Improvement of an elutriation method for estimation of weed seedbank in the soil

V. Smutný[1], J. Křen[1,2]

[1]Mendel University of Agriculture and Forestry in Brno, Czech Republic
[2]Agricultural Research Institute Kroměříž, Ltd., Czech Republic

ABSTRACT

A model experiment was conducted to compare hand extraction (elutriation) under running water and elutriation using the device Analysette 3, the two methods for estimation of weed seedbank in the soil. Technical parameters have been assessed for efficient operating of the device. We studied the time required for elutriation of soil samples and the time for collecting, counting and identifying the separated seeds. No significant difference in the effect of the used elutriation method on results of qualitative and quantitative estimation of weed seedbank densities has been found at any of the three locations differing in soil texture (silty loam, loam and clay loam soil). The time necessary for elutriation of soil samples was highly significantly shorter if the device was used, by 35.5 to 42.9% depending on soil texture vs. hand elutriation. The shortest time was assessed for silty loam soil. By contrast, the time needed for selecting, counting and identifying seeds was shortest for clay loam soil. This time was 46 and 92% longer for loam and silty loam soil, respectively. These differences were statistically highly significant. Comparing the seedbank in the soil, a significantly lower number of weed seeds as well as species was found on silty loam soil vs. the two locations with heavier soils. *Amaranthus retroflexus* was a dominating species at all locations, and on silty loam soil also *Chenopodium album*. Of a total number of 32 weed species detected in our experiment, 28 were annual and only four perennial (*Cirsium arvense, Elytrigia repens, Rumex obtusifolius* and *Sonchus arvensis*).

Keywords: weed seedbank in soil; methods for assessment; elutriation methods; labour consumption

The weed seedbank in the soil is caused by living reproduction organs of weeds. These are seeds and fruits (thereinafter seeds), shoots and root buds of vegetative organs present in the soil or on its surface.

To assess a number of seeds in the topsoil is rather labour- and time-consuming process (Thompson and Grime 1979, Rahman et al. 1995). Some questions concerning particularly soil sampling (a number of samples, sample size for an analysis, a sampling technique – use of various types of core samplers, sampling depth, etc.) have not been defined yet. According to Gross (1990), results can be influenced by the sampling time, a method for estimation and identification of seeds. Findings presented in literature have been obtained by sampling and an analysis of partial samples (Dvořák and Krejčíř 1974), and based on the analysis of an average sample (Dečkov 1975).

There are two methods for enumeration of weed seeds in the soil: a separation method when seeds are collected from the soil sample and counted, and a vegetation method when the seeds are left in sampled soil to germinate. Then, individual species are identified based on morphological characteristics of weed seedlings.

The separation methods include elutriation (extraction by washing) and flotation methods. A common aim of these methods is to separate seeds from soil using physical principles. The seeds can be extracted from soil samples by hand (wheeling sieves under running water) or using various elutriation devices. For example, Gross and Renner (1989), Wiles et al. (1996) and Miller et al. (1998) used devices of different construction.

The separated seeds are identified and counted. Seed viability has to be determined (a vegetation or non-vegetation method) for both methods in order to detect a number of living (germinable) seeds. Only such seeds are able to infest the soil.

The elutriation method is based on flushing the soil sample placed on sieves with running water when a proportion of non-elutriated particles remains on sieves: mineral (sand, grits, etc.) and organic (seeds, post-harvest residues, roots, etc.). In this way, the volume of the sample is reduced, which makes collecting, identifying and counting seeds in the remained proportion easier (Gross 1990).

In flotation methods, seeds are separated directly from the soil sample using the so-called flotation solutions. The seeds are added to a liquid with a density greater than that of the seeds so that they can be skimmed off (Hayashi 1975). Based on different specific weight, lighter seeds are separated from heavier mineral proportion.

The objective of the study was to evaluate applicability of an elutriation device for estimation of a weed seedbank in the soil. The attention was paid particularly to quality (effects on damage and loss of seeds during extraction), labour intensity and time consumption for various soils differing in particle size.

Table 1. Soil characteristics of individual locations

Location	Soil texture	Proportion of clayey particles (%)	Bulk density ($g.cm^{-3}$, average value)			
			0–30 cm	0–10 cm	10–20 cm	20–30 cm
1	silty loam	15.8	1.35	1.30	1.42	1.35
2	loam	39.6	1.38	1.31	1.43	1.40
3	clay loam	57.1	1.42	1.33	1.41	1.51

MATERIAL AND METHODS

In 2000, a model experiment was conducted to compare two techniques for estimation of potential weed seedbank in the soil using an elutriation method. The number of weed seeds in soil samples was assessed by hand elutriation under running water (a classical method) and using a device (elutriator). The obtained results and speed of assessment were compared.

