Timing of Insecticide Application for Cabbage Maggot Control in Seeded Turnip on the Central Coast of California

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Timing of Insecticide Application for Cabbage Maggot[1] Control in Seeded Turnip on the Central Coast of California

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Abstract. Because infestation by cabbage maggot, *Delia radicum* (L.), does not peak immediately after planting seeds, experiments in 2014 and 2015 determined the effect of timing insecticide application for control on direct-seeded turnip, *Brassica rapa* var. *rapa* (L.). Treatments were one chlorpyrifos application either at planting or 2 weeks after planting. Twenty turnip roots were sampled three times starting 2 weeks after the second application. Roots were evaluated for the number of roots infested with cabbage maggots and severity of damage on a scale of 0 = no injury, through 9 = no root hairs or >90% root destroyed. In both years, incidence of cabbage maggot was significantly less in turnip roots treated with insecticide 2 weeks after planting than at planting. Implications of these results for management of cabbage maggot on the Central Coast of California are discussed.

Introduction

Cabbage maggot, *Delia radicum* (L.) (Diptera: Anthomyiidae), is a destructive pest of crucifers, worldwide (Coaker and Finch 1971), and has become an important pest causing severe yield loss on the Central Coast of California (Joseph and Martinez 2014). The annual value of cruciferous crops is >US$1 billion in California (USDA NASS 2016). In the Salinas Valley of California, cruciferous crops are grown on >34,408 ha and valued at >US$679 million (Monterey County Crop Report 2014). Crucifer crops damaged by cabbage maggot are broccoli (*Brassica oleracea* var. *italica* Plenck), cauliflower (*B. oleracea* L. var. *botrytis*), cabbage (*Brassica oleracea* L. var. *capitata* L.), broccoli raab (*Brassica rapa* L. subspecies *rapa*), and Brussels sprouts (*Brassica oleracea* L. var. *gemmifera*). The crops are produced year around on the Central Coast of California. Cabbage maggots are found in crucifer crops and crucifer weeds (Johnsen and Gutierrez 1997, SVJ unpublished data).

Cabbage maggot flies lay eggs in the soil around the base of a plant. A single female can lay 300 eggs under laboratory conditions (Finch 1974). Legless, 8-mm-long, white maggots feed on the taproot and affect plant development. After feeding for about 3 weeks, the maggot pupates in the surrounding soil for 2-4 weeks before emerging into an adult fly (Harris and Svec 1966). The most common above-ground symptoms of cabbage maggot in the root are yellowing, stunting, and slow growth (Natwick 2009).

[1](Diptera: Anthomyiidae)

In other crucifer-growing regions, cabbage maggot pupae diapause during the winter months, which enabled researchers to accurately determine emergence of adult flies in the spring and for the subsequent generations (Walgenbach et al. 1993, Jyothi et al. 2003, Dreves et al. 2006). However, on the Central Coast of California, cabbage maggot pupae rarely undergo diapause because the temperature rarely is below freezing (Johnsen and Gutierrez 1997) in winter (December through March). This unique environment possibly enables cabbage maggot flies to remain active even in winter, producing multiple overlapping generations throughout the year. Research on the Central Coast of California showed that infestation by cabbage maggots in direct-seeded broccoli could be severe throughout the growing period, except the first 30 days after seed was planted (Joseph and Martinez 2014). Typically, insecticide targeting cabbage maggot is applied immediately after planting seeds and before irrigation by sprinkler. Efficacy studies with at-planting application of insecticide failed to reduce infestation by cabbage maggot (Joseph 2014). This suggested that insecticide applied at planting might be early relative to cabbage maggot phenology and thus, delaying application might be more effective. Research showed that cabbage maggots can be suppressed for more than 1 month after application of organophosphate insecticide, particularly chlorpyrifos, because residue persisted for an extended period (Getzin 1985, Chapman and Chapnan 1986). The objective of the study was to determine effects of insecticide on cabbage maggot when applied once either at-planting or a few weeks later.

