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Biology and Control of Galinsoga parviflora, Overview of a literature survey

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1. Introduction

The review described in this report is a subactivity of the project 'Preventieve maatregelen ter beheersing van probleemonkruiden' (Preventive measures to control specific weed species), one of the projects of the BO- research program 'Plant gezondheid' (Plant health), theme 4 'Effectief en duurzaam middelen pakket' (Effective and sustainable control measures) subsidised by the Dutch ministry of LNV.
Farmers, both organic and conventional, contracters, and the Dutch Plant Protection Service were asked to identify the most problematic weed species in the Netherlands at present and in the near future.
In total 19 species were identified:

- 13 annuals:
  Stellaria media, Polygonum persicaria, Polygonum aviculare, Polygonum convolvulus, Alopecuris myosuroides, Panicum verticillatum (Setaria verticillata), Panicum lineare, Amaranthus retroflexus, Æthusa cynapium, Poa annua, Chenopodium album, Solanum nigrum, Galinsoga parviflora and *Geranium molle,* and
- 6 perennials:
  Cyperus esculentus, Cirsium arvense, Persicaria amphibia, Mentha arvensis, Stachys palustris, and *Rorippa sylvestris.*

This report describes the results of the literature survey on the biology and control of *Galinsoga parviflora*.

2. *Galinsoga parviflora*; biology

2.1 Geographic Distribution

The Netherlands

In 1935 *G. parviflora* only occurred on sandy soils in the Netherlands. At that time, gallant soldier findings were reported in Weurt, Soest, Soestdijk, Baarn, Bussum, Apeldoorn, Terborg, Laren, Assen, Nieuw-Weerdinge, Slochteren, Haren and Rhenen (Van Poeteren 1935). At that time, the species was regarded as non problematic, because it is not wind or animal dispersed; its spread was regarded as 'coincidental events'. Nowadays, the species is widely spread in the Netherlands. it is, however, less common in the following areas: Wadden, Northern Clay district, and Flevoland. The species can be found on dry as well as moist soils, as long as they have high nutrient levels (Anonimous 2007).

World wide

Galinsoga parviflora is a weed of disturbed habitats and agricultural areas, occurring in most of the temperate regions and subtropical regions of the world (Warwick and Sweet 1983). It can be found in flower beds, vegetable gardens, cultivated fields with low-growing crops, roadsides, waste ground, railway yards and dumps (Warwick and Sweet 1983). The species is present in agricultural areas in North and South America, Europe, Asia, Africa and Australia (Canne 1977; Warwick and Sweet 1983). *Galinsoga parviflora* originates from the Anders in Peru (Stoffert 1994), Central America (Anonimous 2007).
In the eighties the species has become a problem in low-growing vegetable crops such as beans, cabbage, peppers and tomatoes in northeastern North America (Ivany and Sweet 1973). In Europe, *G. parviflora* is a major weed in cultivated crops (Warwick and Sweet 1983). The spread in Germany took place between 1800 (when it was introduced from France in a botanical garden in Berlin) and 1910. In that year it was found in Niedersachsen and Hamburg (Stoffert 1994).The species is found at altitudes of 40 to 3,600 m (Canne 1977). The species is not a problem in dry areas where irrigation is needed for vegetable production (Ivany 1975).

2.2 Life cycle

Galinsoga parviflora is an annual plant, that can reach a hight of 60 cm. The stems are erect or spreading with many branches (Canne 1977). The leaves are longer than they are wide and the margin is wavy (Ivany 1975). The flower heads are 3.5- 5.0 mm long and 2.0-6.0 mm wide (Warwick and Sweet 1983). One to three flower heads are produced at the ends of the branches (Ivany 1975). The first flower head is usually produced after the main axis has formed seven nodes (Ivany 1975). The species has a slender taproot with multiple secondary roots. The plants are often shallowly rooted and show poor development of the taproot and extensive growth of secondary and adventitious roots from the base of the stem (Canne 1977). The stems are green to reddish purple (Canne 1977). *G. parviflora* flowers year round when the climate is permitting, or until the first frost. Seeds are able to mature on frozen plants (Stoffert 1994).

