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Abstract and summary

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Revised thresholds for cabbage stem flea beetle on oilseed rape

by

David B. Green

ADAS Woodthorne, Wergs Road
Wolverhampton, WV6 8TQ

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ABSTRACT

The aim of the study was to investigate a field-based method using water traps to provide information in early autumn on the need for control of cabbage stem flea beetle. At each of 71 sites (27, 25 and 19 sites in autumn 2004, 2005 and 2006 respectively) in central, eastern and northern England, four yellow water traps 25 cm in diameter were placed on the soil surface in winter oilseed rape crops soon after drilling or at early crop emergence. Two traps were sited on the crop headland with two traps within the field; 12 and 24 metres from the crop headland. Weekly and total catches of cabbage stem flea beetles in traps were recorded between crop emergence and late October or early November. Peaks of adult activity were recorded in late September or early October with higher totals of beetles recorded in each year of the study in central and northern England than in eastern England. Plant samples were collected in December to determine the number of larvae per plant and seventeen from the total of 71 sites subsequently developed infestations averaging two or more larvae per plant.

Regression analysis using data from all 71 sites showed that mean numbers of larvae per plant were significantly related to mean number of adults per water trap ($P < 0.001$). An infestation averaging two larvae per plant was likely to be attained from an average of 36 (SE 3.2) adults per trap with 69.3% of the variance explained. Regressions testing the relationships between adult numbers and larval infestations for each of the three study years were also significant (P = or < 0.001). Regressions were tested for headland or field-sited traps with two larvae per plant likely to be attained from means of 33 and 40 beetles per trap respectively.

The use of water traps enabled successful decisions to be made whether to spray or not at 87% of sites using a mean of 36 beetles per water trap. Overall predictive success was improved to 89% if the lower or upper 95% confidence limit values of 30 and 43 respectively per trap were used. Similar predictive successes were also obtained from headland or field-sited traps with correct treatment decisions made at 86% and 90% of sites respectively.

At sites where infestations averaging two or more larvae per plant were recorded, predictions of the need for control using the lower 95% confidence limit value of 30 cabbage stem flea beetle adults per water trap enabled 82% correct treatment decisions to be made, compared with 65% of correct treatment decisions using the median and upper 95% confidence limit values of 36 and 43 adults per water trap. A threshold value for water trap catches averaging 30-35 per trap was shown to be an action threshold above which an autumn pyrethroid spray treatment would be justified, irrespective of whether an earlier seed treatment had been applied.

In autumn 2004, four yellow sticky traps were compared with water traps as predictive methods at 27 sites. Sticky traps caught fewer cabbage stem flea beetles than water traps with a mean of 1.3 per sticky trap compared with a mean of 8.0 per water trap. A significant regression was obtained ($P < 0.001$) with 51.0% of variance explained with two larvae per plant likely to be attained from a mean of 5.7 beetles per sticky trap. The use of sticky traps provided a poor predictive method compared with water traps and the method tested did not predict the two sites in 2004 where above threshold numbers of larvae developed.

Regressions between larval numbers and plant, cotyledon and first true leaf damage were also tested at 52 sites in the first two years of the study during harvest years 2005 and 2006. Although larval numbers were significantly correlated with plant and cotyledon damage, only 14.0% and 10.8% of variance was explained and these methods were overall poor predictors of larval damage with only 20% of sites that developed larval infestations greater than two per plant being correctly predicted for treatment.

SUMMARY

Oilseed rape is attacked by a complex of pests and in recent years, cabbage stem flea beetle (*Psylliodes chrysocephala*) has become one of the most important insect pests during the establishment phase of autumn-sown crops. Its range has expanded into north-eastern England and Scotland, from initial infestation strongholds in southern and eastern England. Adult cabbage stem flea beetles emerge from aestivation from mid to late-August onwards and lay eggs in the soil after a period of feeding on the cotyledons and leaves of newly-emerged crops. The resulting larvae burrow into the plants and feed within the leaf petioles or stems during the autumn and winter period.