Soil sampling

Soil samples were collected in spring 2000 (25–26 April) at three sites with different soil texture at Žabčice (179 m above sea level, 49°01' N, 16°37' E) located 25 km south of Brno. It is a warm and dry region with annual average temperature of 9.1°C and annual precipitation of 518 mm. The samples were always taken following soil tillage before sowing and planting. Bulk density was assessed (using steel cylinders of 100 cm^3 volume) as a mean of values measured at three depths (0–10 cm, 10–20 cm and 20–30 cm) and in three replications at each of examined locations. Proportions of clayey particles (< 0.01 mm) were assessed by a pipetting method. Based on this assessment, soil texture was determined as silty loam, loam and clay loam soil. Characteristics of the locations are given in Table 1.

A plot of 25 m^2 (5 × 5 m) was marked out at each of these locations. Five random samples were taken from this area. A soil core sampler with a circle base of 8.0 cm in diameter and 15.0 cm long (volume 753.6 cm^3) equipped with spring mechanism (making its emptying easier) was used. A total depth of sampling was 30.0 cm. Dried samples were mixed by hand in a bag. From the mixed sample, two 200-g samples were taken for analyses (one for hand elutriation, the other for a device). Ten samples were analysed per location and extraction method as replications. A total number of samples analysed was 3 × 2 × 10 = 60.

Analysis of soil samples

A modification of the methodology according to Dvořák and Krejčíř (1974) was used for estimation of a number of weed seeds in individual samples.

The soil is placed into a beaker and water is added to about 1 cm over the soil, for 24 h. After this time, the material is poured into a shaking bottle, which is shaken in a horizontal autoclave for 30 min in order to disaggregate the soil.

Then the content of a beaker is elutriated on a metal sieve with mesh size of 0.25-mm with a mild flow of running water (a rubber tubing connected to a tap) until all particles less than 0.25 mm are washed away (washings are completely clear).

The above-mentioned hand elutriation under running water was compared with performance of a device Analysette 3 (vibratory sieve shaker, Fritsch Firm) composed of a set of sieves with 200-mm diameter, 50-mm height and different mesh size. We chose sieves with mesh size of 0.25, 0.50, 1.0 and 2.0 mm. A soil sample (pre-treated by

Table 2. Comparison of results obtained in both elutriation methods (analysed sample – 200 g dry soil; *LSD*, $P < 0.05$)

Location	Elutriation method	Examined character			
		number of entire seeds	number of healthy seeds	species number (entire seeds)	species number (healthy seeds)
Silty loam soil	hand elutriation	31.90	12.00	8.80	6.60
	elutriation using a device	33.70	13.50	8.70	7.50
	least significant difference (*LSD* 5%)	4.19	1.98	1.13	1.10
Loam soil	hand elutriation	48.30	18.40	11.20	6.40
	elutriation using a device	54.20	20.50	10.20	7.60
	least significant difference (*LSD* 5%)	7.74	3.76	1.36	1.37
Clay loam soil	hand elutriation	49.50	17.40	11.80	7.20
	elutriation using a device	43.80	17.50	12.10	7.90
	least significant difference (*LSD* 5%)	6.21	2.35	1.95	1.51

dissagregation) was put on the top sieve and sprayed with water from three nozzles. Speed and efficiency of elutriation was affected by vibration of sieves in vertical direction. The amplitude of vibration from 0.5 to 3.0 mm and simultaneously the time for flushing was adjusted.

The remaining parts on the sieve (non-elutriated proportion of mineral and organic particles larger than 0.25 mm and weed seeds) were rinsed into a beaker and filtered. The proportion that remained on filter paper was dried at a room temperature and weed seeds were collected using tweezers and a preparation needle, identified and counted. Due to small dimensions of seeds, it was necessary to use a magnifying lens or stereoscopic microscope (magnification 5–10×).

The results obtained for average samples were corrected to the area of 1 m^2 using the coefficient:

$$C = 10\,000.h.O_v/g$$

where: h – depth of taking partial samples (cm)
O_v – bulk density ($g.cm^{-3}$)
g – weight of an average sample (g)

The detected seeds were classified into the categories entire and healthy. The category of entire seeds included the seeds that appeared visually intact and/or injured but viable. The healthy seeds were considered those that were firm, resistant to preparation needle pressure. If seeds are broken, the content appears white. This analysis, the so-called pressure analysis (belonging among non-vegetation methods for assessment of seed viability), has been used by a number of authors (Kropáč 1966, Roberts and Ricketts 1979, Dvořák and Krejčíř 1980, Rahman et al. 1995).

