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# VARIABILITY OF THE ALIEN SPECIES *ANTOXANTHUM ARISTATUM* BOISS. (*POACEAE*) IN THE WIELKOPOLSKA LOWLAND (WESTERN POLAND)

*Key words:* Anthoxhantum aristatum, *variability, habitat*

**Abstract.** Morphological variability of *Anthoxanthum aristatum* Boiss. populations was examined. Multivariate statistical analysis of 24 morphological characters of the panicle obtained from six sample populations (138 specimens) collected in different habitats was carried out. The analysis of variance ANOVA indicated significant morphological variations among samples. The principal component analysis (PCA) revealed three groups of samples. These groups are not completely separated from each other and sometimes overlap. Canonical discriminate analysis (CDA) proved useful for variety discrimination of characters such as: panicle length and length of internodes, spikelets on the second and the middle branching from the panicle top and upper glume. Weak correlations were detected between morphological differentiation of *A. aristatum* populations and the habitat type they occupied.

## Introduction

Invasions by alien plant species cause major conservation problems in many regions of the world. In most cases, the spread of alien species is associated with human activities such as cropping and the use of alien plants for landscaping and erosion control, fragmentation of habitats and urbanization, among others. Understanding the process of invasion requires information on ecological traits of alien species as well as the susceptibility of habitats to be invaded (Booth et al., 2004; Davis, 2003).

*Anthoxanthum aristatum* Boiss. (Annual Vernal Grass, *Poaceae*) is distributed naturally in the Mediterranean basin and in the Atlantic areas of southern Europe and north-western Africa. It is characterised by narrow habitat requirements and occurs mostly in oligotrophic, segetal habitats, rarely in sandy roadsides. This specificity caused that, in some regions in Central Europe (especially Germany), the species is observed to withdraw from certain sites (Schneider et al., 1994). In Poland, *A. aristatum* was first recorded at the end of the $19^{th}$ century in the West, almost simultaneously in Silesia and Pomerania (Rola, Kuźniewski, 1979; Tokarska-Guzik, 2005). In the following decades, it spread across Central Poland towards the eastern border of the country, reaching it in

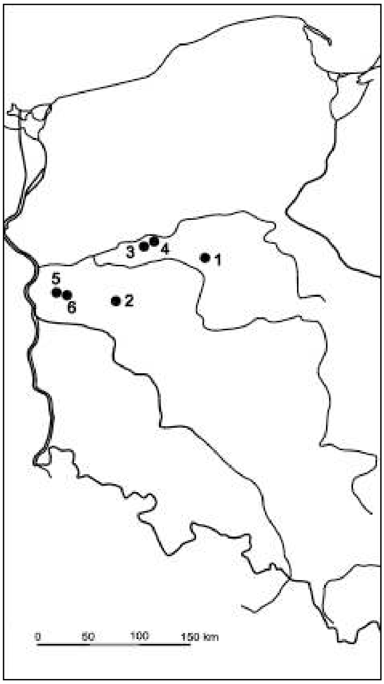



Fig. 1. Collection sites of *Anthoxanthum aristatum* samples in western Poland. 1—6 — population numbers

the last decade of the 20th century (Ciosek, Skrzyczyńska, 1997). High level of morphological diversity of *A. aristatum* was reported by many authors (Latowski, 2005; Pimentel et al., 2007; Pimentel et al., 2010; Drapikowska et al., 2008); hence, the aim of our study was to examine morphological variations within and among *A. aristatum* populations in different phases of chorological expansion, using numerical taxonomy and morphometry methods.

## Material and Methods

The material for the study came from six populations located in the Wielkopolska Lowland (Western Poland) (Fig. 1). Samples were taken from a ruderal and segetal population, i.e. a habitats most frequently occupied by this species in Poland (Table 1). Out of each population, 9-34 tufts were collected with numerous generative tillers. For morphometric studies, 24 traits of generative organs were chosen and scored (Table 2).