The larvae of cabbage stem flea beetle are normally considered to be more damaging than the adults. A control threshold for control of larvae that was previously used in the UK was an average of five larvae per plant providing an average 0.34 t/ha yield response from an effective, autumn-applied insecticide treatment. This threshold was updated in 2006 to reflect the favourable economics of control using pyrethroid sprays and is currently an average of two larvae per plant providing an average response to spraying of 0.16 t/ha worth around £40/ha at the present oilseed rape average price of £250/t. Treatment with a pyrethroid insecticide, if well-timed to coincide with the early stages of larval invasion, provides control of 70-80% or more and provides an option for cost-effective control where required.

Control of cabbage stem flea beetle relies heavily on the use of autumn-applied pyrethroid insecticides and, since 2002, on imidacloprid + beta-cyfluthrin applied as an insecticidal seed treatment. Large numbers of adult beetles feeding in crops from establishment can kill plants, but normally the larvae are more important economically with feeding damage occurring in leaf stalks and plant stems, typically from mid-late October and continuing overwinter. An economic-action threshold for control in autumn can be determined by plant dissection or assessment of leaf scarring. However, these methods provided a result that was often too late for autumn-applied insecticide sprays to be applied where necessary; usually as convenient tank mixes with autumn-applied herbicides and/or fungicides.

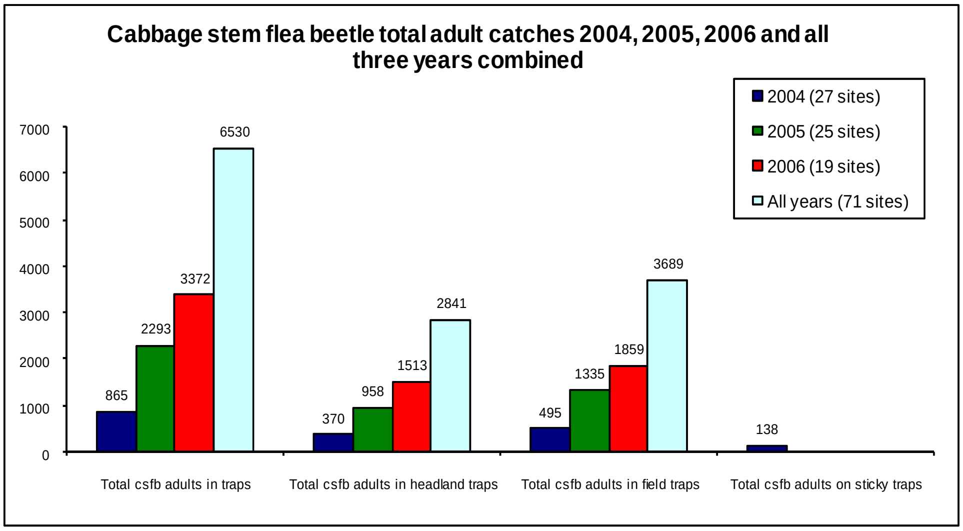
The three-year HGCA-funded study titled ‘Revised thresholds for cabbage stem flea beetle’ started in July 2005. The field-based study was conducted in a total of 71 commercial winter oilseed rape crops in central, eastern and northern England. The overall aims were to determine whether the number of cabbage stem flea beetle adults caught in ground-placed water traps or on vertically-mounted sticky traps could be used to predict the subsequent larval infestation and therefore the need for autumn control with pyrethroid sprays. A secondary objective was to determine whether larval infestations could be predicted from cabbage stem flea beetle adult damage to plants, cotyledons and first true leaves. A longer-term objective was to determine whether the method could be reliably used to update Decision Support System models currently being developed and tested for use on winter oilseed rape.

At each site, four yellow water traps 25 cm in diameter were placed on the soil surface in winter oilseed rape crops at early crop emergence, with two traps on the crop headland and two traps within the field at distances of 12 and 24 metres from the crop headland. Traps were left in place until late October or early November. Each week, the traps were reset with fresh water plus a few drop of detergent to reduce surface tension and the number of cabbage stem flea beetles in each trap was recorded to enable the total autumn catch to be determined.

