MANAGEMENT OF ONION CULTURAL PRACTICES AS A MEANS TO CONTROL THE EXPRESSION OF IRIS YELLOW SPOT VIRUS

Clinton C. Shock, Erik B. G. Feibert, and Lamont D. Saunders
Malheur Experiment Station, Oregon State University, Ontario, OR

Lynn Jensen
Malheur County Extension Service, Oregon State University, Ontario, OR

Krishna Mohan
University of Idaho, Parma, ID

Introduction

Onion plants infected with iris yellow spot virus (IYSV) can progressively lose leaf area, resulting in reduced yield and reduced bulb size. The virus is transmitted by onion thrips (*Thrips tabaci*). The incidence of IYSV can be increased by inadequate control of onion thrips, which have become increasingly resistant to pyrethroid and organophosphate insecticides. A certain degree of varietal tolerance to thrips and IYSV has been determined (Shock et al. 2007). However, management factors such as irrigation, fertilization, and straw mulching that reduce plant stress might reduce the intensity of thrips and IYSV infestations. This trial tested the response of four onion varieties to water stress level, irrigation system, nitrogen fertilizer rate, and straw mulching.

Materials and Methods

The onions were grown on an Owyhee silt loam previously planted to wheat. In the fall of 2006, the wheat stubble was shredded and the field was irrigated and disked. Soil analysis indicated the need for 127 lb phosphate (P_2O_5)/acre, 80 lb sulfur (S)/acre, 7 lb maganese (Mn)/acre, 3 lb zinc (Zn)/acre, and 1 lb/acre of boron (B), which were broadcast in the fall of 2006 after disking. The field was then moldboard-plowed, groundhogged, roller-harrowed, fumigated with Telone® C-17 at 20 gal/acre, and bedded.

Onion seed of four varieties ('Evolution', D. Palmer Seed Co., Yuma AZ; 'Vaquero' and 'Joaquin', Nunhems, Parma ID; 'Charismatic', Seminis Seed Co., Saint Louis, MO) was planted on March 22 at 260,000 seeds/acre in double rows spaced 3 inches apart. Each double row was planted on beds spaced 22 inches apart with a customized planter using John Deere Flexi Planter units equipped with disc openers. Drip tape (Toro Micro-Irrigation, El Cajon, CA) was laid at 4-inch depth between the 2 double onion rows at the same time as planting. The distance between the tape and the center of each double row was 11 inches. The drip tape had emitters spaced 12 inches apart and a flow rate of 0.22 gal/min/100 ft.

The onion rows received 3.7 oz of Lorsban 15G® per 1,000 ft of row (0.82 lb ai/acre) and the soil surface was rolled on March 23. Onion emergence started on April 8. On May 4, alleys 4 ft wide were cut between plots, leaving plots 23 ft long. From May 9 through May 10, the seedlings were hand thinned to a plant population of two plants/ft of single row (6-inch spacing between individual onion plants, or 95,000 plants/acre).

The experimental design was a split-split plot randomized complete block with four replicates. The main plots were the irrigation treatment (Table 1). Each irrigation plot was split into two nitrogen (N) rates (100 or 200 lb N/acre). Each N rate split plot was split into the four varieties. Each variety split-split plot was 4 double onion rows wide and 23 ft long.

Table 1. Irrigation treatment specifications, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Treatment	Irrigation system	Irrigation criterion[a]	Irrigation intensity
		cb	inches per irrigation
1	Drip	10	0.12
2	Drip	15	0.24
3	Drip	20	0.48
4	Drip	30	0.48
5	Drip	15/25[b]	0.24/0.48[c]
6	Sprinkler	20	0.48
7	Drip/optional sprinkler	20	0.48
8	Furrow	20-25	16.0[d]
9	Furrow/optional sprinkler	20-25	16.0

[a]soil water tension at 8-inch depth.
[b]15 cb until July 31, then 25 cb thereafter.
[c]0.24 inch/irrigation until July 31, then 0.48 inch/irrigation thereafter.
[d]total water applied based on limited furrow inflow measurements.

Wheat straw was applied to one plot of each irrigation treatment in replicate one or two at random, leaving the remaining replicate untreated. Similarly, wheat straw was applied to one plot of each irrigation treatment in replicate three or four at random, leaving the remaining replicate untreated. Straw was applied to the center bed (area between middle two double rows) of each split-split plot on June 26. Straw was applied at 1,300 lb/acre. Soil temperature was measured with four temperature probes installed at 2-inch depth in the bed center in each irrigation plot in replicates one and two. Soil temperature measurements were recorded hourly using a datalogger.

The sprinkler- and furrow-irrigated plots (treatments 6,8, and 9) had the drip tape removed in late May. The sprinkler plots (treatments 6,7, and 9) had four sprinklers at the plot top and another four at the plot bottom. The risers were 3 ft tall and spaced 14.7 ft apart. The first riser was located at the plot corner. Each riser had a guard preventing the nozzle from applying water to the adjacent plots. The sprinklers were R10 turbos

(Nelson Irrigation, Walla Walla, WA) with 0.75-gal/min flow control nozzles. The sprinkler water application rate was 0.16 inch/hour at a pressure of 35 psi .

Each furrow-irrigated plot (treatments 8 and 9) had a gated pipe and tail ditch. At each irrigation, the onions were irrigated for 12 hours until July 1, 24 hours until August 15, and 12 hours until the last irrigation on August 31.

Onions in each drip- and sprinkler-irrigated plot (treatments 1-7) were irrigated automatically and independently according to the irrigation criterion and intensity predetermined for each treatment (Table 1). The irrigation duration for each treatment was adjusted so that when irrigated the maximum number of times, all irrigation systems had the capacity to deliver up to a maximum of 0.48 inch of water per day. The furrow-irrigated onions were irrigated manually when the soil water tension (SWT) at 8-inch depth reached 20 to 25 cb. The drip- and furrow-irrigated onions with optional sprinkler irrigation (treatments 7 and 9) received sprinkler irrigation of 0.48 inch of water once a week during the hottest part of the growing season starting on July 5 and ending on August 15.

