THE BASIC ENVIRONMENT AND *Lymantria dispar* L. (LEPIDOPTERA, EREBIDAE) INFESTATIONS

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Abstract. The basic environment of an insect is constituted of three components: 1. biotic factors (food abundance, food quality, number of natural enemies, number of competitors), 2. abiotic factors (landscape, soil, climate) and 3. accidental negative factors (weather, human activity, catastrophes). These factors, together with the density of the insect population, determine the favourability of the basic environment for the individuals of this population. This paper analyses the type of relationships that occurred between the environmental conditions of the populations of *Lymantria dispar*, especially, of variable conditions associated with the stational and stand factors and the infestation level registered in 2012, in the forests managed by Bals Forest District. By graphical analysis and principal component analysis (PCA), there were established the determinant factors in the appearance and development of the outbreaks of *L. dispar*. The share of oak trees species in the forest composition, density (consistency) and some qualitative characteristics (age, provenance, condition of vegetation, etc.) and the xeric character of the location (lithologic substratum, position on the slope, slope, exposure, etc.) were variables with significant influence in the emergence of *L. dispar* infestations. These variables of the basic environmental can act as stimulating or disturbing factors of the populations, thus determining the favourability of the respective forest for *L. dispar*.

Keywords: *Lymantria dispar*, infestation, basic environment, favourability, PCA.

Rezumat. Mediul de bază şi infestările cu *Lymantria dispar* L. Mediul de bază al unei insecte este constituit din trei componente: 1. factori biotici (abundența hranei, calitatea hranei, numărul de duşmani naturali, numărul de competitori), 2. factori abiotici (landșaftul, climă, sol) şi 3. factori negativi întâmplători (vremea, activităţi umane, catastrofe). Aceste trei componente, împreună cu densitatea populației determină favorabilitatea de trai a indivizilor acelei populaţii. Lucrarea analizează tipul relaţiilor care se realizează între condiţiile mediului de bază al populaţiilor de *L. dispar*, în special al acelor variabile asociate cu factorii staţionali şi de arboret, şi nivelul infestărilor înregistrat în anul 2015, în arboretele din Ocolul sivic Balş. S-au stabilit factorii determinanţi în apariţia şi dezvoltarea gradaţiilor de *L. dispar* prin analiza grafică şi analiza componentelor principale (PCA),. Proporţia de participare a speciilor de cvercinee în compoziţia arboretelor, consistenţa şi unele caracteristici calitative ale acestora (vârsta, proveniența, starea de vegetaţie) precum şi caracterul xeric al locului (substratul litologic, poziţia pe versant, panta, expoziţia) au fost variabilele cu influenţa semnificativă în apariţia infestărilor cu *L. dispar*. Aceste variabile ale mediului de bază pot acționa ca disturbatori sau stimulatori ai populaţiilor, determinând favorabilitatea pentru *L dispar* a pădurii respective.

Cuvinte cheie: *Lymantria dispar*, infestare, mediu de bază, favorabilitate, PCA.

INTRODUCTION

The territory of Romania is entirely located within the temperate zone, namely at the interference of two zonal climates - steppe and forest steppe and three regional climates: the Central European (suboceanic), the Eastern European (continental) and the Southeastern European (sub-Mediterranean influences).

In these conditions, in deciduous forests, especially in oak forests, there negatively acts on a series of defoliating insects such as *Tortrix viridana* Linnaeus 1758, various species of Geometridae (winter moths), *Lymantria dispar* Linnaeus 1758, *Malacosoma neustria* Linnaeus 1758, *Euproctis chrysorrhoea* Linnaeus 1758, *Thaumetopoea processionea* Linnaeus 1758, etc.

Of all these species, *L. dispar* proved to have the greatest damaging potential over time, producing ample gradations of eruptive-pulsating type with a variable cyclicity, depending on the phytogeographical area, stational conditions and characteristics of tree stands.

Generally, the basic environment of an insect is constituted of biotic (host abundance, host quality, number of enemies, number of competitors), abiotic (landscape, soil, climate) and disturbance (weather, human activity, catastrophes) factors (BERRYMANN, 1986).

Previous research achieved in Romania and abroad showed that, among these factors, the stational factors and the structural characteristics of trees have a determinant role in the emergence and development of *L. dispar* gradations (DAVIDSON et al., 2001; DOANE & McMANUS, 1981; ILYINYKH et al., 2011; MUZIKA et al., 1996; NEȚOIU, 2013; TOMESCU, 2015).

