Stability of resistance to Fusarium head blight and *Fusarium* toxin accumulation in winter wheat lines evaluated in years 2016 and 2017 in two experimental locations

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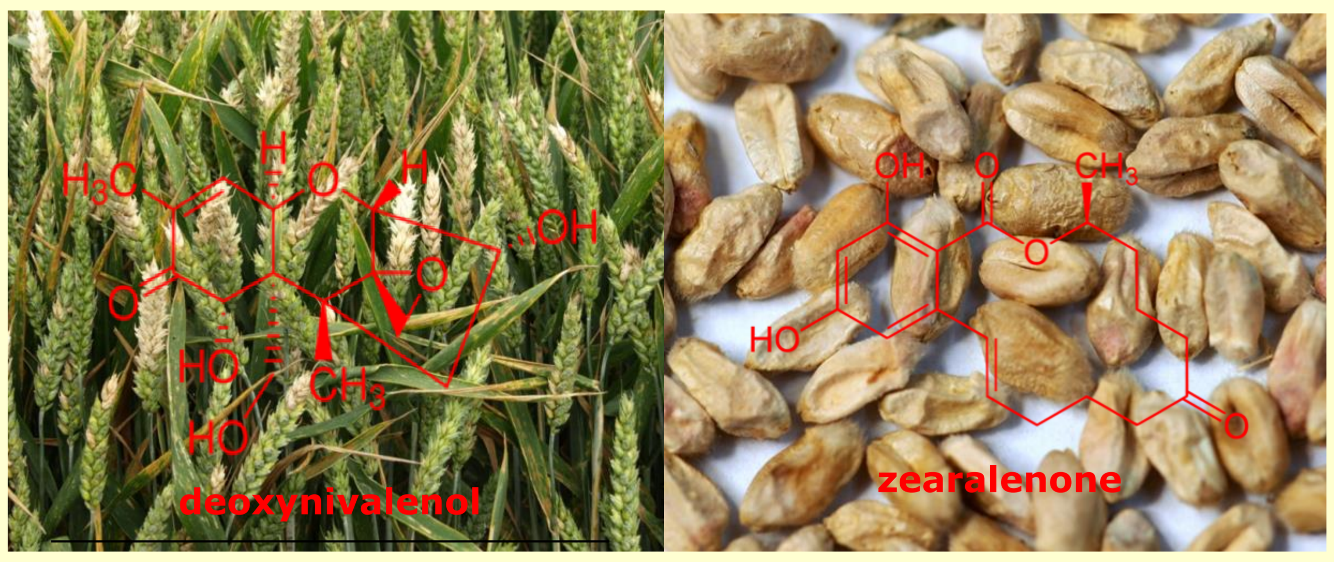

Fusarium head blight (FHB) is a disease of cereals caused by *Fusarium* fungi (mainly *F. culmorum* and *F. graminearum*). These fungi produce toxic metabolites - mycotoxins, with phyto-and zootoxic effects. In the grain of wheat the most common are toxins belonging to trichothecenes B: deoxynivalenol (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 through their chemical modification (class 1) or blocking synthesis (class 2).

The aim of the research was to assess the variability of winter wheat genotypes in response to infection with *F. culmorum* by examination of the above-mentioned types of resistance and finding genotypes combining resistance of all types and showing stability of reaction over different environments.

Materials and method

To select the forms of winter wheat combining different types of resistance 49 lines were evaluated in the field experiments in two locations (Poznań, Radzików) in years 2016 and 2017. They included eight resistant checks (R): 20828 [*Fhb1*-], A40-19-1-2, Arina, Fregata, S 10 [*Fhb1*+], S 30 [*Fhb1*+], S 32 [*Fhb1*+], UNG 136.6.1.1 [*Fhb1*+]; three susceptible checks (S); two lines with a high accumulation of trichothecenes (TOX). Wheat heads were inoculated at the full flowering stage with the spore suspension of aggressive isolates of *F. culmorum* producing DON 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 spiklest 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 kernel number = FDK). Using the techniques liquid and of gas chromatography as well as immunoenzymatic tests the contents of ergosterol, DON, acetyl derivatives of DON, NIV and ZEN in the grain was analysed.

