Hungarian University of Agriculture and Life Sciences

WEED FLORA ANALYSIS OF CANARY GRASS AND DRY PEA IN THE AREA OF GYOMAENDRŐD AND SZARVAS, IN ECOLOGICAL AND CONVENTIONAL FIELDS

Doctoral (PhD) dissertation theses

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Gödöllő

2024

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1. INTRODUCTION AND OBJECTIVES

The growing demands for healthy food ingredients with a traceable history, as well as the changing environmental conditions - especially the extreme rainfall distribution, and the uncertain crop market, which also moves between extremes, encourage Hungarian farmers to change, to reconsider the range of cultivated plants, resulting in changing Hungarian arable crop production (EUROPEAN ENVIRONMENT AGENCY 2024).

In our country, canary grass and dry peas equally belong amongst the small area grown crops, however, in some regions, their cultivation on arable land has been a continuous, successful and profitable practice for decades. Currently, the cultivation volume of both plants is increasing, furthermore, their domestic and export markets are also characterized by stable demand (FAO 2022). They fit well into crop rotation and are favourable pre-crops for a wide range of cultivated plants. Their cultivation is expected to become more and more widespread in the upcoming years. As in the cultivation of all field crops, effective weed control is of critical importance in the case of canary grass and dry peas (MARSHALL et al. 2003). However, the list of herbicidal active ingredients available for the treatment of cultivated plants is very short, which is expected to decrease even further in addition to the continuous withdrawal of plant protection active ingredients authorized in the European Union and Hungary (AGROMÉDIUM 1, 2). In the future, full compliance and consideration of the integrated weed control principles will be even more important, farming systems without herbicide weed control will be appreciated.

The research work regarding the dry peas was carried out between 2017-2020 in the areas of Békés and Csongrád-Csanád county: on the outlying areas of Gyomaendrőd and Szarvas, and in Békés county on the outlying areas of Gyomaendrőd regarding the canary grass. I have analysed the ecological and conventional weed conditions of both cultures in all four years. My goal was to comprehensively evaluate the weeding of cultivated plants, while taking into account the variables influencing the changes of the weed flora. The assessment of the soil, environment, and management of the analysed fields was based on own and farmers' measurements and observations, I have summarized and analysed the data of the performed weed registrations per production system, per culture, per field. This was followed by a statistical analysis of the effect of the various descriptive variables on weed infestation and the composition of the weed vegetation.

During my work, I sought answers to the following questions:

- What are the typical weed species of the canary grass and dry pea cultures and what is the extent of their coverage in the examined area?
- Can weeds be kept at an acceptable level without the use of herbicides in canary grass and dry pea crops?
- What are the dangerous and problem-causing weeds of organic and conventional farming regarding canary grass and dry pea cultures?
- Which soil, environmental and farming variables have the greatest influence on the weed ratio of the canary grass and dry pea cultures?

2. MATERIAL AND METHOD

The circumstances of the examination

The research work was carried out between 2017 and 2020 in the south-eastern part of Hungary in Békés county (in case of the dry pea, some of the examined fields were located in Csongrád-Csanád county) on the outlying areas of Gyomaendrőd and Szarvas. I have analysed the ecological and conventional weed areas of both cultures in all four years. The examined areas were used as rice fields until the beginning of the 1990s, the aftereffects in terms of weed vegetation can be felt to this day.

The examination in Gyomaendrőd was carried out the in the areas of Agrofém Ltd. (canary grass and dry peas), and the examination in Szarvas was carried out in the areas of Agroselect Ltd. (dry peas). Both companies are engaged in crop cultivation on approximately 1,000 ha. The crop production is influenced by unfavourable soil conditions in case of both farms. Their cultivated plants are winter wheat, winter barley, spelt wheat, sunflower, red sorghum, white sorghum, canary grass, dry peas, vetch, and oil-seed pumpkin.

The climate of the area is continental, often with very cold winters and even extremely hot summers. The rainfall supply is characterized by an average higher than that of the Great Plain. Only 80-100 km air line away from the area, are the chains of the Transylvanian Mountains, the Béli Mountains, the Bihar Mountains, and the Vigyázó Mountains, due to which the annual rainfall is 550-600 mm. The number of hours of sunshine per year is also high in national terms, approaching 2400 hours. (METEOBLUE 2024)

During the examination, I have carried out weed analysis in canary grass and spring dry pea crops. The same plant varieties were sown on each field and in each vintage year, in case of canary grass it was the Kisvárdai 41, and in the case of the dry peas was the Nany.

The basic autumn cultivation of the areas can be divided into three groups: ploughing, loosening and shallow cultivation. In all cases, ploughing was done at a depth of 30 cm with a rotary plough, loosening at a depth of 35 cm with a medium-deep loosener, and shallow cultivation with a heavy disc at a maximum depth of 15 cm.