2.2.1 Reproduction

In general, a plant flowers after 41-60 days (Ivany 1975; Stoffert 1994) and produces seeds after 52 -74 days after emergence and are capable of immediate germination (Warwick and Sweet 1983). Flowering is independent of the length of the photoperiod (tested for photoperiods of either 8 or 16 days) (Ivany and Sweet 1973). In a pot experiment, plants grew taller and flowered earlier at higher moisture levels (Rai and Tripathi 1983); up to eight days earlier than at low moisture levels. A high moisture level was achieved by watering the plants daily, a low moisture level by watering the plants every 10 days. Seeds mature rapidly and are viable about two weeks after the firsts appearance of the flowerhead (Ivany 1975). *G. parviflora* is uniformly diploid n=8 (Warwick and Sweet 1983). The seeds have an averaged weight of 0.267 mg (Rai and Tripathi 1983).

According to Ivany (1975) newly formed seeds can germinate immediately and have a germination percentage of 95 or higher. The species has no dormancy (Martinez-Ghersa, Ghersa et al., 2000). However, the maximum germination percentage found in a laboratory test was 26.4% (Espinosa-García, Váquez-Bravo et al., 2003).

Germination takes predominantly place in May and June (De Groot and Duivenvoorden 1982), but it is also observed during fall in September and October (Massop 1982) until the first frost (Canne 1977). Germination percentages are higher in sandy soils (clay 18%, silt 10% and sand 72%) than in clay soils (34% clay, silt 20% and sand 46%) (Rai and Tripathi 1983). At high densities and low moisture levels, the germination can be reduced from over 90% to 20% on sandy soils and from over 50% to 20% on clay soils (Rai and Tripathi 1983). The fertility of the plants is density dependent; at high densities (from 10 seeds per pot, equivalent to 300 plants per m^2) the number of plants producing fertile seeds reduces significantly (Rai and Tripathi 1983).

Ivany and Sweet (1973) tested the germination of *G. parviflora* seeds at constant temperatures of 10, 20, and 30 °C in either complete darkness or under a 16 h photoperiod. The species germinated best in the light and at 20 °C (Figure 1). The seeds were able to germinate in the dark at 10 °C. Ivany and Sweet (1973) also showed that the emergence of seeds decreases with increasing burial depth. Already at a depth of 0.5 cm the emergence was reduced from 86.0 to 1.0%. This strong decrease indicates that the species requires light to germinate. This last result is in accordance with Warwick and Sweet (1983) who state that the seeds have a strong light dependency and do not germinate in the dark, and the results of Karlsson et al. (2008) who found no germination of *G. parviflora* seeds in complete darkness and almost 100% germination in the light (Karlsson, Tamado et al., 2008). The high germination percentage in the dark at 10 °C in the first experiment of Ivany and Sweet (1973) is probably caused by a combination of favourable circumstances such as gas exchange. In general, the seeds are light dependent and the light depency is independent of temperature; even at optimal temperatures seeds do not germinate in complete darkness (Warwick and Sweet 1983). According to De Groot and Duivenvoorden (1982) the optimal constant germination temperature varies between 16 and 17 °C (De Groot and Duivenvoorden 1982).

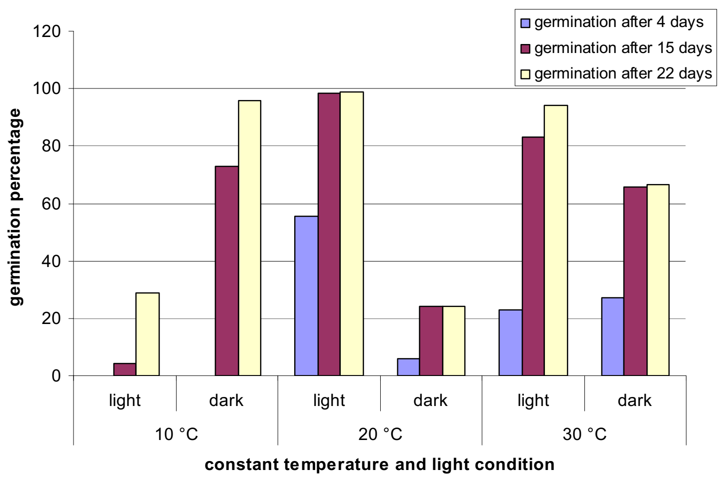

Figure 1. Germination percentage of G. parviflora seeds under constant temperatures and two light conditions. After Ivany and Sweet (1973).

