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RESEARCH ON THE INTERACTION PECULIARITIES OF COMMON WHEAT WITH *FUSARIUM OXYSPORUM* ISOLATES

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Abstract. The purpose of the research was to establish the cluster organization of *Fusarium oxysporum* isolates, collected in different localities of the Republic of Moldova, the variability and heritability of wheat plant growth and development traits in interaction with the pathogen. Methods for isolating and identifying fungi, preparing culture filtrates, infecting plants, morphometric, and statistical data processing were applied. Treatment of common wheat grains with culture filtrates of 9 *F. oxysporum* isolates, demonstrated their different virulence, which allowed their successful classification into clusters with different pathogenic potential. Factorial analysis of the weight of plant genotype, *F. oxysporum* isolate and their interaction in the source of variation of growth characters demonstrated that the genotype recorded: 48 ... 63%, the isolate factor: 17 ... 23%, the *genotype x isolate* interaction – 11 ... 23%. Relatively high values were recorded for the heritability coefficient in the broad sense (0.53 ... 0.69) and genetic advantage (13.39 ... 24.74%) for growth and development traits in the interaction of common wheat with *F. oxysporum* isolates, which reveals the high opportunities for creating resistant wheat genotypes in limited terms.

Keywords: Fusarium oxysporum, grown traits, virulence, wheat.

INTRODUCTION

Plant-fungal interactions can have beneficial or detrimental effects on host plants and can give rise to various changes at both the plant and fungal levels. The reduction or prevention of fungal diseases of plants depends on resistant crop varieties or fungicide treatment. Plant-fungal interactions need to be known to understand the mechanisms of fungal plant diseases, their prevention, and to improve plant productivity [1].

Incorporating genetic resistance into crop plants is considered the most effective and sustainable solution to combat root rot. However, resistance is often quantitative in nature, i.e. variable and dependent on environmental conditions. The genetic method of combating the disease by creating resistant genotypes is considered a safe and ecologically harmless way to reduce the consequences of root rot. However, it should be noted that it is quite difficult to solve this problem due

to the specificity of the *plant x pathogen* interaction, a specificity that is most directly reflected in the variability and heritability of growth traits.

The heritability pattern of a trait is important for plant breeding because it provides information on the extent to which a particular trait can be transmitted from parent to offspring [2], and heritability estimation provides information on the level of genetic control of the trait [3]. High broad-sense heritability, associated with high genetic progress, reveals the significant contribution of additive genetic variance in trait expression and the fact that selection based on these traits plays a vital role in improving quantitative traits [4].

The genotypic coefficient of variation is the best index for assessing genetic variance, and high heritability coefficients for different traits indicate a high contribution of the genotypic component [5]. To quantify variability and compare traits, the genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advantage are assessed according to [6].

In connection with the complexity of the factor systems on which the manifestations of root rot in wheat depend, the purpose of the research was to establish the cluster organization of *F. oxysporum* isolates, collected in different localities of the Republic of Moldova, the variability and heritability of plant growth and development traits in interaction with the pathogen.

MATERIALS AND METHODS

As research material, 3 genotypes of common winter wheat served – L S/BT/S, L Sel./Accent, Moldova 16 and 9 isolates of *F. oxysporum* from 3 different localities – Br F.o.1, Br F.o.2, Br F.o.3 (Braviceni commune), V F.o.1, V F.o.3, V F.o. 5 (Chișinău city), L F.o.2, L F.o.3, L F.o.5 (Leova city). *F. oxysporum* isolates were selected according to the principle of the difference in geographical areas from which they were sampled and the ability to grow at high temperature (35°C) *in vitro* conditions. Thus, the isolates from Braviceni commune Br1, Br2, Br3 were moderately resistant (MR), susceptible (S), resistant (R); Chișinău town – V1, V3, V5 – moderately resistant (MR), resistant (R), susceptible (S); Leova town – L2, L3, L5 – resistant (R), moderately resistant (MR), resistant (R), respectively.

Culture filtrates (CF) were prepared on the basis of Cszapek liquid nutrient medium. After inoculation with fungal mycelium, Cszapek medium was maintained for 21 days at 24°C [7].

