The breeding of spring rapeseed and brown mustard for resistance to Fusarium blight

O A Serdyuk, V S Trubina, L A Gorlova

V.S. Pustovoit All-Russian Research Institute of Oil crops, 17, Filatova street, Krasnodar, 350038, Russia

E-mail: oserduk@mail.ru

Abstract. During the growth season, the plants of rapeseed (Brassica napus L.) and brown mustard (Brassica juncea L.) are affected by various diseases: Fusarium blight, Verticillium blight, Alternaria blight, and others. The cultivation of rapeseed and mustard varieties resistant to diseases is a cost-effective and environmentally safe way to protect plants from diseases. The aim of the work was to evaluate the new breeding material of spring rapeseed and brown mustard for resistance to Fusarium blight in the form of tracheomycotic wilting of plants to continue breeding work to develop varieties of these crops. In 2017-2020, we carried out a phytopathological evaluation of new breeding samples of rapeseed and brown mustard for resistance to Fusarium blight. As a result, we selected a valuable breeding material of spring rapeseed and brown mustard resistant to Fusarium blight infection, which also exceeds the standard by economic characters. The productivity of the best selected samples is higher than the varieties Tavrion and Nika by 0.13-0.59 and 0.18-0.28 t/ha, respectively, the oil content of seeds – by 0.2-2.0 and 1.2-2.1 %, respectively. These samples will be used as donors of Fusarium blight resistance in breeding work during development of new varieties of spring rapeseed and brown mustard in the central zone of Krasnodar region.

1. Introduction

Currently, spring rapeseed (Brassica napus L.) and brown mustard (Brassica juncea L.) are the main members of oil crops of the cabbage family (Brassicaceae) all over the world. Both winter and spring forms of these crop are of value. The seeds of rapeseed and mustard are used to produce edible oil, which has a unique biochemical composition and is a source of essential omega-3 and omega-6 fatty acids. The oil is also used as a biofuel. The seed meal of these crops, which contains a large amount of protein, is a feed source for farm animals. It is balanced in amino acid composition, contains a large amount of fat, available nitrogen and phosphorus [15]. Mustard seeds and cake are used in medicine and as a seasoning [6]. In addition, rapeseed and mustard are used as green manure crop that improve the physical properties of the soil and its fertility [7-10].

Spring rapeseed and brown mustard belong to oil crops and along with sunflower, soybean, oil flax, white mustard can be affected by the same diseases during the growth season: Fusarium blight, Verticillium blight, Alternaria blight, and others [11-14].

The research, carried out in the central zone of the Krasnodar region in recent years, shows that Fusarium blight in the form of tracheomycotic wilting of plants caused by fungi of the genus Fusarium is one of the most common and harmful diseases on spring rapeseed and brown mustard [15]. The pathogen infection occurs through the root system, which leads to blocking of the conducting vessels
in the stem, premature drying of rapeseed and mustard plants, and a decrease in the quantitative and qualitative indicators of seed yield. The most optimal conditions for the development of the disease are an average temperature of 25-27 °C and a small amount of precipitation during the growth season of crops (0.1-15 mm).

The cultivation of disease-resistant rapeseed and mustard varieties is a cost-effective and environmentally safe way to protect plants from diseases. The evaluation of the breeding material of crops for disease resistance is an important part of the breeding process because it allows searching for resistance donors to develop new varieties without yield losses and the necessity to use plant protection chemicals.

In 2013-2015, at V.S. Pustovoit All-Russian Research Institute of Oil Crops (VNIIMK), as a result of the phytopathological evaluation of the breeding material, we identified the samples of rapeseed and mustard, immune and resistant to the disease [15]. They were used in breeding work during intraspecific hybridization.

The aim of the work was to evaluate the new breeding material of spring rapeseed and brown mustard for resistance to Fusarium blight to continue breeding work to develop varieties of these crops.

2. Materials and methods

We carried out the research in 2017-2020 at V.S. Pustovoit All-Russian Research Institute of Oil Crops (Krasnodar). Each year, we evaluated the breeding material of rapeseed and mustard in the amount of 300 samples of each crop in the field against a natural infectious background, we carried out the recording at the stage of yellow-green pod, when the signs of plant affection by disease are manifested most intensively.