Assessed numbers of seeds were evaluated by analysis of variance (ANOVA) with consequent test of differences in average values using least significant difference (*LSD*). Wilcoxon (non-parametric) test was used to verify the significance of differences in seed numbers of individual species according to the method used for elutriation.

RESULTS

Comparison of data obtained at all three locations (with different soil texture) did not show any significant differences in effects of elutriation methods (hand elutriation and using the device) on results of qualitative and quantitative estimation of potential weed infestation. At all locations, both methods enabled to detect seeds (both entire and healthy) of identical weed species. There were no significant differences in numbers of entire and healthy weed seeds in total between the two examined methods. The obtained results are presented in Table 2.

In most weed species, no significant difference was found in a number of entire seeds between the two methods (Table 3). A significantly higher number of entire seeds were found for *Consolida regalis* at hand elutriation. By contrast, a significantly higher number of entire seeds were assessed for *Cirsium arvense* at elutriation using the device. Seeds of *Rumex obtusifolius* were detected at hand elutriation and seeds of *Sonchus arvensis* at elutriation using the device only (on average 0.1 piece per sample in both cases). Comparison of cases when different numbers of weed seeds were assessed at hand elutriation or using the device is below:

Number of cases	Silty loam	Loam	Clay loam
Higher seed number assessed at hand elutriation	6	10	11
Higher seed number assessed using the device	10	9	11
Identical seed number at both elutriation methods	7	9	7

In both methods, the time necessary for elutriation of a soil sample of 200 g depended on soil texture (Table 4). In both cases, the shortest time was needed for elutriation of silty loam soil samples followed by loam soil samples, and most time was necessary for clay loam soil samples. Use of the device vs. hand elutriation highly significantly shortened the time by 35.5–42.9%. More time was saved in soils containing a greater proportion of clayey particles. These values were obtained using the device with two sieves only; 2.0- and 0.25-mm mesh size. An appropriate level of vibration was 1.0 to 2.0 mm (a medium value). Water inflows of 1.5 and 1.0 $1.min^{-1}$ were suitable for silty loam and clay loam soil, respectively. At the higher water inflow than the outflow of elutriated soil and higher vibration, water can leak at elutriation of clay loam soils through sieve sealing.

The time required to collect, count and identify weed seeds (Table 4) was on average of all assessments 11.2 min for clay loam soils. The average time was 46 and 92% longer for loam and silty loam soils, respectively. The differences were statistically highly significant.

A total time necessary for an analysis of a soil sample of 200 g did not differ markedly depending on soil texture (21.7–29.6 min).

If seed numbers were corrected to 1 m^2 using coefficient C, the following values (average values obtained using both methods of elutriation) were assessed:

Number	Silty loam	Loam	Clay loam	*LSD* (5%)
Entire seeds per m^2 in total	66420^a	106088^b	99365^c	6619
Healthy seeds per m^2 in total	25819^a	40262^b	37169^{bc}	3175
Species detected at assessment of entire seeds*	8.75^a	10.70^b	11.45^c	0.27
Species detected at assessment of healthy seeds*	7.05^a	7.00^a	7.55^a	0.74

* average number per sample
Different letters (a, b, c) indicate significant differences among soil textures in particular characters examined (*LSD*, $P < 0.05$)

The significantly lowest number of entire and healthy seeds as well as the lowest number of weed species found at the assessment of entire seeds were recorded at the location with silty loam soil. The proportion of healthy seeds of the total number of entire seeds was 38.87% on silty loam, 37.95% on loam soil and 37.40% on clay loam soil.

Species diversity was largest on clay loam soil; 28 vs. 22 species on silty loam soil. Figure 1 shows the percentage of regularly occurring species (their occurrence was higher than one piece per sample) in individual soil textures. On silty loam soil, only four regularly occurring species were found vs. 9 species on loam and clay loam soil. *Amaranthus retroflexus* was a dominating species at all locations. Its proportion ranged between 30.03 and 53.85%. The second most frequent species *Chenopodium album* occurred on silty loam soils at almost identical amount as *Amaranthus retroflexus* (29.42% vs. 30.03%). This species occurred less on loam and clay loam soil (from 7.86 to 8.98%); species composition of other regularly occurring weeds was similar in both soil textures. Of a total number of 32 weed species whose seeds were detected during the experiment, 28 were annual and only four perennial (*Cirsium arvense*, *Elytrigia repens*, *Rumex obtusifolius* and *Sonchus arvensis*).

