Field surveys for insects associated with Amaranthus spp. (Amaranthaceae) in Switzerland and their suitability for biological control

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Field surveys for insects associated with *Amaranthus* spp. (Amaranthaceae) in Switzerland and their suitability for biological control

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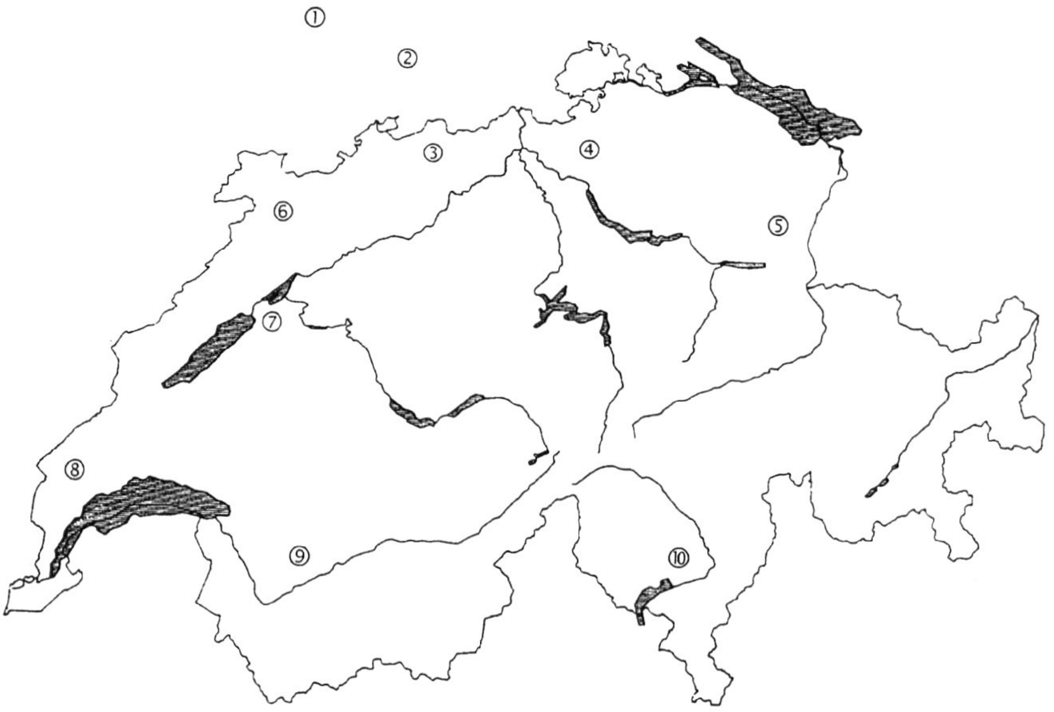
In Switzerland, several *Amaranthus* species cause locally serious problems as weeds in maize, vegetables, potatoes, sugar beet and beans. Because of herbicide tolerance and resistance, and increasing public pressure for more sustainable crop production, interest in alternative weed control methods is increasing. Biological control using insects could contribute to a satisfactory level of control of these weeds. Field surveys were carried out for insects (and pathogens) associated with *Amaranthus* species. Ten locations in Switzerland and in neighbouring countries were visited at monthly intervals. The surveys produced a total of 137 phytophagous insect species collected from *A. retroflexus*, *A. bouchonii* and *A. powellii*: 30 Coleoptera, 47 Homoptera, 34 Heteroptera, 14 Lepidoptera, 11 Thysanoptera, and 1 Orthoptera species. For most of the species found *Amaranthus* spp. were not known as host plants. It was found that all species collected are either polyphagous or possibly oligophagous, and none monophagous. The surveys revealed also that no herbivore insect species from the area of origin has been accidentally introduced into Europe. Based on the extended field surveys it would seem that none of the species of phytophagous insects associated with target *Amaranthus* spp. in Europe has a potential as biological control agent. Therefore, it is proposed to carry out additional surveys in the southern part of North, as well as in Central and South America, the centres of origin of the noxious *Amaranthus* species occurring in Europe, to locate potential biological control agents. Stem and root mining insects would be of greatest interest because they would fill empty niches.

Keywords: *Amaranthus*, weed, insects associated, biological control.

INTRODUCTION

Within a European research programme the work carried out intended to provide basic information on potential biological control of pigweeds (*Amaranthus* spp.) in Europe. The target pigweed species originate from America and were introduced into Europe in the 19th century (SAUER, 1967). In Switzerland several *Amaranthus* species, mainly *A. retroflexus* LINNAEUS, *A. powellii* S.WATSON, and *A. bouchonii* THELLUNG cause locally serious problems in agriculture. An inquiry revealed that crops having amaranth infestations are maize, vegetables, potatoes, sugar beets and beans (BÜRKI, 1997). Because of herbicide tolerance and resistance, and increasing public pressure for more sustainable crop production, interest in alternative weed control methods is increasing (BEURET, 1988; MAIGRE, 1991; JÜTTERSONKE & ARLT, 1992; SCHROEDER *et al.*, 1993). Biological control using insects could contribute to a satisfactory control of these weeds.

According to a comprehensive literature review (EL AYDAM & BÜRKI, 1997), the species of phytophagous arthropods associated with *Amaranthus* spp. in Europe were largely unknown. Therefore, a survey needed to be made before potential biocontrol agents could be identified, studied and screened. A survey was also neces-



Location	Altitude	Coordinates	Crop 95	Crop 96	*Amaranthus*
① Rouffach (F)	203 m	53,3°N/5,5°E	road side	maize	*ret, pow*
② Bad Krozingen (D)	239 m	53,3°N/5,9°E	maize	maize	*bou*
③ Rheinfelden AG	295 m	629.1/269.3	wheat	maize	*ret*
④ Otelfingen ZH	419 m	673.0/256.4	vegetables	maize	*bou, pow*
⑤ Haag SG	440 m	754.9/231.7	maize	maize	*ret, pow*
⑥ Courroux JU	420 m	595.3/244.7	sugar beet	potatoes	*pow*
⑦ Witzwil BE	431 m	572.6/202.7	sugar beet	maize	*ret*
⑧ Changins VD	402 m	509.4/139.4	maize	maize	*bou, pow*
⑨ Conthey VS	478 m	589.2/117.5	vegetables	asparagus	*ret, bou, pow*
⑩ Gudo TI	205 m	715.6/113.9	maize	maize	*ret, pow*

Fig. 1. Locations of insect surveys. *Amaranthus* species: ret = *retroflexus*, bou= *bouchonii*, pow = *powellii*.

sary to detect herbivores which may have been introduced accidentally from the areas of origin, and which were possibly occurring in Europe without any impact on the target weeds (examples in JULIEN, 1992).

MATERIAL AND METHODS

During the summers of 1995 and 1996, a total of eight extended surveys for insects were made. Ten locations in Switzerland and neighbouring countries were visited once a month from June to September (Fig. 1). The locations were chosen in different geographical and climatical regions. In central Switzerland samples could not be taken because *Amaranthus* spp. are not occurring there. Further, one location was situated in the German Rhine Valley and one in the French Alsace where pigweeds are weeds mainly in maize production.

Each location was characterized by analysing the soil, identifying the *Amaranthus* species occurring as well as their density (*Amaranthus* plants per m^2: average of 5 times 5 samples in both years of investigation), and listing other weed species growing at these sites: Rouffach (51 pl/m^2, *Chenopodium album* LINNAEUS, *Chenopodium polyspermum* LINNAEUS, *Echinochloa crus-galli* PALISOT DE BEAUVOIS); Bad Krozingen (57 pl/m^2, *C. album*, *Polygonum persicaria* LINNAEUS, *Convolvulus arvensis* LINNAEUS); Rheinfelden (126 pl/m^2, *E. crus-galli*, *Senecio vulgaris* LINNAEUS, *Sonchus* sp.); Otelfingen (61 pl/m^2, *P. persicaria*, *Galinsoga ciliata* (RAFINESQUE) BLAKE, *Agropyron repens* (LINNAEUS) PALISOT DE BEAUVOIS, *Amaranthus lividus* LINNAEUS); Haag (125 pl/m^2, *P. persicaria*, *C. album*, *E. crus-galli*); Courroux (47 pl/m^2, *C. album*, *C. arvensis*); Witzwil (38 pl/m^2, *C. album*, *Polygonum aviculare* LINNAEUS, *P. persicaria*); Changins (31 pl/m^2, *C. album*, *Euphorbia platyphyllos* LINNAEUS, *P. persicaria*); Conthey (87 pl/m^2, *C. album*; *P. persicaria*); Gudo (41 pl/m^2, *C. album*).

