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Project leader:	Mike Lole, ADAS
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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

I declare that this work was done under my supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headline

- Turnip sawfly is unpredictable in activity and should be monitored locally in areas where potential problems are greatest. Control of the pest on baby-leaf salads may have to rely on crop covers or pyrethroid insecticides; the latter option is not available for watercress growers.

Background and expected deliverables

In 2006, turnip sawfly (TSF) caused significant economic damage to growers of watercress and baby-leaf Cruciferous crops. There appeared to have been a large-scale immigration of the insects from continental Europe which led to the damage. Concern that climate change might result in the immigration establishing a permanent population of significant size in southern England led to this work.

The aims of the work were:

- To investigate a link between the growing of oilseed rape in the watercress-growing areas and the severity of infestation of watercress
- To assess the feasibility of a monitoring system for TSF.
- To determine the host-plant preferences of TSF with a view to decoy-trapping the insects at watercress-growing holdings
- To investigate non-chemical control methods for TSF
- To assess the relative efficacy of pesticides available for TSF control in baby-leaf Cruciferous crops.

Summary of the project and main conclusions

Turnip sawfly caused economic damage to watercress and baby-leaf brassicas in southern England in 2006, and anticipation of further problems in the following years was, to a large extent, responsible for the initiation of this piece of research into the pest. It was feared that large areas of oilseed rape in the watercress-growing areas would act as an autumn breeding site for third-generation TSF and that invasion of watercress beds by adults originating from populations overwintered in oilseed rape fields would result in repeated economic damage to the crop as a result of larval grazing and/or contamination with adults or larvae.

These fears now appear to be largely unfounded. Monitoring of turnip sawfly activity in 2007-9 using sticky traps has not shown the presence of a consistent population of

damaging proportions and there has been relatively few complaints from growers in the last three years, most of these resulting from contamination of watercress or baby-leaf salads by adult TSF.

It is speculated therefore that the widespread damage seen in southern England in 2006 may have been the result of a large-scale immigration of TSF from continental Europe. Such invasions are known to occur from time to time, but will be sporadic since they can only occur during periods of suitable weather for migration (warm and dry, with winds from the right quarter). Trapping did not detect a large-scale immigration in 2007, 2008 or 2009.
The inconsistency of the results of the trapping in 2007-9 indicates that it is unlikely that a national early-warning system for TSF could be produced. However, this is not to say that trapping is of no use. It should be used on a local scale as it's a very useful guide to TSF activity in individual fields.

Chemical control of TSF on watercress is problematical as there are hardly any insecticides approved for use on the crop. Other ways of preventing damage were investigated in this project. The most important of these were physical barriers. Investigation of the relative efficacy of bird netting, two types of insect-proof mesh and horticultural fleece in excluding TSF showed clearly that whilst the netting had no deterrent effect the meshes were, surprisingly, superior to the fleece. A second method of exclusion that was considered consisted of barrier fences, similar to those which have been used commercially to reduce carrot-fly damage in carrot. Fences will only be effective in deterring a flying insect if they are tall enough to prevent the insects flying over them, so the flight activity of TSF was investigated. Sticky traps placed at various heights showed that, in host crops, most flying took place at a height of about 1 metre. However, a proportion of the activity took place at heights of up to 4 metres (the highest tested), and since it seems unlikely that it would be economic to erect insect-proof fences of this order of height, it is unlikely that barrier fences will be suitable for excluding TSF.

Turnip was selected as a suitable candidate plant to act as a decoy trap crop for use in watercress-growing, where covering crops with mesh is difficult because of the size of the beds and where there are no effective, approved insecticides. The idea was that TSF might be attracted away from the watercress by the turnips, which could then be sprayed with insecticide to control the insects, resulting in reduced damage to the watercress. Plots of turnip were sown alongside watercress beds at

four sites and in two consecutive years. Invasion of the turnips and of the adjacent watercress by TSF was then monitored using both sticky traps and direct observation. Unfortunately, the results were inconclusive. In neither year was there sufficient invasion of either the watercress or the adjacent trap crop to give any meaningful results.

Six candidate pesticides with approval for use on baby-leaf brassicas were included in a trial to assess their relative efficacy for TSF control. Three of these pesticides were pyrethroid insecticides (alpha cypermethrin (as Contest), cypermethrin (as Toppel 10) and deltamethrin (Decis)) which have contact action and some residual effect. The remainder consisted of nicotine (No-Fid), fatty acids (Savona) and plant extracts (Majestik), all of which have contact action only.

The trial showed that the habit of young TSF larvae of feeding on the underside of leaves gave them some protection from contact-action pesticides. However, because the pyrethroids tested all have residual action for a few days after application they remained active for long enough for ingestion of treated leaf material by the TSF larvae as they grew to give an acceptable level of control. The non-pyrethroid products tested however have no residual action and although they gave some initial knock-down they were not as effective as the pyrethroids.

The project's conclusions were as follows:

1. Trap catches of turnip sawfly vary considerably between sites, and between the same site in different years.
2. The only consistent feature of the population dynamics of TSF in southern England is that there is likely to be a peak of adult activity during August.
3. Other peaks of activity may sometimes occur, typically in either June or September, but when they do they are unpredictable in both size and timing.
4. Using a trapping system to provide an early warning of changes in TSF activity may only work on a local scale.
5. Mass immigrations of TSF occur infrequently. The invasion of 2006 was not followed by further immigrations in 2007, 2008 or 2009.
6. Covering vulnerable crops with insect-proof mesh is an effective way of minimising TSF damage without using insecticides, but horticultural fleece is less likely to prevent infestation occurring.

7. Turnip sawflies are strong fliers and will fly at heights of at least 4m above the ground. Exclusion fences are not therefore likely to be effective against this pest.
8. Pyrethroid insecticides are effective for use against TSF on baby-leaf Cruciferous crops.
9. There are no effective pesticides for use in watercress.
10. Adult TSF are more likely to be attracted to turnip, tat-soi or mizuna than to other Cruciferous crops. For trap-cropping, therefore, these are likely to be the most effective crops.
11. The effectiveness of decoy-trapping, by growing a crop attractive to TSF on land adjacent to watercress and then spraying it when activity is occurring, has not been established due to low levels of TSF in experiments during 2008 and 2009.

Financial benefits

The financial benefits of this project are not quantifiable. The work has shown that turnip sawfly is as yet largely unpredictable in its population size and in its periods of activity, so that it is probably not currently worthwhile initiating routine control measures. There may be savings involved here. The project has also shown that insect-proof fences are impractical, and that horticultural fleece is much less effective as a barrier to TSF than insect-proof mesh, which may again forestall unnecessary investment in these areas.
Direct financial benefit is difficult to identify.

Action points for growers

- Turnip sawfly activity is unpredictable on a wide scale, but local monitoring using yellow sticky traps in crops which attract the insect could provide a useful early warning of significant activity, especially in those areas of southern England that could be subject to mass invasions of TSF from continental Europe. Growers of susceptible crops would be well advised to monitor TSF activity routinely between June and September inclusive using sticky traps.

- Should significant numbers of the insect be detected then control may be necessary, but the options are few. In watercress, there are no insecticides

that have approval for use on the crop that are likely to be effective against TSF. The only solution here may be the deployment of insect-proof mesh covers for the duration of the activity period of the insect. Insect-proof covers may also be effective in baby-leaf salad crops, but the option of using pyrethroid insecticides to reduce the number of ovipositing adults present or to control the developing larvae is also available for these crops. Growers should consider how they might employ either method of control before significant TSF problems develop.

