

Effect of Irrigation Management on Sour Skin of Onion

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ABSTRACT

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The incidence of sour skin of onion, caused by *Pseudomonas cepacia*, was greater in plots irrigated by overhead sprinklers than in plots irrigated by furrow the entire season or irrigated by sprinklers until bulbing and then by furrow. In three trials that varied the rate of water delivered by sprinklers (2.5–6.7 mm of water per hour, which is about the range used in commercial fields), there was no correlation between millimeters of water applied and incidence of disease. In an experiment using extreme differences in sprinkler irrigation (0.6–9.3 mm of water per hour), however, the number of infected onions was positively correlated with millimeters of water applied. There was no significant difference in number of rotted onions between two planting densities (52 and 79 plants per meter). Onions inoculated at weekly intervals from 3 wk before bulb formation to 1 wk after bulbing developed external disease symptoms at the same time, about 3 wk after bulbing.

Sour skin of onion (*Allium cepa* L.), caused by *Pseudomonas cepacia* (Burkh.) Palleroni and Holmes (1), is a

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serious disease of processing onions in California's Central Valley. The bacteria enter plants through wounds or the leaf blade axils of young leaves and progress down the leaf to the corresponding scales in the bulb (3). The infected leaf develops a watery rot in the onion neck, turns light brown, and is easily removed from the plant. In advanced stages, infected scales discolor and separate from healthy portions of the onion. Severe outbreaks

can result in rejection of entire lots of onions at the processing plant.

Moisture appears to be an important limiting factor in disease progress. Wounds and the leaf axil of young leaves must be water-soaked for infection to occur (3). Older leaves are apparently less susceptible to infection because they lack an upright growth habit that holds water (2). Lesions develop most rapidly when bacteria move in intercellular spaces, an activity that requires free water in onion tissues (3). The relationship of sprinkler irrigation, the preferred method of irrigation in most onion fields in California, to some of these factors is unknown. The objectives of this study were to determine the influence of method of irrigation, millimeters of water applied by sprinkler irrigation, and plant density on the incidence of sour skin in processing onions.

MATERIALS AND METHODS

Inoculum preparation. The isolate of *P. cepacia* used in all experiments in this study was originally cultured from a diseased onion by J. V. Leary (University

of California, Riverside). Plants were inoculated with *P. cepacia* by one of two methods. In most experiments, a water suspension of approximately 10^6 cfu of *P. cepacia* per milliliter (determined by dilution plating or spectrophotometrically) from 48-hr-old cultures grown on King's medium B was sprayed on the plants until runoff with a compressed-air sprayer adjusted to about 1.72×10^5 Pa (25 psi). In part of one experiment, inoculum consisted of 1- to 2-cm chips of onion bulbs inoculated with a suspension of *P. cepacia* and incubated for 24 hr. The chips were then scattered over the surface of the onion beds.

Method of irrigation. South Port White Globe onions were direct-seeded on 64 five-row beds 91.4 m long with 101.6-cm centers at the University of California West Side Field Station, Fresno County, in January 1987 and 1988. Plant density was 66–79 and 52–66 plants per meter of bed in 1987 and 1988, respectively. The field was irrigated with sprinklers using Rainbird 20JH heads (Rainbird Sprinklers, Glendora, CA) with straight-bore nozzles (28-mm-diameter orifice) until the plants developed three or four leaves, which occurred in mid-April of each year. The fields were then divided lengthwise into four sections of 16 beds each. Sprinklers on 61-cm risers at 9.1-m intervals were placed between the center two rows of each section. In addition, gated pipe was laid transversely across the field at 22.7-m intervals, creating 16 sections to accommodate four replications (in a randomized complete block design) of the following four irrigation regimes: 1) furrow irrigation all season; 2) sprinkler irrigation until bulbing, then furrow irrigation for the remainder of the season; 3) sprinkler irrigation to 30 days past bulbing, then furrow irrigation for the remainder of the season; and 4) sprinkler irrigation all season. In this study, bulbing is defined as that time when the bulb is about two times the diameter of the neck, which occurred in late May in both years. Each week there were two 6-hr sprinkler sessions and one furrow irrigation. The final irrigation was in the first week in July of each year.

