Effects of management and environmental factors on weed species composition of soyabean and oil pumpkin fields in Hungary

Final report

Question

Which environmental and management factors are the most important determinants of arable weed species composition in soyabean and oil pumpkin fields across Hungary?

Methods

The abundance of weed flora and environmental, management and site context factors were measured in 262 soyabean (Fig. 1.) and 180 oil pumpkin (Fig. 2.) fields, representing the entire country. Data were analysed by redundancy analysis (RDA) after backward variable selection. For each variable the gross and net effect on weed species composition were calculated. Variation partitioning based on RDA was used to assess the relative effects of the groups of explanatory variables.

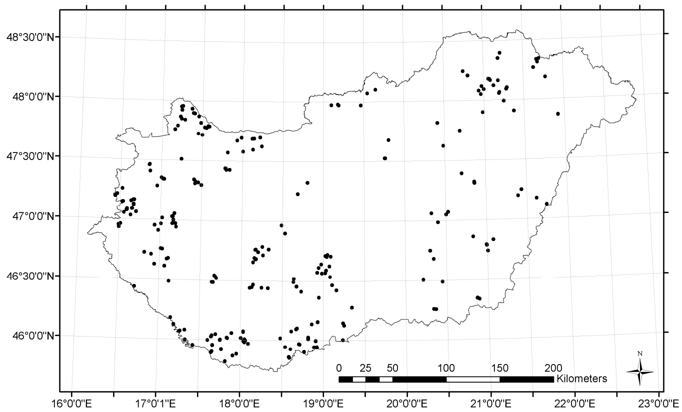

Fig. 1 The distribution of the 262 surveyed soyabean fields across Hungary (a single point may represent multiple fields).

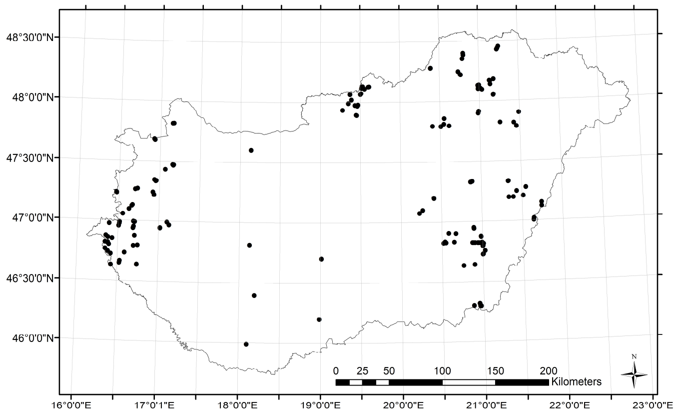

Fig. 2 The distribution of the 180 surveyed oil pumpkin fields across Hungary (a single point may represent multiple fields).

Results

Soyabean fields

In soyabean fields altogether 154 weed species were recorded. *Chenopodium album, Ambrosia artemisiifolia, Hibiscus trionum, Echinochloa crus-galli* and *Convolvulus arvensis* were the top five dominant and frequent weeds. The full RDA model (comprising 38 explanatory variables) explained 25.15 % of the variance, while, the reduced model (comprising 24 explanatory variables) still explained 21.61% of the total variation in species data. Fourteen predictors (crop cover, preceding crop, date of sowing, fertiliser K, field size, tillage system, tillage depth, soil P_2O_5 and Mg content, S-metolachlor, clomazone, imazamox, metribuzine and mechanical weed control) were dropped during the backward selection process. According to the pRDA all of the 24 remaining variables has significant net effects with plot location, temperature and soil texture being the most influential (Table 2). In the reduced RDA ordination (Fig. 3), the first axis can be most related to the explanatory variables soil humus and potassium content and precipitation, while the second axis is strongly correlated with soil pH, temperature, cultivar maturity and propaquizafop herbicide. Consequently, the positive direction of the first axis is correlated with nutrient- and potassium-rich soils in the drier regions, typically with *H. trionum* and *C. album*. Low axis 1 values, on the other hand, refer to fields poor both in humus and K, in more humid regions, and generally with *A. artemisiifolia* in the weed flora. Samples from the cooler regions, which are also typically characterized with acidic soils and the presence of the *E. crus-galli* generally exhibit low values on the second RDA axis. In contrast, sites in the warmer regions with more basic soils and the frequent presence of *Sorghum halepense* are characterized with high axis 2 values. The variation partitioning of the RDA model revealed that environmental variables altogether account for 4.3 times the variance of cultural variables, 2.5 times that of weed-management alone, 1.6 times the variance of all management variables together and 5.2 times that of site variables (Fig. 4).