Science Section

Introduction

Caterpillars of the turnip sawfly (*Athalia rosae*) are spectacular defoliators of brassicas; serious infestations are capable of completely skeletonising plants. Although well-known in the past as a pest of turnips, turnip sawfly (TSF) has been virtually absent as a pest of agricultural importance in the UK for much of the last 60 years. However, in recent years, populations have been increasing again, and in 2006 TSF infestations were widespread across much of southern and eastern England, including significant populations on oilseed rape, mustard, baby leaf brassicas and watercress, prompting concern that, if more frequent hot summers occur as a result of climate change, TSF is likely to become a regular pest. Although past TSF outbreaks have occurred in hot dry summers when mass migrations have arrived in the UK from the continent, there was concern that the high populations in 2006 may have supplemented the overwintering population in the UK to the extent that the pest may become a more regular pest on UK crops.

Adult TSF are predominantly orange in colour, with two black patches on the thorax and black joints on all legs (giving the latter a black and yellow 'hooped' appearance). The adults usually first appear in May. Eggs are laid in slits along the margins of host-plant leaves, each female being capable of laying 50 to 300 eggs. The larvae hatch in six to eight days, depending on temperature, and feed on the underside of leaves. They develop a distinctive velvety-black appearance (hence the name 'black palmer') and feed for 10 to 13 days before moving into the soil to pupate. As a defence mechanism, larvae accumulate glucosinolates from their food plant(s) and release concentrated globules of these toxins to deter predators. Adults emerge after about 21 days spent as pupae. There are usually up to three generations over the summer, and pupae from the final generation overwinter in the soil in silken cocoons.

Controlling sawflies in watercress is particularly difficult as the presence of adults or larvae in the harvested watercress, and the feeding damage caused by larvae, severely reduces crop quality. There are also no suitable pesticides available for this crop. Even minor infestations on baby leaf brassicas make the harvest of a marketable crop very difficult due to the presence of both damaged leaves and live or dead larvae.

There are no UK label recommendations for the insecticidal control of TSF. Although pyrethroid insecticides are approved in France for control of TSF on oilseed rape, mustard, cabbage, radish and 'aromatic plants', these cannot be used on or near watercourses and are therefore unsuitable for watercress production. Growers therefore require an environmentally-acceptable means of combating the pest. On baby leaf brassicas, it is likely that effective control with currently-available insecticides can be achieved, but data on effective rates and timing are required.

The objectives of the project were therefore to:

- Develop an early warning system for TSF on watercress by establishing the relationship between adult emergence in oilseed rape, catches of adults on sticky traps/trap plants in watercress and levels of egg-laying in watercress.
- Evaluate the efficacy of novel methods for turnip sawfly control in watercress
- Determine the efficacy against TSF of insecticides currently approved on baby leaf brassicas.

Early Warning System

Year 1 (2007)

Aim

The aim of this work was to determine the relationship between the timing of emergence of TSF adults from overwintering sites in oilseed rape and the arrival of first generation adults in nearby watercress beds.

Site Location

Work was done in Dorset at and adjacent to The Watercress Company site at Waddock Cross, Dorchester, and the Vitacress site at Hollybush, Bere Regis. The oilseed rape site used was at Roke Farm, Bere Regis.

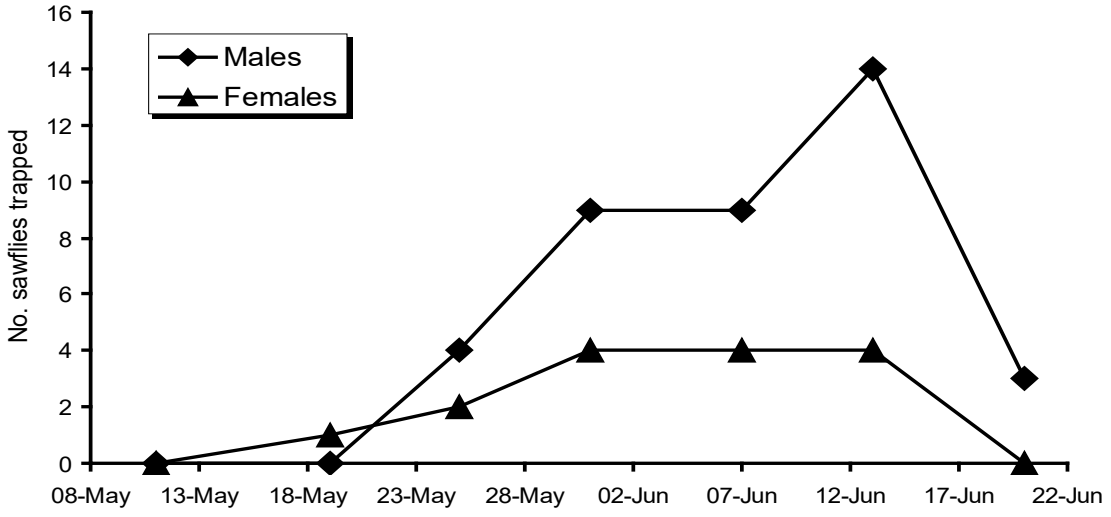
Methods

Two yellow sticky traps (Agralan, UK) of 254 x 202 mm were placed in the headland of the oilseed rape field on 11 May 2007. One yellow sticky trap was set out adjacent to watercress beds at Hollybush and Waddock Cross. The oilseed rape site was 0.8 miles from Hollybush and 4.6 miles from the Waddock site. Traps were checked at approximately weekly intervals until the end of June in order to determine the period of first generation activity.

Results

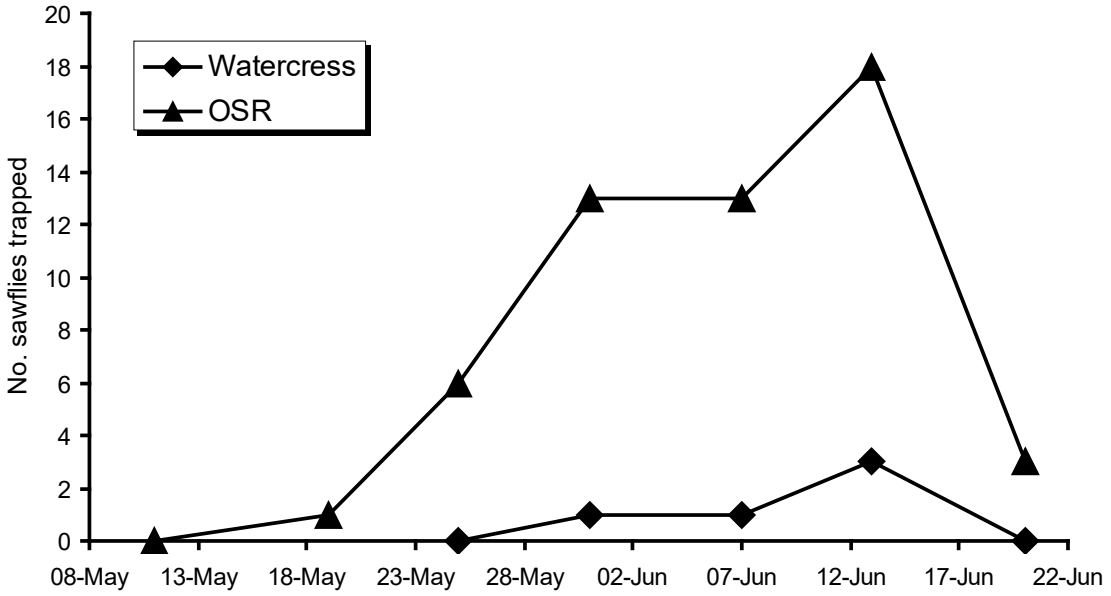
TSF adults were first caught at the oilseed rape site on 19 May 2007, and continued to be caught in the oilseed rape crop until 20 June 2007 when the crop had become too mature to retain any sawflies (Figure 1). Sawflies migrated from oilseed rape crops between 1 and 12 June 2007 when a warmer spell of weather allowed them to fly longer distances. Increased numbers were found arriving at watercress and baby leaf farms over this period.

