59), T_5 – the third fungicide treatment (beginning-end of flowering / BBCH 60–69).

In the east and south of Ukraine, one application may be sufficient in the phase of lateral shoot development (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39 or during the period of growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59.

In the south of Ukraine, only one fungicide treatment is usually applied to winter rape grown on bogar. However, if there is frequent precipitation during the growing season, the number of treatments may be increased to two.

Fungal infections in oilseed rape and fungicides against them [165]:

Some pathogens enter the plant directly through the epidermis. These are, for example, the causative agents of downy mildew – fungi from the marsupial class. Once on the plant, the spores of these fungi germinate and drill through the cuticle with their seedlings, penetrate the tissue, providing nutrition and staying on the affected surface. This fungus develops on the surface of plants (exoparasite). In most cases, the infection, once in the plant, develops inside it, either in the intercellular spaces or in the cell (endoparasite). Typical endoparasites are the causative agents of cabbage clubroot, potato cancer and fungi that cause downy mildew. The development of parasites inside the plant makes it difficult to destroy them, so the protective measures used are more often aimed at preventing infection of plants than at destroying pathogens that have already penetrated.

All fungicides are divided into two groups according to their selectivity: fungicides effective against downy mildew fungi (Oomycetes) and fungicides effective against true powdery mildew fungi (Ascomycetes, Basidiomycetes, Deuteromycetes).

The following fungicides are used against downy mildew (peronospora) in winter rape: Azoxin 0.6–0.8 l/ha (azoxystrobin. 250 g/l); Capital 1–1.2 l/ha (azoxystrobin. 150 g/l + ciproconazole. 60 g/l + epoxiconazole. 50 g/l); Simetra 0.5–1 l/ha (azoxystrobin. 200 g/l + isopyrazam. 125 g/l); Arbalet 0.6–1 l/ha (azoxystrobin. 200 g/l + flutriafol. 120 g/l); Frigate 0.6–1.2 l/ha (dimethomorph. 180 g/l + cymoxanil. 125 g/l); Healer 1.8–2.5 kg/ha (metalaxyl. 80 g/kg + mancoceb. 640 g/kg); Acanto Plus 0.5–1 litres/ha (picoxystrobin. 200 g/l + ciproconazole. 80 g/l); Custodia 1–1.2 litres/ha (tebuconazole. 200 g/l + azoxystrobin. 120 g/l); Bolivar Forte 0.5–1 l/ha (tebuconazole. 240 g/l + cresoxim-methyl. 125 g/l); Aliette 1.2–1.8 kg/ha (aluminium fosetyl. 800 g/kg); Amistar Extra. 0.75–1 l/ha (azoxystrobin. 200 g/l + ciproconazole. 80 g/l).

The following fungicides are used against true powdery mildew fungi (Ascomycetes, Basidiomycetes, Deuteromycetes) in winter rape: Azoxin 0.6–0.8 l/ha; Capital 1–1.2 l/ha; Simetra 0.5–1 l/ha; Arbalet 0.6–1 l/ha; Spirit 0.5–0.7 l/ha (epoxiconazole. 160 g/l + azoxystrobin. 240 g/l); Forsazh 0.5 l/ha (carbendazim. 500 g/l); Kamzol 1–1.5 l/ha (metconazole. 60 g/l); Acanto Plus 0.5–1 l/ha; Pictor 0.5 l/ha (boscalid. 200 g/l + dimoxystrobin. 200 g/l); Tinazol. 0.5 l/ha (propiconazole. 250 g/l); Tilmore 0.9–1 l/ha (protioconazole. 80 g/l + tebuconazole. 160 g/l); Thaler 0.5–1 l/ha (tebuconazole. 250 g/l); Suprem 1–1.5 l/ha (tebuconazole. 133 g/l + prochlorazole. 267 g/l); Kiper 0.8–1 l/ha (tebuconazole. 162.5 g/l + thiabendazole. 250 g/l); Custodia 1–1.2 l/ha; Bolivar Forte 0.5–1 l/ha; Acadia 0.8–1 l/ha (tebuconazole. 200 g/l + azoxystrobin. 120 g/l + biological complex Acts 350); Yutaka 1–1.4 l/ha (thiophanate-methyl. 350 g/l + tebuconazole. 100 g/l + cyflufenamide. 6.3 g/l); Bayzafon 0.5–1 kg/ha (triadimefon. 250 g/kg); Alterno 0.5–1 l/ha (pyraclostrobin. 130 g/l + metconazole. 80 g/l); Propulse 0.8–0.9 l/ha (fluopyram. 125 g/l + protioconazole. 125 g/l); FlutriVit 0.5 l/ha (flutriafol. 250 g/l); Impact T 0.6–1 l/ha (flutriafol. 117.5 g/l + carbendazim. 250 g/l); Phoenix Duo 0.5–0.6 l/ha (flutriafol. 187 g/l + thiophanate-methyl. 310 g/l); Amistar Extra. 0.75–1 l/ha.

Table 3.40

Classification of fungicides used in oilseed rape by chemical composition and mechanism of action on the pathogen [165]

Class	Active ingredient	By method of penetration	Mechanism of action on the pathogen
Benzimidazoles	Benomyl	Systemic	Group B (FRAC) – inhibitors of cell division
	Carbendazim	Systemic	
	Thiabendazole	Systemic	
Thiophanates of urea phenyl	Thiourea methyl	Systemic	Group B (FRAC) – inhibitors of cell division
Dithiocarbamates	Maikotseb	Contact	Group M (FRAC) – contact fungicides with multi-site action
	Azoxystrobin	Systemic	
	Dimoxystrobin	Systemic	
Strobilurins	Cresoxim-methyl	Systemic	Група C (FRAC) – inhibitors клітинного дихання
	Picoxystrobin	Systemic	
	Pyraclostrobin	Contact	
Imidazoles	Prochloraz	Systemic	Group G (FRAC) – inhibitors of sterol synthesis in the membrane
Pyrazole carboxamides	Isopyrazam	Systemic	Group C (FRAC) – inhibitors of cellular respiration
Pyridine carboxamides	Boscalid	Systemic	Group C (FRAC) – inhibitors of cellular respiration
Pyridine-ethyl benzamides	Fluopyram	Systemic	Group C (FRAC) – inhibitors of cellular respiration
	Diphenoconazole	Systemic	
	Epoxiconazole	Systemic	
	Metconazole	Systemic	
	Protocoiazole	Systemic	
Triazoles	Propiconazole	Systemic	Group G (FRAC) – inhibitors of sterol synthesis in the membrane
	Tebuconazole	Systemic	
	‘Griadimephon	Systemic	
	Ciproconazole	Systemic	
	Flutriafol	Systemic	
Phenylamines (acylalanines)	Metalaxyl-m	Systemic	Group G (FRAC) – inhibitors of sterol synthesis in the membrane
Phenylacetamides	Diglufenamide	Systemic	Inhibition of apresorium formation, spore formation, mycelium development and growth of fungal colonies
Ethyl phosphonates	Aluminium phosphate	Systemic	Group U (FRAC) – fungicides of unknown mode of action

There are practically no fungicides that can control downy mildew (peronosporosis), sclerotinia (white rot) and grey rot at a high level.

During the development of lateral shoots (renewal of vegetation in spring) – growth in the length of the main shoot / BBCH 20–29 – BBCH 30–39 (T_3) on winter rape, it is recommended to apply one-component preventive preparations or two-component contact-systemic fungicides: Azoxin 0.6–0.8 l/ha; Kapital 1–1.2 l/ha; Simetra 0.5–1 l/ha; Arbalet 0.6–1 l/ha; Fregat 0.6–1.2 l/ha; Spirit 0.5–0.7 l/ha; Healer 1.8–2.5 kg/ha; Acanto Plus 0.5–1 l/ha; Custodia 1–1.2 l/ha; Bolivar Forte 0.5–1 l/ha; Aliette 1.2–1.8 kg/ha; Amistar Extra. 0.75–1 l/ha; Lametil 0.5–0.6 l/ha; Fast and Furious 0.5 l/ha; Thaler 0.5–1 l/ha.

In the stage of growth in the length of lateral shoots – budding / BBCH 40–49 – BBCH 50–59 (T_4), it is proposed to spray plants with two-component contact-systemic preparations or systemic fungicides: Capital 1–1.2 l/ha; Simetra 0.5-1 l/ha; Crossbow 0.6–1 l/ha; Spirit 0.5–0.7 l/ha; ealer 1.8–2.5 kg/ha; Acanto Plus 0.5–1 l/ha; Kustodia 1–1.2 l/ha; Bolivar Forte 0.5–1 l/ha; Amistar Extra. 0.75–1 l/ha; Kamzol 1–1.5 l/ha; Thaler 0.5–1 l/ha; Flutivit. 0.5 l/ha; Bayzafon 0.5–1 kg/ha.

In the period from the beginning to the end of flowering / BBCH 60–69 (T_5), it is recommended to apply systemic fungicides or contact-systemic preparations: Capital 1–1.2 l/ha; Arbalet 0.6–1 l/ha; Spirit 0.5–0.7 l/ha; Acanto Plus 0.5–1 l/ha; Custodia 1–1.2 l/ha; Bolivar Forte 0.5–1 l/ha; Amistar Extra. 0.75–1 l/ha; Kamzol 1–1.5 l/ha; Bayzafon 0.5–1 kg/ha.

The world experience of controlling some diseases in cruciferous crops is also valuable (Table 3.42). For example, against white rust, the results showed that all preparations significantly outperformed the untreated control in reducing the intensity of the disease. The treatment, which included foliar spraying with mancozeb 75% WP 0.2% followed by metallaxyl 8% + mancozeb 64% WP 0.2%, was the most effective among all treatments in controlling the disease, where the lowest disease intensity (1.40%) and the highest disease reduction (90.43%) were recorded compared to the control.

The treatment, which included foliar application of mancozeb 75% WP 0.2% followed by hexaconazole 5% EC 0.05% and foliar application of mancozeb 75% WP 0.2% followed by propiconazole 25% EC 0.05%, which were statistically not inferior to each other in terms of disease control, showed a decrease in disease intensity by 2.77 and 3.23 percentage points of disease intensity and 81.07 and 77,92% compared to the control, respectively. The other foliar treatments showed low to moderate disease control efficacy, while spraying with mancozeb 75% WP alone was the least effective.