Insects were collected using a sweep net (diameter 30 cm) and from plant samples dissected. At each locality 200 sweepings (four times 50) were made. The diameter of the sweeping net was 30 cm. In 1995, a closed net was used and the insects collected after a few sweepings were removed by a pooter. In 1996 an improved net was used: at the bottom of the net a small plastic tube was fixed by a rubber ring. So, the whole sample including insects and plant parts (mainly flowers and seeds) fell directly into the tube which was closed immediately after sweeping. In the lab, the samples were checked for insects. In addition, a total of 220 plants, 100 in June, 50 in July and in August, and 20 in September, were randomly selected and dissected for insect attack in the laboratory. Furthermore, the *Amaranthus* population at each locality was observed during 30 minutes for insects feeding on the plants. Immature stages of insects collected were reared to adulthood and forwarded for identification.

Similar surveys for phytophagous insects associated with *Amaranthus* spp. were carried out in Slovakia during the summers of 1995 and 1996 (VRÁBLOVÁ; PhD Thesis, in prep.). In Hungary, insect collections were made on both weedy and crop amaranths between 1992 and 1995 using the same methods (SZENTKIRÁLYI, in prep.).

RESULTS AND DISCUSSION

In the laboratory, some 4,400 plants were dissected. With the exception of a few eggs of *Lygus* bugs (Heteroptera, Miridae), no insects were found in the stems and roots. Very few stems were mechanically damaged; in these damaged plant parts fungi and a few arthropods (Thysanoptera and mites) were sometimes found. In contrast, stem-mining by larvae of *Lixus subtilis* STURM. (Coleoptera, Curculionidae) was quite frequent in Slovakia and Hungary (pers. comm. CAGÁN and SZENTKIRÁLYI, respectively). The climate in Switzerland seems to be too cold for this thermophile weevil.

Tab. 1. Bugs (Heteroptera) collected on *Amaranthus* spp. in Switzerland and neighbouring areas. Loc. = number of locations, Dev. = developmental stage, I = imago (adult), L = larva, * = laboratory reared.

Family / *Species*	**Dev.**	**1995**	**1996**	**Total**	**%**	**Loc.**	**Food plants (literature)**
Miridae							
Dicyphus (Brachyceroea) globulifer (FALLEN)	I	1	1	2	0.09	1	polyphagous
Leptopterna dolobrata (LINNAEUS)	I	1	-	1	0.05	1	Poaceae
Stenodema (Brachystira) calcaratum (FALLEN)	I	1	-	1	0.05	1	Poaceae
Notostira elongata (GEOFFROY)	I+L	11	18	29	1.38	6	Poaceae
Trigonotylus coelestialium (KIRKALDY)	I+L	45	36	81	3.84	8	Poaceae
Phytocoris (Ktenocoris) singeri E. WAGNER	I	1	3	4	0.19	2	*Rumex conglomerata*
Adelphocoris lineolatus (GOEZE)	I+L	26	26	52	2.47	8	Fabaceae
Lygocoris (Apolygus) lucorum (MEYER-DÜR)	I	1	2	3	0.14	1	*Urtica, Artemisia, Tanacetum*
Lygus gemellatus (HERRICH-SCHÄFFER)	I	2	-	2	0.09	2	*Artemisia campestris*
Lygus pratensis (LINNAEUS)	I+L*	27	51	78	3.70	9	polyph. on weeds and trees
Lygus rugulipennis POPPIUS	I+L*	236	157	393	18.65	10	polyphagous on weeds
Lygus spp. larvae	L	180	211	391	18.55	10	
Heterotoma planicornis (PALLAS)	I	1	-	1	0.05	1	phyto- and zoophagous
Melanotrichus flavosparsus (C. SAHLBERG)	I+L	98	186	284	13.48	10	Chenopodiaceae
Plagiognathus arbustorum (FABRICIUS)	I	2	7	9	0.43	3	polyphagous on weeds
Plagiognathus (Poliopterus) albipennis (FALLEN)	I	1	-	1	0.05	1	*Artemisia*
Chlamydatus (Euattus) pullus REUTER	I	2	-	2	0.09	2	*Rumex, Artemisia, Achillea*
Miridae spp. larvae	L	38	-	38	1.80	8	
Anthocoridae							
Orius niger (WOLFF)	I+L	101	131	232	11.01	9	pollen (also zoophagous)
Orius majusculus (REUTER)	I	35	89	124	5.88	10	pollen (also zoophagous)
Orius minutulus (LINNAEUS)	I	17	30	47	2.23	10	pollen (also zoophagous)
Orius spp.	I	108	13	121	5.74	10	pollen (also zoophagous)
Orius spp. larvae	L	52	64	116	5.50	10	pollen (also zoophagous)
Piesmatidae							
Piesma maculatum (LAPORTE)	I	7	1	8	0.38	4	Chenopodiaceae
Lygaeidae							
Nysius senecionis (SCHILLING)	I	1	-	1	0.05	1	*Senecio*
Nysius ericae (SCHILLING)	I+L	18	3	21	0.99	1	*Artemisia, Thymus, Calluna*
Lygaeidae spp. larvae	L	2	-	2	0.09	1	
Coreidae							
Coreus marginatus (LINNAEUS)	I+L*	11	2	13	0.61	2	*Rumex*
Rhopalidae							
Corizus hyoscyami hyoscyami (LINNAEUS)	I	6	1	7	0.33	2	Asteraceae
Rhopalus (Brachycarenus) tigrinus (SCHILLING)	I	1	-	1	0.05	1	Chenopodiaceae
Rhopalus subrufus (GMELIN)	I	2	-	2	0.09	2	*Vincetoxicum, Geranium*
Stictopleurus punctatonervosus (GOETZE)	I	3	1	4	0.19	2	*Senecio, Achillea*
Pentatomidae							
Aelia acuminata (LINNAEUS)	I	1	-	1	0.05	1	Poaceae
Palomena prasina (LINNAEUS)	L	1	-	1	0.05	1	*Urtica* and trees
Palomena viridissima (PODA)	I+L*	2	7	9	0.43	6	*Urtica* and trees
Holcostethus vernalis (WOLFF)	I	1	-	1	0.05	1	polyphagous on weeds
Carpocoris fuscipinus (BOHEMAN)	L	1	-	1	0.05	1	*Asteraceae*, cereals
Eurydema oleracea (LINNAEUS)	I+L*	7	-	7	0.33	4	Brassicaceae
Nezara viridula (LINNAEUS)	I+L	12	1	13	0.61	1	*Zea, Brassica, Corylus*
Pentatomidae spp. larvae	L	3	1	4	0.19	4	
Total		**1066**	**1042**	**2108**	**100.00**	**10**	

Sweep netting was a very efficient method for insect collection. The number of insect species collected from leaves and flowers of *Amaranthus* spp. was surprisingly high. Our survey revealed 137 insect species to be associated with *Amaran-*

Tab. 2. Bugs collected in Rheinfelden on 23 August 1996 from different plant species: *Amaranthus retroflexus* LINNAEUS (AMARE), *Chenopodium album* LINNAEUS (CHEAL), *Beta vulgaris* LINNAEUS (BETVU), *Zea mays* LINNAEUS (ZEAMA), *Helianthus annuus* LINNAEUS (HELAN) and *Urtica dioica* LINNAEUS (URTDI).

