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Towards the management of field bindweed (*Convolvulus arvensis*) and hedge bindweed (*Calystegia sepium*) with fungal pathogens and cover crops

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The bindweeds *Calystegia sepium* and *Convolvulus arvensis* are difficult to control chemically. *Calystegia sepium* is often a problem in maize or in vineyards, while *C. arvensis* is an important weed of cereals. The biological control of these weeds with insects or fungal pathogens has been investigated since 1970. More than 600 fungi collected in countries throughout Europe have been isolated in our laboratories. The isolates with the highest and most stable pathogenicity against bindweed belong to the genus *Stagonospora*. In a field trial in maize in 1995, one of these *Stagonospora* isolates stopped the increase of ground coverage by the bindweeds. In response to public concern about environmental problems caused by modern agriculture, new cropping systems are being developed. Underseeding maize with a living green cover achieves good control of a large spectrum of the weed flora typical of conventional tillage systems. However, *C. sepium* and *C. arvensis* remain as problems. The research reported shows that *C. sepium* is partly suppressed by the green cover, but escapes control by climbing the stems of the maize plants. Therefore, the application of spores of *Stagonospora* sp. in a maize field underseeded with a living green cover may allow a large or a complete reduction of the herbicide input and promote a more sustainable agriculture.

Keywords: Biological control; bindweed; new cropping systems; *Calystegia sepium*; *Convolvulus arvensis*; *Stagonospora*; mycoherbicide; fungal pathogens; green soil cover.

Introduction

Field bindweed (*Convolvulus arvensis* L.) and hedge bindweed (*Calystegia sepium* (L.) R. Br.) are perennial, noxious weeds in Europe and many agricultural areas of the world (Weaver and Riley, 1982; Maillet, 1988). Field bindweed has been described as the twelfth worst weed in the world (Holm *et al*., 1977). Bindweeds are a serious problem in grapes, raspberries, beans and maize; the yields of winter wheat can be reduced by one-third and summer-growing crops by three-quarters (Phillips, 1967). Bindweeds reduce the crop value through competition and by interfering with the harvest procedures. In addition, field bindweed provides a breeding site for insects attacking adjacent crops (Tamaki *et al*., 1975) and serves as an alternative host for viruses which cause plant diseases (Feldman and Gracia, 1977; Holm *et al*., 1977). The control of bindweed with mechanical and chemical methods is difficult because of its vigorous regeneration capacity. Some control but not eradication is obtained with chemical herbicides (Wiese and Rea, 1959; Derscheid *et al*., 1970; Westra *et al*., 1992). The selective herbicides in use are 2,4-D, dicamba, picloram (Westra *et al*., 1992) and imazapyr (Schoenhals *et al*., 1990); glyphosate, a non-selective herbicide, is also used (Westra *et al*., 1992). Once a bindweed population is established it is very difficult to control. Repeated applications of herbicide may stop shoot growth and reduce the amount of root, but, even after applications for several years, some root growth, from which further shoots can develop, remains (Timmons, 1949).

Convolvulus arvensis, an important weed in cereal production (Holm *et al*., 1977), has slender, twining stems (1–3 m long) which spread over the soil surface and other plants. The funnel-shaped, white or pinkish flowers, 1.5–3 cm wide and long, with two bracts approximately 1.5 cm below the flower, are borne in the leaf axils. The simple, alternate leaves are up to 6 cm long and 3 cm wide. The root system of *C. arvensis* may extend through a soil zone 6 m in diameter and up to 9 m deep (Holm *et al*., 1977).

Calystegis sepium is a pest in maize and vineyards, but is also troublesome in cereals (see the section on new cropping systems). Its creeping and climbing stems can be up to 5 m long and bear longer (length >6 cm) leaves than *C. arvensis*. The flowers are white, 4–6 cm long and funnel shaped (Maillet, 1988).

Bindweeds produce numerous seeds (10^7 ha^{-1}) which survive for 20–30 years in the soil (Timmons, 1949).

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Calystegia sepium prefers moist soils whereas *C. arvensis* is more tolerant of dryness (Maillet, 1988).