Table 2 Gross and net effects of the explanatory variables on the weed species composition in soyabean fields identified using (p)RDA analyses with single explanatory variables

	Gross effect		Net effect			
Factors	Explained variation (%)	R^2_{adj}	Explained variation (%)	R^2_{adj}	F	p-value
Plot location	1.729	0.0154	1.729	0.0164	10.6686	0.001
Temperature	2.397	0.0221	1.497	0.0140	9.2379	0.001
Soil texture	1.416	0.0122	0.951	0.0083	5.8672	0.001
Soil Ca content	1.289	0.0110	0.872	0.0074	5.3807	0.001
Flumioxazin	0.987	0.0079	0.817	0.0069	5.0423	0.001
Soil K content	2.334	0.0214	0.771	0.0064	4.7611	0.001
Precipitation	3.199	0.0301	0.719	0.0058	4.4393	0.001
Pendimethalin	1.040	0.0085	0.664	0.0053	4.0978	0.001
Cultivar maturity	1.643	0.0126	0.799	0.0050	2.4642	0.001
Organic manure	0.732	0.0054	0.616	0.0048	3.804	0.001
Soil pH	1.654	0.0146	0.551	0.0041	3.3998	0.001
Fertiliser P	0.499	0.0031	0.550	0.0041	3.3943	0.001
Altitude	1.803	0.0161	0.547	0.0040	3.3758	0.001
Dimethenamid	1.038	0.0085	0.478	0.0033	2.9527	0.001
Propaquizafop	0.596	0.0040	0.453	0.0030	2.7935	0.001
Row spacing	0.763	0.0057	0.426	0.0028	2.6287	0.003
Fertiliser N	0.487	0.0029	0.417	0.0027	2.5762	0.003
Bentazon	0.438	0.0024	0.409	0.0026	2.5241	0.004
Quizalofop-p-ethyl	0.168	-0.0003	0.398	0.0025	2.4542	0.006
Quizalofop-p-tefuril	0.538	0.0034	0.387	0.0024	2.39	0.005
Soil Na content	0.752	0.0056	0.370	0.0022	2.282	0.005
Linuron	0.645	0.0045	0.354	0.0020	2.1829	0.006
Soil humus content	2.207	0.0202	0.342	0.0019	2.1132	0.01
Thifensulfuron	0.278	0.0008	0.324	0.0017	2.0014	0.012