The results of measurements were processed using STATISTICA 8.0 software. The morphometric data matrix was standardized to reduce the effects of different characters that were to be compared. All characters followed a normal or log-normal distribution, confirmed by the Shapiro-Wilk test. Descriptive statistics were calculated (arithmetic average, standard deviation, minimum and maximum). Moreover, to determine the variation degree of each trait, a variation coefficient (V) was established. In order to de-

*Table 1.* **Ecological characteristics and geographic positions of the studied *A. aristatum* populations**

| Population number | Number of samples | Habitat | Geographic location |
|---|---|---|---|
| 1 | 30 | an arable land; in rye crops on acidic, dry and impoverished sands | N 52°44`51.3``<br>E 16°45`59.9`` |
| 2 | 24 | an arable land; in rye crops on acidic, dry and impoverished sands | N 52°12`24.2``<br>E 16°04`38.3`` |
| 3 | 34 | an arable land; in rye crops on acidic, dry and impoverished sands | N 52°52`08.6``<br>E 16°14`41.3`` |
| 4 | 13 | an edge of a pine forest; a habitat similar to natural one | N 52°52`36.3``<br>E 16°14`18.8`` |
| 5 | 28 | fallow-land | N 52°09`32.3``<br>E 14°53`20.7`` |
| 6 | 9 | an edge of a pine forest; a habitat similar to natural one | N 52°09`38.8``<br>E 14°53`29.5`` |

termine statistical significance of trait mean values of the populations in question, the factor variance ANOVA *F*-statistics was used. The significance level was examined with Sheffe's test. The Principal Component Analysis (PCA) allowed examination of mutual relationships between the populations in the system of two first principal components.

Canonical Discriminant Analysis (CDA) was performed to evaluate the respective characters distinguishing *A. aristatum* morphotypes (Sneath, Socal, 1973). CDA is a multivariate technique that determines the linear combination of input variables, maximizing the ratio of variance among specimens in populations from different habitats to the variance within groups based on *F*-statistics (Sneath, Socal, 1973). Mahalanobis distances were used to describe interpopulation variability and tests of significances between centroids were calculated.

*Table 2.* **List of morphometric traits accounted for in the analysis *A. aristatum* populations**

| Trait number | Trait description |
|---|---|
| | Panicle |
| 1 | panicle length |
| 2 | number of nodes in a panicle |
| 3 | length of the first internode |
| 4 | length of the second internode |
| 5 | length of the third internode |
| 6 | length of the fourth internode |
| 7 | length of the fifth internode |
| | Spikelet |
| 8 | length of a spikelet on the second branching from a panicle top |
| 9 | number of spikelets on the second branching from a panicle top |
| 10 | length of a spikelet on the middle branching |
| 11 | number of spikelets on the middle branching |
| 12 | length of a spikelet on the bottom branching |
| 13 | number of spikelets on the bottom branching |
| | Glumes |
| 14 | length of a bottom glume from the spikelet on the middle branching |
| 15 | width of a bottom glume from the spikelet on the middle branching |
| 16 | length of an upper glume |
| 17 | width of an upper glume |
| | Lemmas and paleas |
| 18 | length of a sterile flower palea from the spikelet on the middle branching |
| 19 | length to the awn node of a sterile flower palea |
| 20 | length from the awn node of a sterile flower palea |
| 21 | length of a sterile flower lemma |
| 22 | length of the awn node of a sterile flower lemma |
| 23 | length of lemma |
| 24 | length of palea |