Species	AMARE	CHEAL	BETVU	ZEAMA	HELAN	URTDI
Miridae						
Trigonotylus caelestialium				3		
Trigonotylus caelestialium larvae				11		
Adelphocoris lineolatus		1				13
Lygus pratensis	1	41				
Lygus rugulipennis		60	1			
Lygus spp. larvae	5	1025	13		5	
Melanotrichus flavosparsus		314				3
Melanotrichus flavosparsus larvae		563				
Plagiognathus (Poliopterus) albipennis		1				
Anthocoridae						
Orius niger	4				3	2
Orius niger larvae		14				
Orius majusculus	8	11	4	77	179	26
Orius minutulus	4	3		34	75	11
Orius spp. larvae	1	7	7	11	15	14
Piesmatidae						
Piesma maculatum						1
Rhopalidae						
Corizus hyoscyami hyoscyami	1					
Pentatomidae						
Palomena viridissima			1			
Palomena viridissima larvae						5
Unidentified / other species		11	10			5
Total	**24**	**2051**	**36**	**136**	**277**	**80**

thus spp., whilst only 28 insect species were recorded in the European literature (EL AYDAM & BÜRKI, 1997). Complete lists of the species of phytophagous insects collected during 1995 and 1996 are given in each of the following sub-chapters. When only a single or a few individuals of a species were found, their association with *Amaranthus* spp. is considered doubtfull. Only species occurring more frequently or at several locations sampled are considered to be associated with the target weed. However, the degree of association can only be determined by rearings. Therefore, larvae and nymphs collected were reared to adulthood if possible. Feeding tests were made with adults of insect species frequently collected. For the last two columns in the Tabs. 1-8, the food plant indices of GÜNTER & SCHUSTER (1990) (for Heteroptera), DOGUET (1994) (for Alticinae), LOHSE (1981) (for Curculionidae), SPULER (1908) (for Noctuidae), KALTENBACH (1987) (for Microlepidoptera) and PATCH (1938) (for Aphidina) were used. For the Thysanoptera the informations of ZUR STRASSEN (pers. comm.) and for the Cicadina those of REMANE (pers. comm.) were used.

Bugs (Hemiptera: Heteroptera)

The insect taxa most frequently associated with *Amaranthus* spp. were the Heteroptera, which were found at all locations throughout summer (Tab. 1). A total of 42 species has been identified, 34 of which are phytophagous. The dominant species were those in *Lygus*: *L. rugulipennis* POPPIUS, *L. pratensis* (LINNAEUS) and

L. gemellatus (HERRICH-SCHÄFFER). According to the literature, all three species live polyphagously on ruderal plants (WAGNER, 1952), but are now first recorded for *Amaranthus* spp. Notable is also a record of a species new for Switzerland (OTTO & BÜRKI, 1996), *Phytocoris* (*Ktenocoris*) *singeri* E. WAGNER which was found at Gudo. Bugs in *Orius* are recorded in literature as zoophagous but they can feed also on pollen (SCHMIDT-TIEDEMANN & SELL, 1997). It is not known which food they prefered in the flowerheads of *Amaranthus* spp. plants. Species which normally have other host plants and from which only single individuals were found, may have just accidentally rested on *Amaranthus* plants.

The number of bugs collected was very similar during both years as well as within and between different locations (Tabs. 9 and 10). The largest number of species and individuals was found at Conthey and Bad Krozingen. In contrast, Haag, Courroux and Rheinfelden seemed to be the less attractive locations for bugs. Most of the bugs found are polyphagous. According to the literature (WAGNER, 1952; GÜNTER & SCHUSTER, 1990), none of the phytophagous species was known to be associated with *Amaranthus* spp. (see Tab. 1). In order to estimate the degree of association of bugs with amaranths, a comparative insect collection from another five plant species was made. It turned out that most of the bugs collected from *Amaranthus* spp. were also found on other plant species (Tab. 2). Only 26 of some 2,600 individuals collected belonged to species which were not found on amaranths (Tab. 1 and Tab. 2). Interestingly, many more bug individuals were collected from these associated plant species (mainly *Chenopodium album*) than from pigweeds. According to GÜNTER & SCHUSTER (1990), *Melanotrichus flavosparsus* C. SAHLBERG is known to be associated with plants in the family Chenopodiaceae.

Flea beetles (Coleoptera: Chrysomelidae, Alticinae)

At the collection site near Changins high numbers (up to 27 individuals/m^2) of flea beetles were collected. Since TISLER (1990) reported serious attack by the alticine flea beetle *Disonycha glabrata* FABRICIUS on *A. retroflexus*, a potential incidental introduction of this species into Europe was suspected. However, the major-

Tab. 3. Flea beetles (Chrysomelidae, Alticinae) collected on *Amaranthus* spp. in Switzerland and neighbouring areas. Only imagines were found. Loc. = number of locations.

Species	**1995**	**1996**	**Total**	**%**	**Loc.**	**Food plants (literature)**	**Pest on (lit.)**
Chaetocnema concinna MARSHAM	2	2	4	0.37	3	Polygonaceae, Chenopodiaceae	sugar beet
Chaetocnema hortensis GEOFFROY	7	5	12	1.12	6	Poaceae, Cyperaceae, Poaceae	cereals
Chaetocnema laevicollis THOMSON	28	1	29	2.73	6	Cyperaceae, Juncaceae	
Chaetocnema tibialis ILLIGER	569	384	953	89.57	8	Chenopodiaceae, **Amaranthaceae**	sugar beet
Epitrix pubescens KOCH	15	5	20	1.88	2	Solanaceae	
Longitarsus kutscherae RYE	1	5	6	0.56	4	*Plantago* spp., Lamiaceae	
Longitarsus melanocephalus DEG.	-	1	1	0.09	1	*Plantago* spp.	
Longitarsus pellucidus FOUDRAS	-	3	3	0.28	1	*Convolvolus arvensis*	
Longitarsus pratensis PANZER	1	1	2	0.37	2	*Plantago* spp.	
Longitarsus rubiginosus FOUDRAS	1	2	3	0.28	2	*Calystegia* spp.	
Phyllotreta astrachanica LOPATIN	1	-	1	0.09	1	*Rorippa islandica*	
Phyllotreta striolata FABRICIUS	4	1	5	0.47	3	Brassicaceae	
Phyllotreta undulata KUTSCHERA	21	1	22	2.07	4	Brassicaceae	cabbage, rape
Psylliodes chrysocephala LINNAEUS	-	3	3	0.28	1	Brassicaceae	rape
Total	**650**	**414**	**1064**	**100**	**10**		

ity of the flea beetles collected near Changins were later identified as *Chaetocnema tibialis* ILLIGER, an occasional (native) pest on sugar beet (Tab. 3). Of the 14 flea beetle species found on *Amaranthus* spp., *C. tibialis* was the only species previously recorded as being associated with amaranths (DOGUET, 1994). The surveys in 1995 and 1996 differed only slightly in species composition: *Phyllotreta astrachanica* LOPATIN was collected only in 1995, and another three species, *Longitarsus pellucidus* FOUDRAS, *Psylliodes chrysocephala* LINNAEUS and *Longitarsus melanocephalus* DEG. only in 1996.

The number of flea beetle species collected in 1995 and 1996 was similar (Tab. 9), but the number of individuals higher in 1995 than in 1996 (Tab. 10). This was mainly due to higher abundance of *C. tibialis* which occurred at eight of the ten locations. *Chaetocnema tibialis* was also found on other plant species investigated: *Amaranthus retroflexus* (9 individuals), *Chenopodium album* (33), *Beta vulgaris* (7) and *Urtica dioica* (2). As observed for bugs, *C. album* hosted more flea beetles than *A. retroflexus*.

Another chrysomelid, the tortoise beetle, *Cassida nobilis* LINNAEUS (Coleoptera: Chrysomelidae), was found in small numbers but in all phenostages (egg, larva, pupa and imago) at Bad Krozingen, Rheinfelden, Rouffach and Witzwil. After laboratory rearing, adults overwintered and layed eggs the following summer. This species is a known pest on sugar beet, mainly in eastern European countries. In recent years it has become a serious pest in former USSR (BICHUK *et al.*, 1986) together with *Cassida nebulosa* LINNAEUS, with which it is often confused (NUZHDIN, 1989). Adults migrate to overwintering sites and colonize the crop fields the following spring (BICHUK *et al.*, 1986).

Weevils (Coleoptera: Curculionidae)

Of the 15 weevil species found (Tab. 4), only *Sitona lineatus* LINNAEUS was known to feed occasionally on leaves of *Amaranthus* species (FISHER & O'KEEFFE, 1979). This species is better known as a crop pest. In Poland, *S. lineatus* is the most common beetle in *faba*-bean plantations (CZERNIAKOWSKI & CZERNIAKOWSKI,

Tab. 4. Weevils (Curculionidae) collected on *Amaranthus* spp. in Switzerland and neighbouring areas. Only imagines were found. Loc. = number of locations.