Figure 1 summarises the incidence of adult cabbage stem flea beetle adult activity for each of the three study years. Mean numbers of beetles were 8.0, 22.9 and 44.4 per water trap in autumn 2004, 2005 and 2006 respectively. Combined trap catches for the three study years totalled 3,689 and 2,841 cabbage stem flea beetle adults in field-sited and headland-sited water traps respectively. In autumn 2004, catches on sticky traps were compared with catches in water traps at

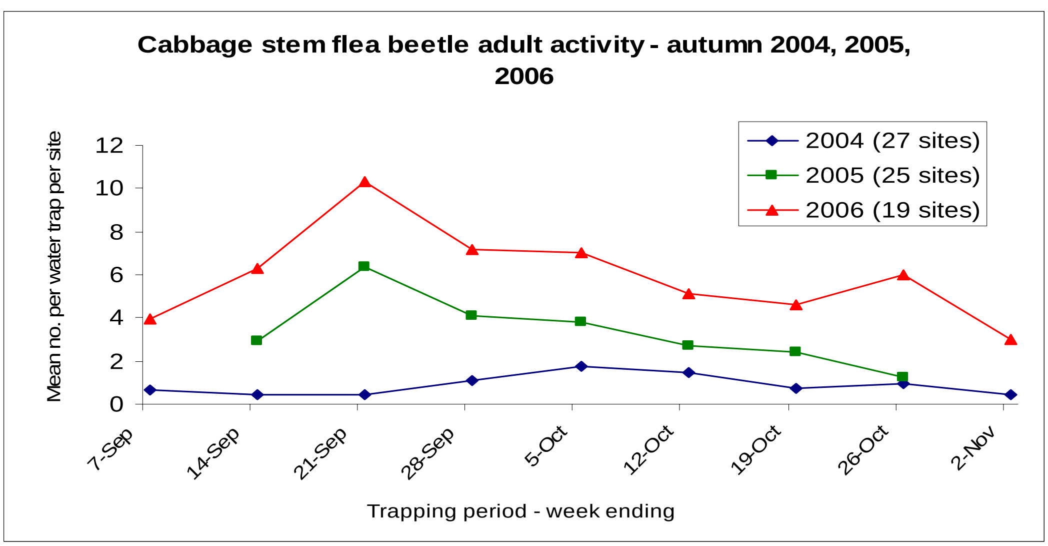
27 sites. The total catch of 865 in water traps in autumn 2004 was 6.3 times as high as the total catch of 138 on sticky traps.

Figure 1. Summary plot showing total number of cabbage stem flea beetle adults caught in four water traps at 71 sites; totals in two headland or two field-sited traps at 71 sites and total number on four sticky traps at 27 sites in autumn 2004.



Peaks of adult activity were recorded in late September or early October (Figure 2). Higher totals of beetles were recorded in each year of the study in central and northern England than in eastern England.

Figure 2. Summary plot for mean number of cabbage stem flea beetle adults per site for each weekly trapping period in autumn 2004, 2005 and 2006.



In the first study year, first catches were recorded in the first week of September 2004 during the early stages of crop emergence. A peak of adult activity was recorded in early October, followed by decreasing activity until mid October and a short-term increase in activity in late October before trap catches declined in early November. Peaks of autumn activity were recorded in late September 2005 and 2006 (Figure 2). The pattern of adult activity in each of the three years of the study was similar to that described by Alford (1979) who noted that the number of adults peaked in late September or early October and then declined.

Sampling of plants for larvae was undertaken, usually in early-mid December, to determine the number of larvae per plant and the number of plants and leaves infested. Totals of 25 plants (year 1) and 20 plants (years 2 and 3) were randomly sampled from unsprayed crop areas at each of the study sites. Plant samples were returned to the laboratory for damage assessment to record larval number and size; and percentages of plants and leaves infested by larvae (Tables 1 and 2).

Table 1. Mean number of cabbage stem flea beetle larvae per plant by survey region and for all sites in harvest years 2005, 2006 and 2007 (number of sites in brackets).

Harvest year	Survey region			
	Central England (32 sites)	Eastern England (23 sites)	Northern England (16 sites)	All sites (71 in total)
2005	0.70 (12)	0.00 (9)	0.05 (6)	0.32 (27)
2006	2.55 (11)	1.03 (8)	1.57 (6)	1.75 (25)
2007	3.08 (9)	0.46 (6)	3.00 (4)	2.24 (19)

Following the increased incidence of adult cabbage stem flea beetles between autumn 2004 and 2006 (Figure 1), larval infestations also increased with means of 0.32, 1.75 and 2.24 larvae per plant in harvest years 2005, 2006 and 2007 respectively (Table 1). Seventeen from the total of 71 sites subsequently developed larval infestations greater than a control threshold of two larvae per plant. The incidence of mean adult beetle damage to plants, cotyledons and first true leaves also increased during the three year study period (Table 2).