DISCUSSION

The elutriating device Analysette (Fritsch Firm) has proved to be useful for estimation of weed seedbank. Benz et al. (1984) used a similar instrument from Retsch

Table 3. Proportions of seeds of individual species in samples elutriated by hand and using a device (average numbers of entire seeds present in 200 g of dry soil)

Soil texture	Silty loam			Loam			Clay loam		
Weed species	elutriation method			elutriation method			elutriation method		
	hand	device	difference	hand	device	difference	hand	device	difference
Amaranthus retroflexus L.	9.8	9.9	–0.1	25.8	29.4	–3.6	21.9	20.4	1.,5
Anagallis arvensis L.	0.4	0.4	0	0.7	0.4	0.3	0.8	1	–0.2
Atriplex patula L.	0.6	0.5	0.1	0.5	0.1	0.4	1	0.4	0.6
Avena fatua L.	–	–	–	0.2	0.2	0	0.8	0.9	–0.1
Capsella bursa pastoris (L.) Medik	–	–	–	–	–	–	0.3	0.2	0.1
Cirsium arvense (L.) Scor	–	–	–	0.2	0.1	0.1	1.1	2.1	–1*
Consolida orientalis (Gay) Sch.	–	–	–	1.5	1.5	0	1.3	2.2	–0.9
Consolida regalis Gray.	0.1	0.3	–0.2	0.4	0.4	0	1.2	0.2	1*
Echinochloa crus-galli (L.) Beauv	0.6	0.3	0.3	1.8	2.4	–0.6	1.4	1.8	–0.4
Elytrigia repens (L.) Desv.	0.5	0.4	0.1	0.4	0.4	0	0.5	0.5	0
Euphorbia helioscopia L.	0.1	0.1	0	–	–	–	0.4	0.2	0.2
Fagopyrum convolvulus (L.) Grossh	0.5	0.5	0	1.4	2	–0.6	1.6	0.8	0.8
Galium aparine L.	0.6	0.6	0	1.8	2.5	–0.7	1.7	1.6	0.1
Hyoscyamus niger L.	–	–	–	0.2	0.1	0.1	0.4	0.6	–0.2
Chenopodium album L.	9.4	9.9	–0.5	3.9	5.3	–1.4	3	3.9	–0.9
Chenopodium hybridum L.	0.7	0.9	–0.2	0.1	0.1	0	0.1	0.2	–0.1
Lamium sp.	2.9	3.4	–0.5	0.2	0.1	0.1	0.7	0.7	0
Melandrium noctiflorum L.	0.4	0.4	0	2.3	11.8	0.5	1	1.4	–0.4
Panicum miliaceum var. *ruderale* L.	–	–	–	0.3	0.3	0	–	–	–
Papaver rhoeas L.	–	–	–	–	–	–	0.4	0.5	–0.1
Polygonum aviculare L.	0.5	0.7	–0.2	–	–	–	0.3	0.2	0.1
Polygonum lapathifolium L.	0.2	0.1	0.1	1.7	2.6	–0.9	1	0.9	0.1
Rumex obtusifolius L.	0.1	–	0.1	0.1	0.1	0	–	–	–
Setaria glauca (L.) Beauv	–	–	–	0.2	0.2	0	–	–	–
Sinapis arvensis L.	0.3	0.3	0	0.4	0.2	0.2	1.1	1.1	0
Solanum nigrum L.	–	–	–	0.1	0.1	0	0.7	0.8	–0.1
Sonchus arvensis L.	0.2	0.1	0.1	–	0.1	–0.1	0.2	0.2	0
Stellaria media L.	0.4	0.5	–0.1	0.7	0.9	–0.2	0.5	0.3	0.2
Thlaspi arvense L.	2.1	2.7	–0.6	0.9	0.7	0.2	0.6	0.1	0.5
Tripleurospermum maritimum (L.) Sch.	0.3	0.4	–0.1	1.1	0.6	0.5	0.2	0.2	0
Veronica sp.	0.9	0.9	0	0.2	0.4	–0.2	0.6	0.6	0
Viola arvensis Murr.	0.3	0.4	–0.1	1.1	1.3	–0.2	0.1	0.1	0