The poor control of bindweeds by herbicides has stimulated studies on biological control since 1970. Insects and gall mites have been considered (Rosenthal and Carter, 1977; Rosenthal and Platts, 1990) and the gall mite *Aceria malherbae* Nuzzaci (Acari: Eriophyidae), imported from Greece, has been released as a potential biological control agent in some states of the USA (Boldt and Sobhian, 1993). The reports of biological control of fungi mainly concern *Phomopsis convolvulus* Ormeno used at the three- to five-leaf stage of *C. arvensis* (Ormeno-Nuñez *et al*., 1988; Morin *et al*., 1989) and *Phoma proboscis* Heiny (Heiny, 1990; Heiny and Templeton, 1991). Phytotoxic metabolites of *P. convolvulus* have been analysed (Tsantrizos *et al*., 1992). An additional alternative to chemical control is the use of a living soil cover (Ammon, 1993; Ammon and Serafin, 1996). In this study we examine a possible combination of biological control of bindweed with fungal pathogens and crop management practices including the use of living soil cover.

Biological control of *C. arvensis* and *C. sepium* with fungal pathogens

Preliminary field survey

Since 1982, the Institute of Plant Sciences, Zürich, Switzerland, has been collecting diseased *C. arvensis* and *C. sepium* throughout Europe. In addition, specimens have been obtained from S. Hasan, CSIRO, Montpellier, France and E.-E. Trujillo, University of Hawaii, USA. In total, 271 cultures representing 44 species in 30 genera were isolated and screened for pathogenicity (the data for the cultures from *C. arvensis* are presented in Table 1). The best candidates, all *Stagonospora* sp., were tested for host specificity and their potential evaluated in preliminary field trials in different locations conducted with 2–4 month old bindweed plants of various ecotypes. Five fungi were successful against *C. sepium* and two against *C. arvensis*. For example, at Eschikon, Switzerland, isolate 214 Ca reduced the ground cover by *C. sepium* in maize by 82% in 1990 and by 63% in 1991. In contrast, less control was achieved during 2 years of field trials at Montpellier, France (Hasan *et al*., 1992).

Additional surveys of *C. arvensis* infestations at 15 sites across the south of England and two sites in the north of England by the group in Long Ashton have produced 268 pathogenic fungus isolates. These include *Phomopsis, Fusarium, Alternaria* and *Phoma* spp. Only *Phoma exigua* Desmazieres strains were found to be sufficiently effective to be considered as a potential mycoherbicide. Although *P. exigua* is normally a virulent pathogen of potato, the four strains isolated were not pathogenic to potato or to 16 other crops (M.P. Greaves and M.D. MacQueen, unpublished). The identity of the strains, which were all morphologically distinct, was confirmed by both the Commonwealth Mycological Institute (CMI), Kew, UK and the Centraalbureau voor Schimmelcultures (CBS), Baarn, The Netherlands.

In laboratory experiments (M.P. Greaves and M.D. MacQueen, unpublished), each strain of *P. exigua* was shown to kill *C. arvensis* seedlings when applied to the foliage at the three- to five-leaf stage (10^6 conidia ml^{-1}) using an air brush sprayer and spraying to run-off. The sprayed plants were given 18 h exposure to dew and then transferred to the glasshouse or were kept in humid propagation boxes without prior exposure to dew. In both cases, lesions were visible 2 days after spraying, the leaves were totally necrotic after 4–5 days and the stems had died after 7 days. There was no regrowth from the roots. The treatment of mature plants with well-developed root systems resulted in stem death in 7–10 days but this was followed some 10–14 days later by regrowth from the roots. After approximately 2 years subculture and storage on slopes all four isolates suddenly lost their virulence. Attempts to re-establish the virulence, by passage across the host, failed. Therefore, for convenience, subsequent research at Long Ashton concentrated on the *Stagonospora* sp. isolated by the Zürich group. All the *P. exigua* isolates were placed as confidential deposits in the CMI collection. The original sites of sampling were clearly documented. Subsequent visits have confirmed that the disease is still present.

The genus Stagonospora

Stagonospora, a genus of the Deuteromycota, class Coelomycetes, contains more than 350 species, which are mostly poorly described. The most important species is *Stagonospora nodorum* Berk. (*Septoria nodorum* Berk.; telemorph: *Leptosphaeria nodorum* Müller). *Stagonospora* sp. produces brown lesions on the leaves of bindweeds.

Our *Stagonospora* strains grow well *in vitro* between 15 and 27 8C. Spores are produced in mass on V8 agar and, to some extent, on several sterilized cereal grains (e.g. wheat, maize, barley and millet). None of the strains that are aggressive on *C. sepium* cause major disease symptoms on *C. arvensis* and vice versa. On bindweeds, they cause typical brown lesions on the leaves followed by defoliation, the reduction of plant growth and, occasionally, the death of young seedlings in the greenhouse. No attack was observed on the stems or roots. The strains appear to produce one or more phytotoxins.