Species	1995	1996	Total	%	Loc.	Food plants (literature)	Pest on (literature)
Catapion seniculus KIRBY	1	-	1	1.09	1	*Trifolium* spp.	*Trifolium* spp.
Ceutorhynchus floralis PAYKULL	1	1	2	2.17	2	Brassicaceae	
Ceutorhynchus pallidactylus MARSHAM	3	-	3	3.26	1	Brassicaceae	
Ceutorhynchus pulvinatus GYLLENHAL	1	-	1	1.09	1	*Sisymbrium* spp.	
Ceutorhynchus sp.	-	2	2	2.17	1		
Nanophyes marmoratus GOEZE	1	1	2	2.17	2	*Lythrum* spp.	
Protapion assimile KIRBY	2	-	2	2.17	2	*Trifolium* spp.	
Protapion fulvipes FOURCROY	3	-	3	3.26	1	*Trifolium medium*	
Rhinoncus bruchoides HERBST	21	8	29	31.52	5	*Polygonum* spp.	
Rhinoncus perpendicularis REICH	1	2	3	3.26	3	*Polygonum* spp.	
Sibinia pellucens SCOPOLI	1	-	1	1.09	1	*Melandrium* spp.	
Sitona lepidus GYLLENHAL	4	1	5	5.43	2	Fabaceae	*Medicago sativa*
Sitona lineatus LINNAEUS	36	-	36	39.13	4	Fabaceae, ***A. retroflexus***	*Pisum sativum*
Sitona hispidulus FABRICIUS	1	-	1	1.09	1	Fabaceae	
Tychius picirostris FABRICIUS	1	-	1	1.09	1	*Trifolium* spp.	
Total	**77**	**15**	**92**	**100**	**8**		

Tab. 5. Moths (Lepidoptera) collected on *Amaranthus* spp. in Switzerland and neighbouring areas. Loc. = number of locations.

Species	1995	1996	Total	%	Loc.	Food plants (literature)	Pest on (lit.)
Geometridae							
Alcis repandata (LINNAEUS)	-	3	3	5.17	2	polyphag. on trees, shrubs, weeds	
Noctuidae							
Agrotis exclamationis LINNAEUS	-	13	13	22.41	2	polyphagous	different crops
Autographa gamma (LINNAEUS)	-	3	3	5.17	3	polyphagous	clover
Calocestra microdon GUENEE	1	2	3	5.17	2	*Coronilla, Saponaria, Silene*	
Discestra trifolii HUFNAGEL	-	-				Chenopodiaceae, Leguminosae	clover
Emmelia trabealis (SCOPOLI)	1	-	1	1.72	1	*Convolvulus arvensis*	
Mamestra brassicae LINNAEUS	3	3	6	10.34	4	polyph. on Brassicac., Chenopod.	salad, cabbage
Mamestra oleracea LINNAEUS	-	3	3	5.17	3	polyphagous	vegetables
Noctua pronuba (LINNAEUS)	-	1	1	1.72	1	polyphagous	
Phlogophora meticulosa (LINNAEUS)	-	1	1	1.72	1	polyphagous	
Spodoptera exigua HÜBNER	2	-	2	3.45	1	*Polygon., Convolv.,* ***Amaranthus***	
Xestia c-nigrum LINNAEUS	1	9	10	17.24	3	*Verbascum, Epilobium*	
Plutellidae							
Plutella xylostella LINNAEUS	8		8	13.79	1	Brassicaceae, ***A. viridis***	cabbage, rape
Pterophoridae							
Emmelina monodactyla LINNAEUS	-	4	4	6.93	1	*Convolvolus*	
Total	**16**	**42**	**58**	**100**	**10**		

1994). LANDON *et al.* (1995) observed that at emergence, *S. lineatus* was extremely polyphagous and fed on various legumes without showing any specific preference for pea. Sensitivity to the food plant became only apparent during the reproductive period. *S. lineatus* was then capable of distinguishing between different leguminous crops as well as different varieties of peas. During an experiment evaluating a range of varieties of white clover for resistance to feeding by *S. lineatus* some varieties were less favoured than others (MURRAY, 1996).

Besides *S. lineatus* only one other weevil species was found regularly: *Rhinoncus bruchoides* HERBST. All other species were recorded very rarely, five of them only as single individuals. At three locations no curculionids were found on *Amaranthus* spp. (Tab. 9).

Moths (Lepidoptera)

All identified Lepidoptera were found as larva and laboratory-reared on *Amaranthus* spp. leaves. In total, 58 individuals belonging to 15 species could be reared sucessfully to adulthood. Most belong to Noctuidae (Tab. 5). They are all known polyphagous species and some, like *Discestra trifolii* HUFNAGEL, *Mamestra brassicae* LINNAEUS, *Agrotis exclamationis* LINNAEUS, *Xestia c-nigrum* LINNAEUS, and *Autographa gamma* LINNAEUS are well-known crop pests (STAN *et al.*, 1987). On the other hand, *Spodoptera exigua* HÜBNER could be seen indirectly as a beneficial insect species. It was found feeding on pigweed (*Amarantus hybridus*) growing in maize fields in Florida (TINGLE *et al.*, 1978). This noctuid is not normally a pest of maize in Florida but is known to serve as a host of several parasitoid species that attack an important maize pest, *S. frugiperda* (J.E. SMITH). Another pest is the diamondback moth *Plutella xylostella* LINNAEUS (Plutellidae) of which outbreaks are reported, e.g. on oilseed rape in Sweden (WAERN & EKBOM, 1995). In India, *P. xylostella* is also noxious on the cultivated *Amaranthus viridis* (VISHAKANTAIAH &

GOWDA, 1975). Research is being carried out to select effective *Trichogramma* species to control *P. xylostella* (HASSAN, 1993).

It has to be noted that many more caterpillars were collected than shown in Tab. 5. However, during laboratory rearing 4 % of all the larvae turned out to be parasitized. In Tab. 5 only those moth species are listed which developed to adult. Since it is known, that some parasitoids are rather niche specific than host specific (BAUMANN & VIDAL, 1990), their potential impact on introduced phytophagous insect species needs to be considered.

Cicadas (Hemiptera, Homoptera: Cicadina)

Some 36 species of cicadas were collected from amaranths. The predominant family were the Cicadellidae (leafhoppers) of which two species, *Empoasca pteridis* (DAHLBOM) (= *Empoasca solani* CURTIS) and *Zyginidia scutellaris* (HERRICH-SCHÄFFER), were found in large numbers (Tab. 6). Leafhoppers, an important virus vector, proliferated in the field: imagines, nymphs and exuviae were found on *Amaranthus* spp. leaves. The different results between years may have been due to the different sweeping nets used (see material and methods). Cicadas, especially their larvae, can easily be overlooked when collected with a pooter from the sweeping net in the field. In addition, they are very agile and some of them may have escaped in 1995 when the unmodified net was used. However, at some locations quite similar numbers of cicadas were collected in both years (Tab. 10).

There were no *Amaranthus* spp. known to be host plants of Cicadina. It can be suggested that species, which normally have other host plants and from which only single individuals were found, may have been staying just accidentally on the *Amaranthus* plants (e.g. species of Delphacidae which are exclusively arboricol). On the other hand, larvae of the two most frequently occurring species, *E. pteridis* and *Z. scutellaris*, were reared in the laboratory on *Amaranthus* spp. to adulthood. However, *Z. scutellaris* is exclusively known to feed on Poaceae. In the Mediterranean *Z. scutellaris* is a pest on maize. Most of our collection sites were located in maize fields. The larvae reared were mature nymphs when collected and developed within two days to adults. It would seem that these nymphs stayed only by accident on *Amaranthus* spp. and could develop successfully because in the last days before molting to imagines the quantity of liquid sucked is more important than quality (pers. comm. Prof. Dr. Reinhard REMANE, University of Marburg, Germany).

The other predomiant species, *E. pteridis*, has been reared as well on amaranth plants in the lab. It is suggested that it can use *Amaranthus* spp. as alternative hosts (pers. comm. Prof. Dr. Reinhard REMANE). The suitability of 13 weed species as food-plants for another *Empoasca* species, the crop pest *E. fabae* HARRIS, was tested by LAMP *et al.* (1984). Although e.g. *A. retroflexus* was accepted as host plant, the laboratory studies suggested that the weed species are less suitable as hosts compared to the crop (e.g. lucerne and broad bean).

Aphids (Hemiptera, Homoptera: Aphidina)

Eleven species of aphids were collected, all belonging to the family Aphididae. The highly polyphagous species *Aphis fabae* SCOPOLI, *Macrosiphum euphorbiae* THOMAS and *Myzus persicae* SULZER are known to feed on *Amaranthus* species (PATCH, 1938; STEGMAIER, 1950).