We used the spring rapeseed variety Tavrion and spring brown mustard variety Nika of the VNIIMK breeding as a standard for economic characters.

We determined the Fusarium blight prevalence by the commonly accepted formula (1):

\[
P = \frac{n}{N} \times 100 \%
\]

where \( P \) is the disease prevalence, %;
\( n \) is the number of affected plants in a sample, pcs;
\( N \) is the total number of counted plants in a sample, pcs.

We divided the disease prevalence into low, medium, and high:
- low – up to 10 % of plants on a plot are affected;
- medium – 11-50 % of plants on a plot are affected;
- high – 51 % and more plants on a plot are affected.

We determined the intensity of Fusarium blight affection of plants by the following scale:
0 points – healthy plant;
1 point – dry out, 1-2 branches change color to light yellow;
2 points – dry out, 3-4 branches change color to light yellow;
3 points – dry out, 5-7 branches change color to light yellow;
4 points – dry out, all branches and a stem change color to light yellow.

We calculated the Fusarium blight development according to the commonly used formula (2):

\[
f = \frac{\sum(a \times b)}{\sum(n \times k)} \times 100 \%
\]

where \( R \) is the disease development, %;
\( \Sigma(a \times b) \) is the sum of products of the number of affected plants (a) by the corresponding affection point (b);
\( N \) is the total number of the counted plants (healthy and affected) in a sample;
\( k \) is the highest affection point.

We divided the disease development into low, weak, average, and strong:
- low – up to 10 %;
We carried out the evaluation of rapeseed and mustard material for resistance to Fusarium blight using a 10-point scale according to the degree of a sample affection:

- 0 points – all plants are healthy;
- 1 point – up to 10 % of affected plants with a low disease development;
- 2 points – 11-20 % of affected plants with a low and weak disease development;
- 3 points – 21-30 % of affected plants with a low, weak, and average disease development;
- 4 points – 31-40 % of affected plants with a low and average disease development;
- 5 points – 41-50 % of affected plants with a low, average, and strong disease development;
- 6 points – 51-60 % of affected plants with an average and strong disease development;
- 7 points – 61-70 % of affected plants with an average and strong disease development;
- 8 points – 71-80 % of affected plants with a strong disease development;
- 9 points – 81-100 % of affected plants with a strong disease development.

Using the presented scale, we divided all breeding materials of rapeseed and mustard according to the resistance degree into the following groups [13]:

- 0 points – immune;
- 1-2 points – resistant;
- 3-4 points – weakly resistant;
- 5-6 points – weakly susceptible;
- 7-9 points – susceptible.

We carried out the phytoexamination of the affected parts of rapeseed and mustard plants in the laboratory conditions according to the established practice. We identified the pathogens using a Motic BA300 microscope, at 40x magnification.

We determined the oil content of rapeseed and mustard seeds on a Matrix-1 IR spectrometer.

### 3. Results and discussion

As a result of sowing surveys of the breeding samples of spring rapeseed and brown mustard in 2017-2020, we revealed the plants affection by the following diseases: Fusarium blight (the pathogens are *Fusarium spp.*), sclerotinia, or white rot (the pathogens are *Sclerotinia sclerotiorum* (Lib.) De Bary.), powdery mildew (the pathogen is *Erysiphe communis* Grev. *f. brassicae* Hammar L.), downy mildew (the pathogen is *Hyaloperonospora brassicae* (Gäum.) Göker, Voglmayr, Riethm., Weiss & Oberw.), Alternaria blight (the pathogens are *Alternaria spp.*). We determined that one of the most common diseases during the years of research was Fusarium blight in the form of tracheomycotic wilting of plants (Figure 1).

In laboratory conditions, we identified fungi *Fusarium oxysporum* Schlecht., emend. Synd. et Hans, *F. sporotrichiella* Bilai and other species of the genus *Fusarium*. from the parts of rapeseed and mustard plants affected by Fusarium blight.

