The Relationship between Diseases Index of Septoria Leaf Blotch, Leaf Rust and Yield Losses in Bread Wheat Cultivar in Albania

Vrapi Hekuran1, Gixhari Belul2, Kashta Fato3, Sulovari Halit2 and Ruci Thanas1
1. Department of Plant Protection, Faculty of Agriculture and Environment, Agricultural University of Tirana, Tirana 1000, Albania
2. Albanian Genebank, Agricultural University of Tirana, Tirana 1000, Albania
3. Department of Crop Production, Faculty of Agriculture and Environment, Agricultural University of Tirana, Tirana 1000, Albania

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Abstract: Both grain yield and disease performance are important factors to consider for winter wheat (Triticum aestivum) cultivar selection. However, disease index and yield data are often presented separately, making it difficult to compare values across multiple environments. Two-year investigations (2009-2010), in which eight common wheat lines/genotypes were included to test their susceptibility against wheat LR (leaf rust) Puccinia triticina f. sp. tritici Roberge ex Desm., and the SLB (Septoria/Stagonospora leaf blotch) complex Septoria tritici Desm. and Stagonospora nodorum, were carried out in the experimental field of ATTC (Agriculture Technology Transfer Centre) of Lushnje (Albania). The objective of this study was to use a rank-based method to compare cultivars based on yield and disease performance combined across multiple environments. Analysis of variance revealed the presence of an important and significant variability in the experimental materials used to evaluate the susceptibility and the resistance of common wheat lines against SLB and LR. There were high negative correlations between yield—S. tritici (0.6683) and yield—P. recondita f. sp. tritici (0.5261). The negative effects of two pathogens have shown “the parallel”/similar negative influences on yield trait and there was a high positive correlation (0.7631) between S. tritici and P. recondita f. sp. tritici. According to study results the lines Regina × L-776, IKB-P6 and Bullgar 3 × KB 703 have shown good results of resistance (R) level against S. tritici and P. recondita f. sp. tritici.

Key words: Wheat, disease index, leaf rust, Septoria tritici blotch.

1. Introduction

Winter wheat is one of the most important cereal crops in Albania. Diseases, especially leaf diseases, of wheat are causing important losses of the yield. Since the 1990, wheat has been grown under increasingly intensive management regimes in part of the farms. These changes in the cropping system have increased incidence and severity of the wheat diseases [1].

In Albania, large economic losses are mainly due to rust epidemics (usually Puccinia triticina) and Septoria tritici leaf blotch (mainly Septoria tritici) [1, 2]. Conditions that favor development of these diseases usually coincide with conditions that favor crop growth and their main effects are to reduce yield and quality in years with the highest productive potential [3]. SLB (Septoria leaf blotch), caused by the fungus Mycosphaerella graminicola (Fuckel) Schroeter (anamorph: Septoria tritici Roberge in Desmaz) is a major disease of wheat (Triticum aestivum L. em. Thell) worldwide. In highly susceptible cultivars, this disease may reduce grain yield by 50% [3]. Where environmental conditions are favorable for disease development, yield losses ranging from 20% to 43% have been reported, Septoria leaf blotch can reduce the economic value of

Corresponding author: Vrapi Hekuran, master, main research field: disease resistance in plant pathology. E-mail: hvrapi@gmail.com.
wheat by decreasing both grain yield and quality [4].

Wheat leaf rust (caused by *Puccinia recondita* f. sp. *tritici*; *Prt*) is widespread throughout Europe, and is regarded as an important disease in many eastern and western (European country considered the disease a threat in north-western regions of Europe, as well as a permanent problem in southern and south-eastern regions) [5].

The cultivation of wheat since 1990 under increasingly intensive management has increased the incidence and severity of its diseases [1, 2]. At the Agricultural University of Tirana trials for wheat breeding has been in place in the last five decades enabling also long-term resistance trials [1, 2]. Genetic resistance is the most profitable control approach for all leaf diseases from both economical and ecological perspectives. Growing resistant wheat cultivars is one of the most economical and effective methods of control wheat LR (leaf rust) (*Puccinia triticina* f. sp. *Tritici* Roberge ex Desm.), and the SLB (*Septoria tritici* Desm.). In the wheat growing region of Lushnje, which contributes with 26% of the total wheat surface in Albania, these environmental conditions are common during the tiller and shoot forming phases [6]. Management of these diseases should be based on the use of resistant varieties since the persistence of available fungicides is not sufficient to protect the plant during the whole cycle [4]. This study was conducted to determine the relationship of the wheat LR (*Puccinia triticina* f. sp. *tritici* Roberge ex Desm.) and the SLB (*Septoria tritici* Desm.) index at the soft dough stage to yield losses for eight bread wheat cultivars.

