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Research paper

Evaluating integrated pest management tactics for onion thrips and pathogens they transmit to onion

Ashley Leach[a,*], Stephen Reiners[b], Marc Fuchs[c], Brian Nault[a]

[a] Department of Entomology, Cornell University, New York State Agricultural Experiment Station, 630 W. North Street, Geneva, NY 14456, United States
[b] Horticulture Section, School of Integrative Plant Science, Cornell University, New York State Agricultural Experiment Station, 630 W. North Street, Geneva, NY 14456, United States
[c] Plant Pathology and Plant-Microbe Biology Section, School of Integrative Plant Science, Cornell University, New York State Agricultural Experiment Station, 630 W. North Street, Geneva, NY 14456, United States

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ABSTRACT

Onion thrips (*Thrips tabaci*) is a significant pest of onion worldwide, causing both direct and indirect damage to the crop. Integrated pest management of onion thrips should improve profitability and sustainability of onion production. Promising management approaches include reducing nitrogen application rates, using thrips-resistant cultivars and implementing action threshold-based insecticide programs. However, the impact of these integrated pest management approaches on thrips densities and damage, crop yield, and thrips-associated plant diseases like iris yellow spot (IYS) (caused by *Iris yellow spot virus*) and bacterial center rot (caused by *Pantoea agglomerans* and *P. ananatis*) remains largely unknown. In a two-year field trial in New York, combinations of varying levels of nitrogen applied at planting (67, 101 and 140 kg ha^{-1}) and different insecticide programs (standard weekly insecticide program and action threshold-based insecticide program) were evaluated for onion thrips management in onion cultivars that had moderate resistance ('Avalon'), low resistance ('Delgado') and no resistance ('Bradley') to onion thrips. Results indicated that regardless of cultivar, nitrogen did not affect larval thrips densities, onion yields, IYS or bacterial center rot. Across all cultivars, insecticide use (both programs) significantly reduced larval thrips densities and damage, IYS severity and incidence, and increased onion yield. Insecticide use did not consistently affect the incidence of bacterial center rot. Both insecticide programs reduced onion thrips larval densities by 60–81% relative to the untreated control, but the action threshold-based application program used 2.8 fewer applications than the standard program. 'Avalon' had low thrips densities and IYS disease, but required the same number of insecticide applications as 'Bradley'. Onion yields in both insecticide programs were statistically similar in both years, and bulb weights averaged 10–54% more than those in the untreated control. Our results indicated that growers can reduce nitrogen levels at planting and insecticide use without compromising control of either onion thrips or IYS disease or onion bulb yields.

1. Introduction

Integrated insect pest management often addresses the direct effects of insect feeding damage to a crop, but does not consider the impacts of indirect effects such as those arising from plant pathogen-insect interactions. Onion thrips (*Thrips tabaci* Lindeman) is an example that exacts both direct and indirect effects on its host, onion (*Allium cepa* L.). Severe infestations of onion thrips can account for substantial onion yield reductions if unmanaged (Fournier et al., 1995; Nault and Shelton 2008; Rueda et al., 2007). As a direct pest, onion thrips adults and larvae feed on onion leaves, decreasing photosynthetic potential, and thereby reducing bulb size (Boateng et al., 2014; Lewis 1997). Damage to leaves also induces physiological stress, which accelerates leaf senescence (Kendall and Bjostad, 1990; Levy and Kedar, 1970) and reduces bulb size. Bulb weight losses as high as 60% have been reported from onion thrips damage (Rueda et al., 2007), which tends to vary based on location, severity of infestation, and environmental stress (see review by Gill et al., 2015).

As an indirect pest of onion, onion thrips has been associated with an array of viral, bacterial and fungal plant pathogens (Dutta et al., 2014; Gent et al., 2006; McKenzie et al., 1993). Onion thrips is the principal vector of the economically significant tospovirus, *Iris yellow spot virus* (IYSV) (genus *Tospovirus,* family *Bunyaviridae*), which reduces size and quality of bulbs (Gent et al., 2004; Muñoz et al., 2014). Under

* Corresponding author.
E-mail address: al2282@cornell.edu (A. Leach).