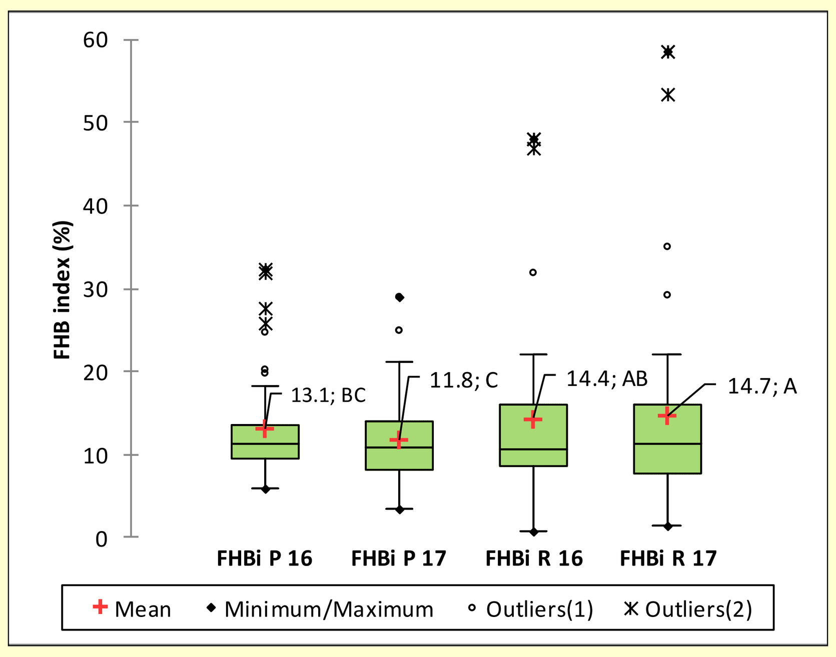

Figure 1. Fusarium head blight index (FHBi) in four environments: two years — 2016, 2017; two locations—Poznań (P), Radzików (R) for 49 winter wheat lines. Rectangles show the first quartile, the median and the third quartile. Whiskers show the lower and upper limit beyond which the values are outliers. Means marked with the same letters are not significantly different.

Results

Average FHB index over four environments was 13.5%; the range of variation from 0.7 to 58.7% (Fig. 1). Average FHB indexes in the environments were similar, however they differed significantly. Average FHB indexes for the 49 lines tested in experiments in 2016 and 2017 correlated significantly (r=0.632 - 0.845). Lines with stable reaction in all four environments were identified - resistant: six resistant checks except Arina and A40-19-1-2 and lines: AND 260/10, KOH 275, POB 0211, POB 0514, POB 679/03, SMH 7983, STH 032, STH 2041; susceptible: DD 548/09 (tox), NAD 10079 (S), SMH 8694 (S), SMH 8816 (S) (Fig. 2). Susceptible lines showed higher variability of reaction in different environments that resistant ones. The most stable was reaction of three resistant lines POB 679/03, STH 2041, KOH 275 and SMH 7983.

Resistant line 'POB 679/03'