These results are in line with previous studies that found the effectiveness of metalaxyl 8% + mancozeb 64% WP (Ridomil MZ) in controlling the intensity of white rust development on mustard leaves. Similar to these results, it was also reported on the effectiveness of hexaconazole and propiconazole in the fight against white rust of mustard.

The data presented in Table 3.41 showed that spraying different fungicides separately or each fungicide in sequence with mancozeb 75% WP (0,2%) significantly reduced the incidence of Alternaria compared to the control, but the level of effectiveness varied depending on the treatment, In general, combinations of two fungicide sprays, i,e, mancozeb 75% WP at 45 days after emergence followed by four other fungicide sprays at 45 days after emergence until 60-65 days after emergence, reduced the degree of Alternaria damage compared to all treatments with a single spray,

The treatment, which included foliar spraying with mancozeb 75% WP 0.2% followed by spraying with hexaconazole 5% EC 0.05%, was the best among all treatments in the fight against the disease, where the lowest disease intensity (2.07%) and the maximum disease reduction (75.44%) were recorded compared to the control, The variant containing foliar application of mancozeb 75% WP 0.2% followed by propiconazole 25% EC 0.05% differed slightly from the control, with a disease intensity of 2.10% and protection against the disease of 75.09% compared to the control.

Foliar application of mancozeb 75% WP 0,2% followed by difenconazole 25% EC 0,05%, which is the next most effective treatment against the disease, showed 2.33 per cent disease development and 72.36 per cent reduction in disease intensity compared to the control.

Other products showed low or moderate efficacy against the disease, allowing to achieve from 2.33 to 4.63 per cent of disease development. Among the single sprays, hexaconazole 5% EC 0.05% was the best in reducing disease severity (67.14%) compared to the control. The obtained results coincide with the data of previous researchers, who claimed that spraying with mancozeb followed by spraying with hexaconazole reduced the degree of mustard damage by Alternaria.

Table 3.41

Combination of active ingredients of fungicides used in oilseed rape [165–172]

Active substance (single use)	In combination with other research	In combination with two doctoral degrees
Benomyl	–	–
Carbendazim	Flutriafol	–
Thiabendazole	Tebuconazole	–
Thiophanate-methyl	Flutriafol	Tebuconazole + digitalis
Mankotseb	Metalaxyl-m	–
Azoxystrobin	Isopyrazam, Flutriafol	Ciproconazole + epoxiconazole
	Epoxiconazole Tebuconazole Ciproconazole	–
Dimoxystrobin	Boscalid	–
Cresoxim-methyl	Tebuconazole	–
Picoxystrobin	Ciproconazole	–
Pyraclostrobin	Metconazole	Calcium prohexadione + mepiquat chloride
Prochloraz	Tebuconazole	–
Isopyrazam	Azoxystrobin	–
Boscalid	Dimoxystrobin	–
Fluopyram	Protoconazole	–
Diphenoconazole	Paclobutrazole	–
Epoxiconazole	Azoxystrobin Mepiquat chloride	Azoxystrobin + ciproconazole
Metconazole	Tebuconazole Pyraclostrobin	–
Protoconazole	Tebuconazole Fluopyram	–
Propiconazole	Tebuconazole	–
Tebuconazole	Propiconazole	–
Triadimephon	–	–
Ciproconazole	Picoxistrobin Azoxystrobin Azoxystrobin	Azoxystrobin + epoxiconazole
Flutriafol	Carbendazim Thiophanate-methyl	–
Metalaxyl-m	Mankotseb	–
Diglufenamide	–	Thiophanag-methyl + tebuconazole
Aluminium phosphate	–	–

Similar to our results, they reported, that propiconazole is an effective fungicide in the control of Alternaria lesions of mustard.

The treatment, which included foliar spraying with mancozeb 75% WP 0.2% followed by metallaxyl 8% + mancozeb 64% WP 0.2%, provided a maximum average yield of 13.48 centner/ha, which is 59.15% higher than the control, slightly inferior to the treatment, which included foliar spraying with mancozeb 75% WP 0.2% followed by hexaconazole 5% c.e. e. 0.05%, where the yield was 12.94 centner/ha. The foliar application of mancozeb 75% WP 0.2% followed by propiconazole 25% EC 0.05% was the next most potentially effective in providing a yield of 11.90 centner/ha (Table 3.42). The highest incremental cost-benefit ratio of 9.57 was achieved with a foliar spray of hexaconazole 5% EC 0.05%, followed by a treatment that included a spray of mancozeb 75% w/w 0.2% followed by hexaconazole 5% c.e. 0.05% and foliar application of mancozeb 75% c.e. 0.2% followed by propiconazole 25% c.e. 0.05%, which provided a cost-benefit ratio of 5.42 and 3.21, respectively.

These results are supported by several previous studies that reported higher mustard yields when foliar sprayed with mancozeb 75% w.c., hexaconazole 5% w.c. and mancozeb 75% w.c. at 0,2% w.c., propiconazole 25% w.c. and metalaxyl 8% + mancozeb 64% w.c. [172]. In general, the active ingredients of fungicides and biological control agents for cruciferous diseases that were studied during 1965–2022 are presented in Tables 3.43 and 3.44.

It should also be noted [173], that an informal top list of fungicides for the protection of cruciferous crops has been compiled based on the results of long-term evaluations and trials. This top list includes the following fungicides in Ukraine:

Amistar Extra fungicide by Syngenta. Active ingredients: ciproconazole, 80 g/l, azoxystrobin, 200 g/l. The product guarantees high profits and yields by preventively acting on most pathogens (grey and white rot, phomosis). It provides vegetation extension and high photostability. It is applied two times during the growing season. Most effective in the early stages of diseases. Compatible with most pesticides.

Fungicide *Acanto Plus* by Corteva Agriscience. A product from the chemical group of strobilurins + triazoles (picoxystrobin, 200 g/l, ciproconazole, 80 g/l) that will protect the potential yield. It provides a pronounced physiological effect in intensive crop cultivation technologies.

Reduces its sensitivity to stress factors and pests. Guarantees healthy growth and normal development. Overcomes Alternaria and Cylindrosporium. It is necessary to spray the field with seedlings twice.

Table 3.42

Effectiveness of different fungicides against common diseases of mustard oilseed rape in the field [165–172]

Variant number	Variants of fungicide application	White rust		Alternariosis		Harvest centner/ hectare	Severity higher than control (%)	Yield to control ratio
		Percentage of disease intensity	Decrease to control (%)	Percentage of disease intensity	Decrease to control (%)			
T 1	One-time spraying of mancoceb 5% WP 0,2%	10.70 (19.08)	26.86	5.40 (13.41)	35.94	9.51	12.28	1: 1.35
T 2	Single spraying of metalaxyl 8% + mancozeb 64% WP 0,2%	4.17 (11.72)	71.50	4.63 (12.40)	45.08	10.87	28.34	1: 1.16
T 3	Single spray hexaconazole 5% EC 0,05%	5.80 (13.87)	60.36	2.77 (9.54)	67.14	11.17	31.88	1: 9.57
T 4	Single spraying of difenconazole 25% EC 0.05%	7.87 (16.32)	46.21	4.57 (12.44)	45.79	9.79	15.58	1: 0.64
T 5	Single spray propiconazole 25% EC 0.05%	6.47 (14.71)	55.78	3.60 (10.86)	57.30	10.18	20.19	1: 3.21
T 6	T–1 + T–2	1.40 (6.16)	90.43	2.40 (8.87)	71.53	13.48	59.15	1: 2.22
T 7	T–1 +T–3	2.77 (9.55)	81.07	2.07 (8.26)	75.44	12.94	52.77	1: 5.42
T 8	T–1 + T–4	4.57 (12.29)	68.76	2.33 (8.72)	72.36	10.45	23.38	1: 0.59
T 9	T–1 + T–5	3.23 (10.33)	77.92	2.10 (8.33)	75.09	11.90	40.50	1: 3.03
T 10	Control (water spraying)	14.63 (22.49)	–	8.43 (16.87)	–	8.47	–	1: 1.35
	SSD ($P = 0.05$)	2.10		1.76		2.46		
	CV (%)	8.97		9.33		13.20		

Table 3.43

Screening of active ingredients of fungicides used and studied in the world practice against the main diseases of cruciferous crops (for the period 1965–2022) [174]

Active ingredient of the fungicide	Phomosis	Sclerotoniosis	Sclerotoniosis	Alternariosis	Clubroot	Grey rot	TuYV virus	Vericillium wilt	Peronosporosis
Tebuconazole	+	+	+	+					
Boscalide	+	+	+	+		+		+	
Prochloraz	+	+	+	+		+			+
Azoxystrobin	+	+	+	+		+		+	
Metconazole	+	+	+	+					
Proticonazole	+	+	+						
Dimoxistrobin	+	+		+		+		+	
Flutriafol	+								
Kiproconazole	+	+	+						
Difenoconazole	+	+	+						
Fluazinam		+			+				
Cazofamide					+				
Fluquinconazole	+								
Imazalil	+		+						
Lambda-cyhalothrin							+		
Metalaxyl	+		+						
Thiabendazole	+		+						
Trifloxystrobin		+	+						
Beta-ciflutrin	+								
Carbetamide			+						
Cantranilipron							+		
Fludioxonil		+							
Fluxapiroxad	+								
Imidacloprid	+								
Mepiquat	+								
Propizamide			+						
Pyraclostrobin	+								
Teflutriene							+		
Thiophanatemethyl		+							

Camzol Defenda fungicide. Moderately hazardous agent of the third class (chemical group of triazoles, active ingredient methconazole, 60 g/l) of toxicity, produced in the form of a soluble concentrate. It has a number of advantages:

– forms a branched and strong root system;
– Does not lose its properties under adverse weather conditions;
– eliminates variegation during the growing season and increases the chances of a high-quality harvest;
– increases the seed ripening cycle.

It is able to destroy the cell membranes of pathogens, distributing in the plant acropetally. Prevents the formation of mycelium and has a therapeutic effect. Stops yellowing of crops It is not recommended to mix with preparations that form a strongly alkaline environment. Before complex use, conduct a compatibility test.

BASF fungicide Pictor. The active ingredients are boscalid and dimoxystrobin. It promotes successful crop cultivation and stable yields, actively destroys pathogens of major diseases. It is characterised by high biological efficacy and long-term preventive effect. It is safe for bees. One field treatment is enough. It is used most often after the flower petals fall off.

