PAPER 104

GEOGRAPHIC DISTRIBUTION ASSESSMENT OF THE MAIN WHEAT LEAF DISEASES IN ALBANIA

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ABSTRACT

Geographic distribution assessment of the main leaf and head diseases infection of wheat as leaf rust (*Puccinia recondita*), powdery mildew (*Blumeria graminis*), wheat leaf blotch (*Septoria tritici*) and *Fusarium ssp*., using a total of 720 geo-referenced disease points, observed on 24 wheat farmers economy selected randomly in six different ecological wheat areas of Albania (Berat, Dibra Elbasan, Fieri, Korca and Shkodra) during five seasons was carried out. The infection degree of wheat diseases per each famer and year was assessed on circular areas (with 15 km radius) using standard methods of diseases evaluation. Spatial analysis found significant differences between different ecological growing wheat areas related to the infection degrees and maps containing geographic distribution of wheat diseases per each area were performed. Variance analysis and comparisons for all quantitative pairs using Tukey-Kramer test (alpha 0.05) show the Dibra areas, representing less degree of wheat diseases, were found as more healthy and suitable for growing of wheat. Korca district areas, well known for wheat production, were found highly infected by *S. tritici* and relatively healthy by *B. graminis*. Ecological areas of Fieri were found infected by all of wheat diseases and especially very infected by *P. recondita* and *Fusarium ssp*. Shkodra areas showed also high diseases infection. Cluster analysis showed high similarity between Berat and Elbasan areas where infection of wheat leafs was found in moderate degrees. Principal component analysis showed the *P. recondita* and *S. tritici*, highly correlated among them (significant r = 0.72) were the principal sources of diseases infection in the observed wheat growing areas of Albania.

Key words: Ecological areas, geographic distribution, wheat leaf diseases.

INTRODUCTION

Cereals have played a significant role in the evolution of human civilization and the wheat (*Triticum aestivum*) is the largest cereal grain crops in the world. It provides food to 36% of the global population, and contributes 20% of food calories of the world population. The increasing yield potential of wheat has indisputable importance in solving world hunger issue, but wheat production is influenced greatly by global climatic changes (Singh et al., 2006). *Triticum* species, including common wheat, are vulnerable to rust diseases that may cause severe economic losses in certain circumstance Cooke BM. 2006. Leaf rust is possibly the most widespread of the wheat rusts, and occurs in most wheat growing areas (Knott, 1989). Abdel Hak *et al.,* (1980) estimated crop losses of up to 50% due to leaf rust infection in Egypt. Bockus et al. 2010 announced wheat yield losses ranging from 20 to 43% when environmental conditions are favourable for disease development. An epidemic of leaf rust in Western Australia in 1992 affected more than 100,000 ha of wheat and caused yield losses of up to 37% (McIntosh *et al*., 1995).
Common wheat is one of the most important cereal crops in Albania. In spite of Albanian farmer's efforts to increase the wheat production in the country, the yield of wheat per hectare is much lower as compared to other developed agriculture countries. The reason for lower yield is lack of investments, not proper crop rotation, and introduction of new unknown varieties (not adapted to the growing area conditions and often susceptible varieties). According to Hasani et al. (2002), the leaf diseases of wheat (as *Septoria tritici*, *Blumeria graminis*) are causing important losses of the yield every year. Since the 1990 wheat was grown under small farming management regimes and in often in the same part or areas of the farms. Ruci et al., (2007) reported the cropping systems used during two latest decades have increased incidence, severity and the leaf diseases progress curves.
Septoria tritici is the major foliar disease of common wheat crops and often causes significant loss. In general high mean temperature, high relative humidity and high plant density favour pathogenic development. The primary

infections of *Septoria leaf* blotch in wheat, caused by *Septoria tritici*, were observed during the end of autumn season. This disease is called as a foliar disease of autumn-sown wheat (*Triticum aestivum*) crops. There is a strong relationship between crop disease and development and weather conditions (Shaw et al., 1993). The results indicate that warm winter (late January to early March) and heavy rainfall between May and June favour disease development. The environmental conditions required for wheat rust infection have been well defined in Temperature x leaf wetness combination studies (CPC 2003; Vallavieille Pope et al., 1995). Rainfall during stem extension assists disease spread into the upper leaves of the canopy (Shaw & Royle 1986). Yield losses occur when the top two or three leaves, which are important contributors to grain filling, become infected (Shaw & Royle 1989; Thomas et al. 1989). Powdery mildew, caused by *Blumeria graminis*, was observed every year under the Albanian climate conditions. This diseases result harmful only in cases when high seed rates and wheat plant density were used, or when it is used high level of nitrogen and a few numbers of (susceptible) varieties.