2. Materials and Methods

2.1 Locations and Experimental Design

In conjunction with the National Test of Seeds and Saplings Office in the experimental fields ATTC (Agricultural Technology Transfer Centre) Lushnje (40°57′06″N, 19°41′08″E), Albania, disease index (*DI* = *Imc*) and grain yield data were collected over two growing seasons, 2008-2009 and 2009-2010, here after referred to as 2009 and 2010. Wheat cultivars are planted in randomized blocks with four replications. Each plot was 20 m². Agro-technical practices have been the same based on type protocol established previously for the distance of planting, seed rate, doses of fertilizers, hoeing, etc..

2.2 Plant Material

In the National Test of Seeds Office were planted eight promising cultivars for production for the two years study period (Bullgar 3 × KB 703 (L1), IKB-P6 (L2), LVS -93 (L3), Ni 792 (L4), Progresi (L5), Regina × L-776 (L6), Salgema (L7), Dajti (X kontroll) (L8). Cultivars planted in the performance tests included both public and private materials and experimental lines submitted by small grain breeders.

2.3 Disease Assessments

2.3.1 Times Assessments

Assessment of Septoria leaf blotch and Wheat leaf rust were made two times each Zadoks: GS (growth stage) 60 and GS 75. Two measures were obtained per stem for each leaf disease: incidence (presence or absence of disease anywhere on the plant) and severity (percentage of each leaf with disease symptoms). The leaves that were assessed changed as the growing season progressed [7]. For both the GS 60 and GS 75 assessments, disease incidence and severity were assessed on the upper two leaves (flag and flag⁻¹)

2.3.2 Visual Estimation

Visual estimation of disease severity from natural infection by Septoria leaf blotch (*Septoria tritici* Roberge in Desmaz) and Wheat leaf rust (caused by *Puccinia recondita* f. sp. *tritici*; *Prt*) was used. Assessment of Septoria leaf blotch (*Septoria tritici* Roberge in Desmaz) and Wheat leaf rust (caused by *Puccinia recondita* f. sp. *tritici*; *Prt*) infections has been based on SADs (standard area diagrams) the percent of covered leaves surface occupied by the disease (Tables 1 and 2).
Severity and diffusion of infection were obtained by resorting to the McKinney index [8]. The Imc (McKinney Index) was obtained by using Eq. (1):

\[
DI (\text{Imc}) = \frac{\sum (f \times v)}{(N \times X)} \times 100
\]

(1)

where,
- \(f\) = infection class frequencies;
- \(v\) = number of plants of each class;
- \(N\) = total of observed plants;
- \(X\) = highest value of the evaluation scale.

In order to have a clear behaviour for each genotype of cultivars, a categorization of modified McKinney Index (Imc) has been made as follows: I—no pycnidial formation (Imc < 1%); VR—very resistant where average pycnidial density (Imc = 1%-5%); R—resistant of average pycnidial density (Imc = 5%-15%); MR—moderately resistant—average pycnidial density coverage (Imc = 15%-30%); MS—moderately susceptible of average pycnidial density coverage (Imc = 30%-40%); S—susceptible of pycnidial density greater (Imc > 40%) [9-13].

### 2.3 Yield Analysis

Total yield was assumed to be related to the components of yield (number of tillers, number of kernels per head, and 500 kernel weight) by Eq. (2):

\[
y = t \times k \times w \times c
\]

(2)

where, \(y\) = grain yield in kilograms per hectare; \(t\) = number of tillers per meter row; \(k\) = number of kernels per head where number of heads is assumed to equal number of tillers in a given area; \(w\) = weight of 500 kernels; \(c\) = a constant that includes correction for differences in units.
2.4 Statistical Date Analysis

All statistical analyses were performed using GLM (general linear modeling) procedure with Means Comparisons for each pair using student’s t-tests calculated in SAS 2009 software (SAS Institute Inc. 2009) [14].

All the observations in the experimental field and dependent variables were subjected to analysis of variance (ANOVA). Distances between wheat genotypes using hierarchical clustering method and correlations coefficients between characters were calculated for all traits analyzed in the study. SE (standard error) and coefficient of variation (CV in %) were also computed.