The volume of water delivered by sprinklers was measured twice each year with 7.8-cm-diameter catch cans placed halfway between risers in the second bed on both sides of each line. The cans were 46 cm above ground level. Sprinklers delivered an average of 2.5 and 3.8 mm of water per hour in 1987 and 1988, respectively. The total seasonal amounts of water for treatments 1 through 4, including furrow irrigations, were 63.3, 61.9, 55.6, and 48.9 cm in 1987 and 96.5, 94.6, 92.6, and 91.5 cm in 1988. Variation in pump pressure and an increase in the number of irrigations because of weather conditions accounted for the differences

in total amounts of water between 1987 and 1988. The numbers of sprinkler irrigations, exclusive of those prior to the beginning of the experiments, for treatments 1 through 4 were 0, 11, 18, and 21 in 1987 and 0, 17, 25, and 29 in 1988. Rainfall after March was negligible in both years.

Plots were located on the second beds from each side of sprinkler lines and centered between risers and on the corresponding two beds in the furrow-irrigated sections. Both beds in each section were divided into three 3.1-m subplots, which were noninoculated or inoculated with *P. cepacia* by the two methods described earlier. The inoculum suspended in water was applied between the fourth and fifth hours of two regularly scheduled sprinkler irrigations in the first and third weeks of June in both years. In the other method of inoculation, chips from three onion bulbs were scattered over the bed surface of each 3.1-m subplot in the first week in June 1987 and in April 1988. The chip inoculum was applied earlier in 1988 than in 1987 to ensure the presence of the bacterium at bulbing. Preliminary experiments indicated that timing of inoculation did not influence disease incidence, since the onions did not become susceptible until bulbing.

Disease incidence was evaluated in mid-July. All bulbs in the subplots were cut just below the shoulder; disease incidence was expressed as the percentage of bulbs with internal discoloration. Tissue from representative diseased bulbs was cultured on King's medium B and nutrient agar for recovery of *P. cepacia*. The identify of *P. cepacia* was confirmed in all experiments by the production of a nonfluorescent, yellow diffusible pigment in the agar and the development of sour skin symptoms on slices of onion inoculated with the suspect bacterium.

Yield data were collected in August 1987 and July 1988. Fresh weights of all bulbs from 6.1 m of the third bed (noninoculated) on both sides of the sprinkler line and the corresponding beds in the furrow-irrigated plots were recorded in 1987. Identical measurements were taken from 3.1 m per plot in 1988. Percentage of soluble solids in a sample of about 30 macerated onions from each plot was measured with a refractometer.

The effect of timing of inoculation was studied in 1988. Single inoculations of bacterial suspensions were applied to 1.5-m sections of beds in each plot. The inoculum was applied as described earlier at weekly intervals for 5 wk beginning in early May. Onions were evaluated for external symptoms of sour skin from mid-May to mid-July. A similar experiment was conducted at the University of California, Davis, in 1988 in sprinkler-irrigated onions.

Volume of overhead irrigation. South Port White Globe onions were direct-seeded in December 1985, in six-row beds with 101.6-cm centers at the University of California Kearney Agricultural Center, Parlier. The field was irrigated uniformly with sprinklers as needed until the plants had five or six leaves, which occurred in early May. At that time, the field was divided into two 26-bed sections. Each section had one sprinkler line installed parallel to and between its center two beds. Nine 91.4-cm risers, fitted with Rainbird 20JH heads and controlled droplet nozzles, were located at 4.6-m intervals along each line. This riser spacing provided uniform wetness between risers parallel to lines and a linear decrease in quantity of water delivered with distance away from lines. The diameter of nozzle orifices for one line was 24 mm and that for the other was 28 mm. Sprinklers were operated by a pump adjusted to 3.45×10^5 Pa (50 psi). The water reached 12 beds on each side of each line. Irrigations were approximately weekly; each was 6 hr long. Volume of water delivered at each irrigation was measured with catch cans as described above. The cans were equidistant between two risers in the second, fifth, eighth, and eleventh beds away from and on both sides of each sprinkler line. There were four replicate cans at each distance away from the sprinkler lines.

Four 3.7-m plots, centered between risers, were located in the second, fifth, eighth, and eleventh beds on both sides of the lines. Each plot was divided into two 1.8-m subplots, which were randomly assigned a low (52 plants per meter) or high (79 plants per meter) plant population density. These two densities were established when plants had four or five leaves by transplanting and thinning. There were eight replications of paired plots for each distance from the line. The experiment was analyzed as a modified split block combined over sprinkler types. The plants were inoculated 5 and 13 June during the fifth hour of two regularly scheduled irrigations with a water suspension of *P. cepacia*.