Materials and Methods

The study was done in a commercial planting of 'Tokyo' baby turnip (*Brassica rapa* var. *rapa* L.) near Prunedale, CA, in 2014 and 2015. The baby turnip crop is typically harvested within 2 months after planting seed. Turnip seeds were planted directly into six lines on 203.2-cm beds. The seeds were densely planted so spacing between plants was ~2 cm or less. The experimental plot was a single, 203.2-cm bed 300 m long.

The treatments were one chlorpyrifos application at 1367.12 g per ha at planting and 2 weeks after planting seeds. The treatments were replicated five times in a randomized complete block design. A tractor-mounted sprayer was used to broadcast insecticide with 560.7 liters of water per hectare. The experiment was done twice in 2014 and once in 2015 on different lots in the same commercial field. The first experiment was planted on 21 April 2014, and at-planting and 2-week after planting insecticidal treatments were applied on 21 April and 5 May, respectively. The second experiment in 2014 was planted on 19 June, and insecticide was applied on 19 June (at planting) and 5 July (2 weeks after planting). In 2015, the experiment was planted on 26 March and insecticide applied on 26 March and 11 April at planting and 2-week after planting, respectively. Plants treated at planting were not treated 2 weeks after planting and vice versa.

Twenty samples of turnip roots were collected from each replication 2 weeks after the second treatment. For all three experiments, three samples were collected 1 or 2 weeks apart, and a final sample was collected near harvest. Samples for the first experiment in 2014 were collected on 19 May and 3 and 9 June, whereas, for the second experiment in 2014, samples were collected on 22 July and 8 and 20 August. In 2015, samples were collected on 24 April and 1 and 8 May. Samples were transported in plastic bags to the University of California Cooperative

Extension Entomology laboratory where roots were evaluated for damage by cabbage maggot.

Evaluated were the number of roots with cabbage maggot-feeding damage (of 20 plants sampled) and severity of injury on all roots. A scale was used to determine severity of damage by cabbage maggot; a root was scored 0, not infested; 1, infested or >90% root hairs present; 2, 80-90% root hairs present; 3, 70-79% root hairs present; 4, 60-69% root hairs present; 5, 50-59% root hairs present or <25% root destroyed; 6, 40-49% root hairs present or 25-49% root destroyed; 7, 30-39% root hairs present or 50-74% root destroyed; 8, 20-29% root hairs present or >75-89% root destroyed; or 9, no root hairs present or >90% root destroyed. The scale values from 20 plant roots were averaged for each replication. Student's *t*-test with PROC TTEST in SAS (2012) ($\alpha = 0.05$) was used to analyze data on number of injured roots and average severity of injury for each sample date in all experiments. Means and standard error were calculated using PROC MEANS in SAS.

Results and Discussion

In the first experiment in 2014, the number of roots infested with cabbage maggot larvae was not significantly different between application timing treatments in the first, second, or third (Fig. 1A) samples. Severity of injury by cabbage maggot was significantly greater when treated at planting than 2 weeks later in the first ($t = -2.5$, df = 8, $P = 0.036$) and second ($t = -3.2$, df = 8, $P = 0.014$) samples but not between treatments in the third sample (Fig. 1B).

In the second experiment in 2014, the number of cabbage maggot-infested roots was significantly greater when treated at planting than 2 weeks after planting for the second sample ($t = -3.6$, df = 8, $P = 0.019$); however, the first and second samples were not significantly different between treatments (Fig. 2A). Cabbage maggot damage to roots was significantly more severe when insecticide was applied at planting than 2 weeks after treatment during the second ($t = -2.9$, df = 8, $P = 0.019$) and third ($t = -3.1$, df = 8, $P = 0.015$; Fig. 2B) samples. Severity of damage by cabbage maggot larvae was not significantly different between treatments of the first sample. In 2015, incidence and severity of feeding injury were significantly different only in the third sample (incidence: $t = -6.1$, df = 8, $P < 0.001$; severity: $t = -5.4$, df = 8, $P < 0.001$) but similar between treatments in the first and second samples (Fig. 3).

