Field-scale variability of weediness on arable land

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ABSTRACT

Weed mapping was conducted on 2 fields in Central Bohemia to characterize the spatial structure and temporal stability of weed populations over four years (1999–2002). A number of plants for each species and the total weed coverage were investigated on the grid points. To determine the weed infestation variability, and the Patchiness-Index was calculated. Use of Surfer-software, and weed maps were created. For single weed species occurrence the correlation between 1999 and 2000 was calculated. The results document heterogeneous occurrences of weeds, especially *Cirsium arvense* (PI = 9.09–15.86), *Tripleurospermum maritimum* (PI = 11.01–217.30) and *Galium aparine* (PI = 4.61–7.70), whereas *Viola arvensis* and *Stellaria media* were distributed more homogeneously. Weed grasses occurred in all years slightly. *G. aparine* is characterized by relatively high spatial stability.

Keywords: weed infestation; weed mapping; weed population dynamics; spatial variability; temporal variability; precision farming

Weed populations were often found to be spatially heterogeneous within the field (Cardina et al.1997, Clay et al. 1999). This variability has still been ignored for management decisions in the praxis. The pesticides are mostly applied uniformly across the fields. Site-specific weed control (patch spraying) in the sense of precision farming principles assume, that areas with weed infestation below the defined thresholds are not treated or the doses are adjusted according to weed infestation (Sökefeld et al. 2000, Gerhards et al. 2000). This allows reduction of the variable costs of herbicides and diminishes the environmental contamination. The degree of spatial variability affects the effectiveness of the site-specific application. The higher variability, the more favourable is the precision weed control. Weed mapping techniques must be precise enough to screen actual weediness. It is necessary to investigate the ways of simplifying and a more precise detection of weeds and mapping procedure. For some weed species, the high degree of spatio-temporal stability is typical. There is no need to carry out the mapping every year, but historical maps for the forecasting of weediness can be used. Unfortunately, it is limited only to some species. In this paper, variability and stability of weed infestation across the field during years is described.

MATERIAL AND METHODS

Weed mapping was carried out in 1999–2002 in Central Bohemia. The data was collected from 61 ha and 70 ha fields, where winter wheat (WW) and winter rape (WR) were grown. Both fields were managed by practical farming with classical management. A rectangular grid 40 × 40 m (20 × 40 m) was established with use of GPS (Global Positioning System) along tramlines (Figures 2 and 6). In every grid point, a quadrate of 0.25^2 or 1 m^2 in 2 replications was used for identification of all species and counting of plants. Because of low threshold by *Galium aparine* was for this species investigated the area of 10 m^2 for each point. The mapping parameters for each year are summarized in Table 1. In winter wheat, the weed mapping was performed always in April, closely before post-emergence herbicide application, whereas the winter rape field was mapped already in November.

Weed species, their density and total weed coverage was evaluated for each grid point. Lloyd's Patchiness-Index (Lloyd 1967) was calculated for each species to determinate the heterogeneity of weed occurrence:

$$PI = (m + s^2/m - 1)/m$$

m = mean weed density of all samples

s^2 = variance

If PI > 1, the weed population is patchy distributed across the field. With increasing index, the patchiness increases.

For selected occurred weed species, the Pearson's correlation coefficient between years was calculated for the locality Klucov. The number of plants per m^2 on 93 grid points was for that purpose compared. Weed maps were created using Surfer-software.

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Table 1. Characteristics of the fields and mapping methods

Field	Field area (ha)	Year	Crop	Grid raster	Number of points	Quadrat size (m^2)
Klucov	61	1999	WW	80 × 80	93	0.25
Klucov		2000	WW	40 × 40	369	2 × 1
Klucov		2001	WR	80 × 80	93	2 × 1
Klucov		2002	WW	20 × 40	711	2 × 1 (2 × 5)
Trebovle	70	2001	WW	40 × 40	426	2 × 1 (2 × 5)

RESULTS

Weed spatial variability

Total weed infestation showed lower variability than single species in both fields (Figures 1 and 7). Reason for this effect consists in the mutual substitution of weed species.

In the locality Klucov the weed patches were situated mainly in the lower part of the field in all years. *Galium aparine* as the most important weed was distributed patchy. The area with density below the threshold (0.2 plants per m^2) represents 44.8% to 72.6% of total area depending on the year (Figures 3 and 4).