The influence of variable amounts of water on disease incidence was also tested by altering nozzle orifice size in two commercial onion fields in Kern County and in one field at the University of California, Davis. The experiment was conducted in a field of fresh market onions in Kern County in 1987 and in fields of processing onions in the other two trials. Plots were established between two adjacent sprinkler lines 16 beds apart. Two opposite pairs of sprinklers, forming a square, were fitted with nozzles with orifices 24, 28, or 32 mm in diameter. Four replications of each treatment (orifice size) were arranged in a randomized complete block design.

Table 1. Effect of sprinkler and furrow irrigation on incidence of sour skin rot and yield of onion

Irrigation schedule	Rotted onions (%) ^y						Mean fresh weight (kg/m)		Mean soluble solids (%)	
	1987			1988			1987	1988	1987	1988
	Spray	Chip	Non-inoculated	Spray	Chip	Non-inoculated				
Furrow all season	0.3 a ^z	0.9 a	0.1 a	6.7 a	1.2 a	4.4 a	5.0 a	8.8 a	23.0 a	13.6 a
Sprinkle to bulbing, furrow rest of season	1.2 a	1.2 a	0.2 a	6.6 a	1.1 a	1.2 a	5.3 a	9.9 a	23.7 a	15.0 a
Sprinkle to 30 days past bulbing, furrow rest of season	9.5 b	9.1 b	1.6 b	17.4 b	2.6 a	1.1 a	4.3 a	9.3 a	22.9 a	14.0 a
Sprinkle all season	29.9 c	30.2 c	4.6 b	42.9 c	21.2 b	13.5 b	4.2 a	9.1 a	22.5 a	14.0 a

^yValues are means of four replications of about 200 onions each. Spray = suspension of cells of *Pseudomonas cepacia* sprayed twice onto leaves of onions in June. Chip = inoculated, chopped onion pieces scattered over beds in early June in 1987 and late April in 1988. Bulbing occurred in late May of both years.

^zMeans in each column followed by the same letter do not differ significantly according to Duncan's multiple range test ($P = 0.05$). Analysis was performed on arcsine transformed data.

Amounts of water delivered to the plots were estimated on two occasions using catch cans scattered throughout the plots. Irrigations were every 4–7 days; each was 2–4 hr long. A 9.1-m long section of one of the center beds in each plot was inoculated with a water suspension of *P. cepacia* during two regularly scheduled irrigations in the first and third weeks of June. All bulbs in the center 3.1 m of each treated bed in the 1987 Kern County trial and 100 bulbs in each plot in the other trials were cut and evaluated for disease in mid-July. Fresh weights of bulbs in 3.1 m in each treatment were measured.

RESULTS

Method of irrigation. The incidence of sour skin in onions inoculated by spraying a bacterial suspension was significantly less ($P = 0.05$) in the two treatments employing furrow irrigation for most or all of the season than in the two treatments irrigated by sprinkler for most or all of the season (Table 1). Similar results were obtained in the plots inoculated with infected onion chips in 1987. The highest percentage of rot occurred in plots irrigated by sprinkler all season. There were no significant differences in fresh weight of bulbs or percentage of soluble solids between the four irrigation systems in either year. *P. cepacia* was readily recovered from symptomatic tissue in this and all other experiments.

Symptoms of sour skin were first observed in all treatments in the third week of June in both years, regardless of when the plants were inoculated (Table 2). The effects of furrow and sprinkler irrigation on incidence of disease were not altered by varying the dates of inoculation. The results of the trial at the University of California, Davis, were similar (*data not shown*).

Volume of overhead irrigation. Incidence of sour skin rose with increasing amounts of water in the line source experiment (Fig. 1). The rate of increase was significantly greater ($P = 0.05$) in the plots irrigated from the 28-mm-diameter orifices than from the smaller

Table 2. Effect of inoculation date on incidence of sour skin of onion^y

Irrigation schedule	Plants with external symptoms of sour skin in mid-July (%)				
	Date of inoculation				
	6 May	13 May	20 May	27 May	10 June
Furrow all season	0.0 a ^z	0.0 a	0.0 a	0.0 a	0.3 a
Sprinkle to bulbing, furrow rest of season	0.8 a	0.0 a	0.9 a	0.0 a	0.0 a
Sprinkle to 30 days past bulbing, furrow rest of season	5.8 b	5.7 b	5.6 a	2.5 b	4.9 a
Sprinkle all season	13.8 c	11.8 c	15.2 b	8.0 c	15.5 b

^yPlants were inoculated with a single application of a suspension of cells (10^9 cfu/ml) of *Pseudomonas cepacia* on each date.

^zValues are means of four replications of 1.5 m of bed. Means in each column followed by the same letter do not differ significantly according to Duncan's multiple range test ($P = 0.05$). There were no significant differences between dates of inoculation within any irrigation treatment.