Considering that in the Romanian forests these stational and stand characteristics vary greatly from one stand to another, we aimed at comparatively analysing in a first stage, in a graphical form, the levels of infestation caused by *L. dispar* given this diversity, then using probabilistic models, to determine the contribution of each of these characteristics to the emergence and development of the gradations. These characteristics of the basic environment can act as disturbing or stimulating factors of the populations, thereby determining the favourability of the respective forest stands for *L. dispar*.

Knowing the influence of these characteristics on *L. dispar* individuals or populations will help us establish the favourability of forest stands for infestations and, thus, to assess the risk of graduation appearance and development. The variables that will prove, after processing the data by Principal Component Analysis (PCA), as having significant influence on the degree of infestation, will be considered main parameters in risk assessment in the future.

MATERIAL AND METHODS

In 2011/2012 generation, the defoliator *L. dispar* entered gradation, variably infesting the oak stands in Bals Forest District, (Olt County) on a surface of about 3,500 ha. In most of the infested forest stands (95% of the surface), the defoliator was in its incipient stage, with fecundities of over 700 eggs and parasitation of 1-3%, but also in its numerical growth stage (5% of the surface), with fecundity between 450 and 650 eggs and parasitation of 3-6%; the forecasts made in the autumn of 2011 indicated probable defoliations, varying from stand to stand, from very low to very high.

Stational and forest stand characteristics were taken from the management plan of Bals Forest District. Thus, from the total of 1,578 management units infested with *L. dispar* in the autumn of 2011, there were extracted the main stational characteristics (altitude, exposure, slope, topography, soil type, type of litter, etc.), structural (the share of oak species in the composition, percent of ground covered by shrubs, consistency) and qualitative characteristics of trees (age, production class, tree crown condition, provenance) considered determinant variables of the basic environment specific to the defoliating insect, which were coded according to the specificity of each.

In order to calculate the intensity of infestation and determine the degree of infestation of each forest stand, there were collected data regarding species, base diameter, number of egg-masses per tree and their degree of ravaging, expressed as a percentage, at the level of the sampled units, on transects of 100 trees. The average fecundity of the population females was determined on samples of 50 full egg-masses (undisturbed by oophagous predators), sampled from many groups of homogenously infested units. In the laboratory, using specific methods (SIMIONESCU et al., 2000), it was determined the degree of eggs parasitation and infertility and it was established the average number of viable eggs from an average egg-mass. Based on the population density at the level of each unit, expressed by the average number of viable eggs per average diameter tree, belonging to a particular host species, as well as on the critical numbers calculated according to the host species, average diameter and gradation stage, it was determined the intensity of infestation (***). The degree of infestation for each forest stand was established by grouping infestations in three categories, depending on the intensity of infestation: low – 1-25%; moderate – 26-50% and high – over 51%.

Knowing the stational and structural features of the forest stands, as well as the intensity of infestations, there were analysed, in a first stage, graphically and then statistically, the relationships established between these characteristics, considered as independent variables and the degree of infestation, as dependent variable.

The statistical data processing was done using STATISTICA software by applying the correlation analysis and the Principal Component Analysis (**PCA**).

We used the PCA because this method allows the visualization of multi-dimensional spaces, specific to oak stands in Romania, by summarizing the initial variability and their reduction to some main uncorrelated components, which take most of the variant of the initial data with a minimum loss of information (DOUGLAS et al., 1997). In this regard, there were analysed eight variables, representing the main stational and stand characteristics: slope exposure (**exp**), litter type (**lit**), consistency (**cns**), class production (**clp**), age (**vrt**), drying degree (**usc**), percent of ground covered by shrubs (**sba**), the share of oak species in the composition of forest stands (**Quercus**), considered determinants of the specific basic environment of the populations of *L. dispar*. The data processing by PCA was made according to the three categories of infestations (low, moderate and high).

As the size order of the basic environment characteristics considered in the experiment and their measurement units are very different, the application of PCA was done on data normalized and standardized by the standard deviation (**sd**) of each variable.

RESULTS AND DISCUSSIONS

Basic environment characteristics and *Lymantria. dispar* infestation degree.