Bayer's Propulse fungicide. A two-component product that is used during the flowering period and contains the latest active ingredients fluopyram and protioconazole. Provides a high weight of 1000 seeds of the crop. Blocks mitochondrial respiration of pathogen cells, blocks ergosterol. If necessary, combine with liquid fertilisers, insecticides, growth regulators.

Thaler Defenda fungicide. A preparation (active ingredient tebuconazole, 250 g/l) with a pronounced stop effect, which has a preventive effect of growth inhibitors. Active against a wide range of pathogens, not phytotoxic.

Quickly stops the growth of mycelium, penetrating into plants in 1–2 hours. It is resistant to rainfall washout. It is able to stop the growth of winter mass and improve winter hardiness characteristics, ensure high-quality formation of lateral shoots. The last treatment before harvesting should be carried out no later than 30 days before harvest.

Agronomists recommend using flutriafol and oritebuconazole-based protectants on rapeseed crops. These active ingredients penetrate the leaf surface and additionally protect other parts of the plant. Systemic fungicides even protect young shoots that appear after treatment.

Spraying winter rape in autumn prolongs plant photosynthesis and stops the growth of ground mass. Plastic substances accumulate in the root collar of the crop, and branched roots accelerate their growth.

The use of combined preparations allows sowing rapeseed in the early stages and increasing the crop's winter hardiness. Single-component fungicides do not have this effect.

The fungicidal effect of strobilurins (azoxystrobin) is due to their ability to inhibit mitochondrial respiration of pathogen cells. Strobilurins are most effective when used in the early stages of infection, as they inhibit conidial germination, initial mycelial growth and prevent spore formation [175–176].

Table 3.44

Microorganisms and counter-pathogens used in the world practice against major diseases of cruciferous plants (for the period 1965–2022) [175–179]

Biological control agent	**Sclerotoniosis**	**Phomosis**	**Vericillium wilt**	**Alternaria**	**Clubroot**	**Peronosporosis**	**White spotting**
Bacillus subtilis	+	+		+	+	+	+
Azotobacter	+	+		+		+	
Coniothyrium minitans	+	+					
Trichoderma asperellum	+	+		+		+	
Paecilomyces lilacinus	+	+					
Pseudomonas fluorescens	+	+	+				
Serratia plymuthica	+	+	+				
Trichoderma harzianum	+	+					
Trichoderma sp.	+	+					
Bacillus cereus	+	+					
Bacillus megaterium	+	+					
Gliocladium catenulatum					+		
Leptosphaeria biglobosa	+	+					
Paenibacillus polymyxa			+				
Stenotrophomas maltophilia			+				
Talaromyces falvus	+	+					
Trichoderma viride	+	+					

Compounds from the triazole class (tebuconazole), penetrating into the fungal cell, inhibit the synthesis of ergosterol, a compound necessary for the fungus to exist [177–178]. Ergosterol, the main sterol of many fungi, is essential for the formation and functioning of biomembranes, cell division, growth and reproduction [179].

Attention should also be paid to preventive measures for disease control in cruciferous crops. Preventive measures to protect spring and winter cruciferous crops from diseases include, first of all, compliance with scientifically sound crop rotation with return to the previous place of cultivation not earlier than in 3–4 years. In particular, it is noted that the main cause of plant diseases is improper crop rotation. For example, it is better to sow rape after legumes, early potatoes, and annual grasses. Undesirable predecessors are radish, mustard, and cabbage.

Notes [180], that all sown areas in Ukraine cover 32 million hectares. Scientifically based crop rotations suggest that 10% of the area, or 3 million hectares, should be allocated to rapeseed. Together, sunflower and rapeseed account for a fifth of the sown area. That is, almost twice as much land is planted to these "heavy" industrial crops as is allowed by crop rotation standards. The author of the study also notes that there is a negative aspect to growing the crop: the likelihood of competition between bioenergy crops, including rapeseed, and consumer plants. After all, growing rapeseed for many years in one place (without change) leads to a violation of biological balance and soil degradation. The lack of appropriate cultivation technologies for this crop provokes the undesirable consequences.

Cruciferous crops are of great agrotechnological and agrobiological importance in crop rotation. For example, winter rape is able to penetrate deeply (more than 2 m) into the lower soil layers with its root system, ensuring the supply of autumn and winter moisture, its retention and improving soil aeration. Rapeseed has a highly developed taproot, which reaches a diameter of 1–3 cm in the upper part, but is very sensitive to soil compaction in the tilth and subsoil layers. Strong lateral roots extend from the central taproot. The development of fine roots and root hairs is weak, which explains the slow absorption of nutrients and their significant use, with the exception of phosphorus. Provided that the crops are well cared for, it cleans the field of weeds, improves the agrophysical properties of the soil, and releases the field early. Ploughing green mass has a positive effect on the content of organic matter, nitrogen, phosphorus, potassium, and trace elements in the soil, and prevents the development of root rot, which causes great damage to grain crops, especially wheat. Rapeseed is a good precursor for winter wheat and for summer sowing of perennial grasses, including alfalfa and post-harvest buckwheat. Rapeseed should not be returned to its original place in the crop rotation until 4–5 years later. Under the current structure of sown areas, winter rape is sown after winter cereals. For winter rapeseed, it is most advisable to create specialised rapeseed-grain crop rotations with maximum saturation with these crops. This improves the phytosanitary condition of the soil, the phytosanitary condition of subsequent grain crops, and reduces the damage to these crops by root rot, various leaf and stem spots by 15–20%, as its root residues have a detrimental effect on pathogens in the soil. Due to the content of sulphur compounds (glucosinolates) in the plant, rapeseed has a fumigant effect when decomposed in the soil, disinfecting the soil for subsequent crops. It significantly improves the soil structure and loosens it, as almost 90% of the roots are concentrated in the topsoil at a depth of 20 cm. The increase in grain yields after winter rape reaches 3-6 centner/ha without additional costs for the purchase and application of fertilisers. The biological activity of the soil increases by 10–15%, nutrient losses with infiltration water under the leaching regime of the soil are reduced by 50%, disease damage to wheat sown on a layer of perennial grasses is reduced by 30–50%, and grain yields increase by 5–10 centner/ha.

In the research of the same author [181], it is noted that the return of winter rape and other cabbage crops in the crop rotation to their previous place no earlier than 4–6 years later significantly improves the phytosanitary condition of the soil. Scientifically based inclusion of rapeseed in crop rotation is essential for high and sustainable yields and economically viable production. Therefore, the maximum permissible saturation of the crop rotation with rapeseed and the necessary pause during its cultivation and the choice of a predecessor are also essential. According to D. Shpaar, the possible concentration of rapeseed crops in the crop rotation is 20–25% of arable land, but with a mandatory three- to four-year break. Studies have shown that a one-year pause in rapeseed cultivation can reduce yields by up to 60%. When rape is planted after rapeseed, the seed yield is reduced by 25% compared to the yield in the crop rotation. If sugar beet is grown in the crop rotation, the time gap between rapeseed crops increases to 5–6 years.

In practice, one field should be occupied by four- and five-field crop rotations. The introduction of such crop rotations has a positive effect on the productivity of other crops.

The predecessor of winter rape should be a crop that is harvested early so that tillage and sowing can be carried out in time. The best predecessors of winter rape are annual grasses, early harvested cereals and legumes, perennial grasses after the first mowing, and early potatoes. Cereal grasses, cereals – wheat, rye, triticale – are considered poor predecessors of rapeseed.

Spring rape is also an excellent predecessor in the crop rotation. Although the root system penetration is not as deep as that of winter rape, it covers the soil surface better than winter rape due to the high density of plants in the topsoil. After harvesting, the crop residues are much smaller and therefore better able to release nutrients that remain for the next crop in the rotation. Spring rape leaves behind looser soil, thus creating optimal conditions for minimal tillage for the next crop (an element of biologisation of agriculture). Its value as a predecessor is similar to that of winter rape. In a scientifically based crop rotation, the share of rape should not exceed 20–25% of the total area [182].

Mustard crops are placed after black or busy fallow, cereal grains and legumes. Mustard should not be sown after rapeseed, oilseed flax, beetroot, sunflower, millet and annual grasses, although mustard itself plays a positive role in crop rotation. It can be returned to the previous place of cultivation only after 4–5 years. Heavy, flooded and saline soils are unsuitable for sowing mustard.

Mustard requires high-quality soil cultivation, so its preparation is aimed at accumulating moisture, accelerating the decomposition of plant residues, destroying pathogens and weeds, and creating a levelled moist soil layer at the depth of seed placement. Pre-sowing tillage, which is carried out when the soil is physically ripe, also plays an important role. If for some reason the soil was not levelled in the autumn, harrowing is required. To create an optimum seedbed, the field is cultivated to a depth of 4–5 cm across or at an angle to the ploughing. The unevenness of the cultivation depth should not exceed ± 1 cm. The best effect can be achieved by using combined tillage tools.

Thus, mustard is placed in the crop rotation after those crops that allow for good soil preparation, but the ideal predecessor is fallow. It is not recommended to grow it after cabbage crops and sunflower. It is an excellent predecessor for many crops. Mustard can be returned to its original place in the crop rotation after four years at the earliest.

In field crop rotations, spring ryegrass is best planted after cereals and row crops. It is a good predecessor for spring wheat.

Be sure to remember [181], that crop rotation modelling is one of the most important tasks in modern agriculture. It can both create difficulties for farmers and open up new opportunities for them, in particular in the effective preventive control of the prevalence of cruciferous crop diseases. The complexities and requirements for crop rotation in agriculture are constantly growing: due to their effective crop protection and economic pressure, crop rotations are dominated by particularly high-yielding and cost-effective crops. For example, due to increasing resistance to weeds and pests and the shrinking scope for chemical crop protection, short rotations are becoming obsolete. Expanding crop rotations to include new crops is not always economically feasible.

Extended crop rotation can contribute to solving these agricultural problems through its flexibility and diversity. Of course, economic aspects should also be taken into account in crop rotation modelling [182]:

– Maintaining soil and crops in a healthy state;
– promoting species and biodiversity;
– reducing vulnerability to pests and diseases;
– sustainable business success.