Figure 1. Trap catches of male and female sawflies in oilseed rape at Bere Regis, 2007



Female TSF were caught on yellow sticky traps at both the Hollybush and Waddock Cross watercress sites between 7 and 13 June. Adult TSF were most numerous on watercress at Waddock Cross from 9 -12 June corresponding with the main migration from oilseed rape crops. The first appearance of TSF in watercress was c. 2 weeks after the first recorded emergence from the oilseed rape site (Figure 2).

Figure 2. Relative timing of trap catches of sawflies (males and females combined) in watercress and oilseed rape, 2007



Observations in baby leaf crops have confirmed that activity commences at around 10.00 h on sunny days and continues until at least 17.00 h. TSF adults spend a lot of time feeding on suitable nectar sources; hedge and cow parsley are preferred as nectar sources.

Very few larvae were found in oilseed rape crops suggesting that they will not be a major source of second generation adults. More larvae were found on the wild hosts charlock and hedge mustard, which are likely to be the main sources of the second generation.

Years 2 and 3 (2008/9)

Aim

In years 2 and 3 it was decided to extend the monitoring to a number of different sites and to maintain it throughout the summer months. The purpose of this was firstly to check whether TSF activity occurred consistently and concurrently at different sites, thus making the development of a general early-warning system feasible, and secondly to see if it was possible to detect an immigrant population by maintaining a chain of trap sites around the south-east of England, where immigration was most likely to occur.

Site Locations

The sites used in 2008 were Waddock Cross, Dorchester, Dorset (courtesy of The Watercress Company), Pinglestone, New Alresford, Hampshire (courtesy of Vitacress Ltd), Deal, Kent (courtesy of Intercrop Ltd) and various farms in Suffolk (courtesy of Eastern Counties Growers). Because of the short-term nature of baby-leaf salad crops, at most sites individual fields only featured for a few weeks. This resulted in a total of 22 sites being used for monitoring during the year. Sites growing watercress are however used for most of the year and so featured more consistently in the monitoring.

In 2009, the following sites were used:

The Watercress Company - Waddock Cross (watercress/turnip) and New Alresford, Hants (watercress) plus local rented fields (mizuna).

Vitacress Ltd - St Mary Bourne (watercress/turnip) and Warnford (watercress).

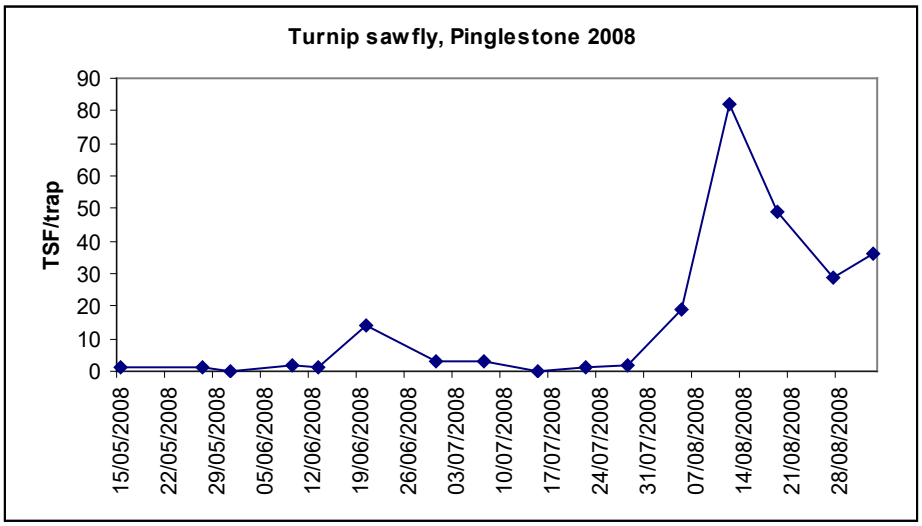
Methods

At each monitoring site two wooden pegs (19 mm x 38 mm x 300 mm) were hammered into the ground 380 mm apart, so that a two-sided yellow sticky trap 400 mm x 220 mm could be attached to each by foldback clips, exposing both sticky surfaces. The traps were at approximately crop height. The traps were changed weekly for fresh ones and the exposed traps were sent to ADAS Rosemaund for any turnip sawflies caught to be identified and counted.

Results

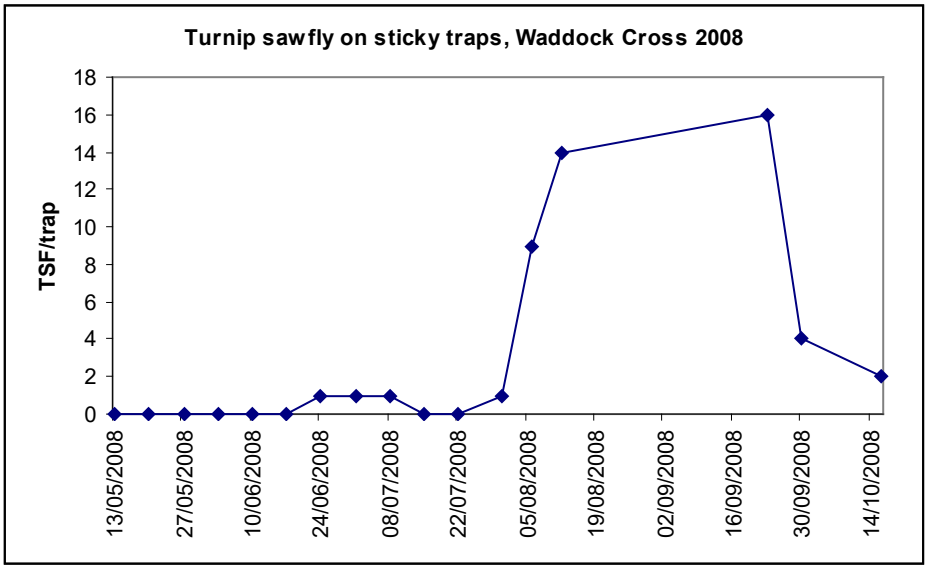
The sticky trapping showed that turnip sawfly activity varied considerably during one year, between different years and between different sites (See appendix 1). This is most conveniently illustrated by reference to Figures 3 – 6 inclusive, below.

