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Thrips tabaci (Thysanoptera: Thripidae) and *Iris yellow spot virus* Associated with Onion Transplants, Onion Volunteers, and Weeds in Colorado

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Abstract. Infestation by onion thrips, *Thrips tabaci* Lindeman, was determined on transplants of onion (*Allium cepa* L.) received in Colorado during March and April from out-of-state sources (Imperial Valley, CA; near Phoenix, AZ; and southern Texas) during 2004 to 2008. In the 5 years of the study, 50 to 100% of the transplant lots sampled arrived infested with thrips. Among infested transplant lots, the overall number of thrips averaged 0.15 to 0.63 per plant, with as many as four per plant in some lots. *T. tabaci* was the dominant thrips species in all seasons and locations of transplant origin. In addition, 19 of 83 (23%) tested lots had plants positive for *Iris yellow spot virus*. *Iris yellow spot virus* and *T. tabaci* were detected in volunteer onion plants as early as 1 May, a few weeks after the summer onion crop was planted, suggesting a possible role of infected volunteer plants in perennation of the virus between onion crops. *Iris yellow spot virus* and *T. tabaci* were detected in many common weeds including blue mustard (*Chorispora tenella* (Pall.) DC), common purslane (*Portulaca oleracea* L.), field bindweed (*Convolvulus arvensis* L.), flixweed (*Descurainia sophia* Webb & Berth.), prickly lettuce (*Lactuca serriola* L.), and redroot pigweed (*Amaranthus retroflexus* L.) in early spring near onion fields in Colorado during 2006 to 2009. Confirmation that *Iris yellow spot virus* and *Iris yellow spot virus*-infective thrips overwintered in volunteer onions and some common winter annual and perennial weeds emphasizes that managing volunteer onions and weeds is important for management of iris yellow spot, in addition to planting transplants free of thrips and the pathogen.

Introduction

Thrips are a key insect pest of onion (*Allium cepa* L.) grown in Colorado and North America (Capinera 2001). Problems associated with thrips have increased with the establishment of *Iris yellow spot virus* (Gent et al. 2006), a tospovirus damaging onion and vectored by the onion thrips, *Thrips tabaci* Lindeman; and tobacco thrips, *Frankliniella fusca* (Hinds) (Srinivasan et al. 2012). Iris yellow spot is an immediate and serious threat to sustainable and productive onion-cropping systems in the U.S., and the recent detection of the disease in numerous onion-producing countries emphasizes the need to develop economically sound and effective IPM strategies.

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Loss resulting from infestation by thrips depends on multiple factors, including abundance of thrips, weather conditions conducive to reproduction of thrips, plant growth stage at the time of infestation, susceptibility of cultivars to feeding and oviposition damage by thrips, and/or infection by viruses vectored by thrips (Lewis 1973). Onion growers in the western U.S. rely on insecticide to manage thrips. However, conventional insecticides (carbamates, organophosphates, and pyrethroids) have become ineffective in controlling thrips because of resistance in several onion-production regions (Aldosari 1995, Shelton et al. 2003, Allen et al. 2005).

Colorado is a leading onion-producing state with 2,500 ha of onions reported in 2013, and the crop is valued at more than $30 million (USDA 2014). The onion crop is primarily grown from seed, but significant acreage (10-15%) is established with transplants from southern- and western-growing areas such as Arizona and southern California to accelerate harvest and marketing opportunities. Thrips are known to move with transplants, and anecdotal reports suggest problems with thrips are more severe on the plantings. Between 1984 and 1986, Schwartz et al. (1988) examined 53 onion lots shipped into Colorado that originated from Arizona or Texas and found upon receipt that some transplant lots were infested with thrips. Infestation by thrips on onion transplants imported into New York was quantified by Hsu et al. (2011), although the species of thrips were not identified.

In Colorado, *Iris yellow spot viru*s has been detected in volunteer onion plants from bulbs left in the field at harvest, growing in ensuing crops of dry bean (*Phaseolus vulgaris* L.), alfalfa (*Medicago sativa* L.), field corn (*Zea mays* L.), and carrot (*Daucus carota* ssp. *sativus* (Hoffm.) Arcang) (Gent et al. 2004). Larentzaki et al. (2007) commented on the importance of annual weeds such as common lambsquarters (*Chenopodium album* L.) and redroot pigweed (*Amaranthus retroflexus* L.) as hosts for sustaining thrips following the onion crop. *T. tabaci* has been reported to overwinter on perennial or winter annual crops including alfalfa, clover (*Trifolium* spp.), and winter wheat (*Triticum* sp.) (Schirck 1951, North and Shelton 1986, Chambers and Sites 1989) which serve as hosts when reproduction by *T. tabaci* and *Frankliniella* spp. resumes in spring (Schirck 1951, North and Shelton 1986).