In addition to being as versatile as possible, attention is paid to crop rotations, in which crops that are not very compatible with each other are separated from each other for long periods of time. Crop rotation also needs to be adapted to the terrain and other operating conditions and must meet economic requirements. Positive effects can be achieved, for example, by alternating leafy vegetable and stem crops and by alternating spring and winter crops. This offers advantages in the control of common and cereal weeds. Different sowing dates can counteract the overproduction of certain species, as weeds also include species that germinate in autumn or spring. In addition, the weed control options in the context of crop protection can be expanded as a result.

It is noted that [183], that pathogens of fungal or animal origin that are favoured by short rotation crop rotation can be summarised under the term "crop rotation diseases". They occur in almost all types of crops. Important crop rotation diseases include, for example, blackleg in cereals, root and stem rot in rapeseed or sugar beet nematodes. The emergence of problematic weeds, such as foxtail, is favoured by short rotations. Controlling them is becoming increasingly difficult due to their increasing resistance to many active ingredients.

This resistance is built up over many years through the use of pesticides with similar mechanisms of action and is found in fungal, animal and plant pests. As crop-specific pathogens are more likely to occur in short rotations and are treated with the same range of active ingredients, the effects of crop protection product resistance are exacerbated. In addition, there are increasingly stringent regulations on the approval of new and prohibition of already approved plant protection products, which further restrict the change of active substance.

In accordance with the EU's Common Agricultural Policy, European farmers are already obliged to implement crop rotations on their farms. In addition to the mandatory approach, the economic and environmental benefits of a balanced crop rotation also play a role. Breaks in the cultivation of the same crop can significantly reduce common crop rotation diseases by interrupting pathogen infection cycles. This will help to save pesticide costs and, due to the less frequent use of the active ingredient, protect against the loss of product effectiveness.

In the case of cruciferous vegetables, yields can also be limited by infection with clubroot, a soil-borne pathogen that can survive for years thanks to its permanent spores. Verticillium blight is caused by fungal pathogens and leads to painful ripening. Only an integrated concept based on agricultural measures such as cultivating varieties (hybrids) that are well resistant to verticillium or varieties (hybrids) that are resistant to Eremonotus myriocarpus can help to control these pathogens in the long term. A break of at least 3 years is recommended when growing rapeseed. In addition, no other type of cruciferous plant should be introduced into the crop rotation.

A balanced rotation between stem and leaf crops is the basis of a good crop rotation, and the same crop should always be grown intermittently to break the cycles of infection by fungal and animal pathogens.

Growing resistant varieties such as oil radish and mustard in a rotation with beetroot can reduce the number of nematodes in the soil. Choosing the wrong green manure crop can also increase the impact of diseases. In the case of oilseed rape and beetroot, growing cruciferous crops as green manure promotes the spread of clubroot, so oil radish and mustard are not suitable as green manure crops. Farmers also have a need: the decision on what to grow should not only depend on the marginal income from the main crop, but should also take into account the benefits for the entire crop rotation when choosing crop types.

Cruciferous crop residues should also be taken into account (due to the reservation of pathogens common to all cruciferous species), in particular the well-known problem of the active and long period of germination capacity of cruciferous crop residues due to the reserve of seeds in the soil [182].

In all rapeseed growing zones, seeds that fall into the soil during harvesting can germinate in autumn and spring if moisture is available. Winter rapeseed residue overwinters very well in winter crops and resumes vegetation in spring. The sprouted cruciferous carrion is a reserve pathogen and contributes to the re-infection of cruciferous crops when they are returned to the same field with an interval of less than 3–4 years. Rapeseed fall is a serious problem, especially in broadleaf crops. Therefore, it is best to grow winter wheat or other cereals after rape. In cereal crops, rape residue is well destroyed by simple herbicides based on 2,4-D, dicamba, florasulam or mixed preparations containing these active ingredients. Crop rotation is therefore the most effective and cheapest method of controlling rape carrion. Rapeseed carrion plants that appear in other crops are weeds and cause the same damage as weeds.

When planning to control rapeseed carrion with herbicides, you must first clarify which hybrid was sown on the field – conventional or Clearfield (herbicide-resistant), and only then buy the product.

Rapeseed stubble can germinate even after several years. This phenomenon often occurs after ploughing, when the lower layers of soil containing rapeseed are exposed to the surface.

In any farming system, rapeseed from the previous season can germinate and compete for valuable resources such as water and nutrients with the main crop, as well as become a potential host for diseases and insects.

Preventing carrion from becoming a problem requires advance planning and the use of the right control methods.

To which herbicides can rapeseed resist?

Rapeseed varieties and hybrids with different resistance to herbicides are widespread in the world:

– Conventional rapeseed without herbicide resistance is available in Ukraine;
– IMI-resistant/Nopasaran/Clearfield/CL – available in Ukraine;
– Resistant to glyphosate/GT/RR (GMO);
– Resistant to triazine/TT (GMO);
– With double resistance to glyphosate and triazine (TT + RR);
– With double resistance to Clearfield and triazine (CL + TT).

In general, the choice of rape fall control method will depend on what crop will be grown after rape [182].

During desiccation, a special adhesive, Elastik, can be added to the tank mixture (0.8–1.0 l/ha) to reduce seed shedding during harvesting. The use of modern combines and specialised rapeseed harvesters (rapeseed table) helps to minimise seed losses. In this case, it may not be necessary to use herbicides to control the fallen crop.

The most effective method of controlling rapeseed fallow, in particular herbicide-resistant fallow, is to maintain crop rotation.

Rapeseed is a broadleaf crop, so it is best to sow cereals (grains) after it. In cereal crops, it is quite easy to destroy rapeseed carrion. If broad-leaved crops (rape, sunflower, soybeans, sugar beet, vegetables, flax, safflower, chickpeas, peas, etc.) are sown after rape, then it will be difficult and expensive to control the fallen crop. In addition, the accumulation of common diseases (e.g. sclerotinia) and pests can reduce the yield of the following crop. Therefore, to avoid unnecessary costs and yield losses, it is better not to sow broadleaf crops after rape.

When planning a crop rotation after Clearfield rape, you should also keep in mind the crop rotation restrictions.

In addition, effective methods of preventing and limiting the spread of pathogens in cruciferous crops include

– liming acidic soils;
– deep ploughing as part of the main tillage system;
– application of the calculated dose of phosphorus and potassium fertilisers and no more than 20% of the required nitrogen fertilisers for sowing;

– mandatory soil compaction before sowing;
– pre-sowing seed treatment.

It is also necessary to introduce the main approaches of crop residue management in cruciferous crop production technology. Rapeseed residues in particular are becoming a real incubator. After all, on crops that producers do not plan to treat with a cracking preventive agent, up to 30% of seeds can fall off per hectare (at a yield of 35 centner/ha, this amounts to almost a tonne of untreated infected seeds). On such a field, you can find a whole bunch of diseases that partially remain in the soil and partially spread to neighbouring fields. The situation is even worse with sclerotinia. This disease is insidious because of its extremely high damage (up to 50% of losses), the inability to remedy the situation when signs of disease have already appeared, and the extended spore life in the soil (six to eight years).

Thus, an effective integrated system for protecting cruciferous crops from diseases must combine several components:

– Crop rotation is the main preventive measure that improves the phytosanitary condition of crops and naturally regulates the dynamics of pests.
– Soil cultivation: stubble peeling and ploughing help to decompose crop residues, which contain pathogens; maintaining the optimal sowing depth, which promotes friendly germination.
– Fertilisation.
– Seed treatment.
– Sowing only zoned varieties and hybrids.
– Fungicide treatments.

The strategy of fungicide protection [183] should be based on preventive control, before the onset of disease symptoms. If, for various reasons, a preventive fungicide was not applied in time, it is necessary to use products that have a strong therapeutic effect. Thus, in terms of fungicide use, preventive fungicide treatments are possible and appropriate. In particular, the experience of using such treatments on winter rape is valuable. As a rule, in this case, a certain selected preparation is used 10–14 days before the projected date of the long-term development cycle of the relevant pathogen based on the already mentioned forecast of pests and diseases for a particular region. In many cases, this method requires constant monitoring of agrophytocenoses for signs of certain pathogens, as well as daily monitoring of plant condition and hydrothermal conditions for 5–7 days. For example, winter rape is affected by diseases throughout the growing season. Already in autumn, in the 2–6 leaf stage, powdery mildew, cylindrosporium, downy mildew, alternaria, and phomosis can occur. By the way, owners rarely pay attention to disease damage in autumn, mistakenly believing that autumn disease damage will not carry over to spring. However, spring phomosis is always a consequence of autumn infection. The first mature ascospores are formed on the remains of winter rape in autumn, and sporulation continues in spring. Ascospores are spread by air currents and, unlike conidia, can travel long distances. And during the period of vegetation recovery, the damage caused by certain diseases has often already become systemic and tissue-based, and subsequent fungicide application will be significantly less effective and efficient.

In the case of winter cruciferous crops, and in particular the most important representative of winter rape, the strategy for its protection against diseases is based on monitoring data and forecasts of their spread depending on the weather conditions prevailing during the autumn period.

Timely monitoring of winter rape crops is extremely important: autumn weed infestation, pest damage and disease infestation of young plants leads to a significant loss of the assimilation surface of plants, undesirable removal of the growth point above the soil surface, slower development of the root system, and reduced plant resistance to adverse environmental conditions, all of which significantly increases the risk of plant death and freezing in winter, and contributes to the damage to plants in spring by snow mould, root bacteriosis, blackleg, alternaria, downy mildew, phomosis, Fusarium and Verticillium wilt, white and grey rot and other diseases. These diseases are very dangerous for winter oilseed rape and require constant monitoring and plant protection.

The most effective protection of winter rapeseed against diseases will only be achieved if measures in the autumn period are aimed primarily at radically limiting or eliminating the source of infection, blocking or slowing down the spread of infection during the early vegetation period, increasing plant resistance to infectious diseases and adverse weather factors.

In order to obtain objective data on the phytosanitary condition of winter rape seedlings in terms of disease spread, it is necessary to clearly distinguish between the diagnostic signs of each disease. It is from this point of view that the previous sections of the monograph will be useful here.

The expediency of chemical protection of winter oilseed rape crops in autumn against diseases and the timing of crop treatment is usually associated with the phenological phases of plant development that are most favourable for infection by their pathogens. Two criteria should be taken into account when dealing with rapeseed diseases: the spread of the disease, the degree of plant damage and the short-term forecast of each disease.