Figure 3. Turnip sawfly trap catches, Pinglestone, New Alresford, 2008



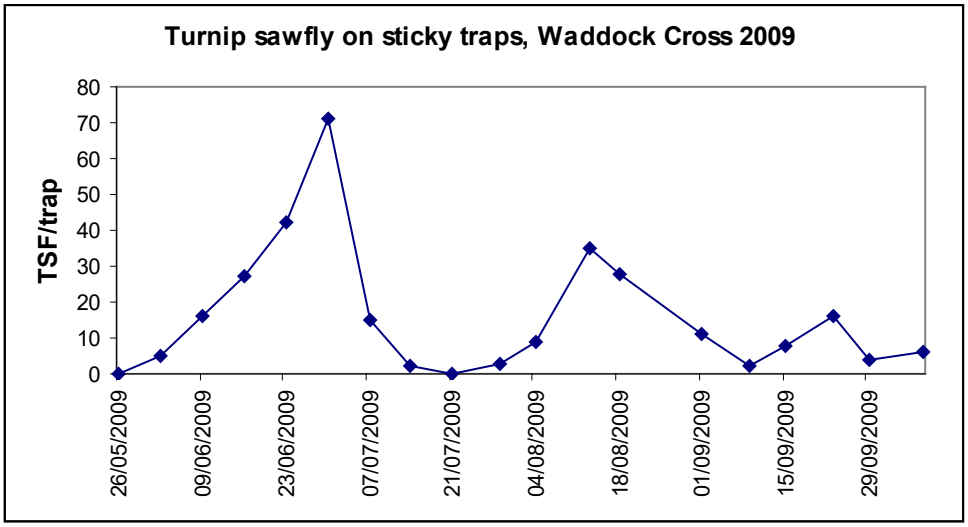
Little activity was detected until the middle of June at Pinglestone in 2008 (Fig 3). Trap catches then faded away in July. In August, a large peak of activity was detected that lasted for most of the month.

Figure 4. Turnip sawfly trap catches, Waddock Cross, Dorchester 2008.



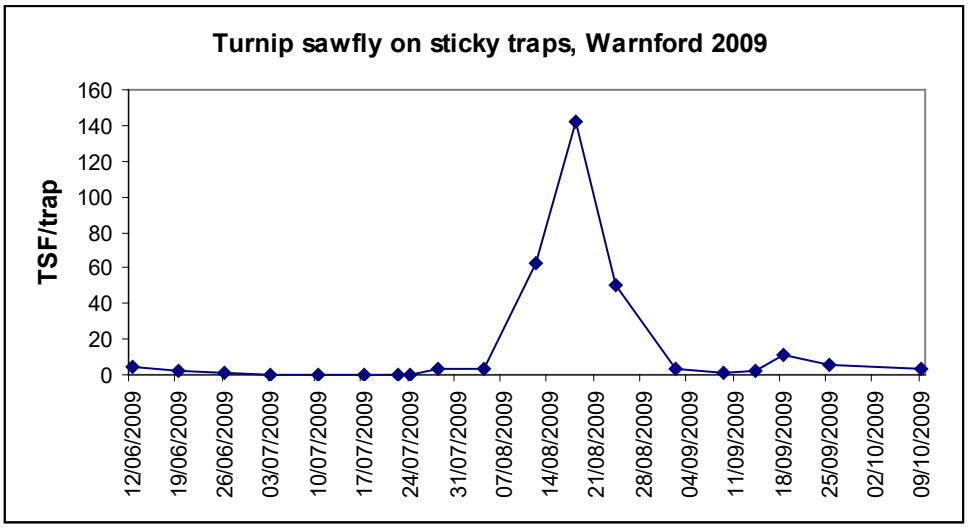
There was little activity between May and early August at Waddock Cross in 2008 (Fig 4), at which point trap catches rose to a drawn-out peak that persisted almost into October.

Figure 5. Turnip sawfly trap catches, Waddock Cross, Dorchester 2009.



There were three clear peaks of activity at the Waddock Cross site in 2009 (Fig 5). The first of these occurred at the end of June, then there was a second, lower peak in the middle of August and a third, lower still, in late September.

Figure 6. Turnip sawfly trap catches, Warnford, Hants, 2009.



In contrast to the situation at Waddock Cross, at Warnford there was very little activity detected before early August. Trap catches then rose to a peak in the middle of the month. There was a hint of further activity in mid-September

Discussion

The overall conclusion to be drawn from the turnip sawfly monitoring work is that it is likely to be very difficult to devise an early-warning system that will apply simultaneously to all watercress-growing sites, due to the inconsistencies in size of trap catch and timing of peaks of activity between sites. The only feature consistent between sites and years seems to be that there will be a peak of activity in August.

The size of this peak is unpredictable, and it may, or may not, be proceeded by a peak of activity in June or be followed by one in September. Even if these peaks occur, they are likely to be variable in size from year to year and may not result in significant levels of damage to crops.

This does not, however, mean that monitoring turnip sawfly activity is unlikely to be worthwhile. Yellow sticky traps seem to be efficient in attracting the adults and the insects themselves are large and relatively easy to recognise after a little practice. Traps situated in susceptible crops and scanned regularly for TSF should provide useful information on the levels of activity in that crop and at least provide reassurance when the local population is minimal.

It is likely, if unconfirmed, that the severity of the crop damage in 2006 was due at least in part to large numbers of TSF migrating into the UK from continental Europe. Part of the reason for monitoring TSF using sticky traps was to see if these would provide an early warning of such a migration, which should cause a sudden, significant rise in the numbers of insects being caught on the traps at the majority of sites. Despite monitoring throughout the highest-risk periods in 2008 and 2009, no such sudden dramatic increase in catches at multiple sites was detected, so either a mass immigration did not occur or the traps failed to detect it. The ability of a sticky-trapping system to detect a mass immigration remains unproven.

Efficacy of novel control methods

Aim

The aim of this work was to determine whether non-chemical means of control could be used, particularly on watercress, to prevent or reduce the level of TSF infestation. Work was done to investigate the effect of crop covers, the potential of different brassica (and related) species to act as trap crops, and the height of flight of TSF adults, the latter as a precursor to possible work on fences as an exclusion technique.

Site Location

Work on crop covers was done at Church Farm, Tincleton, Dorset (courtesy of The Watercress Company). Small-scale studies on the attractiveness of different potential host plants were done at Waddock Cross (The Watercress Company) and Mullens Farm, Pewsey, Wiltshire (Vitacress Salads Ltd). Height of flight of TSF adults was assessed at Church Farm and Mullens Farm, and subsequently, in the second year of the project, at Waddock Cross (The Watercress Company) and Pinglestone Farm, New Alresford (Vitacress Salads Ltd). Decoy crops were sown at Waddock Cross in 2008 and 2009, at Pinglestone in 2008 and at St Mary Bourne (Vitacress Salads Ltd) in 2009.

Methods

Crop covers: a regenerated bed of Tatsoi (*Brassica rapa* var. *rosularis*) was used to test four different crop covers. These were bird netting, Enviromesh, Enviromesh Plus and Envirofleece, all manufactured by Agralan and sourced through Chase Organic Gardening. Both grades of Enviromesh have apertures of approximately 2 x 1 mm. 4 m lengths of bed were covered on 28 August 2007 and 2 x 1 m^2 areas of crop covered by each treatment were assessed 18 days later (15 September 2007) for the presence of TSF larvae.

Host-plant attractiveness: Planters of six representative crop types were deployed at two sites (Tincleton and Pewsey) on 20 June 2007. Host plants were sown on 6 June in troughs 800 mm x 180 mm x 170 mm, filled with potting compost. Two species were sown per trough. The crop species tested are given in Table 1.

Table 1. Potential host plants used to determine relative attractiveness to TSF

Common name	Latin name
Charlock	*Sinapsis arvensis*
White mustard 'Tilney'	*Sinapsis alba*
Mustard 'Osaka Purple'	*Brassica juncea*
Tatsoi 'Tah Tsai'	*Brassica rapa* v. *rosularis*
Turnip 'Market Express'	*Brassica rapa*
Watercress	*Nasturtium officinale*
Saisai leaf radish	*Raphinus sativus*
Oilseed rape	*Brassica napus*

Height of flight of TSF: in 2007, at both sites, yellow sticky traps were attached to a vertical stake at intervals of 0.4, 1.6, 2.8 and 4.0 m above the ground. Traps were set up on 12 September 2007 and removed on 15 September 2007, after which they were assessed for the presence of TSF adults.