High aggregation level was found also by *Cirsium arvense*, which formed only small nests distributed across the field (Figure 5). A High Patchiness-Index for *Stellaria media, Capsela bursa-pastoris* and *Tripleurospermum maritimum* was partially caused by low infestation in general. These species tended to occur mainly in the field margins. In contrast, *Viola arvensis* was observed at high infestation levels in most years and showed a lower variability (Figure 6). In 2000 it was present on 82% of raster points, in 2002 on 79% of points. Only low grass weed infestation was observed in all years. *Apera spica-venti* was found on this field only in 2002.

Figure 1 in contrast to Figure 2 shows, that only the number of plants was a criterion for weed in-

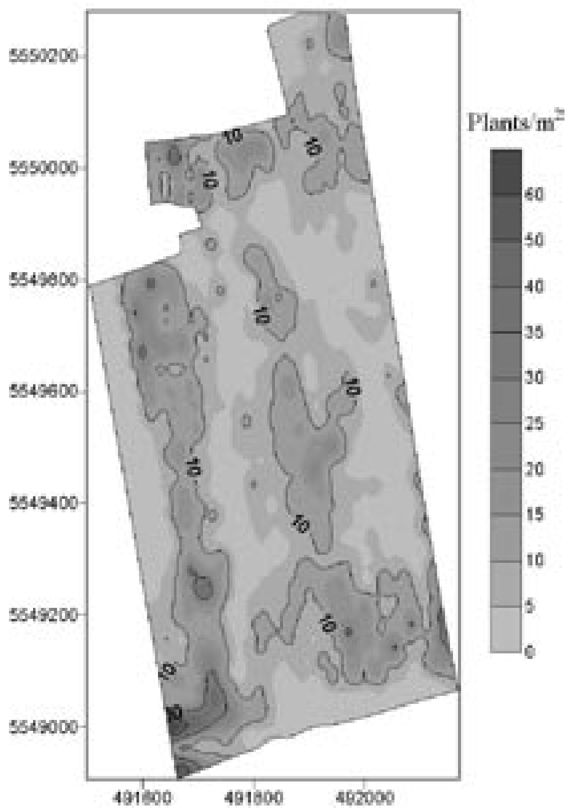

Figure 1. Total weed infestation in the field Klucov (2002)

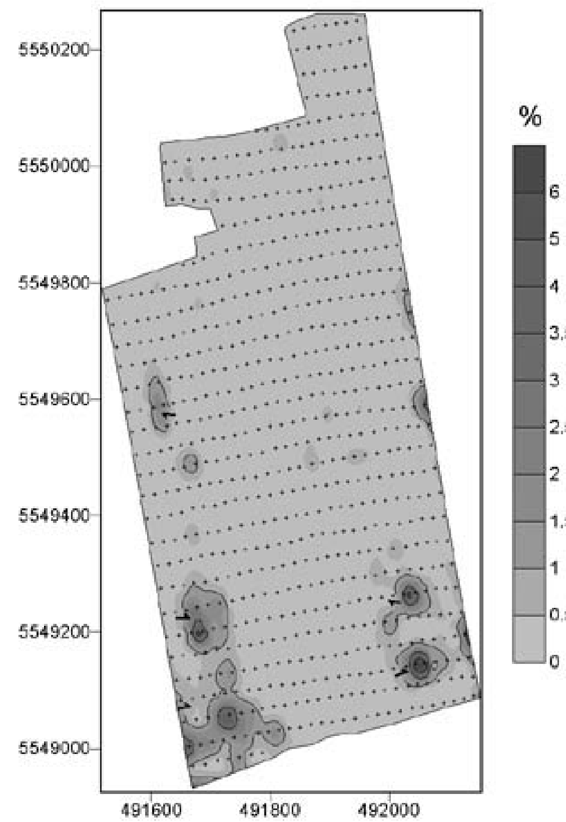

Figure 2. Weed coverage in the field Klucov (2002)