* significant difference ($P < 0.05$) assessed by Wilcoxon (non-parametric) test

Table 4. The time required for individual procedures of the method for estimation of weed seedbank (200-g sample)

Soil texture (proportion of clayey particles)	Time of elutriation (min)		*LSD* (1%)	Time necessary to collect, count and identify separated seeds (min)	*LSD* (1%)	Total time consumption (min)
	by hand	device				
Silty loam (15.8%)	6.2	4.0**	0.51	21.5[a]	0.92	25.5–27.7
Loam (39.6%)	11.6	7.2**	0.73	16.4[b]		23.6–28.0
Clay loam (57.1%)	18.4	10.5**	0.89	11.2[c]		21.7–29.6

** highly significant difference ($P < 0.01$)
Different letters (a, b, c) indicate significant differences among soil textures in particular characters examined (*LSD*, $P < 0.01$)

Firm for the same purpose. They tested if seeds were not lost during elutriation using the sieves with mesh size of 4.0, 2.0, 1.0, 0.5 and 0.25 mm. They mixed seeds of 17 species with sterile ground (100 seeds per species with 500 g of dry ground). They tested on what sieves seeds of individual species remain at dry sieving and then using an elutriation method. Their results show that seeds *Fagopyrum convolvulus*, *Galium aparine* and *Avena fatua* remained on sieves with mesh size of 2.0 mm, *Polygonum lapathifolium*, *Echinochloa crus-galli*, *Thlaspi arvense* and *Sinapis arvensis* on sieves at 1.0-mm diameter, *Stellaria media*, *Amaranthus retroflexus* and *Poa annua* at 0.5-mm diameter and only *Apera spica-venti* and *Matricaria chamomilla* at 0.25-mm diameter. Some species had larger diameters of seeds at wet elutriation vs. dry sieving, which was caused by swelling.

The obtained data showed that the mesh size of the lower sieve was suitable. An average size of seeds of common weeds exceeds 0.25 mm (Dvořák and Krejčíř 1974). For these reasons, seeds of *Orobanche minor* (the least size 0.2 mm), *Sonchus arvensis* (0.25 mm) or *Achilea millefolium* and *Erigeron canadense* (0.2–0.3 mm) could be lost. Other species having small seeds include *Capsella bursa pastoris* (the least size 0.3 mm), *Papaver rhoeas*, *Agrostis stolonifera* and *Matricaria chamomilla* (0.3–0.4 mm) and *Myosotis arvensis* (0.4 mm). A mesh size of the smallest sieve of 0.25 mm was used also by other authors, such as Tulikov (1976), Teo-Sherrell et al. (1996), Cardina and Sparrow (1996). A number of authors used the smallest sieve with a larger mesh size: 0.318 mm (Wiles et al. 1996), 0.355 mm (Miele et al. 1998) and 0.500 mm (Feldman et al. 1997).

Weed seeds were not damaged by the device or during the classical hand elutriation method. It is possible to assume that seeds can exhibit visually apparent changes. These are, for example, a loss of petals, glumes, etc. However, they do not cause a loss of germination power, i.e. they do not influence weed seedbank.

Use of all four sieves (0.25, 0.50, 1.0 and 2.0 mm) as mentioned in the chapter Material and Methods was not suitable. During elutriation, the sieves vibrate in the vertical direction and a great number of seeds remain in openings of the similar size as the seeds. That makes removing the seeds with a rinser difficult, particularly out of sieves with a mesh size of 0.5 and 1.0 mm. Stupnicka-Rodzynkiewicz et al. (1998) used only two sieves with a mesh size of 4.0 and 0.2 mm. Other authors used more sieves with various mesh size placed above each other and did not mention the above problems. Tulikov (1976) elutriated soil samples on sieves with mesh sizes of 2.0, 1.25, 1.0, 0.75, 0.5 mm and on a sieve with mesh size of 0.25 mm. Similarly, Kropáč (1966) used an elutriation method with sieves with mesh size of 5.0, 2.0, 1.0, 0.5 and 0.25 mm, and Ambrosio et al. (1997) 5.0, 0.5 and 0.2 mm.

