

Fusarium head blight and Fusarium toxins accumulation in grain of winter wheat breeding lines inoculated with Fusarium culmorum

Tomasz Góral¹, Halina Wiśniewska², Piotr Ochodzki¹, Dorota Walentyn-Góral¹, Maciej Majka², Iga Grzeszczak¹

¹Plant Breeding and Acclimatization Institute – National Research Institute, Radzików, 05-870 Błonie, Poland

²Institute of Plant Genetics, Polish Academy of Sciences, Strzeszyńska str. 34, 06- Poznań, Poland

E-mail: t.goral@ihar.edu.pl



Fusarium head blight (FHB) is a disease of cereals caused by *Fusarium* fungi (mainly *F. culmorum* and *F. graminearum*). These fungi produce toxic metabolites - mycotoxins, with phyto- and zootoxic effects. In the grain of wheat the most common are toxins belonging to trichothecenes B: deoxynivalenol (DON) and nivalenol (NIV), as well as zearalenone (ZEN). There are several types of resistance to FHB: type I – resistance to infection, type II – resistance to spread of *Fusarium* within the head, type III – resistance to *Fusarium* kernel damage. Other types of resistance are: tolerance to FHB or to mycotoxins (DON) (type IV) and type V - resistance to the accumulation of toxins in the grain by their chemical modification (class 1) or blocking synthesis (class 2).

The aim of the research was to assess the variability of winter wheat lines in response to infection with *F. culmorum* by assessment of the above-mentioned types of resistance and finding lines combining resistance of all types.

Materials and methods

Resistance of 77 lines/cultivars was evaluated in the field experiments in two locations (Poznań, Radzików). They included five resistant checks (R): '20828' [*Fhb1*-], 'A40-19-1-2', 'Arina', 'Fregata', 'UNG 136.6.1.1' [*Fhb1*+]; five lines derived from crosses of 'Sumai 3' cultivar with winter wheat cultivars (four with *Fhb1* gene); six susceptible check lines (S); three high yielding check cultivars. Wheat heads were inoculated at the full flowering stage with the spore suspension of aggressive isolates of *F. culmorum* producing DON, NIV and ZEN. Head infection severity as well as disease incidence were assessed. From these values Fusarium head blight index (FHBi) was calculated reflecting the percentage of infected spikelets in all of the spikes on a plot. The proportion *Fusarium* damaged kernels was determined visually by splitting the sample into healthy looking kernels and kernels showing different symptoms of damage by *Fusarium*. The value of the FDK (= *Fusarium* damaged kernels) was calculated as a percentage of damaged kernels in whole sample (based on mass = FDK m or kernel number = FDK #). Using the technique of gas chromatography and immunoenzymatic tests the contents of DON, acetyl derivatives of DON, NIV and ZEN in the grain was analyzed.



Tabela 1. Resistance to Fusarium head blight and *Fusarium* kernel damage, and the content of ergosterol and *Fusarium* toxins in grain of 58 lines and 19 check cultivars/lines of winter wheat