The product is selected based on the species composition of pathogens. At early sowing dates, when there is a risk of overgrowth of plants and a consequent decrease in their winter hardiness, fungicides based on active ingredients with retardant properties are preferred (metconazole; tebuconazole and its mixtures with other active ingredients, mixtures of difenoconazole and paclobutrazole; protioconazole and fluopyram). These products not only effectively inhibit the spread and development of Alternaria, phomosis and other plant diseases, but also inhibit leaf growth and increase plant resistance to extreme weather conditions. They are primarily used on early winter rape crops, thickened crops, in the presence of carrion in crops, and when excessive doses of nitrogen fertilisers are applied, when there is a risk of overgrowth and reduced winter hardiness.

To increase the technical effectiveness of fungicides, one of the plant growth regulators is added to the working suspensions or emulsions, which promote strong plant development, formation of a larger photosynthetic surface, and thickening of the root system. Usually, plants treated with one of these regulators have a healthy appearance, with rosette leaves of dark green colour.

It is important to control pests of cruciferous crops in parallel with planning the use of fungicides. Therefore, it is important to plan for the combined use of insecticides with fungicide treatments, as most cryptic bugs, cruciferous fleas, rapeseed borer, weevils and leaf-eating pests are highly active at the beginning of the growing season, and control of these pests prevents mechanical damage to rapeseed tissues. These mechanical damages are responsible for 90% of fungal infections in rapeseed plants.

It is also important to assess the degree of infection with cruciferous disease in previous years, as the most dangerous pathogens can persist in the soil for up to 7–10 years. If rapeseed is returned to its original place in the crop rotation after 3–4 years (typical for Ukraine), the disease is provoked. It can be provoked by cracks caused by spring frosts – when there is intensive regrowth and a sharp drop in temperature at night – the parenchymal tissue cracks and infection passes through the cracks.

With regard to crop rotation, it should be borne in mind that crop rotation is the main preventive and necessary agronomic measure. Crop rotation allows you to regulate the number of potential, mostly specialised pests and significantly limit their development. Rapeseed should be returned to the same place no earlier than in 4–5 years. According to I.P. Markov, high and stable yields of winter and spring rapeseed are obtained by introducing specialised rapeseed crop rotations with maximum saturation with grain crops, where the share of rapeseed is up to 20–25%. At the same time, the best predecessors of cruciferous crops are black and fallow land, legumes, cereal crops, potatoes, corn, annual and perennial grasses. The spatial isolation of this year's cruciferous crops from last year's crops also limits the spread of aerogenous infection by pathogens. It is also important to increase the resistance of plants to pathogens by optimising their nutrition. In this regard, the use of a mixture of humates and trace elements (boron, magnesium, manganese) is extremely effective, especially in early spring foliar feeding, as it provides an additional incentive for plants to grow more rapidly, form generative organs, and stimulate chloroplast activity, while humic and fulvic acids act as antistressants after nighttime temperature drops and after herbicide treatments. The actual system of fungicide application and their possible combination in the form of tank mixtures should also be properly planned. They allow to increase the economic efficiency of measures, improve labour productivity, minimise the pesticide load on the soil by reducing the consumption rates of each product and reduce the number of treatments and, accordingly, mechanical damage to crops. The preparation of a tank mix is not a mechanical mixing of randomly selected components. This is a field of complex organic chemistry combined with the requirements of agronomic science.

Tank mixtures are divided into groups according to their purpose:

Mixtures of single-functional products (herbicide + herbicide), but with different mechanisms of action. Multifunctional preparations for the simultaneous destruction of various harmful objects (herbicide + insecticide, fungicide + retardant). Mixtures of mineral fertilisers with pesticides. Mixtures of fungicides, micronutrient fertilisers and retardants for seed treatment, etc. When planning tank mixtures, the stage of crop development should be taken into account. The timing of application of all components of the tank mix should coincide. It is also necessary to ensure that the crop is not stressed at the time of treatment. Only compatible products should be used for the preparation of tank mixtures. Incompatible are those pesticides that, when mixed, change physical properties, have a phytotoxic effect on the crop or reduce the effectiveness against harmful objects. And one more note, for winter cruciferous crops, in terms of disease control, first of all, it is necessary to pay attention to those crops that were overgrown when they came in for wintering. As such plants are most often affected by a complex of pathogens of root rot, phomosis, typhoid and other pathogens. At the same time, it should be remembered that protection against diseases and pests is only one of the levers for obtaining a high quality rapeseed crop – for this, all elements of technology must be followed. Therefore, if a producer's main goal is to get a consistently high crop yield, it is impossible to save on technology and neglect the timing of the necessary treatments with protection products and mineral fertilisers.

List of references for the Chapter 3

1. Dierks R., Heitefuss R. (1995) Integrierter Landbau. Aufl. DLG.Verlag Frankfurt Mail. 1995. 440 p.
2. Shpaar D. (1994) Plant resistance. *Protection and quarantine of plants*. № 6. P. 10–11.
3. Anon. Varietes of oilseed rape (1984) Farmers' leaflet. *National Institute of Agricultural Botany Cambridge.* 1984. № 9. P. 11–19.
4. Lacoste L. (1977) La necrose du collet du colza sous Faction de Phoma lingam (Tode) Desm. et de sa forme sexuee Leptosphaeria maculans (Desm.) *Ces. et de Not. Joumees Int. sur le colza.* P. 279–284.
5. Ansan-Melayan D., Rouxel T., Balesdent M.H. (1995) Tetrad analysis of Leptosphaeria maculans interaction with Brassica napus cultivars. Proc. *9th Intern. Rapeseed Congress.* Vol. 4. P. 1251–1253.
6. Thomas J.E., Wedgwood E.F. (1998) Potential for exploiting resistance to stem canker (Leptosphaeria maculans) in cultivars of winter oilseed rape. *IOBC/WPRS Bulletin.* Vol. 21. № 5. P. 91–95.
7. Busch H. (1991) Variety breeding for disease in double-low winter oilseed rape in Germany – situation and results. *IOBC/WPRS Bulletin.* Vol. 14. № 6. P. 212–218.
8. Jedryczka M., Lewartowska E., Frencel I., Drobnik M. (1994) Wykorzystani melody selekcji in vitro do otrzymania roslin rzepaku o zwiekszonej odpornosci na sucha zgnilizne kapustnych. II Prace Ogrodu. *Botanicznego PAN.* P. 369–373.
9. Bansal V.K.. Kharbanda P.D., Stringam G.R., Thiagarajah M.R., Tewari J.P. (1993) A comparison of greenhouse and field screening methods for blackleg resistance in doubled haploid lines of Brassica napus. *II Plant Disease-1993-V.* Vol. 78. P. 276–281.
10. Ballinger D.J., Salisbury P.A. (1995) Selection techniques for blackleg resistance in canola. Proc. 9th Intern. *Rapeseed Congress.* Vol. 4. P. 1260–1262.
11. Potter T.D., Salisbury P.A., Ballinger D.J., Wratten N., Mailer R.J. (1995) Comparison of historical varieties of rapeseed and canola in Australia. Proc. *9th Intern. Rapeseed Congress*. Vol. 1. P. 365–367.
12. Rakow G., Downey R.K. (1993) Profit summer rape. *Plant Science.* Vol. 73. № 1. P. 189–191.
13. Oelck M.M., MacDonald R., Belyk M. (1995) Registration, safety assessment and agronomic performance of transgenic cancia cv. "Innovator" in Canada. Proc. 9th Intern. Rapeseed Congress, United Kingdom. Vol. 4. P. 1430–1431.
14. Alabouvette C., Brunin B., Louvet J. (1974) Recherches sur la maladie du colza due a Leptosphaeria maculans (Desm.) Ces. Et de Not. 4 Pouvoir infectioux des pycnidiospores et sensibilite varietal. *Annales de Phytopathologie*. Vol. 6. P. 265–275.
15. Wittern I., Kriiger W. (1985) Sporenkeimung von Phoma' lingam (Tode ex FR.) Desm. und Resistenzprufung bei Raps in Gewachshaus. *Phytopathologische Zeitschrift*. Vol. 113. P 113–124.

16. Chevre A.M., Eber F., Thies P.L., Barret P., Brun H., Tanguy X., Renard M. (1995) Establishment of a chromosomic map and blackleg resistance analyses from Brassica napus – Brassica nigra addition and recombinant lines. Proc *9th Intern. Rapeseed Congress*. Vol. 4. P. 1217–1219.

17. Roy N.N. (1984) Interspecific transfer of Brassica juncea type high blackleg resistance to Brassica napus. *Euphytica*. Vol. 33. P. 295–303.

18. Plumper B., Sacristan M.D. (1995) Asymmetric somatic hybrids Sinapis alba (+) Brassica napus. Proc. *9th Intern. Rapeseed Congress*. Vol. 4. P. 1240–1242.

19. Grezes-Besset B., Grison R., Villeger M.J., Nicolas C., Toppan A. (1995) Field testing «against four fungal pathogens of transgenic Brassica napus plants constitutively expressing a chitinase gene. Proc. *9th Intern. Rapeseed Congress*. Vol. 3. P. 781–783.

20. Markov I.L. (1995) Optimisation of fungicide application on winter rape depending on variety resistance and intensity of disease development. Information *Bulletin of the All-Union Research Institute of Plant Protection*. Vol. 31. P. 130–131. (in Ukrainian)

21. Yanagida M., Sato K., Nasu H. (1976) On the new rape variety Tourada. Bull. *Aomori Field Crop Hort. Exp. St.* P. 63–72.

22. Markov I.L. (1998) Evaluation of winter and spring pinaka varieties for resistance to Alternaria. Scientific Bulletin of the National Academy of Sciences. *Protection of plants*. № 7. P. 17–23. (in Ukrainian)

23. Tripathi N.N.б Kaushik CD., Yadav T.P. (1980) Alternaria Leaf Spot resistance in raya. *Haryana Agricultural University journal of research.* Vol. 10. № 2. P. 166–168.

24. MacDonald M.V., Ingram D.S. (1986) Towards the selection in vitro for resistance to Alternaria brassicicola (Schw.) Wilts., in *Brassicae napus* ssp. Oleifera (Metzg.) Sinsk. Winter oilseed rape. *The New Phytologist.* Vol. 104. № 4. P. 621–629.

25. Lukas J.A., Crute I.R., Sheriff C., Gordon P.L. (1988) The identification of a gene for race specific resistance to Peronospora parasitica (downy mildew) in *Brassica napus* ssp. oleifera (oilseed rape). *Plant pathology.* Vol. 37. P. 538–545.