Ivany and Sweet (1973) tested the germination under alternating temperatures as well. Alternating temperatures (20/30 °C and 20/10 °C) generated the fastest germination (Figure 2). The germination percentages (93-97%) observed at those alternating temperatures are similar as for constant temperatures between 20 and 30 °C in the light (Ivany and Sweet 1973).

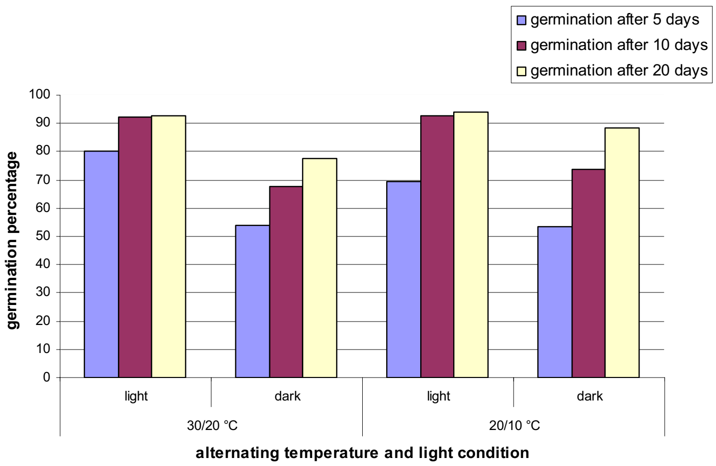

Figure 2. *Germination percentage of G. parviflora seeds under alternating temperatures and two light conditions. After Ivany and Sweet (1973).*

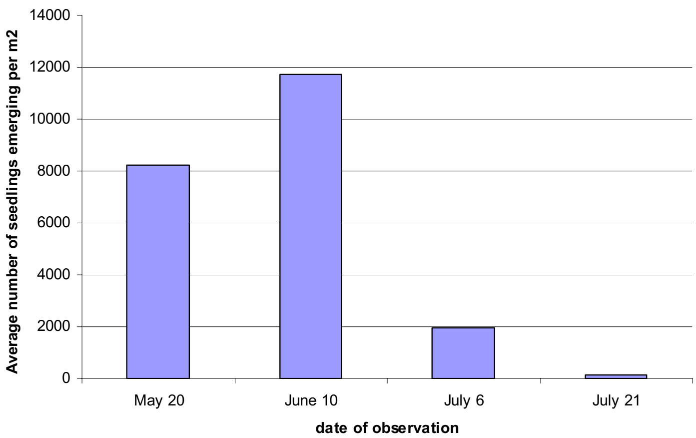

Figure 3. *Emergence of G. parviflora seedlings in a field in NY. After data from Ivany and Sweet (1973).*

The maximum germination depth for *G. parviflora* is 1.0 cm, the optimum germination depth is 0 mm (98% germination and emergence) and at a depth of 0.25 cm germination and emergence is 56% (Ivany 1971) cited in (Warwick and Sweet 1983). Ivany and Sweet (1983) found that 11,000 seedlings per 0.5 m^2 were able to emerge in an agricultural field in New York, USA, from May till July (see also Figure 3).

Table 1. Seed production in relation to factors as plant density, crop and soil type.

Seeds (#/plant)	Seed production (#/m²)	Plant density (#/m²)	Crop	Soil type (NPK)	Literature source
7,358		1 plant 9 wks old	greenhouse experiment		(Ivany 1975)
400,000		max. seed production of 1 plant			(Warwick and Sweet 1983)
		22,000	fallow, uncultivated		(Ivany and Sweet 1973)
390	123,240	316	monoculture *G. parviflora*	low*	(Rai and Tripathi 1987)
599	189,284	316	monoculture *G. parviflora*	medium*	(Rai and Tripathi 1987)
613	193,708	316	monoculture *G. parviflora*	high*	(Rai and Tripathi 1987)
300,000		max. seed production of 1 plant	unmentioned	unmentioned	(Stoffert 1994)

** See Table 2 for a description of these levels.*

Rai and Tripathi (1987) investigated the effect of the NPK levels in the soil on the seed production of *G. parviflora* plants. The plants were grown in monocultures in the greenhouse at densities equivalent to 316 plants per m^2. The NPK levels were classified as low, medium and high, and are described in Table 2. *G. parviflora* produced on average 390 seeds per plant on a soil with a low level, 599 seeds per plant on a medium level and 613 seeds per plant on a high level soil (Rai and Tripathi 1987).