During each of the three years of the study, most of the heaviest larval infestations were recorded at sites in the Midlands. A total of 32 sites were monitored in the Midlands and 14 sites (44% of total) developed infestations greater than a mean of two larvae per plant. In this region, the heaviest larval infestation of 10.3 larvae per plant was recorded in Shropshire in harvest year 2006. Infestations were low at the majority of sites in eastern England, although an exception was one site in Norfolk in harvest year 2006 where a mean of 4.85 larvae per plant was recorded. In northern England, low infestations were recorded at the majority of sites although, in North Yorkshire, a mean of 10.6 larvae per plant was recorded at one site in autumn 2006. This was the heaviest infestation recorded at any of the 71 monitoring sites during the three-year study.

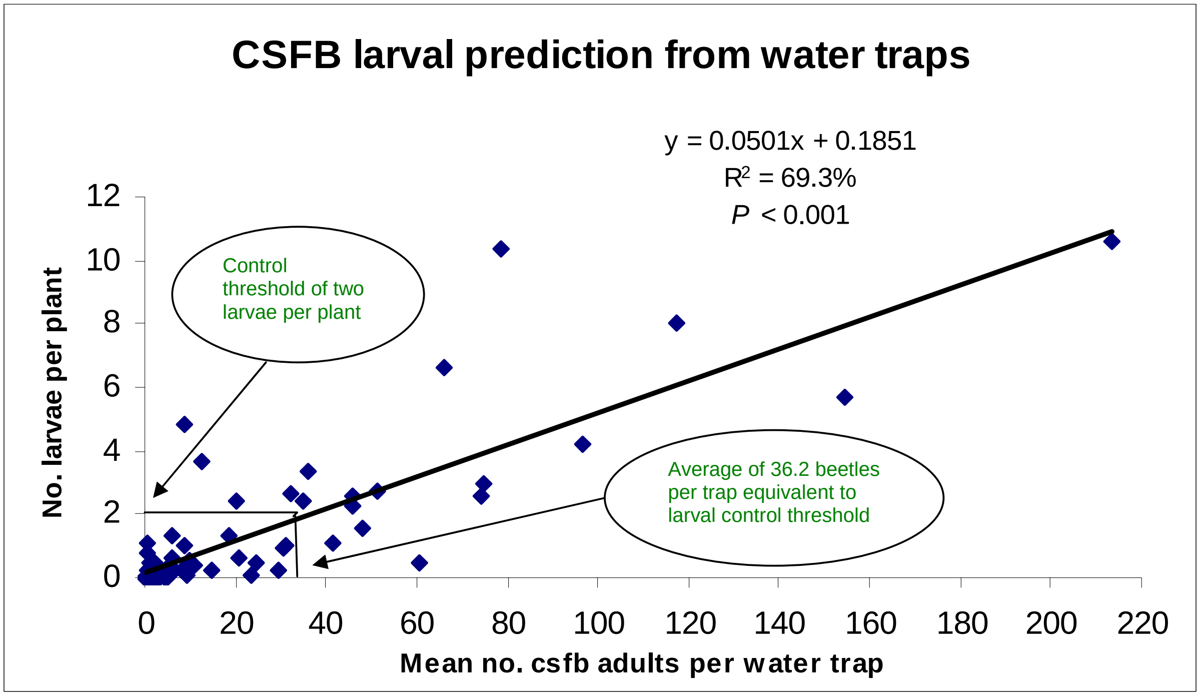
Table 2. Mean percentage of plants and leaves infested by cabbage stem flea beetle larvae in harvest years 2005, 2006 and 2007.

Harvest year	Mean percentage of plants infested	Mean percentage of leaves infested
2005	11.9	5.5
2006	44.2	18.5
2007	54.7	24.8

Regression analyses enabled the relationship to be tested between mean number of larvae per plant and mean number of adults in traps to determine whether it was possible to predict the number of larvae per plant from the number of cabbage stem flea beetle adults in traps. Regressions were also tested for larval number against mean numbers of plants, cotyledon and first true leaves damaged by the adult beetles.