The datalogger made irrigation decisions for each drip- and sprinkler-irrigated plot every 6 hours. The irrigation decisions for each plot were based on the average SWT. The irrigations were controlled by the datalogger using a controller (SDM CD16AC controller, Campbell Scientific, Logan, UT) connected to solenoid valves in each plot. The water for the drip and sprinkler plots was supplied by a well that maintained a continuous and constant water pressure of 35 psi. The pressure in the drip lines was maintained at 10 psi by pressure regulators in each plot. The amount of water applied to each plot was recorded daily at 8:00 a.m. from a water meter installed between the solenoid valve and the drip tape. The automated irrigation system was started on June 4. Irrigations were terminated on August 31.

The amount of water applied and the amount of water infiltrated to the furrow-irrigated plots was estimated from measurements of furrow inflow and outflow. The difference between inflow and outflow is the amount of water infiltrated. The inflow and outflow measurements were taken every 2 hours on 4 furrows in each of 2 plots during 3 irrigations. Inflow was determined by measuring the volume of water coming out of the gate in 15 seconds. To measure outflow, trapezoidal flumes were installed at the furrow ends. Outflow was determined by measuring the level of the water in the flume. Flume water level measurements were converted to flow rate using an equation developed by measurements of flume water height and outflow.

Soil water tension was measured in each plot with four granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT (Shock et al. 1998a). The GMS were connected to the datalogger via four multiplexers (AM 410 multiplexer, Campbell Scientific, Logan, UT). The datalogger read the sensors and recorded the SWT every hour.

Onion evapotranspiration (ET_c) was calculated with a modified Penman equation (Wright 1982) using data collected at the Malheur Experiment Station by an AgriMet weather station. Onion ET_c was estimated and recorded from crop emergence on April 8 until the final irrigation.

Starting on May 29, the high N split plots in each irrigation main plot received 40 lb N/acre and the adequate N split plots received 20 lb N/acre weekly until the last application on June 25. The N fertilizer for the drip plots was injected through the drip tape as uran. The N fertilizer for the sprinkler plots was applied as urea broadcast on the surface of the onion beds. The N fertilizer for the furrow plots was applied as urea to the top half of each furrow. The total amount of N applied was 200 lb N/acre to the high N treatment and 100 lb N/acre to the adequate N treatment.

The onions were managed to minimize yield reductions from weeds, pests, diseases, and nutrient deficiencies. Weeds were controlled with an application of Roundup® at 1 qt/acre on April 6, Prowl® at 1 lb ai/acre on April 13, Goal® at 0.1 lb ai/acre, Buctril® at 0.3 lb ai/acre, and Select® at 0.25 lb ai/acre on May 11. On May 15, Aza-Direct® at 0.0062 lb ai/acre and Success® at 0.25 lb ai/acre were applied for thrips control. Starting on June 1 and ending August 7, the field was sprayed weekly with Aza-Direct at 0.0062 lb ai/acre and Success at 0.25 lb ai/acre with a backpack sprayer.

Thrips populations were measured weekly in each split-split plot starting May 23 and ending August 7. Thrips populations were measured by counting the total number of thrips on each of 15 plants per split-split plot.

Onion plant maturity was evaluated subjectively in each plot by visually rating the percentage of onions with the tops down and the percent dryness of the foliage. The percent maturity was calculated as the average percentage of onions with tops down and the percent dryness. All plots were evaluated for maturity on August 13 and August 29. The number of bolted onion plants in each plot was counted.

Onions in each plot were evaluated subjectively for severity of symptoms of iris yellow spot virus (IYSV) and powdery mildew (*Leveillula taurica*) on August 28. Each plot was given a rating on a scale of 0 to 5 of increasing severity of symptoms, where 0 = no symptoms, 1 = 1-25 percent of foliage diseased, 2 = 26-50 percent of foliage diseased, 3 = 51-75 percent of foliage diseased, 4 = 76-99 percent of foliage diseased, and 5 = 100 percent of foliage diseased.

The onions were lifted on September 13 to cure in the field. Onions from the middle two rows in each plot of the full season trial were topped by hand and bagged on September 17. The bags were put in storage on September 21. The storage shed was ventilated to maintain air temperature as close to 34°F as possible. Onions were graded out of storage on December 12-14, 2007.

During grading, bulbs were separated according to quality: bulbs without blemishes (No. 1s), split bulbs (No. 2s), neck rot (bulbs infected with the fungus *Botrytis allii* in the neck or side), plate rot (bulbs infected with the fungus *Fusarium oxysporum*), and black mold (bulbs infected with the fungus *Aspergillus niger*). The No. 1 bulbs were graded according to diameter: small (<2.25 inches), medium (2.25-3 inches), jumbo (3-4 inches), colossal (4-4.25 inches), and supercolossal (>4.25 inches). Bulb counts per 50 lb of supercolossal onions were determined for each plot of every variety by weighing and counting all supercolossal bulbs during grading.

One sample from each plot was saved during grading for rating of single centers. After grading, 25 onions ranging in diameter from 3.5 to 4.25 inches were rated. The onions were cut equatorially through the bulb middle and, if multiple centered, the long axis of the inside diameter of the first single ring was measured. These multiple-centered onions were ranked according to the diameter of the first single ring: "small" had diameters less than 1.5 inches, "medium" had diameters of 1.5-2.25 inches, and "large" had diameters greater than 2.25 inches. Onions were considered functionally single centered for processing if they were single centered or had a small multiple center.

Treatment differences in yield, grade, maturity, single centeredness, thrips counts, and disease severity ratings were compared using three-way analysis of variance (ANOVA) where factor A was irrigation treatment, factor B was replicate, factor C was N rate, and factor D was variety. Treatment differences in water applied and water use efficiency were compared using one-way ANOVA, where factor A was irrigation treatment and factor B was replicate. Means separation was determined with Fisher's least significant difference test at the 5 percent probability level, LSD (0.05).

Results and Discussion

For plots without straw mulch, the average daily maximum soil temperature was higher for the drier treatments (Table 2). Straw mulching resulted in a reduction in average daily maximum soil temperature. Straw mulching did not have any effect on onion yield or grade (data not shown) in this trial.