No	Line/cultivar	Group	FHBi (%)	FDK m (%)	FDK # (%)	ERG (mg/kg)	TCT B (mg/kg)	ZEN (mg/kg)	Resistance*
1	S 38 [Fhb1-]	R	3.9	2.5	1.7	4.4	2.458	0.078	-1.200
2	S 32 [Fhb1+]	R	4.8	1.6	2.0	6.3	2.553	0.085	-1.141
3	S 43 [Fhb1+]	R	3.6	2.3	1.3	6.1	3.745	0.141	-1.131
4	S 10 [Fhb1+]	R	6.6	4.5	3.4	5.8	3.370	0.126	-1.025
5	POB 679/03	lines	7.7	3.4	2.9	8.0	4.765	0.160	-0.933
6	20828 [Fhb1-]	R	3.8	6.1	7.7	7.9	5.160	0.142	-0.859
7	S 30 [Fhb1+]	R	7.8	5.6	6.6	7.0	4.335	0.148	-0.847
8	Fregata	R	3.7	5.0	5.3	10.4	7.575	0.166	-0.817
9	POB 0111	lines	9.0	6.8	7.3	5.2	4.368	0.238	-0.796
10	SMH 7983	lines	8.3	4.0	4.7	5.7	4.723	0.490	-0.787
11	POB 170/04	lines	9.8	5.1	5.3	9.1	5.735	0.232	-0.747
12	STH 2041	lines	7.1	5.8	6.6	11.5	5.743	0.248	-0.721
13	STH 032	lines	7.1	4.7	5.0	13.6	6.423	0.285	-0.706
14	NAD 13015	lines	8.7	6.9	7.9	7.0	5.510	0.302	-0.702
15	STH 008	lines	9.5	6.9	7.5	9.8	5.278	0.204	-0.698
16	A 40-19-1-29	R	5.2	9.0	9.9	9.5	6.820	0.156	-0.685
17	POB 0211	lines	9.5	6.1	7.1	13.5	6.405	0.218	-0.616
18	UNG 136.6.1.1 [Fhb1+]	R	6.5	7.3	8.0	11.5	8.683	0.289	-0.582
19	STH 105	lines	10.3	8.0	9.6	11.2	7.113	0.119	-0.571
20	AND 4023/14	lines	8.0	10.1	12.0	8.9	6.908	0.228	-0.543
21	STH 9059	lines	11.0	6.7	7.9	8.0	5.565	0.638	-0.522
22	POB 0514	lines	7.3	6.8	7.8	11.0	6.003	0.911	-0.445
23	KBP 04 164	lines	10.5	6.4	7.4	10.9	7.538	0.717	-0.418
24	KBP 10 40	lines	9.2	7.8	9.4	12.3	7.478	0.572	-0.413
25	POB 457/07	lines	13.9	11.3	11.9	11.6	7.075	0.213	-0.391
26	MOB 5578/06	lines	8.9	7.0	7.7	14.2	10.553	0.485	-0.381
27	KBP 10 58	lines	11.9	8.8	10.5	15.1	9.865	0.182	-0.348
28	NAD 13017	lines	7.7	11.6	14.1	12.5	7.735	0.433	-0.335
29	KBP 275	lines	7.1	9.8	10.8	14.9	5.993	0.300	-0.300
30	NAD 13016	lines	7.6	9.6	12.2	16.8	7.328	0.608	-0.284
31	KBP 08 20	lines	18.1	7.7	8.5	14.0	9.848	0.305	-0.255
32	POB 0114	lines	10.0	7.5	10.0	18.1	8.833	0.637	-0.228
33	HRSM 752	lines	17.8	9.2	10.2	15.8	9.143	0.303	-0.205
34	NAD 13014	lines	9.3	10.4	12.8	12.4	8.045	0.820	-0.201
35	NAD 13024	lines	15.3	12.2	13.4	12.4	9.360	0.339	-0.189
36	POB 0112	lines	11.0	5.8	7.4	10.5	5.848	1.533	-0.176
37	SMH 7974	lines	12.2	8.3	9.3	18.4	8.123	0.846	-0.150
38	Arina	R	11.0	9.7	10.7	18.5	8.960	0.773	-0.130
39	NAD 11053	lines	13.1	9.9	11.4	17.1	11.283	0.455	-0.130
40	DM 3873/10	lines	16.8	11.8	13.2	16.9	9.069	0.285	-0.125
41	LAD 463/05	lines	9.2	10.8	13.1	26.0	10.025	0.288	-0.120
42	POB 759/04	lines	10.9	9.1	9.7	21.4	8.633	0.879	-0.093
43	POB 0616	lines	8.7	10.1	11.3	26.0	7.885	0.295	-0.092
44	KBP 05 271	lines	10.8	10.4	12.4	22.0	11.383	0.532	-0.048
45	POB 0212	lines	15.5	8.7	10.9	19.9	8.878	0.683	-0.045
46	NAD 260/10	lines	9.7	10.3	11.6	24.7	14.478	0.297	-0.038
47	MOB 28 301206	lines	16.0	7.7	8.6	22.0	12.018	0.545	-0.029
48	NAD 4019/14	lines	15.1	10.0	9.8	26.2	13.215	0.398	0.034
49	DD 408/07-3	lines	18.1	8.7	10.6	18.3	12.620	0.476	0.036
50	NAD 14012	lines	18.0	9.6	11.3	20.6	12.923	0.379	0.042
51	SMH 9168	lines	16.0	12.2	15.1	17.8	10.323	0.514	0.049
52	STH 102	lines	11.6	14.3	16.4	21.6	11.498	0.411	0.055
53	NAD 394/07	lines	17.7	8.4	8.9	21.4	10.758	0.836	0.070
54	POB 1013/10	lines	16.0	9.9	11.5	16.8	11.933	0.811	0.073
55	AND 82/11/50	lines	15.6	7.0	10.7	23.0	15.028	0.390	0.078
56	AND 105/02	lines	9.9	9.6	11.3	27.7	15.640	0.431	0.082
57	DD 557/07	lines	17.3	7.8	8.9	23.8	12.385	0.706	0.099
58	DM 2566/11	lines	12.3	9.0	10.8	30.9	13.240	0.475	0.106
59	DM 272809	lines	15.0	12.5	14.3	24.6	15.644	0.346	0.207
60	NAD 245/13	lines	16.9	8.8	10.2	20.1	12.075	1.132	0.219
61	DCh 47 67/07	lines	14.4	9.9	10.3	30.2	18.543	0.684	0.296
62	DD 548/09	lines	16.3	11.8	13.8	25.4	14.601	0.670	0.310
63	RGT Kilimanjaro	cultivars	20.8	12.2	15.8	20.5	12.608	1.029	0.454
64	KBP 05 284	lines	24.4	11.1	12.4	24.2	17.228	0.791	0.535
65	DD 559/07	lines	18.2	8.3	10.4	48.1	18.058	0.350	0.568
66	KBP 08 13	lines	17.3	10.3	11.9	22.5	14.975	1.692	0.597
67	DL 423/11/2	lines	15.5	23.5	25.4	26.4	14.523	0.759	0.697
68	NAD 16/078	S	32.0	15.8	17.3	24.1	15.058	0.684	0.737
69	C 3779/10	S	13.0	8.6	9.6	60.8	30.973	0.391	1.036
70	AND 4008/10	S	19.7	9.9	11.8	56.4	22.263	0.899	1.081
71	SMH 8694	S	39.2	14.5	18.0	28.3	14.763	1.083	1.094
72	SMH 8816	S	41.8	17.1	21.4	24.9	16.059	0.955	1.200
73	Patras	cultivars	25.5	15.1	22.1	54.2	23.073	0.730	1.452
74	Artist	cultivars	30.9	18.3	22.0	40.7	21.575	1.404	1.551
75	DL 325/11/2	S	37.1	21.6	23.0	37.1	25.628	1.555	1.831
76	DL 358/13/4	S	63.2	40.5	42.1	54.5	27.790	2.047	3.242
77	DL 358/13/4	S	51.4	30.5	34.6	74.3	39.833	4.195	4.376
Means			14.7	9.9	11.4	20.3	11.205	0.601	