Recent survey and field experiments

In summer and autumn 1994, diseased bindweed plants were collected in Romania and England. One isolate, a *Stagonospora* sp., was tested at Eschikon near Zürich in a maize field with an established bindweed population during the summer of 1995. Spores were applied at 3 3 10^6 spores ml^{-1} at 300 l ha^{-1} with a conventional backpack sprayer (motorized pump and 1.5 m spray boom with three

Table 1. Fungal strains isolated from *C. arvensis* L.

Classes	Species	Number[a]
Agonomycetes	*Rhizoctonia* sp.	4
Ascomycetes	*Chaetomium* sp.	2
	Hypoxylon bipapillatum Berk. & Curtis	1
	fragiforme Kickx	2
	Pleospora herbarum Rabenhorst	5
	Sordaria fimicola Cesati & de Notaris	2
	macrospora Auerswald	1
	Sporormiella minima Ahmed & Cain	1
Basidiomycetes	*Aureobasidium pullulans* Arnaud	5
Coelomycetes	*Ascochyta* sp.	1
	Colletotrichum dematium Grove *gloeosporioides*	4
	Panzig & Saccardo	4
	Phoma cava Schulzer	2
	pomorum von Thümen	2
	Phoma sp.	12 (3)
	Septoria sp.	17 (9)
	Stagonospora sp.	5 (4)
	Stagonospora/Ascochyta	2
Hyphomycetes	*Acremonium curvulum* Gams	2
	Acremonium sp.	1
	Alternaria alternata von Keissler	3
	tenuissima Wiltshire	5
	Alternaria sp.	8
	Bipolaris sp.	1
	Botrytis cinerea Persoon:Fries	1
	Cladosporium tenuissimum Cooke	1
	Epicoccum purpurascens Ehrenberg	4
	Fusarium arthrosporioides Sherbakoff	6
	lateritium Nees:Fries	3
	oxysporum Schlechtendahl:Fries	6
	solani Saccardo	7
	tricinctum Saccardo	2
	Fusarium sp.	1
	Geniculosporium serpens Chesters & Greenhalgh	1
	Goniotrichum sp.	1
Hyphomycetes	*Humicola grisea* Traaen	1
	Hyalodendron sp.	1
	Noedulisporium sp.	4
	Ovularia sp.	2
	Periconia igniaria Mason & Ellis	1
	Trichoderma sp.	1
Oomycetes	*Rhizopus stolonifer* Vuillemin	1
Non determined		1
Mycelia sterila		17
	28 genera	154 (16)

[a]The number in parentheses are the number of isolated strains pathogenic for *C. arvensis* and with a reduced host range.
The strains were isolated from 57 specimens collected in Germany, France, Italy, Austria, Switzerland, Czechoslovakia and Yugoslavia.

Teejet 800067 nozzles operating at 2 bar). The control plots were repeatedly treated with Benomyl (fungicide) to prevent spread of the sprayed fungus. Untreated plots were sprayed with neither fungal spores nor Benomyl.

The percentage ground cover with bindweed in the *Stagonospora*-treated plots did not increase during the 3 weeks after treatment, while in the untreated plots it increased by 48% and in the control plots by 115% (Fig. 1).

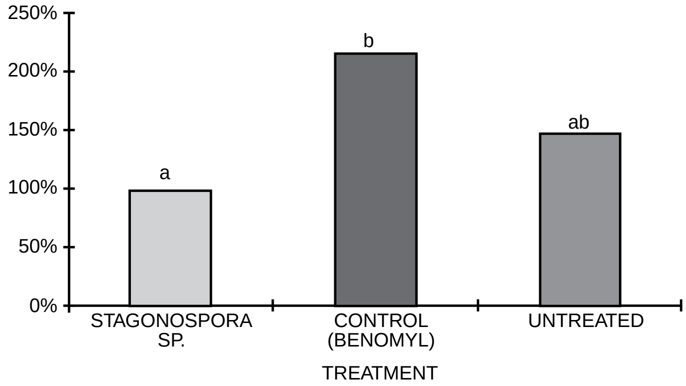

Fig. 1. Development of percentage ground coverage with bindweed 3 weeks after the application of *Stagonospora* sp. (100% = ground coverage before the application; field trial 1995 at Eschikon, Switzerland). Columns with the same letter are not significantly different at the 5% level using the Student's *t*-test.