Wheat grains were kept for 18 hours in CF after which they were rinsed 2 times with distilled water and placed on filter paper moistened with distilled water in Petri dishes, 30 grains in each. After 6 days of cultivation at 18-19°C, the seedlings were subjected to morphometric measurements (germination, %; radicle length, mm; stem length, mm; seedling length, cm). The vigor index was calculated based on the formula: germination (%) x seedling length (cm).

To analyze the genetic variability of wheat seedling growth traits, the methods proposed by [6] were used: where σ^2_g – genotypic variance; σ^2_{ph} – phenotypic variance; σ^2_e (error variance, or VE) = MSE; h^2 – broad heritability coefficient; PCV – phenotypic coefficient of variation; GCV – genotypic coefficient of variation; X – general mean of the trait; GA – genetic advantage; K – selection differential = 2.06 at 5% selection pressure; σ_{ph} – general standard deviation of the trait.

The experiment was carried out in 3 repetitions. The data were statistically processed according to variance analysis, clusterian (dendrograms – agglomerative-iterative method, *k*-means – centroid method), factorial analysis in the STATISTICA 7 software package.

RESULTS AND DISCUSSIONS

Biometric analysis data demonstrated that the characters of the genotypes under study reacted differently to the treatment of grains with culture filtrates (CF) of *F. oxysporum* isolates, their sensitivity depending on both the genotype of the plant and the isolate (Fig. 1).

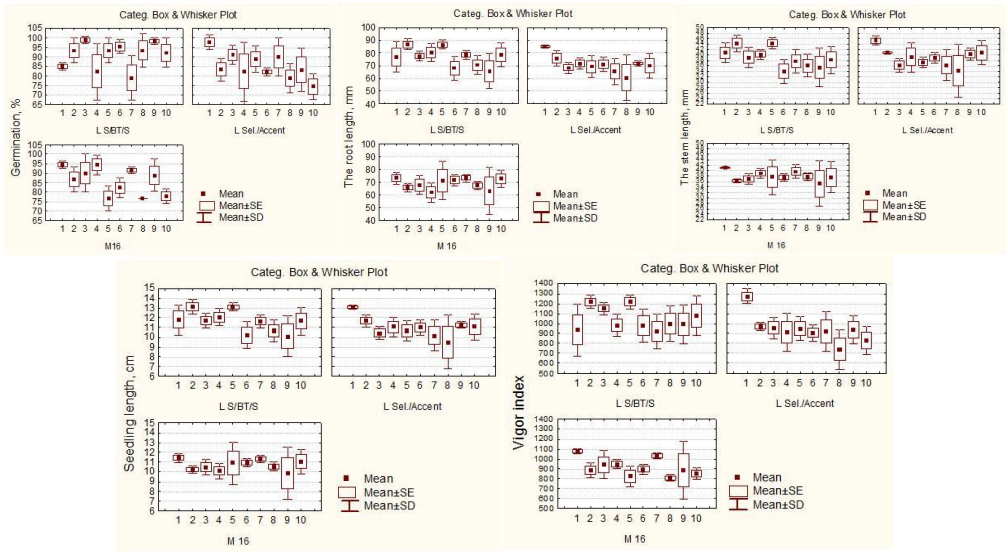


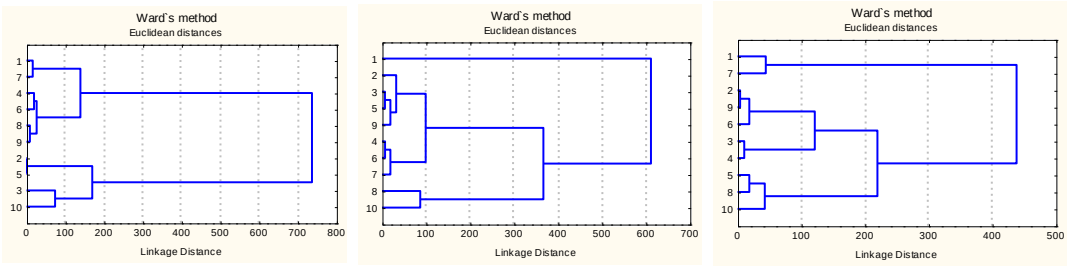
Figure 1. Influence of the *F. oxysporum* culture filtrates on growth characteristics of common winter wheat plants