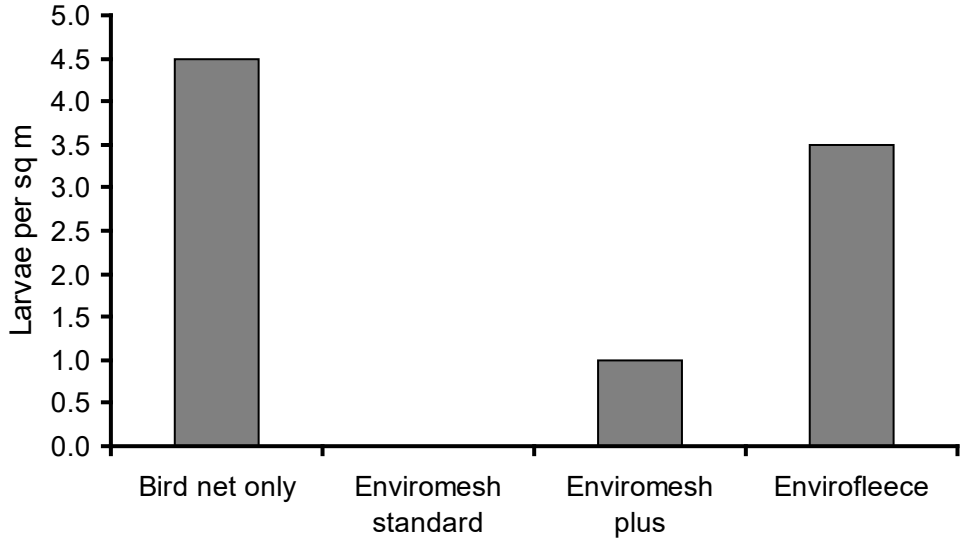
Because the stakes to which the traps had been attached in 2007 proved not to be sufficiently robust, in 2008 the traps were attached instead to conveniently-situated telegraph poles in fields growing baby-leaf salad Crucifers. Traps were affixed with drawing pins at heights of 0.1, 1.0, 2.2 and 3.3 m above the ground. At both sites they were set up on July 3rd, and they were retrieved on August 11th (Waddock Cross) and August 29th (Pinglestone), after which the number of TSF on each trap was assessed.

Decoy crops: turnip was chosen as a potential decoy crop to keep TSF away from watercress, for two reasons. Firstly, turnip is very attractive to TSF, and secondly it is a hardy, biennial plant with a long season so that it could be relied on to have foliage present between spring and autumn. Seeds of culinary turnip cv Manchester Market (Elsom's seeds Ltd) were sown in prepared seedbeds as close as feasible to commercial watercress beds at all sites, in both years. Sowings were made in early-mid May so that plants would be available for TSF colonisation from early June onwards. Yellow sticky traps were positioned at ground level in the crop and as close as possible to adjacent watercress beds, to aid assessment of the relative attractiveness of the two crops. Both the turnips and the adjacent watercress were examined at regular intervals throughout the summer period in both years for signs of oviposition by TSF and for evidence of larval feeding on the foliage.

Results and Discussion

Crop covers: the results of the crop covers experiment are shown in Figure 7.

Figure 7. TSF larvae $m^{2\ -1}$ on Tatsoi at Tincleton under different crop covers



The Enviromesh standard and Enviromesh plus were effective at preventing or eliminating TSF larval infestation. Surprisingly, Envirofleece was ineffective, particularly as no holes were evident and it remained well sealed around the edges. It is possible that sufficient crop odour built up under the fleece to stimulate the sawflies to lay eggs on or through its surface.

Host-plant attractiveness: at Tincleton after eight days exposure the plants were removed for examination. No eggs or larvae were found. During three observation periods, single TSF adults were seen to land on the turnip and Tatsoi plants, but not the other species. Pigeons damaged the plants at Mullens, which were replaced with a different batch and then covered with bird netting.

Field observations in 2008 and 2009 confirmed that the baby-leaf brassica known as mizuna was attractive to adult TSF.

Height of flight of TSF: the trap system used at Mullens Farm in 2007 did not remain stable and did not give useful results. The traps at Tincleton did produce some results but the catches of TSF were very small and could not be relied upon to give an accurate picture of the flight habits of TSF. The trap system used in 2008 was much more robust than that used in 2007, and catches on both sets of traps in 2008 were much larger than those in 2007, so that the 2008 results are more likely to be reliable. The results from Tincleton in 2007 are given in Figure 8, and those from Waddock Cross and Pinglestone in Figure 9.

Most TSF were caught on traps at around 100 cm above ground level, but a significant proportion were caught at levels higher than this and the insect is plainly capable of strong flight. This is not surprising, as TSF is known to be able to migrate to the UK from continental Europe, given favourable temperatures and winds. In contrast, 98% of cabbage root fly (*Delia radicum*), on the traps at Tincleton were caught on the lowest trap.

Figure 8. Trap catches of TSF adults at different heights above the ground – Tincleton 2007.

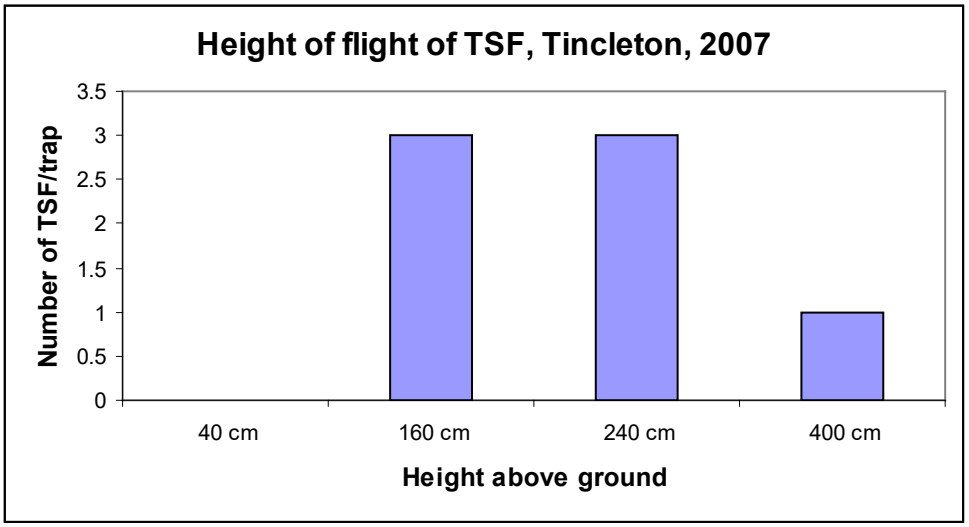
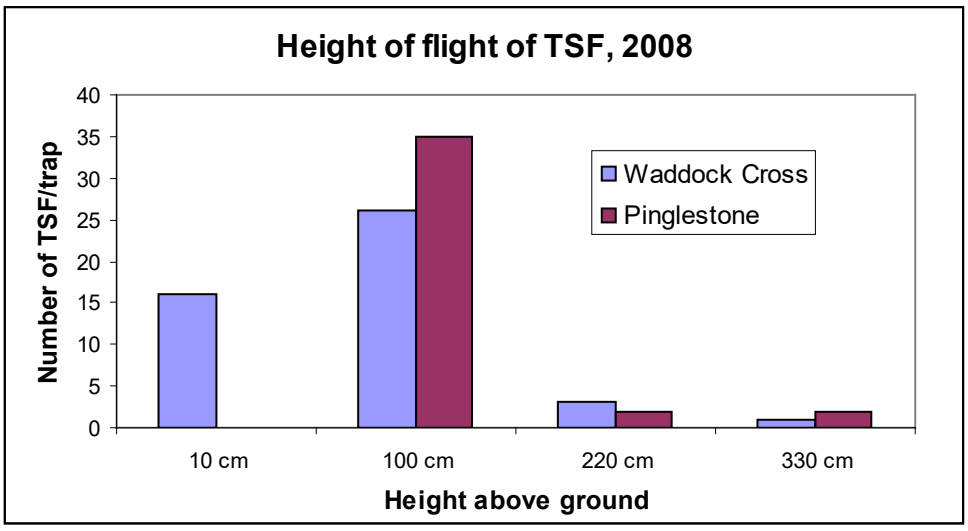