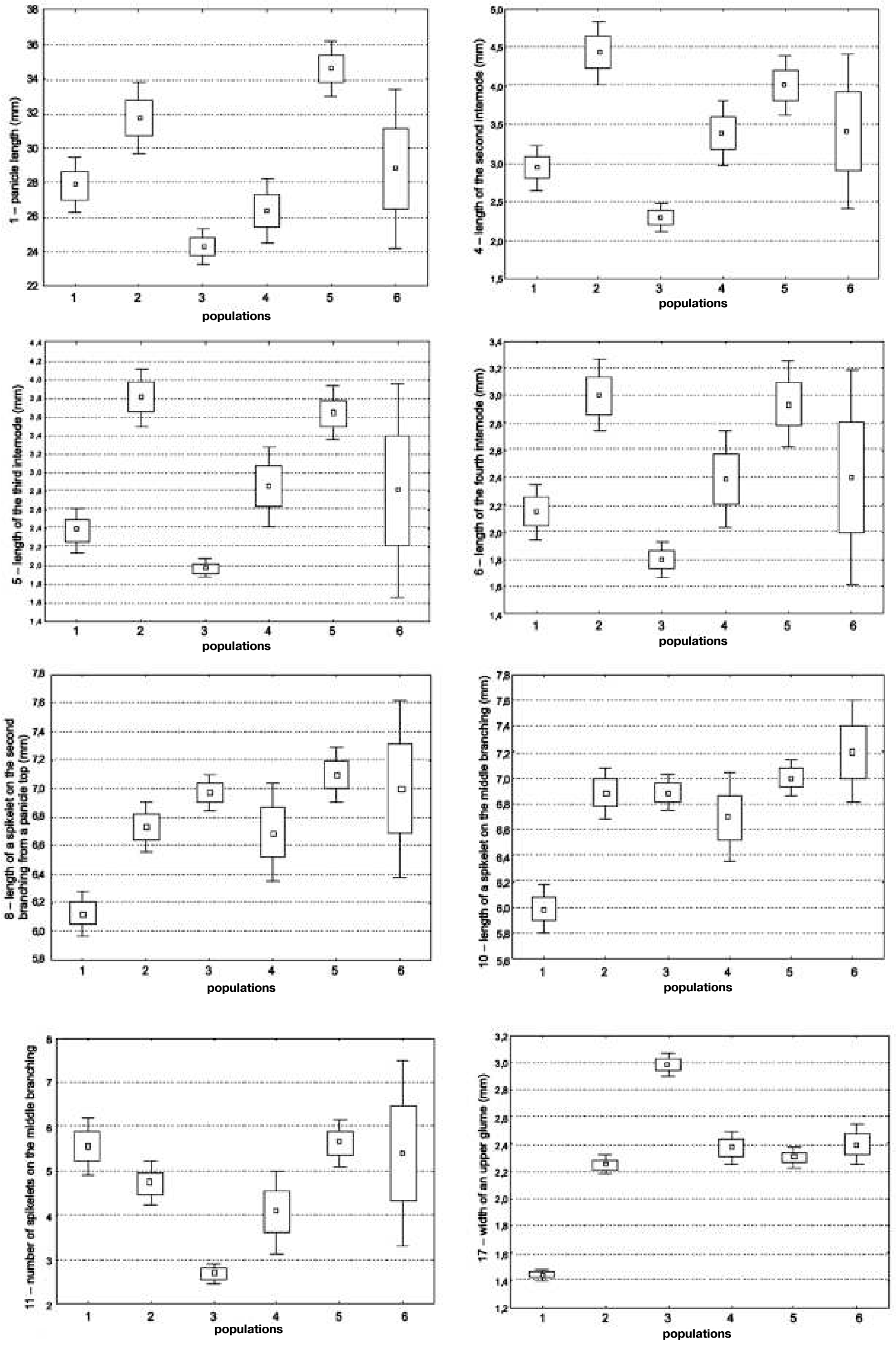
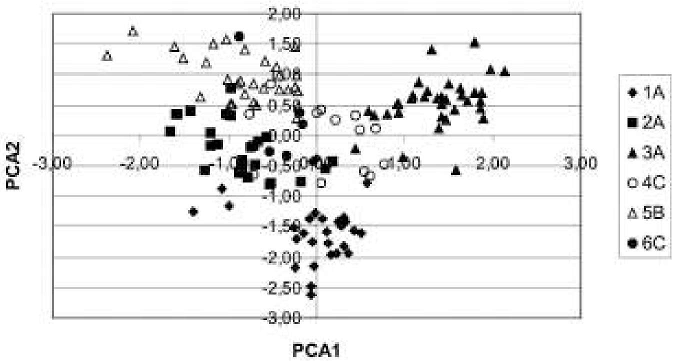



Fig. 2. Box plots for selected morphological characters of *Anthoxanthum aristatum* distinguishing populations 1 and 16 from arable land

Fig. 3. Results of analyses of principal components for populations of *Anthoxanthum aristatum* from different habitats (A – arable land, B – fallow land, C – edge of a pine forest) in the system of the first three principal discriminant variables. PCA1 = 29.33 %, PCA2 = 18.53 %




## Results

The samples of *A. aristatum* were characterized using the following characters: minimum, maximum, arithmetic mean, standard deviation, and variation coefficient. The F coefficient, calculated on the basis of ANOVA variance, makes it possible to determine the impact of particular traits on the inter- and intraspecific variation in question. Most of the analysed traits were of great statistical importance in the analysis of the examined variation (Table 3).