The method of weed analysis

During the weed analysis, I have examined eight randomly placed sample areas per time and per field. The sample areas were 1 m2 per recording point. The sample areas in each field were randomly selected. In 8 plots (ZALAI et al. 2012), 1 x 1-meter squares, which were selected by excluding the 24-meter strip measured from the edge inside the field, at a distance of at least 10 and at most 20 meters, I assessed the percentage of weeds present per species its cover (NÉMETH - SÁRFALVI 1998). I determined the weeding values based on the average weeding of the sample areas per field and present them in the thesis. The sample areas and then the fields were evaluated based on the number of weed species present, their cover values, and their distribution (Shannon diversity index, SHANNON 1948).

Applied mathematical and statistical methods

During the content and statistical evaluation of the results, I have evaluated the weeding data collected in dry pea and canary grass cultures separately for each culture.

As a first step in the data preparation, I have averaged the cover values of each species within the eight sampling locations of each field to calculate the average weed composition of the fields. Afterwards, in order to show the general importance of each species, I have calculated both the average coverage value (main average) and the frequency of their appearance, in proportion to the investigated fields, in all the investigated areas. Furthermore, during the statistical evaluation, I used the values of the coverage data averaged per field modified by Hellinger transformation (HELLINGER 1909) in order to minimize the differences between the effects of variables measured on a different scale and/or with different distributions (LEGENDRE - GALLAGHER 2001).

In order to verify the independence between the descriptive soil, vintage year and farming variables, I have performed an intercollinearity test by calculating the generalized variance inflation factors (GVIF), separately for the canary grass and dry pea cultures. During this procedure, the models set up for each plant crop were reduced by a number of factors until all the remaining variables in the test model gave a GVIF value below 5 (FOX 2016).

In the next step, Shannon diversity index was calculated based on total weed coverage per field, the number of species (species richness) per field, and the average weeding per field (SHANNON 1948).

In case of both cultures, total weed coverage, the number of species per field, Shannon diversity index, and in the case of canary grass, the change in yield was evaluated separately using analysis of covariance (ANCOVA) - included in the narrowed model based on non-interacting variables during the intercollinearity test – based on soil, environmental, and farming variables. Based on the ANCOVA, significant continuous variables were further evaluated using Pearson's correlation, and significant categorical variables with the Tukey HSD test. In the case of the Tukey HSD test, in the pairwise comparison, I marked the results with the same letter or letters where the means are not significantly different from each other (CHAMBERS et al. 1992, SOPER et al. 1917, YANDELL 1997).

As the next step of the statistical processing, I used redundancy analysis (RDA) to evaluate the interaction of the soil, environmental and farming variables and their effect on the weed vegetation composition, separately for both examined plant cultures. In the analysis, only those species are included that were present on at least 10% of the fields, separately for each culture.

To analyse the full and pure effect of descriptive variables, I have used the LOSOSOVÁ et al. (2004) method, according to which the total effect of each variable with one-factor RDA, while the pure effect was analysed with partial RDA, in the latter case, the effect of the variable was obtained after subtracting the effects of the other variables from the total explanatory effect. After the analysis, the explained variation and the corrected R^2 values were presented. In order to show the relationship between the significant factors and the weed species, I identified the 10 species with the largest explained differences for each partial RDA model, as well as the relationship of these species to the given descriptive variable.

Microsoft Excel 2023 was used for the presented data preparation, and R statistical environment (Comprehensive R Archive Network; R Development Core Team; ver.: 4.3.2) and vegan (Community Ecology Package; ver.: 2.5-4), car (Companion to Applied Regression; ver.: 3.1-2), MASS (Modern Applied Statistics with S; ver.: 7.3-58.3) program package was used. All statistical evaluations were performed at the 95% reliability level.

3. RESULTS AND THEIR DISCUSSION

Weed vegetation of canary grass

The average weed coverage of the examined fields during the study was 10.8%. According to Figure 1, late summer annual weed species occurred in the largest number with a total coverage value of 8.4%, and geophyte species were also significant, with a coverage of 2.0%. The most common weed species were *Echinochloa crus-galli* (4.2%), *Cirsium arvense* (1.6%), *Xanthium italicum* (1.6%), and *Setaria viridis* (1.0%). Additionally, weed species such as *Hibiscus trionum* (0.8%), *Chenopodium album* (0.4%), *Convolvulus arvensis* (0.3%), *Ambrosia artemisiifolia* (0.2%), *Persicaria lapathifolia* (0.2%), and *Avena fatua* (0.1%) occurred at cover values below 1%.