Figure 9. Trap catches of TSF adults at different heights above the ground – Waddock Cross and Pinglestone, 2008



Decoy crops: In both years the turnip decoy crops thrived and produced a good crop of foliage that persisted throughout the duration of the decoy cropping period. Sticky trapping in the decoy crops of turnip and adjacent watercress was completed in both 2008 and 2009, and the results of this are presented in Figures 10 and 11.

The results are contrasting. In 2008, there were a few TSF on the trap in the turnip crop in mid-June, but hardly any on the trap in the watercress. Numbers were highest on both traps in August, with the catches on the turnip trap at this time being much higher (8-fold) than those on the watercress. In 2009, however, the situation was reversed. Numbers were highest on both traps in mid-June, with few present in August, and the peak catch was about 5 times greater on the watercress trap than on the turnip trap. Thus, the two results contradict themselves. In 2008 turnip appeared to be more attractive to TSF than watercress, so there seemed to be some potential in the use of turnip as a decoy crop near watercress. In 2009, the position was reversed.

Figure 10. Turnip sawfly catches on sticky traps in watercress and turnips, Pinglestone 2008

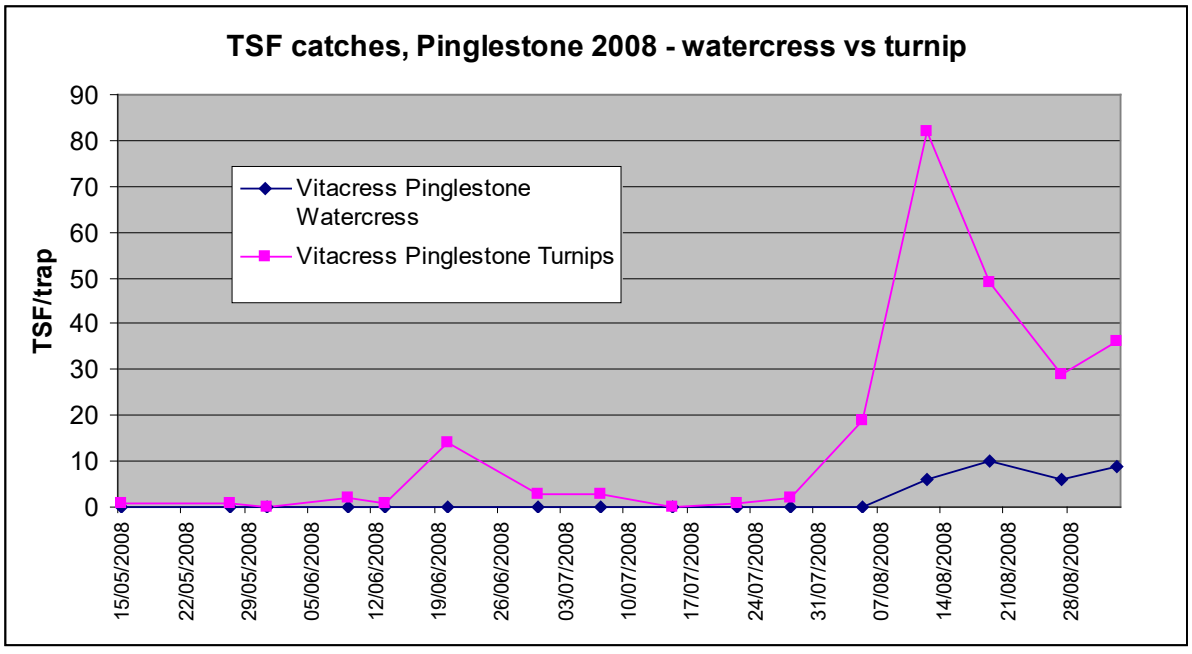
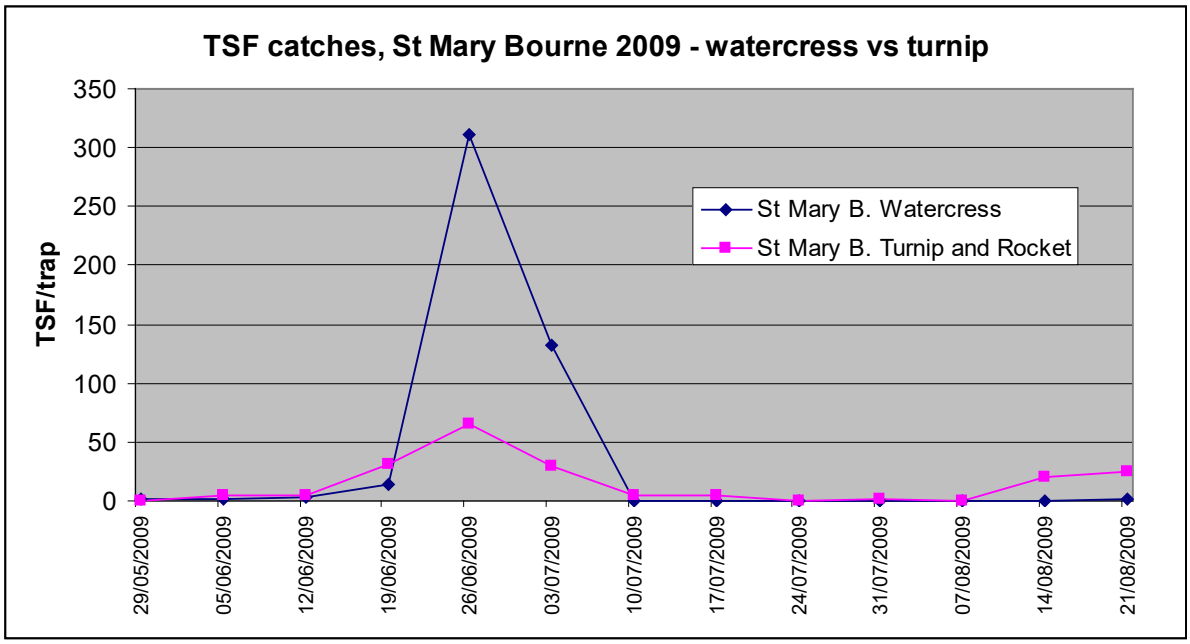


Figure 11. Turnip sawfly catches on sticky traps in watercress and turnips, St Mary Bourne, 2009.



In both years, no damage caused by turnip sawfly was observed in either the turnips or the watercress, so it may simply be that local populations at the chosen sites were too low for any meaningful results to be achieved.

Efficacy of currently-approved insecticides against TSF

Aim

To compare the efficacy of six chemical treatments in controlling turnip sawfly on baby-leaf brassicas.

Site location

The work was done at Church Farm, Tincleton, Dorset (courtesy of The Watercress Company) on two beds of regenerated Tatsoi.

Experimental design

The experiment was a randomized complete block design with seven treatments replicated five times. Plot size was one bed width (1.35 m) x 10 m. Treatments are given in Table 2.