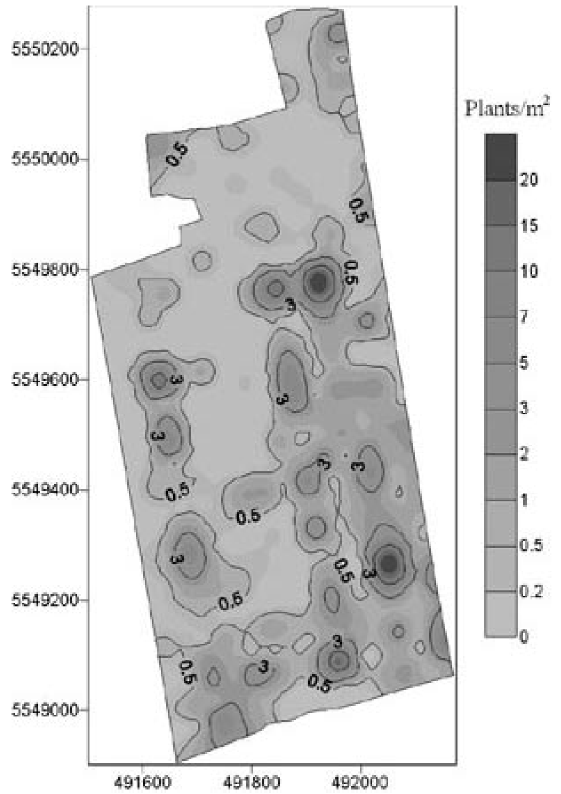

Figure 3. Occurrence of *Galium aparine* in the field Klucov (2000)

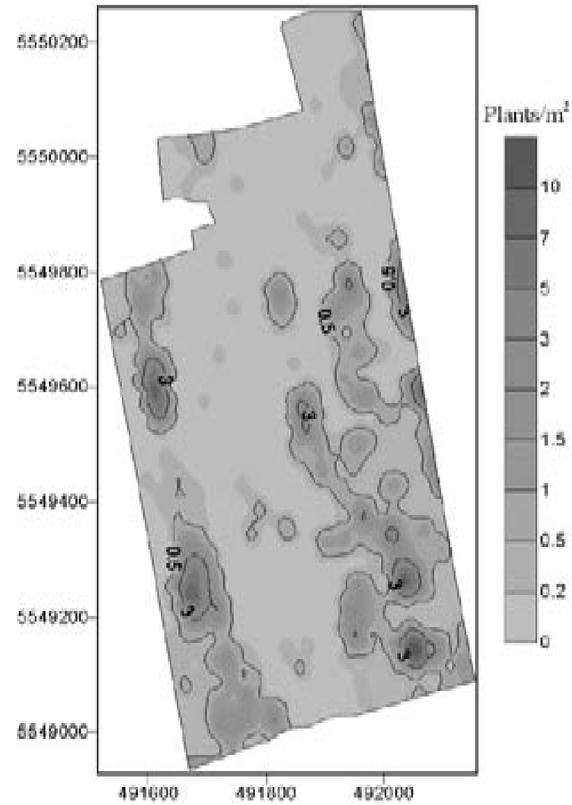

Figure 4. Occurrence of *Galium aparine* in the field Klucov (2002)

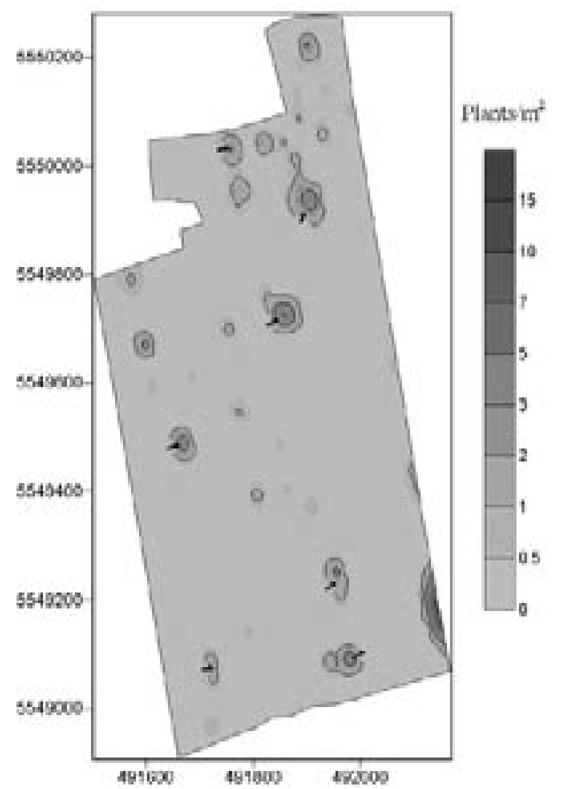

Figure 5. Occurrence of *Cirsium arvense* in the field Klucov (2002)