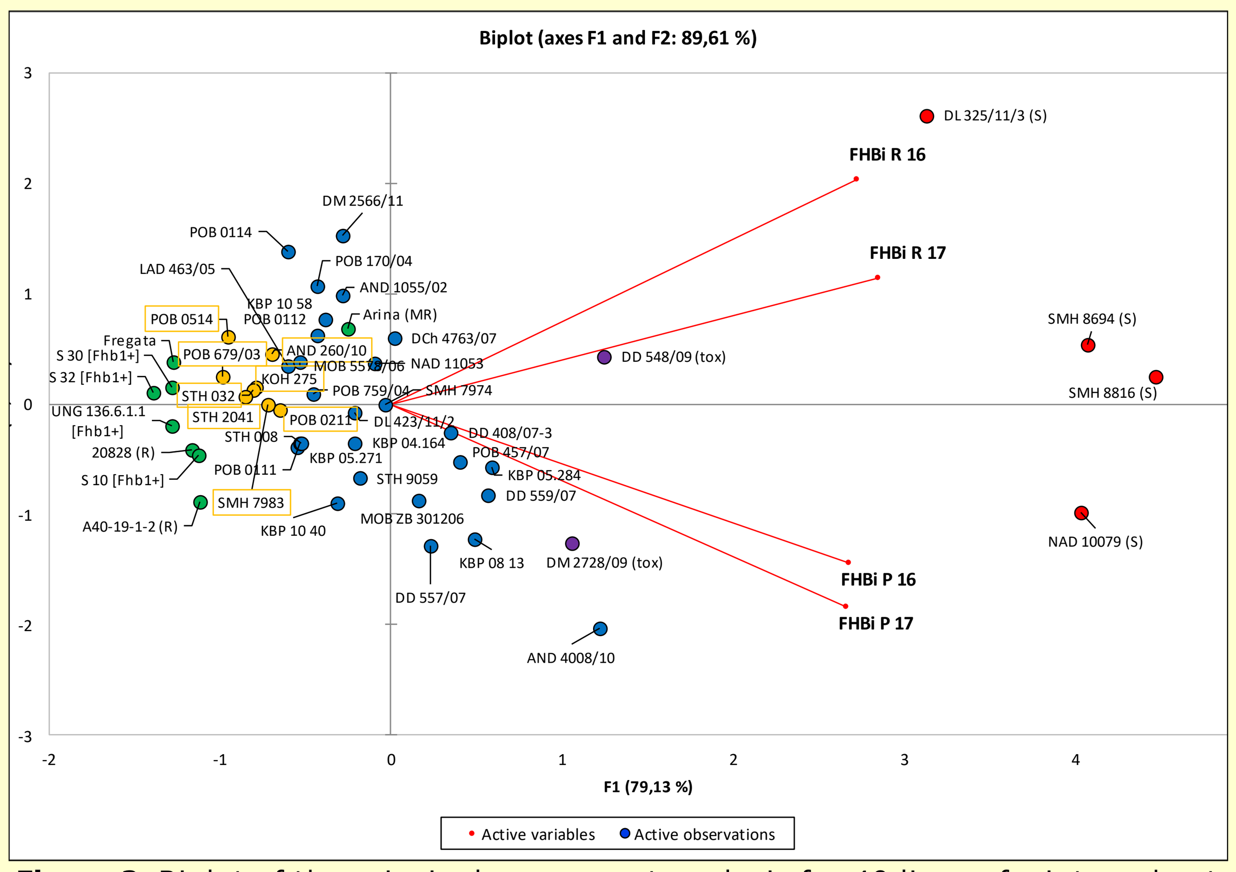

Figure 2. Biplot of the principal component analysis for 49 lines of winter wheat. Two first components explained 89.61% of the variability of resistance to Fusarium head blight measured with FHB index (FHBi) in Poznań and Radzików in 2016 and 2017. Vectors indicate the direction of the increase of the value of the variables. Red circles—susceptible checks, violet circles—toxin checks, green circles—resistant checks, orange circles—the most resistant lines the most resistant to head infection.