The number of aphids collected varied importantly between locations as well as between the two years (Tab. 7). One reason for the difference between the two

Tab. 6. Cicadas (Hemiptera, Homoptera: Cicadina) collected on *Amaranthus* spp. in Switzerland and neighbouring areas. Loc. = number of locations, Dev. = developmental stage, I = imago (adult), L = larva, * = laboratory reared, (vir.) = vector of virus diseases.

Family / *Species*	Dev.	1995	1996	Total	%	Loc.	Food plants (literature)
Delphacidae							
Dicranotropis hamata (BOHEMAN)	I	5	-	5	0.29	1	Poaceae, pest on cereals (vir.)
Laodelphax striatella (FALLEN)	I	42	95	137	7.87	10	Poaceae, maize (vir.)
Javesella pellucida (FABRICIUS)	I	12	34	46	2.64	10	Poaceae, pest on cereals (vir.)
Delphacidae Larvae	L	-	9	9	0.52	1	
Cercopidae							
Neophilaenus campestris (FALLEN)	I	-	2	2	0.11	1	polyphagous on weeds
Philaenus spumarius (LINNAEUS)	I	1	1	2	0.11	2	polyphagous on weeds
Membracidae							
Stictocephala bisonia KOPP & YONKE	I	3	-	3	0.17	1	polyphagous on Fabaceae
Cicadellidae							
Cicadella viridis (LINNAEUS)	I+L	2	1	3	0.17	2	polyphagous, pest on alfalfa
Aphrodes sp.	L*	-	2	2	0.11	1	polyphagous on ruderal plants (vir.)
Anaceratagallia sp.	I	2	4	6	0.34	3	polyphagous on weeds and shrubs
Emelyanoviana mollicula (BOHEMAN)	I	-	4	4	0.23	4	polyphagous on weeds and shrubs
Empoasca vitis (GÖTHE)	I	8	19	27	1.55	5	polyphagous on woody plants (vine)
Empoasca decipiens PAOLI	I	8	9	17	0.98	4	polyphagous on weeds and shrubs
Empoasca pteridis (DAHLBOM)	I+L*	78	288	364	20.88	10	polyphagous, potataoes, tomatoes
Empoasca sp.	I+L*	26	35	61	3.51	10	polyphagous on weeds and shrubs
Chlorita sp.	I	2	20	22	1.26	6	Asteraceae
Kybos sp.	I	1	-	1	0.06	1	trees ; *Salix, Betula*
Eupteryx aurata (LINNAEUS)	I	1	5	6	0.34	2	Asteraceae, Lamiaceae, Apiaceae
Eupteryx atropunctata (GOEZE)	I	4	14	18	1.03	5	Asteraceae, Lamiaceae, Apiaceae
Eupteryx sp.	I	1	3	4	0.23	2	Urticaceae, Lamiaceae
Typhlocyba bifasciata BOHEMAN	I	-	1	1	0.06	1	trees ; *Carpinus, Ulmus*
Zyginidia scutellaris (HERR.-SCHÄFF.)	I+L*	98	286	384	22.10	10	maize (vir.)
Arboridia ribauti (OSSIANNILSSON)	I	1	3	4	0.23	3	trees ; *Carpinus, Quercus*
Macrosteles sardus RIBAUT	I	1	6	7	0.40	4	polyphagous on weeds
Macrosteles cristatus (RIBAUT)	I	2	15	17	0.98	5	polyphagous on weeds
Macrosteles laevis (RIBAUT)	I	19	66	85	4.89	10	polyphagous, pest on cereals (vir.)
Macrosteles sexnotatus (FALLEN)	I	18	72	90	5.17	9	polyphagous on weeds
Macrosteles sp.	I+L*	42	149	194	11.10	10	polyphagous on weeds
Euscelis incisus (KIRSCHBAUM)	I+L	13	22	35	2.01	7	Fabaceae
Euscelidius variegatus (KIRSCHBAUM)	I+L	26	21	47	2.70	7	polyph. on mono- and dicotyledons
Artianus interstitialis (GERMAR)	I	-	1	1	0.06	1	Poaceae
Hardya tenuis (GERMAR)	I	-	4	4	0.23	1	Poaceae
Cicadula persimilis (EDWARDS)	I	-	2	2	0.11	2	*Dactylis glomerata*
Mocydia crocea (HERRICH-SCHÄFFER)	I	-	2	2	0.11	2	Poaceae
Mocydiopsis sp.	L	-	1	1	0.06	1	Poaceae
Psammotettix alienus (DAHLBOM)	I	60	35	95	5.46	8	polyphagous, pest on cereals (vir.)
Psammotettix confinis (DAHLBOM)	I	-	2	2	0.11	1	polyphagous
Psammotettix sp.	L	10	-	10	0.57	2	polyphagous
Acrocephalus longiceps (KIRSCHB.)	I	3	2	5	0.29	2	Poaceae
Errastunus ocellaris (FALLEN)	I+L	8	6	14	0.80	3	*Agropyron*
Mocuellus collinus (BOHEMAN)	I	-	1	1		1	*Agropyron*
Total		**497**	**1243**	**1740**	**100.0**	**10**	

years may be the sweep net used (see Cicadas and Material and Methods). Another reason may be the life strategy of these insects. That is, in spring, a fundatrix lands on a plant and starts a new population by parthenogenetic reproduction. This population increases within a relatively short time if weather conditions are ideal. A clear result is the restricted seasonal occurrence of aphids on *Amaranthus* species. In July

Tab. 7. Aphids (Homoptera: Aphidina) collected on *Amaranthus* spp. in Switzerland and neighbouring areas. Only imagines were found. Loc. = number of locations.

Species	1995	1996	Total	%	Loc.	Food plants (literature)	Pest on (literature)
Acyrthosiphon sp.	0	10	10	1.47	2		
Acyrthosiphon pisum (HARRIS)	0	70	70	10.26	5	Fabaceae, *Polygonum*	peas
Aphis fabae SCOPOLI	1	132	133	19.50	9	polyphagous, *Amaranthus*	beans
Aphis sp.	38	43	81	11.88	8		
Brachycaudus cardui LINNAEUS	0	2	2	0.29	1	Asteraceae, *Prunus*	
Capitophorus hippophaës (WALKER)	0	2	2	0.29	1	*Hippophäe, Polygonum*	
Hyperomyzus sp.	0	13	13	1.91	3		
Macrosiphum euphorbiae THOMAS	44	103	147	21.55	10	polyphagous, *Amaranthus*	potatoes, tomatoes
Myzus persicae SULZER	0	23	23	3.37	5	polyphagous, *Amaranthus*	potatoes, tomat., beets
Rhopalosiphum padi LINNAEUS	3	7	10	1.47	6	*Prunus padus,* Poaceae	cereals, maize
Sitobion avenae FABRICIUS	10	121	131	19.21	9	Poaceae	cereals, maize
unidentified imagines	0	3	3	0.44	3		
unidentified larvae and nymphs	13	44	57	8.36	9		
Total	**109**	**573**	**682**	**100**	**10**		

1995 and 1996, 95 % and 97 %, respectively, of all aphids were collected. Later, in August and September, only single individuals were found.

According to the literature, only in a few cases aphids were used as weed biological control agents. In 1986, *Aphis chloris* KOCH was introduced into Australia to control *Hypericum perforatum* LINNAEUS (JULIEN, 1992). WILLIS *et al.* (1993) studied the interaction between physiological stress and arthropod herbivory by the aphid *A. chloris* and a mite (*Aculus hyperici* LIRO) on *H. perforatum*. Individually, each stress factor reduced measures of plant growth. The combination of several stress factors decreased plant growth slightly more than the product of their separate effects, suggesting that there is a weak, positive interaction exacerbating the damage caused by each stress factor. Another example is the aphid *Brachycaudus rumexicolens* (PATCH) which causes a significant reduction in achene (fruit) size in the weed *Emex australis* STEINHEIL. An indirect effect of a reduction in achene size is the loss of seed dormancy and as a consequence a reduction of seed longevity in the soil (SCOTT *et al.*, 1996).