Starting from the definition of the basic environment of a species of insects made by BERRYMANN (1986), in analysing the populations of *L. dispar* from the oak forests of Romania, it was considered that this environment is mainly determined by the structural and stational characteristics of the stands.

The food source of *L. dispar* caterpillars is mainly represented by the foliage of oaks trees. Consequently, the composition of the stands dominated by oaks species plays an important role in the emergence and evolution of the defoliator gradation. At the same time, the presence or absence of the undergrowth and its distribution on the surface is part of the category of structural characteristics of stands, as factors of the insect basic environment.

The analysis of the way infestations with *L. dispar* are distributed depending on the share of oak species in the composition of stands, as well as on the percent of ground covered by shrubs (Fig. 1), revealed that the stands in the composition of which there are more than 50% oak species and shrubs species are represented on less than 0.3 of the surface offer favourable conditions for the development of infestations.

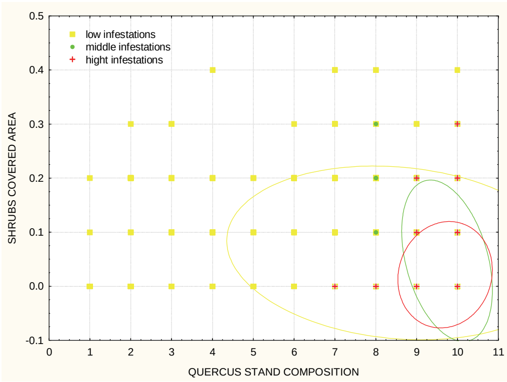

Figure 1. Distribution of infestations with *L. dispar* in the forest stands from Balş Forest District, generation 2011/2012, according to the share of oak species to their composition and the percent of ground covered by shrubs, n=1,578, p=0.05.

Generally, the crown density of a forest stand, expressed in tenths, characterizes the environment inside that forest stand, and thus, it represents an important structural characteristic in defining the basic environment of *L. dispar* insect. The forest stands with low crown density (0.1-0.5) and high percent of ground covered by shrubs (> 0.3 area) are unfavourable to the defoliator infestations (Fig. 2). Instead, the forest stands with a crown density of 0.8-0.9 and a percent of ground covered by shrubs below 0.2 of the area, offer favourable conditions for the infestation with *L. dispar* and, thus, they can be considered susceptible to defoliation.

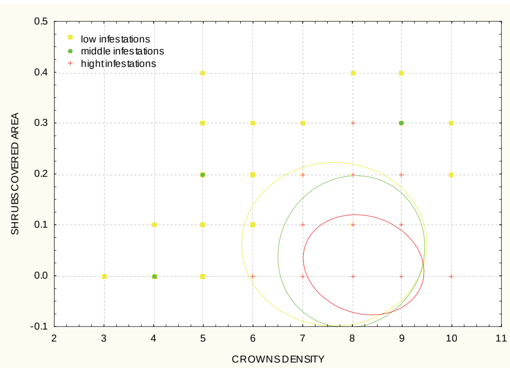

Figure 2. Distribution of infestations with *L. dispar* in the forest stands from Balş Forest District, generation 2011/2012, according to their consistency and the percent of ground covered by shrubs, n=1578, p=0.05.

As at the time infestations occurred (the autumn of 2011), we could not determine the tree crown condition, a parameter considered decisive for the emergence and evolution of *L. dispar* gradations (NEŢOIU, 1998); in our analysis, it was introduced the production class of the forest stand as a variable, which is directly correlated with the tree crown condition of the respective forest stand (NEAGU & BADEA, 2008).

The stands classified in higher production classes (I-II) create an environment less favourable to the infestations with *L. dispar*, while those in the average production classes (III-IV) can be considered favourable to infestations (Fig. 3).

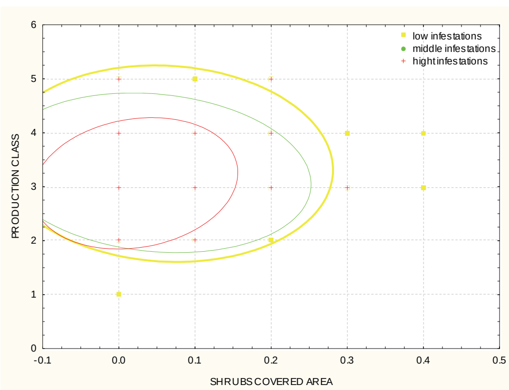

Figure 3. Distribution of infestations with *L. dispar* in the forest stands from Balş Forest District, generation 2011/2012, according to their production class and the percent of ground covered by shrubs, n=1,578, p=0.05.

