Case Studies for Precision Agriculture

J. ŠILHA[1*], P. HAMOUZ[4], V. TÁBORSKÝ [2], K. ŠTÍPEK[1], J. ŠNOBL[3], K. VOŘÍŠEK [5], L. RŮŽEK[5], L. BRODSKÝ[1] and K. ŠVEC[2]

[1]Department of Agrochemistry and Plant Nutrition, [2]Department of Plant Protection, [3]Department of Crop Production, [4]Department of General Plant Production and Agrometeorology, [5]Department of Microbiology and Biotechnology, Czech University of Agriculture Prague, 165 21 Prague-Suchdol, Czech Republic

[*]E-mail: silha@af.czu.cz

Abstract

The results of spatial variability of plant-available soil nutrients (P, K, Mg) and soil pH are described in this paper. Experiment was realized on the field of area 72 ha (orthic luvisol), located in the area of Český Brod. The use of coefficient of variation as a criterion of variability of soil agrochemical properties and yield on the field showed the following: the highest variability was observed in available P, the second highest variability was in available K, and the lowest variability of main non-mobile nutrients was in the available Mg. Soil pH was the lowest of all measured soil properties. Although the highest correlation coefficient between the soil available P content and soil pH was established, the process of spatial dependence was not detected. Detailed field scouting and others data can be important elements, as can complex decision rules, taking into account additional factors such as the characteristics of crop protection agents and preferences of the farm manager. This paper illustrates, how to plant nutritions, crop protection, crop production might be integrated to support these diseases and weeds management decisions.

Keywords: soil agrochemical properties; septoria disease; LA; GLA; weed infestation; yield of wheat; soil biological characteristics

INTRODUCTION

Decision tools can be used to systematically define the pest management problems experienced by a range of decision markers and so determine current constraints, identify research gaps, and assess the feasibility of "novel" methods of control. In this way, decision tools can highlight those issues on which future policy, research, development and extension strategies should be targeted to maximize the chance of successful implementation SECHER (1998).

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 sense of precision farming principles assumes, that areas with weed infestation below the defined thresholds are not treated or the doses are adjusted according to weed infestation (GERHARDS *et al.* 2000). This allows reduction of the variable costs of herbicides and limits the environmental contamination. The degree of spatial variability affects the effectiveness of the site-specific application. The higher variability, the more favorable is the precision weed control.

MATERIAL AND METHODS

As can be seen in BRODSKÝ *et al.* (2001), the Třebovle field was sampled in 2000 from soil profile 0–30 cm using the point sampling method, with regular grid

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Project No. MSM 412100005.

square pattern of 40 × 40 m across the whole field (426 soil samples). 14 individual core samples were taken from each point from circle area with a radius of 3 m from the center point. The Mehlich III solution method was used to determine the available P, K and Mg. Soil pH was determined in 0.2M KCl extract. Map plots (Figures 5 and 6) were processed in software Surfer v 7 (Golden Software) with the default girding method settings (interpolation – kriging with the default linear variogram). For the comparison of the content of available nutrients with yield of wheat (CASE-AFS) the coefficient of variation was used.

Monitoring of a cereal diseases at GS 30–32 leaf-sheath erect to 2nd node check for latent infection of eyspot *Tapesia* spp. Which is detected by ELISA test. 1 AgU/ml = 2.6 ng of *Tapesia* spp. Low infestation are from 0–80 AgU/ml, and severe infestation are the level over 160 AgU/ml such as a critical number for decision use of a fungicide. Septoria diseases at flag leaf visible (GS 39), to flag leaf sheath opening (GS 47) which is a critical-time for foliage protection. Start of heading GS 51 to end of heading GS 59 is a critical for ear protection especially against septoria disease, that is determined at the level of 160 AgU/ml for application of an approved fungicide is recommended TÁBORSKÝ *et al*. (2000).