The importance of weeds as overwintering hosts for *Iris yellow spot virus* and thrips associated with onion has been less documented. Weeds may serve as bridge (perennation) species allowing *Iris yellow spot virus* and infective thrips to survive between onion-growing seasons. The virus has been confirmed in various non-allium plant species including common lambsquarters, common purslane (*Portulaca oleracea* L.), kochia (*Kochia scoparia* (L.) Schrad.), prickly lettuce (*Lactuca serriola* L.), puncturevine (*Tribulus terrestris* L.), redroot pigweed, and spiny sowthistle (*Sonchus asper* (L.) Hill) (Cosmi et al. 2003, Nischwitz et al. 2012, Sampangi et al. 2007, Hsu et al. 2011). Surveys have not determined the potential role of common species of weeds in and along field edges in onion-production areas of Colorado.

The purpose of this study was to determine (1) the extent and species of thrips and iris yellow spot on transplants shipped into Colorado from U.S. onion transplant-production areas and (2) if volunteer onions and common weeds associated with onions in Colorado also provide a source of thrips and/or iris yellow spot-infected plants.

Materials and Methods

Transplant Sources. Seedling transplants received by Colorado onion producers from out-of-state sources during March and April 2004 to 2008 were surveyed. In 2004, 2007, and 2008, 14, 16, and 12 lots of transplants of 10, nine, and 10 cultivars, respectively, were sampled. Transplants originated from either the Imperial Valley of California or areas south and west of Phoenix, AZ. In 2005 and 2006, 22 and 26 lots of transplants of 16 and 17 cultivars, respectively, were evaluated. The samples in 2005 and 2006 originated from the Imperial Valley, CA; near Phoenix, AZ; Peach Springs, AZ; and southern Texas. Onion transplant cultivars evaluated were in the three common market classes of: red – 'Mercury', 'Redwing', 'Rumba', 'Salsa', and 'Stockton Red'; white – 'Aspen', 'Cometa', 'Sierra Blanco', 'Sterling', and 'White Sweet Spanish'; and yellow – 'Caballero', 'Candy', 'Charismatic', 'Exacta', 'Granero', 'Renegade', 'Texas Super Sweet', 'Viceroy', 'Vision', 'Walla Walla', 'Western Giant', and 'Yula'.

From each transplant lot of sufficient size, five to 10 bundles each containing approximately 50 seedling plants were evaluated; in some cases, fewer bundles (two to five) were provided by the supplier. From the bundles per lot, 200 to 500 plants were selected arbitrarily and examined for the presence of thrips. Remaining plants were destructively sampled to assay for the presence of *Iris yellow spot virus*. Approximately 1 g of leaf tissue (approximately one mature leaf of larger seedlings or all leaves of small seedlings) was removed from each seedling by ethanol-sterilized scissors. The leaf tissue from each plant was assayed individually for iris yellow spot infection using the modified double antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA) as provided by Agdia, Inc. (Elkhart, IN) and modified by Gent et al. (2004). Absorbance values at 405 nm that were at least three times greater than those of the healthy check were considered positive. Generally, optical density values were less than 0.2 for negative checks, and ranged from 0.8 to greater than 2.5 for infected seedlings and positive checks. To verify DAS-ELISA results, RNA was extracted from symptomatic areas of onion leaves of representative plants, and a portion of the nucleocapsid (N) gene was amplified by reverse transcription-polymerase chain reaction as described by Pappu et al. (2006). Amplicons were cloned, sequenced, and compared to the N-gene sequence of *Iris yellow spot virus* isolates deposited in GenBank (Accession No. DQ233477). Reference isolates of *Iris yellow spot virus* from Colorado-grown transplanted onion plants were deposited with H. R. Pappu, Department of Plant Pathology, Washington State University, Pullman, WA.

Sampling Volunteer Onions and Weeds. Volunteer onions and perennial and winter annual weed species in and around fields with a history of onion production, thrips, and iris yellow spot during the previous season were sampled during March to May 2006 to 2009. At the sites, green plant tissue (foliar, stem, and floral) was collected from volunteer onion plants and weeds. During March to May there had been limited, if any, dispersal of thrips because volunteer onions and weeds had only recently emerged or resumed growth. New crop onion seedlings were small (one or two seedling leaves), and examination revealed few if any thrips. Although spring emergence of thrips was not monitored, Larentzaki et al. (2007) reported that emergence of *T. tabaci* from overwintering sites in New York began in early May, with peak emergence during the last half of May. Therefore, the time of sampling probably was indicative of thrips and infection by *Iris yellow spot virus*

because of successful overwintering rather than dispersal and infection from newly planted onion crops.

