Resistance to fusarium ear rot in maize: heritability and trait associations

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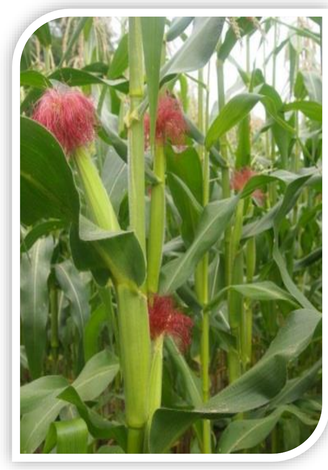
- In Poland maize is important for food and feed production. Each year the cropping area is ab. 1 mln ha (more than 500 thousands ha for silage and ab. 500 thousands ha for grain).
- Red and pink ear rots caused by *Fusarium* spp. are important factors affecting the yield and its quality, mainly because of contamination with mycotoxins produced by the fungi.
- The development of resistant host genotypes strongly depends on availability of sources of resistance and information on host pathogen interactions.
- The mode of inheritance of resistance appears to differ: additive, possibly non-additive effects, digenic and polygenic patterns have been identified. It depends on several components such as resistance to initial infection, resistance to fungal degradation of silk tissues, resistance to fungal spread by through a wax layer in the grain or grain morphology and chemical compounds of the pericarp.
- The accumulation of toxins can also be affected by the plant genotype. Although selection is effective to reduce disease severity after inoculation with *F. graminearum*, additional genes seemed to affect grain DON concentration (i.e., ratios DON/DS in grains depended on genotype), indicating that specific mechanisms are present in the plant affecting DON production by de fungus and additional genetic progress would be achieved by including grain DON concentration as a selection parameter.



OBJECTIVE

The present research was conducted to estimate heterosis, heritability and correlation coefficients to ear rot, mycotoxin accumulation ability and trait association in set of F_1 crosses generated from resistant and susceptible parents.

MATERIALS AND METHODS

- Plant material: inbreed lines (S1, S2, K9, S7, S8, K2, K3, K4, K6, K1) and F_1 populations
- *Fusarium graminearum* (GER) ear rot severity tests
  - Field experiments were conducted in three replications - Central Poland (Radzikow). For each genotype eight plants were inoculated with *F. graminearum* and 8 plants were used as a control in each replication. Because of different ears morphology - kernel inoculation method was used (9 days after silking). Disease development was visually assessed during harvesting time using 1 - 7 scale.
- Mycotoxin content
  - DON content was evaluated in grain samples with RIDA®QUICK SCAN using immunochromatographic tests.
- Ears morphology
  - Cob and silks length (separately, covered and not covered by husks) were measured (cm). Additionally, anthocyanin content in silks was described.
- Relationships between disease severity, DON contamination, anthocyanin content and ear morphology were calculated using Pearson correlations.

Results

Ear rot severity, toxin content under natural infection and after inoculation *F. graminearum*, plant height, ear morphology and antocyjan content of parental elite inbreed lines and their crosses