26. Nashaat N.L., Rawlinson C.J. (1994) The response of oilseed rape (Brassica napus ssp. oleifera) accessions with different glucosinolate and erucic acid contents to four isolates of Peronospora parasitica; (downy mildew) and the identification of new sources of resistance. *Plant pathology*. Vol. 43. P. 278–285.

27. Zhao Q. (2002) Untersuchung zur Anfalligkeit blutenblattloser rapslinier gegeniiber mit Hilfe von Serologischen Verfahren. Mitt. Biol. Bundesanst. Land – und Forstwirt. *Berlin – Dahlem.* № 390. P. 441.

28. Hu B.C., Chen F.X., Li Q.S., Li C. (1995) Stem rot (*Sclerotinia sclerotiorum*) tolerance and disease avoidance in CMS lines of *Brassica napus*. Proc. *9th Intern. Rapeseed Congress*. Vol. 2. P. 1211–1213.

29. Brun H., Tribodet M., Renard M., Plessis J., Tanguy X. (1987) A field study of rapeseed (*Brassica napus*) resistance to Sclerotinia sclerotiorum. Proc. *7th Intern. Rapeseed Congress.* Vol. 5. P. 1216–1221.

30. Mullins E., Quinlan C., Jones P. (1995) Studies of partial resistance to Sclerotinia sclerotiorum in oilseed rape. Proc. 9th *Intern. Rapeseed Congress*. United Kingdom. Vol. 4. P. 1280–1282.

31. Lewartowska M., Jedryczka I. (1994) Frencel II Rastenievedni nauki. T. 7. P. 252–254.

32. Crute I.R., Gray A.R., Crisp P. (1980) Variation in Plasmodiophora brassicae and resistance to clubroot disease in Brassicas and allied crops. *Plant Breeding.* Vol. 50. P. 91–104.

33. Sacristan M.D., Gerdemann-Knorck M., Shieder O. (1989) Incorporation of hydromicin resistance in *Brassica nigra* and its transfer to *B. napus* through asymmetric protoplast fusion. *Theoretical and Applied Genetics*. Vol. 78. P. 194–200.

34. Boyko M.I. (1988) Recommendations for the control of pests, diseases and weeds on spring rape crops. K. 30 p. (in Ukrainian)

35. Krostitz J. (1986) Bekampfung der Schleswig – Holstein. *Gesunde pflanzen. JG-38.* № 10. P. 482–485.

36. Rapeseed diseases: rare, but very accurate (2023). URL: https://superagronom.com/articles/129-hvorobi-ripaku-ridko-ale-duje-vluchno (date of application 25.03.2023). (in Ukrainian)

37. Steck U. (1990) Pflanzenschutz – Strategie im Raps. *RAPS.* Vol. 8. № 2. P. 60–63.

38. Robak J., Rod J. (1991) Integrated method of club root control in Brassicas. Kouf. «Integrovana Produkce Leleniny». *Olomouc.* Vol. 32. № 1. P. 24–26.

39. Vozenikova B. (1992) The influence of the peppermint (Mentha piperita Huds.) on healing the soils infected by clubroot (Plasmodiospora brassicae War.). *Ochr. rostlin.* Vol. 23. № 3. P. 237–238. (in Ukrainian)

40. Recommendations for growing rape for seed and feed (2015) / edited by M.I. Abramik. Ivano-Frankivsk-Obroshyno. 18 p. (in Ukrainian)

41. Semenenko A.V., Syadrista O.B. (2005) Under stable warming. Phytosanitary status and recommendations for the protection of major crops. *Quarantine and plant protection*. № 5. P. 1–7. (in Ukrainian)

42. Technology of rape cultivation and use (1996) / edited by T. Melnychuk. Ivano-Frankivsk. 35 p. (in Ukrainian)

43. Shpaar D., Makovsky N. (1995) Rape cultivation. Kyiv. 103 p.

44. DSV-Raps-Berater (2001). Krankheiten und Schadlinge. Lippstadt: Deutsche Saatveredelung. 36 p.

45. Sadowski Cz., Zielinski D., Klepin J., Zawislak K. (1995) The health status of winter rape cultivated for many years with monoculture and crop rotation. Proc. *9th Intern. Rapeseed Congress*. Vol. 4. P. 1231–1233.

46. Schnug E., Ceynova J. (1990) Phytopathological aspects of glucosinolates in oilseed гаре. *Journal of Agronomy and Crop Science*. Vol. 165. P. 319–328.

47. Zvara J. (1981) Vliy pH pudy na one mocnem vybranych drunu brukvovitych rostlin nadorovitosti (Plasmodiophora brassicae War.). Fysiol. a ekol. fytopatogen. hub. Mezinar. symp., Praha, 2-4 Cerv., 1981», Praha. P. 138–141.

48. Singh U.P., Singh K.P., Shahi D.K. (1991) Carpogeruc germination of Sclerotica sclerotiorum in Some Soil Samples differing in physico-chemical properties. Soil. Vol. 23. № 3. P. 241–243.

49. Penaud A., Le R. (1992) Phoma: pour mieux positionner les traitements. *Oleoscope*. № 11. P. 16–17.

50. Grigoriev E.V., Postovalov A.A. (2018) Reaction of spring rape to the treatment of crops with liquid mineral fertilizers. *Bulletin of the Upsala State Agricultural Academy*. Vol. 41. № 1. P. 60–63.

51. Spaar D. (1992) Integrated farming. Berlin: BOA Bibl. 90 c.

52. Savchuk Y.M. (2017) Limitation of development of winter rape diseases depending on sowing time and microfertilisers. *Bulletin of Agrarian Science. February.* P. 72–74. (in Ukrainian)

53. Sakhnenko V.V. (2018) Phytosanitary role of agricultural technology in integrated protection of winter rape against diseases. *Protection and quarantine of plants*. №. 8. P. 11–16. (in Ukrainian)

54. Rapeseed (1998) / Edited by V.D. Gaidash. Ivano-Frankivsk: Siversiya LTD. P. 14–15. (in Ukrainian)

55. Sekun M.P., Snizhok O.V. (2018) Improvement of technology of winter rape protection against pests in Western Polissya. *Protection and quarantine of plants.* Issue 64. P. 150–161. (in Ukrainian)

56. Sakhnenko V.V. (2020) Phytosanitary role of agricultural technology in integrated protection of winter rape against diseases. *Protection and quarantine of plants*. № 7. P. 10–18. (in Ukrainian)

57. Morozov O.M. (1992) Cytological aspects of the relationship between plants and phytopathogenic fungi. *Mycology and Phytopathology*. Issue 26. No. 1. P. 67–75. (in Ukrainian)

58. Savchuk S., Fernando W.G.D., Parks P.S. (2001) Potential for biocontrol of Sclerotinia sclerotiorum on Canola. *Canadian Journal of Plant Pathology*. Vol. 23. № 2. P. 192–193. (in Ukrainian)

59. McQuilken M.P., Mitchell S.J., Fenlon J.S., Archer S.A. (1995) Effects of Caniothynum minitans on Sclerotial Survival and apothecial production of Sclerotinia sclerotiorum in field – grown oilseed rape. *Plant pathology*. Vol. 44. № 5. P. 883–896.

60. Dandurand L.-M., Pvachel D.M., Knudsen R.G. (2000) Combined effects of Brassica napus seed meal and Trichoderma harzianum on two soil borne plant pathogens. *Canadian Journal of Microbiology.* Vol. 46. № 11. P. 1051–1057.

61. Zrobok O.M., Bobrus S.V. (2010) Efficiency of fungicides application in the protection of spring rape from pathogens in Polissya. *Agribiology.* T. 69. Issue 2. P. 75–79. (in Ukrainian)

62. Petsold S. (2007) Protection of rapeseed from diseases and pests. *Proposal.* № 3 (141). P. 98–99. (in Ukrainian)

63. Vyshnivskyi P.S.B. Remez G.G. (2005) General features of spring rape cultivation. *Agronomist*. № 1. P. 77–79. (in Ukrainian)

64. Gauet O. (2006) Spring rape – key elements of high yields. *Proposal*. № 2. P. 54–55.

65. Svydyniuk I.M. (2005) System of protection of spring rape under intensification. *Agronomist.* № 1. P. 80–81. (in Ukrainian)

66. Shchokin V. (2006) Ways to intensify rapeseed cultivation. *Proposal.* № 4. P. 42–45. (in Ukrainian)
67. Afanasiev O.I. (1990) Workshop on chemical plant protection. K. 147 p. (in Ukrainian)
68. Ciferri R., Baldacci E., Barbensi G., Gavalli L. (1943) Judagini tossicomaetriche Jugli anticrittogamici Atti dell'Istituto. *Botanico dell'Università di Pavia*. Ser. 5. Vol. 1. P. 85.
69. McQuilken M.P. (1995) Effects of Caniothyrium minitans on Sclerotial Survival and apothecial production of Sclerotinia sclerotiorum in field – grown oilseed rape Z M.P. *Plant pathology.* Vol. 44. № 5. P. 883–896.
70. Maude R.B., Humperson-Jones F.M. (1980) Studies of the seed-bome phases of dark leaf spot (Alternaria brassicicola) and grey leaf spot (Alternaria brassicae) of brassicae. *Annals of Applied Biology.* Vol. 95. P. 311–339.
71. Vaysse C., Marmion R., Eagles D. (1990) Programme de protection du colza avee les. *Defense vegetation*. Vol. 44. № 262. P. 28–32.
72. Kaspers H.R., Siebert R. (1989) Folicur (Tebuconazole) – ensatzmoglichkeiten gegen rapsk rankheiten. *Pflanzenschutz.* Vol. 42. № 2/3. P. 131–148.
73. Bolton B.J., Adam N.M. (1992) The use of tebuconazole for disease control and subsequent effects on lodging in oilseed rape. Brighton Crop. Prot. Conf.: Pests and Diseases. P. 675–680.
74. Maczynska A., Krzyzin'ska B., Drzewiecki S. (2001) Wptyw roznych terminow stosowania fungicydow nazdrowotnose tyszczyn rzepaku ozimego. *Post. ochr. rost*. Vol. 41. № 2. P. 638–642.
75. Leisse N., Haarhoff S. (1992) Wirtschaftliche Bedefung von Rapskrsnkheiten und ihre Kontrolle durch das Fungicid Markant. Mitt. Biol. Bundesanst., Land- und Forstwirt. Borlin-Dahlem. № 238. P. 422.
76. Pakdaman B.S., Komajanil S., Afshari H.A., Mohammadi E. (2002) In vitro studies on the possibility of integrated control of rape seed white stem rot disease through the application of prevalent herbicides and Trichoderma Species. Mitt. Biol. Bundesanst. Land – und Forstwirt. Berlin-Dahlem. № 390. P. 91.
77. Bowerman P., Brokenshire T., Prasanna K.P.R. (1993) Evolution of fungicides against Sclerotinia sclerotiorum. *Annals of Applied Biology*. Vol. 122, Suppl 10. P. 42–43.
78. Grzeskowiak A. (2003) System nawozenie "Police". A. Grzeskowiak Police :Agencja DCS. VII wydanie. 67 p.
79. Poradnik ochorony roslin (2020) BASF. Polska. 96 p.
80. Likhochvor V.V. (2008) Plant growing. Technologies of growing agricultural crops. Lviv: Ukrainian technologies. 800 p. (in Ukrainian)
81. Kosylovych G., Petrosiuk D. (2011) Efficiency of fungicides use for protection of winter rape against diseases. Proceedings of the *International Scientific Forum.* Lviv: LNAU. P. 108–112. (in Ukrainian)
82. Intensive technology of winter rape cultivation (2018). Kyiv: Min. AIC. 32 p. (in Ukrainian)
83. Kots S.Y., Peterson N.V. (2005) Mineral elements and fertilisers in plant nutrition. K.: Logos. 150 p. (in Ukrainian)