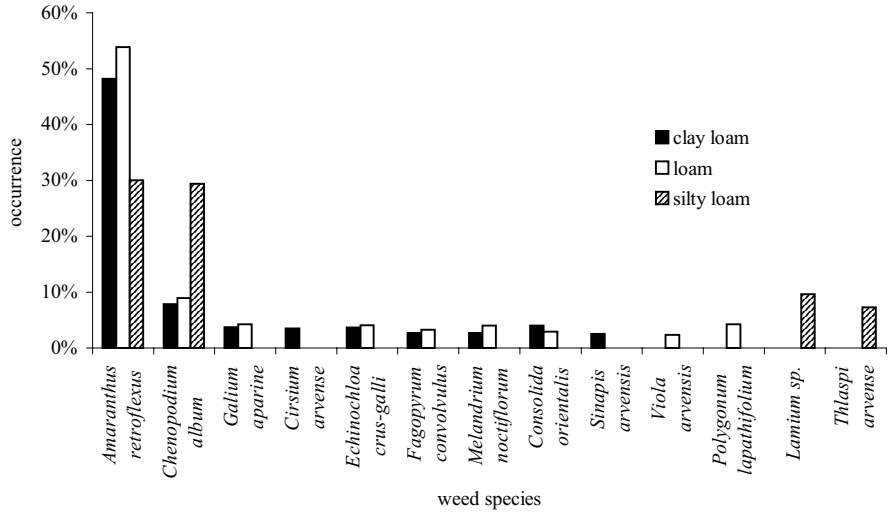

Figure 1. Percentage of most occurring species (only those whose occurrence was higher than one piece per sample)

The model experiment showed that the time for soil elutriation using the device Analysette 3 was highly significantly shortened vs. hand elutriation by 35.5–42.9%. The time necessary for elutriation of one soil sample of 200 g using the device ranged between 4.0 and 10.5 min and by hand elutriation between 6.2 and 18.4 min. This time was also influenced by soil texture; it was longer for elutriation of heavier soils. According to Benz et al. (1984), a total time necessary for elutriation of a sample of 500 g varies from 5 to 7 min. Wiles et al. (1996) report the time 60 to 75 min for elutriation of 36 samples of 300 g (1.7 to 2.1 min per sample) in relation to soil texture. Fay and Olson (1978) needed 2 to 10 min for 3- and 5-kg samples, Kovach et al. (1988) 6 min for 1-kg samples and Gross and Renner (1989) 10 min for 60-g samples. In comparison with these data, Teo-Sherrell et al. (1996) indicate 90 to 150 min for elutriation of a sample of 1020 cm^3.

If the device is used, the process can be more efficient using one more set of sieves. While seeds are being removed from sieves (it is mostly the lower sieve with mesh size of 0.25 mm), another soil sample can be elutriated.

After elutriation, collecting the seeds from non-elutriated proportion, their identifying and counting are rather labour intensive. This process is more time and labour consuming in silty loam soil samples where a greater portion of solid particles remains that hamper collecting, counting and identifying seeds. Moreover, these mineral particles often look like some seeds. The time required for collecting, counting and identifying seeds ranged from 11.2 min in clay loam soil, 16.4 min in loam soil up to 21.5 min in silty loam soil. The obtained results suggest that collection, identification and counting the seeds extracted from elutriated soil sample are difficult due to sand content (Wiles et al. 1996). Therefore, it is useful to separate specifically lighter organic particles (including seeds) from inorganic proportion by means of liquids of higher density. There are many so-called flotation solutions for this purpose. Numata (1984), for instance, separated seeds from non-elutriated proportion using 50% solution of potash (K_2CO_3); Medd (1992) and Miller et al. (1998) used a solution of calcium chloride ($CaCl_2$) at the specific weight of 1.36 $g.cm^{-3}$. All flotation solutions have to be examined if seeds are not lost during separation and if germination power is not influenced. Use of this separation technique is substantiated in silty loam soils in which there is a high proportion of non-elutriated mineral particles (sand).

The data in Table 3 demonstrate sufficient accuracy at preparation of the examined sample and consistent results obtained at hand elutriation and elutriation using the device. The differences found for most species were not statistically significant. The statistical significance was determined for two species only, which is 6.25% of total species number.

Labour consumption for counting and identifying seeds is influenced by a level of weed seedbank. The highest amount of weed seeds in analysed samples was found at the location with loam soil (more than 1 milliard.ha^{-1}). By contrast, the lowest number was in silty loam soil (0.6 milliard.ha^{-1}). This can be explained by the fact that loam to clay loam soil provide favourable conditions (water and nutrient supply) for growth and reproduction of most weed species. A sufficient amount of available water content in soil is a major limiting factor for plant growth (both crops and weeds) at the dry site Žabčice, and particularly on silty-loam soils. Heavier soils are favourable for a broad spectrum of weeds that do not have other specific requirements to the location. This explains assessed numbers of regularly occurring species at individual locations when the lowest species diversity was found on silty loam soil in comparison with loam and clay-loam. At all three locations, the weed seedbank in the soil included *Amaranthus retroflexus* and on silty loam soil also *Chenopodium album*, i.e. annual species with tremendous reproduction ability and economic importance. On the contrary, perennial species occurred rarely.