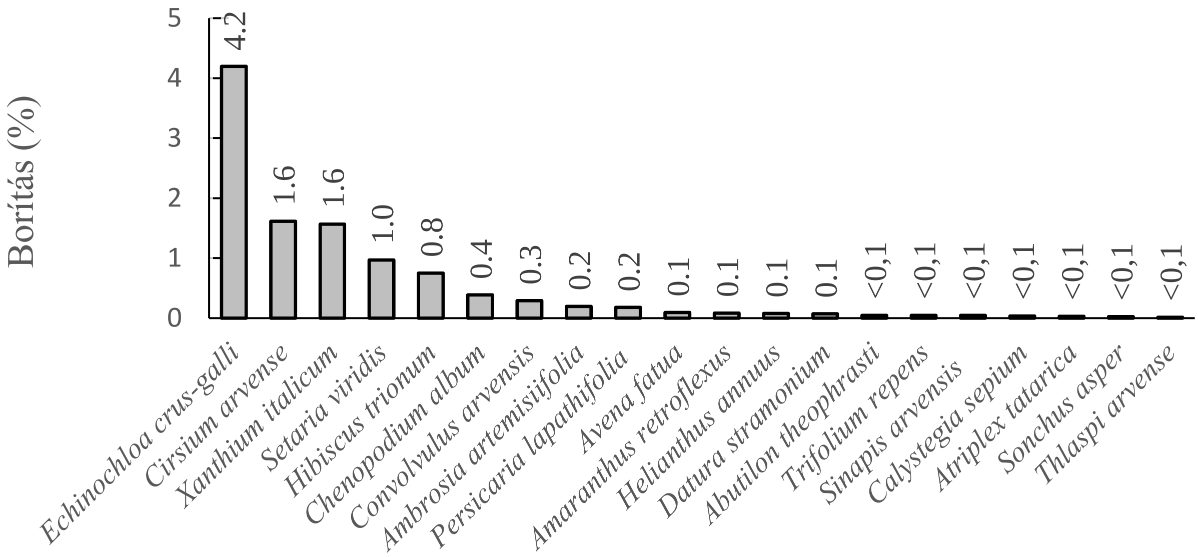

Figure 1: Average coverage (%) of the most important weed species of the examined canary grass fields

The distribution of weed cover on the canary grass fields according to life form groups showed the emphasis of late summer annuals. T4 weeds contributed for 79.8% of all weeding. G3 weed species covered only 17.8%, T3 species 1.7%, G1 and T2 weeds infected a very low 0.4 and 0.3%, respectively. Species belonging to the H life form group only caused harmful competition at a very low 0.01% (Figure 2).

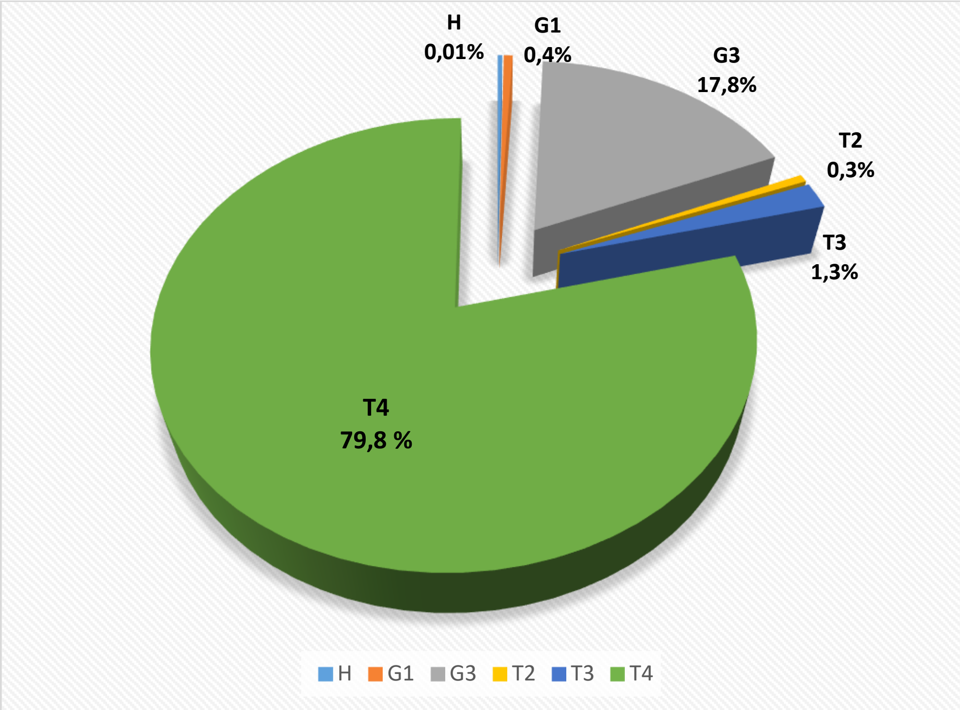

Figure 2. The average cover values of the weed species of the studied canary grass fields, divided by life form groups

In case of the canary grass fields, the frequency of weed species shows a parallel with the coverage values. Members of the T4 life form group again occurred with the highest frequency of 71.7%, followed by the G3 species with 16.8%, then the T3 and T2 species with 4.9 and 2.5 by %. In this case, the members of the H and G1 lifestyle groups significantly lagged behind the other groups with frequency values of 2.5 and 1.6%.