Mean numbers of larvae per plant at 71 sites were significantly related to mean number of adult beetles per water trap ($P < 0.001$). A mean of two larvae per plant was likely to be attained from an average of 36.2 (SE 3.20) beetles per water trap with 69.3% of the variance explained (Figure 3) providing lower and upper 95% confidence limits between 29.8 to 42.6 beetles per trap. For predictive purposes, these values were subsequently tested in relation to correct or incorrect recommendations to treat or not to treat.

Figure 3. Cabbage stem flea beetle larval predictions from water trap catches at a total of 71 sites in harvest years 2005, 2006 and 2007.



Regressions of larval numbers were tested against mean number of beetles per water trap for each of the three years of the study. Two larvae per plant were predicted from means of 40.7 (SE 13.60. $P < 0.001$) beetles per water trap in harvest year 2005; 27.3 beetles per trap (SE 4.40, $P < 0.001$) per trap in 2006 and 39.3 (SE 6.21. $P = 0.001$) per trap in 2007. Regressions were also tested for headland-sited or field-sited traps with two larvae per plant likely from means of 32.9 (SE 3.49, $P < 0.001$) and 40.1 (SE 3.19. $P < 0.001$) beetles per trap respectively.

Larval infestations greater than a control threshold of two larvae per plant developed at a total of 17 from 71 sites (24% of total). Five sites developed infestations greater than five larvae per plant; two sites developed more than ten larvae per plant. Table 3 summarises the number and percentage successes for use of water trap catches for the prediction of larval infestations at the 17 sites where a control threshold of two larvae per plant was reached. An assumption is made that sites would have been recommended for spray treatment where larval numbers developed to two or more per plant.

If the median value derived from regression analysis of 36.2 adults per trap (Figure 3) was used to predict the need for treatment, correct treatment decisions were made at 11 from 17 sites (65% predictive success) where infestations developed to two or more larvae per plant. Using the lower 95% confidence limit of 29.8 (rounded to 30) beetles per trap, 14 from 17 predictions for the need to treat above threshold infestations were correct and use of this value enabled the predictive success to be improved to 82% (Table 3). Use of the upper 95% confidence limit of 42.6 9rounded to 43) per trap provided the same result in terms of predictive success as 36.2 beetles per trap with 11 correct 'to spray' decisions made for the 17 sites with two or more larvae per plant.

Infestations of less than two larvae per plant were recorded at 54 sites and the predictive success for these sites is next considered with the assumption that a usable predictive method will not advise treatment unnecessarily at an unacceptably high number of sites. Table 3 shows that if the median value of 36.2 beetles per water trap was used as a predictor, a total of 51 correct ‘no treatment’ decisions were made at the 54 sites with fewer than two larvae per plant (94% correct decisions not to treat). At the lower (more risk averse) 95% confidence interval value of 29.8 per trap, a total of 49 correct ‘no treatment’ decisions were made providing a predictive success of 91%. At the upper 95% confidence interval value of 42.6 per trap, a total of 52 correct ‘no treatment’ decisions were made at 63 sites monitored providing a predictive success of 96% (as summarised in column 4 of Table 3).

Table 3. Summary of prediction accuracy of ‘to spray’ and ‘no spray required’ decisions. Percentage of correct decisions made from mean water trap catches in brackets.

Water trap threshold tested (mean no. beetles per water trap)	Total no. sites above water trap catch shown in column 1	Correct decision to spray (% of sites in brackets).	Correct decision not to spray (% of sites in brackets)	Total number of correct decisions	Total number of incorrect decisions	Overall % success of predictive method tested
>36.2 (median value)	14	11 (65%)	51 (94%)	62	9	87%
>29.8 (lower 95% confidence limit value)	19	14 (82%)	49 (91%)	63	8	89%
>42.6 (upper 95% confidence limit value)	13	11 (65%)	52 (96%)	63	8	89%

Table 3 assumes that a decision to treat would be taken at the 17 from 71 sites that developed larval infestations of two or more per plant and that no treatment would be recommended at 54 from 71 sites with fewer than two larvae per plant.

Taking all decisions into account, the percentages of correct decisions to spray or not to spray were similar for the three categories tested for catches averaging 29.8, 36.2 or 42.6 beetles per water trap. Predictive-success rates ranged from 87% for the median value of 36.2 per trap to 89% for means at the lower and upper 95% confidence limits of 29.8 and 42.6 cabbage stem flea beetle adults respectively per water trap as summarised in the final column of Table 3.