Results suggested that delayed application of effective insecticide suppresses cabbage maggot. In a previous study, Joseph and Martinez (2014) showed cabbage maggot flies did not lay many eggs at the base of crucifer plants until 3 weeks after plant emergence, despite adult cabbage maggots in the field during early stages of plant development. Also, infestation by cabbage maggot tends to be continuous after the 3-week stage depending on local pest pressure and crop disturbances (e.g., harvest) in surrounding fields (Joseph and Martinez 2014). In this study, severity of injury between at-planting and delayed treatments was diffused by the third sample possibly because of severe infestation during the later stages of crop development. Severe early infestation by maggots can cause serious stand loss (SVJ unpublished data). Typically in the Salinas Valley, insecticide targeting cabbage maggot is applied immediately after seeds are planted.

Although chlorpyrifos residue persists for more than a month after application (Getzin 1985, Chapman and Chapman 1986), it can leave the site through run-off

(Hunt et al. 2003). Delaying insecticide application would increase the likelihood of intercepting cabbage maggot larvae seeking roots. In the Salinas Valley of California, use of organophosphate insecticides including chlorpyrifos is regulated (CEPA 2013). This stringent regulation is forcing growers to seek alternate insecticides for cabbage maggot control. Previous study showed clothianidin, thiamethoxam, and spinetoram as well as pyrethroid insecticides such as zeta-

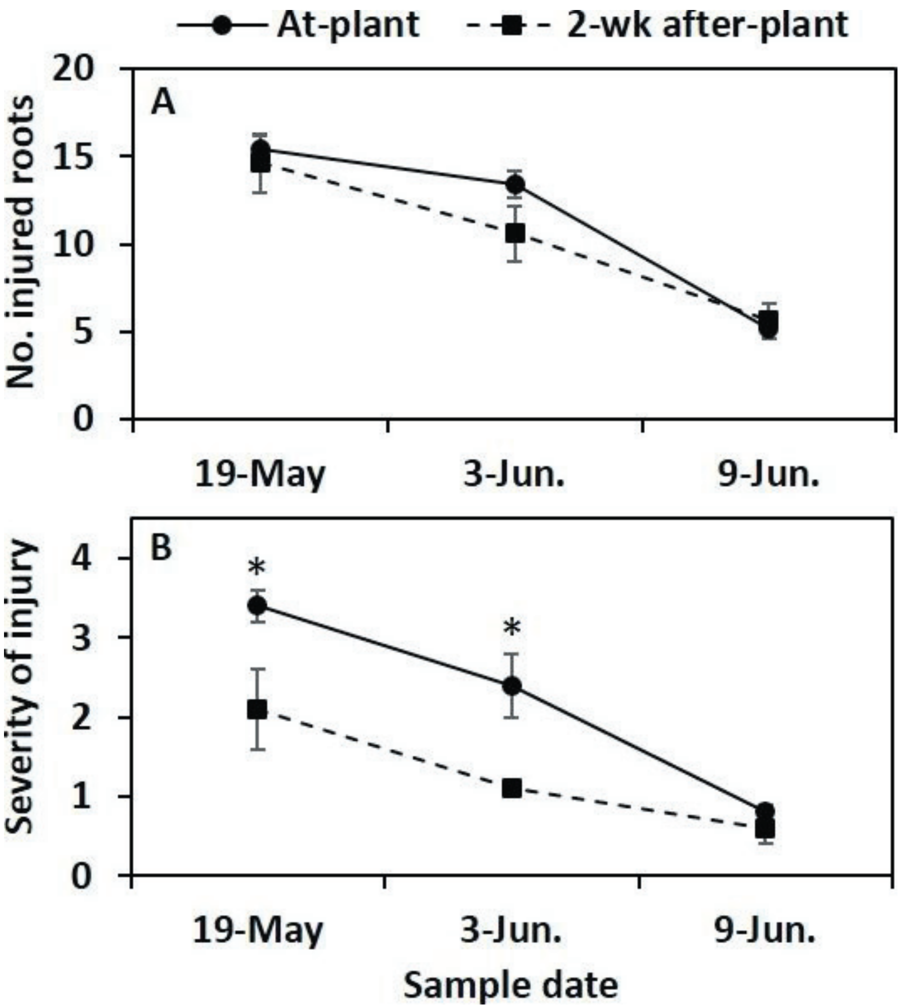

Fig. 1. Mean (± SE) number of cabbage maggot-infested roots per plot (A) and average severity of cabbage maggot injury per plot (B) in the first 2014 experiment. The notations above pairs of chlorpyrifos application timing indicate significant difference (*P*: * <0.05; ** <0.01, and *** <0.001) at α = 0.05 (Student's *t*-test).