Table 2. NPK data of the soil types applied in the experiment of Rai and Tripathi (1987).

NPK niveau	Organic (%)	Total N (%)	Available P (ppm)	K (meg 100 g^{-1})	pH
Low	2,01	0,15	0,15	0,70	6,17
Medium	2,04	0,30	0,31	1,59	5,92
High	2,12	0,47	0,49	2,29	6,28

Long distance dispersal of seeds is mainly through man. Locally *G. parviflora* is mainly wind dispersed (Salisbury 1961).

2.2.2 Dormancy

Freshly harvested seeds of *G. parviflora* are non dormant (Ivany 1975; Warwick and Sweet 1983; Martinez-Ghersa, Ghersa et al., 2000) and are able to germinate in the field from early May until frost (Ivany and Sweet 1973).

2.2.3 Survival

The length of seed survival in soil reported varies from two years (Espinosa-García, Váquez-Bravo et al., 2003) to 10 years when stored in soil (De Groot and Duivenvoorden 1982; Stoffert 1994). However, the viability differs between achene morphs (Espinosa-García, Váquez-Bravo et al., 2003): ray achenes have a higher survival rate in soil than disc achenes. The germination rate of the latter is higher (Espinosa-García, Váquez-Bravo et al., 2003). In general the species survives from year to year through seeds overwintering on or under the soil surface (Warwick and Sweet 1983).

The species is not frost tolerant (Warwick and Sweet 1983).

The predation percentage by birds, rodents and insects of seeds of this species is unknown. However, the predation of other species can be significant. In a study by Westermann et al. (2003) it was shown that predation of *Avena fatua*, *Stellaria media*, and *Chenopodium album* seeds by rodents, vertebrates and invertebrates can be over 90% in a fortnight.

3. Management

3.1 Non-chemical

3.1.1 Competition and crop choice

The emergence of *Galinsoga parviflora* is influenced by the presence of a wheat canopy. The wheat canopy alters the thermal and light environment in such a way that Galinsoga seeds are not able to germinate and emerge to the same extent as in bare soil (Kruk, Insausti et al., 2006). However, this is only true for the second generation. In the first 90 days after crop emergence, germination and emergence of *G. parviflora* seeds is unaffected by the wheat. The plants belonging to this generation are able to complete their life cycle and produce seeds again. The second generation has a reduced germination and emergence as a result of the wheat canopy (Kruk, Insausti et al., 2006).

Reduction in yield of vegetables from competition with Galinsoga is dependent on the crop, with little or no losses with competitive crops to as much as 50% reduction in less competitive crops (Warwick and Sweet 1983). The species prefers open communities, in which there is little competition for light (Warwick and Sweet 1983). At a reduced light intensity the fresh weight of the plants is reduced as well (Ivany and Sweet 1973); at an intensity of 89,000 lux the plants produced 36.3 gram fresh weight, at 56,000 lux 22.3 and at 17,000 2.2 gram of fresh weight (Ivany and Sweet 1973). This response to shading would explain the restriction of these weeds to low-growing crops.

Ivany (1971) compared the growth of *G. parviflora* under three different densities,equivalent to 3, 11, and 44 plants per m^2. The higher the density, the lower the fresh weight per plant, although the fresh weight per unit area increased.

The seeds have little to now dormancy, which makes removal of an infestation from a field within 3-4 years possible, provided that no new seeds are produced. To do so, (Warwick and Sweet 1983) advise to grow dense crops such as green manures or pastures for at least 3 years.

3.1.2 Nutrient management

Galinsoga spp. prefer high levels of N,P, and K for good growth (Warwick and Sweet 1983). Ivany (1971) (Ivany 1971) found that growth of the species was reduced at low nutrient levels, that flowering was inhibited in the absence of N, and reduced in the absence of P and K, and that the root weight was increased at low levels of N and K. Gallant soldier is not sensitive to pH and a low organic matter content of the soil is favourable for the species (Otto 2007).

3.1.3 Mechanical cultivation

Mechanical cultivation, hand hoeing and removal of weeds are effective against light to moderate infestations (Warwick and Sweet 1983). However, the latter two are very time consuming and not very cost effective.
The species responds in a similar way to mechanical treatments as Stellaria media does (Rommie van der Weide, personal communication). Several tools are available for the control of these kind of weeds. Table 3 gives an overview of the available tools (Schans van der, Bleeker et al., 2006).