The lower 95% confidence limit value of 29.8 per trap gave the highest success rate (82%) at predicting sites where economic damage (larval number greater than two per plant) was likely and where treatment would have been justified. Although the predictive value of 65% for 36.2 per trap is clearly lower than the result obtained for 29.8 per trap, the result should be put into context. Two sites recorded only marginally lower water trap catches of 35 and 36 beetles per trap with a water trap catch averaging 32 per trap at one further site. Inclusion of these sites would then have provided the same ‘to spray’ result as that obtained from 29.8 per trap. Use of the 29.8 per trap threshold indicated that three more sites were correctly identified for treatment compared with the use of 36.2 per trap, although two more sites (5 and 32) with water trap catches marginally above 29.8 per trap (see also Table 17) would have been recommended for treatment unnecessarily.

The upper 95% confidence limit value of 42.6 per trap enabled 11 from 17 correct decisions (65%) to be made for treatment where the larval infestation was greater than two larvae per plant. This value provided the greatest percentage (96%) of successful predictions for sites where treatment would not have been recommended (52 correct decisions at 54 sites). However, as it was a relatively poor predictor of sites where treatment would have been justified, this might be expected to prejudice the use of this value as a predictive threshold on economic grounds.

In summary, it was concluded that a prediction on the need for larval control based on means of 29.8-36.2 (rounded to 30-35 beetles per trap) should be considered for adoption as an advisory threshold for water trap catches of cabbage stem flea beetles.

Predictive successes were also tested from cabbage stem flea beetle adult catches in headland or field-sited traps. If successful predictions could be made using two traps rather than four, this might be expected to make the method more attractive to agronomists and farmers with a requirement to monitor infestation levels of cabbage stem flea beetles in winter oilseed rape crops.

For headland-sited traps, regression analysis indicated two larvae per plant from a mean of 32.9 beetles per trap with 62.2% of the variance explained and a standard error of 3.49 providing 95% confidence limits of 32.9 +/- 7.0 and values between 25.9 and 39.9 beetles per headland-sited trap. For field-sited traps, regression analysis indicated that two larvae per plant were likely to be attained from a mean of 40.1 beetles per trap with 73.2% of the variance explained and a standard error of 3.19 providing 95% confidence limits of 40.1 +/- 6.32 and values between 33.8 and 46.4 beetles per field-sited trap. Overall for headland and field-sited traps, correct predictive decisions were made at 86% and 90% of sites respectively (as summarised in more detail in Tables 19 & 20) providing similar levels of accuracy to those obtained from the use of four water traps per site. With wider confidence interval values for larval predictions made from beetle catches in two headland or two field-sited traps compared with four traps in total, the accuracy of predictions made from two traps only will often be lower than using four traps per site. A trap catch at the lower, more risk-averse lower 95% confidence limit value of 33.8 beetles per field-sited water trap is recommended for adoption as an alternative method of monitoring should time preclude the use of four traps per site. This value enabled the same number (14 from 17) of correct predictions of the need to treat where larval infestations developed to two or more per plant as the prediction made using the lower 95% confidence interval value obtained from the use of four traps per site.

In autumn 2004 (year 1 of the study only), four vertically-mounted, yellow sticky traps of dimensions 20 x 10 cm were compared with water traps at 27 sites for use as a predictive method to determine larval infestation. Sticky traps caught fewer cabbage stem flea beetles than water traps with means of only 1.3 adults per trap compared with 8.0 per water trap. A significant regression was obtained ($P < 0.001$) with 51.0% of variance explained with two larvae per plant likely to be attained from a mean of 5.7 beetles per sticky trap. Cabbage stem flea beetle larval numbers were low in the first year of the study and infestations greater than two larvae per plant were recorded at two sites only; neither of which were successfully predicted from sticky trap catches. The use of sticky traps provided a poor predictive method compared with water traps, although greater predictive success might have been obtained if higher infestations of cabbage stem flea beetle larvae had been recorded.