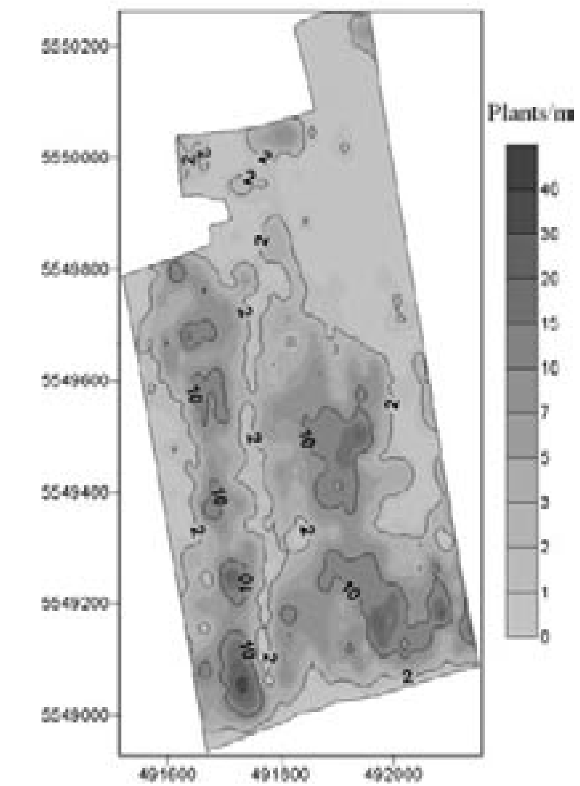

Figure 6. Occurrence of *Viola arvensis* in the field Klucov (2002)

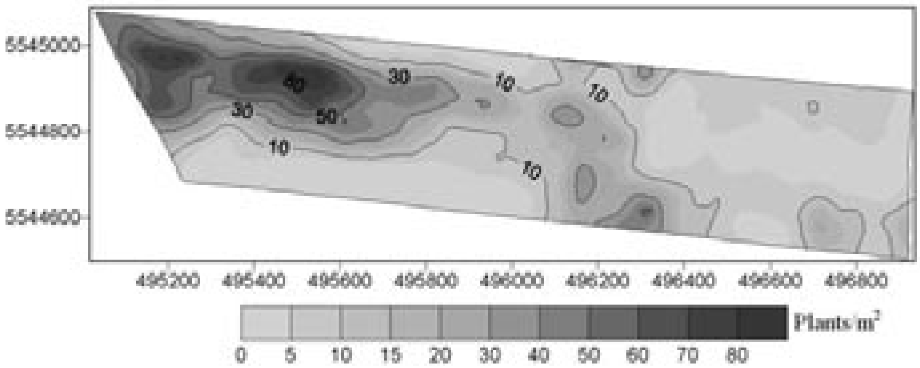

Figure 7. Total weed infestation in the field Trebovle (2001)

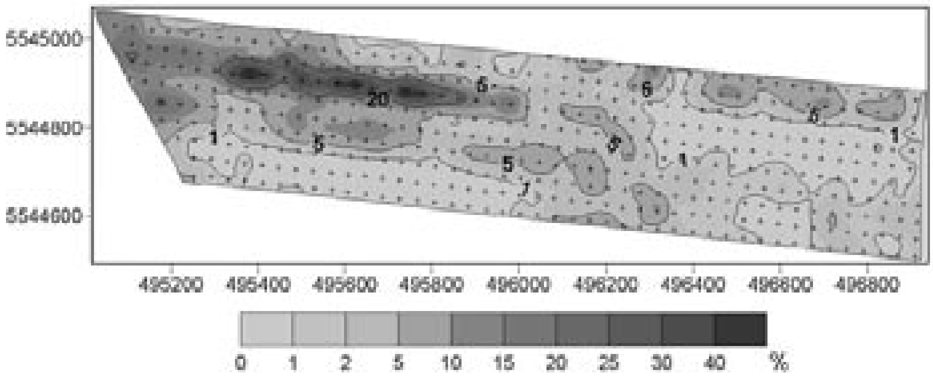

Figure 8. Weed coverage in the field Trebovle (2001)