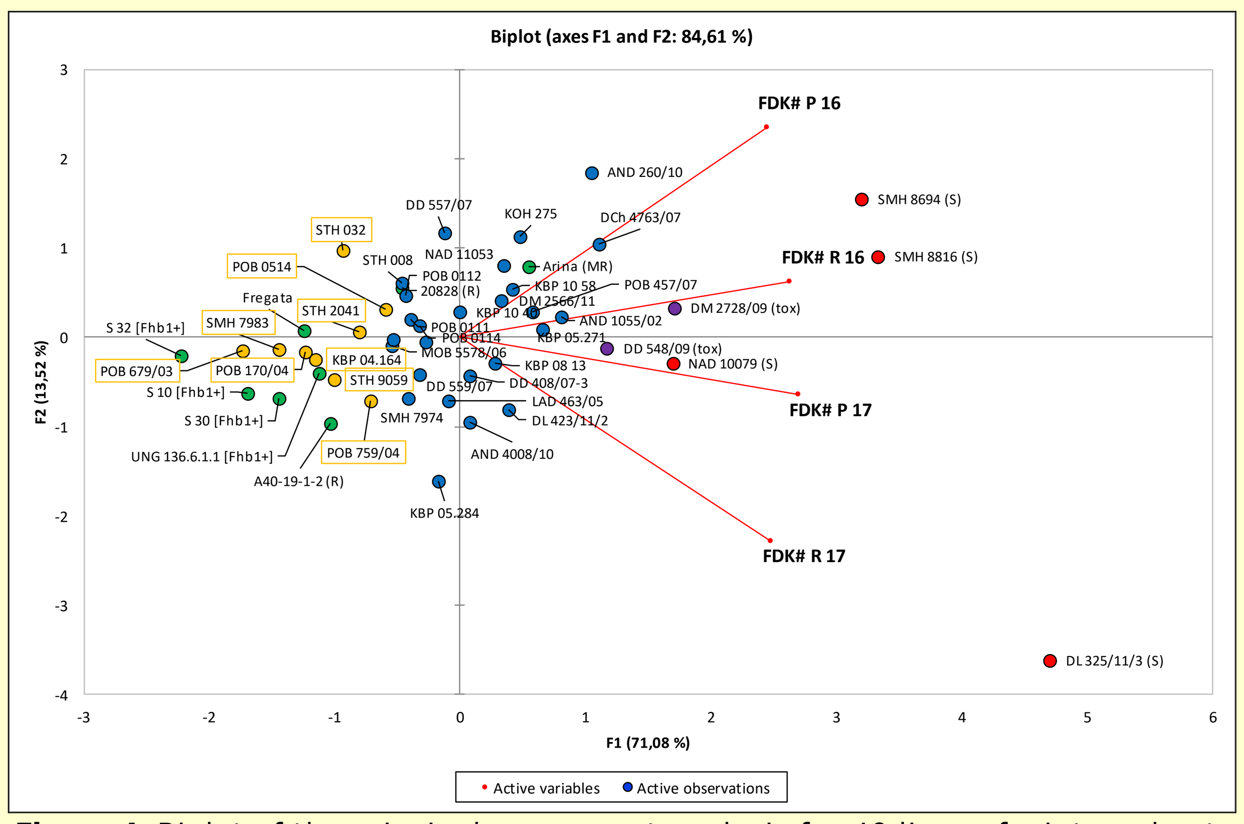

Figure 4. Biplot of the principal component analysis for 49 lines of winter wheat. Two first components explained 84.61% of the variability of resistance to Fusarium head blight measured with proportion of *Fusarium* damaged kernels (FDK) in Poznań (P) and Radzików (R) in 2016 and 2017. Vectors indicate the direction of the increase of the value of the variables. Red circles—susceptible checks, violet circles—toxin checks, green circles—resistant checks, orange circles—lines the most resistant to kernel damage.

Average FDK over four environments was 11.5%; the range of variation from 1.6 to 35.6% (Fig. 3). Average FDK values in Poznan and Radzików in 2016 and 2017 were similar, despite FDK in 2017 in Radzików, which was significantly lower. It resulted from low precipitation in Radzików after inoculation. Average FDK values for the 49 lines tested in experiments in 2016 and 2017 correlated significantly (r = 0.475 - 0.685), however coefficients were lower than for FHB indexes. Lines with stable reaction in all six environments were identified - resistant: five checks: S 32 [Fhb1+], Fregata, UNG 136.6.1.1, S 10 [Fhb1+], S 30 [Fhb1+], and lines: SMH 7983, POB 679/03, POB 170/04, KBP 04.163, STH 9059, STH 2041; susceptible: SMH 8694 (S), SMH 8816 (S), DM 2728/09 (tox), NAD 10079 (S) (Fig. 4). Susceptible lines showed higher variability of reaction in different environments that resistant ones. The most stable was reaction of highly resistant checks — S 32 [Fhb1+], S 10 [Fhb1+], S 30 [Fhb1+], Fregata and resistant lines — POB 679/03 and SMH 7983.

