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Estimation of adaptability of the maternal lines of the winter rapeseed hybrids bred at the V.S. Pustovoit All-Russian Research Institute of oil crops in the central zone of the krasnodar region, Russia

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ABSTRACT

In 2018-2020, the maternal lines of winter rapeseed, *Brassica napus* L. developed at the V.S. Pustovoit All-Russian Research Institute of Oil Crops: 1681, 1840-2, 1860, 39712, 39859, 39880, 40059, and 40177 were studied. The purpose of the research was a comparative estimation of the maternal lines of the winter rapeseed hybrids by calculated statistic parameters of adaptability, environmental and genetic plasticity, stability, stress resistance in the central zone of the Krasnodar region in different years. Indicators of environmental plasticity and stability were calculated by seed yield of the maternal lines of the winter rapeseed hybrids for three years due to the procedure by SA Eberhart, WA Rassell as revised by VA Zykin. To calculate a coefficient of a linear regression, the environmental indexes characterizing the variability of lines production conditions were defined. Stress resistance and genetic plasticity were determinated due to the equation by AA Rossielle & J Hamblin. Potential productivity and adaptability were identified by the procedure of LA Zhivotkov. The conditions of the 2020 were satisfactory for winter rapeseed plants growth and development. The average yield of the maternal lines was equal to 4.83 ton ha^{-1}. The conditions of 2018 and 2019 were not quite favorable, since the environmental index was negative (*Ij*= -0.14 and -1.23), and average yield was 3.33 and 2.24 ton ha^{-1}, respectively. The comparative estimation of the maternal lines of the winter rapeseed hybrids developed at the V.S. Pustovoit All-Russian Research Institute of Oil Crops by the parameters of the ecological plasticity and stability in the Krasnodar region showed that the line 39712 having the average seed yield per year of 3.70 ton ha^{-1} combines a high level of plasticity, adaptability, stability and is characterized by a high genetic plasticity. This line possesses high responsibility to the advanced cultivation conditions. The line 39880 with the average yield of 3.57 ton ha^{-1} also is characterized by environmental and genetic plasticity and adaptability. The lines 39859 and 40177 demonstrated the highest stability and resistance to the stress factors of environments. They are very adaptive to deterioration of the weather conditions. The selected maternal lines are very interesting for breeding of winter rapeseed hybrids of the Russian origin.

Key words: Winter rapeseed, Adaptability, Plasticity, Stability, Stress resistance.

Article type: Research Article.

INTRODUCTION

The problem of crop yield level increase is very relevant and is associated in most cases with the problem of yield stabilizing. Modern requirements of agricultural production dictate the need to create highly productive and flexible genotypes of agricultural crops. Scientists aimed at examining the adaptability, ecological plasticity and stability of various agricultural crops that have a wide cultivation area and are characterized by a wide range of yield values (Rybas 2016; Seregina 2018). In foreign studies on rapeseed, scientists emphasize the relevance of

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studying the adaptability of this culture to environmental conditions. Due to the strong influence of the environment on productivity, high adaptability of rapeseed genotypes is required (Pavlista *et al.* 2011; Nowosad *et al.* 2016; Bibi *et al.* 2018; Ze'en *et al.* 2020). Moreover, the concepts of plasticity and stability in domestic and foreign literature are interpreted in different ways, which complicates the assessment of these parameters and their use in selection (Steigenga 2005). Breeders have proposed a number of techniques to assess the adaptability, plasticity, and stability of genotypes of different crops (Eberhart & Russel 1966; Tai 1971; Zhivotkov *et al.* 1994). Breeding programs in all rapeseed breeding institutions around the world focus on the development and study of commercial CMS-based hybrids. In the process of creating highly productive winter rapeseed hybrids, *Brassica napus* L., they perform the selection of maternal and paternal lines aligned by biometric characteristics and better economically-valuable indicators, characterized by ecological plasticity, which is less dependent on environmental factors.

Modern varieties and hybrids of winter rape have a fairly high yield potential, which is not fully realized. An essential role in the creation of new rapeseed genotypes should be assigned to the assessment of ecological plasticity and stability parameters. The ecological stability of rapeseed genotypes, their resistance to environmental factor limitation and the ability to produce a high and stable yield attract the attention of most breeders. As is known, breeding for high productivity often leads to a significant decrease of rapeseed adaptability. Increasing the adaptive potential of new rapeseed varieties and hybrids is a priority task of modern breeding (Seregina 2018). The main feature of selection for adaptability is the control of ecological plasticity and stability of genotypes. Environmental plasticity is understood as the average response of a variety to the changes in environmental conditions, and stability is the deviation of empirical data in each environmental condition from this average response (Ponomareva 2018).