* average of standardized values of FHBi, FDK #, ERG, TCT B and ZEN

Fusarium head blight index correlated highly significantly with *Fusarium* kernel damage and concentration of trichothecenes and zearalenone in the grain (Table 2). The lowest was the correlation coefficient for ERG, the highest for FDK #. *Fusarium* kernel damage correlated significantly with concentrations of all the toxins. The highest coefficient was found for 3AcDON, the lowest for DON. Contents of ergosterol (indicator of the amount of mycelium in the grain) correlated significantly with head infection severity, *Fusarium* kernel damage and toxin concentrations. The highest coefficient was found for the sum of trichothecenes B, the lowest for ZEN.

Table 2. Correlation coefficients between the average values of the Fusarium head blight index, *Fusarium* kernel damage and the average content of ergosterol and *Fusarium* toxins in grain of winter wheat lines.

Variables	FHBi	FDK m	FDK #	ERG	DON	3AcDON	NIV	TRT B
FDK m	0.831							
FDK #	0.842	0.986						
ERG	0.701	0.668	0.698					
DON	0.681	0.658	0.669	0.919				
3AcDON	0.811	0.802	0.810	0.829	0.848			
NIV	0.805	0.757	0.792	0.830	0.737	0.790		
TRT B	0.770	0.738	0.757	0.946	0.972	0.888	0.875	
ZEN	0.729	0.694	0.701	0.620	0.600	0.760	0.722	0.685