Management of wheat leaf 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. Genetic resistance is considered as the most profitable control approach for all wheat leaf diseases from both economical and ecological perspectives. Growing wheat cultivars with genetic resistance to leaf rust is more economical, more effective and the most practical method of controlling this disease (Kolmer, J.A. 2001). According to Kolmer *et al*., (2003) effective leaf rust resistance in wheat cultivars is dependent on the virulence of the regional populations of the leaf rust. There is a high interest in the discovery, characterization, and deployment of diseases resistance genes because many of new wheat cultivars, introduced recently in Albania, are/result susceptible to the major foliar disease of common wheat.

Geographic distribution of wheat leaf diseases is not known prior to data analysis, because wheat leaf diseases are not uniformly distributed in space and between different ecological growing wheat areas. So, a successful collecting of information, related to distribution of wheat leaf diseases help to understand better the development and propagation of diseases and may improve control strategy. Because the Albanian territory has highly heterogeneous environmental conditions and often favourable to the wheat leaf diseases, the aim of this study was to assess the geographic distribution, and degree of severity of the main wheat leaf diseases that infect and attack the wheat crop in Albania.

MATERIAL AND METHODS

Assessment of the geographic distribution of the main leaf and head diseases infection of common wheat as leaf rust (*Puccinia recondita*), powdery mildew (*Blumeria graminis*), wheat leaf blotch (*Septoria tritici*) and *Fusarium ssp*., using a total of 720 geo-referenced disease points, was carried out. Information about the presence of common wheat leaf diseases was gathered from four wheat farmers' economies, selected randomly per each of the six different ecological wheat areas of Albania, during five growing seasons. Wheat areas of Berat (BR), Dibra (DI), Elbasan (EL), Fieri (FR), Korca (KO) and Shkodra (SH), were the district areas used for the assessment of geographic distribution and the disease incidence (di) of the main wheat leaf diseases. The presence of wheat leaf diseases was carried out per each wheat farmers' economy, and on circular buffer zones of 15 x 15 km radius per each targeted district. Geo-referenced disease points, observed on all wheat farmers' economy were spatially represented as presence points and mapped using DIVA-GIS (Hijmans et al. 2001; Gixhari et al., 2012; Gixhari et al., 2014).

Observations for determining wheat leaf diseases incidence were conducted on each wheat farmers' economy using standard methods of diseases evaluation (Vrapi et al., 2012) in early April until end of May to the first decade of June, which corresponds with intensive incidence of wheat infection in the respective district wheat areas. Assessment and comparison of diseases incidence (as percentage of infection) was realized calculating the average presence of the main wheat leaf diseases per each districts of Albania. The measurement of diseases incidence was realized analysing: the number of observations where a wheat leaf disease was present (present = 1; absent = 0) per wheat farmers' economy and per district and the percentage of occupancy (or incidence) by a specific wheat leaf disease (= indicator of presence / or absence of a particular disease). Differences between farmers economy related to the agronomy factors used were not taken into account in this study and were included into the environmental and climate conditions of zone.

Statistical Analysis: All recorded data in percent of diseases incidence were first transformed in arcsine value (angular transformation or degree) using the formula: $Y = \text{arcsine} \sqrt{p} = \sin^{-1} \sqrt{p}$; where p is the proportion and Y is the result of the transformation. ANOVA and comparison analysis for all mean pairs using Tukey-Kramer test ($\alpha = 0.05$), cluster analysis and Principal Components Analysis on Correlations were carried out to identify the significant variability between incidence of diseases and between ecological wheat areas and the proportion of the total variance each factor (disease) accounts for. All statistical data were elaborated in SAS-JMP Statistical Discovery 2012.