84. Kosylovych G.O., Venger I.E. (2015) Pesticide use in the system of winter rape protection against pests and diseases. *Bulletin of LNAU. Series: agronomy*. № 19. P. 154–161. (in Ukrainian)

85. Kosylovych G.O., Kohanets O.M., Yurkevych N.E. (2009) Efficiency of fungicides use for protection of rape against diseases. Proceedings of the *Interdisciplinary forum*. Lviv: LNAU. P. 127–130. (in Ukrainian)

86. Vaisov A.R. (2009) Influence of fungicides on the formation of winter rape yield. *Protection and quarantine of plants*. № 5. P. 21–23. (in Ukrainian)

87. Antonenko O.F. (2006) Diseases of winter and spring rape and measures to increase the resistance of varieties and hybrids: PhD thesis ... Doctor of Agricultural Sciences: 06.01.11 / Antonenko Oleksii Fedorovych ; National Agrarian University. K. 39 p. (in Ukrainian)

88. Antonenko A.F. (1984) Downy mildew of rape and measures to combat it in the forest-steppe of the Ukrainian SSR: Candidate of Agricultural Sciences: 06.01.11. Kyiv. 116 p. (in Ukrainian)

89. Antonenko O.F. (2011) Resistance of spring rape varieties (powdery mildew). *Quarantine and protection of plants*. № 5. P. 8–9. (in Ukrainian)

90. Diseases of rapeseed (2001). Plant protection. № 12. P. 14. (in Ukrainian)

91. Arista Life Sciences Ukraine (2012): winter rape protection system in autumn is a guarantee of successful wintering and high yields. *Proposal.* № 7. P. 72–75. (in Ukrainian)

92. Bondar T. (2005) Protecting spring rape with mycosone. *Grain and bread*. № 2. P. 47. (in Ukrainian)

93. Protection of spring rape seedlings (2007). *Agricultural Journal of Ukraine*. № 1. P. 32. (in Ukrainian)

94. Dovgan S.V. (2008) What threatens rapeseed crops. *Quarantine and protection of plants*. № 10. P. 3–6. (in Ukrainian)

95. Dukach V. (2008) Spring guard (rape, protective plants). *Agricultural Journal of Ukraine*. № 2. P. 52–56. (in Ukrainian)

96. Protection of winter rape in autumn (2007). *Agronomist*. № 3. P. 166–167. (in Ukrainian)

97. Antonov P.F. (2008) Protection of rapeseed. *Protection and quarantine of plants*. № 3. P. 69. (in Ukrainian)

98. Savchuk M.M. (2012) Protection of rapeseed. *Protection and quarantine of plants*. № 1. P. 53–84. (in Ukrainian)

99. Zubova T.I. (2005) Phytopathogenic and phytotoxic properties of species of the genus fusarium link:Fr. isolated from the root system of spring rape. *Scientific Bulletin of the National Agrarian University*. Issue 91. P. 105–113. (in Ukrainian)

100. Krupsky A. (2011) Winter rape: optimisation of nutrition and protection. *Proposal.* № 5. P. 89. (in Ukrainian)

101. Markov I. (2010) Forecast of rape diseases development. *Proposal*. № 5. P. 54–63. (in Ukrainian)

102. Markov I.L. (2012) Forecast of rape diseases development in 2012 and measures to limit their harmfulness. *Agronomist*. № 1. P. 104–111. (in Ukrainian)

103. Markov I.L., Polosenko V.E. (2007) The harmfulness of white rot on winter and spring rape. *Scientific Bulletin of the National Agrarian University.* Issue 116. P. 200–204. (in Ukrainian)

104. Melnychuk M.D. (2009) Comparative assessment of protection systems for winter rape and other crops by the consequences of environmental impact. *Scientific Bulletin of the National Agrarian University.* Issue 134. Part 1. P. 20–29. (in Ukrainian)

105. Mikhailenko S.V. (2009) Diseases of rapeseed. *Quarantine and plant protection*. № 5. P. 2–5. (in Ukrainian)

106. Muntian T.A. (2007) Diseases of rapeseed. *Agricultural Journal of Ukraine*. № 1. P. 29–31. (in Ukrainian)

107. Petrochenko D. (2008) Diseases of winter rape. *Grain.* № 8. P. 38–44. (in Ukrainian)

108. Serdiuk O.A. (2012) Comparative evaluation of the effectiveness of triazole group preparations against sclerotinia and phomosis on winter rape. *Protection and quarantine of plants*. № 5. P. 21–23. (in Ukrainian)

109. Tribel S.O. (2012) Rapeseed: problems of phytosanitation and improvement of the effectiveness of protective measures (protection against pests). *Seed production*. № 2. P. 6–15. (in Ukrainian)

110. Fokin A. (2009) Rape protection system (rape diseases). *Proposal*. № 2. P. 98–103. (in Ukrainian)

111. Schichert A. (2010) Rapeseed: early spring protection for a high yield! *Proposal*. № 2. P. 78–81. (in Ukrainian)

112. Poliakov O., Nikitenko O. (2018) Reliable care for rape after the restoration of vegetation. *Proposal*. № 5. P. 94–96. (in Ukrainian)

113. Markov I. (2018) Winter and spring rape: spread of diseases in 2018. *Proposal*. № 3. P. 132–139. (in Ukrainian)

114. Storchous I. (2017) Technology of rape cultivation according to the Clearfield system. *Proposal*. № 7–8 (Special Issue). P. 32–34. (in Ukrainian).

115. Yakovlev R. (2015) Protection of winter rape in the spring and summer growing season. *Proposal.* № 3. P. 90–94. (in Ukrainian)

116. Avramchuk A. (2022) Rapeseed diseases: rarely, but very accurately. URL: https://superagronom.com/articles/129-hvorobiripaku-ridko-ale-duje-vluchno (accessed 31.03.2023). (in Ukrainian)

117. Bondar T. (2017) Root rot of rapeseed. *The Ukrainian Farmer*. № 9. P. 100–102. (in Ukrainian)

118. Spring care of rapeseed without risks (2019). *Grain.* № 2. P. 100–101. (in Ukrainian)

119. Demydenko S. (2018) Features of preparation for harvesting winter rape. Reducing losses and improving quality. *Agronomist*. № 2. P. 88–92. (in Ukrainian)

120. Dolya M., Bondarieva L. (2014) Resource-saving technology of winter rape cultivation. *Proposal.* № 12. P. 64–67. (in Ukrainian)

121. Zozulia O., Malyna H. (2022) Technology of winter rape protection in spring. URL: https://www.syngenta.ua/news/ripak-ozimiy/tehnologiya-zahistu-ozimogo-ripaku-uvesnyaniy-period (accessed 31.03.2023). (in Ukrainian)

122. Kirichenko A., Grinchuk K., Antipov I. (2018) Viral diseases of rapeseed. *Proposal.* № 9. P. 138–140. (in Ukrainian)
123. Malyna G.V., Zozulia O.L. (2015) Protection of winter rape in the spring and summer period. *Agronomist*. № 1. P. 72–73. (in Ukrainian)
124. The main technological aspects of growing and protecting winter rape in autumn. (2022). URL: https://www.zerno-ua.com/ journals/2011/senty-abr-2011-god/osnovni-tehnologichniaspekti-viroshchuvannya-ta-zahistu-ozimo-go-ripaku-vosinniy-period (accessed 31.03.2023). (in Ukrainian)
125. Vlashchuk A., Zheltova A., Klopakova O., Dziuba M. (2017) Winter rape: how to preserve the harvest. *Proposal.* № 7–8 (Special issue). P. 41–44. (in Ukrainian)
126. Sergienko V. (2015) Application of fungicides in rapeseed crops. *Proposal.* № 9. P. 98–103. (in Ukrainian)
127. The system of optimal spring fertilisation and high-quality protection against diseases and pests on winter rape crops (2023). URL: https://arsenalagro.com.ua/sistema-optimalnogovesnyanogo-pidzh/ (accessed 31.03.2023). (in Ukrainian)
128. Diseases of winter rape and measures for their prevention. (2023). URL: https:// agroexp.com.ua/uk/bolezni-ozimogo-rapsa-i-mery-ihprofilaktiki (accessed 31.03.2023). (in Ukrainian)
129. Pests and diseases of rapeseed. (2023). URL: https://www.eridon.ua/ shkidniki-ta-hvorobi-ripaku (accessed 31.03.2023). (in Ukrainian)
130. Cherniaieva I.M. (2015) Faer is a unique fungicidal seed treatment for sunflower and rapeseed. *Agronomist.* № 4. P. 48–49. (in Ukrainian)
131. Shita O., Sergienko V. (2017) Fungicides and retardants on rape. *Proposal.* № 9. P. 116–118. (in Ukrainian)
132. Storchous I. (2018) Rapeseed: how to get rid of competitors. *Proposal.* № 9. P. 132–136. (in Ukrainian)
133. Storchous I. (2018) Noisy mixtures. Joint application of pesticides. *Grain*. № 6. P. 172–175. (in Ukrainian)
134. Poliakov O., Nikitenko O. (2018) Features of care for winter rape crops during wintering. *Proposal*. № 2. P. 82–83. (in Ukrainian)
135. Maryutin F.M. (2008) Phytopathology / F.M. Maryutin, V.K. Panteleev, M.O. Bilyk; edited by F.M. Maryutin. Kharkiv: Espada. 548 p.
136. Optimisation of integrated protection of field crops: a reference book (2006) / edited by V.V. Kirichenko, Y.G. Krasylovets. Kharkiv: Magda LTD. 252 p. (in Ukrainian)
137. Pysarenko V.M. (2002) Plant protection: ecologically sound systems / V.M. Pysarenko, P.V. Pysarenko. Edition 2, revised and supplemented. Poltava: InterGraphics. 353 p. (in Ukrainian)
138. Subin V.S. (2004) Integrated plant protection / V.S. Subin, V.I. Olefirenko. K. : Higher Education. 328 p. (in Ukrainian)
139. Antonenko O.F., Siminsky I.A., Manishevsky V.M. (2011) Resistance of spring rape varieties against downy mildew and phomosis. *Quarantine and protection of plants.* № 5. P. 8–9. (in Ukrainian)