Horizontally: 1 – H_2O, 2 – Br1, 3 – Br2, 4 – Br3, 5 – V1, 6 – V3, 7 – V5, 8 – L2, 9 – L3, 10 – L5

The difference in the average of the 9 *F. oxysporum* isolates compared to the control was in the case of *germination*: +6.8%, -14.4%, -9.4%; *radicle length:* -0.1%, -18.6%, -11.4%; *stem length*: -4.9%, -15.3%, -8.3%; *seedling length*: +0.2%,

-17.6%, -7.0%; *vigor index*: +13.5%, -29.3%, -16.7%, respectively, for the genotypes L S/BT/S, L Sel./Accent, Moldova 16. It is worth mentioning that the genotype L S/BT/S differed from the other two in that the values of growth and development characters in the 9 variants with FC were practically at the level of the control variant (H_2O), and in the case of germination, FC that stimulate the character were also recorded. This denotes the resistance of the genotype to the action of all *F. oxysporum* isolates.

Cluster analysis using the dendrogram construction method demonstrated that the classification of isolates based on the effect on germination (%), radicle length (mm), stem length (mm), seedling length (cm), and vigor index is different for the 3 genotypes, which denotes that the similarity of isolates according to virulence capacity depends on the genotype of the wheat plant (Fig. 2).



L S/BT/S **L Sel/Accent** **Moldova 16**

Figure 2. Dendrogram of distribution of *F. oxysporum* isolates based on their action on the growth and development organs of common wheat plants
Horizontally: 1 – H_2O, 2 – Br1, 3 – Br2, 4 – Br3, 5 – V1, 6 – V3, 7 – V5, 8 – L2, 9 – L3, 10 – L5

Through the centroid classification analysis (*k*-means method) of the isolates, it was found that the intercluster variance was greater than the intracluster variance for the 3 wheat genotypes and, at the same time, for all the analyzed characters, which reveals a successful classification of the isolates based on virulence capacity (Tab. 1-3).

It is worth noting that in the case of the resistant genotype L S/BT/S, the ratio of intercluster variance to intracluster variance is much lower than in the case of L Sel./Accent and M16. This indicates that although the differentiation of isolates into virulence clusters was successful for L S/BT/S, the differences between clusters are less pronounced than in the case of the other 2 genotypes.

Table 1. Intra- and intercluster variance analysis in the reaction of wheat genotype L S/BT/S with *F. oxysporum* isolates

Variant	Intercluster variance (1)	df	Intracluster variance (2)	df	F	p	Ratio 1/2
Germination, %	226.1	2	189.24	7	4.18	0.06	1.20
The length of the radicle, mm	227.2	2	224.03	7	3.55	0.09	1.01
The length of the stem, mm	62.2	2	46.30	7	4.70	0.05	1.34
The seedling length, mm	5.3	2	4.45	7	4.21	0.06	1.19
Vigor index	105442.3	2	10092.21	7	36.57	0.00	10.45

Table 2. Intra- and intercluster variance analysis in the reaction of wheat genotype L Sel./Accent with *F. oxysporum* isolates

Variant	Intercluster variance (1)	df	Intracluster variance (2)	df	F	p	Ratio 1/2
Germination, %	306.8	2	103.01	7	10.42	0.01	2.98
The length of the radicle, mm	272.7	2	105.64	7	9.04	0.01	2.58
The length of the stem, mm	45.1	2	43.11	7	3.66	0.08	1.05
The seedling length, mm	5.4	2	2.68	7	7.04	0.02	2.02
Vigor index	162437.3	2	7142.64	7	79.60	0.00	22.74

Table 3. Intra- and intercluster variance analysis in the reaction of wheat genotype M16 with *F. oxysporum* isolates