The collected plants, a composite of stems, leaves, flowers, and/or seeds from five to 25 plants per sample site, were divided for three measurements. One portion of the sample was used for extraction of thrips in an alcohol wash, which were subsequently identified to species. A second portion of the plant collection was tested by DAS-ELISA for *Iris yellow spot virus*. Tissue samples from volunteer onions and 29 weed species were extracted using a leaf press, and the sap was tested using DAS-ELISA (Gent et al. 2004). The final portion of the plants was placed in isolation cages with two pots of seedling onion plants (three- to four-leaf stage) free of thrips and *Iris yellow spot virus*. The volunteer onions or weeds were allowed to dry for 10 days during which thrips moved to the seedlings. The onion seedlings were subsequently removed and thrips eliminated by single application of a combination of Movento (active ingredient spirotetramat; Bayer CropScience, Research Triangle Park, NC), Radiant (active ingredient spinetoram; Dow AgroSciences LLC, Indianapolis, IN), and Regent (active ingredient fipronil; BASF Corp., Research Triangle Park, NC) insecticides at recommended application rates of 0.39, 0.63, and 0.39 ml per liter, respectively. Onion plants were allowed to grow and incubate in the absence of thrips for as long as 6 weeks, after which they were assayed for the presence of *Iris yellow spot virus* by using DAS-ELISA.

Sampling for Thrips. In the initial survey of onion transplants in 2004, with the exception of samples received 16 April, samples from lots were refrigerated immediately upon receipt and processed to extract thrips within 2 weeks. The 16 April lots arrived in crates and were not refrigerated. Thrips development continued in the stored onions, so the original numbers of thrips could not be quantified, although the presence and species of thrips were determined and recorded.

In 2005 to 2008, samples from lots were refrigerated immediately upon receipt and processed to extract thrips within 3 days. In addition, in 2005, a subset of onion transplants was bagged and incubated at room temperature in a laboratory for 45 days and sampled later for thrips. Resampling was done to measure thrips development in the stored onion transplants and to identify infestations that were undetectable or contained only immature stages during the first sampling.

To extract thrips, the leaves and neck area of each plant were placed into flasks containing 70% ethanol, onions opened to expose the neck area, and stirred to dislodge thrips. After all plants from a sample were washed, the alcohol was poured through a fine-mesh nylon screen to strain out insects. A total of 200 to 500 plants was sampled from each collection, and the thrips were subsequently stored in 70% ethanol for later examination. The total number of thrips was counted, and adults were identified to species (Speyer 1934, Bailey 1957, Stannard 1968, Mound et al. 1976, Mound and Walker 1982, Mound and Kibby 1998, Nakahara 1994). When only immature thrips were present, keys by Kirk (1987, 1996) and Heming (1991) were used to identify the thrips to species. Reference specimens were deposited in the C. P. Gillette Museum of Arthropod Diversity at Colorado State University, Fort Collins, CO.

Differences in the mean number of thrips per plant and the incidence of seedlings with *Iris yellow spot virus* among the regions where transplants were produced were analyzed using a generalized linear mixed model. Production region was considered a fixed factor, and cultivar within region and year were considered random factors. The response variable was assumed to be normally distributed and an “identity” link function was specified. Negative variance estimates were allowed

in the analysis when variance estimates for random factors were 0. The incidence of *Iris yellow spot virus* was log-transformed to normalize residuals and stabilize variances. Least square means were compared by *F*-protected LSD. The GLIMMIX procedure in SAS 9.4 (SAS Institute, Cary, NC) was used for analyses.

Results and Discussion

Transplant Sources. Thrips were detected in seven of 14 (50%) lots in 2004 (Table 1). Thrips were detected in six of nine (66.7%) transplant lots from the Imperial Valley, and one of five (20%) samples from the Phoenix area. Infested samples had an average of 0.29 thrips per plant. *T. tabaci* was found in seven samples, *Frankliniella ewarti* (Sakimura & O'Neill) in six, *Scirtothrips longipennis* (Bagnall) in one, and *Scolothrips sexmaculatus* (Pergande), a polyphagus predator of mites, in one of the 14 lots (Mahaffey 2006, Mahaffey and Cranshaw 2010).