140. Antonenko O.F., Manishevskyi V.M. (2014) Phomosis of spring rape and the influence of treatments on the development of the disease and crop productivity. *Quarantine and plant protection*. 2014. № 1. P. 5–6. (in Ukrainian)

141. Dankevych L.A., Votselko S.K., Zakharova O.M. (2013) Identification of bacterial pathogens of rapeseed by fatty acid composition of cell lipids. *Microbiological Journal.* № 4. P. 47–52. (in Ukrainian)

142. Luhovskyi K.P. (2010) Disease control in winter rape crops: effectiveness of Karamba fungicide application, in crops. *Quarantine and protection of plants*. № 1. P. 19–22. (in Ukrainian)

143. Antonenko O.F., Nychyporuk O.M., Panchenko Y.S., Havryliuk L.L. (2013) Resistance of winter rape varieties against root bacteriosis. *Quarantine and plant protection*. № 12. P. 5–6. (in Ukrainian)

144. Strotman K. (2013) Cruciferous clubroot is a dangerous disease of rape. *Agronomist*. № 3. P. 96–98. (in Ukrainian)

145. Vinnichuk T., Kovalenko O., Bolokhovska V. (2013) Biological products against diseases. *Proposal*. № 4. P. 92–93. (in Ukrainian)

146. Markov L.I. (2011) Integrated protection of cabbage from diseases. *House, garden, vegetable garden*. № 1. P. 8–10. (in Ukrainian)

147. Yushchenko L. (2013) Biological agents in plant protection. *Proposal*. № 1. P. 72–74. (in Ukrainian)

148. Markov I.L. (2013) Biological method of plant protection against diseases. *Agronomist.* № 3. P. 60–62. (in Ukrainian)

149. Diseases of rapeseed. Scales for determining the immunity of varieties to the most common diseases and their application in evaluation methods (2001). *Plant Protection*. № 12. P. 14. (in Ukrainian)

150. Abramik M.I., Korzhan S.I., Kiforuk I.M. (2004) Recommendations for the cultivation of winter rape. Ivano-Frankivsk. 14 p. (in Ukrainian)

151. Sytnyk I.D. (2002) Alternaria of rapeseed and methods of its assessment. *Plant Protection*. № 12. P. 8–9. (in Ukrainian)

152. Shpaar D. Rapeseed and rape. Cultivation, harvesting, storage and use. K.: Zerno. 2012. 368 p. (in Ukrainian)

153. Kuzmenko N.V., Krasylovets Y.G., Lytvynov A.E. (2012) Chemical protection of spring rape against pests and diseases. *Bulletin of Poltava State Agrarian Academy*. № 1. P. 25–29. (in Ukrainian)

154. Babayants O. (2016) Karamba Turbo on rapeseed – profit is in your hands. *Agronomist*. № 3. P. 366–368. (in Ukrainian)

155. Growth regulators in crop production (2007). Recommendations for use. SE Interdepartmental Scientific and Technological Centre "Agribiotech" of the National Academy of Sciences of Ukraine and the National Academy of Sciences of Ukraine. 27 p. (in Ukrainian)

156. Savenkov V.P. (2012) Efficiency of application of fungicides with growth-responsive action under spring rape. Materials of the International Scientific Conference. Kyiv. ASPT. P. 126–131. (in Ukrainian)

157. Babayants O. (2021) Alterno and Pictor – reliable protection of rapeseed for the sake of harvest. *Proposal*. № 4 (260). P. 1–4. (in Ukrainian)

158. Pinchuk N.V., Vergeles P.M., Kovalenko T.M. (2021) Efficiency of protection of winter rape crops from pests. *Agriculture and forestry.* № 3 (22). P. 119–134. (in Ukrainian)

159. Pinchuk N.V., Vergeles P.M., Kovalenko T.M., Okrushko S.E. (2019) General phytopathology. Vinnytsia: VNAU. 276 p. (in Ukrainian)

160. Kardash O. (2022) Efficiency of fungicide application in the agrocenosis of winter rape in the conditions of the farm "Havest", Chudniv district, Zhytomyr region. Deposited master's thesis in the repository of VNAU. 63 p. (in Ukrainian)

161. Sauermann V. (2013) Rape: from harvesting to the next sowing. *Agronomist.* № 2 (40). P. 98–101. (in Ukrainian)

162. Petrosiuk D. (2011) Use of fungicides for protection of winter rape from diseases. Proceedings of the interdisciplinary student forum. Lviv: LNAU. P. 41–42. (in Ukrainian)

163. Handbook on plant protection (1999) / edited by M.P. Lisovyi. K.: Urozhay. P. 270–276. (in Ukrainian)

164. Fungicide schemes for rapeseed. (2023). URL: https://superagronom.com/blog/917-gerbitsidniy-zahist-ozimogo-ripaku-v-klasichniy-sistemi-ta-clearfield. (in Ukrainian)

165. Khablak S. (2023) Fungicidal protection of rapeseed: disease harmfulness and application schemes. URL: https://superagronom.com/blog/918-fungitsidniy-zahist-ripaku-shkodochinnist-hvorob-ta-shemi-vnesennya. (in Ukrainian).

166. Sharma R.N., Mureliya S. (2022) Control of prevailing diseases in rapeseed-mustard. *The Pharma Innovation Journal*. SP-11. № 7. P. 43–46.

167. Prasad R A., Kumar D., Kumar V., Kumar M., Kumar D. (2017) Symptoms and management of white rust/blister of Indian mustard (Albugo candida). *International Journal of Current Microbiology and Applied Sciences*. Vol. 6. Is. 10. P. 1094–1100.

168. Basavaraj K., Rathi A.S., Gurav N.P., Punia R., Kumar A. (2020) Evaluation of selected fungicides for the management of white rust of Indian mustard. *Journal of Oilseeds Research*. Vol. 37. № 2. P. 99–103.

169. Singh N., Srivastava A.K., Narain U. (2006) Efficacy of fungicides against Alternaria blight of mustard. *International Journal of Plan Sciences*. Vol. 1. P. 311–312.

170. Kumar R.A., Rathi A.S. (2018) Management of Alternaria blight in Indian mustard through fungicides under field conditions. *International Journal of Chemical Studies*. Vol. 6. № 2. P. 2042–2044.

171. Bairwa S.K., Prasad D., Shekhawat U.S., Rai P.K., Ramswaroop K. (2015) Disease management in Indian mustard (Brassica juncea) through integrated approaches. *Annals of Agricultural Research New Series.* Vol. 36. P. 251–257.

172. Das R. (2016) Identification of resistant source against Alternaria blight disease of rapeseed-mustard. *Journal of Crop and Weed.* Vol. 12. № 2. P. 134–136.

173. Khangura R., Sokhi S.S. (2000) Efficacy of Ridomil MZ and protectant fungicides to control white rust (Albugo candida) and their effect on seed yield, oil content and fatty acid composition in mustard. *Animal Production Science.* Vol. 40. № 5. P. 699–706.

174. TOP-6 fungicides to protect rapeseed from diseases. (2023). URL: https://lnzweb.com/ua/blog/top-6-fungitsid-zahistu-ripaku (in Ukrainian)

175. Wallenhammar A.C., Vilvert E., Bergqvist S. (2022) Scientific evidence of sustainable plant disease protection strategies for oilseed rape (Brassica napus) in Sweden: a systematic map. *Environmental Evidence*. Vol. 11 e 22.

176. Strobilurins. Agroindustrial portal. (2023). URL: https://www.agroxxi.ua/stati/strobiluriny.htm (accessed 31.03.2023).

177. Tyutierev, S.L. (2010) Mechanisms of interaction of fungicides on phytopathogenic fungi. K: Niva. 172 p. (in Ukrainian)

178. Active substances of pesticides. Pesticides. (2023). URL: http://www.pesticidy.ua/group_substances/strobilurin (accessed 31.03.2023).

179. Tebucanazole. Plant and seed protection products. (2023). URL: http://s-ah.ua/protection-of-plants/fungicides/tebukonazol-60 (accessed 31.03.2023).

180. PPDB: PesticidePropertiesDataBase. Modeofaccess: (2023). URL: http://sitem.herts/ac/uk/aeru/ppdb/en/index.htm (accessed 31.03.2023).

181. Shuvar I. (2023) The value of rapeseed as a predecessor and its place in crop rotation. 2023. URL: http://agro-business.com.ua/agro/ahronomiia-sohodni/item/541-tsinnist-ripaku-iak-poperednyka-ta-ioho-mistse-v-sivozmini.html# (accessed 31.03.2023). (in Ukrainian)

182. Crop rotation in agriculture. (2023). URL: https://www.kws.com/ua/uk/agroservis/sivozmina/ (accessed 31.03.2023). (in Ukrainian)

183. Rapeseed fall and its control in other crops. (2023). URL: https://www.agronom.com.ua/padalytsya-ripaku-ta-yiyi-kontrol/ (accessed 31.03.2023).