The average season SWT increased with the increasing irrigation criteria for the drip-irrigated treatments (Table 3). The average SWT for the two furrow-irrigated treatments was not different than the wettest drip-irrigated treatment (10 cb). The two furrow-irrigated treatments were irrigated at a wetter criterion than had been planned. As expected, the furrow-irrigated treatments had a greater oscillation in soil water than the wetter drip-irrigated treatments, getting wetter during irrigations and drier between irrigations (Fig. 1).

The furrow-irrigated treatment with optional sprinkler irrigation had the highest total amount of water applied, followed by the other furrow-irrigated treatment (Table 3). The treatment drip irrigated at 30 cb had the lowest total water applied. The total ET_c for the season was 33.8 inches. All treatments applied more water than ET_c except the treatment drip irrigated at 30 cb. Water use efficiency increased with the reductions in water applied for the drip-irrigated treatments. The furrow-irrigated treatments had the lowest water use efficiency.

Thrips population reached a maximum in mid-June and then decreased (Fig. 2). The thrips population was low for all plots, only exceeding the recommended threshold for the initiation of control measures on June 14 at 17.7 thrips/plant, based on 15-25 thrips/plant (Jensen 2005). There were significant differences in thrips counts only between treatments on June 14, June 20, and for the weekly May 23 through August 7 season average (Table 3). On June 14 and on average, the two furrow-irrigated treatments had among the highest thrips counts. On June 20, the treatments drip irrigated at 20 and 30 cb had among the highest thrips counts. The sprinkler-irrigated treatment had among the lowest thrips counts on June 14, June 20, and on average.

Iris yellow spot virus symptoms in 2007 were extremely few (Table 3). There were statistically significant differences between treatments and varieties, but these differences were too small for meaningful conclusions to be drawn.

Powdery mildew symptoms were also very few, with the sprinkler-irrigated treatment having among the lowest symptom severity rating. The variety Evolution had the highest powdery mildew severity rating, followed by Joaquin. Charismatic and Vaquero had practically no powdery mildew (Table 4).

Averaged over varieties and N rates, the two furrow-irrigated treatments had the highest total yield, marketable yield, and supercolossal yield, followed by the treatments drip irrigated at 10, 15, 20, 15/25 cb, and the treatment drip irrigated at 20 cb with optional sprinkler irrigation (Table 5). The furrow-irrigated treatments were maintained wetter than intended, and wetter than is often desirable for furrow irrigation due to the risk of bulb decomposition. Drip irrigation at 30 cb and sprinkler irrigation at 20 cb resulted in the lowest total yield, marketable yield, and supercolossal yield. Drip or furrow irrigation with optional sprinkler irrigation did not significantly increase onion yield. Increasing the SWT irrigation criterion from 15 to 25 cb after August 1 did not affect onion yield in this trial.

The response of the varieties individually to the irrigation treatments was not different from the variety average, except for Evolution and Joaquin. Evolution had significantly lower total yield and marketable yield when furrow irrigated with optional sprinkler irrigation compared to furrow irrigation only. Joaquin had significantly higher total yield and marketable yield when furrow irrigated with optional sprinkler irrigation compared to furrow irrigation alone. Averaged over irrigation treatments and N rates, Charismatic had the highest and Vaquero had the lowest supercolossal bulb yield. Averaged over irrigation treatments and N rates, Vaquero had the highest marketable onion yield and Joaquin and Evolution had the lowest marketable onion yield.

There was no significant interaction of N rate with irrigation and variety. Averaged over irrigation treatments and varieties, the highest total yield, marketable yield, and supercolossal yield were obtained with the lower N rate of 100 lb N/acre.

The furrow-irrigated treatments and the treatment drip irrigated at 30 cb had among the lowest percentage of functionally single-centered bulbs (Table 6). Sprinkler irrigation resulted in among the highest percentage of single-centered bulbs for Vaquero and

Joaquin. Evolution and Joaquin had the highest and Charismatic had the lowest percentage of single-centered bulbs.

Drip irrigation at 10 cb and the furrow-irrigated treatments had among the lowest maturity on August 13 and August 29. Vaquero and Charismatic were the most mature and Evolution and Joaquin were the least mature on August 29 (Table 6). Sprinkler irrigation resulted in the highest amount of bolting.

Conclusions

As we noted above, differences that cultural practices might make on IYSV expression were negligible due to low thrips pressure and very low IYSV pressure observed in these studies in 2007. We expect that variety and irrigation treatment responses might be different with higher thrips and IYSV pressure. The results of this trial show that higher soil moisture achieved with the wetter treatments resulted in higher onion yield and grade. The higher yield and grade achieved with furrow irrigation compared to drip irrigation in this trial might not be realistic on a commercial scale. The plots in this trial were only 23 ft long, allowing extremely wet and uniform furrow irrigation. Such extremely wet and uniform furrow irrigation is difficult to achieve on a commercial scale without risk of over-irrigation and bulb decomposition in a considerable part of the field. In a year with higher thrips and IYSV pressure, furrow irrigation might not perform as well, as suggested by the higher thrips counts in the furrow-irrigated plots. Furrow irrigation also resulted in a lower percentage of functionally single-centered bulbs. Previous research at the Malheur Experiment Station has also shown that, with both furrow and drip irrigation, frequent irrigations to maintain high soil moisture can result in high yield and grade, but in years with rainfall, very wet conditions also result in higher losses to storage decomposition (Shock et al. 1998b, 2000).

The higher onion yield and grade achieved in this trial with the low N rate (100 lb N/acre) is in agreement with previous results showing that onion yields often show little response to N fertilizer in furrow or drip irrigations (Miller et al. 1993; Shock et al. 2001, 2004). High amounts of N can be provided to an onion crop by natural sources such as N mineralization and N in irrigation water (Shock et al. 2001, 2004). The only reason that the 200 lb N/acre was used in this trial was the possibility that higher N might help IYSV-infected plants to sustain leaf area and productivity. This idea could not be tested in 2007 due to low IYSV pressure.

The treatments tested in this trial need to be tested in other years with higher IYSV pressure.