Average FHB indexes and FDK values for the 49 lines tested in experiments in 2016 and 2017 correlated significantly (r=0.433 - 0.817).

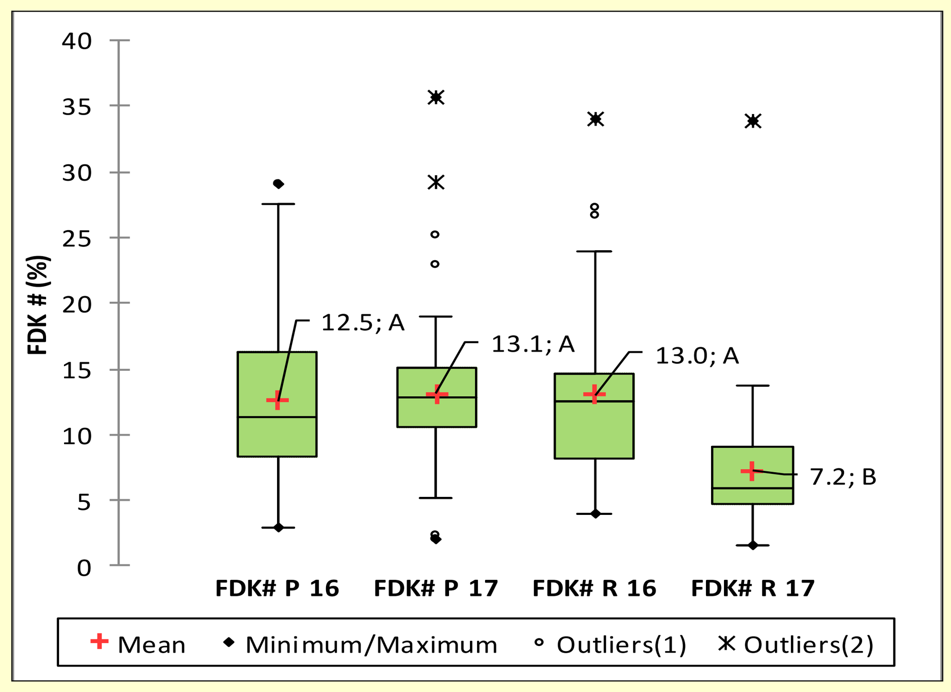

Figure 3. Fusarium damaged kernels (FDK) in four environments: two years — 2016, 2017; two locations — Poznań (P), Radzików (R). Rectangles show the first quartile, the median and the third quartile. Whiskers show the lower and upper limit beyond which the values are outliers. Means marked with the same letters are not significantly different.