Between the consistency of the stands and their production class, there is an interaction that determines a favourable environment for the growth and development of *L. dispar* populations. Thus, there is noticed a tendency of extension of the infestations even in the stands characterised by a lower consistency (0.6-0.7), classified in the fifth production class, as well as in the stands with high density, namely the second production class (Fig. 4).

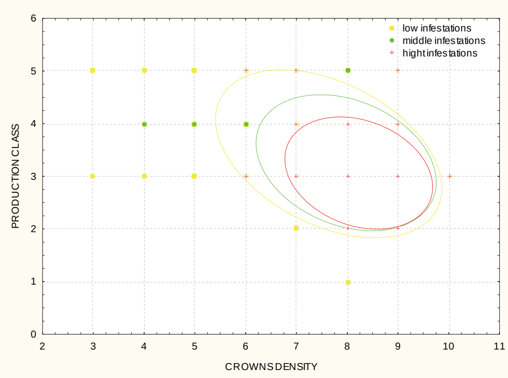

Figure 4. Distribution of infestations with *L. dispar* in the forest stands from Balş Forest District, generation 2011/2012, according to their consistency and production class, n=1,578, p=0.05.

The stands located in sunny or semi-sunny areas, which are also usually drier, offer a propitious environment for the growth and development of *L. dispar* individuals or populations and, thus, they can be considered favourable to infestations (Fig. 5).

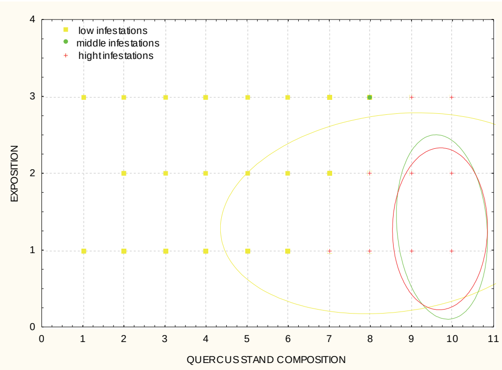

Figure 5. Distribution of infestations with *L. dispar* in the forest stands from Balş Forest District, generation 2011/2012, according to the share of oak species to their composition and the exposure of the slopes where they are located, n=1,578, p=0.05. Exposition: 1- sunny; 2 – intermediary; 3 – overshadowed.

On the background of the current climate change, which led, in time, to a slight aridization of the environment, there have emerged the premises of a tendency of extension of the infestations even within the stands with a relatively full consistency, located in semi-shaded areas (Fig. 6).

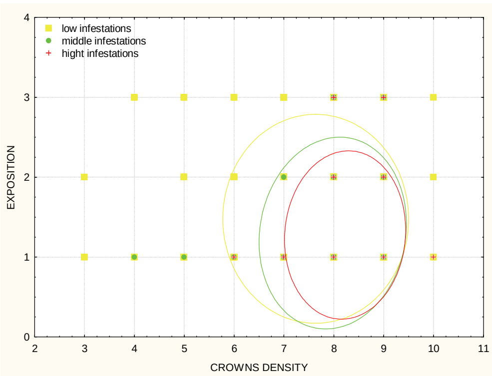

Figure 6. Distribution of infestations with *L. dispar* in the stands from Balş Forest District, generation 2011/2012, according to their crown density and slope exposure, n=1,578, p=0.05. Exposition: 1- sunny; 2 – intermediary; 3 – overshadowed.

The influence of the basic environment on *L. dispar* infestations.

The results obtained in the comparative graphical analysis achieved in the previous paragraph gave an overview of how variation of stational and stand characteristics induced conditions more or less favourable to the growth and development of the individuals or populations of *L. dispar*.

In order to visualize the multidimensional spaces specific to the oak stands infested by *L. dispar*, it was used PCA as a safe method of summarizing the initial variability and reduction to two or three dimensions without significant loss of explaining the total variance. PCA was applied after the normalization and standardization of the data recorded in the 1,578 management units of Bals Forest District infested by *L. dispar*, generation 2011/2012, with the standard deviation of each variable.

To test whether such indices are calculated independently or not, we analysed the matrix of the correlation coefficients (Table 1), which describes the relationship between the analysed variables.