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Table 2. Average daily maximum soil temperature at 2-inch depth for onions with and without straw mulch and submitted to 9 irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Irrigation system	Irrigation criterion	Straw	No straw
	cb	°F	°F
Drip	10	74.0	75.8
Drip	15	73.7	80.6
Drip	20	77.8	85.5
Drip	30	77.0	88.2
Drip	15/25	73.9	75.2
Sprinkler	20	74.6	75.1
Drip/spr.	20	76.3	86.6
Furrow	20-25	76.0	75.4
Furrow/spr.	20-25	74.7	77.8
Average		75.4	80.0
LSD (0.05) average straw vs. no straw		3.4	

Table 3. Average hourly soil water tension, total water applied, marketable yield, and water use efficiency (cwt marketable yield per inch of water applied) for onions submitted to nine irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Irrigation system	Irrigation criterion	Average hourly soil water tension	Standard deviation	Total water applied[a]	Marketable yield	Water use efficiency
	cb	cb		inches	cwt/acre	cwt/inch
Drip	10	11.7	3.4	44.7	1001.5	22.8
Drip	15	15.1	2.7	42.4	1037.0	24.4
Drip	20	17.6	3.3	37.8	1002.4	26.6
Drip	30	24.1	5.5	30.4	951.3	31.3
Drip	15/25	17.2	4.4	38.0	1041.6	27.5
Sprinkler	20	17.8	5.2	37.9	912.9	24.8
Drip/spr.	20	17.3	3.2	37.3	1034.7	28.0
Furrow	20-25	13.5	6.8	273.7	1153.2	4.2
Furrow/spr.	20-25	13.8	5.3	286.1	1150.8	4.0
LSD (0.05)		2.3	2.3	6.3	56.2	4.1

[a]includes 2.1 inches of precipitation. For the furrow irrigated plots, the total water applied was estimated from limited furrow inflow measurements. Based on inflow and outflow measurements, the total amount of water infiltrated in the furrow plots was estimated to be 66.9 inches for the furrow treatment and 79.3 inches for the furrow with optional sprinkler irrigation treatment.

Table 4. Thrips counts, iris yellow spot virus (IYSV), and powdery mildew (PM) leaf damage severity ratings in response to irrigation system and variety, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007. Continued on next page.

Irrigation system	Irrigation criterion	Thrips counts			Disease severity rating[a]	
		6/14	6/20	5/7-8/23 average	IYSV	PM
	cb	------------------- No./plant -------------------			------ Scale of 0-5 ------	
		Evolution				
Drip	10	15.7	7.7	5.3	0.50	1.44
Drip	15	19.1	6.4	6.1	0.50	1.81
Drip	20	16.9	8.1	6.0	0.50	1.00
Drip	30	15.2	10.8	5.0	0.50	0.56
Drip	15/25	17.5	6.2	5.5	0.50	1.19
Sprinkler	20	16.7	6.9	5.4	0.50	0.06
Drip/spr.	20	17.1	8.0	6.1	0.50	0.88
Furrow	20-25	23.6	7.1	6.2	0.44	0.88
Furrow/spr.	20-25	24.2	6.9	6.4	0.50	0.69
	average	18.4	7.6	5.8	0.49	0.94
		Vaquero				
Drip	10	18.8	7.8	5.8	0.56	0.13
Drip	15	16.5	6.6	6.3	0.56	0.06
Drip	20	19.7	9.1	6.3	0.56	0.06
Drip	30	21.4	9.5	5.9	0.50	0.00
Drip	15/25	17.8	5.7	5.6	0.50	0.00
Sprinkler	20	18.7	6.3	5.4	0.50	0.00
Drip/spr.	20	19.2	7.9	6.4	0.56	0.00
Furrow	20-25	23.7	7.1	7.0	0.50	0.00
Furrow/spr.	20-25	24.0	7.4	6.3	0.50	0.06
	average	19.9	7.5	6.1	0.53	0.03
		Joaquin				
Drip	10	17.3	5.8	4.7	0.50	0.94
Drip	15	17.0	6.5	5.8	0.50	1.13
Drip	20	20.4	8.4	5.7	0.50	0.69
Drip	30	17.6	9.4	5.4	0.63	0.44
Drip	15/25	17.8	5.9	5.3	0.50	0.63
Sprinkler	20	15.0	6.6	4.6	0.50	0.00
Drip/spr.	20	17.1	6.7	5.6	0.44	0.19
Furrow	20-25	21.3	7.0	5.8	0.50	0.44
Furrow/spr.	20-25	21.8	6.7	5.7	0.44	0.31
	average	18.4	7.0	5.4	0.50	0.53

Irrigation system	Irrigation criterion	Thrips counts			Disease severity rating[a]	
		6/14	6/20	5/7-8/23 average	IYSV	PM
	cb	No./plant			Scale of 0-5	
		Charismatic				
Drip	10	12.6	6.1	4.5	0.50	0.06
Drip	15	12.2	5.3	4.9	0.50	0.13
Drip	20	15.6	6.7	5.2	0.50	0.06
Drip	30	13.3	8.0	4.7	0.50	0.00
Drip	15/25	13.5	5.3	4.3	0.50	0.06
Sprinkler	20	13.8	5.5	4.2	0.50	0.00
Drip/spr.	20	12.3	7.1	4.9	0.44	0.00
Furrow	20-25	18.5	5.4	5.7	0.44	0.00
Furrow/spr.	20-25	16.2	6.0	5.1	0.38	0.00
	average	14.2	6.2	4.8	0.47	0.03
		Average over varieties and N rates				
Drip	10	16.1	6.8	5.1	0.52	0.64
Drip	15	16.2	6.2	5.8	0.52	0.78
Drip	20	18.1	8.1	5.8	0.52	0.45
Drip	30	16.9	9.4	5.3	0.53	0.25
Drip	15/25	16.7	5.8	5.2	0.50	0.47
Sprinkler	20	16.0	6.3	4.9	0.50	0.02
Drip/spr.	20	16.4	7.4	5.7	0.48	0.27
Furrow	20-25	21.7	6.6	6.2	0.47	0.33
Furrow/spr.	20-25	21.5	6.7	5.9	0.45	0.27
	average	17.7	7.1	5.5	0.50	0.39
LSD (0.05)						
Irrigation		3.9	2.1	0.8	0.04	0.24
N rate		NS	NS	NS	NS	NS
Variety		1.2	NS	0.2	0.04	0.09
Irrig. X N rate		NS	NS	NS	NS	NS
Irrig. X Var.		NS	NS	NS	NS	0.28
N rate X Var.		NS	NS	NS	NS	NS
Irrig. X N rate X Var.		NS	NS	NS	NS	NS

[a]0 = no symptoms, 1 = 1-25% of foliage diseased, 2 = 26-50% of foliage diseased, 3 = 51-75% of foliage diseased, 4 = 76-99% of foliage diseased, and 5 = 100% of foliage diseased.

