Crop Protection 67 (2015) 102–108

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Evaluation of insecticides and application methods to protect onions from onion maggot, *Delia antiqua*, and seedcorn maggot, *Delia platura*, damage

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ARTICLE INFO

Article history:
Received 27 June 2014
Received in revised form
3 October 2014
Accepted 7 October 2014
Available online

Keywords:
Delia antiqua
Delia platura
Allium cepa
Seed treatment
Spinosad

ABSTRACT

Onion maggot, *Delia antiqua* (Meigen), and seedcorn maggot, *Delia platura* (Meigen), are important pests of spring-sown onions, *Allium cepa* L. Larvae of both species feed on developing epicotyls and roots of young onion plants often resulting in seedling mortality. Cultural controls used in combination with the insecticide chlorpyrifos are currently the standard practice for maggot control in the western USA. However, cultural controls are only partially effective and reliance on chlorpyrifos has several potential problems including future availability and development of resistance. Insecticides including clothianidin, imidacloprid, spinosad, and thiamethoxam were evaluated in California, USA in 2011–2013 to identify efficacious alternatives to chlorpyrifos. Some insecticides were applied in multiple ways including seed treatment, in-furrow application at planting, and rototiller incorporation prior to planting. Onion plant population, vigor, and yield were measured to assess insecticide efficacy. Maggots reduced onion plant populations by more than 65% of the seeding rate in the untreated controls. Seed treatments with spinosad or clothianidin + imidacloprid were the best alternative to chlorpyrifos for minimizing onion mortality from maggot feeding. Onions treated with both seed treatments had similar or higher plant populations and bulb yields compared to chlorpyrifos. The efficacy of spinosad was greatly improved when applied as a seed treatment compared to an in-furrow application at planting or when incorporated into the soil with a rototiller prior to planting. Spinosad seed treatment increased onion plant populations by 256%, 76%, and 853% compared to untreated controls in 2011, 2012, and 2013, respectively. Conversely, in-furrow and rototill-incorporated applications of spinosad were similar to the untreated control in terms of onion plant population and yield. Seed treatments with newer chemistries could provide an efficacious alternative to chlorpyrifos for protecting onions from maggot damage in western onion production systems.

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1. Introduction

Onion maggot, *Delia antiqua* (Meigen), and seedcorn maggot, *Delia platura* (Meigen), are devastating pests in spring-seeded onions (*Allium cepa* L.) grown in California and the western USA (Orloff et al., 2010; Rinehold et al., 2013). Most western growers use a preventive insecticide application at planting along with cultural controls to prevent crop loss. Granular or liquid formulations of chlorpyrifos applied in-furrow at planting have been the predominant insecticide for maggot control (Orloff et al., 2010; Reiners and Petzoldt, 2004; Rinehold et al., 2013). Chlorpyrifos has been effective for maggot control, but relying solely on chlorpyrifos places great selection pressure on western maggot populations to develop resistance similar to other parts of North America (Carroll et al., 1983; Harris and Svec, 1976). Regulation restricting chlorpyrifos use in California due to detection in surface water is also a possibility which could leave western onion growers with few tested alternatives if chlorpyrifos is phased out.

Economic damage from maggot feeding in California onion fields was documented as early as 1942 (Lange, 1944). Both maggot species have multiple generations per year (Eckenrode et al., 1975; Rinehold et al., 2013). First generation larvae cause the greatest

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http://dx.doi.org/10.1016/j.cropro.2014.10.002
0261-2194/Published by Elsevier Ltd.

economic damage by feeding on developing epicotyl and roots of seedling onion often resulting in plant death and significant reduction in onion stand density (Taylor et al., 2001). Second and third generation onion maggots feed on expanding onion bulbs typically causing minimal economic loss unless onions are diseased, as maggots have difficulty penetrating healthy, older onion plants (Eckenrode and Nyrop, 1986).

Management recommendations for maggot in most onion-production areas are focused on a combination of cultural controls and insecticide application at planting because non-chemical control measures alone usually do not adequately prevent economic damage (Orloff et al., 2010; Rinehold et al., 2013). Disposal of onion residue and cull piles, avoidance of fields with undecomposed organic matter, and refraining from successive onion crops without crop rotation are effective cultural controls that reduce onion maggot overwintering success and discourage *Delia* oviposition in onion fields (Orloff et al., 2010; Rinehold et al., 2013). Planting in conditions that favor rapid onion emergence and delaying planting until later in spring can also lessen the severity of maggot damage (Eckenrode et al., 1975; Nault et al., 2011).

Onion seed treatments with clothianidin, cyromazine, fipronil, and spinosad were shown to effectively control onion maggot in New York, USA and Ontario, Canada (Hoepting et al., 2004; Nault et al., 2006a; Taylor et al., 2001). Seed treatments offer several advantages including alternative modes of action to chlorpyrifos and less active ingredient per unit area compared to in-furrow drench. In addition a spinosad seed treatment provides organic growers with an effective insecticide option (Nault et al., 2006a).