RESULTS

Spatial analysis found significant differences between degree of infections and wheat leaf diseases distribution in different ecological growing wheat areas. Maps containing geographic distribution of 720 geo-referenced wheat leaf disease points, observed in all six different wheat areas, were performed (Figure 1) using DIVA-GIS (Hijmans et al. 2001; Gixhari et al., 2012; Gixhari et al., 2014). Study results showed that the symptoms of infections (presence = 1, absence = 0) of the main wheat leaf diseases (*Puccinia recondita; Blumeria graminis; Septoria tritici and Fusarium ssp*.,) were found present on all of the wheat farmers' economy during five growing season. But the degree of incidence of each wheat leaf diseases observed on the wheat farmers' economy included on the circular areas (with 15 km radius) was found different between different ecological wheat areas under the observation (Figure 1).

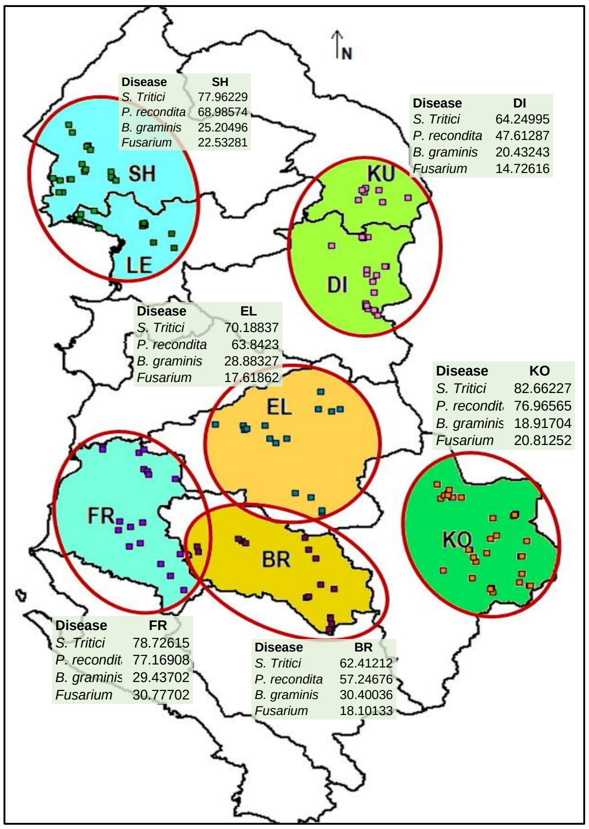

Figure 1. Distribution and incidence of wheat leaf diseases.

Analysis of variances show the presence of an important significant variability related to the geographic presence and degree of incidence of the wheat leaf diseases. The F ratio values, significant at the $P_{0.05}$ and $P_{0.01}$ levels of the probability, proved the significance of the variability found among the fourth main wheat leaf diseases (*P. recondita*; *B. graminis; S. tritici* and *Fusarium ssp*.) surveyed in all wheat areas analysed. In this study F ratio values ranges from $P_{0.0029}$ to $P_{0.0007} < P_{0.05)}$ (Table 1).

Comparisons for all quantitative pairs using Tukey-Kramer test (q* = 3.17804 and α = 0.05) proved the presence of significant differences between four wheat leaf diseases (*Puccinia recondita; Blumeria graminis; Septoria tritici* and *Fusarium ssp*.) related to the percentage of diseases infection observed in wheat district areas included in the study. The analysis ranged the significant variability in different classes or levels where the levels not connected by same letter are significantly different (Table xxx). Results of this study demonstrate that there were two major wheat leaf diseases (*S. tritici* and *P. recondita*) that showed higher incidence of infection in all targeted wheat areas analysed. Disease presence and higher incidence of infection was found for *S. tritici* and *P. recondita* especially in the wheat area of Korca, Fieri and Shkodra districts.

Calculated disease incidence (di) caused by *S. tritici* range from a maximum of 82.662250[a] (KO wheat areas) to a minimum of 62.412000c (BR wheat areas), and disease incidence caused by *P. recondita* ranged from a maximum of 77.169083[a] (FR wheat areas) to a minimum of 47.612872[c] (wheat areas of DI district). In our study presence of infection caused by S. tritici was found highly correlated with *P. recondita* (r = 0.72) and with *Fusarium ssp*. (r = 0.67). Moderate disease incidences (di) were found for *Fusarium ssp*. and for *B. graminis*. Calculated disease incidence ranged from 14.726161b to 30.777021[a] for *Fusarium ssp*. and from 18.917042[c] to 30.400362[a] for *B. graminis*. Wheat areas of FR and SH results more infected by *Fusarium ssp*. in comparison to the other districts wheat areas. Leaf disease known as powdery mildew caused by *B. graminis*, was found in high percentage in the wheat areas of BR, EL and FR districts (di = range respectively from 30.400362[a] to 29.437016[ab]). It seems that climate conditions of these districts have been/resulted favourable in the development and distribution of infection caused by *B. graminis*. Wheat areas of KO and DI districts were found less infected by *B. graminis* in comparison to the other districts wheat areas. Detailed and comparison analysis for all mean pairs using Tukey-Kramer test (q* =