Table 3. Overview of available mechanical weed control tools.

Tool	Optimum weed stage	Optimum crop stage	Suitable for use in
harrow	cotyledon to 2-leaf	between sowing and emergence of crop	beans, celery, vereals, cole varieties, grass seed, green maize, leeks, potatoes, sown onions, spinach and sweet corn
hoe	cotyledon to 4-leaf	with discs of tunnel blades protecting the crop plants in the cotyledon to 4 leaf stage, usage is possible until the crop covers the soil completely or crop damage appears	all sown or planted rowcrops with a minimum row spacing of 15 cm
brush weeders	cotyledon to 4-leaf	with a crop protection tunnel, usage is possible from the seedling stage	all sown or planted rowcrops with a minimum row spacing of 25 cm
strip rotary cultivator	cotyledon to 15 cm	from the seedling stage until crop damage	all sown or planted rowcrops with a minimum row spacing of 30 cm
weed-fix	cotyledon to 4-leaf	from the seedling stage until crop damage	all sown or planted rowcrops with a minimum row spacing of 50 cm
finger weeder	cotyledon to 2-leaf	from the two-leaf stage	almost all sown or planted crops
torsion weeder	cotyledon to 2-leaf	well-rooted crops until the crop plants grow together	almost all sown or planted rowcrops with a minimum row spacing of 25 cm
Pneumat	cotyledon to 4-leaf	well-rooted crops until the crop plants grow together	almost all sown or planted crops
flame weeder	cotyledon to 2-leaf	before emergence: all stages after emergence: spring sown onions 4-6 leaves chicory 3-4 leaves	pre emergence: all crops post emergence: sown leek, spring-sown onions, chicory between rows: almost all sown or planted rowcrops with a minimum row spacing of 30 cm

3.1.4 Mulch

In intensive commercial production a black plastic mulch is highly effective against *Galinsoga parviflora* (Warwick and Sweet 1983).

3.1.5 Thermal control

In an onion crop, gallant soldier was treated twice during the growing season of the crop with steam (water vapour). The steam was applied when the weeds had one to two true leaves. Weeds and onions were exposed to the vapour for two seconds during each treatment. *G. parviflora* was controlled with 100%, however the authors do not mention the yield loss or the damage to the onions (Virbickaite, Sirvydas et al., 2006).

3.2 Biological control

Galinsoga parviflora acts as an alternate host for many insects, viruses and nematodes that affect various crop species (Warwick and Sweet 1983). *G. parviflora* is an alternative host to wilt virus that infects tomatoes, and for cucumber mosaic virus, curly top virus and aster yellow viruses, all of which are able to infect many crop species (Batra 1979). *G. parviflora* can serve as a host for the following nematode species: Ditylenchus dipsaci, Meloidogyne species, Heterodera marioni and Heterodera schachtii (Bendixen et al., 1979 in (Warwick and Sweet 1983).

At Java in Indonesia, the leaves are eaten by humans (Batra 1979).

3.3 Chemical control

Gallant Soldier can be controlled with Goltix (metamitron) (Wevers 1989). In maize *G. parviflora* can be controlled pre-emergence with Dual Gold or Frontier Optima. After crop emergence a mixture of Mikado or Callisto and Milagro or Samson will give a good control of the species. The new herbicide Clio will also effectively reduce the number of gallant soldier plants in maize. Titus can also be effective, althought not every maize crop is resistant to this herbicide and during certain circumstances such as high temperatures, the risk of crop damage will be high.
In cereals Ally, Artus, Basagran and Primus can be used to control the species. In winter wheat and winter barley Azur can be used in early spring. Betanal Expert, Betanal Quattro, Frontier Optima, Dual Gold, Goltix and Safari can be used in sugarbeet. Linuron and Boxer are used in potatoes (Hoek and Weide 2007). For an overview of available herbicides in the main crops, see Tables 4-8.

Table 4. Overview of allowed herbicides in the Netherlands in maize and the sensitivity of gallant soldier (after Hoek and Van der Weide, 2007).