According to the performed covariance analysis (ANCOVA), several soil and management factors, as well as seasonality, significantly influenced weeding, the number of species per field, the Shannon diversity index, and yield level. Of all the variables, the vintage year effect had the greatest influence on weeding. Comparing the very high coverage values of 10.9% and 23.8% in 2018 and 2020, and 6.1% and 2.4% in 2017 and 2019, very large vintage year differences can be seen. The vintage year effect also clearly influenced the crop yield. In the years with heavy weed infestation, the average yield was 39% lower than in the less weedy years of 2017 and 2019.

According to the performed redundancy analysis (RDA), the composition of the weed flora was primarily influenced by the year of data collection (21.06%), the S content of the soil (5.96%) and the autumn-sown preceding crops (5.93%), but a total of 8 factors were significant in the model below. The total variance explained by RDA was 21.62%, 21.06% and 9.26% for soil, vintage year and pre-crop in order (Figure 3).

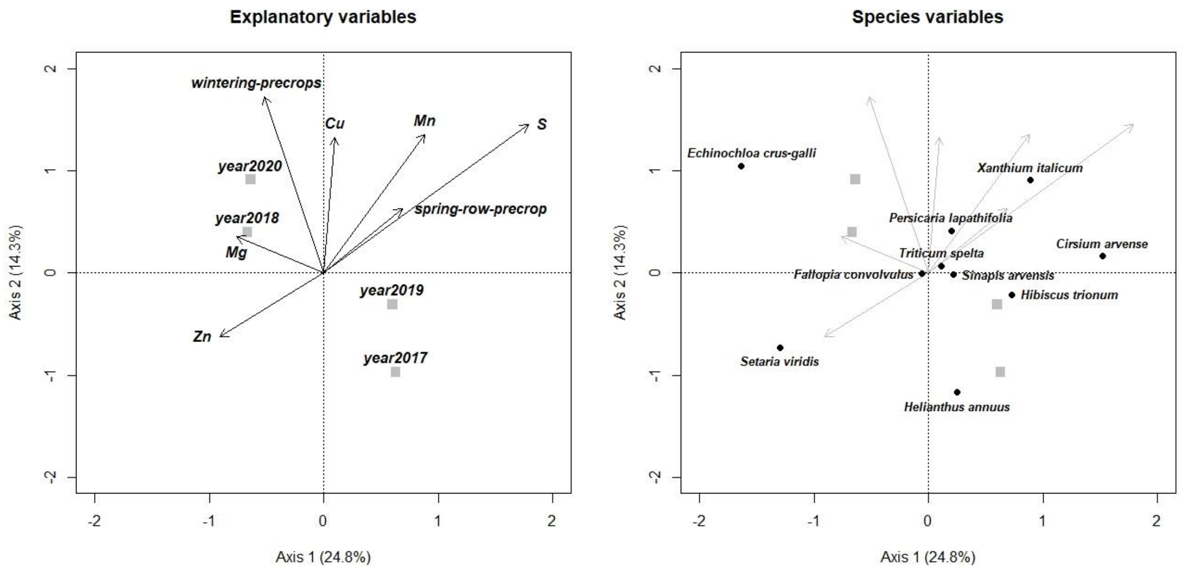

Figure 3. Ordination diagrams of the redundancy analysis (RDA) model in canary grass culture (Arrow: numerical variable; square: factorial year variable; circle: species).

Weed vegetation of dry pea culture

According to Figure 4, late summer annuals accounted for more than half of the weed coverage (13.3% in total). In addition to the annuals, the coverage percentage of geophyta species was the next highest in the examined areas. The weed species with high coverage, which reached more than 1% coverage, were: *Echinochloa crus-galli* (late summer annual; 6.03 %), *Convolvulus arvensis* (geophyte; 4.48 %), *Cirsium arvense* (geophyte; 1.73 %), *Xanthium italicum* (late summer annual; 1.63 %) and *Hibiscus trionum* (late summer annual, 1.42 %). In addition to the weed species, volunteer crops such as *Triticum spelta*, *Triticum aestivum* and *Brassica napus* appeared in the areas with 0.46%, 0.17% and 0.10% coverage.