Table 1. The matrix of the correlation coefficients between variables.

Variable	Correlation coefficients							
	exp	lit	cns	clp	vrt	usc	sba	Quercus
exp	1.000000	-0.051866	0.018940	0.015231	-0.001833	-0.001391	-0.012678	0.038543
lit		1.000000	0.332006	-0.155548	0.180917	-0.104546	-0.125838	0.149629
cns			1.000000	-0.414903	-0.515406	-0.368825	-0.012152	0.007080
clp				1.000000	0.413899	0.357787	-0.038021	0.119362
vrt					1.000000	0.476072	0.007142	0.097566
usc						1.000000	0.033923	0.103679
sba							1.000000	-0.185019
Quercus								1.000000

The values of the correlation coefficients indicated the presence of several common factors, which motivated the application of a procedure of factorial reduction such as PCA.

After extracting the major components it resulted that only the first three components, according to Kaiser criterion, meet the condition of having eigenvalues greater than 1 (Fig. 7). According to the infestation category, these three components take in around 58-61% of the variance of the input data (Table 2).

Table 2. Summary of the analysis of the major components.

Component	R^2X	R^2X(Cumul.)	Eigenvalues	Iterations
Low infestations				
1	**0.291022**	**0.291022**	**2.328176**	**11**
2	**0.166621**	**0.457643**	**1.332965**	**30**
3	**0.134365**	**0.592008**	**1.074922**	**34**
4	0.123196	0.715204	0.985567	11
5	0.100087	0.815291	0.800699	26
6	0.077111	0.892403	0.616891	41
7	0.074389	0.966791	0.595112	7
Moderate infestations				
1	**0.267669**	**0.267669**	**2.141354**	**16**
2	**0.215635**	**0.483305**	**1.725083**	**15**
3	**0.131863**	**0.615168**	**1.054905**	**12**
4	0.107947	0.723115	0.863580	10
5	0.089043	0.812158	0.712345	15
6	0.085608	0.897767	0.684866	14
7	0.070467	0.968233	0.563733	5
High infestations				
1	**0.270584**	**0.270584**	**2.164672**	**5**
2	**0.173812**	**0.444396**	**1.390496**	**29**
3	**0.140171**	**0.584567**	**1.121369**	**36**
4	0.128177	0.712744	1.025413	12
5	0.098814	0.811558	0.790514	25
6	0.089014	0.900572	0.712116	19
7	0.067643	0.968216	0.541146	6

Figure 7 shows the variation of eigenvalues for all major extracted components, specific to each category of infestation. The curves describing this variation present a sharp downward shift to component 3, which are precisely those major components with eigenvalues over 1, then, the curve gradually flattens.

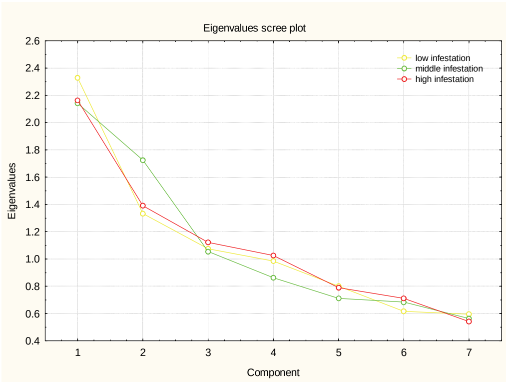

Figure 7. The graph rendering the eigenvalues on infestation categories.

The calculation of the correlation coefficients (**loadings**) between the initial variables and the first three major components shows that the variables corresponding to higher coefficients can be held responsible for data variance.

Thus, component 1 (p1), in the category of low infestations, significantly positively correlates with the following variables – age (0.78), production class (0.72) and drying degree (0.73) and negatively with consistency (-0.76); in the category of high infestations, there are registered significant positive correlations with consistency (0.82) and negative correlations with age (-0.85), drying degree (-0.70) and production class (-0.46) (Fig. 8).