An important indicator of adaptability and ecological plasticity is the resistance of the variety to stress. The higher the stress resistance, the wider the range of adaptive possibilities of the variety (Rossielle & Hamblin 1981; Sapega & Tursumbskova 2010). The creation and cultivation of the most adaptive, ecologically plastic, maternal lines of winter rape, characterized by high genetic flexibility in the hybridization plots, will make it possible to obtain a consistently high yield of seeds of the first-generation hybrids. The aim of the present study was a comparative assessment of the maternal lines of winter rapeseed, *Brassica napus* L. hybrids developed at the V.S. Pustovoit All-Russian Research Institute of Oil Crops for adaptability, ecological plasticity, stability, stress resistance and genetic flexibility in the central zone of the Krasnodar region.

MATERIALS AND METHODS

The study was carried out in 2018-2020 on the experimental fields of the central experimental base of the V.S. Pustovoit All-Russian Research Institute of Oil Crops located in the central zone of the Krasnodar region. We studied the promising maternal lines of winter rapeseed: 1681, 1840-2, 1860, 39712, 39859, 39880, 40059 and 40177. Sowing, phenological observations, accounting and harvesting were carried out according to the method adopted at the V.S. Pustovoit All-Russian Research Institute of Oil Crops (Lukomets 2010).

The indicators of ecological plasticity and stability were calculated according to the method by SA Eberhart, and WA Rassell edited by VA Zykin (Zykin *et al.* 2008). The technique is based on calculating the linear regression coefficient *bi* (ecological plasticity) and the standard deviation from the Si^2 regression line (ecological stability). To calculate the linear regression coefficient, the indices of environmental conditions (I_j) were determined, which characterize the variability of the conditions in which the variety was grown. Stress tolerance (Y_2-Y_1) and genetic flexibility (Y_2+Y_1)/2 were determined according to AA Rossille, and J Hamblin (Rossille & Hamblin 1981). The technique for potential productivity and adaptability determination is based on comparing the general species adaptive response to specific growing conditions, which is implemented and referred to the average yield for the compared lines (Zhivotkov *et al.* 1994). Winter rapeseed plants were exposed to a variety of weather conditions developed in the autumn-winter and spring-summer periods of their growth and development. In this regard, the study of the ecological plasticity and stability of different varieties is very important for this culture under certain growing conditions. The meteorological conditions during the testing period of winter rape maternal lines were significantly different in temperature and moisture supply, which made it possible to give an objective assessment of the lines under study in contrasting environmental conditions.

Weather conditions in different years differed from each other. The moisture regime during the autumn vegetation and temperature during the winter months is especially important for rapeseed (Table 1).

Table 1. Weather conditions during the growing season of maternal lines of winter rapeseed in different years.

Month	Air temperature (°C)			Precipitation amount (mm)		
	2017	***2018***	***2019***	***2017***	***2018***	***2019***
August	26.3	25.7	23.7	11.2	9.1	38.0
September	21.3	19.8	18.5	18.2	99.1	41.0
October	12.2	14.4	13.4	68.8	59.5	34.0
November	6.4	4.1	6.6	49.9	63.0	18.0
December	5.2	2.7	4.0	77.2	67.4	40.0
	2018	*2019*	*2020*	*2018*	*2019*	*2020*
January	1.4	2.9	2.3	27.0	89.0	64.0
February	3.0	3.1	3.8	48.0	29.4	55.0
March	6.3	6.4	9.3	94.0	59.0	18.0
April	13.8	11.9	10.4	26.3	44.0	4.2
May	19.4	19.0	16.4	23.9	53.0	89.0
June	23.5	25.3	22.9	10.6	34.9	37.0

RESULTS AND DISCUSSION

The most satisfactory conditions for the growth and development of winter rapeseed plants were formed in 2020, when the average yield of maternal lines was 4.83 ton ha^{-1}, and the environment index (I_j) was 1.36. The conditions of 2018 and 2019 can be characterized as not entirely favorable, since the environment index was negative (I_j = -0.14 and -1.23), and the average yield was 3.33 and 2.24 ton ha^{-1}, respectively (Table 2).