Active ingredient	Herbicide	Sensitivity[1]
aclonifen	Challenge	3
bentazon	Basagran ea	2-3
terbuthylazin/bentazon	Laddok N	3-4
bromoxynil	Litarol	3
dicamba	Banvel	3
dimethenamide	Frontier Optima	1-4
florasulam	Primus	3
fluroxypyr	Starane	3
foramsulfuron/iodosulfuron	Maïster	3 [2]
isoxaflutol	Merlin	3
mesotrion	Callisto	3
mesotrion/terbuthylazin	Calaris	3
metolachloor	Dual Gold	1-4
nicosulfuron	Samson, Milagro	1
pendimethalin	Stomp	0
rimsulfuron	Titus	3
rimsulfuron+dicamba	Titus + Banvel	4
sulcotrion	Mikado	3
sulcotrion+nicosulfuron	Mikado + Samson	3
terbuthylazin	Gardoprim 500	2
terbuthylazin + bromoxynil	Gardoprim 500 + Litarol	4
topremazone	Clio	3

[1] Efficacy: 0= resistant, 1= low sensitivity , 2= moderate sensitivity, 3= sensitive, 4= high sensitivity.
[2] Only small weeds have a high sensitivity.

Table 5. Admitted herbicides in cereals and the sensitivity of gallant soldier (after Hoek and Van der Weide, 2007).

Active ingredient	Herbicide	Admission in							Sensitivity[1]
		winter wheat	summer wheat	winter barley	summer barley	rye	oat	triti-cale	
aclonifen	Challenge	X							3
bentazon	Basagran	X	X	X	X	X	X	X	2-3
cinidon-ethyl	Vega	X	X	X	X	X	X	X	2
diflufenican/ioxynil/isoproturon	Azur	X		X					3 [2]
florasulam	Primus	X	X	X	X	X	X	X	3
fluroxypyr	Starane	X	X	X	X	X	X	X	3
ioxynil	Actril	X	X	X	X	X	X	X	2
MCPA	several	X	X	X	X	X	X	X	0
Mecoprop	several	X	X	X	X	X	X	X	0
metsulfuron methyl	Ally	X	X	X	X	X	X	X	3
metsulfuron/carfentrazon	Artus	X	X	X	X	X	X	X	3
pendimethalin	Stomp	X				X			0
prosulfocarb	Boxer	X		X					3

[1] Sensitivity: 0= resistant, 1= low sensitivity , 2= moderate sensitivity, 3= sensitive, 4= high sensitivity.
[2] Only small weeds have a high sensitivity.

Table 6. Admitted herbicides in sugarbeet and the sensitivity of gallant soldier (after Hoek and Van der Weide, 2007).

Active ingredient	Herbicide	Sensitivity[1]
chloridazon	Pyramin	2-3
clopyralid	Lontrel	3
desmedifam/fenmedifam/ethofumesaat	Betanal expert	3
dimethenamide	Frontier Optima	1-2
ethofumesaat	Tramat	1
fenmedifam	Betanal en andere	3
fenmedifam/desmedifam/ethofumesaat/metamitron	Betanal Quatro	4
fenmedifam/ethofumesaat	Magic T en andere	3
metamitron	Goltix	3
metolachloor	Dual Gold	1-2
triflusulfuron	Safari	3-4

[1] Sensitivity: 0= resistant, 1= low sensitivity , 2= moderate sensitivity, 3= sensitive, 4= high sensitivity.

Table 7. Admitted herbicides in potato and the sensitivity of galland soldier (after Hoek and Van der Weide, 2007).

Active ingredient	Herbicide	Allowed in			Sensitivity[1]
		consumption potato	potatoes for further processing	seed potato	
aclonifen	Challenge	X	X		3
bentazon	Basagran [2]	X	X		2-3
linuron	Afalon	X	X	X	3
metazachloor	Butisan S	X	X		3
metribuzin	Sencor [2]	X	X		3
pendimethaln	Stomp	X			0
prosulfocarb	Boxer	X	X	X	3
prosulfocarb+metribuzin	Boxer + Sencor [2]	X	X		4
rimsulfuron	Titus	X	X		3

[1] Sensitivity: 0= resistant, 1= low sensitivity , 2= moderate sensitivity, 3= sensitive, 4= high sensitivity.
[2] Only small weeds have a high sensitivity.

Table 8. Admitted herbicides in other crops (after Hoek and Van der Weide, 2007).