Examining the distribution of weed coverage regarding to life form groups, the high values of late summer annuals are also conspicuous. 63.2% of all weed infestations were caused by T4 weeds in the examined pea fields. G3 weed species also occurred on a large area (29.5%), T3 and T2 weeds were infected in only 3.7 and 3.2%, respectively, species belonging to the G1 and H life form groups were negligible with values below half a percent (Figure 5).

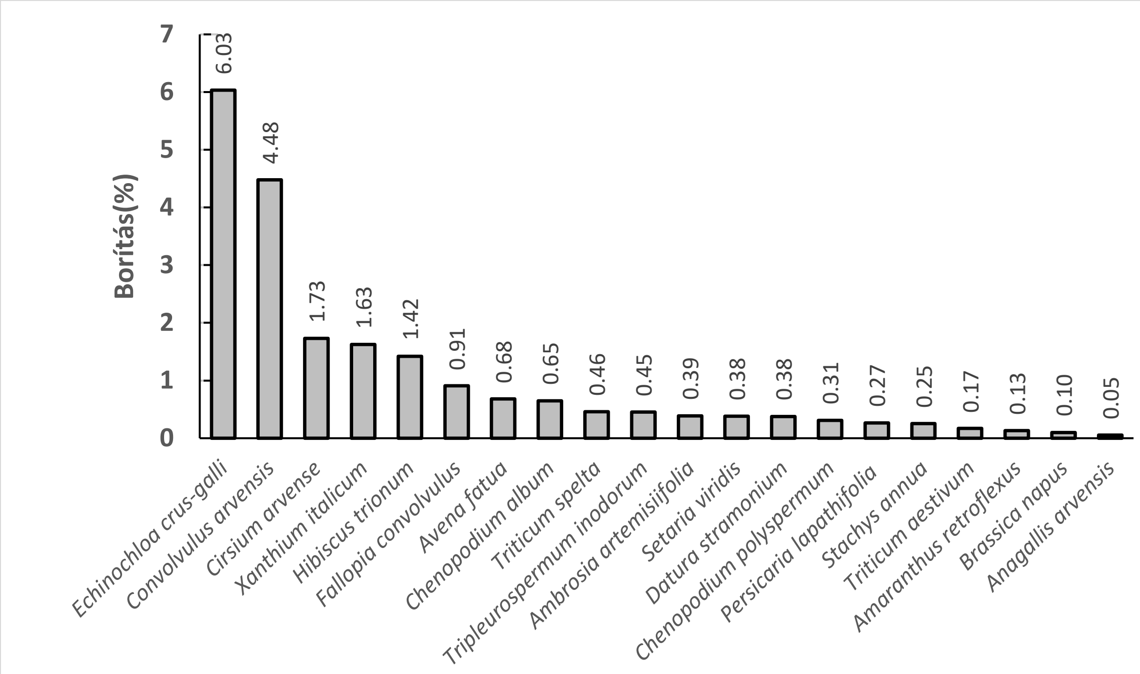

Figure 4: Average coverage (%) of the most important weed species of the examined dry pea fields

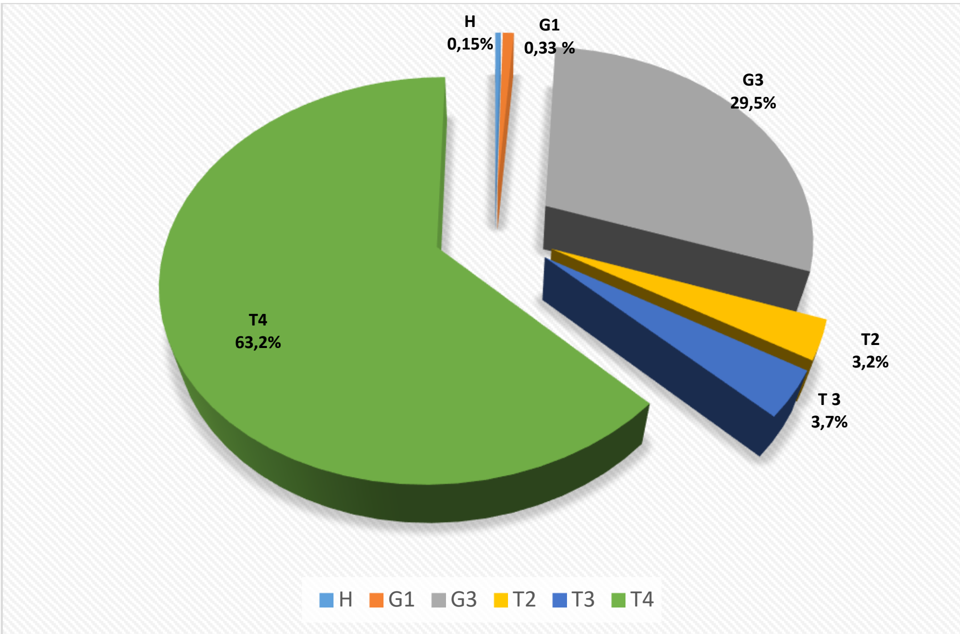

Figure 5: The average coverage values of the weed species of the examined dry pea fields, divided by life form groups