Assessments of adult cabbage stem flea beetle feeding damage on plants, cotyledons and first true leaves were made in harvest years 2005 and 2006. During this period, ten sites from a total of 52 developed infestations of two or more larvae per plant. Regression analysis showed that a mean of two larvae per plant was likely to be attained if a mean of 0.65 plants (65%) was damaged by cabbage stem flea beetle adults. Although the regression between larval number and plant damage was significant ($P = 0.006$), it was overall a poor predictor of larval damage with only 14.0% variance explained. Only two sites (sites 35, 45) from ten with infestations greater than two larvae per plant were correctly predicted for treatment from plant damage assessments, providing an overall predictive success of only 20%. A number of sites also showed an obvious incidence of slug damage, notably in autumn 2005, which complicated the damage assessments for cabbage stem flea beetle. Unless obvious slime was present, leaf grazing damage due to slugs could be difficult to separate from the effects of plant damage caused by cabbage stem flea beetle adults.

Regression analysis of larval number against cotyledon damage showed that an infestation of two larvae per plant was likely if a mean of 0.51 cotyledons (51%) was damaged by cabbage stem flea beetle adults. Although a significant (P = 0.017) regression was obtained, only 10.8% of the variance was explained and a predictive method based on cotyledon damage proved to be of poor predictive value with only two sites (sites 35, 45) that justified treatment being predicted accurately from the ten sites that developed a control threshold averaging two larvae per plant.

Damage to the first true leaf was also tested as a predictor of larval damage. As a non significant (P = 0.334) regression was obtained with only 1.5% of variance explained, this method had no value as a predictive method in this study with none of the sites that developed infestations greater than two larvae per plant being successfully identified for treatment.

In autumn 2006, rectangular traps of dimensions 40 x 30 cm and a water surface area of 1,200 cm^2 were compared with 25 cm diameter round traps with a water surface area of 491 cm^2 at three sites in the Midlands. At two sites, total catches during September and October in 'large' and 'small' traps were similar, indicating that the method was insensitive to trap size. However, in a vigorously-established oilseed rape crop at a third site, the total catch in the large traps was greater than in the round traps possibly because the smaller traps became partially overgrown by crop foliage. As the results were inconclusive for trap size comparisons, more sites would have been required to investigate this aspect more thoroughly. It was, however, determined that round traps 25 cm in diameter were effective at catching cabbage stem flea beetle adults and that mean numbers of larvae per plant were significantly correlated with mean number beetles per water trap.

Thus, the key objective of this HGCA-funded study was met in terms of ability to predict the need for control of cabbage stem flea beetle larvae from catches of adult beetles in water traps. As only 1.5 litres of water were required per 25 cm diameter trap compared with six litres per large rectangular trap, the smaller traps were found to be much more convenient to use in the field than the larger traps. It is therefore recommended that the use of round, yellow water traps of 25 cm in diameter offered a convenient and easily used method of recording adult cabbage stem flea beetle activity for predictive purposes. As the effect of trap size was lower than expected, small variations of trap size would be unlikely to jeopardise the predictive method using yellow water traps.

The effects of plant population on larval numbers were tested at two sites, one in Shropshire and the second in North Yorkshire, in harvest year 2007. At the first site, infestation levels for cabbage stem flea beetle larvae in normally-established crop areas (mean of 36.4 plants/m^2) were compared with infestation levels in crop areas where a low plant population had established naturally (mean of 17.2 plants/m^2). Mean number of larvae per plant averaged 8.1 per plant in the normally-established plant population area compared with a mean of 4.3 larvae per plant in the low plant population area. It is possible that the low plant population areas proved less attractive to adult beetles in the autumn with the result that fewer eggs were laid in sparse crop areas.

At the second site in North Yorkshire being used in the plant population study, infestation levels for cabbage stem flea beetle larvae in normally-established crop areas (mean 49.4 plants/m^2) were compared with infestation levels in crop areas where a low plant population (mean of 21.2 plants/m^2) was achieved by artificial removal of 50% of plants by hoeing at an average four leaf stage. Mean number of larvae per plant averaged 14.9 per plant in the normally-established plant population area compared with 21.9 larvae per plant in the low plant population area. Assuming that similar numbers of eggs had been laid in the normal and artificially-reduced plant population areas, fewer plants were available for larval invasion in the reduced-population area with the result that larval infestation per plant was nearly 50% greater where plants had been removed.

The contrasting results from a preliminary investigation of the effect of plant population on cabbage stem flea beetle larval infestations indicated that more detailed studies would be required to clarify the effects of plant density on infestation incidence.