Table 2. Experimental treatments used for chemical control of TSF (all products are currently approved for use on baby leaf brassicas).

Code	Product	a.i.	Product rate ha^{-1}	Water volume L ha^{-1}
A	Contest	alpha-cypermethrin	67 g	200
B	Toppel 10	cypermethrin	250 ml	200

C	Decis	deltamethrin	300 ml	200
D	No-Fid	Nicotine	1.34 L	200
E	Savona	fatty acids	20.0 L	2000
F	Majestik	plant extract	25 ml	1000
G	Untreated	-	-	-

Single applications of each product were made on 14 September 2007 with a hand-held CO_2-powered sprayer utilising flat-fan nozzles. All treatments were made to the crop with bird netting *in situ*.

Assessments

Numbers of live larvae on plants were assessed 1 and 5 days after treatment (DAT). Assessments were made by plucking plants from a measured area and counting the numbers of live larvae dropping to the ground. Two 0.5 x 0.5 m areas were cleared on the first assessment and one 1 m-square area on the second.

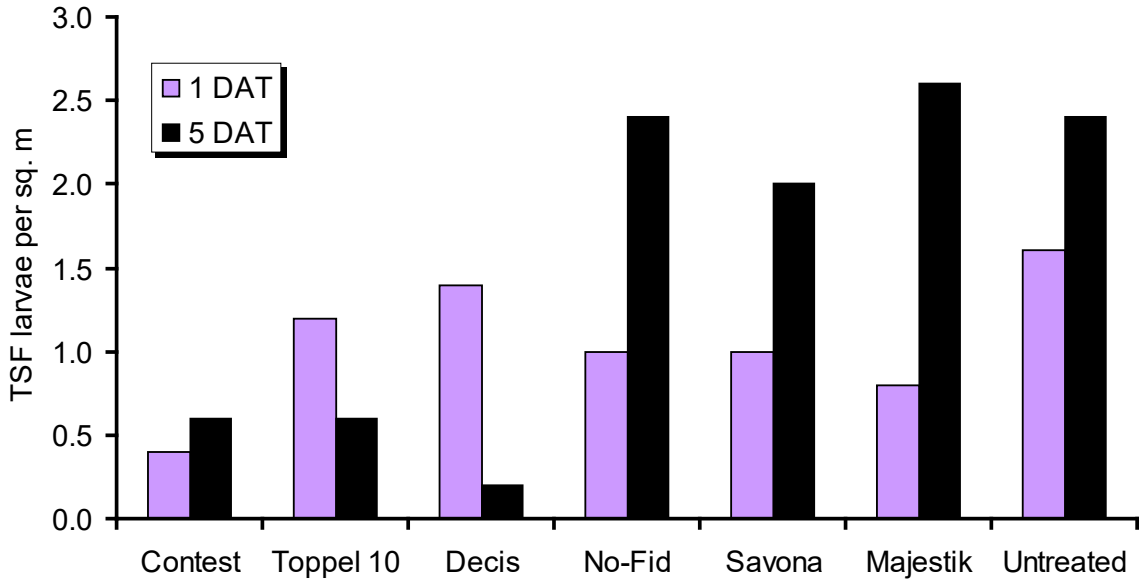
Phytotoxicity was also scored on a 1-10 scale on both occasions.

Results and Discussion

The pyrethroid products (Contest, Toppel 10 and Decis) were more effective than any of the other alternatives tested, particularly by 5 days after treatment (Figure 12). The infestation consisted of second- and young third-stage larvae which stayed feeding mainly on the undersides of the leaves. Pyrethroid insecticides, that can kill by ingestion as well as direct contact, were therefore more effective than the other pesticides, that kill by direct contact only. In practical terms No-Fid, Savona and Majestik may kill large larvae feeding on the upper surface of the leaf, but are unlikely to have a role against larvae in the earlier stages of attack.

None of the treatments caused any phytotoxicity.

Figure 12. Mean number of TSF larvae $m^{2\ -1}$ on Tatsoi 1 day after treatment (1 DAT) and 5 days after treatment (5 DAT).



Analysis of variance (ANOVA) indicated that there were no differences between treatments 1 DAT ($F_{6,24}$ = 0.79, *P* = 0.584; SED = 0.627) or at 5 DAT ($F_{6,24}$ = 1.4, *P* = 0.255; SED = 1.231). However, at 5 DAT all the pyrethroid products (Contest, Toppel 10 and Decis) gave consistently higher numeric reductions in numbers of larvae compared with the other products.
More significant results may have been achieved if the TSF attack had been more severe. Note the low population level on the untreated plants.

Overall Discussion

Turnip sawfly caused economic damage to watercress and baby-leaf brassicas in southern England in 2006, and anticipation of further problems in the following years was, to a large extent, responsible for the initiation of this piece of research into the pest. It was feared that large areas of oilseed rape in the watercress-growing areas would act as an autumn breeding site for third-generation TSF and that invasion of watercress beds by adults originating from populations overwintered in oilseed rape fields would result in repeated economic damage to the crop as a result of larval grazing and/or contamination with adults or larvae.
These fears now appear to be largely unfounded. Monitoring of turnip sawfly activity in 2007-9 using sticky traps has not shown there to be a consistent population of damaging proportions and there have been relatively few complaints from growers in the last three years, most of these resulting from contamination of watercress or baby-leaf salads by adult TSF.
It is speculated therefore that the widespread damage seen in southern England in 2006 may have been the result of a large-scale immigration of TSF from continental Europe. Such invasions are known to occur from time to time, but will be sporadic since they can only occur when periods of suitable weather for migration (warm and dry, with winds from the right quarter). Trapping did not detect a large-scale immigration in 2007, 2008 or 2009.
The inconsistency of the results of the trapping in 2007-9 indicates that it is unlikely that a national early-warning system for TSF could be produced. However, this is not to say that trapping is of no use. Used on a local scale it could be a very useful guide

to activity in individual fields and growers of vulnerable crops could benefit from monitoring.

Because chemical control of TSF on watercress is problematical – there are hardly any insecticides approved for use on the crop – other ways of preventing damage were investigated in this project. The most important of these were physical barriers. Investigation of the relative efficacy of bird netting, two types of insect-proof mesh and horticultural fleece in excluding TSF showed clearly that whilst the netting had no deterrent effect the meshes were, surprisingly, superior to the fleece. A second method of exclusion that was considered consisted of the barrier fences, similar to those which have been used commercially to reduce carrot-fly damage in carrot. Fences will only be effective in deterring a flying insect if they are tall enough to prevent the insects flying over them, so the flight activity of TSF was investigated. Sticky traps placed at various heights showed that, in host crops, most flying took place at a height of about 1 metre. However, a proportion of the activity took place at heights of up to 4 metres (the highest tested), and since it seems unlikely that it would be economic to erect insect-proof fences of this order of height, barrier fences seem unlikely to be suitable for excluding TSF.

Turnip was selected as a suitable candidate plant to act as a decoy trap crop for use in watercress-growing, where covering crops with mesh is difficult because of the size of the beds and where there are no effective, approved insecticides. The idea was that TSF might be attracted away from the watercress by the turnips, which could then be sprayed with insecticide to control the insects, resulting in reduced damage to the watercress. Plots of turnip were sown alongside watercress beds at four sites and in two consecutive years. Invasion of the turnips and of the adjacent watercress by TSF was then monitored using both sticky traps and direct observation. Unfortunately, the results were contradictory in consecutive years, largely because there was insufficient invasion of either the watercress or the adjacent trap crop in either year to give any meaningful results.