Morphological differences and similarities among populations were analyzed in Principal Component Analysis (PCA) based on 24 morphological characters of the panicle. Primary components PCA1 and PCA2 explained altogether 47.86 % of total variation, out of which the former factor described 29.86 % and the latter – 18.53 % of variation (Fig. 2). Table 4 presents the principal components and their corresponding eigenvalues after varimax rotation. The first principal component was strongly associated with the length of the second, third and fourth internode. The second principal

*Table 3.* **Analysis of variance (ANOVA) for morphological traits. F values given in bold face are statistically important at the level p< 0.01**

| Trait | F | Trait | F |
|---|---|---|---|
| 1 | 22.25 | 13 | 10.88 |
| 2 | 50.81 | 14 | 27.14 |
| 3 | 24.93 | 15 | 16.30 |
| 4 | 22.62 | 16 | 23.11 |
| 5 | 30.84 | 17 | 18.62 |
| 6 | 15.13 | 18 | 4.53 |
| 7 | 14.49 | 19 | 9.29 |
| 8 | 14.76 | 20 | 0.65 |
| 9 | 46.69 | 21 | 1.92 |
| 10 | 18.51 | 22 | 14.65 |
| 11 | 19.12 | 23 | 25.83 |
| 12 | 4.52 | 24 | 26.17 |

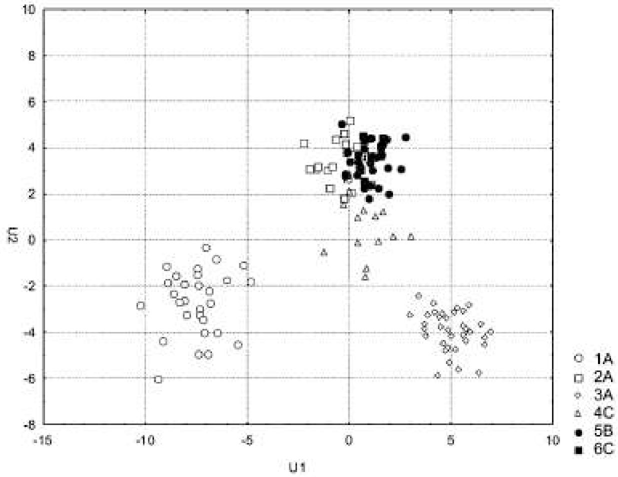



Fig. 4. Results of analyses of discriminant variables for populations of *Anthoxanthum aristatum* from different habitats (A – arable land, B – fallow land, C – edge of a pine forest) in the system of the first three principal discriminant variables. Canonical axis: U1 = 19.29 %, U2 = = 11.21 %

component was strongly related with the length of a spikelet on the second and on the middle branching from the panicle top.

The dispersion diagram showed three groups of samples (Fig. 3). The main group, in the middle of the graph, was composed of populations growing in fallow land and on the edge of a pine forest (2A, 4C, 5B, and 6C). Two other distinguishing groups of samples came from arable land. The calculated PCA 1 reflected individuals from population 3A (shorter panicles and shorter internodes) and PCA2 – population samples 1A (shorter spikelets on the second and the middle branching from the panicle top and narrower upper glumes) (Table 4). Further samples showed continuous variation patterns. Mahalanobis distances among populations were significantly important at the level $P < 0.001$.

Canonical Discriminant Analysis (CDA) (Fig. 4) distinguished two populations from arable land (1A and 3A), the remaining samples were scattered in the middle of the graph.

*Table 4.* **Correlation coefficients between 24 traits and first two principal components (PCA1 and PCA2)**

| Trait | PCA1 | PCA2 | Trait | PCA1 | PCA2 |
|---|---|---|---|---|---|
| 1 | **-0.712** | 0.373 | 13 | -0.532 | 0.027 |
| 2 | -0.586 | 0.464 | 14 | 0.617 | 0.370 |
| 3 | -0.684 | 0.354 | 15 | 0.566 | 0.619 |
| 4 | **-0.768** | 0.200 | 16 | 0.455 | 0.698 |
| 5 | **-0.799** | 0.337 | 17 | 0.448 | **0.702** |
| 6 | **-0.716** | 0.328 | 18 | 0.403 | -0.052 |
| 7 | -0.677 | 0.314 | 19 | 0.532 | 0.065 |
| 8 | 0.018 | **0.744** | 20 | 0.310 | 0.141 |
| 9 | 0.210 | -0.174 | 21 | 0.326 | -0.068 |
| 10 | -0.035 | **0.720** | 22 | 0.581 | -0.057 |
| 11 | -0.636 | -0.143 | 23 | 0.680 | 0.022 |
| 12 | 0.078 | 0.545 | 24 | 0.462 | 0.611 |