Table 5. Onion yield and grade in response to irrigation system, N rate, and variety, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007. Continued on next page.

Irrigation system	Irrigation criterion	Total yield	Marketable yield by grade					No. 2	Small	Rot	Bulb counts >4¼ in
			Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in				
	cb	cwt/acre								%	#/50 lb
				Evolution							
Drip	10	1030.9	935.5	484.2	333.8	114.7	2.7	37.7	2.8	5.4	28.9
Drip	15	1134.5	1032.9	365.7	491.2	170.0	6.1	46.1	2.0	4.6	30.3
Drip	20	1050.0	969.6	349.3	446.2	169.9	4.2	40.4	0.4	3.7	30.3
Drip	30	933.7	855.1	307.2	383.8	158.8	5.3	52.7	1.1	2.6	29.8
Drip	15/25	1066.4	998.2	368.8	447.9	180.5	0.9	32.7	0.0	3.3	29.4
Sprinkler	20	954.0	887.4	302.8	409.7	169.0	5.8	22.3	0.9	4.6	32.2
Drip/spr.	20	1075.3	1003.7	448.6	411.9	134.4	8.8	36.1	1.3	3.2	29.3
Furrow	20-25	1268.0	1209.3	697.9	386.0	123.1	2.3	14.8	0.2	3.4	28.5
Furrow/spr.	20-25	1114.8	1061.8	715.6	282.7	62.0	1.4	17.2	0.5	3.2	27.9
	average	1069.7	994.8	448.9	399.3	142.5	4.2	33.3	1.0	3.8	29.6
				Vaquero							
Drip	10	1148.1	1088.7	455.8	444.5	177.6	10.7	15.0	1.1	3.7	29.4
Drip	15	1109.2	1056.2	382.2	484.0	186.0	4.0	16.5	1.0	3.2	29.5
Drip	20	1061.6	1010.2	327.6	470.5	207.4	4.8	22.8	1.6	2.9	30.0
Drip	30	1042.2	995.5	253.3	476.6	259.4	6.2	20.8	1.7	2.3	29.1
Drip	15/25	1164.5	1100.4	338.5	531.4	228.2	2.2	14.1	2.0	4.1	29.7
Sprinkler	20	1041.6	985.7	234.4	466.8	275.8	8.7	15.4	2.0	3.7	29.7
Drip/spr.	20	1095.7	1047.2	381.7	482.5	179.0	3.9	17.7	1.2	2.7	28.5
Furrow	20-25	1263.1	1211.0	673.0	404.5	130.5	2.9	13.6	3.2	3.0	27.6
Furrow/spr.	20-25	1280.8	1222.9	698.9	386.6	134.3	3.0	15.6	0.2	3.3	27.6
	average	1134.1	1079.8	416.2	460.8	197.6	5.2	16.8	1.6	3.2	29.0
				Joaquin							
Drip	10	1091.4	1018.2	457.5	392.2	165.3	3.2	21.4	0.5	4.7	29.4
Drip	15	1081.9	1008.5	460.2	384.5	158.8	4.9	30.3	0.0	3.9	30.3
Drip	20	1059.5	1016.4	391.6	425.8	192.5	6.4	19.6	1.3	2.1	31.6
Drip	30	1005.8	956.1	347.8	424.2	180.0	4.1	28.2	0.2	2.2	29.4
Drip	15/25	1081.8	1040.5	395.1	448.7	192.9	3.8	16.0	1.3	2.1	30.2
Sprinkler	20	885.8	826.0	237.2	350.0	233.8	5.0	3.7	3.0	6.5	31.1
Drip/spr.	20	1057.6	1003.7	403.7	425.3	165.6	9.1	19.0	1.5	3.1	29.9
Furrow	20-25	1140.7	1053.4	627.5	318.9	101.8	5.1	16.3	0.8	6.3	28.3
Furrow/spr.	20-25	1220.2	1143.1	716.0	319.0	106.6	1.5	20.3	1.2	4.5	28.2
	average	1069.4	1007.3	448.5	387.6	166.4	4.8	19.4	1.1	4.0	29.8