3.17804 and α = 0.05) (Table 1) demonstrate that the ecological wheat areas of FR and SH districts were the most infected areas by all of the four wheat leaf diseases (*Puccinia recondita; Blumeria graminis; Septoria tritici* and *Fusarium ssp*.).

BR wheat district areas were found highly infected by *B. graminis* (di = 30.400362[a]) and moderately infected by other wheat leaf diseases. In this study the infection caused by *B. graminis* was found negatively correlated with *S. tritici* (r = -0.29) and low positively correlated with *P. recondita* (r = 0.05) and with *Fusarium ssp*. (r = 0.33) (Table 1 and Figure 2). Less degree of infection caused by *S. tritici* (di = 62.412000[c]), *P. recondita* (di = 57.246762b[c]) and *Fusarium ssp*. (di = 18.101326[b]) in comparison to other wheat areas, may be dedicated to the low humidity air content and moderate climate conditions of BR areas in months of April, May and June. FR wheat district areas were found highly infected by all wheat leaf disease and especially infection caused by *Fusarium spp*., (di= 30.777021[a]) and *P. recondita* (di = 77.169083[a]) very highly correlated between them (r = 0.80). Wheat areas of FR were found also high infected by *P. tritici* (di = 78.726250[ab]) (Table 1 and Figure 2). High air humidity content and specific warm climate conditions of these zones in April, May and early of June may be probable source/factors that influence the high degree of infections.

Table 1. Wheat leaf disease incidences and means comparisons using Tukey-Kramer test (q*=3.17804, α= 0.05).

Districts	Wheat leaf diseases			
	S. tritici	P. recondita	B. graminis	Fusarium ssp.
BR	62.412000[c]	57.246762b[c]	30.400362[a]	18.101326[b]
EL	70.188500[abc]	63.842299[abc]	28.883269[ab]	17.618625[b]
FR	78.726250[ab]	77.169083[a]	29.437016[ab]	30.777021[a]
KO	82.662250[a]	76.965649[a]	18.917042[c]	20.812524[b]
DI	64.250000[bc]	47.612872[c]	20.432431[bc]	14.726161[b]
SH	77.962250[abc]	68.985737[ab]	25.204956[abc]	22.532812[ab]
F' Ratio	5.4945**	7.3192**	5.5545**	8.8725**
Prob>F	0.0030	0.0007	0.0029	0.0002

The levels not connected by same letter are significantly different; (*) significant at the $P_{0.05}$ and (**) $P_{0.01}$ level of the probability

Korca district areas, well known for wheat production, were found highly infected by *S. tritici* (di = 82.662250[a]) and *P. recondite* (di = 76.965649[a]), and moderate infected by *B. graminis* and and *Fusarium ssp*. (di of these diseases were respectively 18.917042[c] and 20.812524[b]) (Table xxx). High percentage of infections caused by *S. tritici* and by *P. recondita* (highly correlated r = 0.72) in the KO wheat areas may be dedicated to the high air humidity content and often rains during the beginning of the Spring (April, May and June), high number of foggy days, and very warm conditions in the midday during this period. A favourite source of infections may be considered the practice of low crop rotations used in the KO wheat areas. Dibra areas, representing less degree of wheat diseases infection caused by *S. tritici* (di = 64.250000[bc]), *P. recondita* (di = 47.612872[c]) and especially by *B. graminis* and *Fusarium ssp*., (with respectively di = 20.432431[bc] and 14.726161b) seems to be/ were found as more "healthy" and suitable for growing of common wheat (Table 1, Figure 2).