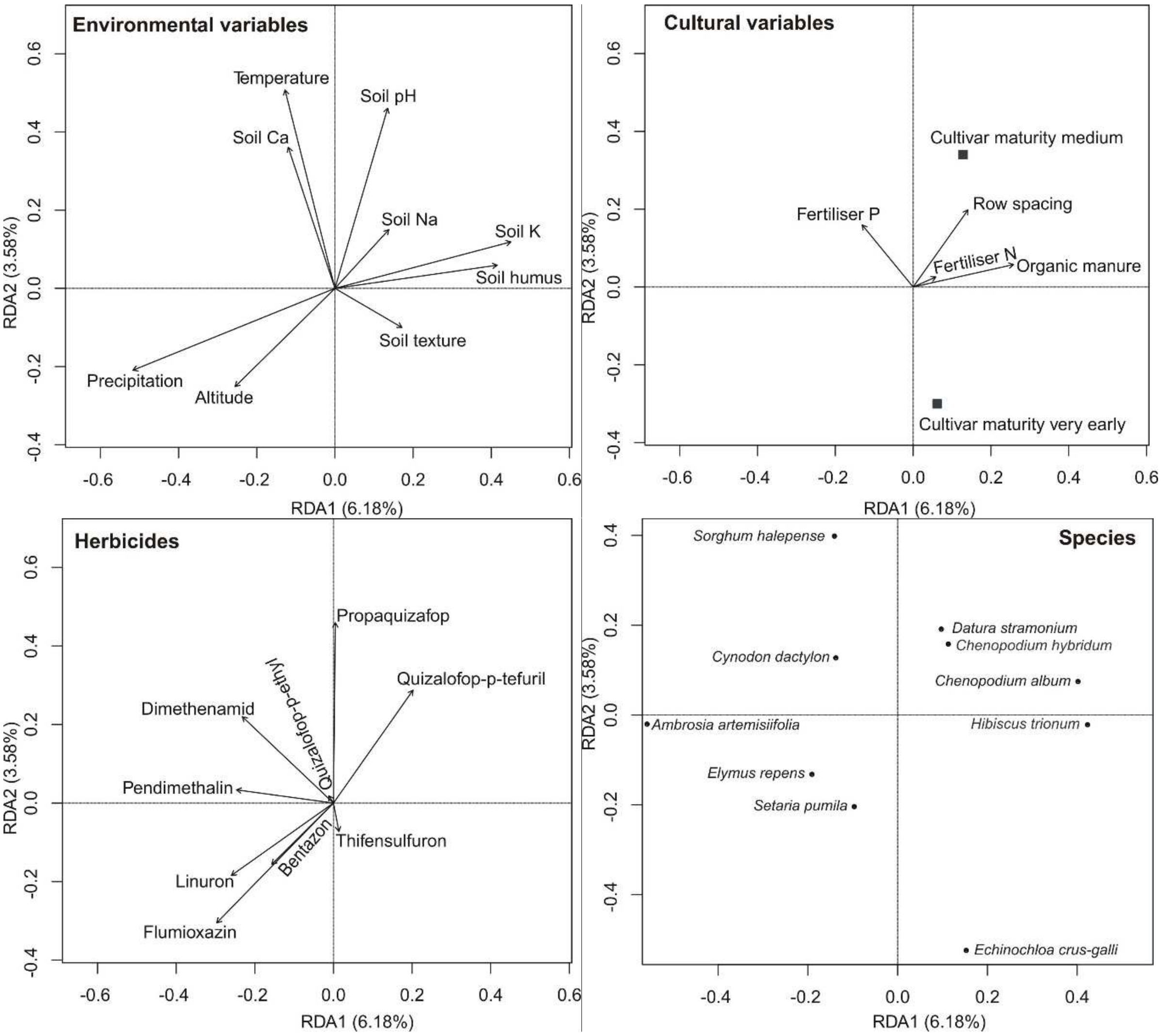

Fig. 3 Ordination diagrams of the reduced RDA model containing the 24 significant explanatory variables and the species in soyabean fields.

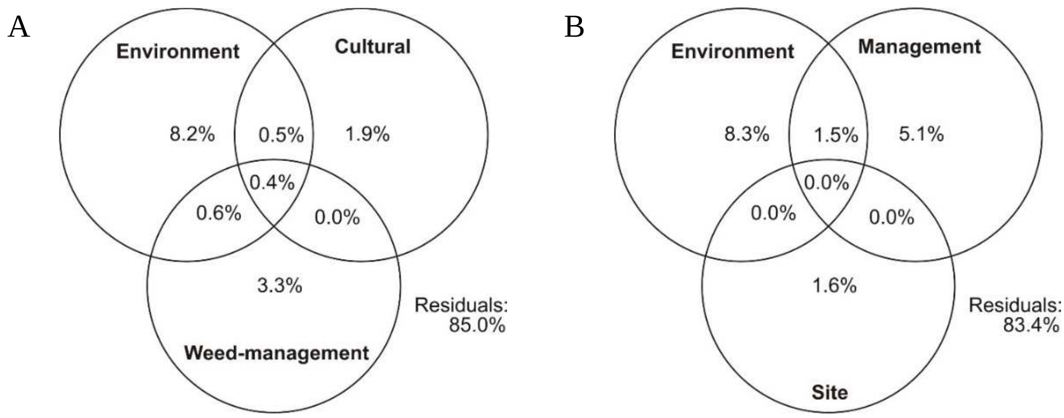

Fig. 4 Percentage contributions of groups of explanatory variables to the variation in weed species composition, identified by variation partitioning. A: *environmental* vs. *cultural* vs *weed-management* variables (*site* variables are among the residuals here); B: *environmental* vs. "management" (including *cultural* and *weed-management*) vs. *site* variables.