In 2005, 21 of 22 (95%) lots were infested with thrips during the original sampling (Table 2). On average, infested samples had 0.33 thrips per plant. During the re-testing of seedlings maintained in sealed plastic and paper bags at room temperature, 10 samples had larger numbers of thrips and six had fewer than in the original sample. The single lot where thrips were not detected in the initial survey, cv. 'Candy' from the Phoenix area, was found infested with *T. tabaci* during resampling. In addition, *F. ewarti* was detected on some samples during resampling, but not during the original sampling.

Table 1. Confirmation of *Thrips tabaci* Present and Infection by *Iris yellow spot virus* (IYSV) among Onion Transplants Received by Colorado Growers during 2004

Origin of lot	Cultivar[a]	Thrips per plant	*Thrips tabaci* present[b]	IYSV confirmation[c]
Phoenix, AZ	'Candy'	0.04	Yes	0/281
	'Cometa'	0.00	No	0/276
	'Rumba'	0.00	No	4/276 (1.4%)
	Unknown	0.00	No	1/239 (0.4%)
	Unknown	0.00	No	0/301
Imperial Valley, CA	'Aspen'	0.00	No	1/460 (0.2%)
	'Rumba'	0.00	No	9/790 (1.1%)
	'Vision'	0.00	No	7/460 (1.5%)
	'Yula'	0.16	Yes	0/578
	'Redwing'	0.38	Yes	NA
	'Mercury'	0.53	Yes	NA
	'Vaquero'	0.50	Yes	NA
	'Sterling'	0.26	Yes	NA
	'Candy'	0.28	Yes	NA

[a]NA = not available for evaluation.

[b]One or more adult and/or larval stages of *Thrips tabaci*.

[c]Infection by IYSV was determined by double antibody sandwich enzyme linked immunosorbant assays (DAS-ELISA) on individual transplant seedlings. Plants were considered positive for IYSV if absorbance of DAS-ELISA was at least three times that of the negative checks.

Table 2. Confirmation of *Thrips tabaci* Present and Infection by *Iris yellow spot virus* (IYSV) among Onion Transplants Received by Colorado Growers during 2005

Origin of lot	Cultivar[a]	Thrips per plant (1st, 2nd rinse)	*Thrips tabaci* present[b]	IYSV confirmation[c]
South Phoenix, AZ	'Candy'	0.00, 1.59	Yes – 1st rinse	0/281
	'Candy'	0.02, 0.91	Yes – both rinses	0/184
	'Salsa'	0.66, 0.64	Yes – 1st rinse	0/184
Phoenix, AZ	'Teton'	0.07, 0.08	Yes – 1st rinse	1/184 (0.5%)
Peach Springs, AZ	'Candy'	0.03, 1.53	Yes – both rinses	0/184
	'Vaquero'	0.03, 1.97	Yes – 1st rinse	0/184
Imperial Valley, CA	'Agula'	0.87, 0.34	Yes – both rinses	0/184
	'Aspen'	0.11, 0.00	Yes – 1st rinse	1/184 (0.5%)
	'Caballero'	0.21, NA	Yes – 1st rinse	1/184 (0.5%)
	'Candy'	0.76, NA	Yes – 1st rinse	0/184
	'Cometa'	0.73, 0.84	Yes – both rinses	0/184
	'Exacta'	0.51, NA	Yes – 1st rinse	1/184 (0.5%)
	'LZ#1433'	0.38, 0.44	Yes – 1st rinse	NA
	'Renegade'	0.64, NA	Yes – 1st rinse	6/184 (3.3%)
	'Rumba'	0.02, 0.09	Yes – both rinses	3/184 (1.6%)
	'Vision'	0.22, NA	Yes – 1st rinse	5/184 (2.7%)
	'Yula'	0.26, 0.17	Yes – both rinses	1/184 (0.5%)
	'Agula'	0.87, 0.34	Yes – 1st rinse	NA
	'Cometa'	0.08, 0.34	Yes – both rinses	NA
	'Redwing'	1.39, 0.27	Yes – both rinses	NA
	'Renegade'	0.17, 0.22	Yes – both rinses	NA
	'Sw. Spanish'	0/10, NA	Yes, 1st rinse	1/184 (0.5%)

[a]The 1st sampling was on 4 April. The 2nd sampling of plants from the same source stored at room temperature was on 21 May. Values not noted by 1st or 2nd are the same for both sampling dates. [b]One or more adult and/or larval stages of *Thrips tabaci*. [c]Infection by IYSV was determined by double antibody sandwich enzyme linked immunosorbant assays (DAS-ELISA) on individual transplant seedlings. Plants were considered positive for IYSV if the absorbance of DAS-ELISA was at least three times that of the negative checks. NA = not available for evaluation.