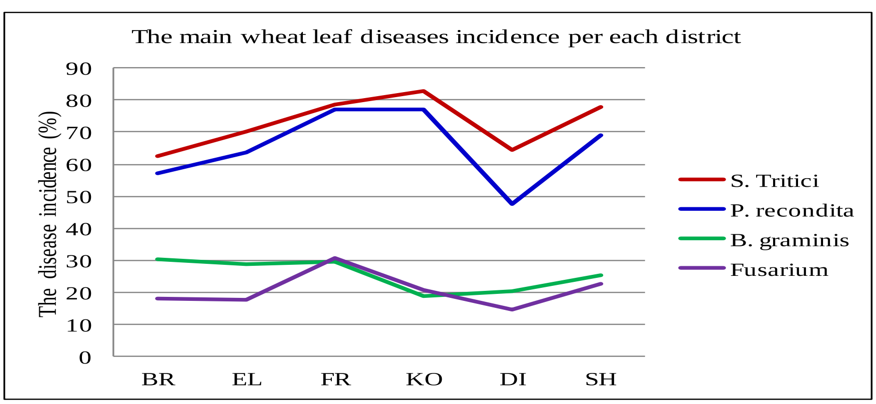

Figure 2. The wheat leaf diseases incidence per each of six districts of Albania

Less degree of infection (in comparison to other wheat areas) may be dedicated to the fresh climate conditions of DI areas in months of April, May and early of June. Shkodra wheat areas showed also high diseases infection especially infections caused by *S. tritici* (di = 77.962250[abc]), *P. recondita* (di = 68.985737[ab]) and *Fusarium ssp*. (di = 22.532812[ab]) (Table 1 and Figure 2).
Cluster analysis on correlations found high similarity between BR and EL areas where wheat leaf infections (except *B. graminis*) were found in moderate percentage of infections (similarity matrix = 93.1341, and coefficient of correlation r = 0.90). High similarity was also found between KO and SH growing wheat areas (similarity matrix 92.5395, and r = 0.73), between FR and KO wheat (similarity matrix 91.6707, and r = 0.81), between SH and FR (similarity matrix 92.4823, and r = 0.74), and among SH and EL areas (similarity matrix 91.8606, and r = 0.84) (Table 2).

Table 2. Similarity and Spearman's R. Correlation Matrix among six targeted wheat areas in Albania

Spearmans R. Correl. Matrix		Similarity Matrix					
	Districts	BR	EL	FR	KO	DI	SH
	BR	*	93.1341	86.4284	83.9202	88.1234	87.7401
	EL	0.9051	*	89.6442	88.8308	87.6932	91.8606
	FR	0.7507	0.7816	*	91.6707	80.9744	92.4823
	KO	0.7956	0.8338	0.8132	*	82.0374	92.5395
	DI	0.7978	0.8235	0.7515	0.7103	*	85.712
	SH	0.8265	0.839	0.7390	0.7338	0.8669	*

Principal Components Analysis on Correlations: Principal Components Analysis on Correlations identified the variances of the principal components and the proportion of the total variance each factor accounts for (Table 3). Based on the mineigen criterion (Kaiser, 1960), and the *scree* test (Cattell, 1966), two principal components, that account for 83.2% of the total variation, are retained for further analysis.

Table 3. Principal components on correlations of main wheat leaf diseases

No.	Eigenvalue	% variance	Cum Percent	ChiSquare	DF	Prob>ChiSq
1	2.0450	51.124	51.124	27.843	5.266	<.0001*
2	1.2835	32.087	83.211	14.945	4.292	0.0062*
3	0.4152	10.380	93.592	1.181	1.939	0.5390
4	0.2563	6.408	100.000	0.000	.	.

PCA results show that the major sources of variation in the measurements are given by the first two PCs. Four quantitative variables (four main wheat leaf diseases) contribute in the total source 100% of variance. Overall, the percentages of total variation accounted for by each of the first two PCs were respectively 51.1% for PC1 and 32.1% for PC2. The proportion of total variation 83.2% more than 75% is acceptable in this kind of studies (Cadima et al., 2001; Jolliffe 2002).

Variation in PC1 (51.1% of total variation) was variability caused by *P. recondita; S. tritici* and *Fusarium ssp*. (with eigenvectors values > 0.30) (Figure 3). These three agents of wheat leaf diseases were the factors (disease sources) with more significant weighting in diseases infections. Their respective eigenvectors values > 0.30 (0.63283; 0.61249; 0.46643), and high positive correlations between *P. recondita; S. tritici* and *Fusarium ssp.* (r range from 0.67 to 0.80) proved the infections caused by these three diseases were more significant and the expected damages will be probably more higher. Variation in PC2 (32.1% of total variation) was mainly result of variability caused by *B. graminis* (eigenvector value 0.81806) and *Fusarium ssp.* (eigenvector value 0.51500) (Table 3, Figure 3).
Results of this study congruent with results of other studies (Knott, et al., 2005); Kolmer, J.A. (2001); Hasani et al., (2002); Ruci et al. (2007) are beneficial to wheat leaf diseases database: geographic distribution assessment of diseases, evaluation of diseases incidence (as percentage of infection) and of principal sources of diseases infection in the observed wheat growing areas of Albania.