The efficacy of alternative insecticides in California is unknown because onion production practices, soil, climate, and seedcorn maggot pressure differ considerably from northeastern USA. In California, onions are primarily grown with sprinkler and drip irrigation and approximately half the acreage is planted at high densities for dehydration processing into flake and powder (Voss and Mayberry, 1999). Seedcorn maggot is a significant pest in California (Schwartz and Mohan, 2008; Smith et al., 2011), thus California growers need to control both seedcorn maggot and onion maggot, unlike some other production areas.

The focus of this research was to evaluate insecticides and insecticide application methods for management of onion maggot and seedcorn maggot in processing onions. Specific objectives were to: a) identify alternatives to chlorpyrifos b) compare the efficacy of seed treatment and in-furrow application of spinosad and neonicotinoid insecticides, and c) determine the compatibility of insecticide seed treatments with fungicides and insecticides commercially applied at planting.

2. Materials and methods

Experiments were conducted at the University of California Intermountain Research and Extension Center (IREC) in Tulelake, California in 2011, 2012, and 2013. The soil type at all three sites is classified as Tulebasin mucky silty clay loam. Organic matter content at all sites ranged from 4 to 5%. The preceding crop at each site was four to five year old established alfalfa that was rototilled and incorporated into the soil two to three months before planting onions. Fields with established alfalfa as the preceding crop were intentionally selected due to the abundance of decaying organic matter in the form of alfalfa crowns and roots. Seedcorn maggot adults are attracted to recently incorporated decaying alfalfa residue (Hammond, 1990), and onion stand loss from maggots is commonly observed in Tulelake onion fields following alfalfa stand removal. The study was conducted on a maggot population with no documented resistance to chlorpyrifos or other insecticide modes of action. Maggot susceptibility to chlorpyrifos is further supported by data that demonstrated greater than 80% onion stand establishment in multiple onion weed control trials conducted at IREC from 2011 to 2013 when treated with chlorpyrifos in-furrow (unpublished data).

Onions were direct seeded matching industry standard practice on May 2, April 28 and April 20 in 2011, 2012, and 2013, respectively. A proprietary American long-day processing onion variety was grown on beds 91 cm wide with four seed-lines spaced 15 cm apart. Plot size in all studies was two beds wide (1.8 m) and 7.6 m long. Onion seed was planted using a custom-made, two-bed vegetable cone planter calibrated for a 5 cm in-row seed spacing and 18 mm seeding depth. Seeds were counted so that the same number of seeds was planted in every plot. This allowed for an accurate stand evaluation and assessment of stand loss resulting from maggot feeding. The seeding rate was 86 seeds per 1 m^2 taking in to account seed lot germination. Germination of the seed lots was 93, 86, and 87% for 2011, 2012 and 2013, respectively. Onions were irrigated with solid-set sprinklers to assure uniform onion emergence and match crop evapotranspiration for the remainder of the growing season. Total applied water was 56, 62, and 78 cm for 2011, 2012, and 2013 respectively. Fertilizer was applied according to pre-plant soil test recommendations (Voss and Mayberry, 1999). Weeds were controlled with herbicides and hand-weeding to prevent weed competition. Foliar sprays of spirotetramat and spinetoram were alternated for a total of three or four applications starting at the seven to nine leaf onion growth stages to keep onion thrips, *Thrips tabaci* Lindeman and western flower thrips, *Frankliniella occidentalis* Pergande populations below 20 thrips per plant.

2.1. Insecticide treatments and application methods

Treatments were arranged in a completely randomized design with six replications. A list of insecticide treatments and rates is presented in Table 1. Seed treatments were applied using a seed coating employing a binder and filler termed, entrustment, as described in Taylor (2003). All seed, including that not treated with insecticide, were treated with thiram at 188 mg ai/100 g (Thiram 42S®, Bayer CropScience LP, Research Triangle Park, NC, USA) using the same seed coating method to manage pathogens that cause damping-off during establishment. The one exception was the raw seed treatment where seed was left completely untreated as a control. In-furrow liquid insecticides were applied using Teejet TP8001EVS nozzles (Teejet Technologies, Wheaton, IL, USA) and granular insecticides were applied with a Gandy fertilizer row applicator (Gandy Company, Owatonna, MN, USA) mounted on the onion planter to apply an 8 cm band directly over the surrounding soil after seed placement but before furrow closure. Rototill incorporated treatments were applied two days before planting using Teejet XR8002VS nozzles that broadcast insecticides immediately before incorporation and bed shaping using a Johnson Plantavator (Johnson Manufacturing, Woodland, CA, USA).

The compatibility of spinosad seed treatment with commercial insecticides and fungicides applied at onion planting was tested in 2013 to assure local onion growers that the in-furrow treatments did not negatively influence the efficacy of spinosad. Some growers expressed concern that the in-furrow treatment might wash off or dilute the insecticide seed coating. The commercial fungicides and insecticides were applied using grower standard practice and included chlorpyrifos, imidacloprid, oxamyl, and tebuconazole.

2.2. Environmental conditions and adult trapping

Weather and accumulated degree-day data were recorded each year. Weather data is available on the California Irrigation