3. Results and Discussion

Two-year investigations (2009-2010), in which eight common wheat lines/genotypes were included to test their susceptibility against Septoria leaf blotch (<i>Septoria tritici</i> Rob) and leaf rust (<i>Puccinia recondita</i>), were carried out in the experimental field of ATTC of Lushnje (Albania).

The trials were set up according to the randomized complete block design at four replications, during two years. Standard agro-technical practices for this wheat types were applied during crop growing. Observation of diseases symptoms and reaction results of common wheat lines against Septoria leaf and leaf rust are summarized in Tables 3 and 4 and Figs. 1 and 2.

3.1 Septoria Leaf Bloch (<i>Septoria tritici</i> Rob) Results

Analysis of variance revealed the presence of an important and significant variability in the experimental materials used to evaluate the susceptibility and the resistance of common wheat lines against SLB. Confrontation of $F$ ratio values $F_{\text{facts}}$ (11.669) is greater than $F_{\text{theory}}$ values (2.49; 3.64) shows the presence of significant differences at $P_{0.05}$ and $P_{0.01}$ levels of probability (Table 4) in plant materials tested (Table 3). The data of Table 3 shows that the significant differences between eight common wheat lines related to their resistance against SLB were also observed. Means comparisons for each pair using student’s $t$ test range common wheat lines into four different levels (a, ab, b and c) where levels not connected by the same letter are significantly different. According to study results the lines L7, L1 and L3 with the small mean values of McKinney’s Index $I$ (Imc) have shown very good results of resistance ($R$) level against SLB. All the other common wheat lines, significantly different or not between them according to student’s $t$ test for means value of McKinney’s

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Disease index &lt;i&gt;Septoria tritici&lt;/i&gt; results 2009-2010 (Imc) in %</th>
<th>Disease index &lt;i&gt;Puccinia recondita&lt;/i&gt; results 2009-2010 (Imc) in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td>Bullgar 3 x KB 703</td>
<td>26.00 ± 7.12</td>
<td>17.24 ± 7.00</td>
</tr>
<tr>
<td>IKB-P6</td>
<td>37.45 ± 4.79</td>
<td>37.45 ± 4.79</td>
</tr>
<tr>
<td>Regina x L-776</td>
<td>28.10 ± 3.97</td>
<td>17.24 ± 7.00</td>
</tr>
<tr>
<td>Ni 792</td>
<td>31.23 ± 4.15</td>
<td>31.21 ± 15.75</td>
</tr>
<tr>
<td>Salgema</td>
<td>29.13 ± 3.39</td>
<td>34.25 ± 3.92</td>
</tr>
<tr>
<td>L V S -93</td>
<td>35.38 ± 4.15</td>
<td>31.20 ± 2.42</td>
</tr>
<tr>
<td>Progresi</td>
<td>20.80 ± 4.85</td>
<td>14.65 ± 7.77</td>
</tr>
<tr>
<td>Dajti (X kontroll)</td>
<td>34.33 ± 5.24</td>
<td>30.18 ± 3.99</td>
</tr>
<tr>
<td>Mean</td>
<td>30.30 ± 1.23</td>
<td>26.68 ± 2.18</td>
</tr>
<tr>
<td>St.dev</td>
<td>5.46</td>
<td>8.86</td>
</tr>
</tbody>
</table>

Levels not connected by same letter are significantly different. a: susceptibility; b: moderately resistant; c: resistance.
Table 4  Analysis of variance for common wheat resistance/susceptibility against *Septoria tritici* Rob. and *Puccinia recondita* (ATTC Lushnje trials: 2009-2010).

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Df*</th>
<th>Sum of squares S. tritici</th>
<th>Mean square S. tritici</th>
<th>F ratio S. tritici</th>
<th>Prob &gt; F S. tritici</th>
<th>Mean square P. recondita</th>
<th>F ratio P. recondita</th>
<th>Prob &gt; F P. recondita</th>
</tr>
</thead>
<tbody>
<tr>
<td>lines</td>
<td>7</td>
<td>1328.4479</td>
<td>1660.6821</td>
<td>189.778</td>
<td>237.240</td>
<td>11.6690**</td>
<td>6.1567**</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Error</td>
<td>24</td>
<td>390.3216</td>
<td>924.8040</td>
<td>16.263</td>
<td>38.533</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. total</td>
<td>31</td>
<td>1718.7695</td>
<td>2585.4861</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Df*: degree of freedom.