Aphids often damage plants indirectly, acting as virus vectors. TIMMERMAN *et al.* (1985) estimated that up to 80 % of certain crops can be infected with the beet western yellows virus (BWYV) by aphids. Theoretically, it seems possible to use aphids as biocontrol agents, acting as a vector for an *Amaranthus* specific virus. TAIWO (1988) described a sap transmissible virus isolated from naturally infected *A. hybridus* plants (crop!) which induced mosaic or mottling, green veinbanding and leaf malformation of inoculated *Amaranthus* plants. The name *Amaranthus* mosaic virus was proposed. On the Internet homepage "Plant Virus Online" (BRUNT *et al.* 1996) a table with viruses attacking 12 *Amaranthus* species is available. Aside from aphids, KOK (1974) considers that thrips, aleyrodids, cicadellids and mites can also be used to transmit plant viruses to weeds. CHARUDATTAN *et al.* (1977) report that a virus collected from a related plant is readily transmissible to the weed *Morrenia odorata* (Asclepiadaceae) by the aphid *Myzus persicae*.

Thrips (Thysanoptera)

Eleven species within three thrips families were found on *Amaranthus* spp. (Tab. 8). Thrips have been found at all ten locations investigated: most common at

Tab. 8. Thrips (Thysanoptera) collected on *Amaranthus* spp. in Switzerland and neighbouring areas. Loc. = number of locations.

Species	1995	1996	Total	%	Loc.	Food plants (literature)	Pest on (lit.)
Aelothripidae							
Aelothrips intermedius BAGNALL	40	5	45	51.14	5	polyphagous	cereals
Aelothrips sp.	1	1	2	2.27	2	polyphagous	
Thripidae							
Frankliniella intonsa (TRYBOM)	-	6	6	6.82	5	polyphagous	
Frankliniella tenuicornis (UZEL)	-	2	2	2.27	2	polyphagous	
Limothrips cerealium HALIDAY	1	6	7	7.95	3	graminicol	
Thrips atratus HALIDAY	2	-	2	2.27	2	polyphagous	
Thrips fuscipennis HALIDAY	4	12	16	18.18	4	polyphagous	
Thrips major UZEL	1	-	1	1.14	1	polyphagous	
Phlaeothripidae							
Haplothrips aculeatus (FABRICIUS)	4	1	5	5.68	3	graminicol	
Haplothrips kurdjumovi KARNY	-	1	1	1.14	1	polyphagous (trees)	
Hoplothrips ulmi (FABRICIUS)	-	1	1	1.14	1	corticol (trees)	
Total	**53**	**35**	**88**	**100**	**10**		

Changins (38 individuals) and least at Haag (1 individual). None of the species found occurred at all locations. *Aeolothrips intermedius* BAGNALL was the most abundant species. In 1995, 34 of the 40 individuals of *A. intermedius* were collected at Changins. All other species occurred only in very small numbers.

It is known from the literature that most of the species found are polyphagous. *Limothrips cerealium* HALIDAY and *Haplothrips aculeatus* (FABRICIUS) are known to feed on grass species. *Hoplothrips ulmi* (FABRICIUS) is recorded to live exclusively on trees.

Thrips are recently being used for biological control of a plant species in Amaranthaceae. In Florida *Amynothrips andersoni* O'NEILL was released to control alligatorweed, *Alternanthera philoxeroides* MART. (GRISEB.) (CENTER, 1994). The feeding activity of the larvae causes stunting of leaf growth; with a total generation time of about 28 days. VOGT *et al.* (1992) investigated the dispersal characteristics of three introduced South American insect species, including *A. andersoni*, their suppressive effects on alligatorweed and the effects of year-to-year weather variations on the seasonal cycles of both the biocontrol agents and the target weed in the southern USA during 1973-83. They suggested that the importance of the biocontrol agents will increase as they hold in check an over-expanding distribution of the target weed.

Although only a few examples are known from the literature, thrips (with their short generation time and their capability to damage plants heavily) should be included in the list of potential biocontrol agents of *Amaranthus* species. However, none of the species collected in Switzerland is suitable as a biological control agent.

Grasshoppers (Orthoptera)

In July 1996 a young nymph of the long-horned grasshopper *Phaneroptera falcata* PODA (Orthoptera: Tettigoniidae) was found at Gudo feeding on *A. powellii* plants. It was laboratory reared to adulthood on *Amaranthus* spp. leaves. This species is reported to occur only at locations with a warm climate (BELLMANN, 1985) feeding on shrubs (e.g. *Prunus spinosa* LINNAEUS; Rosaceae).

Tab. 9. Number of species per location.

SPECIES		BadK.	Chan.	Cont.	Cour.	Gudo	Haag	Otel.	Rhei.	Rouf.	Witz.	JUL	AUG	SEP	TOTAL
Heteroptera	1995	18	9	13	12	9	6	5	8	11	12	18	26	18	34
	1996	13	6	12	9	12	8	11	9	13	10	12	17	13	25
Alticinae	1995	4	3	2	2	-	1	6	3	1	6	8	6	5	11
	1996	2	3	1	1	2	4	5	2	3	4	8	4	6	13
Curculionidae	1995	4	1	1	2	2	-	4	4	-	4	9	7	3	14
	1996	1	2	1	-	1	-	2	1	-	-	5	3	1	6
Lepidoptera	1995	-	2	-	2	1	-	1	-	-	1	5	1	1	7
	1996	1	-	2	4	5	1	-	4	2	1	7	7	3	11
Cicadina	1995	16	16	8	15	13	2	6	12	7	9	19	24	20	25
	1996	18	16	11	10	12	11	17	17	14	16	20	28	23	33
Aphidina	1995	1	3	4	-	2	1	1	-	4	1	5	2	2	5
	1996	10	8	1	7	4	1	3	8	6	7	11	3	1	11
Thysanoptera	1995	2	1	-	1	-	1	1	2	2	2	5	6	1	7
	1996	1	3	2	2	6	-	1	3	-	2	6	6	1	9

Tab. 10. Number of individuals per location.

INDIVIDUALS		BadK.	Chan.	Cont.	Cour.	Gudo	Haag	Otel.	Rhei.	Rouf.	Witz.	JUL	AUG	SEP	TOTAL
Heteroptera	1995	132	138	178	66	163	55	37	62	128	107	165	585	316	1066
	1996	138	30	192	58	94	53	155	58	106	158	192	595	255	1042
Alticinae	1995	14	432	45	5	-	1	36	24	52	41	123	490	37	650
	1996	2	257	3	1	10	18	36	28	3	56	243	142	29	414
Curculionidae	1995	8	1	1	4	2	-	9	18	-	34	20	40	17	77
	1996	2	3	2	-	1	-	5	1	-	1	5	8	2	15
Lepidoptera	1995	-	3	-	2	1	-	8	-	-	2	14	1	1	16
	1996	2	-	3	16	6	1	-	10	3	1	18	20	4	42
Cicadina	1995	71	172	15	10	70	44	7	17	63	28	133	194	170	497
	1996	134	178	17	139	70	142	58	221	135	148	297	568	377	1242
Aphidina	1995	3	50	23	-	3	4	4	-	14	8	104	3	2	109
	1996	183	97	2	77	8	1	13	33	80	79	556	16	1	573
Thysanoptera	1995	2	34	-	3	-	1	1	5	3	4	8	44	1	53
	1996	1	4	9	4	7	-	1	5	-	4	24	10	1	35

Geographic distribution of the insects collected

In the ten locations investigated, the number of species and individuals found per taxon was different as indicated in Tabs. 9 and 10. Species richness was greatest in Changins for most taxa while fewest insects per taxa were collected at the