Weed mapping was carried out in 1999–2002 in Central Bohemia. The data were collected from 72 ha field, where winter wheat was grown. A rectangular grid 40 × 40 m was established with use of GPS (Global Positioning System) along tramlines. In every grid point, a quadrate of 1m^2 in 2 replications was used for identifying of all species and counting of plants. Patchiness-Index was calculated for each species to determinate the heterogeneity of weed occurrence:

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

where: 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. Weed maps were created using software Surfer. In this paper, variability of weed infestation across the field Třebovle (72 ha) 2001 is described.

According to the former experience (RŮŽEK 2001) the average C_{MB} (microbial biomass carbon) level for Czech arable and grassed chernozems (mollisols) is 408.07 ± 78.99 μg C_{MB}/g dry soil. The C_{MB} content in described field using for precision farming is only 340.07 (SD 39.97) μg C_{MB}/g dry soil.

RESULTS

Spatial variability of soil agrochemical properties and yield of wheat

With comparison of yield of wheat and agrochemical properties it is possible to observe that contents of available nutrients (Mehlich III) and yield of wheat were not correlated together. Thus it is possible to assume that the variability of yield was affected by the others biotic and abiotic factors in the field. For the description of spatial dependences the semi-variance analyses was used. The results showed that there are no significant spatial relationships between selected agrochemical properties and yield of wheat.

Table 1. Summary statistics of Třebovle field

Variable/parameter	Yield (t/ha)	P (ppm)	K (ppm)	Mg (ppm)	pH
Average	8,0	35	144	120	6.5
SD	0.9	13.7	36.4	17.4	0.5
Coef. variance (%)	11	39	25	15	8
Minimum	3.2	10	59	68	5
Median	8.2	33	149	121	6.6
Maximum	9.5	91	351	162	7.3
Skewness	–2.43	1.07	1.96	–0.2	–0.68

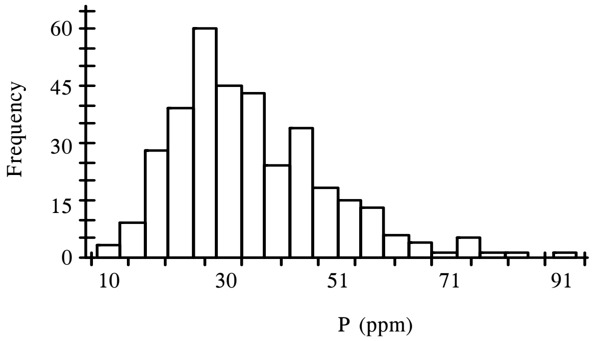

Figure 1. Phosphorus data set histogram

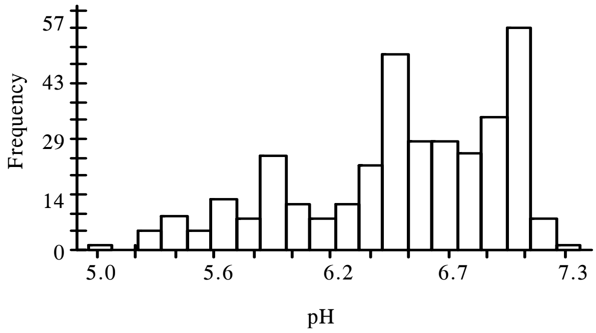

Figure 2. pH data set histogram

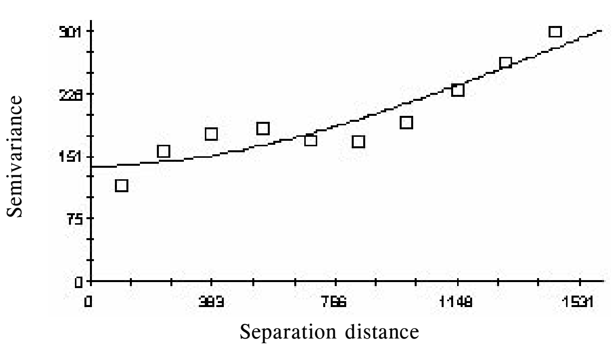

Figure 3. Phosphorus data set empirical variogram and fitted model; the fitted Gaussian model has parameters: a nugget effect of 140 ppm, effective range 3506 m; r^2 = 0.8464 and RSS-residual sums of 3663 (the lowest of all available models)