F_1 population	Bacground (parental lines)	Earliness (days from sowing till silking time)	Aftificial infection		Natural infection		Height (without tassels; cm)	Ear morphology				Antocyjan	
			Ear rot (1-7)	DON (ppm)	Ear rot (1-7)	DON (ppm)		husks density (1-5)	silks length (cm)	corncob lengh (cm)	channel length (cm)	silks (1-5)	core (1-5)
dent and semident													
F11	S2 x S6	78	3,5	35,5	1,0	0,0	240	3,9	6,2	16,9	2,3	1	5
F14	S3 x S5	91	4,6	67,3	1,3	0,3	232	5,0	11,4	21,6	-1,5	2	2
F2	S2 x S8	88	3,1	11,7	1,2	0,0	227	4,0	5,4	16,3	3,4	3	5
F23	S2 x S1	81	3,7	56,2	1,5	0,0	225	3,4	6,8	16,7	3,7	3	4
F24	S4 x S1	83	4,6	116,7	1,3	0,0	228	3,7	10,4	16,9	4,9	3	5
F29	K1 x K2	100	2,9	23,9	1,0	0,0	208	-	-	-	-	3	5
F30	K2 x K1	99	2,9	6,7	1,2	0,0	208	-	-	-	-	2	5
F8	S3 x S7	91	5,3	173,0	1,2	0,0	268	5,0	10,0	19,9	2,3	4	4
F35	K15 x K16	91	3,1	51,4	1,2	0,6	254	4,8	12,1	22,0	-3,0	1	3
F36	K16 x K17	93	3,9	103,9	1,4	0,0	245	5,0	7,7	22,2	-1,1	1	3
F37	K18 x K9	93	3,9	109,2	1,1	0,0	256	-	-	-	-	1	3
F38	K19 x K20	96	3,8	79,8	1,5	0,0	249	-	-	-	-	1	5
F4	S4 x S8	83	4,1	62,9	1,4	0,0	238	3,2	6,3	16,8	3,2	1	5
Average (dent type)		89,8	3,8	69,1	1,3	0,1	237	4,2	8,5	18,8	1,6	2,0	4,2
flint and semiflint													
F13	s8 x S6	81	3,7	39,2	1,1	0,0	235	2,8	4,5	16,8	5,2	2	5
F21	s6 x S2	78	3,9	39,7	1,2	0,0	253	4,0	6,4	18,0	2,1	1	4
F22	s8 x S2	84	4,1	29,0	1,1	0,0	224	3,9	5,7	17,5	2,9	3	5
F25	s6 x S1	78	4,6	52,8	1,0	0,0	223	2,3	7,2	20,7	2,8	1	5
F28	K4 x K6	93	2,4	8,1	1,2	0,0	241	4,0	10,7	21,6	4,2	1	1
F6	s6 x S8	81	3,9	21,4	1,0	0,0	218	2,5	5,0	16,0	3,9	1	5
F7	s7 x S8	94	3,5	42,3	1,2	0,0	217	3,5	6,6	18,0	4,6	3	1
F9	s8 x S7	92	3,4	26,5	1,3	1,2	218	3,7	5,9	16,4	5,7	3	1
F31	K10 x K12	83	4,6	39,6	1,1	0,3	227	3,5	6,3	16,1	6,4	1	1
F32	K11 x K12	83	6,2	200,4	1,5	0,2	213	3,9	6,4	15,0	8,5	1	1
F33	K11 x K13	83	4,8	78,7	1,6	0,8	206	3,6	6,2	16,7	7,3	1	1
F34	K14 x K13	88	5,5	70,0	1,8	1,0	206	3,8	6,2	16,9	6,8	1	2
F10	s1 x S6	78	4,6	96,5	1,1	0,0	220	1,8	6,8	19,5	2,5	1	5
F20	s1 x S2	83	3,5	11,8	1,4	0,0	226	4,0	7,3	14,0	3,4	3	5
F27	K6 x K4	88	3,4	13,0	1,1	0,0	241	4,0	9,5	11,2	5,1	1	1
Average (flint type)		84,5	4,1	51,3	1,2	0,2	225	3,4	6,7	17,0	4,8	2	3
F_1 populations: flint and dent													
Average		87	4	59,5	1,3	0,2	230	3,7	6,8	16,3	3,3	1,8	3,5
S.D.		7	1	57,51	0,3	0,5	19	0,8	2,9	5,5	2,8	1	1,8
CV		8	24,1	96,6	21	333,0	8	22,1	42,4	33,7	85,4	55	51,2
NIR (Fishera)		4,657	0,95	65,165	0,351	0,773	17,793	0,439	1,344	2,226	1,351	0	1,184

Parental inbreed lines

Elite inbreed line	Earliness (days from sowing till silking time)	Aftificial infection		Natural infection		Height (without tassels; cm)	Ear morphology				Antocyjan	
		Ear rot (1-7)	DON (ppm)	Ear rot (1-7)	DON (ppm)		husks density (1-5)	silks length (cm)	corncob lengh (cm)	channel length (cm)	silks (1-5)	core (1-5)
S1	86	6,6	253,0	1,7	0,0	141	3,5	6,7	12,4	6,2	2	4
S2	91	3,1	3,1	1,4	0,2	184	4,1	7,3	12,9	1,3	1	5
K9	91	4,9	127,2	1,6	0,0	193	4,1	5,9	14,4	3,3	1	5
S7	100	4,2	106,8	1,1	0,0	215	3,5	6,9	14,9	5,4	4	1
S8	92	5,3	73,2	1,3	1,4	141	3,5	4,7	13,6	5,4	4	1
K2	100	2,9	20,0	1,4	0,1	163	5,0	7,3	14,3	3,7	2	3
K3	96	4,2	110,4	1,1	0,0	193	2,9	8,3	11,6	6	1	1
K4	93	5,8	42,4	1,5	3,8	204	3,7	7,3	12,6	9,1	1	1
K6	102	5,1	154,7	1,4	1,8	203	3,2	5,3	14,2	3,3	4	5
K1	100	3,9	84,6	1,3	0,0	174	4,0	8,3	11,6	3,5	4	5
Average	95	4,6	97,5	1,4	0,74	181	3,8	6,8	13,3	4,7	2,4	3,2
S.D.	6	1,3	78,3	0,3	1,51	27	0,8	1,4	2,1	2,5	1,4	1,8
CV	6	28,1	80,3	21,1	204,9	15	20	20,1	16	53,1	56,8	57,2
NIR (Fisher; p<0,05)	4,218	1,26	72,334	0,428	1,783	22,838	1,018	1,528	3,595	2,814	0,311	0,73