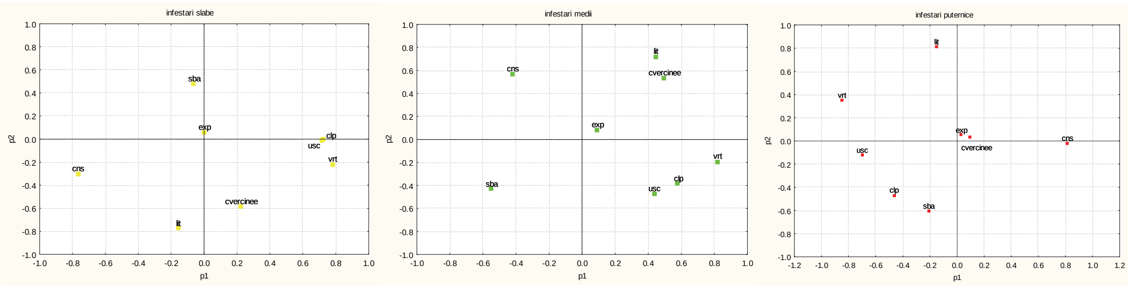

Figure 8. Planar diagrams of the variables distributed according to the first two major components on infestation categories.

Component 2 (p2), in the category of low infestations, present a significant positive correlation with the variable percent of ground covered by undergrowth (0.47) and a negative correlation with litter (-0.78) and share of oak species in the composition of stands (-0.59); in the category of high infestations, there are registered significant positive correlations with litter (0.81) and negative correlations with the percent of ground covered by undergrowth (-0.60) (Fig. 8).

Component 3, in the category of low infestations, significantly positively correlates with the variable exposure (0.62) and negatively with the percent of ground covered by undergrowth (-0.49) and litter (-0.43); in the category of high infestations, significant positive correlations are registered with the share of oak species in the composition of stands (0.74) and exhibition (0.5) and negative correlations with the percent of ground covered by undergrowth (-0.40) (Fig. 9).

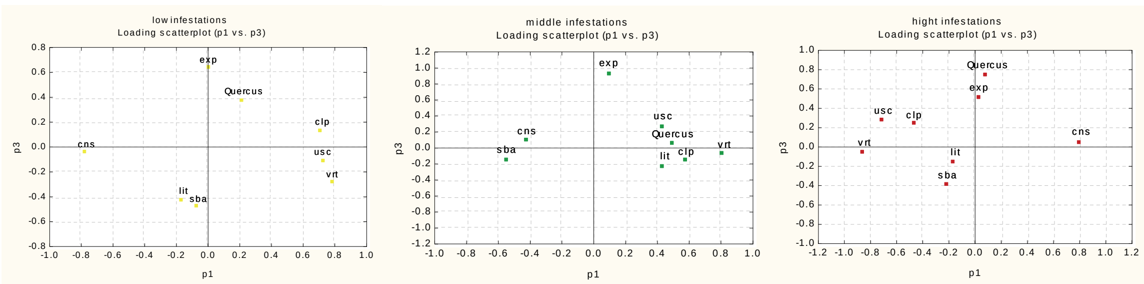

Figure 9. Planar diagrams of the variables distributed according to the first and the third major components on infestation categories.

PCA enabled us to achieve biplot graphs where variables and cases are represented together, in two dimensions (Fig. 10). The standardized values of the variables included in the model provide information on the dispersion of the analysed cases (forest stands), highlighting the aberrant cases that are out of the limits of the confidence interval (1 sd or 2 sd).

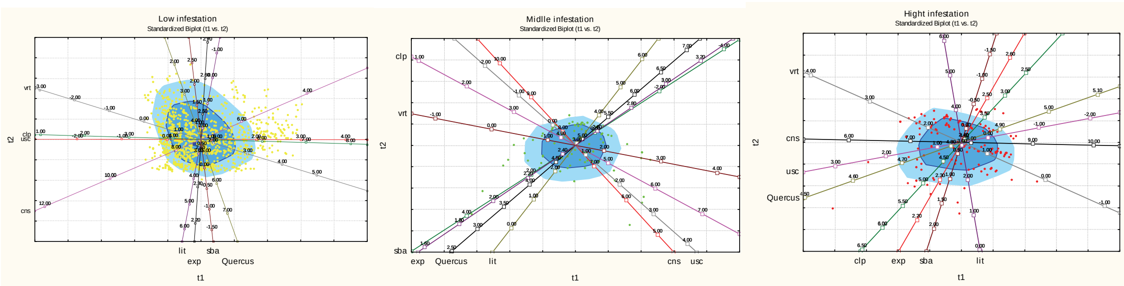

Figure 10. Standardized biplots for infestation classes (confidence interval: 1 sd and 2 sd).