Leaf infection in the *Stagonospora*-treated plots reached 78% compared to only 38% in the untreated plots. In the *Stagonospora*-treated plots 45% of the leaves were dead, with 23% dead in the untreated plots (Table 2). The infections in the untreated plots might indicate that this isolate has the ability to spread or that *Stagonospora* was just generally present in the field. In the Benomyl control plots 14% of the leaves were infected and 6% were dead (Table 2).

Control of bindweeds in new cropping systems

Why new cropping systems?

The development of European agriculture has produced many changes in recent decades. Notably, herbicides have replaced mechanical weed control. Most recently, new crops such as maize, soya and sunflower are sown in late spring rather than in autumn, as is usual with cereals. In addition, we now have less diversity in crop rotation or even monocultures, in particular with maize and increasingly with wheat.

Without the adaptation of tillage and cropping techniques, these changes have given rise to environmental and weed problems. Nitrate losses are high during long fallow winter periods, one of main reasons for the increasing nitrate concentrations in the ground water. Further, the use of persistent, highly active herbicides increases soil erosion because the soils are weed free for longer. In addition, the repeated use of such herbicides results in resistant weeds or a shift of the weed flora. Effective weed control, thus, needed more herbicide and, as a result, herbicides in the ground and surface waters have increased. In addition, there is soil compacting during harvesting of the new, late-harvested crops in fully weed-free soil.

Table 2. Percentage of leaves infected and dead 3 weeks after application of *Stagonospora* sp. (field trial 1995 at Eschikon, Switzerland)

Treatment	% of leaves infected	% of leaves dead
Stagonospora sp.	77.9a	45.4a
Control (Benomyl)	13.8b	6.0b
Untreated	37.8b	23.3ab

Values followed by the same letter are not significantly different at the 5% level using the Student's *t*-test.

An increased perception of and public concern about environmental problems in many countries in the 1990s produced demands for new concepts of land use and lower inputs of pesticides in agriculture and, in particular, in amenity and non-cropped areas. Three main improvements were adapted.

(1) Pesticide use was restricted by environmental legislation in agriculture, forestry, amenity and non-cropped areas. In some countries, herbicides were totally banned in forests and roadsides and their use severely restricted on railway tracks.
(2) Integrated pest management (IPM) was introduced in agriculture, coupled with subsidies in many countries, in addition to prescriptions of land use, crop rotation and tillage techniques.
(3) Organic farming production was increased to meet the demand of an increasing number of consumers. All synthetic pesticides are banned in these production systems.

Intensive research has been started to underpin these changes. New tillage or cropping techniques are being developed and land use systems adapted to the new crops and crop rotation systems. The research also includes the introduction of the new cropping techniques into integrated crop production (ICP) systems and investigation of biological pest, disease and weed control, as potential partners in integrated control programmes.

Integrated production system for maize

Long periods of uncovered soil are regarded as the main reason for ecological problems in maize. These include soil erosion and the movement of adsorbed pesticides, in particular atrazine, into adjacent water bodies. In recent years, it has been shown that maize is only affected by weeds during the critical period lasting from approximately the three- to four to the six- to eight-leaf stage (Koch and Kemmer, 1980; Zink and Hurle, 1990). There is, thus, no need to maintain the field weed free during the whole growing season to permit full yields. A green soil cover produced by underseeding with *Trifolium* species after mechanical weed control is tolerated (Ammon and Scherrer, 1995). Mulch seeding techniques, using the dead plant residues of the preceding crop or a frost- or herbicide-killed catch crop are common practice in many countries. Recent studies have shown that the catch crop need not be ploughed in or removed with herbicides before seeding the maize. Direct seeding of the crop into the living plant cover is possible with appropriate machinery and, in an adapted system, the plants may be kept as living mulch in maize. The timing and the methods of regulating this soil cover mechanically or with herbicides and the influence of the catch crop species on the yield are described in Ammon *et al*. (1995) and Hartwig (1985). In new trials the influence of the green cover on pests, diseases and other soil parameters has been studied. Here we report on the influence on the weed flora, in particular on *C. sepium*.