Active ingredient	Herbicide	Sensitivity[1]	Crop
aclonifen	Challenge	3	peas, beans
asulam	Asulox	3	spinach, chicory, and herbs
bentazon	Basagran	2-3	peas, beans, grass seed, onion, flax, herbs
chloridazon	Pyramin	2-3	beetroot, onion
fenmedifam	divers	3	beetroot, spinach, strawberry
florasulam	Primus	3	grass seed
fluroxypyr	Starane	3	grass seed
ioxynil	Actril	2	grass seed, flax, onion
linuron	e.g. Afalon	3	aspergus, bean, fennel, celery,flax, carrot and herbs
mcpa	divers	0	aspergus, grass seed, flax
metamitron	Goltix	3	beetroot, strawberry seed
metazachloor	Butisan S	3	coldeseed, planted cabbages and leek
metolachloor	Dual Gold	3-4	chicory, strawberry, beans
metribuzin	Sencor	3	Aspergus
pendimethalin	Stomp	0	pea, beans, leek, onions, carrot, grass seed, herbs
prosulfocarb	Boxer	3	onion, grass seed
rimsulfuron	Titus	2	rocket
triflusulfuron	Safari	3-4	chicory

[1] Sensitivity: 0= resistant, 1= low sensitivity , 2= moderate sensitivity, 3= sensitive, 4= high sensitivity.

4. Summary/Conclusions on management options

The biology of gallant soldier shows some characteristics that can potentially be used to improve the control of gallant soldier. The first is the light depency of the seeds for germination. To reduce populations of gallant soldier, seeds can be stimulated to germinate with the use of stale seedbed preparations (Riemens, Van der Weide et al., 2007) and the subsequently emerging seedlings controlled with machinery covered with black plastic or another material that prevents light reaching the soil surface. The machinery used to control the plants emerging after a stale seedbed preparation should be adjusted to a shallower depth with each treatment to prevent seeds from deeper layers to germinate.
The second one is the shallow maximum germination depth of the seeds. Seeds buried deeper than 1 cm will not germinate and seeds buried for 0.25 cm will already have a 50% reduction in germination. Burial of the seeds will reduce the number of seedlings reproducing within the same season and decrease the number of viable seeds in the soil.
The third characteristic is the low competitive ability for light. Application of green manures or grassland for some years in a row can reduce the emergence and seed bank of the species significantly.

The characteristic that causes most of the problems for farmers with gallant soldier is the number of generations per year. The species is able to germinate and produce fresh seeds in frost-free periods. On top of that, freshly produced seeds can germinate immediately. The consequence is the need for a monitoring system (preferably every two weeks) in combination with a complete control of flowering plants. The strategy should be a 100% control.

Predation on seeds laying on the soil surface can be as high as 90% within 2 weeks for several species (Westerman, Hofman et al., 2003). Seed predation for gallant soldier is unknown. However, if the predation would only be a fraction of the predation of seeds of other species, a strategy that leaves the seeds on the soil surface for rodents, insects and birds to feed on, might be more succesfull than a strategy that immediately buries the seeds.

5. Samenvatting & conclusies

De levenscyclus van knopkruid heeft een aantal eigenschappen die ruimte bieden voor de verbetering van de bestrijding van de soort.
De eerste van deze eigenschappen is de lichtsafhankelijkheid van de zaden voor kieming. Om de populaties van knopkruid te reduceren, kunnen zaden door middel van een vals zaaibed gestimuleerd worden te kiemen (Riemens et al., 2007) en kunnen de zaailingen machinaal bestreden worden met afgedekte machines zodat lichtprikkeling van nieuwe zaden voorkomen wordt. De machines die gebruikt worden om de zaailingen te bestrijden zouden ondieper afgesteld moeten worden met elke nieuwe behandeling om kieming van dieper gelegen zaden te voorkomen.
De tweede is de maximum kiemingsdiepte van de soort. Deze is erg ondiep; zaden die meer dan 1 cm begraven zijn zullen niet kiemen en zaden die 0.25 cm diep begraven liggen zullen een kiemingsreductie van 50% vertonen. Begraven van nieuw geproduceerde zaden zal het aantal zaailingen in hetzelfde groeiseizoen reduceren en het aantal zaden in de zaadbank verminderen.
De derde eigenschap is het geringe competitieve vermogen van de soort voor licht. Toepassing van groenbemesters of grasland gedurende enkele jaren kan de opkomst en de zaadbank van de soort significant reduceren.