Similar to the coverage values, the frequency of occurring species was the highest in late summer annual species and geophyte species during the analysis. Among eight species with a frequency over 50%, the first six were annuals, and two were geophytes. *Echinochloa crus-galli* (74.19%), *Convolvulus arvensis* (67.74%), *Cirsium arvense*, *Chenopodium album* and *Setaria viridis* (each 64.52%) appeared with the highest frequency.

According to the performed covariance analysis (ANCOVA), 7 of the 16 variables included in the narrowed model had a significant effect on all weed coverage. Amongst them, the growth of weed vegetation was caused by the higher pH value of the soils, higher salt and calcium content, their more easterly location in terms of geographical longitude, and the less frequent occurrence of autumn-sown preceding crops. Among the three types of soil examined, the lowest amount of weed coverage was observed in the case of clay soil, 3.86%, while in fields with clay loam soil, weeding occurred on average 19.89%, and in fields with meadow soil, 25.2%. In terms of the test period, no significant deviations were observed in the period between 2017 and 2019 (average: 13.23% - 15.92%), however, in 2020 the highest weed coverage of 39.25% was examined.

The number of species per field describing the diversity of the weed flora and Shannon diversity index values, were usually only influenced by a limited number of variables. In addition, the number of species per field increased as a result of the lower phosphorus content of the soils and the location of the fields - further east. In the case of the examined soil types, I found a statistically verifiable difference only between clay (6.67 species/field) and meadow (9.56 species/field) soils. In the case of Shannon diversity index, the humus content of the soil ($p=0.032$, corr.:-0.28), the potassium content of the soil ($p=0.038$, corr.:-0.29) and the ratio of spring preceding crops ($p=0.019$; corr.: -0.07). The small number of significant effects observed during the analysis of the diversity values confirmed our assumption that analyses describing the weed vegetation at the species level are also needed to accurately evaluate the effect of the descriptive variables.

According to the conducted redundancy analysis (RDA), the year of data collection (15.6%), soil type (10.0%) and farming system (5.8%) had the greatest influence on the composition of the weed flora. In addition to these, a total of nine factors were significant in our model. Total variance explained by RDA, including all soil, environmental and management factors, was 21.3%; 23.0% and 8.8% (Figure 6).

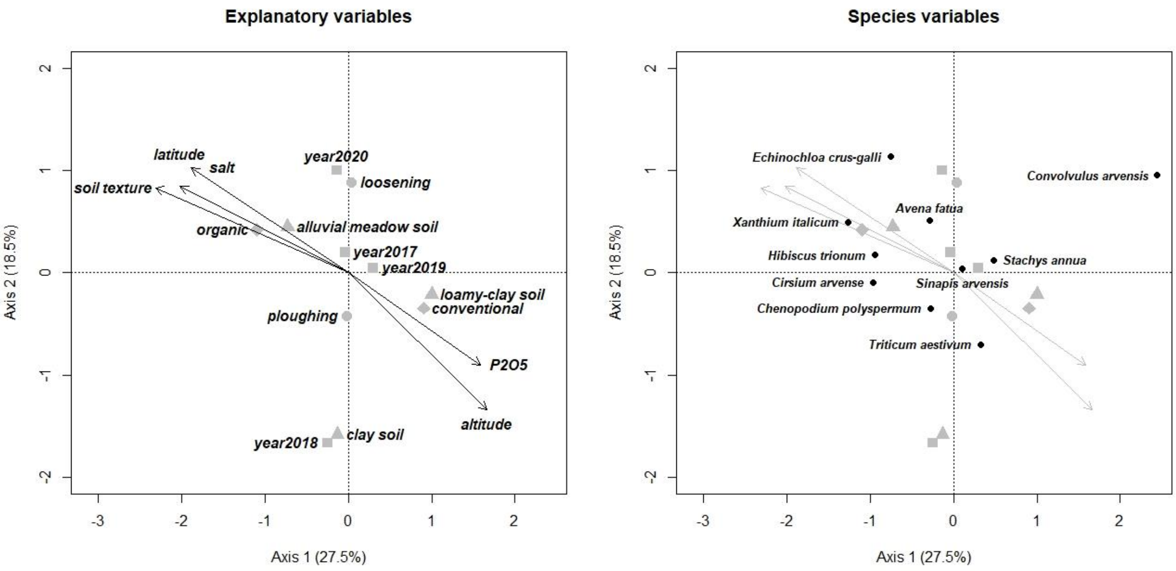

Figure 6: Ordination diagrams of the redundancy analysis (RDA) model in dry pea culture (Arrow: numerical variable; triangle: factorial soil variable; square: factorial environmental variable; grey circle: management factors; black circle: species).