Oil pumpkin fields

Altogether 168 weed species were found. *Chenopodium album, Convolvulus arvensis*, *Echinochloa crus-galli*, *Ambrosia artemisiifolia*, *Hibiscus trionum* and *Setaria pumila* were the most abundant weeds. The full RDA model (comprising 30 explanatory variables) explained 35.39% of the variance, while, the reduced model (comprising 18 explanatory variables) still explained 30.79% of the total variation in species data. According to the pRDA, all of the 18 remaining variables have significant net effects with climatic conditions (precipitation and temperature) being the most influential (Table 3). In addition, the effects of seven further environmental parameters (plot location; Mg, K, Ca, P, and humus content of the soil, as well as soil pH), seven non-chemical management variables (preceding crop, N and P fertilisers, seeding rate, crop cover, cultivating tillage and manual weed control), and two herbicides (S-metolachlor and linuron) were significant (Table 3). In the reduced RDA ordination (Fig. 4), the first axis can be most related to the explanatory variables precipitation and temperature, as well as soil humus and K content, while the second axis is correlated with soil Mg content, cultivating tillage, S-metolachlor, as well as P and N fertilisers. Samples from the cooler, more humid regions, which were also typically characterised with soils poor in potassium and the presence of *A. artemisiifolia*, *Chenopodium polyspermum* and *S. pumila*, generally exhibit positive values on the first RDA axis. In contrast, sites in the warmer and drier regions with more K-rich soils and the frequent presence of *Datura stramonium* and *H. trionum* were characterised with low axis 1 values. The variation partitioning of the RDA model revealed that environmental variables altogether accounted for 3.6 times the variance of non-chemical management variables, 17.8 times that of herbicides and non-chemical management practices stand for five times more variance than herbicides (Fig. 5 A). The relative impact of cultural variables are nearly five times larger than that of mechanical treatments; the relevance of chemical weed control is only slightly larger than that of mechanical treatments; and cultural variables altogether stand for 3.8 times more variance than the chemical weed control variables (Fig. 5 B).

Table 3 Gross and net effects of the explanatory variables on the weed species composition identified in oil pumpkin fields using (p)RDA analyses with single explanatory variables.

	Gross effect		Net effect			
Factors	Explained variation (%)	R^2_{adj}	Explained variation (%)	R^2_{adj}	F	P-value
Precipitation	9.660	0.0938	3.364	0.0333	14.629	***
Temperature	8.064	0.0778	1.805	0.0167	7.8499	***
Soil Mg content	3.191	0.0289	1.595	0.0145	6.9356	***
Preceding crop	2.217	0.0129	1.863	0.0124	2.7004	***
Fertiliser N	1.523	0.0121	1.027	0.0085	4.4645	***
Soil K content	6.713	0.0642	0.864	0.0067	3.7595	***
Fertiliser P	0.928	0.0062	0.863	0.0067	3.7547	***
S-metolachlor	1.926	0.0162	0.845	0.0065	3.6771	***
Cultivating tillage	1.377	0.0107	0.755	0.0056	3.2843	***
Soil pH	5.923	0.0563	0.733	0.0054	3.1901	***
Manual weed control	0.820	0.0051	0.693	0.0049	3.0122	***
Soil humus content	4.343	0.0404	0.677	0.0048	2.9446	***
Soil Ca content	2.894	0.0259	0.655	0.0045	2.8505	***
Seeding rate	1.932	0.0163	0.624	0.0042	2.7135	***
Plot location	0.950	0.0064	0.578	0.0037	2.5143	***
Linuron	1.261	0.9521	0.578	0.0037	2.5131	**
Crop cover	1.351	0.0104	0.566	0.0036	2.4602	**
Soil P content	0.981	0.0067	0.560	0.0035	2.4334	**