Irrigation system	Irrigation criterion	Total yield	Marketable yield by grade					No. 2	Small	Rot	Bulb counts >4¼ in
			Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in				
	cb	---------- cwt/acre ----------								%	#/50 lb
				Charismatic							
Drip	10	1060.8	963.7	482.7	345.9	132.4	2.7	39.9	0.1	5.4	29.0
Drip	15	1125.5	1050.4	514.3	368.3	163.6	4.1	37.5	1.5	3.3	29.3
Drip	20	1070.9	991.9	443.0	371.1	172.4	5.4	40.2	1.7	3.5	28.7
Drip	30	1066.0	998.5	449.3	362.6	178.1	8.4	39.3	1.8	2.5	28.8
Drip	15/25	1150.3	1027.2	467.1	370.3	183.4	6.5	56.0	2.8	5.9	29.7
Sprinkler	20	1008.2	952.3	363.8	373.4	208.3	6.8	24.1	2.3	2.9	29.9
Drip/spr.	20	1156.1	1084.0	492.3	401.6	182.3	7.8	43.3	1.3	2.4	29.4
Furrow	20-25	1216.9	1139.3	724.9	267.1	143.3	4.1	36.69	1.5	3.2	27.1
Furrow/spr.	20-25	1233.4	1175.6	767.9	274.8	126.1	6.7	19.4	2.0	2.9	27.4
	average	1120.9	1042.5	522.8	348.4	165.6	5.8	37.4	1.7	3.6	28.8
				Average over variety and N rate							
Drip	10	1082.8	1001.5	470.0	379.1	147.5	4.8	28.5	1.1	4.8	29.2
Drip	15	1112.8	1037.0	430.6	432.0	169.6	4.8	32.6	1.1	3.8	29.9
Drip	20	1060.5	997.0	377.9	428.4	185.5	5.2	30.7	1.2	3.0	30.2
Drip	30	1011.9	951.3	339.4	411.8	194.1	6.0	35.2	1.2	2.4	29.3
Drip	15/25	1115.7	1041.6	392.4	449.6	196.2	3.4	29.7	1.5	3.9	29.7
Sprinkler	20	972.4	912.9	284.5	400.0	221.7	6.6	16.4	2.1	4.4	30.7
Drip/spr.	20	1096.2	1034.7	431.6	430.3	165.3	7.4	29.0	1.3	2.9	29.2
Furrow	20-25	1222.2	1153.2	680.8	344.1	124.7	3.6	20.3	1.4	3.9	27.9
Furrow/spr.	20-25	1212.3	1150.8	724.6	315.8	107.3	3.1	18.1	1.0	3.5	27.8
	average	1098.5	1031.1	459.1	399.0	168.0	5.0	26.7	1.3	3.6	29.3
	N rate lb N/acre										
	100	1118.2	1048.4	485.4	398.2	160.0	4.9	27.1	1.3	3.7	29.2
	200	1071.8	1006.8	420.1	403.0	178.5	5.2	26.7	1.3	3.5	29.5
LSD (0.05)											
Irrigation		55.3	53.6	97.9	71.4	48.3	NS	11.6	NS	NS	1.5
N rate		42.4	41.2	32.5	NS	18.8	NS	NS	NS	NS	NS
Variety		26.3	27.9	28.2	24.1	17.2	NS	5.4	NS	NS	0.5
Irrig. X N rate		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Irrig. X Var.		79.0	83.5	NS	NS	NS	NS	16.2	NS	NS	NS
N rate X Var.		NS	NS	NS	NS	24.3	NS	NS	NS	NS	NS
Irrig. X N rate X Var.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6. Maturity, bolting, and onion single centers for four onion varieties submitted to nine irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007. Continued on next page.

Irrigation	Irrigation	Maturity			Multiple center			Single center	
system	criterion	Aug. 13	Aug. 29	Bolter	large	medium	small	functional	single
	cb	%							
Evolution									
Drip	10	9.7	29.4	0.2	2.0	3.5	4.8	94.5	89.7
Drip	15	10.3	27.5	0.5	1.5	4.0	11.5	94.5	83.0
Drip	20	14.4	33.1	0.3	5.1	2.9	2.9	92.0	89.1
Drip	30	20.0	43.1	0.0	8.0	4.0	5.0	88.1	83.1
Drip	15/25	11.7	30.0	0.4	4.0	2.5	13.5	93.5	80.0
Sprinkler	20	13.8	27.5	0.9	2.5	3.6	8.6	93.9	85.3
Drip/spr.	20	8.1	25.6	0.0	5.3	3.4	5.0	91.3	86.3
Furrow	20-25	5.3	23.8	0.3	4.5	5.0	9.0	90.5	81.5
Furrow/spr.	20-25	5.3	20.0	0.0	2.5	5.0	9.0	92.5	83.5
	average	11.0	28.9	0.3	3.9	3.8	7.8	92.3	84.5
Vaquero									
Drip	10	25.0	52.5	0.1	3.5	9.0	9.5	87.5	78.0
Drip	15	30.9	55.6	0.2	7.5	4.5	9.5	88.0	78.5
Drip	20	38.4	60.0	0.1	8.0	10.0	17.0	82.3	65.0
Drip	30	46.9	66.3	0.2	5.1	8.6	12.8	86.3	73.5
Drip	15/25	30.9	60.6	0.4	6.5	12.0	8.5	81.5	73.0
Sprinkler	20	27.2	53.8	0.4	6.5	6.0	8.5	88.0	79.0
Drip/spr.	20	26.9	50.6	0.2	9.5	10.0	6.5	80.5	74.0
Furrow	20-25	15.6	46.9	0.3	9.0	8.0	15.0	83.0	68.0
Furrow/spr.	20-25	12.8	38.1	0.1	11.4	9.7	8.6	76.7	67.3
	average	28.3	53.8	0.2	7.4	8.6	10.7	83.9	73.1
Joaquin									
Drip	10	8.8	26.9	0.5	2.5	2.5	8.5	95.0	86.5
Drip	15	10.9	30.0	0.3	1.5	3.0	13.0	95.5	82.5
Drip	20	13.4	36.9	0.3	2.0	3.5	8.5	94.5	86.0
Drip	30	21.6	41.3	0.2	4.0	2.0	8.0	94.0	86.0
Drip	15/25	17.5	31.9	0.7	2.0	1.5	9.0	96.5	87.5
Sprinkler	20	16.3	33.8	1.4	2.0	1.5	4.5	96.5	92.0
Drip/spr.	20	10.3	29.4	0.1	3.0	3.0	10.0	94.0	84.0
Furrow	20-25	7.2	23.1	0.7	4.5	7.5	9.0	88.0	79.0
Furrow/spr.	20-25	5.6	22.5	0.7	2.5	2.5	5.5	95.0	89.5
	average	12.4	30.6	0.5	2.7	3.0	8.4	94.3	85.9
Charismatic									
Drip	10	21.9	90.0	0.2	17.6	11.3	20.4	71.1	50.7
Drip	15	30.6	53.8	0.2	19.5	11.0	25.0	69.5	44.5
Drip	20	28.1	55.0	0.1	15.0	17.0	22.0	68.0	46.0
Drip	30	42.5	60.6	0.2	12.0	23.4	30.3	64.6	34.3
Drip	15/25	26.6	55.0	0.5	18.4	10.9	24.4	70.8	46.4
Sprinkler	20	20.9	44.4	1.4	19.5	16.5	20.0	64.0	44.0
Drip/spr.	20	19.4	46.9	0.1	21.5	14.0	24.5	64.5	40.0
Furrow	20-25	9.7	35.6	1.0	21.0	11.5	13.5	67.5	54.0
Furrow/spr.	20-25	6.6	31.3	0.5	20.0	14.0	19.0	66.0	47.0
	average	22.9	52.5	0.5	18.4	14.4	22.0	67.3	45.3