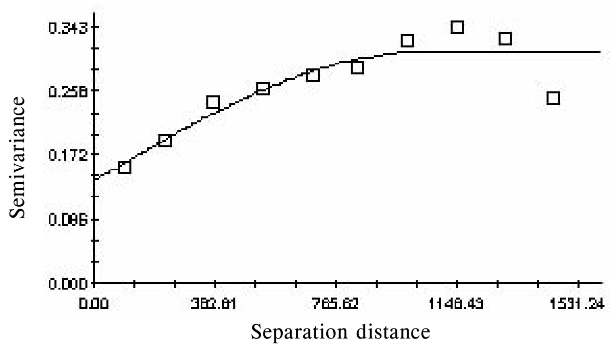

Figure 4. pH data set empirical variogram and fitted model;the fitted spherical model has parameters: a nugget effect of 0.136, range 1037 m; r^2 = 0.817 and RSS-residual sums of squares of 3663 (the lowest of all models)

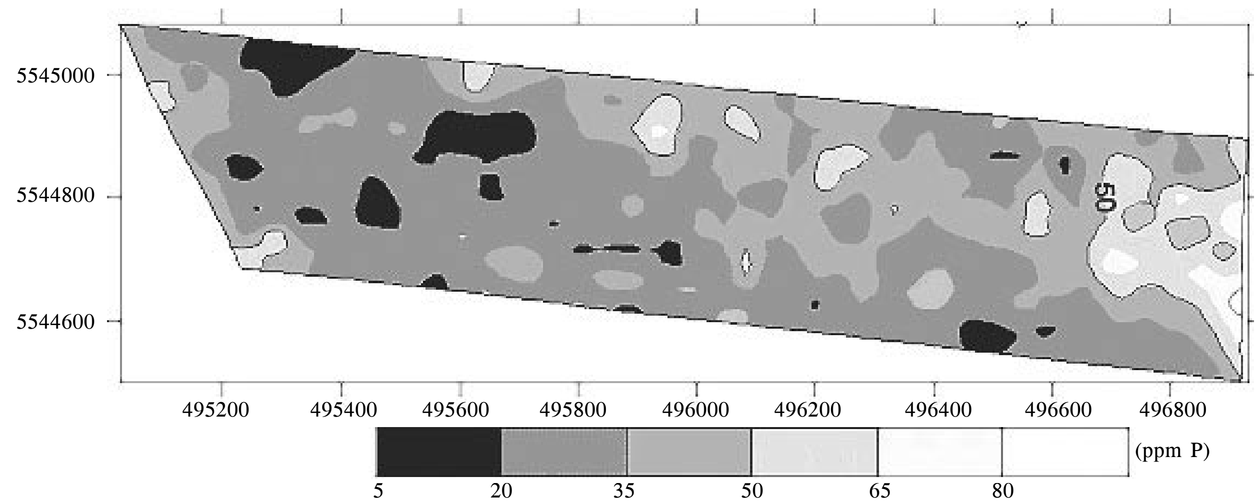

Figure 5. Soil available phosphorus map (Mehlich III)