Materials and methods

Maize cropping with a living mulch

The conventional maize tillage system, ploughing in autumn and seeding maize in bare soil in late spring, is known to favour nitrate losses. A green soil cover – either a catch crop seeded in autumn or an existing meadow – is cut for cattle fodder or flail chopped as green manure in spring before maize seeding. Maize is seeded with a specially constructed rotary band seeder into the living plant sward. The combination includes four band rotovators, working 15 cm deep and 30 cm wide, a winged tine 30 cm wide working at approximately 20 cm depth preceding the rotovator, a band fertilizer operator and a band sprayer to apply the herbicides into the rotovated band (for details see Ammon and Bohren (1996)). Instead of herbicides, a band flamer can be used.

Regulation of catch crops and weeds between the maize rows

A tractor-mounted, four-row (flailer-type) mulcher was used between the maize rows to cut resprouting catch crop plants and weeds 1–3 cm above the soil surface. Normally two mulching procedures at the two- to three- and four- to six-leaf stages of maize are necessary. Such cutting is possible in regions with sufficient precipitation or in living mulch of low competitive ability (Ammon and Bohren, 1996). The regulation with herbicides is dealt with by Ammon *et al*. (1995).

Four year trial to compare living mulch with conventional tillage and to control the weed flora

In a 4 year trial started in 1990, four maize cropping systems repeated on the same plots were tested (the details of method are in Bigler *et al*. (1995a). The influence on important annual weeds in maize, e.g. *Echinochloa crus-galli* (L.) P. B. and late-emerging annual dicotyledoneous species known to be hard to control because of their ability to form atrazine-resistant biotypes was evaluated from 1990 through to 1993. The influence on the most important perennial weed, *C. sepium*, was evaluated from 1991 to 1993. The four cropping systems were as follows.

(1) Conventional tillage (ploughing in autumn) combined with pre-emergent herbicides according to the weed flora to achieve full weed control (‘conventional’).
(2) Conventional tillage with mechanical weed control and an underseeded grass–*Trifolium* mixture at the three- to four-leaf stage of maize (‘underseeded’).
(3) Rotary band seeding in a rye (*Secale cereale* L.) catch crop, seeded in autumn, flail chopped as green manure in spring before maize seeding and interrow mulching at the three- to four-leaf stage of maize. Each year, after the maize harvest, the field was ploughed and the rye catch crop reseeded (‘rye’).
(4) Rotary band seeding in a grass–*Trifolium* meadow. Grass was harvested in autumn and in spring, resprouting grass–*Trifolium* being controlled by interrow mulching at the two- to three- and four- to six-leaf stages of maize. The grass sward was allowed to regrow after the maize harvest, no reseeding being performed during the 3 years (‘meadow’).

One year trial

Conventional tillage was compared to maize underseeded with *Trifolium* (according to Ammon and Scherrer, 1995) and the influence on *C. sepium* was determined by counting the number and length of climbing and creeping shoots and the number of new stolons developed.

Results

The influence of the four cropping systems on the density of the annual weeds are presented in Fig. 2 and on the perennial weed *C. sepium* in Fig. 3.

In the underseeded treatment, the weed density reduction was variable, depending on the development of the grass–*Trifolium* sward (results not shown). In the fourth year with good, early development of the sward, the reduction was higher, but not sufficient, in particular concerning the dicotyledoneous species (Fig. 2B). In the rye treatment, in the first years panicoid grasses and *Chenopodium polyspermum* L. were dominant. In subsequent years, these two species were reduced (Fig. 2A). The control of the dicotyledoneous weeds was not sufficient particularly in the first 3 years (Fig. 2B). Similarly, in the meadow treatment, but only in the first year, panicoid grasses, mainly *E. crus-galli* (L.) P. B., dominated. In subsequent years, these species disappeared. In contrast to the rye treatment, in the meadow treatment the hard to control dicotyledoneous species were fully controlled from the first year on. Therefore this treatment is considered as a strategy to prevent or even control herbicide-resistant biotypes. In this meadow treatment the season-long, living mulch was obviously more competitive to annual weeds