Coefficients significant at P ≤ 0,001; variables log transformed

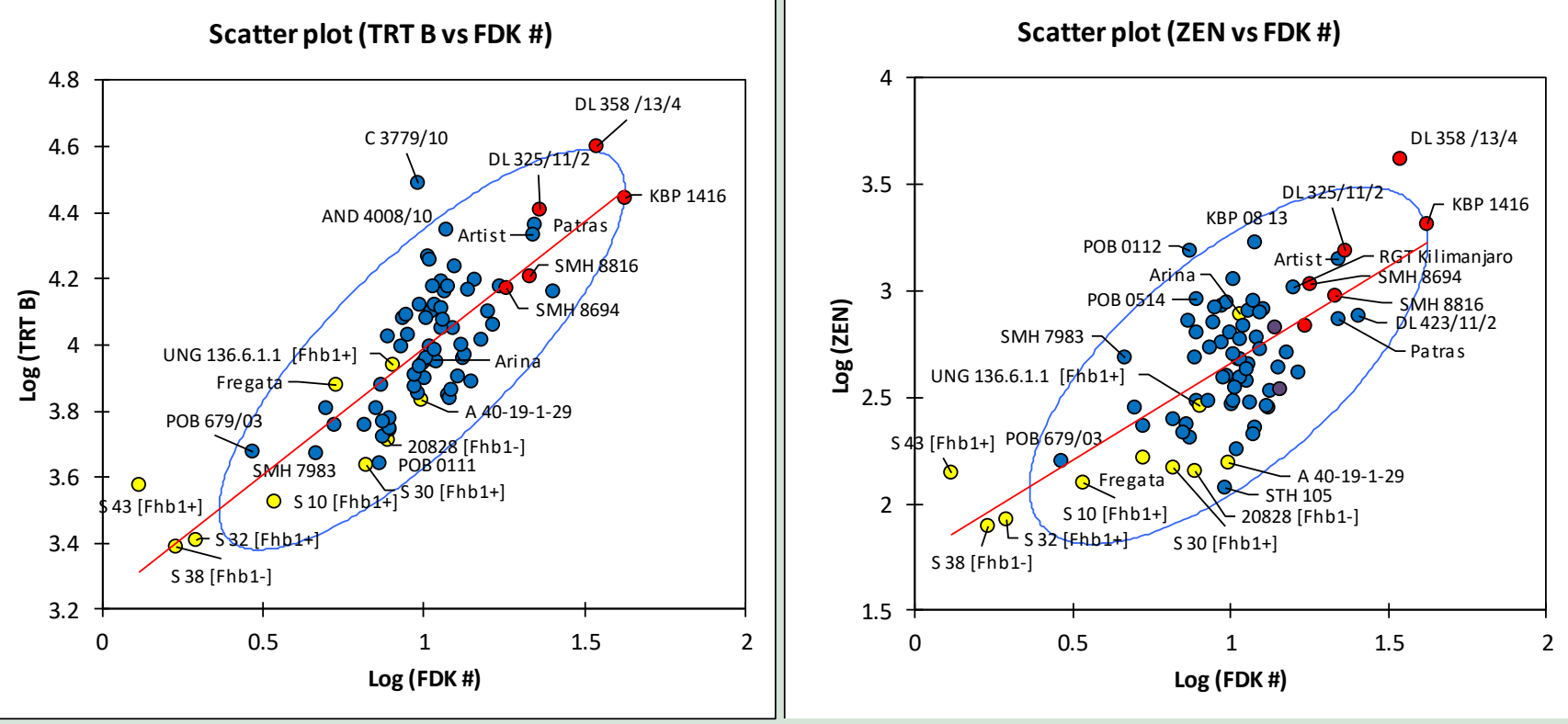


Figure 2. Relationship between *Fusarium* damaged kernels (number) and content of trichothecenes B (TRT B) and zearalenone (ZEN) in grain of 77 lines of winter wheat. Variables log transformed