## Discussion

Resource fluctuations and disturbances are important factors making habitat subject to invasions (Booth et al., 2004; Davis, 2003). Disturbances, in most cases, are connected with human activities. *A aristatum*, an alien, invasive species in Central Europe, is spreading towards eastern borders of Poland. It still remains in its chorological phase of expansion (Jackowiak, 1999) and has achieved the status of epecophyte (epoecophyte), i.e. a species of foreign origin which occupies only sites created or deeply transformed by humans and which remains under constant and strong human pressure (Latowski, 2005). In conditions of Poland, *A. aristatum* is still in the process of spreading during which it crosses successive ecological barriers. This, in turn, may lead to genetic and structural differentiation.

The obtained results showed a relatively continuous pattern of morphological variations among samples of *A. aristatum*. The performed biometric analysis of *A. aristatum* indicated a high range of morphological variation in populations of annual vernal grasses (Pimentel et al., 2010; Drapikowska et al., 2008). The present study verified the former statements. Most invasive species are characterized by high genotypic diversity resulting in phenotypic plasticity (Jackowiak, 1999). In our investigations, PCA revealed considerable inter- and intra-population morphological variations of *A. aristatum*. There were no clear discontinuities between population samples; only two arable-land populations varied from the main group. They could have originated from a few *A. aristatum* specimens, and this fact may explain their lower genetic and phenotypic variation (individuals characterized by shorter panicles, shorter spikelets on the second and the middle branching from the panicle top, and narrower upper glumes). The standard deviation ranges of the abovementioned discriminating characters slightly overlapped, while their mean values clearly differentiated them (Fig. 2). Loss of genetic variation and the subsequent decrease of phenotypic diversity of the populations may have been caused by the founder effect (Lavergne, Molofsky, 2007). CDA analysis tends to provide recognition of two partially separate groups consisting of samples from arable land. Morphological differentiation of samples of the remaining populations (also the field one No. 5) overlapped, and we did not find characters useful for separation of *A. aristatum* populations from different habitats.

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## МІНЛИВІСТЬ АДВЕНТИВНОГО ВИДУ *ANTOXANTHUM ARISTATUM* BOISS. НА ВЕЛИКОПОЛЬСЬКІЙ НИЗОВИНІ (ЗАХІДНА ПОЛЬЩА)

Досліджено морфологічну мінливість популяцій *Anthoxanthum aristatum* Boiss. Здійснено багатовимірний статистичний аналіз 24 морфологічних ознак пахучої трави із шести модельних популяцій (138 особин), зібраних у різних місцезростаннях. Аналіз варіацій ANOVA свідчить про суттєві морфологічні відмінності серед моделей. На підставі аналізу головних компонентів (PCA) виявлено три групи. Вони не повністю відокремелні одна від одної й іноді перкриваються. Канонічний дискремінантний аналіз (CDA) є корисним для різних дискримінантних ознак: довжина волоті та довжина міжвузлів, другий і середній колоски та верхні луски. Слабі кореляції виявлені між морфологічною диференціацією популяцій *A. aristatum* і типами місцезростань, які вони займають.

*Ключові слова*: Anthoxhantum aristatum, *мінливість, місцезростання*.

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## ИЗМЕНЧИВОСТЬ АДВЕНТИВНОГО ВИДА *ANTOXANTHUM ARISTATUM* BOISS. НА ВЕЛИКОПОЛЬСКОЙ НИЗМЕННОСТИ (ЗАПАДНАЯ ПОЛЬША)

Исследовано морфологическую изменчивость популяций *Anthoxanthum aristatum* Boiss. Проведено многомерерный статистический анализ 24 морфологических признаков вида из шести модельных популяций (138 особей), собранных в разных местообитаниях. Анализ вариаций ANOVA указывает на существенные морфологические отличия среди моделей. На основе анализа главных компонентов (PCA) выявлено три группы. Эти группы не полностью обособлены одна од другой и иногда перекрываются. Каноничный дискреминантный анализ (CDA) был успешным для разных дискриминантных признаков: длина волоти и длина межузлий, второй и средний колоски и верхние чешуйки. Слабая корреляции были выявлены между морфологической дифференциацией популяций *A. aristatum* и типами местообитаний, которые они занимають.

*Ключевые слова*: Anthoxhantum aristatum, изменчивость, местопроизрастания.