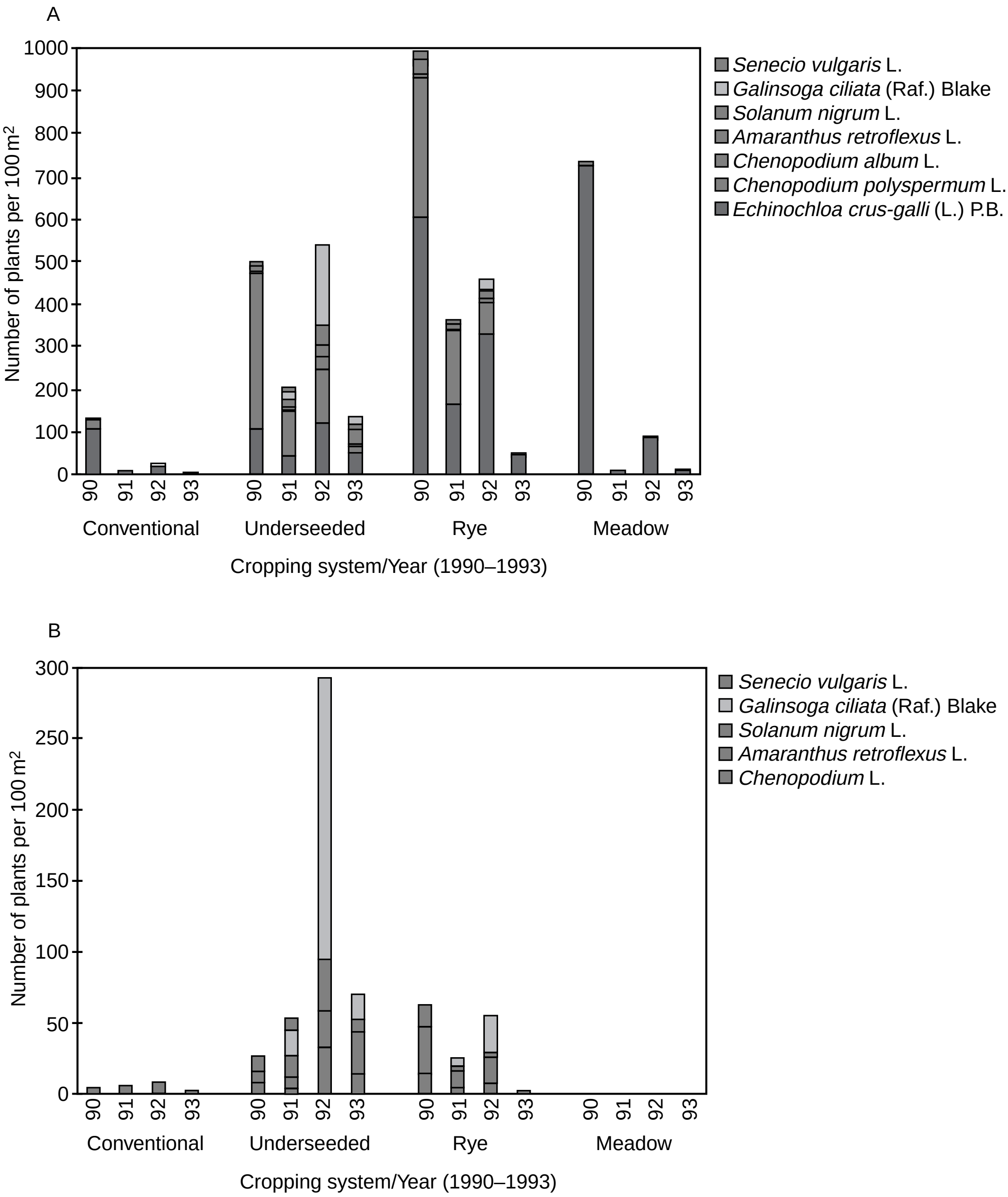

Fig. 2. Densities of selected weeds at harvest in four cropping systems of maize in a 4 year trial (1990–1993). (A) All weeds. (B) Hard to control annual dicotyledoneous weeds.

than rye which dies out after the interrow mulching at the three- to four-leaf stage of maize.

In the conventional treatment, the herbicide combination of atrazine and alachlor was not effective against panicoid grasses and was replaced in the second year by atrazine and metolachlor. In the third year pendimethaline was added to control the atrazine-resistant species and, thus, to achieve a fully weed-free soil, in contrast to the other systems.

The main perennial weed, *C. sepium*, was not effectively controlled in any of the four systems (Fig. 3). Each year, in the conventional and rye treatments, a full dose of dicamba was applied as a spot treatment. Despite this, *C. sepium* remained an important weed, except in 1993 in rye. In the underseeded and meadow systems, dicamba was also used, but at lower concentrations and as very restricted spot treatments in order not to harm the *Trifolium* living mulch. This gave some reduction of *C. sepium*, the greatest mean reduction over the 3 years occurring in the meadow system.