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severe IYSV infections, lesions coalesce and girdle onion leaves, thus inhibiting onion development. Damage by IYSV can range from insignificant to complete yield loss (i.e., no marketable bulbs) (Gent et al., 2006). In a study conducted in Colorado, annual incidence of IYSV varied from 6 to 73% over three years (Gent et al., 2004). Similarly, in New York, Hsu et al. (2010) reported varying IYSV incidences from 0% to 97% over two years. Managing the vector, onion thrips, is currently the primary means for reducing IYSV incidence and severity (Bag et al., 2015; Gent et al., 2006).

Onion thrips also transmits bacterial center rot pathogens (*Pantoea agglomerans* and *P. ananatis*) to onion (Dutta et al., 2014). Center rot is a significant disease that can impact onions in the field and storage. Dutta et al. (2014) isolated both bacterial species in the midgut and feces of adult onion thrips. Subsequent transmission experiments indicated that adults could successfully transmit the pathogen to onion seedlings, with approximately 30 to 70% of seedlings becoming infected. Even when thrips do not directly transmit bacteria, their feeding creates wounds in which pathogenic bacteria likely enter. While bacterial center rot incidence can be variable, bulb yield losses upwards of 75% have been reported in New York (Stivers, 1999). The role that onion thrips management has on the incidence and severity of onion diseases like iris yellow spot (IYS) and bacterial bulb rots has not been thoroughly examined.

Insecticide use is the most common management practice to control onion thrips in commercial onion production (Gill et al., 2015). In many cases, insecticides are exclusively relied upon to manage onion thrips infestations. However, in the past two decades, onion thrips have developed resistance to three chemical classes: pyrethroids, carbamates, and organophosphates. Resistance to these insecticides has been observed in many countries including the United States, Canada, New Zealand, and Australia (Herron et al., 2008; MacIntyre-Allen et al., 2005; Martin et al., 2003; Shelton et al., 2003, 2006). Utilizing multiple management techniques should not only slow the onset of insecticide resistance in onion thrips populations, but also limit harmful environmental effects that may arise from excessive insecticide applications. There are many different pest management techniques that have been reported to control onion thrips infestations (Gill et al., 2015). However, in commercial onion production, the amount of nitrogen applied, cultivar selection, and the type and frequency of insecticides applied have offered the greatest potential for reducing damage by onion thrips and associated plant diseases. Moreover, these management tactics are practical and most likely to be adopted by growers.

Appropriate levels of nitrogen during the growing season are critical to the establishment and development of the onion crop. However, excessive amounts of nitrogen fertilizer have been associated with greater onion thrips densities (Buckland et al., 2013; Malik et al., 2009). Buckland et al. (2013) found that onions treated with 134 kg N ha^{-1} had 23–31% fewer onion thrips than those onions treated with 402 kg N ha^{-1}. Similarly, Malik et al. (2009) reported nearly twice as many thrips on onions supplemented with 200 kg N ha^{-1} compared with 50 to 150 kg N ha^{-1}. Thus, applying low levels of nitrogen fertilizer at onion planting may be an integral component of an onion thrips management program.

Currently, there are no onion cultivars that are completely resistant to onion thrips feeding, but some cultivars are partially resistant and suffer less feeding damage with little to no effect on bulb size. Both leaf waxiness and color have been reported to affect onion thrips densities. Cultivars with yellow-green leaves tend to be ‘semi-glossy’ and support fewer onion thrips, whereas those ‘waxy’ cultivars with blue-green leaves tend to have greater levels of epicuticular wax and are highly susceptible to onion thrips (Boateng et al., 2014; Diaz-Montano et al., 2012a). Damon et al. (2014) found that cultivars with blue-green leaves typically had a high amount of cuticular wax containing the ketone hentriacontanone-16 (H16), and onions with yellow-green, semi-glossy leaves had less cuticular wax and low levels of the H16 ketone. Thus, yellow-green, ‘semi-glossy’ onion cultivars should be included in an onion thrips management program.