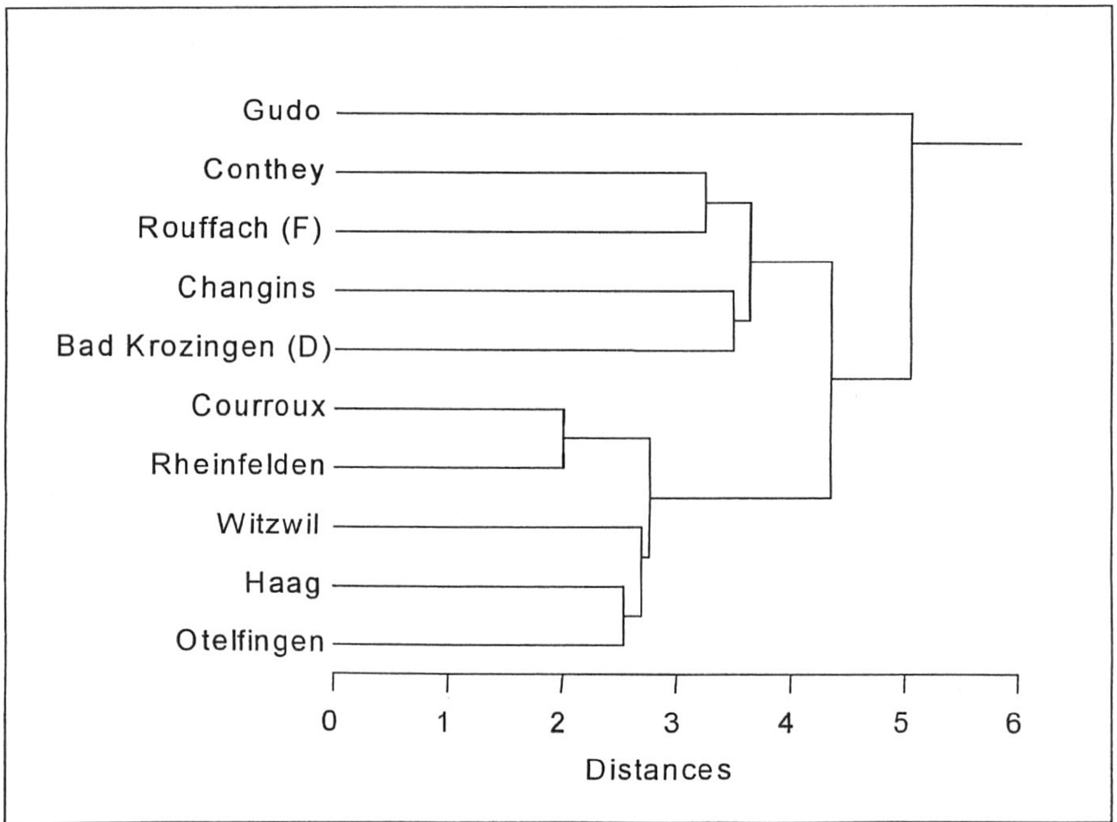


Fig. 2. Dendrogram based on a cluster analytic calculation (Minkowski distance) using the computer programme SYSTAT. Basis were the qualitative and quantitative data of all collected Heteropera at each location.

Haag site. The difference in the number of species found may be due to the fact that, because of poor weather conditions in July 1996, only three collections could be made at the Haag site while four were made at the Changins site. Another potential reason is that maize was grown for several consecutive years at the Haag site, similar to the site at Bad Krozingen, whereas all other collection sites were managed using crop rotation. However, maize is listed (Fig. 1) in other locations for both years as well because different sampling fields, fields containing maize, were chosen in 1995 and in 1996. It was found that *Amaranthus* spp. were growing well in these fields containing maize. Some insects were attracted by crop plants in which pigweeds were growing and occurred only accidentally on amaranths (e.g. *Zyginidia scutellaris*, on maize). Thus, fields where the same crop was cultivated over several years tended to have a lower insect diversity. On the other hand, crop rotation may result in the presence of more polyphagous species, which also feed on amaranths.

Another factor influencing the composition of the insect fauna on *Amaranthus* spp. is the geographic region. A cluster analysis (Fig. 2) was made using the 42 bug species found as a parameter for comparing the ten locations. It turned out that Gudo (Ticino) differred most from all other collection sites. The Alps as a natural barrier may be responsible for this difference. Further, four other locations with a relatively mild climate (Rouffach, Bad Krozingen, Conthey and Changins) formed a group within the dendrogram and the five sites in the Swiss Mittelland formed another group.

CONCLUSIONS

The extensive field surveys carried out during 1995 and 1996 provided a large number of insect species associated with *Amaranthus* spp. in Switzerland. For most of the species found *Amaranthus* spp. were not known as host plants. Without any exception all species found are either polyphagous or oligophagous, but certainly none monophagous. None of the species found developed a closer association with these new host plants during the short period following the introduction of pigweeds into Europe. This assumption is supported by a comparative insect collection showing that many insect species collected from *Amaranthus* spp. also occurred on other plant species in the immediate neighbourhood. The surveys revealed also that no herbivore insect species from the area of origin has so far been accidentally introduced into Europe.

Based on the results of the field surveys it can be concluded that none of the species of phytophagous insects associated with target *Amaranthus* spp. has a potential as biological control agent. Thus, following the theory and practice of classical biological control, surveys will have to be made in southern North, Central and South America, the centres of origin of noxious *Amaranthus* species occurring in Europe, to locate potential biocontrol agents. In the literature only a few insect species native to the Americas are recorded which may be suitable potential biocontrol agents of *Amaranthus* species (EL AYDAM & BÜRKI, 1997). Surveys within the native range of *Amaranthus* species may result in finding other potential biocontrol agents for release in Europe. Stem and root mining insects will be of greatest interest because they can fill empty niches.

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ZUSAMMENFASSUNG

Im Rahmen eines europäischen Forschungsprogramms sollte die vorliegende Arbeit grundlegende Informationen über die Möglichkeit zur biologischen Bekämpfung von Amaranth-Arten (*Amaranthus* spp.) beschaffen. In der schweizerischen Landwirtschaft verursachen Amaranth-Arten (vor allem *A. retroflexus* LINNAEUS, *A. powellii* S. WATSON und *A. bouchonii* THELLUNG) in bestimmten Gebieten grössere Schäden. In einer breit angelegten Umfrage stellte sich heraus, dass vor allem die Kulturen Mais, Gemüse, Kartoffeln, Zuckerrüben und Bohnen betroffen sind. Resistenz gegen verschiedene Herbizidklassen erschweren die Bekämpfung von Amaranth. Die biologische Bekämpfung mit Hilfe von Insekten könnte zu einer besseren Kontrolle dieses Unkrauts beitragen.

In den Sommermonaten 1995 und 1996 wurden an 10 Standorten in der Schweiz und im angrenzenden Ausland alle Insekten gesammelt, die auf Amaranthpflanzen gefunden wurden. Die Aufsammlungen ergaben 137 verschiedene Insektenarten, die auf den drei Arten *A. retroflexus*, *A. bouchonii* und *A. powellii* vorkamen: 30 Coleopteren-, 47 Homopteren-, 34 Heteropteren-, 14 Lepidopteren-, 1 Orthopteren- und 11 Thysanopterenarten. Für die meisten der oft polyphagen Arten war Amaranth als

Futterpflanze aus der Literatur nicht bekannt. Eine vergleichende Insektenaufsammlung auf verschiedenen anderen Pflanzenarten in der näheren Umgebung zeigte, dass viele Insekten, die auf Amaranth gefunden wurden, auch auf diesen Pflanzen vorkamen. Einige der polyphagen Arten sind zudem als Schädlinge von Kulturpflanzen bekannt. Aufgrund dieser Befunde kann gesagt werden, dass keine der gefundenen Insektenarten zur biologischen Bekämpfung von Amaranth in Betracht kommt. Es wird deshalb vorgeschlagen, im Heimatgebiet der *Amaranthus*-Arten (Amerika) nach möglichen spezifischen Gegenspielern des Unkrauts zu suchen. Ein besonderes Augenmerk ist dabei auf in Wurzeln und Stengeln minierende Insektenarten zu richten, da diese ökologischen Nischen in Europa noch nicht besetzt sind.

REFERENCES

BAUMANN, T. & VIDAL, S. 1990. Patterns in the parasitoid complex of the genus *Isocolus* FORSTER (Hym. Cynipidae). *Zool. Anz. 229(1–2)*: 1–12.

BELLMANN, H. 1985. *Heuschrecken beobachten, bestimmen*. Neumann-Neudamm, Melsungen, Germany. 216 pp.

BEURET, E. 1988. *Weeds in vegetable crops: what about soil seed bank and integrated weed control. Weed control in vegetable production*. Proceedings of a meeting of the EC Experts' Group, Stuttgart 28–31 Oct. 1986, pp. 213–221.

BICHUK, Y.P., TRIBEL', S.A., & PRUSSKAYA, N.D. 1986. Beet leaf beetles. *Zashch. Rast. Moskva 6*: 48–50.

BRUNT, A.A., CRABTREE, K., DALLWITZ, M.J., GIBBS, A.J., WATSON, L., & ZURCHER, E.J. (eds.) (1996 onwards) *Plant Viruses Online: Descriptions and Lists from the VIDE Database*. Version 16th January 1997. URL http://biology.anu.edu.au/Groups/MES/vide/

BÜRKI, H.M. 1997. *Investigations on the feasibility of biological control of pigweeds (Amaranthus retroflexus L., A. powellii S. WATS. and A. bouchonii THELL.) with phytophagous insects, fungal pathogens and crop management*. PhD Thesis, University of Bern, Switzerland.