The influence on the abundance in the 4 year trial agrees with the findings of the 1 year trial comparing the

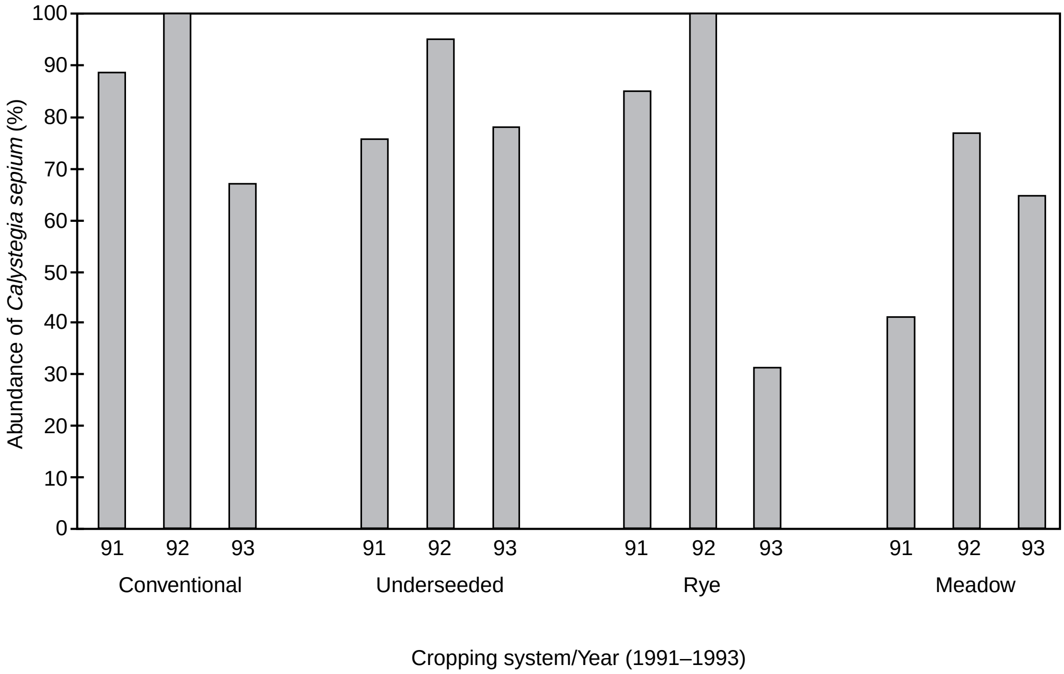

Fig. 3. Abundance (%) of *C. sepium* in four cropping systems of maize rows (32 rows each 26 m long with three repetitions; 100% represents *C. sepium* present in all the interrows).

growth parameters of *C. sepium* in underseeded and conventional maize (Table 3). With a well-developed *Trifolium* cover, the development in the length and number of horizontally spreading shoots decreased and no new stolons were formed. The shoots climbing up the maize stems were not influenced in number, but their development was reduced.

Discussion

Rotary band seeding into living mulch allows an ecologically sound maize cropping system. This includes a green ground cover before maize seeding to lower the nitrate leaching and a living or dead mulch during the maize cropping period to reduce soil erosion and water run-off. The ploughless seeding technique with living mulch reduces new weed emergence. The change of the weed flora prevents the build up of resistant weeds. A ground cover at harvest reduces soil compaction and, after maize harvest, the green cover re-establishes fully in the meadow or underseeded treatments and is therefore well suited for the following crop seeding in spring.

In the rye treatment regrowth is low and so suitable for autumn-sown rotational crops. Experience shows that grasses are good nitrate catch crops, but the release of the nitrate to maize is often too late. If abundant farm manure is not available, legumes should be chosen as catch crops to obtain normal maize yields (Ammon and Bohren, 1996).

According to Jäggi *et al*. (1995), a larger number of earth worms and collembola was found particularly in the meadow treatment. Bigler *et al*. (1995b) found a smaller number of corn borer, aphids and *Ustilago maydis* Corda in the rye and meadow treatments and more predators, in particular spiders and ants (Bigler *et al*., 1995c).