Overall, *T. tabaci* dominated and was the sole species detected in 50% of the lots in 2005. *F. ewarti*, *F. occidentalis*, and *F. schultzei* (Trybom) were in four, five, and eight of the 22 lots, respectively (Mahaffey and Cranshaw 2010). All three *Frankliniella* species were found together in one lot.

In 2006, 100% of the 26 lots were infested with thrips during sampling (Table 3). On average, infested lots had 0.21 thrips per plant. In 2007, 100% of the 16 lots were infested with thrips during sampling (Table 4). On average, infested lots had 0.63 thrips per plant. In 2008, 100% of the 12 lots were infested with thrips during sampling (Table 5). On average, infested lots had 0.40 thrips per plant.

Most onion transplant lots arrived infested with thrips to Colorado, as previously reported by Schwartz et al. (1988). The number of thrips on transplants was associated with the region where onion transplants were produced ($F = 5.38$; $P = 0.0009$). In this study, the greatest number of thrips species was from transplants that originated in the Imperial Valley (pairwise contrast of Imperial Valley versus other production regions, $t = 3.45$, $P = 0.001$). The Imperial Valley production area

Table 3. Confirmation of *Thrips tabaci* Present and Infection by *Iris yellow spot virus* (IYSV) among Onion Transplants Received by Colorado Growers during 2006

Origin of lot	Cultivar[a]	Thrips per plant	*Thrips tabaci* present[b]	IYSV confirmation[c]
South Phoenix, AZ	'Candy'	0.21	Yes	0/214
	'Rumba'	0.27	Yes	0/170
	'Viceroy'	0.07	Yes	0/197
	'Walla Walla'	0.09	Yes	0/156
	'White Sw. Spanish'	0.71	Yes	0/104
Phoenix, AZ	'Candy'	0.18	Yes	0/500
	'Candy'	0.07	Yes	0/500
	'Charismatic'	0.15	Yes	NA
	'Cometa'	0.06	Yes	0/500
	'Granero'	0.24	Yes	0/500
	'Salsa'	0.20	Yes	0/500
Imperial Valley, CA	'Aspen'	0.32	Yes	0/85
	'Aspen'	0.27	Yes	0/500
	'Candy'	0.57	Yes	0/44
	'Exacta'	0.43	Yes	0/47
	'Redwing'	0.76	Yes	0/43
	'Renegade'	0.93	Yes	0/48
	'Renegade'	0.22	Yes	0/500
	'Rumba'	0.76	Yes	0/50
	'Rumba'	0.31	Yes	0/500
	'Vision'	0.87	Yes	0/41
	'Yula'	0.31	Yes	0/58
	'Yula'	0.56	Yes	0/500
City unknown, TX	'Stockton Red'	0.14	Yes	0/205
	'Texas Super Sweet'	0.21	Yes	0/246
	'Walla Walla'	0.74	Yes	0/208

[a]All samples originating from growers were received either 31 March or 1 April. The Texas and South Phoenix samples were from a local nursery and collected 4 April for the South Phoenix samples and 24 April for the Texas samples.
[b]One or more adult and/or larval stages of *Thrips tabaci*.
[c]Infection by IYSV was determined by double antibody sandwich enzyme linked immunosorbant assays (DAS-ELISA) performed on individual transplant seedlings. Plants were considered positive for IYSV if the absorbance of DAS-ELISA was at least three times that of the negative checks. NA = not available for evaluation.

did not supply onions for sampling in the 1984 to 1986 Colorado survey by Schwartz et al. (1988). These contaminated transplants provide an early-season source of thrips that could increase to damaging numbers earlier in transplanted onion crops than on seeded onion crops.

T. tabaci and *F. occidentalis* were the only thrips species reported by Kendall (1987) to be associated with onions in Colorado. Four additional species were detected on seedling transplants in this study and previously reported by Mahaffey and Cranshaw (2010) -- *F. ewarti*, *F. schultzei*, *Scirtothrips longipennis*, and *Scolothrips sexmaculatus*. Other field studies concurrent with this study indicated that *F. schultzei* is established in onion fields in Colorado (Mahaffey 2006).