The regression coefficient (*bi*) characterizes the genotype responsiveness to growing conditions improvement. The higher this indicator, the more significant the ecological plasticity of the line. If *bi* is significantly higher than unity, then the line can be attributed to the intensive type. With the regression coefficient equal to or close to one, it is assumed that a change in line yield corresponds to growing condition change. The calculation of the linear regression coefficient showed that the mother line 39712 has the greatest plasticity, since *bi* is much higher than one and is equal to 1.37. This line is characterized by high responsiveness to cultivation condition improvement. During unfavorable years by weather conditions, it reduces the yield potential (Table 2).

Table 2. Productivity, parameters of plasticity and stability of winter rapeseed maternal lines developed at the V.S. Pustovoit All-Russian Research Institute of Oil Crops, 2018-2020.

Line	Seed yield, ton ha^{-1}			***ΣYi***	***Yi***	***bi***	***Si²***
	2018	**2019**	**2020**				
1681	2.95	2.65	4.71	10.31	3.44	0.82	0.21
1840-2	3.51	1.78	4.90	10.19	3.40	1.19	0.11
1860	3.08	1.48	4.30	8.86	2.95	1.07	0.11
39712	3.69	1.92	5.49	11.10	3.70	1.37	0.05
39859	3.46	2.85	4.50	10.81	3.60	0.64	0.00
39880	2.83	2.49	5.40	10.72	3.57	1.36	0.65
40059	3.62	2.04	5.00	10.66	3.55	1.32	0.20
40177	3.49	2.70	4.30	10.49	3.50	0.72	0.05
∑*Yj*	26.63	17.91	38.60	83.14	-	-	-
Yj	3.33	2.24	4.83	-	3.03	-	-
Ij	-0.14	-1.23	1.36	-	-	-	-

The lines 1840-2, 39880 and 40059 exhibited the reaction norm rate *bi* significantly higher than one and it was equal to 1.19, 1.36 and 1.32. This indicates that in favorable conditions they maximize the potential for yield, and they reduce yield in unfavorable conditions. The line 1860 displayed the reaction norm indicator *bi* = 1.07. This indicates a direct dependence of yield on weather conditions. The lines with the indicator (*bi* = 0.64-0.82) were characterized by reduced plasticity and respond poorly to the changes in cultivation conditions. The deviation of the actual yields from the theoretical ones, calculated on the basis of the average yield and the medium index, shows the line stability measure (Si^2). The less the deviation, the higher the line stability. The lowest Si^2 value was observed at the lines 39859, 39712 and 40177 (0.00-0.05). It can be assumed that these lines are better adapted to worsening weather conditions. Line plasticity elevtion often contributes to its stability decrease. This phenomenon

can be observed for the line 39880 (Si^2 = 0.65) (Table 2). An important indicator characterizing the adaptive potential is the resistance to stressful environmental conditions, which is determined by the deviation of yield. This parameter which is determined by the line yield difference (Y_2-Y_1), exhibits the level of their resistance to stressful growing conditions, and has a negative sign. The stress tolerance of the line is the higher, the smaller the gap between the maximum (Y_1) and minimum (Y_2) yields. Thus, the most stress-resistant lines are 40177 and 39859 with the indicators of -1.60 and -1.65, respectively (Table 3). Genetic flexibility (Y_2+Y_1)/2 indicates the average yield in contrasting conditions of different years. The higher the degree of correspondence between the line genotype and the environmental factors, the higher this value. The lines 39712 and 39880 are characterized by high genetic flexibility with the indicators 3.71 and 3.95, respectively (Table 3).

Table 3. Stress resistance and genetic flexibility of winter rapeseed maternal lines developed at the V.S. Pustovoit All-Russian Research Institute of Oil Crops, 2018-2020.

Line	Yield (ton ha^{-1})		Stress resistance (Y_2-Y_1)	Genetic flexibility (Y_2+Y_1)/2
	max (Y_1)	min (Y_2)		
1681	4.71	2.65	-2.06	3.68
1840-2	4.90	1.78	-3.12	3.34
1860	4.30	1.48	-2.82	2.89
39712	5.49	1.92	-3.57	3.71
39859	4.50	2.85	-1.65	3.68
39880	5.40	2.49	-2.91	3.95
40059	5.00	2.04	-2.96	3.52
40177	4.30	2.70	-1.60	3.50

To obtain objective information on the adaptability of winter rape maternal lines, they calculated the adaptability coefficient (AC) using the method by LA Zhivotkov (Zhivotkov *et al.* 1994). The average adaptability coefficient shows the productive capabilities of the line. In our studies, it varied from 83 to 108 %. Over the years of research (2018-2020), six lines out of eight had the adaptability coefficient above 100 % (Fig. 1).