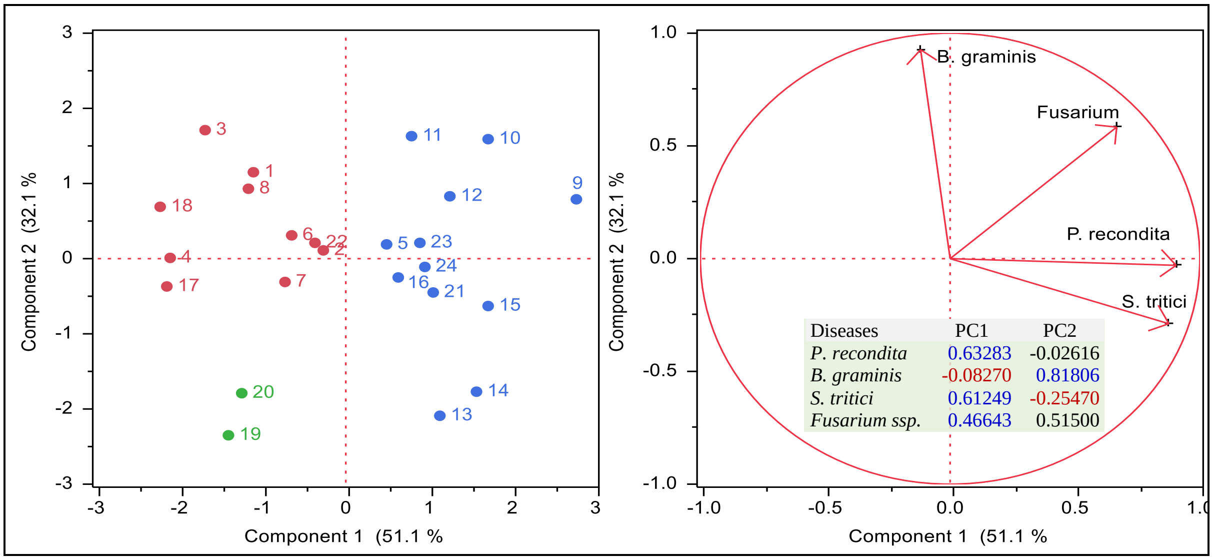

Figure 3. Dimensional relationships among the four sources of wheat leaf diseases infection revealed by principal component analyses.

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CONCLUSIONS

Geographic distribution assessment of the main leaf and head diseases infection of wheat accomplished in this study permitted the first evaluation and characterization of the most important wheat diseases spread in the principal growing areas of common wheat (T. aestivum L.) in Albania.
Spatial analysis and maps containing geographic distribution of wheat diseases per each area found significant differences between different ecological growing wheat areas related to the infection degrees of common wheat by the main leaf diseases.
Variance analysis and comparisons for all quantitative pairs using Tukey-Kramer test (alpha 0.05) show the Dibra areas, representing less degree of wheat diseases, were found as more "healthy" and suitable for growing of wheat. Korca district areas were found highly infected by *S. tritici* and relatively healthy by *B. graminis*. Ecological areas of Fieri were found infected by all of wheat diseases and especially very infected by *P. recondita* and *Fusarium ssp*. Shkodra areas showed also high diseases infection.
Cluster analysis showed high similarity between Berat and Elbasan areas where infection of wheat leafs was found in moderate degrees.
Principal component analysis showed the *P. recondita* and *S. tritici*, highly correlated among them (significant r = 0.72) were the principal sources of diseases infection in the observed wheat growing areas of Albania. Variation in PC1 (51.1% of total variation) was variability caused by *P. recondita; S. tritici* and *Fusarium ssp*. which were the factors (disease sources) with more significant weighting in diseases infections.
The eigenvectors > 0.30, and high positive correlations between *P. recondita; S. tritici* and *Fusarium ssp.* (r range from 0.67 to 0.80) proved the infections caused by these three diseases were more significant and the expected damages will be probably more higher.

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