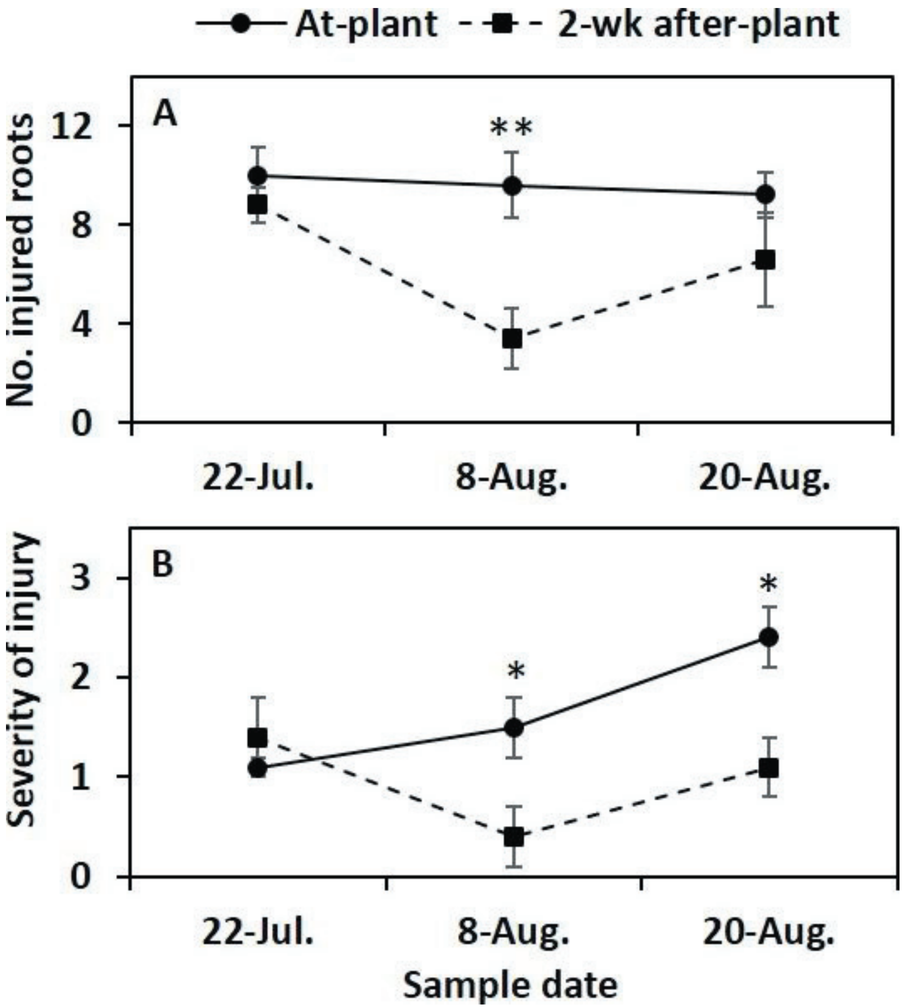

Fig. 2. Mean (± SE) number of cabbage maggot-infested roots per plot (A) and average severity of cabbage maggot injury per plot (B) in the second 2014 experiment. Notations above pairs of chlorpyrifos application timings indicate significant difference (*P*: * <0.05; ** <0.01, and *** <0.001) at α = 0.05 (Student's *t*-test).

cypermethrin, fenpropathrin, bifenthrin, lambda-cyhalothrin, and pyrethrins were effective against cabbage maggot larvae, and efficacy was comparable to chlorpyrifos (Joseph and Zarate 2015). However, alternate insecticides are less persistent because they break down quickly (e.g., spinetoram) or become immobile in soil because they bind to organic matter in contact (e.g., pyrethroid insecticides). Thus, as fewer effective older chemistries (e.g., organophosphate insecticides) are used against cabbage maggot because of use restrictions, delayed application of insecticide is more critical.