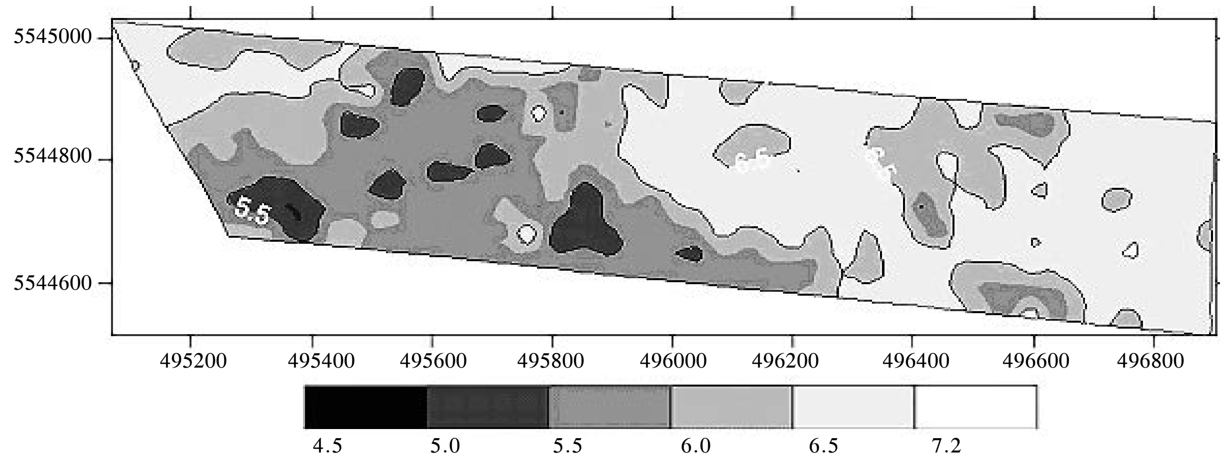

Figure 6. Soil pH map (0.2M KCl)

Therefore site-specific application of fertilizers can be based on the export of nutrients by main product (grain) only.

Agronomic and plant health characteristics of winter wheat cv. Ebi × Třebovle 2001

In Table 2 there are agronomic characteristics such as average leaves area (LA) in cm^2 from 12 main stems of randomized sample in which were 80 stems from each area of the position determined by GPS. At one sampling point were sampled 5 main stems in different GS of winter wheat. At the time of milky ripeness was determined green leaves area (GLA) as a rest of leaves area that was still very important for photosynthesis processes. On fifteen position (1; 2; 3; 7; 8; 9; 13; 14; 15; 19; 20; 21; 25; 26 and 27) were sampled 4 times from the area ¼ m^2 all stems in full ripening stages in grain for the harvesting and calculation the local yield per hectare.

Grower, who is owner of the field at Třebovle has done carried out at GS 32 (leaf-sheath erect to 2nd node) the treatment winter wheat with carbendazim (0.5 kg/ha) against eyspot disease 1 day before detection of *Tapesia* spp., which were on very low level (from 0 to 23 AgU/ml) under a critical number for decision making for the treatment of winter wheat crop. Others infection like as mildew and rust were throughout

Table 2. The leaf area of 1 stem in different GS and level of detection septoria diseases of the crop winter wheat cv. Ebi of Třebovle field in 2001 and yield

Position in crop	GS 39 LA (cm^2)	*Septoria tritici* (AgU/ml)	*Septoria nodorum*	GS 59 LA (cm^2)	*Septoria tritici* (AgU/ml)	*Septoria nodorum*	GS 75 LA (cm^2)	*Septoria tritici* (AgU/ml)	*Septoria nodorum*	GLA (cm^2)	Yield (t/ha)
1	111.4	3	0	93.4	7	0	33.6	160	190	27.99	8.8
2	109.3	0	7	70.6	0	10	32.7	125	168	26.24	9.6
3	108.0	0	3	91.5	5	5	51.4	100	120	39.8	9.5
7	113.0	1	2	76.4	5	17	35.9	160	173	25.75	8.4
8	112.0	4	6	68.4	0	16	32.0	117	170	27.73	8.9
9	102.2	0	2	67.6	0	19	31.8	75	150	28.65	9.2
13	127.3	0	8	70.1	5	9	40.4	120	170	36.91	8.7
14	106.6	4	10	79.7	1	21	38.3	130	183	31.78	8.3
15	99.5	3	5	72.2	0	9	32.2	65	177	27.85	8.2
19	126.0	1	0	89.9	3	7	36.3	105	172	33.23	8.2
20	107.5	0	0	69.5	0	5	31.8	75	177	28.73	8.8
21	106.0	0	8	81.3	0	15	33.8	160	182	30.93	9.2
25	123.3	2	4	77.7	3	11	40.5	164	184	31.74	9.3
26	114.4	3	13	65.3	0	23	34.6	122	170	27.98	9.6
27	92.3	1	5	72.1	6	8	36.9	120	174	32.73	9.7