Irrigation system	Irrigation criterion	Maturity		Bolter	Multiple center			Single center	
		Aug. 13	Aug. 29		large	medium	small	functional	single
	cb	%							
		Average over variety and N rate							
Drip	10	16.3	49.7	0.2	6.0	6.4	10.5	87.5	77.0
Drip	15	20.7	41.7	0.3	7.5	5.6	14.8	86.9	72.1
Drip	20	23.6	46.3	0.2	7.6	8.5	12.9	84.0	71.0
Drip	30	32.7	52.8	0.1	7.2	9.1	13.5	83.8	70.2
Drip	15/25	21.7	44.4	0.5	7.4	6.6	13.5	86.0	72.5
Sprinkler	20	19.5	39.8	1.0	7.6	6.9	10.4	85.5	75.1
Drip/spr.	20	16.2	38.1	0.1	9.8	7.6	11.5	82.6	71.1
Furrow	20-25	9.5	32.3	0.6	9.8	8.0	11.6	82.3	70.6
Furrow/spr.	20-25	7.6	28.0	0.3	9.0	7.7	10.6	82.9	72.1
	average	18.6	41.5	0.4	8.0	7.4	12.1	84.6	72.4
LSD (0.05)									
Irrigation		7.1	11.4	0.4	NS	NS	NS	3.7	NS
N rate		NS	NS	NS	NS	NS	NS	NS	NS
Variety		2.2	6.3	0.2	NS	NS	NS	2.9	3.5
Irrig. X N rate		NS	NS	NS	NS	NS	NS	NS	NS
Irrig. X Var.		6.6	NS	NS	NS	NS	NS	NS	10.6
N rate X Var.		NS	NS	NS	NS	NS	NS	NS	NS
Irrig. X N rate X Var.		NS	NS	NS	NS	NS	NS	NS	NS

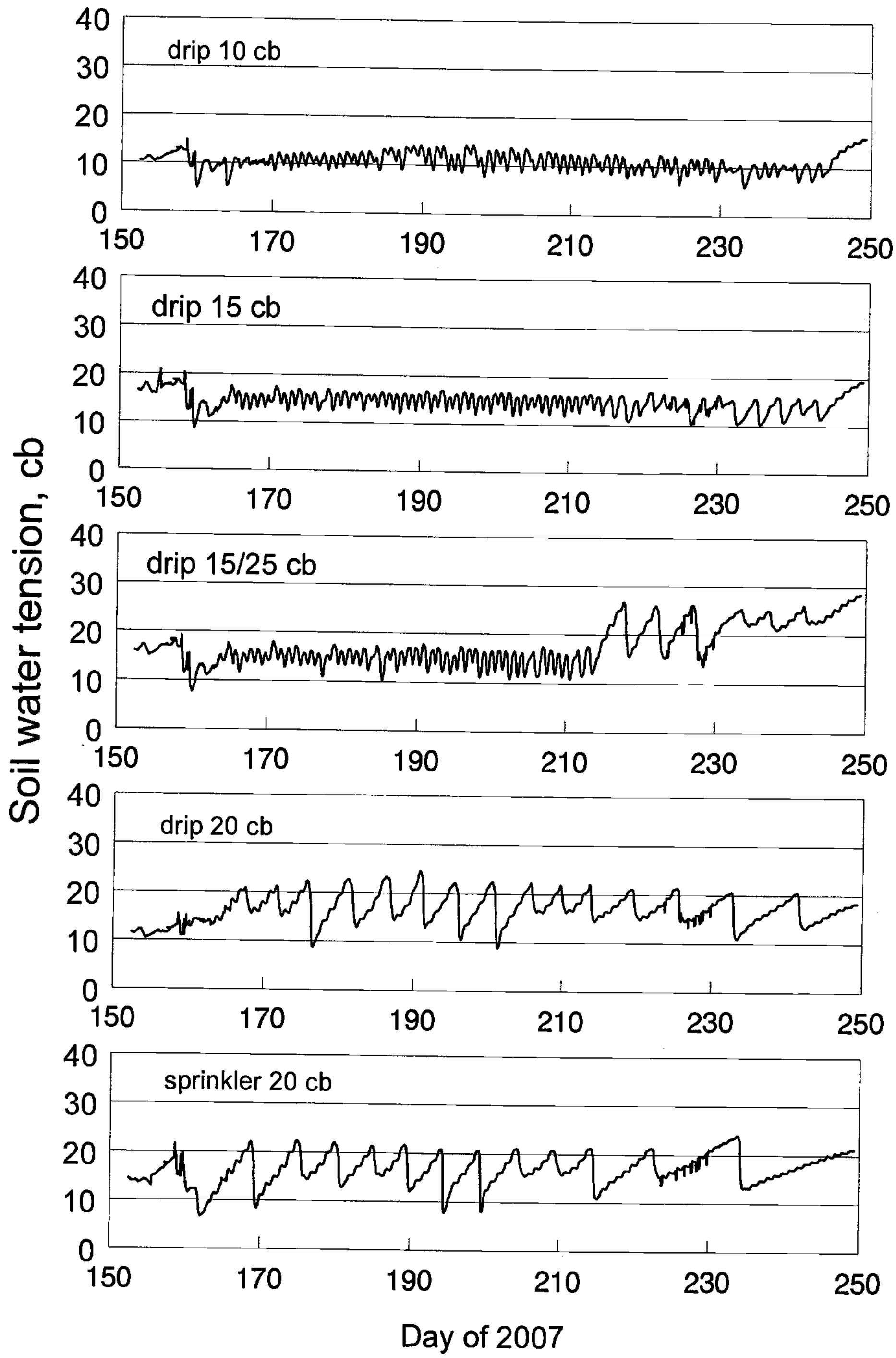

Figure 1a. Soil water tension at 8-inch depth over time for onions submitted to nine irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