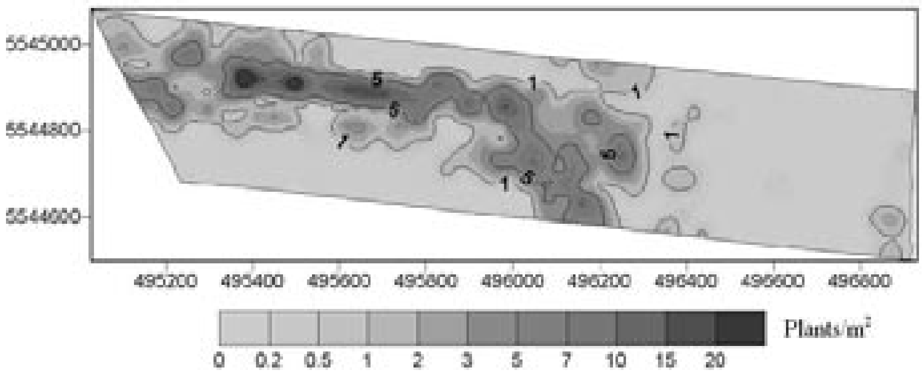

Figure 9. Occurrence of *Galium aparine* in the field Trebovle (2001)

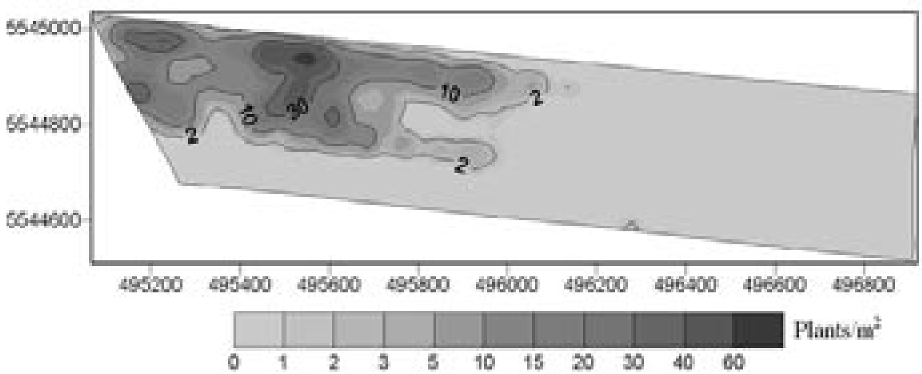

Figure 10. Occurrence of *Viola arvensis* in the field Trebovle (2001)

Table 2. Mean weed density (plants/m^2) and Patchiness-Index for surveyed fields

Weed	Field Klucov								Field Trebovle	
	1999		2000		2001		2002		2001	
	mean	PI	mean	PI	mean	PI	mean	PI	mean	PI
Galium aparine	1.11	4.61	1.28	7.43	0.44	6.67	0.55	7.70	1.93	4.68
Viola arvensis	1.85	5.65	3.86	2.14	7.65	3.26	4.23	2.36	4.35	6.99
Cirsium arvense	4.57	9.09	0.34	9.31	–	–	0.21	15.68	–	–
Veronica persica	–	–	0.83	11.90	0.05	4.18	–	–	2.08	3.67
Stellaria media	–	–	0.13	14.90	–	–	0.06	42.30	1.65	2.37
Lamium amplexicaule	–	–	–	–	–	–	–	–	3.39	5.41
Tripleurospermum maritimum	–	–	0.14	11.01	–	–	0.13	217.30	0.15	16.82
Apera spica-venti	–	–	–	–	–	–	0.54	9.52	–	–
Capsella bursa pastoris	0.08	83.4	0.04	21.4	–	–	–	–	0.45	5.71
Fumaria officinalis	–	–	–	–	–	–	–	–	4.19	5.99
Papaver somniferum	–	–	11.91	2.08	4.13	3.68	–	–	–	–
Weeds total	10.47	2.67	20.93	1.46	17.34	1.63	9.04	1.87	18.68	2.50
Weed cover	–	–	3.46	2.50	–	–	0.38	2.57	5.29	3.21

festation, cannot satisfactory detect the need of herbicide use. From the point of view of competition between crop and weed, the coverage degree of weeds is also important. The weed coverage had not exceeded 1% on 94.6% of area.