Table 4. Confirmation of *Thrips tabaci* Present and Infection by *Iris yellow spot virus* (IYSV) among Onion Transplants Received by Colorado Growers during 2007

Origin of lot	Cultivar[a]	Thrips per plant	*Thrips tabaci* present[b]	IYSV confirmation[c]
South Phoenix, AZ	'Caballero'	0.30	Yes	0/400
	'Sierra Blanco'	0.05	Yes	0/400
	'Aspen'	0.07	Yes	0/300
	'Rumba'	0.02	Yes	0/400
	'Exacta'	0.05	Yes	0/300
	'Candy'	0.11	Yes	0/400
Phoenix, AZ	'Rumba'	0.04	Yes	0/250
	'Vision'	0.05	Yes	0/250
	'Candy'	0.19	Yes	0/250
	'Cometa'	0.02	Yes	0/250
	'Salsa'	0.07	Yes	0/250
Imperial Valley, CA	'Exacta'	0.99	Yes	0/500
	'Vision'	1.27	Yes	0/500
	'Aspen'	0.89	Yes	0/500
	'Candy'	1.92	Yes	0/500
	'Rumba'	4.01	Yes	0/500

[a]More than 80% of thrips found were *Thrips tabaci*, and less than 5% each of other species including *Frankliniella occidentalis*, and/or *F. schultzei*.
[b]One or more adult and/or larval stages of *Thrips tabaci*.
[c]All samples originating from growers were received either 2 April or 9 May. Infection by IYSV was determined by double antibody sandwich enzyme linked immunosorbant assays (DAS-ELISA) performed on individual transplant seedlings. Plants were considered positive for IYSV if the absorbance of DAS-ELISA was at least three times that of the negative checks.

Iris yellow spot virus was positively detected in 19 of 83 (23%) lots sampled from the five onion transplant-production regions in Arizona, California, and Texas during 2004 to 2008. Representative symptomatic plants assayed for the presence of *Iris yellow spot virus* were confirmed positive by RT-PCR, and had 99% N-gene sequence similarity to that of an *Iris yellow spot virus* isolate from Japan (Accession no. AB180919). *Iris yellow spot virus* confirmed by DAS-ELISA varied from 0 to 3.3% among onion lots and cultivars sampled, and confirmed that *Iris yellow spot virus* can be associated with and introduced on transplant seedlings. The incidence of *Iris yellow spot virus* depended on where transplants originated ($F = 2.69$; $P = 0.042$). Among production regions, incidence of *Iris yellow spot virus* was significantly greater on transplants from the Imperial Valley compared to other production regions (pairwise contrast $t = 2.45$, $P = 0.0177$). No positives were confirmed from seedlings with suspicious lesions in the 2006 and 2007 surveys; possibly the virus titer was too low for detection by the DAS-ELISA procedure.

These results confirmed that onion transplants are potential sources of *Iris yellow spot virus* and the vector, *T. tabaci*. Movement of *Iris yellow spot virus*-contaminated transplants could hasten the dissemination of the virus and vector into other states that import transplants produced in the southwestern U.S., as confirmed in New York (Hsu et al. 2011). Interstate movement of infected onion transplants

Table 5. Confirmation of *Thrips tabaci* Present and Infection by *Iris yellow spot virus* (IYSV) among Onion Transplants Received by Colorado Growers during 2008

Origin of lot	Cultivar[a]	Thrips per plant	*Thrips tabaci* present[b]	IYSV confirmation[c]
Phoenix, AZ	'Cometa'	0.06	Yes	1/356 (0.3%)
	'Candy'	0.29	Yes	0/313
	'Rumba'	0.29	Yes	0/248
	'Western Giant'	0.04	Yes	0/232
Imperial Valley, CA	'Exacta'	0.16	Yes	0/156
	'Rumba'	0.70	Yes	1/141 (0.7%)
	'Aspen'	0.06	Yes	0/119
	'Exacta'	0.12	Yes	0/176
	'Sterling'	0.22	Yes	0/183
	'Redwing'	1.70	Yes	1/195 (0.5%)
	'Renegade'	0.35	Yes	0/164
	'Granero'	0.32	Yes	6/270 (2.2%)

[a]Most thrips found were *Thrips tabaci*, followed by *Frankliniella occidentalis*.
[b]One or more adult and/or larval stages of *Thrips tabaci*.
[c]All samples originating from growers were received either 31 March, 18 April, or 21 April. Infection by IYSV was determined by double antibody sandwich enzyme linked immunosorbant assays (DAS-ELISA) performed on individual transplant seedlings. Plants were considered positive for IYSV if the absorbance of DAS-ELISA was at least three times that of the negative checks.

also could facilitate the spread of new strains of *Iris yellow spot virus* and biotypes of *T. tabaci* within and among regions of onion production (Gent et al. 2006). Research is needed to determine the importance of infestation by thrips and *Iris yellow spot virus*-infection of transplants in the epidemiology of iris yellow spot, and to develop management strategies to address both pests during production of onion transplants.