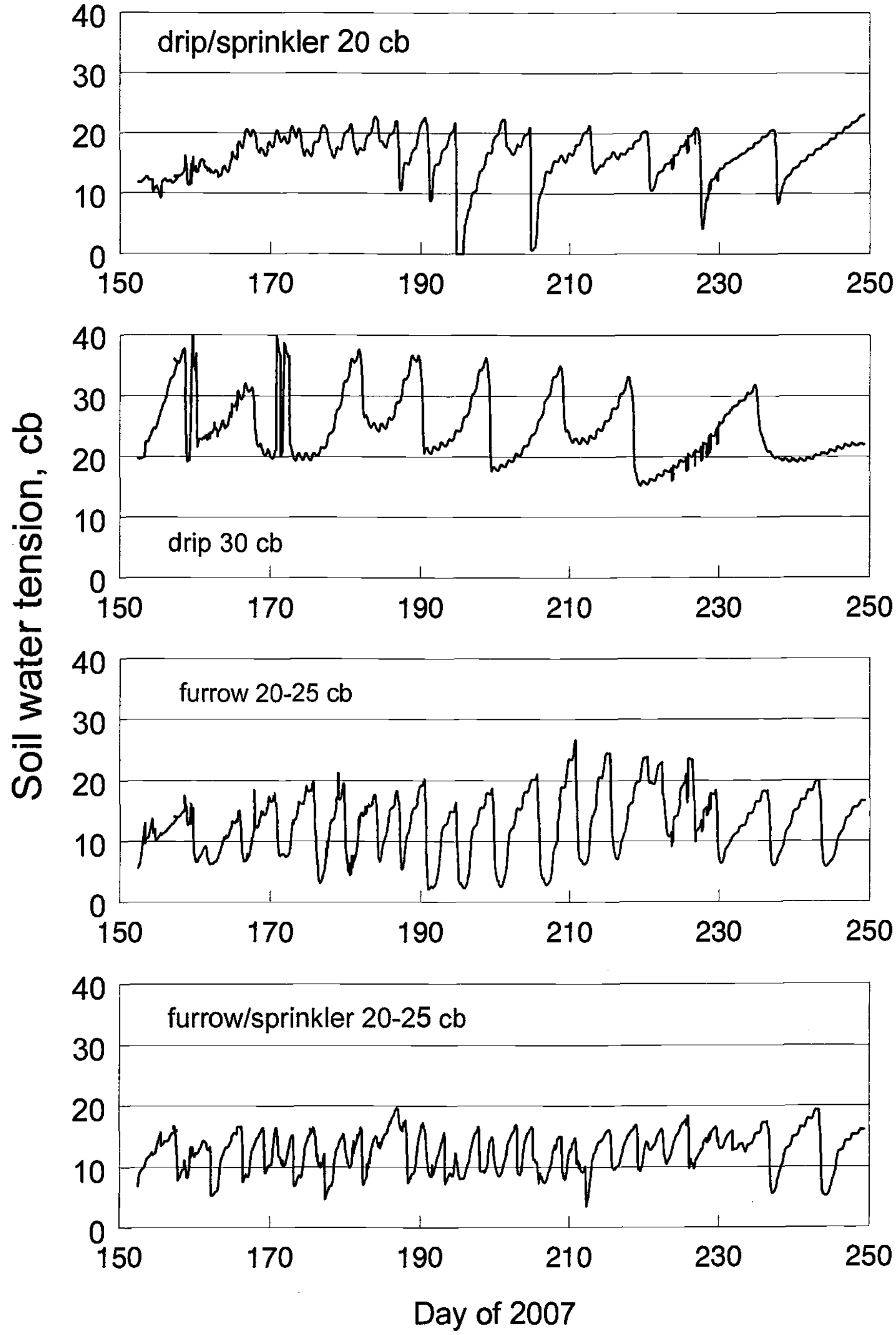

Figure 1b. Soil water tension at 8-inch depth over time for onions submitted to nine irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

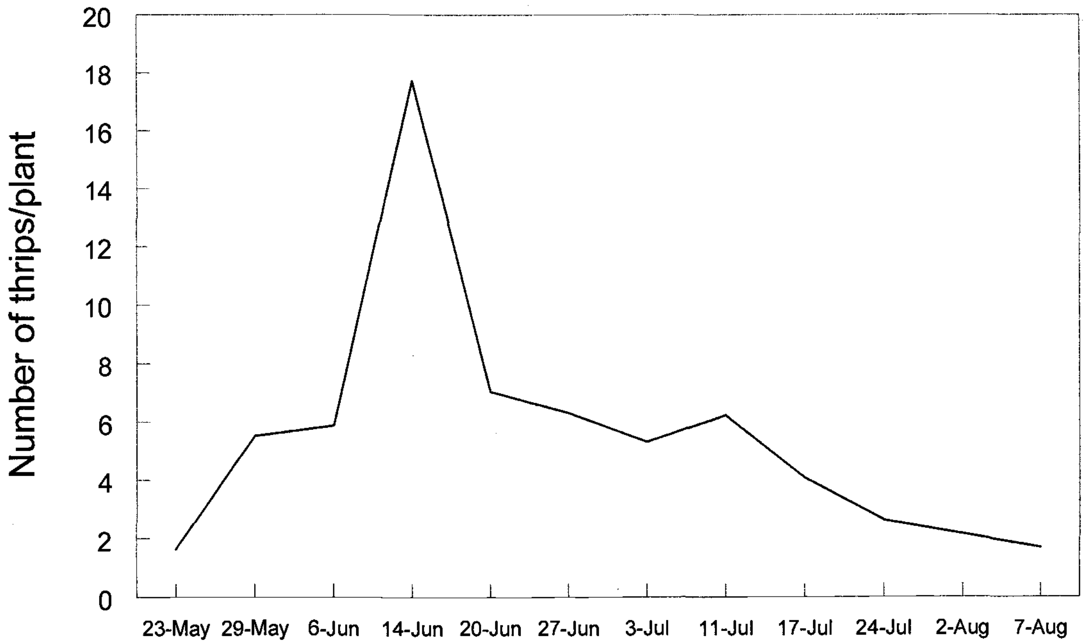

Figure 2. Thrips population counts per onion plant over time. Counts presented here were the average over irrigation treatments, N rates, and varieties (288 plots). On each date thrips on 15 onion plants/plot were counted. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.