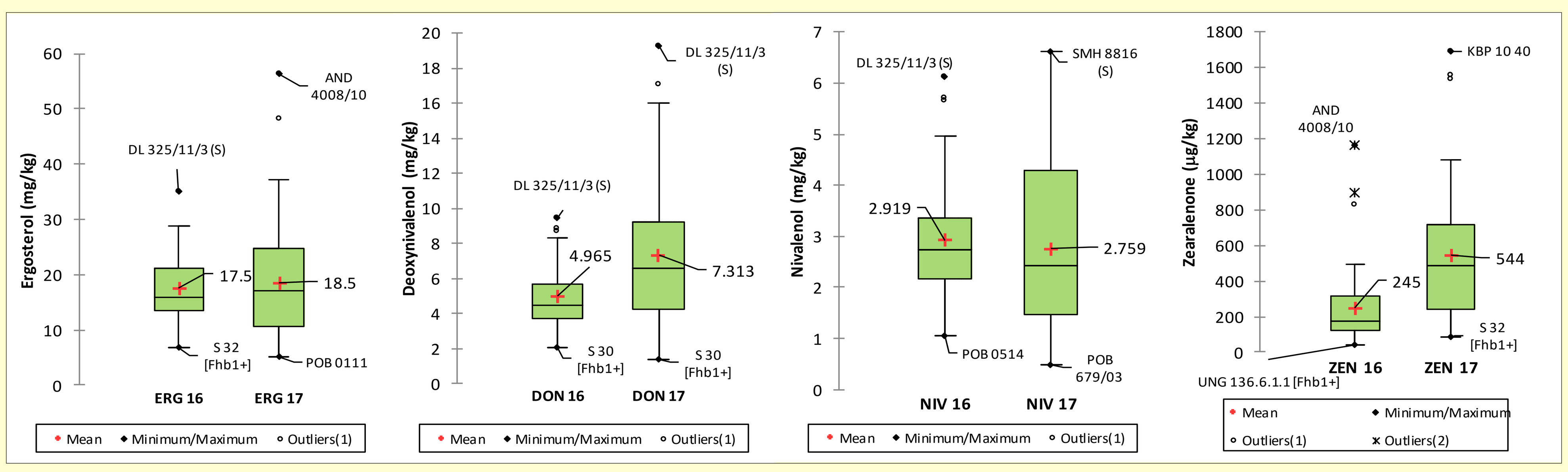

Figure 5. Content of ergosterol (ERG), deoxynivalenol (DON), nivalenol (NIV) and zearalenone (ZEN) in the grain of 49 wheat lines in years 2016 and 2017 (averages from two locations — Poznań, Radzików). Rectangles show the first quartile, the median and the third quartile. Whiskers show the lower and upper limit beyond which the values are outliers.