CENTER, T.D. 1994. *Biological control with insects: the alligatorweed thrips*. Fact Sheet AGR 82, a series of the Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Or: http://hammock.ifas.ufl.edu/txt/fairs/2116

CHARUDATTAN, R., CORDO, H.A., SILVEIRA, G.A., ZETTLER, F.W., & FREEMAN, T.E. 1977. *Obligate pathogens of the milkweed vine, Morrenia odorata, as biological control agents*. Proceedings of the IV International Symposium on Biological Control of Weeds, 1977. Center for Environmental Programs, Institute of Food and Agricultural Sciences, Florida University.; Gainesville, Florida; USA, p. 241.

CZERNIAKOWSKI, Z.W. & CZERNIAKOWSKI, Z. 1994. Sklad gatunkowy chrzaszczy (Coleoptera) oraz nasilenie ich wystepowania na plantacjach bobiku (*Vicia faba* L.) w poludniowo-wschodniej Polsce. *Materialy Sesji Instytutu Ochrony Roslin 34(1)*: 215–221.

DOGUET, S. 1994. *Faune de France, part 80. Coléoptères Chrysomelidae Vol. 2 Alticinae*. Fed. Franc. Soc. Sci. Nat., Paris, France. 694 pp.

EL AYDAM, M. & BÜRKI, H.M. 1997. Biological control of noxious pigweeds in Europe: a literature review of the insect species associated with *Amaranthus* spp. worldwide. *Biocontrol News and Information 18*: 1, 11N–20N.

FISHER, J.R. & O'KEEFFE, L.E. 1979. Food plants of the pea leaf weevil *Sitona lineatus* (LINNAEUS) (Coleoptera: Curculionidae) in northern Idaho and eastern Washington. *Pan-Pacif. Entomol. 55(3)*: 202–207.

GÜNTER, H. & SCHUSTER, G. 1990. Verzeichnis der Wanzen Mitteleuropas (Heteroptera). *Dtsch. Ent. Z., N.F. 37(4–5)*: 361–396.

HASSAN, S.A. 1993. The mass rearing and utilization of *Trichogramma* to control lepidopterous pests: achievements and outlook. *Pesticide Sci. 37(4)*: 387–391.

JULIEN, M.H. 1992. *Biological control of weeds – A world catalogue of agents and their target hosts*. CAB International, Wallingford, UK. Third Edition.

JÜTTERSONKE, B. & ARLT, K. 1992. Die infraspezifische Struktur von Unkrautarten in Beziehung zur Herbizidresistenz. *Z. Pflanzenkrankh. Pflanzensch., Sonderheft XIII*: 475–481.

KALTENBACH, T. 1987. *Kleinschmetterlinge*. Neumann-Neudamm, Melsungen, Germany. 288 pp.

KOK, L.T. 1974. Principles and methodology of biological weed control. *Plant Protect. Bull., FAO 22(4)*: 77–81.

LAMP, W.O., MORRIS, M.J., & ARMBRUST, E.J. 1984. Suitability of common weed species as host plants for the potato leafhopper, *Empoasca fabae*. *Entomologia Experim. Appl. 36(2)*: 125–131.

LANDON, F., LEVIEUX, J., HUIGNARD, J., ROUGON, D., & TAUPIN, P. 1995. Feeding activity of *Sitona lineatus* L. (Col., Curculionidae) on *Pisum sativum* L. (Leguminosae) during its imaginal life. *J. Appl. Entomol. 119(8)*: 515–522.

LOHSE, G.A. 1981. *Die Käfer Mitteleuropas, Vol 10.* Goecke & Evers, Kreefeld, Germany. 311 pp.

MAIGRE, D. 1991. Disponibilité et efficacité de l'atrazine en sol acide: le cas du Tessin. *Revue Suisse Agricult. 2 (3)*: 167–171.

MURRAY, P.J. 1996. Evaluation of a range of varieties of white clover for resistance to feeding by weevils of the genus *Sitona. Plant Varieties Seeds 9(1)*: 9–14.

NUZHDIN, V.F. 1989. Goosefoot tortoise beetle in the Kuban. *Zashch. Rast. Moskva 6*: 31.

OTTO, A. & BÜRKI, H.M. 1996. *Phytocoris (Ktenocoris) singeri* E. WAGNER, eine neue Art für die schweizerische Wanzenfauna (Heteroptera). *Entomol. Ber. Luzern 35*: 47–48.

PATCH, E.M. 1938. *Food-plant catalogue of the aphids of the World.* University of Maine, USA, 431 pp.

SAUER, J.D. 1967 The grain amaranths and their relatives: a revised taxonomic and geographic survey. *Ann. Missouri Bot. Garden 53(2)*: 103–137.

SCHMIDT-TIEDEMANN, A. & SELL, P. 1997. Eignung von Pollen als Nahrung für die räuberische Blumenwanze *Orius minutus* L. (Heteroptera: Anthocoridae). Proceedings of the 49th international symposium on crop protection: part II, Gent, Belgium, 6 May 1997. *Meded. Facult. Landbouwk. Toegep. Biol. Wetensch., Univ. Gent 62(2b)*: 473–482.

SCHROEDER, D., MÜLLER-SCHÄRER, H., & STINSON, C.S.A. 1993. A European weed survey in 10 major crop systems to identify targets for biological control. *Weed Res. 33*: 449–458.

SCOTT, J.K., YEOH, P.B., MORAN, V.C. (ed.), & HOFFMANN, J.H. 1996. *Integration of biological and other weed control against Emex australis in annual pasture-crop rotations.* Proceedings of the 9th international symposium on biological control of weeds, Stellenbosch, South Africa, 19–26 January 1996, 467–471.

SPULER, A. 1908. *Die Schmetterlinge Europas, Band I.* E. Schweizerbartsche Verlagsbuchhandlung, Stuttgart, Germany. 385pp.

STAN, G., COROIU, I., ONISOR, A., TOMESCU, N., CHIS, V., & OPREAN, I. 1987. Capturarea masculilor unor specii de Lipidoptere noctuide daunatoare in capcane feromonale adecive si capcane feromonale cu apa. *Bulet. Protect. Plant. 4*: 9–17.

STEGMAIER, C.E. 1950. *Insects associated with the rough pigweed, Amaranthus retroflexus L. (Amaranthaceae).* Unpublished thesis, Kansas State College of Agriculture and Applied Science, USA, 113 pp.

TAIWO, M.A. 1988. Studies on a virus disease of *Amaranthus hybridus* L. in Nigeria. *Int. J. Trop. Plant Dis. 6(2)*: 195–200.

TIMMERMAN, E.L., D'ARCY, C.J., & SPLITTSTOESSER, W.E. 1985. Beet western yellows virus in Illinois vegetable crops and weeds. *Plant Dis. 69(11)*: 933–936.

TINGLE, F.C., ASHLEY, T.R., & MITCHELL, E.R. 1978. Parasites of *Spodoptera exigua, S. eridania* (Lep.:Noctuidae) and *Herpetogramma bipunctalis* (Lep.Pyralidae) collected from *Amaranthus hybridus* in field corn. *Entomophaga 23(4)*: 343–347.

TISLER, A.M. 1990. Feeding in the pigweed flea beetle, *Disonycha glabrata* FAB. (Coleoptera: Chrysomelidae), on *Amaranthus retroflexus. Virginia J. Sci. 41(3)*: 243–245.

VISHAKANTAIAH, M. & GOWDA, B.L.V. 1975. Record of *Plutella xylostella* LINNAEUS (= *maculipennis* (CURT.)) as a new pest of *Amaranthus viridis* in Karnataka. *Current Sci. 44(23)*: 869.

VOGT, G.B., QUIMBY, P.C. Jr., & KAY, S.H. 1992. Effects of weather on the biological control of alligatorweed in the lower Mississippi Valley region, 1973–83. *Tech. Bull. U. S. Dep. Agric.* No. 1766, iv + 143 pp.

WAERN, P. & EKBOM, B. 1995. Kalmal (*Plutella xylostella*) som skadedjur i varoljevaxter. *Vaxtskyddsnotiser 59(4)*: 111–115.

WAGNER, E. 1952. Blindwanzen oder Miriden. *In*: DAHL, F. (Ed.), *Die Tierwelt Deutschlands*, 41. Teil. Gustav Fischer, Jena, Germany.

WILLIS, A.J., ASH, J.E., & GROVES, R.H. 1993. Combined effects of two arthropod herbivores and water stress on growth of *Hypericum* species. *Oecologia 96(4)*: 517–525.

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