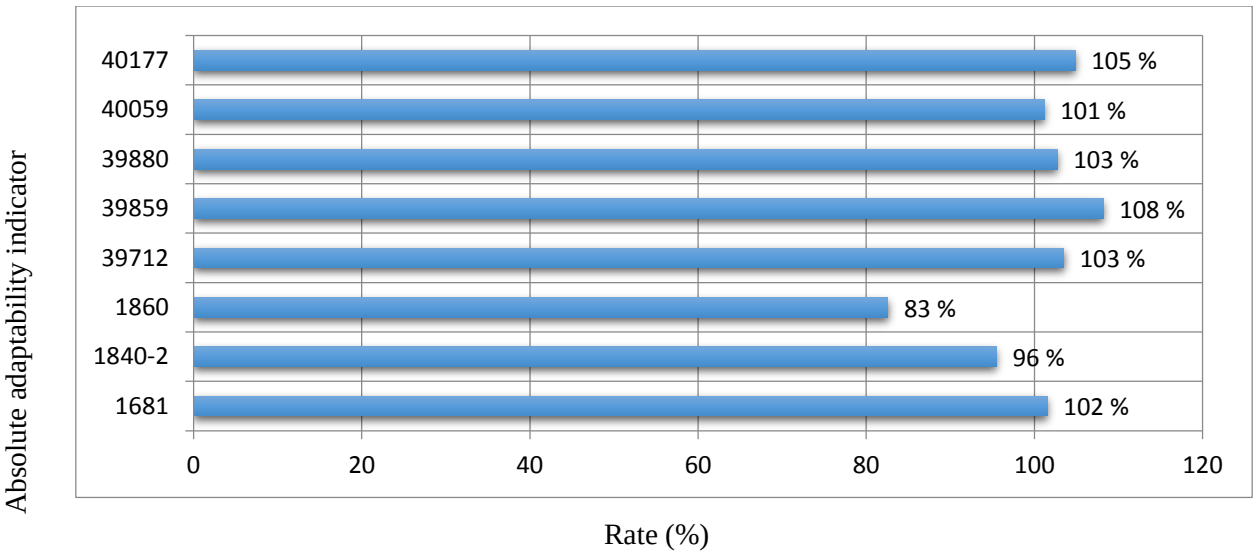

Fig. 1. Adaptability coefficient of the studied maternal lines of winter rapeseed in the conditions of the central zone of Krasnodar region (%).

According to the absolute adaptability indicator, the lines ranked in the following order: 39859 (108%), 40177 (105%), 39712 and 39880 (103%), 1681 (102%) and 40059 (101%). Less adaptive lines: 1840-2 (96%) and 1860 (83 %; Fig. 1).

SUMMARY

Thus, the comparative analysis of the maternal lines of rapeseed hybrids were developed at the V.S. Pustovoit All-Russian Research Institute of Oil Crops. In terms of ecological plasticity and stability, carried out in the central zone of the Krasnodar region, makes it possible to distinguish adaptive lines by calculating the statistical parameters of various mechanisms of ecological stability. The definition of ecological plasticity, used at the final stages of the breeding process, helps to assess the stability and plasticity of the created breeding material. The line 39712 with an average annual seed yield of 3.70 ton ha^{-1} combines a high level of plasticity, adaptability, stability, and is characterized by high genetic flexibility. This line is highly responsive to growing condition improvement. The presented line is the maternal form of the first domestic hybrid of winter rapeseed Debut developed at the V.S. Pustovoit All-Russian Research Institute of Oil Crops. The line 39880 with an average yield of 3.57 ton ha^{-1} has also plasticity, adaptability and has a high genetic flexibility. The lines 39859 and 40177 demonstrated the greatest stability and resistance to the environmental stress factors. These lines have the best adaptability to weather condition deterioration for growth. The selected maternal lines are of practical interest for breeding aimed at winter rape hybrid creation of domestic origin.

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