During field observations, we noted that the brown mustard plants undergo phenological stages 3-4 days earlier than the rapeseed plants. The beginning of flowering is a vulnerable stage for the penetration of the infectious matter of fungi of the genus *Fusarium* into the root system of rapeseed and mustard plants.

The prevalence and development of Fusarium blight in the form of tracheomycotic wilting in breeding nurseries of rapeseed and mustard over the years of research largely depended on the weather conditions prevailing during the growth season of crops: environment temperature and the amount of precipitation. We also observed a difference in the Fusarium blight affection of breeding samples between rapeseed and mustard (Table 1).
Figure 1. Tracheomycotic wilting of plants of spring rapeseed (a) and brown mustard (b) due to the affection of plants by fungi of the genus *Fusarium* spp.

Table 1. The prevalence (P, %) and development (R, %) of *Fusarium* blight on the breeding samples of spring rapeseed and brown mustard, V.S. Pustovoit All-Russian Research Institute of Oil Crops, 2017-2020.

| Year | Rapeseed | Brown mustard |
|------|----------|---------------|
|      | P, %     | R, %          | P, %    | R, % |
| 2017 | 4.0-48.0 | 2.5-29.0      | 0.5-11.0| 0.2-9.0 |
| 2018 | 1.0-10.0 | 1.0-7.0       | 4.0-40.0| 2.0-28.0|
| 2019 | 1.0-6.0  | 0.3-6.0       | 3.0-10.0| 1.0-10.0|
| 2020 | 15.0-55.0| 5.0-24.0      | 5.0-42.0| 2.0-22.0|

During the growth season of both crops in 2017, the average temperature was 11.1-23.6 °C, precipitation was even and amounted to 11.9-304 mm over ten-day periods, which is sufficient for the process of infection of rapeseed and mustard plants through the root system and development of pathogens of *Fusarium* blight. However, during the beginning of flowering of mustard (the last ten days of May), there were developed unfavorable conditions for the pathogens of *Fusarium* blight; during this period, there was an abundant amount of precipitation (62.1 mm). The infection of rapeseed plants with pathogens occurred in the first ten days of June (the beginning of flowering) with a combination of a favorable average temperature (22.1 °C) and a small amount of precipitation (12.2 mm). The prevalence of *Fusarium* blight on rapeseed was 4.0-48.0 % against 0.5-11.0 % on rapeseed, the disease development was 2.5-29.0 and 0.2-9.0 %, respectively.

In 2018, for the entire growth season of rapeseed and mustard, the amount of precipitation over ten-day periods was small (3.0-13.0 mm), which is favorable for the vital activity of *Fusarium* blight pathogens. However, until the end of May, the average temperature was lower than necessary for the optimal development of pathogens (12.4-19.1 °C), which suppressed the prevalence and development
of the disease (1.0-10.0 %). Fusarium blight infection rates are higher on mustard than on rapeseed since there was a joint infection of mustard plants with bacteriosis, which weakened them.

In 2019, the prevalence and development of Fusarium blight on rapeseed and mustard were low and did not exceed 10.0 % due to the unfavorable weather conditions for the development of pathogens: precipitation was even (4.0-31.0 mm), except for the first and last days of May and the second ten days of June, when the amount of precipitation was low (0-5.0 mm). The average temperature reached the optimal level only in the first days of June (23.8 °C).

Weather conditions in 2020 were characterized by uneven precipitation, which did not exceed 28 mm during the growth season of rapeseed and mustard, which is lower than the long-term annual average data. Only in the last ten days of May the amount of precipitation exceeded the long-term annual average data by 3 times (61 mm), and in the first ten days of June, the amount of precipitation decreased by more than 3 times compared to the last ten days of May. The average temperature at that time increased sharply (by 4.7 °C), amounting to 21.0 °C, which created a stressful situation for rapeseed and mustard plants. At the same time, the weather conditions of the first ten days of June were favorable for the vital activity of Fusarium blight pathogens. The combination of these factors led to the rapid and intense affection of both crops by the disease. The prevalence of Fusarium blight on rapeseed samples was from average to strong (15.0-55.0 %), on mustard samples – from low to average (5.0-42.0 %). The disease development on both crops also had a wide range (from low to average) and ranged from 2.0 to 24 %.