3.2 Results for Leaf Rust (*Puccinia recondita*)

Results for leaf rust resistance of eight common wheat lines are given in Table 3 and Fig. 2. Analysis of variance show the presence of an important variability in the experimental plant materials used to evaluate the susceptibility of common wheat lines against LR. *F* ratio value (6.1567 greater than *F*theoric values 2.49, 3.64) show that the differences between plant materials tested were significant at *P*0.05 and *P*0.01 levels of probability (Table 4).

Study results given in Table 3, show that significant differences for resistance against LR *t* among eight common wheat lines were also observed. Means comparisons for each pair using student’s *t*-test grouped common wheat lines into two significantly different levels (a, b). Related to common wheat resistance against leaf rust the common wheat lines, with small mean values of Imc L1, L7 and L3, have shown good level of resistance against leaf rust and these lines were included into *R* group. All the other wheat lines, not significantly different between them according to student’s *t*-test for means value of McKinney’s Index *I* (Imc), have shown MR level against LR. Illustration of these results is given in Fig. 4, where three wheat lines L1, L7 and L3, (the red circles under the mean-axis of Fig. 2), have shown more high level of *R* level against LR than the other wheat lines classified into class a and grouped into MR level (presented by the black circles above mean axis of Fig. 2).

3.3 Results for Yield of Eight Common Wheat Lines

Results for yield of eight common wheat lines attacked by Septoria leaf blotch and leaf rust are given in Table 5 and Fig. 3.

Analysis of variance show the presence of important differences related to yield trait. *F* ratio
value (20.2968) is significant at $P_{0.05}$ and $P_{0.01}$ levels of probability (Fig. 3). Comparison of means for each pair using student’s $t$ test show the significant differences for yield between eight common wheat lines and grouped these lines into three different levels: lines L7 and L3 with the best yield results into class a; lines L1 and L2 into class b, and all other lines into class c. The lines, signed with letter a, were significant at $P_{0.05}$ and $P_{0.01}$ levels of probability (Table 6). These results were also illustrated in Fig. 3, where the best yield lines, signed by the red circles, are situated above all the mean axis see illustration in Fig. 3.

3.4 Influence of Septoria Leaf Blotch and Leaf Rust on Yield of Common Wheat Lines

Results for disease influences on yield of eight common wheat lines, and comparison of means between fact yield (FY), expected yield if all wheat lines were moderate resistant (YifMR) and expected yield if all wheat lines were resistant (YifR) given in Table 5, show: first, the disease influences were in negative value or sense related to yield of the wheat lines; second, the negative means value of these diseases effects on yield was range in a large scale; from 11% to 19%; third, the pressing of diseases effects on wheat yield have not been at the same level for each wheat lines tested; and last, the effects of two pathogens have shown “the parallel” or similar negative influences on yield trait. (see illustration in Fig. 4).

3.5 Correlations between Three Measured Characters Were Also Evaluated for All Wheat Genotypes

Multivariate correlation coefficients (Table 7) show a high and positive correlation (0.7631) between Septoria leaf blotch (Septoria tritici) Rob and leaf rust (Puccinia recondita).

### Table 5 Yield of common wheat lines and means comparisons for each pair using student’s $t$-test and influences of $S. \ tritici$ and $P. \ recondita$ on yield trait (ATTC Lushnje trials: 2009, 2010 and two years means 2009-2010).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Yield of common wheat lines results of 2009, 2010</th>
<th>SLB and LR influences on wheat yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 2009</td>
<td>Year 2010</td>
</tr>
<tr>
<td>Bullgar 3 × KB 703</td>
<td>57.50 ± 6.24</td>
<td>50.40 ± 1.64</td>
</tr>
<tr>
<td>IKB-P6</td>
<td>55.75 ± 3.30</td>
<td>49.51 ± 0.78</td>
</tr>
<tr>
<td>Regina × L-776</td>
<td>67.50 ± 5.92</td>
<td>50.90 ± 1.45</td>
</tr>
<tr>
<td>Ni 792</td>
<td>51.50 ± 2.65</td>
<td>45.71 ± 0.78</td>
</tr>
<tr>
<td>Salgema</td>
<td>52.25 ± 4.27</td>
<td>43.71 ± 1.12</td>
</tr>
<tr>
<td>L V S -93</td>
<td>47.00 ± 2.94</td>
<td>46.07 ± 0.72</td>
</tr>
<tr>
<td>Progresi</td>
<td>66.75 ± 3.10</td>
<td>54.57 ± 0.99</td>
</tr>
<tr>
<td>Dajti (X kontroll)</td>
<td>49.75 ± 4.79</td>
<td>46.62 ± 0.86</td>
</tr>
<tr>
<td>Mean</td>
<td>56.00 ± 4.15</td>
<td>48.44 ± 1.04</td>
</tr>
<tr>
<td>St.dev</td>
<td>7.60</td>
<td>3.53</td>
</tr>
</tbody>
</table>