Volunteer Onions and Weeds. Three thrips species associated with onion crops (*T. tabaci*, *F. occidentalis*, and *F. schultzei*) (Mahaffey and Cranshaw 2010) were also found in surveys of field bindweed, flixweed, and dandelion (*Taraxacum officinale* Weber in Wiggers), as well as volunteer onion. *T. tabaci* was also found on all four samples of blue mustard. Finding these thrips suggested that several winter annual and perennial weeds can serve as overwintering and early-season hosts of thrips.

The dominant thrips species found in most of the volunteer onion and weed samples was *T. tabaci* as shown in Tables 6 and 7. Additional species of thrips associated with onions were found in volunteer onions and overwintering weeds and included *F. occidentalis* and *F. schultzei*. In addition, testing by DAS-ELISA indicated thrips on volunteer onions were viruliferous and able to transmit *Iris yellow spot virus* to onion seedlings in greenhouse assays (Table 7). In addition to volunteer onions, thrips dispersing from spring-collected bindweed, blue mustard, dandelion, flixweed, and western salsify (*Tragopogon dubius* Scop.) successfully transmitted the virus to onion seedlings (Table 6).

With these data, the known host range of *Iris yellow spot virus* continues to increase, and the importance of weeds as reservoirs has been further demonstrated

Table 6. Confirmation of *Iris yellow spot virus* Detection and *Thrips tabaci* Present in Common Weeds during 2006 to 2009 in Colorado

Year	Sample no.	County	Common name[a]	*Thrips tabaci* present[b]	IYSV positive[c]
2006	33	Weld	Flixweed	No	Yes
	55	Mesa	Kochia	No	Yes
	65	Larimer	Prickly lettuce	No	Yes
	83	Weld	Kochia	No	Yes
	99B	Pueblo	Common purslane	No	Yes
	115	Mesa	Gray rabbit brush	No	Yes
	116		Blue mustard	No	Yes
	120		Annual sowthistle	No	Yes
	121		Red stem filaree	No	Yes
	128		Buckhorn plantain	No	Yes
	131		Jointed goatgrass	No	Yes
	133		Field bindweed	No	Yes
2007	232	Mesa	Kochia	No	Yes
	234		Field bindweed	No	Yes
	237		Wild mustard	Yes	Yes
	239		Blue mustard	No	Yes
	242		Prickly lettuce	Yes	Yes
	243		Dandelion	Yes	Yes
	244		Gray rabbit brush	No	Yes
	258		Prickly lettuce	Yes	Yes
	260		Field bindweed	Yes	Yes
	267	Pueblo	Prickly lettuce	Yes	Yes
	274	Weld	Hairy nightshade	No	Yes
	276		Russian thistle	No	Yes
	277		Venice mallow	No	Yes
	278		Common lambsquarters	No	Yes
	282		Common groundsel	No	Yes
	283		Redroot pigweed	No	Yes
	284		Pale smartweed	No	Yes
	292	Delta	Redroot pigweed	No	Yes
2008	340	Larimer	Flixweed	Yes	Yes
	341		Dandelion	Yes	Yes
	342	Weld	Flixweed	Yes**	Yes
	343		Blue mustard	Yes	Yes
	344		Flixweed	Yes**	No
	346		Flixweed	Yes**	Yes
	347	Larimer	Field bindweed	Yes	Yes
	351		Prickly lettuce	No	Yes
	355		Prickly lettuce	Yes	Yes
	357		Flixweed	Yes**	No
	358		Field bindweed	Yes	Yes
	359		Prickly lettuce	No	Yes
	362		Prickly lettuce	Yes	Yes
	367		Western salsify	Yes**	Yes
	369A	Weld	Black nightshade	No	Yes
	369B		Hairy nightshade	No	Yes

	370		Castorbean	No	Yes
	371		Prickly lettuce	No	Yes
	372		Horseweed	No	Yes
	378	Larimer	Field bindweed	No	Yes
	379		Common purslane	No	Yes
	--		Annual sowthistle	Yes	No
2009	408	Adams	Common purslane	No	Yes
	410		Redroot pigweed	No	Yes
	411		Toothed spurge	No	Yes
	501	Larimer	Blue mustard	Yes	Yes
	504		Flixweed	Yes	Yes