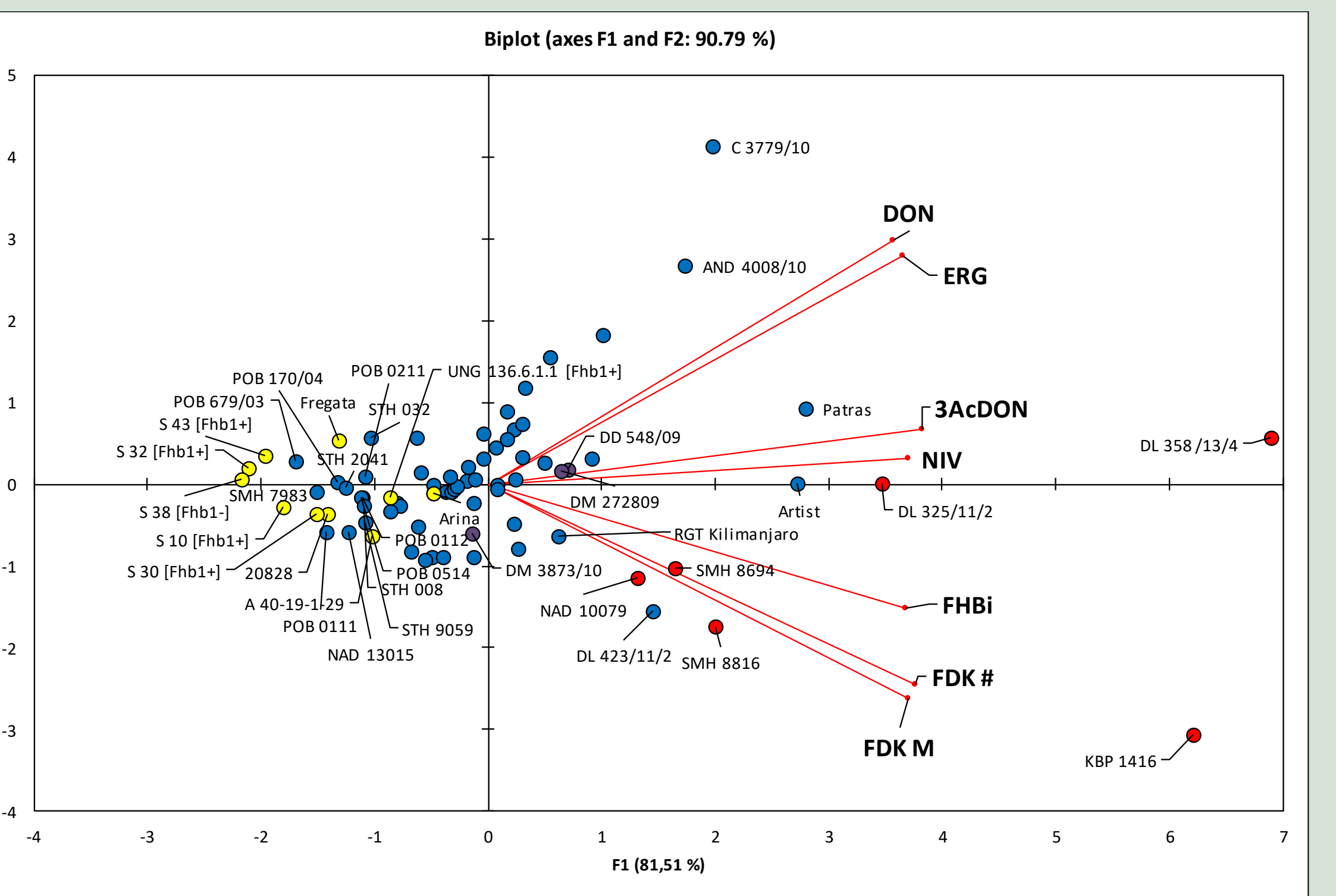


Figure 3. Biplot of the principal component analysis for 77 genotypes of winter wheat. Two first components explained 90.79% of the variability of resistance to Fusarium head blight measured with FHB index (FHBi), *Fusarium* kernel damage (FDK m, FDK #) and contents of ergosterol (ERG), zearalenone (ZEN) and trichothecenes B (TCT B) in the grain in Radzików and Cerekwica. Vectors indicate the direction of the increase of the value of the variables.

Principal component analysis allowed to identify lines that combined different types of FHB resistance, namely: types I + II – FHB index, type III – *Fusarium* kernel damage and ERG content, type IV – accumulation of toxins DON and ZEN (Fig. 3). These were the genotypes: 'S 38 [*Fhb1*-]', 'S 32 [*Fhb1*+]', 'S 43 [*Fhb1*+]', 'POB 679/03', 'SMH 7983', 'POB 170/04', 'STH 2041', 'Fregata', 'S 30' [*Fhb1*+]', '20828 [*Fhb1*-]', 'POB 0111', NAD 13015', 'STH 008', 'STH 9059'POB 0112', 'POB 0514', A 40-19-1-29', 'POB 0211', 'ST 032'.