Levels not connected by same letter are significantly different; LSD 2.06390.
a: high yield per unit; b: moderate yield; c: low yield.

### Table 6 Analysis of variance for common wheat lines yields (two years means, ATTC Lushnje 2009-2010).

<table>
<thead>
<tr>
<th>Source</th>
<th>Df*</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>$F$ Ratio</th>
<th>Prob &gt; $F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lines</td>
<td>7</td>
<td>811.10432</td>
<td>115.872</td>
<td>20.2891</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Error</td>
<td>24</td>
<td>137.06498</td>
<td>5.711</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Total</td>
<td>31</td>
<td>948.16930</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Df*: degree of freedom.
There were also high but negative correlation coefficients between SLB (-0.6683) and yield-LR (-0.5261). Relation between yield and influences of two wheat leaf pathogens were illustrated in scatterplot matrix (red-lines and histograms) see illustration in Fig. 4.

3.6 Analysis of Distances between Wheat Cultivars

Study results for distances between wheat cultivars using hierarchical clustering method, range wheat cultivars into four different cluster groups. Distances of wheat cultivars by cluster analysis: three wheat cultivars included in the 1st group-cluster (Bullgar 3 × KB 703, Regina × L-776 and Progresi) were similar between disease index (Imc in %) and grain yield as it is shown in the dendrogram (Fig. 5). Two wheat cultivars included in the 2nd group-cluster (IKB-P6, Salgema and Ni 792) were similar between disease index (Imc in %) and grain yield. Three wheat cultivars included in the 3rd group-cluster ((Dajti X kontroll), LVS-93 and IKB-P6) were similar between disease index (Imc in %) and grain yield (Fig. 5). The relationship between diseases index of Septoria leaf blotch, leaf rust and yield losses in bread wheat cultivars.
Table 7  Multivariate correlations.

<table>
<thead>
<tr>
<th>Source</th>
<th>Yield 2009-2010</th>
<th>S. tritici 2009-2010</th>
<th>P. recondita 2009-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield 2009-2010</td>
<td>1.0000</td>
<td>-0.6683</td>
<td>-0.5261</td>
</tr>
<tr>
<td>S. tritici 2009-2010</td>
<td>-0.6683</td>
<td>1.0000</td>
<td>0.7631</td>
</tr>
<tr>
<td>P. recondita 2009-2010</td>
<td>-0.5261</td>
<td>0.7631</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Fig. 5  Dendrogram by cluster analysis of different common wheat genotypes for all characters analyzed S. tritici × P. recondita × Yield.

Fig. 6  Scatterplot 3D illustration of Mahalanobis distances and the relationships among S. tritici × P. recondita × Yield (2009-2010).

4. Conclusion

Analysis of variance revealed the presence of an important and significant variability in the experimental materials used to evaluate the susceptibility and the resistance of common wheat lines against Septoria leaf (Septoria tritici) Rob., and leaf rust (Puccinia recondita).

Significant differences were also observed among eight common wheat lines for all agronomic traits.
Average percentage of yield lost between common wheat lines tested ranged from 11% to 19%.

There were high negative correlations between yield-Septoria leaf blotch (Septoria tritici) Rob. (-0.6683) and yield of leaf rust (Puccinia recondita) (-0.5261).

The negative effects of two pathogens have shown “the parallel”/similar negative influences on yield trait and there was a high positive correlation (0.7631) between Septoria leaf blotch (Septoria tritici) Rob. and leaf rust (Puccinia recondita).

According to study results the lines L7, L3 and L1 have shown good results of resistance (R) level against Septoria leaf blotch (Septoria tritici) Rob. and leaf rust (Puccinia recondita).

References