4. CONCLUSIONS AND RECOMMENDATIONS

Overview of the cultures examined in the thesis

The canary grass and the dry pea are two very different crops, but their weed flora and the factors influencing them show many similarities. The total germination of the dry pea fields was on average higher than the canary grass areas. In terms of farming systems, organic fields were weedier than conventional fields for both crops. The most important weed species in the canary grass areas were *Echinochloa crus-galli* (4.2 % cover), *Cirsium arvense* (1.6 %), *Xanthium italicum* (1.6 %) and *Setaria viridis* (1.0 %). For dry pea areas, *Echinochloa crus-galli* (6.03 %), *Convolvulus arvensis* (4.48 %), *Cirsium arvense* (1.73 %), *Xanthium italicum* (1.63 %) and *Hibiscus trionum* (1.42 %) presence was considerable. As shown, *Echinochloa crus-galli* was the most important weed in both cases, and *Cirsium arvense* and *Xanthium italicum* were also important weeds.

In the case of both cultures, T4 weeds accounted for the majority of the cover, and G3 species also appeared with high values. The T3 and T2 weeds appeared on the canary grass and pea fields to an approximately similar extent.

There was a difference in the frequency of weed species. While in the canary grass areas *Hibiscus trionum, Cirsium arvense, Xanthium italicum, Echinochloa crus-galli, Setaria viridis, Chenopodium album*, in the pea fields the order was *Echinochloa crus-galli, Convolvulus arvensis, Cirsium arvense, Chenopodium album, Setaria viridis*.

Weed vegetation of the canary grass fields

The weed infestation of the canary grass has been influenced by 26 variables in my study. The simultaneous monitoring of these variables is essential to determine the most accurate and complete results, as they can have a positive or negative effect on each other. During my study, there were several variables that influenced weediness, but they did not influence the number of weed species per field and/or the Shannon diversity index. Weed control, for example, was a key issue in both organic and conventional farming systems, since without it profitable production is not possible.

The implied covariance analysis (ANCOVA) in the case of canary grass, showed that soil compactness, pH value, and nitrogen content all influence the total weediness of the areas, the number of species per field, the ranking of the importance of the weed species, as well as the crop yield. The results of my research showed that the humus, magnesium, and copper content of the soil, the farming systems, and the autumn preceding crops had an effect on the development of all weeds, the Shannon diversity index, and the yield, but not on the number of species per field. According to my findings, the lime (calcium) and sodium content of the soil and the vintage year had a significant effect on the total weed coverage and yield, but did not affect the number of species per field or the Shannon diversity index. The potassium content of the soil significantly affected the Shannon diversity index and the crop yield, while the zinc content significantly influenced the number of species per field and the crop yield. The phosphorus and sulphur content of the soils, as well as the date of sowing, also significantly influenced all weeds.

The results of the redundancy analysis showed that the vintage year effect had the greatest effect on the evolution of the weed flora, which can be explained by the changing precipitation conditions, since the changes in precipitation were consistent with the changes in the amount of weeds. The previous crops also clearly influenced the composition of the weed flora. According to the redundancy analysis (RDA), the year of data collection (15.6%), soil type (10.0%) and farming system (5.8%) had the greatest influence on the composition of the weed flora. In addition to these, a total of nine other factors had a significant effect in the model. Total variance explained by RDA, including all soil, environmental and management factors, were 21.3; 23.0 and 8.8%.

Weed vegetation of pea fields

As in the case of canary grass, it is important to monitor the different variables simultaneously when examining pea fields, as they can have a positive or negative effect on each other. In the context of organic cultivation, weed control is the cornerstone of plant protection. The farming systems (organic and conventional) mainly differed in the amount of weeds and their coverage values, but at the same time, the diversity of the weed flora, characterized by the number of species per field and Shannon diversity index, was similar. Even though herbicides were used in conventional areas and not in organic areas, the method of nutrient supply was also differed.

The covariance analysis (ANCOVA) during the examination of the pea fields showed that soil type and geographical longitude affect the total weed cover and the number of species per field, but they do not affect the Shannon diversity index. Soil pH value, salinity, lime content, vintage year and the proportion of autumn preceding crops influenced the total weed cover, but they did not have a significant effect on the number of species per field or the Shannon diversity index. The humus content, potassium content and the spring preceding crops of the cultivated areas influenced the Shannon diversity index calculated based on the presence of weed species, but they did not affect the total weed cover or the number of species per field. The phosphorus content of the soils affected only the number of species per field. Soil compactness, altitude, latitude, tillage method and management method were not significant in any of the cases.