Six candidate pesticides with approval for use on baby-leaf brassicas were included in a trial to assess their relative efficacy for TSF control. Three of these pesticides were pyrethroid insecticides (alpha cypermethrin (as Contest), cypermethrin (as Toppel 10) and deltamethrin (Decis)) which have contact action and some residual effect. The remainder consisted of nicotine (No-Fid), fatty acids (Savona) and plant extracts (Majestic), all of which have contact action only.

The trial showed that the habit of young TSF larvae of feeding on the underside of leaves gave them some protection from contact-action pesticides. However, because the pyrethroids tested all have residual action for a few days after application they remained active for long enough for ingestion of treated leaf material by the TSF larvae as they grew to give an acceptable level of control. The non-pyrethroid products tested however have no residual action and although they gave some initial knock-down they were not as effective as the pyrethroids.

Conclusions

1. Trap catches of turnip sawfly vary considerably between sites, and between the same site in different years.
2. The only consistent feature of the population dynamics of TSF in southern England is that there is likely to be a peak of adult activity during August.
3. Other peaks of activity may sometimes occur, typically in either June or September, but when they do they are unpredictable in both size and timing.
4. Using a trapping system to provide an early warning of changes in TSF activity may only work on a local scale.
5. Mass immigrations of TSF occur infrequently. The invasion of 2006 was not followed by further immigrations in 2007, 2008 or 2009.
6. Covering vulnerable crops with insect-proof mesh is an effective way of minimising TSF damage without using insecticides, but horticultural fleece is less likely to prevent infestation occurring.
7. Turnip sawflies are strong fliers and will fly at heights of at least 4 m above the ground. Exclusion fences are not therefore likely to be effective against this pest.
8. Pyrethroid insecticides are effective for use against TSF on baby-leaf Cruciferous crops.
9. There are no effective pesticides for use in watercress.
10. Adult TSF are more likely to be attracted to turnip, tat-soi or mizuna than to other Cruciferous crops. For trap-cropping, therefore, these are likely to be the most effective crops.
11. The effectiveness of decoy-trapping, by growing a crop attractive to TSF on land adjacent to watercress and then spraying it when activity is occurring, has not been established due to low levels of TSF in experiments during 2008 and 2009.

Acknowledgements

We are very grateful to Dr Graham Clarkson of Vitacress Salads Ltd and Mr Jeremy Martin of The Watercress Company for their help in providing sites for the experimental work in this project, and for assisting in the collection of the monitoring data.
We would also like to thank the various farm staff who kindly helped with the sometimes-awkward job of collecting and despatching sticky traps. Without their help this project would have foundered.

Appendices

Appendix 1: TSF Trapping data – number of TSF per sticky trap.

Date	TWC Waddock Cross Watercress	TWC Lower Lewell Fm Tatsoi	TWC Clyffe Fm Tatsoi	TWC Waddock Cross Turnip	TWC Pallington Fm Tatsoi	Intercrop Park Middle 1	Intercrop Park Middle 2	Intercrop New Hill Top	Intercrop New Hill Top	Intercrop Close Bottom A	Intercrop Close Bottom B
13/5/08	0	18									
15/5/08						0	0				
20/5/08	0	2									
23/5/08										1	1
27/5/08	0	31									
30/5/08										0	0
31/5/08											
3/6/08	0	302									
6/6/08										1	6
9/6/08											
10/6/08	0		27								
13/6/08											
16/6/08										15	14
17/6/08	0		31								
19/6/08											
20/6/08											
22/6/08								6	4		
23/6/08											
24/6/08	1		23	7							
30/6/08								3	2		
1/7/08	1		12	7							
7/7/08											
8/7/08	1		9	7							
14/7/08											
15/7/08	0		14	1							
16/7/08											
22/7/08	0		15	2							
24/7/08											
28/7/08											
31/7/08	1		383	1							
5/8/08											
6/8/08	9		294	0							
7/8/08											
12/8/08	14			4	131						
14/8/08											
19/8/08	lost			3	22						
26/8/08				5	38						
27/8/08											
29/8/08											
2/9/08											
4/9/08											
5/9/08				12	12						
19/9/08											
23/9/08	16				8						
30/9/08	4				131						
6/10/08											
16/10/08	2				2						
20/10/08											

Date	Intercrop Juries	Intercrop Juries	Intercrop Bonners Hill A	Intercrop Bonners Hill B	Vitacress Pinglestone Turnips	Vitacress Pinglestone Watercress	Vitacress Mullens Fm Wild Rocquette	Vitacress Mullens Fm Salad Rocquette	ECG Stalham Braceys Rocquette	ECG Tunstead Pattersons Rocquette	ECG Catfield Tatsoi
13/5/08											
15/5/08					1	0					
20/5/08											
23/5/08											
27/5/08					1	0					
30/5/08											
31/5/08					0	0					
3/6/08											
6/6/08											
9/6/08					2	0					
10/6/08											
13/6/08					1	0					
16/6/08											
17/6/08											
19/6/08							41	5			
20/6/08					14	0			1	3	
22/6/08											
23/6/08									9	0	
24/6/08							14	0			
30/6/08					3	0			25	4	
1/7/08							11	3			
7/7/08					3	0				78	1
8/7/08											
14/7/08										37	7
15/7/08					0	0					
16/7/08							2	2			
22/7/08					1	0					
24/7/08	37	14									
28/7/08					2	0					
31/7/08											
5/8/08					19	0					
6/8/08											
7/8/08	44	16									
12/8/08					82	6					
14/8/08	21	21									
19/8/08					49	10					
26/8/08											
27/8/08					29	6					
29/8/08	39	35									
2/9/08					36	9					
4/9/08	17	8									
5/9/08											
19/9/08			0	0							
23/9/08											
30/9/08											
6/10/08	0	0									
16/10/08											
20/10/08			0	0							

Turnip Sawfly Sticky Trap Monitoring 2009

The Watercress Company

Date	Waddock Cross Turnip/WC WC	Lower Lewell Fm Mizuna LL	Nether Moynton Fm Mizuna NM	Drayton Fm, Alresford Watercress D	Hastings Fm Mizuna Ha	Pallington Fm Mizuna Pa	Clyffe Farm Mizuna Cl
26/05/09	0	0		3			
02/06/09	5	17		38			
09/06/09	16		8	48			
16/06/09	27		16	68			
23/06/09	42		41	0			
30/06/09	71			0	218		
07/07/09	15			7	116		
14/07/09	2			5	6		
21/07/09	0				26		
29/07/09	3					293	
04/08/09	9			14		162	
13/08/09	35					273	
18/08/09	28					63	
25/08/09				49			
01/09/09	11						22
09/09/09	2						8
15/09/09	8		36				
23/09/09	16		174				
29/09/09	4		39				
08/10/09	6						15

Vitacress

Date	St Mary B. Watercress SMB W	St Mary B. Turnip and Rocket SMB T/R	Warnford Warnford
29/05/09	2	0	
05/06/09	1	4	
12/06/09	3	4	4
19/06/09	14	31	2
26/06/09	311	65	1
03/07/09	133	29	0
10/07/09	0	4	0
17/07/09	0	5	0
22/07/09			0
24/07/09	0	0	0
28/07/09			3
31/07/09	0	1	
04/08/09			3
07/08/09	0	0	
12/08/09			63
14/08/09	0	20	
18/08/09			142
21/08/09	2	25	
24/08/09			50
27/08/09	19		
02/09/09			3
09/09/09			1
14/09/09			2
18/09/09			11
25/09/09			6
09/10/09			3