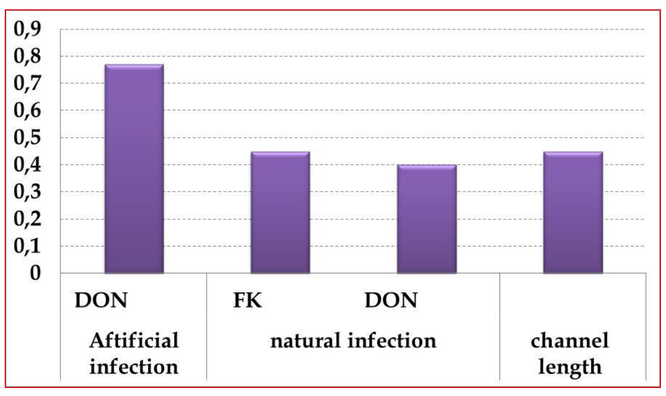
Estimates of mid-parent heterosis (expressed in percent of the mid-parent) for fusarium ear rot, toxin accumulation ability, height, and ear morphology

F_1 population	tasseling (days from sowing till silking time)	Aftificial infection		Height (without tassels; cm)	Ear morphology			
		Ear rot (1-7)	DON (ppm)		husks density (1-5)	silks length (cm)	corncob lengh (cm)	channel length (cm)
F20	-0,06	-0,28	-0,91	0,39	0,05	0,04	0,11	-0,09
F23	-0,08	-0,24	-0,56	0,39	-0,11	-0,04	0,32	-0,01
F2	-0,04	-0,26	-0,69	0,40	0,05	-0,10	0,23	0,00
F22	-0,02	-0,25	-0,53	0,22	0,01	0,15	0,27	-0,15
F7	-0,02	-0,25	-0,53	0,22	0,01	0,15	0,27	-0,15
F9	-0,05	-0,28	-0,71	0,23	0,07	0,02	0,15	0,05
F29	0,00	-0,14	-0,54	0,24	-	-	-	-
F30	-0,01	-0,13	-0,87	0,24	-	-	-	-
F27	-0,09	-0,39	-0,87	0,18	0,15	0,52	-0,16	-0,17
F28	-0,05	-0,56	-0,92	0,18	0,15	0,70	0,61	-0,32

Narrow-sense heritability

	Aftificial infection		Height (without tassels; cm)	Ear morphology				Antocyjan	
	Ear rot (1-7)	DON (ppm)		husks density (1-5)	silks length (cm)	corncob lengh (cm)	channel length (cm)	silks (1-5)	cob (1-5)
1R1	0,01	1587,91	90,943	0,141	3,299	0,064	3,701	0,488	0,78
2R2	0,23	186,66	37,414	0,05	1,347	1,173	0,656	0,488	0,78
Error	0,281	3363,95	24,654	0,324	0,39	9,029	5,1	0,049	3,122
n	30	30	30	24	30	30	30	30	30
narrow-sense heritability									
h^2_{ns}	0,963	0,941	0,994	0,934	0,997	0,804	0,962	0,998	0,938

Relationships between disease severity, DON contamination and ear morphology.



CONCLUSIONS

- The positive heterosis for ear rot resistance and DON content was observed.
- When the two parents components were susceptible or highly susceptible the heterossis effect for disease symptoms was more than 36% and for DON more than 86%.
- Additionally, narrow-sense heritability's h^2_{ns} for ear rot and DON content were very high – depend of combination more than 90%.
- Channel length (to the end of the cover leaves) statistically significantly affected the development of infection
- Antocyjan in the corncob and silks negatively correlated with ear rot severity and DON content

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