[a]Scientific name of each weed that tested positive for IYSV: annual sowthistle = *Sonchus oleraceus* L., black nightshade = *Solanum nigrum* L., blue mustard = *Chorispora tenella* (Pall.) DC., buckhorn plantain = *Plantago lanceolata* L., castorbean = *Ricinus communis* L., common groundsel = *Senecio vulgaris* L., common lambsquarters = *Chenopodium album* L., common purslane = *Portulaca oleracea* L., dandelion = *Taraxacum officinale* Weber in Wiggers, field bindweed = *Convolvulus arvensis* L., flixweed = *Descurainia sophia* (L.) Webb *ex* Prantl, gray rabbit brush = *Chrysothamnus nauseosus* (Pallas) Britt., hairy nightshade = *Solanum sarrachoides* Sendtner, horseweed = *Conyza canadensis* (L.) Cronq., jointed goatgrass = *Aegilops cylindrica* Host, kochia = *Kochia scoparia* (L.) Schrad., pale smartweed = *Polygonum lapathifolium* L., prickly lettuce = *Lactuca serriola* L., redroot pigweed = *Amaranthus retroflexus* L., redstem filaree = *Erodium cicutarium* (L.) L'Her. *ex* Ait., Russian thistle = *Salsola iberica* Sennen, toothed spurge = *Euphorbia dentate* Michx., Venice mallow = *Hibiscus trionum* L., western salsify = *Tragopogon dubius* Scop., wild mustard = *Brassica kaber* (DC.) L.C. Wheeler.
[b]One or more adult and/or larval stages of *Thrips tabaci.*
[c]DAS-ELISA confirmation made according to Gent et al. (2004). [**]Seedling onions were positive for IYSV after transfer of *Thrips taba*ci from original weed sample.

(Gent et al. 2006, Nischwitz et al. 2012, Sampangi et al. 2007). The verification that *Iris yellow spot virus* and viruliferous thrips overwinter in some winter annual and perennial weeds suggests that management of weeds outside of fields could be an important component of management of iris yellow spot.

Although samples from several plant species resulted in DAS-ELISA values that suggested the presence of *Iris yellow spot virus*, results need to be confirmed by RT-PCR assay. Among the samples tested, more than 75% of symptomatic volunteer onions and the following weeds were positive for *Iris yellow spot virus* by DAS-ELISA and preliminary testing with RT-PCR (Schwartz et al., preliminary results): common lambsquarters, kochia, prickly lettuce, and redroot pigweed. *Iris yellow spot virus* was detected in volunteer onion plants as early as 1 May, a few weeks after the summer onion crop was planted, suggesting infected volunteer plants could provide a biological "bridge" or perennation between onion crops. Information on the wider natural host range of iris yellow spot, with some common weeds in our region able to act as potential reservoirs for the virus, is useful for better understanding the disease epidemiology and to design effective disease management strategies that also rely upon insect-free, iris yellow spot-free transplants and cultural practices that reduce sources of nearby volunteer onions.

Table 7. Confirmation of *Iris yellow spot virus* Detection and *Thrips tabaci* Present in Volunteer Onion Plants during 2006 to 2009 in Colorado

Year	Sample no.	County	Sample date	*Thrips tabaci* present[a]	IYSV positive[b]
2006	31	Larimer	1 May	Yes	Yes
	32	Weld		Yes	No
	34			Yes	No
	37			Yes	Yes
	38	Larimer	3 May	Yes	Yes
	42			Yes	Yes
	49		12 May	Yes	No
	51		15 May	Yes	No
	63	Mesa	17 May	Yes	No
	69	Weld	1 June	Yes	Yes
2007	231	Mesa	27 March	Yes	No
	246	Larimer	20 April	Yes	Yes
	247	Weld		Yes	Yes
	255		1 May		Yes
	256		8 May		Yes
	262	Pueblo	10 May		Yes
	263				Yes
	264				Yes
	265				Yes
2008	345	Weld	16 May	Yes	Yes
	348	Larimer	21 May	Yes	Yes
	364	Larimer	22 May		Yes
2009	345	Weld	16 May	Yes	Yes
	348	Larimer	21 May	Yes	Yes
	364	Larimer	22 May		Yes

[a]One or more adult and/or larval stages of *Thrips tabaci*.
[b]DAS-ELISA confirmation made according to Gent et al. (2004).

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