We carried out the evaluation of breeding material for resistance to Fusarium blight in years with a high natural infectious background: rapeseed – in 2017 and 2020, mustard – in 2018 and 2020.

We found that the infestation of rapeseed and mustard with Fusarium blight also depended on the susceptibility of plants. In all the years of research, we did not identify samples of rapeseed and mustard immune to Fusarium blight (Table 2).

### Table 2. The resistance of breeding samples of spring rapeseed and brown mustard to Fusarium blight, V.S. Pustovoit All-Russian Research Institute of Oil Crops.

| Year | The number of samples, % |
|------|--------------------------|
|      | immune | resistant | weakly resistant | weakly susceptible | susceptible |
| 2017 | 0      | 34        | 28               | 38                  | 0         |
| 2020 | 0      | 23        | 46               | 31                  | 0         |
| 2018 | 0      | 39        | 56               | 5                   | 0         |
| 2020 | 0      | 15        | 85               | 0                   | 0         |

We divided the breeding samples of rapeseed according to the affection degree by Fusarium blight in 2017 into resistant (1-2 points), weakly resistant with the affection degree of 3-4 points, and weakly susceptible (5-6 points). The number of disease-resistant rapeseed samples was 34 %. In 2020, the number of such rapeseed samples dropped to 23 %. Most of the samples under the year conditions were weakly resistant with the affection degree of 3-4 points (46 %). The remaining 31 % of rapeseed samples were weakly susceptible with the affection degree of 5-6 points.

In 2018, the number of Fusarium blight-resistant samples of brown mustard was 38 %. The most samples (56 % of the total number) were weakly resistant, and 5 % were weakly susceptible with the affection degree of 5-6 points. In 2020, the number of disease-resistant mustard samples decreased compared to 2018 and amounted to 15 %. The rest of the samples were weakly resistant under the year conditions.

As a result of the analysis of the productive qualities of seeds of rapeseed and mustard samples resistant to Fusarium blight, we established that some of them exceed the standard in terms of productivity and oil content of seeds in both years of phytopathological evaluation (Table 3). We did
not carry out the comparison with the standard in terms of the affection degree of plants by Fusarium blight since the standard variety for economic characters is not a standard for phytopathological evaluation.

### Table 3. The characteristics of the best breeding samples of spring rapeseed and brown mustard resistant to Fusarium blight, V.S. Pustovoit All-Russian Research Institute of Oil Crops.

| No.     | The prevalence of Fusarium blight, % | The development of Fusarium blight, % | Seed productivity t/ha ± to the standard | Oil content of seeds % ± to the standard |
|---------|--------------------------------------|--------------------------------------|------------------------------------------|------------------------------------------|
|         |                                      |                                      |                                          |                                          |
| Spring rapeseed (2017 and 2020)                      |                                      |                                      |                                          |                                          |
| 564/17  | 5.0                                  | 3.0                                  | 2.33 ± 0.13                             | 45.2 ± 0.4                              |
| 567/17  | 7.5                                  | 5.5                                  | 2.37 ± 0.17                             | 46.8 ± 2.0                              |
| 572/17  | 5.0                                  | 2.5                                  | 2.79 ± 0.59                             | 45.0 ± 0.2                              |
| Tavrion (standard)                                  |                                      |                                      |                                          |                                          |
| 495/18  | 9.0                                  | 6.0                                  | 2.00 ± 0.18                             | 48.8 ± 2.1                              |
| 498/18  | 10.0                                 | 7.5                                  | 2.08 ± 0.26                             | 48.6 ± 1.9                              |
| 506/18  | 5.5                                  | 3.0                                  | 2.10 ± 0.28                             | 47.9 ± 1.2                              |
| Nika (standard)                                     |                                      |                                      |                                          |                                          |
| Brown mustard (2018 and 2020)                       |                                      |                                      |                                          |                                          |
| 495/18  | 9.0                                  | 6.0                                  | 2.00 ± 0.18                             | 48.8 ± 2.1                              |
| 498/18  | 10.0                                 | 7.5                                  | 2.08 ± 0.26                             | 48.6 ± 1.9                              |
| 506/18  | 5.5                                  | 3.0                                  | 2.10 ± 0.28                             | 47.9 ± 1.2                              |
| Nika    | -                                    | -                                    | 1.82 -                                  | 46.7 -                                  |