At the same time, the orientation of the axes of the variables in this kind of graph provides information on the relationship between these variables and the major components. For example, the axes of the variable **usc** and **clp**, in the category low infestations, are aligned almost perfectly with component t1, which means that the two variables (drying degree and production class of stands) load a lot of information on this component. Instead, the axes of the variables **Quercus**, **sba**, **exp** and **lit** are almost aligned with component t2, which shows that the respective variables explain most of the variant induced by this component.

The closeness of some variables, highlighted in this type of graph, indicates the correlation between these variables (**clp** with **usc**, **lit** with **exp**, **sba** with **Quercus**, etc.), which is also emphasized Table 1.

CONCLUSIONS

In order to assess the favourability of stands to the infestations caused by *L. dispar*, we achieved an analysis of the conditions offered by the stational and forest stand factors for the growth and development of the individuals or populations of the insect. These factors may act as stimulating or disturbing factors of the respective population.

Certain stational factors, such as relief, exposure and altitude, through the direct or indirect influence they have on the basic environment of the populations of *L. dispar*, proved to be significant predictive variables in the assessment of the forest stand favourability for the growth and development of this defoliator individuals or populations. Starting from the previously made observations during previous graduations, as well as from those mentioned in the specialized literature, where there are cited many probabilistic models used in establishing the influence of the basic environment characteristics on the growth and development of *L. dispar* individuals and populations, the present research is based on the principal component analysis. By applying this method, it was aimed at summarizing the initial variability induced by the multitude of stational and stand characteristics to two or three integrant components, able to explain as much as possible the total variance.

Before applying PCA, there were made comparative graphical analyses regarding the distribution of the infestations with *L. dispar* depending on certain stational and stand characteristics, which are considered variables of the insect basic environment.

By analysing the way infestations with *L. dispar* are distributed depending on the share of oak species in the composition of stands, as well as on the percent of ground covered by shrubs, it resulted that the stands in the composition of which there are more than 50% oak species and shrubs species are represented on less than 0.3 of the surface offer favourable conditions for the development of infestations with *L. dispar*.

Favourable conditions for the growth and development of *L. dispar* populations are also registered in the oak stands with 0.8-0.9 consistency and a low percent of ground covered by shrubs (less than 0.2 of the surface or without shrubs).

The stands from higher production classes (I-II), namely trees characterized by a good vitality, can be considered less favourable to the infestations with *L. dispar* compared to those from the mean and low classes (III-IV), which are more frequently and more intensely infested by the defoliator.

The stands developed on sunny or semi-sunny landforms provide a favourable environment for the infestations with *L. dispar*.

After performing the principal component analysis (PCA), it resulted that the first three components explain about 61% of the total variance of the initial data.

The study of the correlation coefficients (**loadings**) between the initial variables and these three major components extracted by PCA highlighted the variables responsible for data variance.

Component 1, in the category of low infestations, significantly positively correlates with the variables age, class production and dryness degree and negatively correlates with consistency; in the category of high infestations, there are registered significant positive correlations with consistency and negative correlations with age, drying degree and production class.

Component 2, in the category of low infestations significantly positively correlates with the variable percent of ground covered by undergrowth and negatively with litter and the share of oak species in the composition of stands; in the category high infestations, there are registered significant positive correlations with litter and negative correlations with the percent of ground covered by undergrowth.

Component 3, in the category of low infestations presents significant positive correlations with the variable exposure and negative correlations with percent of ground covered by undergrowth and litter; in the category high infestations, there are registered significant positive correlations with the share of oak species in the composition of stands and exposure and negative correlations with percent of ground covered by undergrowth.

The nature of the statistically demonstrated relationships between each major component and some of the variables considered in the model indicates that component 1 is mainly determined by the qualitative characteristics of the forest stand (age, production class, tree crown condition), component 2 is determined by the structural characteristics of the forest stand (the share of oak species in the composition of forest stands, percent of ground covered by shrubs, consistency) and component 3 is determined by the stational conditions, in particular those which determine the xeric character of a location (exposure, slope, topography, soil type).

By knowing the contribution of each variable and the relationships between the basic environment characteristics and the biological potential of the defoliator, it will be easily assessed the risk of the emergence and development of the gradations in a certain forest stand and there will be made recommendations regarding the silvicultural measures to be taken to limit infestations.

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