**P <0.01 and ***P <0.001.

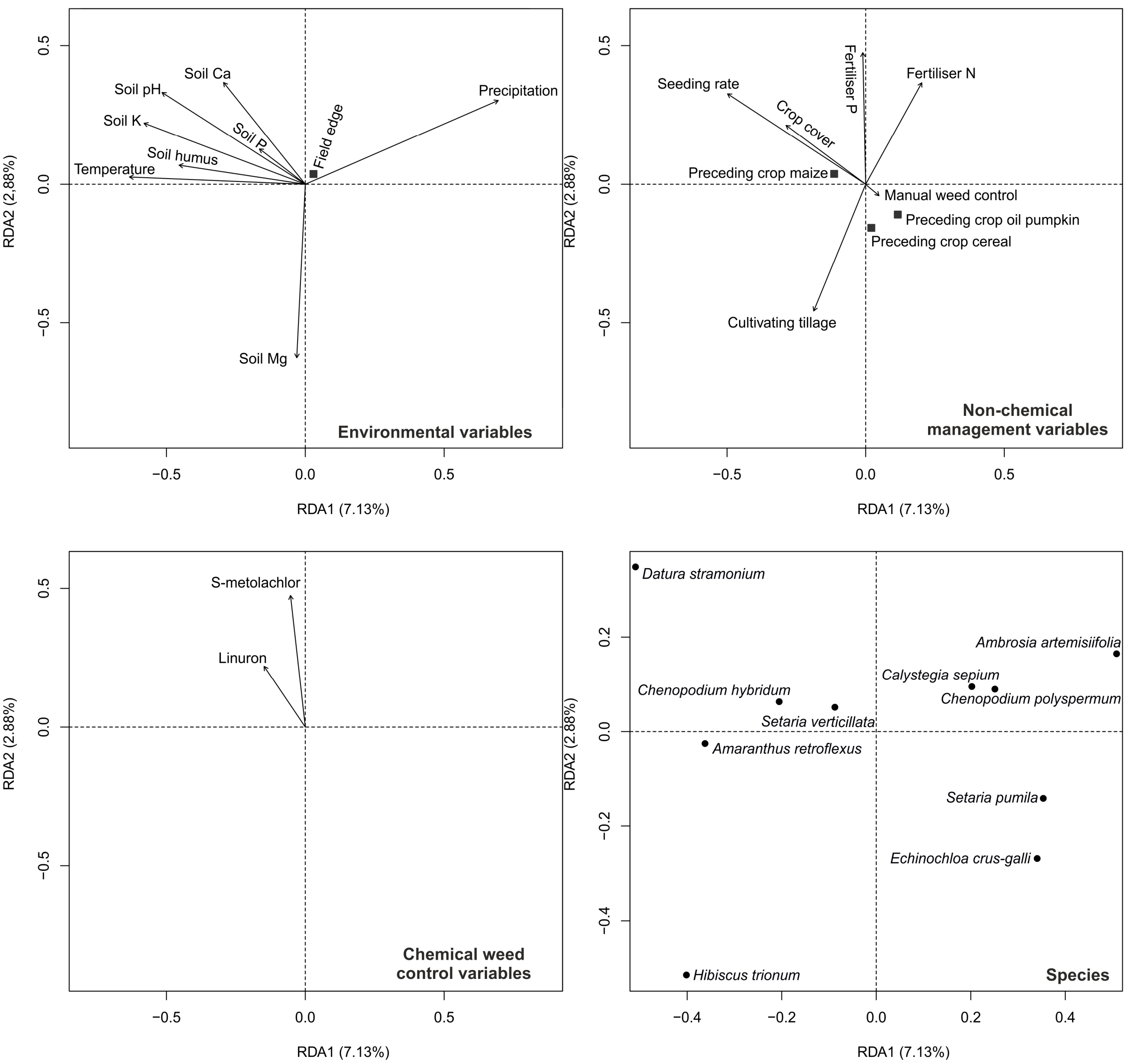

Fig. 4. Ordination diagrams of the reduced RDA model containing the 18 significant explanatory variables and the species in oil pumpkin fields.