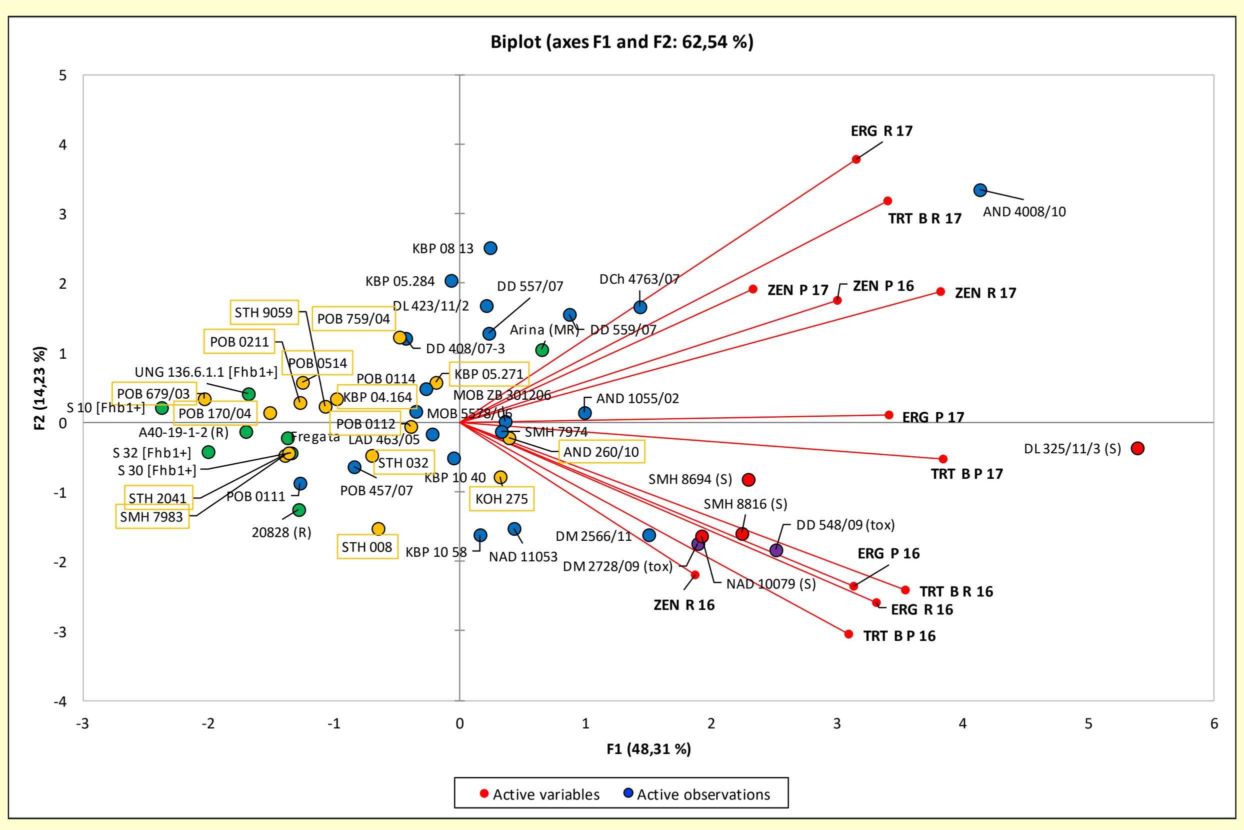

Figure 6. Biplot of the principal component analysis for 49 genotypes of winter wheat. Two first components explained 62.54% of the variability of concentration of ergosterol (ERG), trichothecenes B (TRT B) and zearalenone (ZEN) in grain in Poznań (P) and Radzików (R) in 2016 and 2017. Vectors indicate the direction of the increase of the value of the variables. Red circles — susceptible checks, violet circles — toxin checks, green circles — resistant checks, orange circles — lines the most resistant to head infection and/or kernel damage.

Average ERG content in grain over four environments was 18.0 mg/kg; the range of variation from 2.5 to 65.9 mg/kg (Fig. 5). Average ERG concentration in 2016 and 2017 were similar and not differ significantly. In Radzików average ERG concentration was significantly lower than in Poznań (14.5 and 21.5 mg/kg, respectively). Average DON content in grain over four environments was 6.139 mg/kg; the range of variation from 1.080 to 23.935 mg/kg (Fig. 5). DON content was significantly higher in 2017 than in 2016. In Radzików average DON concentration was significantly higher than in Poznań (6.633 and 5.645 mg/kg, respectively). Average NIV content in grain was 2.893 mg/kg; the range of variation from 0.075 to 11.625 mg/kg (Fig. 5). NIV content was similar in 2017 and 2016. In Radzików average NIV concentration was 3-fold lower than in Poznań (1.108 and 4.570 mg/kg, respectively). Average ZEN content in grain was 395 μg/kg; the range of variation from 0 to 3252 μg/kg (Fig. 5). ZEN content was significantly higher in 2017 than in 2016. In Radzików average ZEN concentration was 14-times lower than in Poznań (53 and 737 μg/kg, respectively).

Lines with stable concentration of *Fusarium* metabolites in all four environments were identified - low conc.: POB 679/03, POB 170/04, POB 0514, STH 9059, STH 20141, SMH 7983, STH 9059; high conc.: DL 325/11/3/(S), SMH 8694 (S), DD 548/09 (tox) (Fig. 6). Four lines (POB 679/03, POB 0514, STH 2041, SMH 7983) combined low head infection, low kernel damage and low toxin accumulation. Three lines (STH 9059, KBP 04.164, POB 170/04) combined low kernel damage and low toxin accumulation and two (STH 032, POB 0211) low head infection and low toxin accumulation.

FHBi and FDK correlated mostly significantly with concentration of *Fusarium* metabolites in four environments (r=0.083-0.837, r=0.302-0.814). ERG, trichothecenes B and ZEN concentration in 2016 and 2017 correlated significantly (r=0.487; r=0.520-0.559; r=0.397, respectively).

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