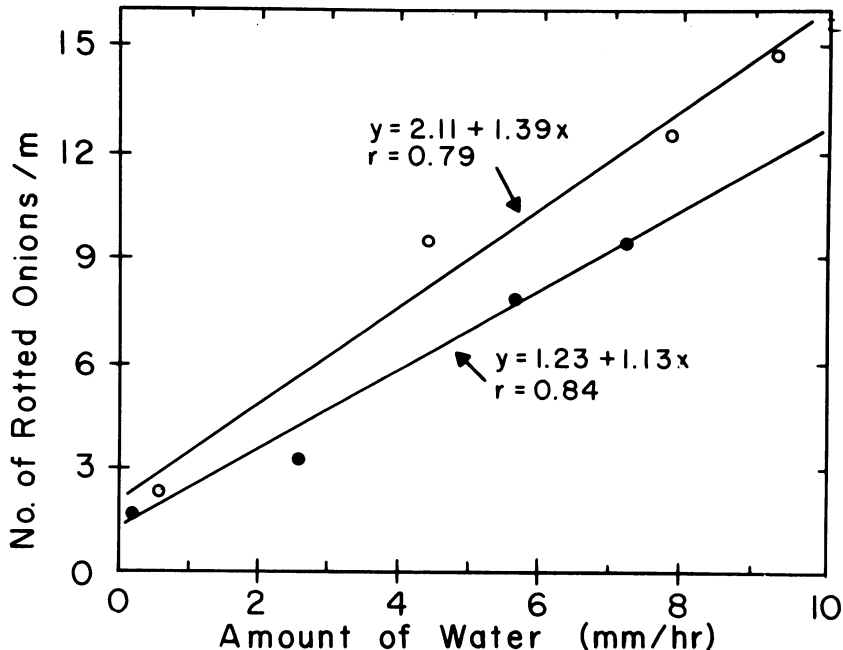


Fig. 1. Relationship between number of onions infected with *Pseudomonas cepacia* and amount of sprinkler irrigation delivered from 24-mm-diameter nozzles (closed circles) or 28-mm-diameter nozzles (open circles). Both are significant at $P = 0.05$.

orifices. The number of diseased onions was not affected by population density for any amount of water from either nozzle size.

There was no correlation between incidence of sour skin and volume of water delivered with the three sizes of

nozzles. The average rates of water delivered from the 24-, 28-, and 32-mm-diameter nozzles were 2.5, 5.1, and 6.7 mm per hour, respectively. The incidence of disease was low (less than 10% in all treatments) in two of the trials but high (63% in all treatments) in the other trial.

In all trials, percentage of soluble solids and yields were not significantly affected by the variable amounts of water.

DISCUSSION

Method of irrigation has a substantial impact on the incidence of sour skin of onions. Season-long overhead irrigation provided a favorable environment for infection by *P. cepacia*, whereas furrow irrigation resulted in almost complete control of the disease. However, the small incidence of disease in onions irrigated by sprinklers from sowing until bulbing (then by furrow) was not expected. Apparently, prior to bulbing, onions are relatively resistant to *P. cepacia* or the environment does not become favorable for bacterial multiplication until after bulbing. In our tests, the final four or five sprinkler irrigations were accompanied by a 150–300% increase in sour skin. Where sour skin is a potential problem, changing from sprinkler to furrow irrigation, at least

from bulbing to the end of the season, is advisable. Our experiment with various inoculation dates supports this suggestion, since symptoms first appear after bulbing. Moreover, only treatments in which sprinkler irrigation was used after bulbing resulted in high levels of disease.

The line source experiment demonstrated a positive correlation between amount of sprinkler irrigation and incidence of sour skin. In that experiment, we correlated incidence of disease with extreme differences in total amounts of water, ranging from almost no water to excessive volumes of water. Onions irrigated with the least amounts of water were small and commercially unacceptable. Our experiments using different sizes of nozzle orifices to vary the amounts of water more closely approximated field conditions. In those experiments, there was no reduction in the incidence of sour skin in plots irrigated with even the smallest volume

of water. Thus, the grower may not be able to reduce the volume of sprinkler irrigation sufficiently to achieve the goal of reducing disease while maintaining optimum yields.

The number of onions with sour skin symptoms did not significantly differ between the low and high plant densities, but the percentage of rotted onions was greater in the low-density plantings. Thus, the potential economic loss to sour skin may be greater in low-density plantings even though the number of infection events may be similar to those in high-density plantings.

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