Locality Trebovle is characterized by cumulating of weeds in the western part of the field, where the degree of weed coverage exceeded 40%. In other parts the coverage was usually lower than 5% (Figure 8). Disproportion between the weed coverage and weed density is less distinct in this case. Aggregated spatial pattern was found by *G. aparine*, which was detected approximately on half of the area (Figure 9), likewise *Viola arvensis*, which occurred in NW-part of the field only (Figure 10). Strong patchy distribution showed also *Fumaria officinalis* and *Tripleurospermum maritimum*. For the last species, the concentration effect was found on the field headland. Most homogeneously occurred *Stellaria media*, which was present at 70.6% of points. The values of weed mean density and PI in all years are summarized in Table 2.

Weed patch stability

A relatively high correlation (up to 0.64) was found for *G. aparine* in most years. Spatial vari-

Table 3. Weed occurrence correlation between observation years within field Klucov

Weed	Correlation coefficient			
	1999–2000	2000–2001	1999–2001	2000–2002
Galium aparine	0.64	0.37	0.39	0.19
Viola arvernsis	0.42	0.53	0.22	0.60
Capsella bursa-pastoris	0.62	–	–	–
Papaver somniferum	–	0.36	–	–
Tripleurospermum maritimum	–	0.40	–	0.12
Veronica persica	–	0.01	–	–
All species	0.05	0.23	–0.04	0.10

ability of this species and changes in localization of nests during two periods are shown in Figure 1. *V. arvensis* shows also satisfactory correlation (0.42 and 0.53) in some years. The correlation for other species was poor, mainly because of the low values of weediness in general or cannot be calculated owing to absence any species in some years. Other species are listed in Table 3.

DISCUSSION

The presented results show that distribution of weed populations on the fields is widely heterogeneous. The obtained patchy weed occurrence favour weed control strategies, that take into account the spatial and temporal variation of weed distribution. Likewise, works of other authors (Nordmeyer and Häusler 2000, Gerhards et al. 2002) documents, that site-specific weed control can often save more than 50% of herbicides.

It is evident on both examined fields, that weed patches are elongated in the direction of movement by soil cultivation. That document impact of cultural operations such as soil tillage (Marshall and Brain 1999) or combine harvesting (Howard et al. 1991) on translocation of weed seeds or other weed propagules. This effect was less transparent by perennial weeds (*Cirsium arvense*). A fact, which we can find, changes in weediness in transversal direction much faster, needs to be considered by the choice of field sampling strategy. Density of the sampling grid should respect this effect in both directions and the square-grid is therefore not suitable.

In the year 2002 on the field Klucov where sampling grid 20 × 40 m was used, a higher rate of changes in transversal direction was observed. *Galium aparine* and *Apera spica-venti* showed also in adjacent sprayer track rows high differences in their weediness.

A patchiness index as an indicator of aggregation degree of weed population is suitable especially for those species with higher occurrence, because low abundance of the species strongly increases the PI values. Despite of this, the high value of PI always signalise the possibility of herbicide cost saving.

Relatively low values of correlation coefficient of some species signalising low temporal stability of weed patches can be caused partially by inaccuracies in GPS navigation. Fluctuating values of correlation coefficient, which may be even higher for a longer period than for consecutive years, tell us about the dependence of weed occurrence on the year conditions. We can expect then a higher real rate of stability. Though, the use of historical maps as a basis for site-specific herbicide treatment is only limited. A key problem with site-specific weed management still remains with data acquisition. In contrast to other field characteristics such as soil properties (Brodský et al. 2001), the weed mapping should be more intensive. Hand mapping is a very time consuming process. In the range that this is acceptable from the mapping cost point of view, it is not able to detect all the important weed patches especially for those weed species with low economic thresholds as *Galium aparine*. For the future, optical sensors seem to be usable in some crops (Sökefeld 1997, Gerhards et al. 1998, Wartenberg and Dammer 2002). But even these systems can not sample all the area continually and therefore it will be also necessary to create proper sampling strategy for them.