CONCLUSION

No significant differences were found between results of qualitative and quantitative estimation of potential weed densities in the soil using the elutriating device Analysette 3 in comparison with hand elutriation of weed species seeds. Between the two techniques, there was no significant difference in a number of entire seeds in most weed species.

In both elutriation methods, the time required for elutriation of a soil sample of 200 g depended on soil texture. Use of the device highly significantly reduced the time by 35.5–42.9% in comparison with hand elutriation. Despite that most time was saved in soils with a higher proportion of clayey particles, elutriation of clay-loam soils remains most time consuming. By contrast, the time necessary for collecting, counting and identifying the separated seeds was longest in silty loam soil that contain a high proportion of non-elutriated particles that look like (in both shape and colour) some seeds. Therefore, it necessitates greater attention and concentration, which leads towards earlier fatigue. Time consumption for heavier soils is also influenced by weed seedbank.

Using the device Analysette 3, only two sieves with mesh sizes of 0.25 and 2.0 mm proved sufficient. If sieves with 0.5- and 1.0-mm mesh sizes were used, seeds of a similar size remained in the sieves. Appropriate vibration (amplitude) was from 1.0 to 2.0 mm (a medium value). Water inflow depends on the content of clayey particles in elutriated soil. For silty loam soil, water inflow is suitable to adjust to 1.5 $l.min^{-1}$ and for clay loam soil to 1.0 $l.min^{-1}$.

When weed seedbank in the soil was compared at three locations differing in soil texture, significantly lower numbers of weed seeds as well as species were assessed in silty loam soil vs. both heavier soils. *Amaranthus retroflexus* was a dominating species at all lo-

cations and on silty loam soil also *Chenopodium album*. Data on a level of seedbank densities of these regularly occurring species can be an important basis for prediction of actual weed infestation at the presented locations.

This study was conducted within the project MSM: 462100001 funded by the Ministry of Education, Youth and Sports of the Czech Republic.

REFERENCES

Ambrosio L., Dorado J., Del Monte J.P. (1997): Assessment of the sample size to estimate the weed seedbank in soil. Weed Res., *37*: 129–137.

Benz W., Koch W., Moosman A. (1984): Ein Extraktionsverfahren zur Bestimmung des Unkrautsamenpotentials in Böden. Z. Pfl.-Krankh. u. Pfl.-Schutz, Sonderheft X: 109–114.

Cardina J., Sparrow D.H. (1996): A comparison of methods to predict weed seedling populations from the soil seedbank. Weed Res., *44*: 46–51.

Dečkov Z. (1975): Weed seeds in the soil of some regions in the central part of the Danubian plain. Rast. Nauki, *12*: 148–157.

Dvořák J., Krejčíř J. (1974): A contribution to the study of weed seedbank in topsoil. Acta Univ. Agric. Brno, *22*: 453–461. (In Czech)

Dvořák J., Krejčíř J. (1980): Effects of crop alternation and herbicides on weed seed disruption and distribution in topsoil. Acta Univ. Agric. Brno, *28*: 25–33. (In Czech)

Fay P.K., Olson W.A. (1978): Technique for separating weed seed from soil. Weed Sci., *26*: 530–533.

Feldman S.R, Alzugaray C., Torres P.S., Lewis P. (1997): The effect of different tillage systems on the composition of the seedbank. Weed Res., *37*: 71–76.

Gross K.L. (1990): A comparison of methods for estimating seed numbers in the soil. J. Ecol. Oxford, *78*: 1079–1093.

Gross K.L., Renner K.A. (1989): A new method for estimating seed number in the soil. Weed Sci., *37*: 836–839.

Hayashi I. (1975): The special method of inventory of buried seed population of weeds. Workshop on research methodology. Weed Sci., *1*: 32–38.

Kovach D.A., Thill D.C., Young F.L. (1988): A water-spray system for removing seed from soil. Weed Technol., *2*: 338–341.

Kropáč Z. (1966): Estimation of weed seeds in arable soil. Pedobiologia, *6*: 105–128.