Variant	Intercluster variance (1)	df	Intracluster variance (2)	df	F	p	Ratio 1/2
Germination, %	369.9	2	84.84	7	15.26	0.00	4.36
The length of the radicle, mm	83.6	2	75.10	7	3.90	0.07	1.11
The length of the stem, mm	16.1	2	8.88	7	6.33	0.03	1.81
The seedling length, mm	1.7	2	0.80	7	7.26	0.02	2.13
Vigor index	61916.1	2	5979.12	7	36.24	0.00	10.36

Through descriptive statistical analysis (Tab. 4-6), the clusters of isolates that produced the most significant inhibitions of growth traits were found, but the presence of isolates L2 (R), L5 (R) (or. Leova) in the cluster with the strongest negative effect for all 3 genotypes is observed.

Table 4. Descriptive statistics of clusters of *F. oxysporum* isolates in interaction with the wheat line L S/BT/S

Variant	Mean, %	σ	Member of the cluster
Cluster 1, n = 3			
Germination, %	95,23	3.18	2 – Br1 (MR), 3 – Br2 (S), 5 – V1 (MR).
The length of the radicle, mm	83,77	5.26	
The length of the stem, mm	42,53	2.97	
Seedling length, mm	12,63	0.81	
Vigor index	1199,25	38.15	
Cluster 2, n = 5			
Germination, %	92.32	6.13	4 – Br3 (R), 6 – V3 (R), 8 – L2 (MR), 9 – L3 (R), 10 – L5 (S).
The length of the radicle, mm	72.70	6.48	
The length of the stem, mm	36.78	2.44	
The seedling length, mm	10.94	0.88	
Vigor index	1007.78	42.06	
Cluster 3, n =2			
Germination, %	81.95	4.31	1 (M – H_2O), 7 – V5 (S).
The length of the radicle, mm	77.85	1.06	
The length of the stem, mm	39.25	2.19	
The seedling length, mm	11.71	0.11	
Vigor index	928.12	10.30	

Factorial analysis of the weight of plant genotype, *F. oxysporum* isolate, genotype x isolate interactions in the source of variation of the characters under study returned the genotype that recorded: 48, 63, 51, 60%, respectively, of germination, radicle length, seedling length, vigor index. The weight of the isolate factor constituted: 20, 17, 23, 17%, and of genotype x isolate interaction – 23, 11, 14, 15%, respectively, of germination, radicle length, seedling length, vigor index (Fig. 3).

By calculating the genetic parameters of genotypic (σ^2_G) and phenotypic (σ^2_{Ph}) variance, it was found that the broad sense heritability coefficient (h^2) varied within the limits of 0.53 ... 0.69, which denotes a relatively high capacity for hereditary transmission of growth characters in the interaction of wheat plants with *F. oxysporum* isolates.

Table 5. Descriptive statistics of clusters of *F. oxysporum* isolates in interaction with the wheat line L Sel./Accent

Variant	Mean, %	σ	Member of the cluster
Cluster 1, n = 1			
Germination, %	97.77	0.00	1 – (H_2O).
The length of the radicle, mm	85.32	0.00	
The length of the stem, mm	45.24	0.00	
The seedling length, mm	13.05	0.00	
Vigor index	1276.73	0.00	
Cluster 2, n = 7			
Germination, %	85.88	3.94	2 – Br1 (MR), 3 – Br2 (S), 4 – Br3 (R), 5 – V1 (MR), 6 – V3 (R), 7 – V5 (S), 9 – L3 (R).
The length of the radicle, mm	70.55	3.24	
The length of the stem, mm	38.45	1.87	
The seedling length, mm	10.90	0.50	
Vigor index	935.89	23.93	
Cluster 3, n =2			
Germination, %	76.67	3.11	8 – L2 (R), 10 – L5 (R).
The length of the radicle, mm	65.24	6.51	
The length of the stem, mm	37.58	4.70	
The seedling length, mm	10.26	1.08	
Vigor index	783.58	60.88	

Table 6. Descriptive statistics of clusters of *F. oxysporum* isolates in interaction with the wheat line M16