The experiments were in commercial turnip fields persistently infested by cabbage maggot. Turnip was selected because cabbage maggot-feeding injury on turnip is clear and could be accurately documented. Insecticide was applied using a commercial sprayer to simulate grower standard.

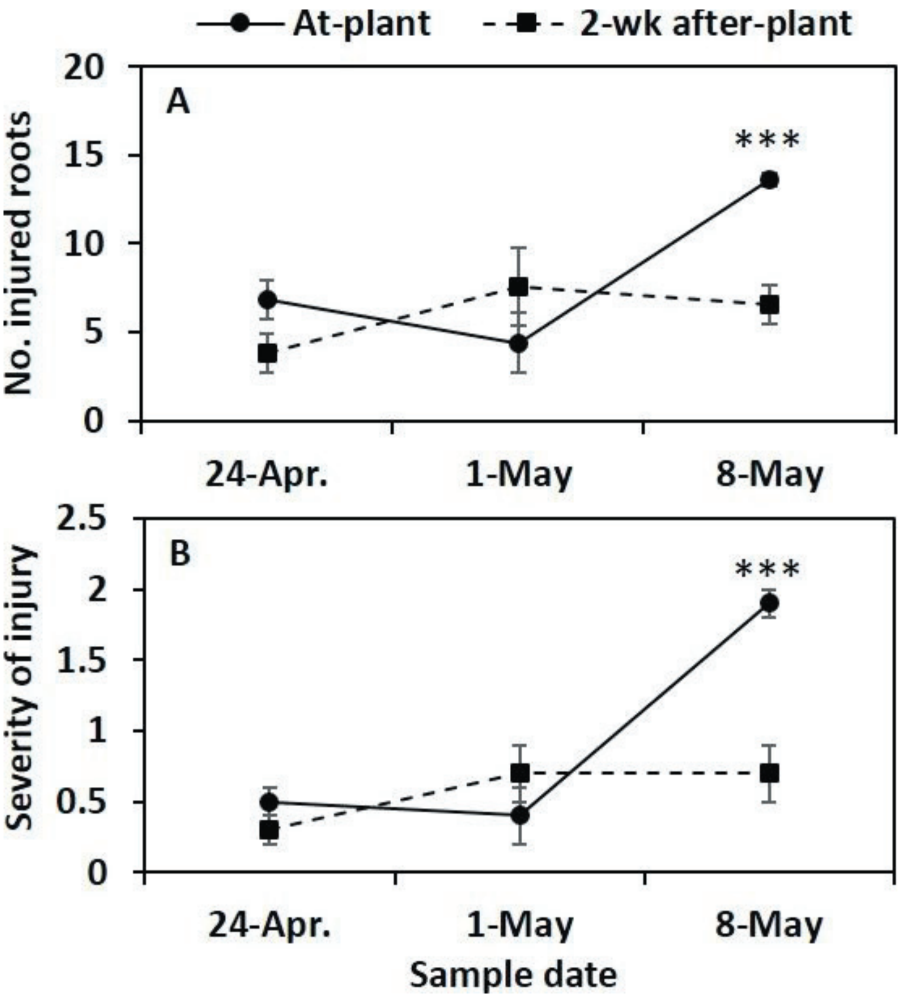

Fig. 3. Mean (± SE) number of cabbage maggot-infested roots per plot (A) and average severity of cabbage maggot injury per plot (B) in 2015 experiment. The notations above pairs of chlorpyrifos application timings indicate significant difference (*P*: * <0.05; ** <0.01, and *** <0.001) at $\alpha = 0.05$ (Student's *t*-test).

In conclusion, data showed a delayed insecticide application (opposed to at-planting) would improve cabbage maggot control in direct-seeded crucifer in the Salinas Valley. It is not clear if transplanted crucifer would benefit from delayed insecticide application because bigger plant size of transplants likely influence invading cabbage maggot flies that probably use visual and olfactory cues to locate hosts to lay eggs (Hawkes et al. 1978, Prokopy et al. 1983). Future research will examine feasibility of integrated tactics such as the cultural and biological control strategies with timing of insecticide application to manage cabbage maggot.

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