The living mulch system described here can be used in regions with high precipitation. In dryer climates or with competitive living mulches, e.g. many grasses, such as

Table 3. Development of *C. sepium* in maize with and without underseeded *Trifolium* (mean of plants)

	'Climbing' shoots		'Creeping' shoots				New Stolons
	Number	Mean height (m)	Number	Length (m)			
				Minimum	Maximum	Mean	
Without *Trifolium*	1.7	1.2	6.7	0.3	5.6	2.5	25
With *Trifolium*	2.0	0.6	0.9	0.3	2.2	0.7	0

Lolium species, mulch regulation with herbicides is necessary to avoid maize yield losses. Non-residual herbicides such as glyphosate or those used at pre-emergence of maize are preferable (Ammon *et al.*, 1995). The choice of catch crop, skilled seeding and the timely regulation of the living mulch are of key importance in the success of these systems.

One main maize weed, *C. sepium*, is suppressed but not sufficiently controlled either by mulching or by herbicides applicable selectively in a living mulch system with maize. In these circumstances a specific control agent is necessary. A biological control agent would be an ideal solution. Often, biological methods are not suited because of their restricted weed control spectrum. However, this restriction is less problematic in ecological farming or in IPM, where conventional herbicides are proscribed or should be avoided as far as possible. The suppressing effect of the mulch may permit the use of relatively low virulence pathogens, such as *Stagonospora* sp. as a parasite of *C. sepium* and *C. arvensis*. Current work suggests this approach is promising.

The example shows that the overall environmental and agronomic problems cannot be solved simply by changing conventional pest control to integrated control (IPM). New tillage techniques and sound crop rotations are also necessary. Weed control must be changed from weed eradication to a vegetation management system within ICP.

Conclusions and outlook

Concern regarding the use of chemical herbicides has resulted in a demand for alternatives in weed control. New cultivation practices and crop management strategies may reduce the input to and impact of chemicals on agricultural crops. Underseeded green cover can reduce the need for chemical weed control. In maize underseeded with a living green cover, good control is achieved for a large spectrum of the typical weed flora known to develop with conventional tillage systems. Nevertheless *C. sepium* and *C. arvensis* remain as weed problems. The experiments presented show that *C. sepium* is only partly suppressed by the green cover, being able to escape control by climbing up the stems of the maize plants. Therefore, an additional control is necessary.

The control of a weed species with a fungal pathogen (mycoherbicide) has been successful in several cases (Greaves, 1996). Our research has shown that several isolates of *Stagonospora* sp. attack *C. sepium* and *C. arvensis* and field experiments have shown that they can reduce or stabilize ground cover by the weed. Further steps in the development of a possible mycoherbicide will be field trials under different environmental conditions. For this, studies of the efficacy of *Stagonospora* sp. to control bindweed will have to be performed in various European countries.

The effectiveness of a biocontrol agent can be increased by formulation which should be designed to increase both the efficiency of application and efficacy of the control agent. One of the main limitations to mycoherbicides is the requirement of a lengthy dew period. We are now testing different formulations to reduce the dew period needed for a good infection process. Another possibility of increasing the effectiveness may be the combination of a control agent with low dosages of herbicides. Sharon *et al.* (1992) increased the susceptibility of the weed *Cassia obtusifolia* L. to the mycoherbicide CASST® (*Alternaria cassiae* Jurair & Khan) by adding a sublethal dose of glyphosate, resulting in a specific suppression of the weed's elicited defence response.

The combination of a maize field underseeded with a living green cover with the application of spores of *Stagonospora* sp. may be a way of achieving an ecologically healthier production of maize. Future field experiments with this cropping system will show the effectiveness of this combination.

The underseeding of maize with a living green cover can be limited by environmental conditions. The main restriction appears to be water availability for the maize and the green cover together. Therefore the production system outlined will be practical only in areas with sufficient moisture during the vegetation period and will be used in the near future only in a small part of the maize production. It will remain a niche market. However, niche markets can be good areas for biological control agents. Other possible niche markets for the biological control of bindweed include forest nurseries, horticulture and non-crop situations such as gardens and parks.

After application in the field, the epidemiology and dispersal of the control agent must be studied. The use of DNA technology appears to be the most promising way. We are presently developing genetic markers which will allow us to track the biocontrol agent released in the field.

Biological control of bindweed with *Stagonospora* appears promising. Its integration in a weed management system may even improve the potential of the pathogen. In maize, the combination of the pathogen with cover crops may allow the control of typical weed flora.

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