The use of thresholds to manage onion thrips in onion has been examined for the past three decades (Fournier et al., 1995; Nault and Huseth, 2016; Rueda et al., 2006; Shelton et al., 1987). Consistently, researchers have reported that insecticides applied following action thresholds can provide effective thrips control. Hoffmann et al. (1995) found that an action threshold-based insecticide program provided equivalent thrips control as a standard insecticide program, but the action threshold-based program reduced insecticide applications by 37%. Nault and Huseth (2016) also compared an action threshold-based insecticide program with a standard insecticide program (weekly applications) and found equal levels of thrips control, but the action threshold-based program reduced insecticide applications between 34 and 46%. Additionally, onion bulb weights were equivalent following the standard and action threshold-based programs.

The purpose of our study was to 1) examine the effect of an integrated pest management program that combined the aforementioned thrips management techniques (low nitrogen rate at planting, thrips-resistant onion cultivar, and an action threshold-based insecticide program) on onion thrips densities, damage and onion yield, and 2) examine the effect of this integrated pest management program on the incidence and severity of two thrips-associated plant diseases, iris yellow spot and bacterial rot, in onion. We hypothesized that a reduced rate of nitrogen paired with an action threshold insecticide program would provide effective thrips and disease management without compromising marketable yield. Moreover, we expected the greatest reduction in agri-chemical input (lower amount of nitrogen and fewer insecticide applications) in the cultivar with the highest resistance to thrips.

2. Materials and methods

2.1. Experimental design

Field studies were conducted on a commercial onion farm near Elba, NY in 2015 and 2016. Soil type at the test sites was ‘Carlisle’ muck (NRCS, 2016). Three onion cultivars ranging from moderate levels of resistance to no resistance to onion thrips were chosen based on their leaf waxiness and color (Damon et al., 2014; Diaz-Montano et al., 2012a). ‘Avalon’ (Crookham Co., Caldwell, ID) has yellow-green, semi-glossy foliage and has a moderate level of resistance to thrips, while ‘Delgado’ (Bejo Seeds, Inc., Oceano, CA) has green, semi-glossy foliage and has a low level of resistance to thrips. ‘Bradley’ (Bejo Seeds, Inc., Oceano, CA) has blue-green, waxy foliage and is highly susceptible to thrips. All cultivars are intermediate to long-day, yellow onions with similar days to harvest; ‘Avalon’ matures in 115 days, ‘Delgado’ in 118 days and ‘Bradley’ in 118 days. Fields were planted using a vacuum seed planter with approximately 646,000 onion seeds per hectare on 28 Apr 2015 and 16 Apr 2016. Seeds were treated with FarMore FI500 (mefenoxam [0.15 g ai/kg of seed], fludioxonil [0.025 g ai/kg of seed], azoxystrobin [0.025 g ai/kg of seed], spinosad [0.2 mg ai/seed] and thiamethoxam [0.2 mg ai/seed]) and Pro-Gro (carboxin [7.5 g ai/kg of seed] and thiram [12.5 g ai/kg of seed]) to improve plant establishment by protecting seedlings from maggots (*Delia* spp.) and seedling diseases.

Because each cultivar has a different yield potential, bulb yields were not compared among cultivars. Therefore, each cultivar was planted into separate blocks that were 28 m x 40 m. All three blocks were contiguous and separated from each other by only 1–3 m. Within each cultivar, there were nine treatments in a 3 (nitrogen rate) x 3 (insecticide program) factorial. Nitrogen rates were 67, 101 and 140 kg ha^{-1}; insecticide programs were standard weekly applications, applications based on an action threshold and an untreated control. Nitrogen rates were chosen according to current grower practices and management guidelines in New York: 140 kg N ha^{-1} (standard rate), 101 kg N ha^{-1} (28% reduction from the standard rate), and 67 kg N ha^{-1} (52% reduction from the standard rate) (Reiners and