Medd R.W. (1992): Techniques for monitoring seed banks of annual grass weeds on arable soil. In: Proc. 1st Int. Weed Control Congr., Melbourne, Australia, *2*: 333–335.

Miele S., Macchia M., Cozzani A. (1998): Prediction of weed flora emergence from buried seed reserves in sugar beet. In: Weed seedbanks: determination, dynamics and manipulation. Asp. Appl. Biol.: 29–36.

Miller A.C.E., Lutman P.J.W, Wright K.J., Wright G. McN. (1998): A preliminary report on patterns of seedbank decline and the relationship between seedbank and seedling emergence for seven arable weed species in winter wheat. In: Weed seedbanks: determination, dynamics and manipulation. Asp. Appl. Biol.: 59–67.

Numata M. (1984): Analysis of seeds in the soil. In: Knapp R. (ed): Sampling methods and taxon analysis in vegetation science. Dr. W. Junk, The Hague: 161–169.

Rahman A., James T.K., Grbavac N., Mellsop J. (1995): Evaluation of two methods for enumerating the soil weed seedbank. In: Proc. 48th N. Z. Plant Protec. Conf.: 175–180.

Roberts H.A., Ricketts M.E. (1979): Quantitative relationships between the weed flora after cultivation and the seed population in the soil. Weed Res., *18*: 41–48.

Stupnicka-Rodzynkiewicz E., Hochól T., Labza T., Pula J. (1998): Influence of fallow on weed seedbanks. In: Weed seedbanks: determination, dynamics and manipulation. Asp. Appl. Biol.: 237–242.

Teo-Sherrell C.P.A., Mortensen D.A., Keaton M.E. (1996): Fates of weed seeds in soil: a seeded core method of study. J. Appl. Ecol., *33*: 1107–1113.

Thompson K., Grime J.P. (1979): Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats. J. Ecol., *67*: 893–921.

Tulikov A.M. (1976): Sposob vydelenija semjan sornjakov po parusnosti iz mineralnoj frakcii počvy. Izv. Timirjazev. Seľ.-Choz. Akad., *2*: 39–46. (In Russian).

Wiles L.J., Barlin D.H., Schweizer E.E., Duke H.R., Whitt D.E. (1996): A new soil sampler and elutriator for collecting and extracting weed seeds from soil. Weed Technol., *10*: 35–41.

Received on February 14, 2002

ABSTRAKT

Zefektivnění vyplavovací metody pro stanovení zásoby semen plevelů v půdě

V modelovém pokusu bylo porovnáváno ruční vyplavování pod proudem tekoucí vody a vyplavování pomocí přístroje Analysette 3 pro stanovení zásoby semen plevelů v půdě. Byly stanoveny technické parametry pro efektivní práci s přístrojem. Byla sledována doba vyplavování půdních vzorků a doba potřebná k vybírání, počítání a identifikaci separovaných semen. Na žádné ze tří lokalit lišících se od sebe půdním druhem nebyl zjištěn průkazný rozdíl použitého způsobu vyplavování na výsledky kvalitativního a kvantitativního stanovení potenciálního zaplevelení. Při práci s přístrojem se oproti ručnímu vyplavování statisticky vysoce významně zkrátila doba vyplavování o 35,5 až 42,9 % v závislosti na půdním druhu. Nejkratší doba vyplavování byla zjištěna u lehké půdy. Doba potřebná k výběru, počítání a identifikaci semen byla naopak nejkratší u těžké půdy. U středně těžkých půd byla tato doba v průměru o 46 % a na lehkých půdách o 92 % delší,

tyto rozdíly byly statisticky vysoce významné. Při porovnání zásoby semen plevelů v půdě byl zjištěn statisticky průkazně nižší počet semen plevelů, ale i druhů na lehké půdě oproti oběma lokalitám s těžšími půdami. Dominantním druhem na všech lokalitách byl *Amaranthus retroflexus* a na lehké půdě také *Chenopodium album*. Z celkového počtu 32 druhů plevelů, jejichž semena byla v pokusu zjištěna, bylo 28 jednoletých a pouze 4 víceleté (*Cirsium arvense*, *Elytrigia repens*, *Rumex obtusifolius* a *Sonchus arvensis*).

Klíčová slova: zásoba semen plevelů v půdě; metody stanovení; způsoby vyplavování; pracovní náročnost

Corresponding author:

Ing. Vladimír Smutný, Mendelova zemědělská a lesnická univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika, tel.: + 420 5 45 13 31 16, fax: + 420 5 45 13 31 07, e-mail: smutny@mendelu.cz