REFERENCES

Brodský L., Vaněk V., Száková J., Štípek K. (2001): Spatial heterogenity of soil properties. Rostl. Výr., *47*: 521–528.

Cardina J., Johnson G.A., Sparrow D.H. (1997): The nature and consequence of weed spatial distribution. Weed Sci., *45*: 364–373.

Clay S.A., Lems G.J., Clay D.E., Forcella F., Ellsbury M.M., Carlson C.G. (1999): Sampling weed spatial variability on a fieldwide scale. Weed Sci., *47*: 674–681.

Gerhards R., Sökefeld M., Kühbauch W. (1998): Einsatz der digitalen Bildverarbeitung bei der teilschlagspezifischen Unkrautkontrolle. Z. Pfl.-Krankh. Pfl.-Schutz, Sonderh. XVI: 273–278.

Gerhards R., Sökefeld M., Timmermann C., Kühbauch W. (2002): Site-specific weed control in maize, sugar beet, winter wheat, and winter barley. Precis. Agr., *3*: 25–35.

Howard C.L., Mortimer A.M., Gould P., Putwain P.D., Cousens R., Cussans G.W. (1991): The dispersal of weeds: seed movement in arable agriculture. Proc. Brighton Crop Prot. Conf. Weeds: 821–828.

Gerhards R., Sökefeld M., Timmermann C., Krohmann P., Kühbauch W. (2000): Precision weed control – more than just saving herbicides. Z. Pfl.-Krankh. Pfl.-Schutz, Sonderh. XVII: 179–186.

Lloyd M. (1967): Mean crowding. J. Anim. Ecol., *36*: 1–30.

Marshall E.J.P., Brain P. (1999): The horizontal movement of seeds in arable soil by different soil cultivation methods. J. Appl. Ecol., *36*: 443–454.

Nordmeyer H., Häusler A. (2000): Erfahrungen zur teilflächenspezifischen Unkrautbekämpfung in einem Praxisbetrieb. Z. Pfl.-Krankh. Pfl.-Schutz, Sonderh. XVII: 195–205.

Sökefeld M. (1997): Automatische Erkennung von Unkrautarten im Keimblattstadium mit digitaler Bildverarbeitung. [Dissertation.] Univ. Bonn.

Sökefeld M., Gerhards R., Kühbauch W. (2000): Teilschlagspezifische Unkrautkontrolle – von der Unkrau-

terfassung bis zur Herbizidapplikation. Z. Pfl.-Krankh. Pfl.-Schutz, Sonderh. XVII: 227–233.
Wartenberg G., Dammer K.H. (2002): Erfahrungen bei der Verfahrensentwicklung zur teilflächenspezifischen Herbizidanwendung in Echtzeit. Z. Pfl.-Krankh. Pfl.-Schutz, Sonderh. XVIII: 443–450.

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ABSTRAKT

Variabilita výskytu plevelů na orné půdě v rámci pozemku

V letech 1999 až 2002 byl na dvou pozemcích ve středních Čechách mapován výskyt plevelů v ozimé pšenici. V pravidelné síti bodů byl sledován počet rostlin jednotlivých druhů plevelů a jejich celková pokryvnost. Pro stanovení stupně variability byl vypočten pro jednotlivé druhy plevelů i pro celkové zaplevelení Patchiness-index. Pomocí programu Surfer byly na základě získaných dat vytvořeny mapy zaplevelení. K posouzení stanovištní stability plevelných populací byla vypočtena korelace mezi výskytem plevelů v jednotlivých letech. Výsledky ukazují nerovnoměrný výskyt jednotlivých druhů, zvláště *Cirsium arvense* (PI = 9,09–15,86), *Tripleurospermum maritimum* (PI =11.01–217,30) a *Galium aparine* (PI = 4,61–7,70). Korelační koeficient mezi oběma roky, vypočtený pro *Galium aparine*, poukazuje na poměrně vysokou stanovištní stabilitu.

Klíčová slova: heterogenita zaplevelení; mapy zaplevelení; stanovištní stabilita; precizní hospodaření

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