The productivity of the best samples of spring rapeseed exceeded the standard variety Tavrion by 0.13-0.59 t/ha and amounted to 2.80-3.26 t/ha, the oil content – by 0.2-2.0 % and amounted to 46.8-48.6 %.

The productivity of the best samples of brown mustard exceeded the standard variety Nika by 0.18-0.28 t/ha, amounting to 2.00-2.10 t/ha; the oil content – by 1.2-2.1 %, amounting to 47.9-48.8 %.

The best identified samples will be used in the breeding process to develop new high-yielding, with high oil content and Fusarium blight-resistant varieties of spring rapeseed and brown mustard.

### 4. Conclusion

We selected a valuable breeding material of spring rapeseed and brown mustard, resistant to Fusarium blight affection, which also exceeds the standard by economic characters. The productivity of the best selected samples is higher than the varieties Tavrion and Nika by 0.13-0.59 and 0.18-0.28 t/ha, respectively, the oil content – by 0.2-2.0 and 1.2-2.1 %, respectively. These samples will be used as donors of resistance to Fusarium blight in breeding work during the development of new varieties of spring rapeseed and brown mustard in the central zone of the Krasnodar region.

### References

[1] Woźniak E, Waszkowska E, Zimny T, Sowa S and Twardowski T 2019 *Front Plant Sci.* **10** 1-423
[2] Rahman M, Khatun A, Liu L and Barkla B J 2018 *Molecules* **23**(1) 231
[3] Chen J, Bian X, Rapp G, Lang J, Montoya A, Trethewan R, Bouyssiere B, Portha J F, Jaubert J N, Pratt P and Coniglio L 2019 *Industrial Crops and Products* **137** 597–614
[4] Das K, Bhattacharya M and Ghosh M 2020 *Pharma Nutrition* **14** 100224
[5] Ravi S, Karthikeyan A, Kumar R N and Balaji E 2020 Augmentation of performance and Emission distinctiveness of heavy duty constant pressure combustion engine supplemented through n-butanol-mustard oil-diesel composition *Materials today: PROCEEDINGS*. Available online 27 November
[6] Szöllősi R 2020 *Nuts and Seeds in Health and Disease Prevention (Second Edition)* pp 357–364
[7] Fontana M, Bragazza L, Guillaume T, Santonja M, Buttlar A, Elfouki S and Sinaj S 2021 J. of Environmental Management 285 112061
[8] Zhao B, Xu R, Fengfeng Ma F, Li Y and Lu Wang L 2016 J. of Environmental Management 184(3) 569–574
[9] Yang Z, Xu M, Zheng S, Nie J, Gao J, Liao Y and Xie J 2012 J. of Integrative Agriculture 11(4) 655–664
[10] Friberg H, Edel-Hermann V, Faivre C, Gautheron N, Léon Fayolle L, Faloya V, Montfort F and Steinberg C 2009 Soil Biology and Biochemistry 41(10) 2075–2084
[11] Escamilla D, Rosso M L and Zhang B 2019 Food Sci. & Nutrition 7(10) 3194–3205
[12] Molinero-Ruiz L 2019 Sunflower and climate change / Tournesol et changement climatique 26 2
[13] Serdyuk O A, Trubina V S and Gorlova L A 2020 BIO Web Conf. 21 00031
[14] Dixit S, Jangid V K and Grover A 2020 Plant Physiology and Biochemistry 155 626-636
[15] Serdyuk O A, Shipitsevskaya E Yu, Trubina V S and Gorlova L A 2017 The innovative research and development for scientific support of production and storage of ecologically safe agricultural and food products: collection of materials of the II International scientific-practical conference (Krasnodar) pp 180–183