The physical and chemical attributes of soils, soil type, soil structure, humus content, and phosphorus content significantly influenced the occurrence of weed species. The weeding effect of the increase in lime content was also confirmed in this study.

According to the redundancy analysis, the year of the study and soil parameters had the greatest effect on the weed composition of the pea fields. Similar to the canary grass areas, the effect of the year can be largely explained by changing precipitation conditions, since these changes in the precipitation were consistent with the changes in the weed composition.

5. NEW SCIENTIFIC RESULTS

1. I have identified that the most important weeds in the canary grass culture in the examined area belonged to the T4 and G3 life form groups, which in order of importance are: *Echinochloa crus-galli, Cirsium arvense, Xanthium italicum, Setaria viridis, Hibiscus trionum, Chenopodium album, Convolvulus arvensis, Ambrosia artemisiifolia, Persicaria lapathifolia, and Avena fatua.*

2. I have identified the most significant weeds in dry pea culture in the examined area belonged to the T4 and G3 life form groups, which in order of importance are: *Echinochloa crus-galli, Convolvulus arvensis, Cirsium arvense, Xanthium italicum, Hibiscus trionum, Fallopia convolvulus, Avena fatua, Chenopodium album, Triticum spelta, Tripleurospermum inodorum*.

3. I found that in the case of the canary grass culture, the effect of the year and the nitrogen content of the soil significantly influence weed cover, the Shannon diversity index and the yield. Additionally, organically farmed areas are more than three times weedy as conventional areas, but neither the number of weed species per field nor the Shannon diversity index changes as a result of farming systems.

4. In the case of the dry pea culture, I found that the extent of weeding was facilitated by the higher pH value, higher salt and calcium content of the soil, their more easterly location in terms of geographical longitude, and the lower frequency of autumn preceding crops. Among the soil types, the meadow cast soils were the weediest. With the exception of 2020, the vintage year effect did not show a significant difference.

5. In both canary grass and dry pea cultures, I found that both the totality of soil factors and the totality of environmental factors - including the vintage year effect - have a greater impact on the composition of weed vegetation than management factors combined.

6. Analysing the effect of soil factors, I found that in the case of canary grass, the sulphur, copper, magnesium, manganese, and zinc content of the soil, while in the case of peas, the type, firmness, salt, and phosphorus content of the soil influence the composition of the weed vegetation.

7. I found that – in both canary grass and dry pea cultures - the vintage year as an environmental factor had the greatest effect on the composition of the weed vegetation.

8. I found that in case of canary grass, only the pre-crop, and in the case of the dry peas, only the farming method and tillage affect the composition of the weed vegetation among the farming variables.

6. PUBLICATIONS OF THE AUTHOR RELATED TO THE TOPIC OF THE DISSERTATION

Journal articles:

KOVÁCS E.B., CSÍK D., DORNER Z., ZALAI M. (2023): Effect of environmental, soil and management factors on weed flora of field pea in South-East Hungary. In: *Agronomy*, 13, 1864. https://doi.org/10.3390/agronomy13071864

ZALAI M., KOVÁCS E.B., IVÁNYI D., DORNER, Z. (2024): How the management and environmental conditions affect the weed vegetation in canary grass (*Phalaris canariensis* L.) fields. In: *Agronomy*, 14, 1169. https://doi.org/10.3390/agronomy14061169

KOVÁCS E.B., ZALAI M. (2018): Konvencionális és ökológiai héjnélküli olajtök, borsó és fénymag kultúrák gyomnövényzetének összehasonlítása Gyomaendrőd és Szarvas térségében. In: *Magyar Gyomkutatás és Technológia*, 19: 37-48.

Abstracts published in conference publications:

KOVÁCS E.B., DORNER Z., ZALAI M. (2018): Konvencionális és ökológiai borsótáblák gyomnövényzetének összehasonlítása Gyomaendrőd térségében. In: *64. Növényvédelmi Tudományos Napok*, Budapest, pp. 71.

KOVÁCS E.B., ZALAI M. (2019): Konvencionális és ökológiai héjnélküli olajtöktáblák gyomnövényzetének összehasonlítása Gyomaendrőd és Szarvas térségében. In: *65. Növényvédelmi Tudományos Napok*, Budapest, pp. 75.

KOVÁCS E.B., ZALAI M. (2020): Konvencionális és ökológiai fénymagtáblák gyomnövényzetének összehasonlítása Gyomaendrőd térségében. In: *66. Növényvédelmi Tudományos Napok*, Budapest, pp. 74.

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