De eigenschap die de meeste problemen voor telers oplevert is het aantal generaties per jaar. Knopkruid is in staat om te kiemen en zaden te produceren in vorst-vrije periodes. Bovendien kunnen net geproduceerde zaden direct kiemen. Door een monitoringssysteem (bij voorkeur elke twee weken) te combineren met een bestrijding van bloeiende planten kan de soort mogelijk effectief bestreden worden. Daarbij moet het wel de strategie zijn de bloeiende planten voor 100% te bestrijden.

Predatie van zaden die op het grondoppervlak liggen kan voor verschillende soorten oplopen tot 90% van de zaden binnen twee weken na zaadval (Westerman et al., 2003). Echter, over de predatie van knopkruidzaden is weinig tot niets bekend. Echter, als we er vanuit gaan dat de predatie van knopkruidzaden ook maar een fractie is van de predatie van andere soorten, kan een strategie die de zaden gedurende een aantal weken op het oppervlak laat liggen voor knaagdieren, insecten en vogels, succesvoller zijn dan een strategie die de zaden direct begraaft.

Er zijn een aantal mogelijkheden die de levenscyclus van knopkruid biedt, om strategiën ter bestrijding van de soort te ontwikkelen. Het verdient aanbeveling de hierboven beschreven opties in het veld te toetsen en te vergelijken.

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Appendix I.
Natural enemies of *G. parviflora*: insects

Organism	Literature Source
Aceratagallia sanguinolenta	(Batra 1979)
Acylomus sp.	
Aceratagallia sanguinolenta	
Agromyzid sp. Immature	
Aleyrodinae sp.	
Ancyloxypha numitor	
Aphis sp.	
Cerodontha dorsalis	
Chaetocnema denticulata	
Chaetocnema pilicaria	
Chlortettix viridius	
Clastoptera xanthocephala	
Colpha ulmi	
Conoderus nellus	
Dactynotus ambrosiae	
Delphacodes puella	
Deltocephalinae sp.	
Draeculacephala Portola	
Ectopsocopsis cyrptomeriae	
Empoasca	
Empoasca abrupta	
Endria inimica	
Entomobrya knaba	
Eurythrips sp.	
Exitianus exitiosus	
Frankliniella fusca (Hinds)	
Frankliniella tritici (Fitch)	
Frankliniella williamsi Hood	
Geometrid larvae	
Graminella nigrifrons	
Graphocephala versuta	
Gryllus sp. Nymphs	
Halictus ligatus	
Heliothis verescens	
Heliothis zea	
Heraeus plebejus	
Hyadaphnis foeniculi	
Hypogastruta matura	
Idionus kennecotti	
Latalus sayi	
Liposelidae sp.	
Liriomyza sativae	
Lygus lineolaris	

Organism	Literature Source
Macrosiphum euphorbiae	
Macrosteles fascifrons	
Melanagromyza sp.	
Noctiud larvae	
Notoxus sp.	
Nysius raphnus	
Occemyia sp. Nr. Propinqua Adams	
Oecanthus quadripunctatus	
Oidaematophorus sp. 2	
Orthoneura nitida	
Orthotylus sp.	
Ostrinia sp. Larvae	
Philaenus spumarius	
Planicephalus flavocostatus	
Pleuroprucha nr. Insularia	
Polymerus basalis	
Psuedaplusia sp.	
Sanctanus cruciatus	
Sanctanus sanctanus	
Scaphytopius frontalis	
Schizocerella pilicornis	
Spanogonicus albofasciatus	
Sphaerophoria contigua	
Systena blanda	
Toxomerus marginatus	
TRialeurodes abutilonea	
Trigonotylus saileri	
Udea rubigalis	
Villa (Paravilla) sp.	
Xyonysius californicus	

Appendix II.

Natural enemies of *G. parviflora*: fungi

Organism	Literature Source
Alternaria alternate Fusarium oxysporum	(Espinosa-García, Váquez-Bravo et al., 2003)

Appendix III.

Natural enemies of *G. parviflora*: nematodes and viruses

	Organism	Literature Source
Virus	Cucumber mosaic virus Curly top virus Aster yellow virus GMV (Galinsoga Mosaic Virus)	(Batra 1979)
Nematodes	*Ditylenchus dipsaci* *Meloidogyne species* *Heterodera marioni* *Heterodera schachtii*	Bendixen et al., 1979 in (Warwick and Sweet 1983)
	Meloidogyne chitwoodi	(Kutywayo and Been 2006)