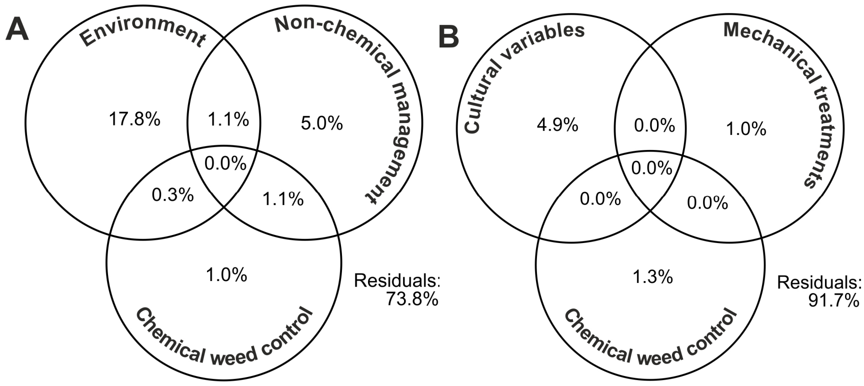

Fig. 5. Percentage contributions of groups of significant explanatory variables to the variation in weed species composition, identified by variation partitioning. A: environmental vs. non-chemical management vs. chemical weed control variables; B: cultural vs. mechanical vs. chemical components of weed management (environment variables are among the residuals here).

Conclusions

Our results in soyabean fields indicated that the effects of environmental factors on weed species composition can be stronger than those of management variables even for intensively cultivated fields. This is in accordance with similar surveys in other Hungarian crops and other European studies. Nevertheless, in any study applying correlative statistical models, the length of a gradient exerts an obvious positive bias on the strength of its effect, and it is also easy to see that the length of ecological gradients is primarily determined by the ecological tolerance of the surveyed crop type in this case. Despite the relatively weak influence of management factors, the responses of the most noxious weed species to the studied cultural and weed-management variables can be used to customize weed management strategies. Ensuring a quickly closing crop canopy by narrow row spacing can offer a generally efficient tool against a broad range of weed species. Furthermore, high amounts of N fertiliser, as well as the proper selection of herbicides can be also efficient to suppress individual weed species. Due to the differences in light conditions and management intensity, the weed vegetation in field edges and field cores differs remarkably, and in case of high infestation of pernicious weeds, weed management strategies should also focus on field edges.

In agreement with our preliminary expectations, we found that the predictors with the strongest impact on oil pumpkin weed vegetation were the environmental variables with the longest gradients in the sample. We also managed to detect a highly significant influence of non-chemical management factors on the weed flora, even if our study was not based on controlled field experiments, but a broad-scale field survey. Although, our analysis documented some influence of the herbicide treatments, variation partitioning showed an almost equal relevance of chemical and mechanical weed management and a much larger relative impact of non-chemical than chemical practices on the weed vegetation. The responses of the most abundant weed species to the studied variables can be used to improve weed management strategies. Even if the short height of pumpkin connected to its weak weed-suppressive ability might be disadvantageous for the outcome of some cultural practices, our study suggests that oil pumpkin can be successfully grown also in more “eco-friendly” ways.

Related publications

Pinke G, Blazsek K, Magyar L, Nagy K, Karácsony P, Czúcz B & Botta-Dukát Z (2016). Weed species composition of conventional soyabean crops in Hungary is determined by environmental, cultural, weed management and site variables. *Weed Research* 56, 470–481.

Pinke, G., Karácsony P, Czúcz B & Botta-Dukát Z (2017). When herbicides don't really matter: Weed species composition of oil pumpkin (*Cucurbita pepo* L.) fields in Hungary, *Crop Protection* (In press), http://dx.doi.org/10.1016/j.cropro.2017.06.018