Table 3. Mean weed density (plants/m^2) and Patchiness-Index within field Třebovle

Weed	Mean	*PI*	Weed	Mean	*PI*
Galium aparine	1.93	4.68	*Matricaria inodora*	0.15	16.82
Viola arvensis	4.35	6.99	*Fumaria officinalis*	4.19	5.99
Lamium sp.	3.39	5.41	*Capsella b. pastoris*	0.45	5.71
Veronica sp.	2.08	3.67	Weeds total	18.68	2.50
Stellaria media	1.65	2.37	Weed cover	5.29	3.21

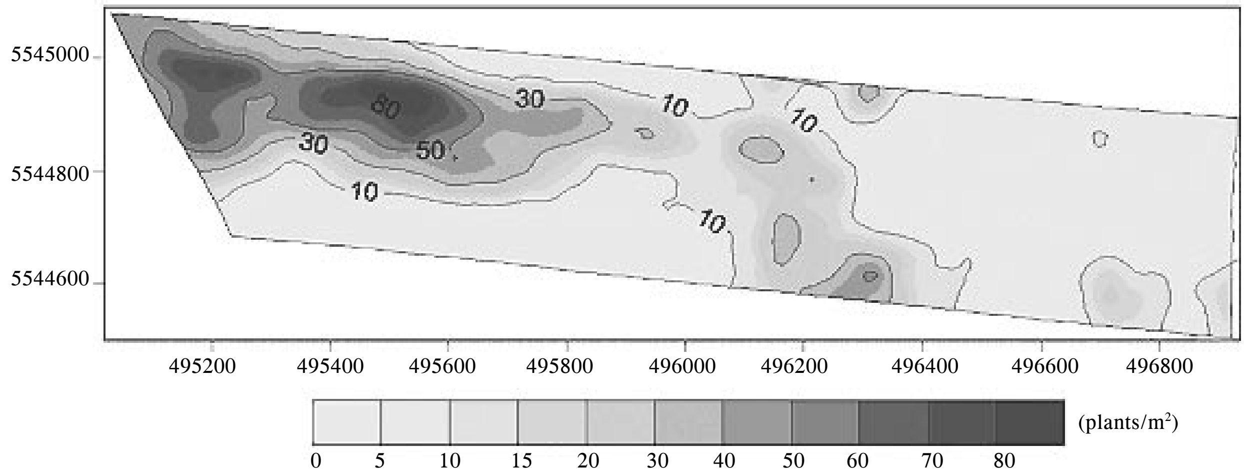

Figure 7.Total weed infestation in the field Třebovle 2001

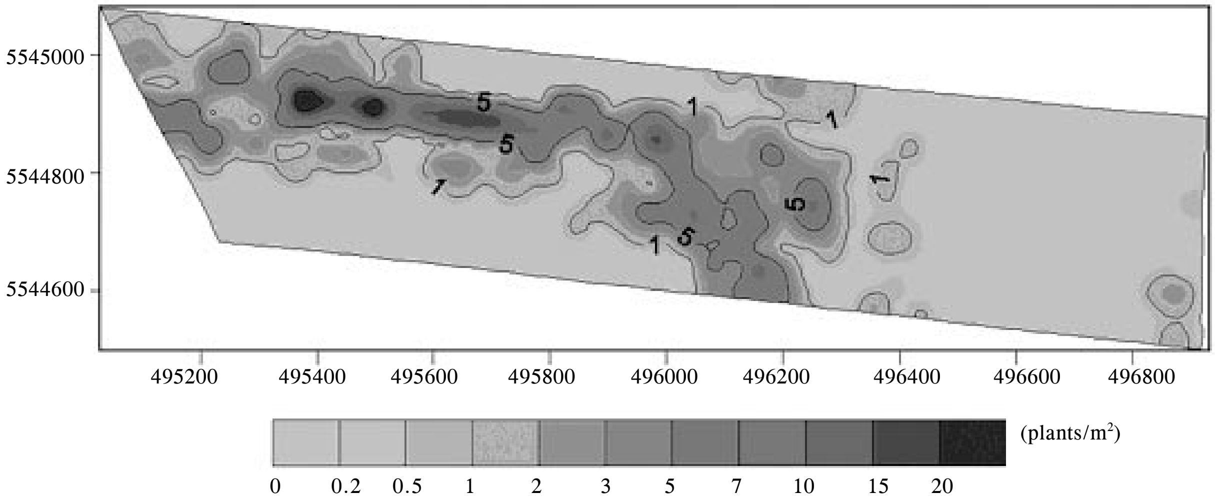

Figure 8. Infestation of *Galium aparine*

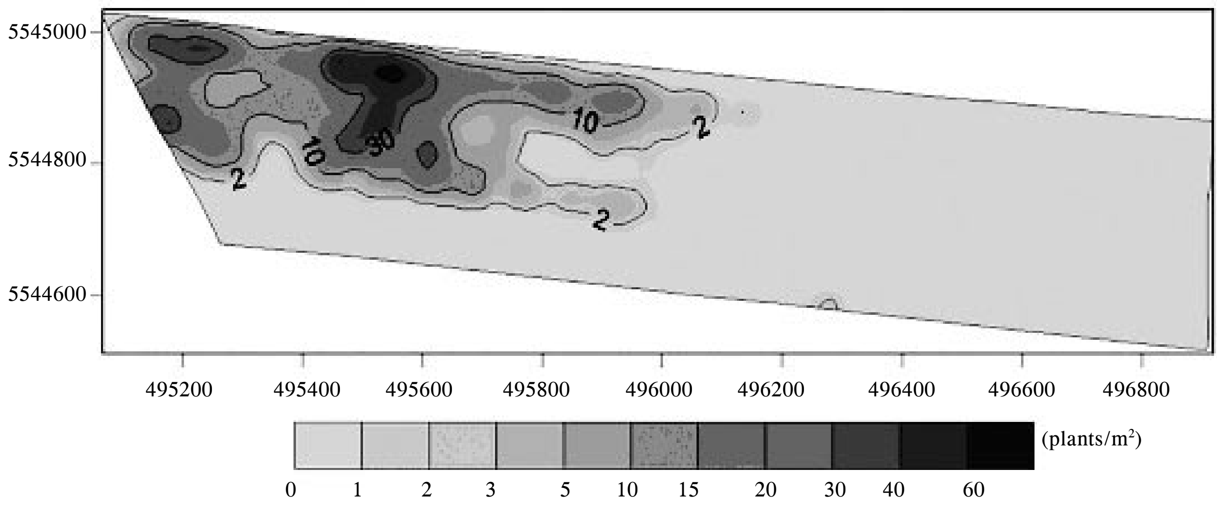

Figure 9. Infestation of *Viola arvensis*

Table 4. Microbial characteristics of soil – locality: Třebovle; 2001: wheat; 2002: rape