Varian	Mean, %	σ	Member of the cluster
Cluster 1, n = 2			
Germination, %	93.06	1.96	1 – (H_2O), 7 – V5 (S).
The length of the radicle, mm	73.26	0.05	
The length of the stem, mm	40.33	1.08	
The seedling length, mm	11.36	0.10	
Vigor index	1056.65	31.37	
Cluster 2, n = 5			
Germination, %	88.45	4.48	2 – Br1 (MR), 3 – Br2 (S), 4 – Br3 (R), 6 – V3 (R), 9 – L3 (R).
The length of the radicle, mm	66.17	3.90	
The length of the stem, mm	37,0	1.39	
The seedling length, mm	10.31	0.41	
Vigor index	912.95	31.35	
Cluster 3, n =3			
Germination, %	77.05	0.63	5 – V1 (MR), 8 – L2 (R), 10 – L5 (R).
The length of the radicle, mm	70.57	2.68	
The length of the stem, mm	37.66	0.15	
The seedling length, mm	10.82	0.25	
Vigor index	829.76	23.06	

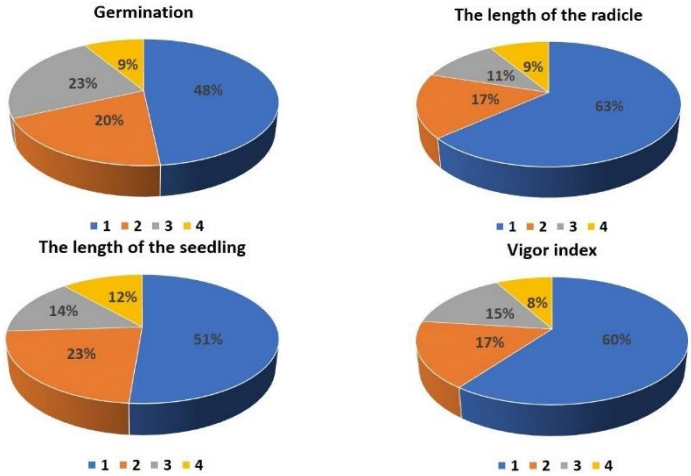


Figure 3. Share of plant genotype factors (1), isolate (2), genotype x isolate interactions (3), random factors (4) in the source of variation in growth and development traits of common wheat

Table 7. Variability and heritability of common wheat growth characters in interaction with *F. oxysporum* isolates

Parameter	Germination	The length of the radicle	The length of the seedling	Vigor index
σ^2_G	85.03	153.3	1.73	43572
σ^2_{Ph}	140.3	226.6	3.24	63548
h^2	**0.61**	**0.68**	**0.53**	**0.69**
GCV, %	10.55	17.13	11.83	21.55
PCV, %	13.55	20.82	16.23	26.03
GAM, %	13.44	18.77	13.39	24.74

The genotypic coefficient of variation (GCV, %) and genetic advantage (GAM, %) recorded medium-high values: 10.55 ... 21.55%, 13.39 ... 24.74%, respectively. The association of relatively high values of the h^2 and GAM (%) parameters reveals real opportunities for obtaining common wheat genotypes resistant to the fungus *F. oxysporum*.

CONCLUSIONS

Treatment of common wheat grains with culture filtrates of 9 F. oxysporum isolates, collected in different areas of the Republic of Moldova (Brăviceni commune, Chișinău city, Leova city), and distinguished according to their

resistance to high temperature (35°C), demonstrated their different virulence, which allowed their successful classification into clusters with different pathogenic potential.

Factorial analysis of the weight of plant genotype, *F. oxysporum* isolate and their interaction in the source of variation of growth characters demonstrated that the genotype recorded: 48, 63, 51, 60% in the source of variation of germination, radicle length, seedling length, vigor index, respectively. The weight of the isolate factor constituted: 20, 17, 23, 17%, and of *genotype x isolate* interaction – 23, 11, 14, 15%, respectively, of germination, radicle length, seedling length, vigor index.

Relatively high values were recorded for the heritability coefficient in the broad sense (0.53 ... 0.69) and genetic advantage (13.39 ... 24.74%) for growth and development traits in the interaction of common wheat with *F. oxysporum* isolates, which reveals the high opportunities for creating resistant wheat genotypes in limited terms.

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