Position in the field	C_{MB}[1] (μg/g dry soil)	C_{EX}[2] (μg/mg C_{MB})	C_{MB}/C_{org} (%)
90/1	357.5 ± 37.9	53.9 ± 14.6	2.47
90/2	350.8 ± 53.7	60.8 ± 25.1	2.47
90/3	328.4 ± 60.0	66.9 ± 43.5	2.34
90/4	364.2 ± 28.4	59.1 ± 22.0	2.39
90/5	346.3 ± 28.4	70.8 ± 35.5	2.23
214/1	315.0 ± 53.7	94.6 ± 48.7	2.46
214/2	317.3 ± 69.5	101.3 ± 57.1	2.47
214/3	335.2 ± 63.2	99.7 ± 49.4	2.66
214/4	332.9 ± 60.0	102.4 ± 56.4	2.61
214/5	353.0 ± 19.0	83.4 ± 15.7	2.85
LSD[3] $d_{\alpha\ min}$ 0.05 (0.01)	111.9 (159.2)	89.1 (126.7)	0.92 (1.31)

[1]C_{MB} – microbial biomass carbon (average ± SD)

[2]C_{EX} – microbial extracellular carbon extractable by 0.5 mol/l K_2SO_4

[3] Fischer's Least Significant Difference

Table 5. Results of evaluation – locality: Třebovle; 2001: wheat; 2002: rape

Position in the field	Ranking based on three biological criteria[1]	Position in the field	Ranking based on three biological criteria[1]
90/1	1	90/5	6
214/5	2	214/4	7
90/4	3	90/3	8
90/2	4	214/2	9
214/3	5	214/1	10

[1] three biological criteria: 1 mg C_{MB}/g dry soil; [2]ratio C_{MB}/Corg (%); [3]mgC_{EX}/mg C_{MB}

growing period after the first spraying and mainly after second spraying by two fungicides (Caramba 0.6 l/ha + Amistar 0.5 l/ha), infestation by septoria disease were on very low level in the crop. According data in Table 3, the level of severity septoria disease in the GS 59 was still on low level, but later in the GS 75 was increased over critical number 160 AgU/ml. In the GS 75 for fungicide treatment is too late.

Spatial and temporal characterictics of weediness used for site-specific weed control in precision farming

- Total weed infestation showed lower variability than single species (Figure 7). The most important species *Galium aparine* was distributed heterogeneously – the area below the threshold (0.2 plants/m^2) represents 42.6% of total area.
- This locality is characterized by the cumulation of weeds in the western part of the field, where the degree of weed coverage exceeded 40%, whereas in other parts coverage was usually lower than 5%. *G. aparine* (Figure 8) and Viola arvensis (Figure 9) showed irregular pattern whereas Stellaria media was distributed more homogeneously. Only low grass weed infestation was observed in the field.The values of weed mean density and *PI* are summarized in Table 3.
- The obtained patchy weeds occurrence, in favour of site-specific weed management.

References

BRODSKÝ L., VANĚK V., SZÁKOVÁ J., ŠTÍPEK K. (2001): Spatial heterogeneity 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., TIMMERMANN C., KROKMANN P., KÜHBAUCH W. (200): Precision Weed Control – more than just saving herbicides. Z. Pfl.-Krankh. Pfl.-Schutz, Sonderh., **XVII**: 179–186.

RŮŽEK L. (2001): Vzájemné vztahy abiotických a biotických parametrů půdy. In: Pedologické dny 2001, Brno 28.–29. 5.: 93–95. (ISBN 80-7157-526-7)

SECHER B.J.M. (1998): Delivering biological understanding in an agricultural context. In: Invited Papers Abstr. Vol. 1. 3.1. 2S 7th Int. Congr. Plant Pathol., Edinburgh, Scotland.

TÁBORSKÝ V., RYŠÁNEK P., KAZDA J., STÁREK V., SVOBODOVÁ A. (2000): Monitoring of plant diseases and pests in precise farming. In: Proc. 6th Int. Conf. Reasonable use of Fertilizers Focused on Precision Farming. Department of Agrochemistry and Plant Nutrition, Czech University of Agriculture, Prague: 49-55.