Optimizing overhead sprinklers: Pressure effects on application rate, distribution of water, and pumping costs.

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Overhead sprinklers have an important role in the production of many cool season vegetable crops. Because sprinklers can be used to uniformly moisten the soil surface, they are used for germinating shallowly planted vegetable seed and for establishing transplanted vegetable crops. Sprinklers also provide a practical method to irrigate crops such as baby lettuce and baby spinach which may reach maturity in less than 30 days and have too many plant rows on a bed to be practically configured for surface drip. Other vegetable commodities such as broccoli are not sufficiently valuable to incur the extra costs associated with the use of drip irrigation.

Irrigation run-off often occurs on soil types when the infiltration rate decreases to less then the application rate of the sprinklers. In an unsaturated state, most soils have high infiltration rates, but as soils are irrigated and the pores become saturated, water infiltrates slower into the soil. Additionally, some soil types are susceptible to crusting due to the impact of water droplets from sprinklers. The soil crust impedes infiltration of water into the soil, thereby increasing run-off.

Reducing the application rate of overhead sprinklers may be one method to reduce run-off. For example, if water is infiltrating at an average rate of 0.15 inches per hour and the sprinkler system is applying water at 0.25 inches per hour (0.1 in/hr greater than the infiltration rate), reducing the application rate of the sprinkler to 0.2 inches per hour (0.05 in/hr greater than the infiltration rate) could reduce run-off by 50%.

The challenge is to reduce the application rate without reducing the uniformity of the sprinklers. We have noted that some farming operations pressurize overhead impact sprinklers to pressures greater than pressures recommended by the manufactures of the sprinkler heads. For example, we have measured nozzle pressures for the ½ inch brass impact heads, (Rainbird 20JH) between 60 psi and 70 psi. Reducing the system pressurized from 60 psi to 40 psi, could reduce the application rate by 18% for nozzles with a 7/64" diameter orifice (Table 1).

The question remains whether lower pressured would reduce the uniformity of the sprinklers. We conducted tests to determine the effect of nozzle pressure on the distribution profile of water from new Rainbird 20JH sprinkler heads using nozzles with a 7/64" diameter orifice. We placed the heads on a test stand and operated them under normal wind conditions and collected water in buckets radiating in 8 directions from the sprinkler head, spaced at 2 foot increments. We also used *Sprinkler Profile and Coverage Evaluation* (SPACE) software from the Center for Irrigation Technology, Cal State University Fresno to estimate distribution uniformities under different lateral pipe spacings and pressure scenarios.

Results:

The average flow rate with a 7/64” nozzle was 2.31 gal/min at 40 psi and 2.84 gal/min at 60 psi. These flow rates were slightly higher than reported by Rainbird (Table 1), but the relative differences were similar. Lowering the pressure from 60 to 40 psi reduced the flow rate from the sprinkler heads by 18%.

Applied water collected at varying distances from the sprinkler head were expressed as a percentage of total applied water in Figures 1 and 2. We measured no significant differences in the relative amounts of water applied at pressures of 40 psi and 60 psi at wind speeds of 4.5 mph (Figure 1) and between 6 and 7 mph (Figure 2). With a higher wind speed, a greater portion of water was applied within 15 feet of the sprinkler head (Figure 2) compared to a slightly lower wind speed (Figure 1). These results should be a reminder that wind speed has much more effect on the distribution of water from a impact sprinkler head than nozzle pressure.

Using the SPACE overlap program and the distribution profiles from Figure 1, we evaluated the uniformity of overhead sprinklers operated at pressures of 40 and 60 psi. Spacing between heads along the sprinkler pipe was assumed to be 30 feet. Table 2 presents estimated distribution uniformity and scheduling coefficient for sprinklers operating at pressures of 60 and 40 psi for various distances between lateral pipes. Predicted distribution uniformities were 83% or greater for all pipe configurations at wind speeds of less than 5 mph. The predicted distribution uniformities for 60 and 40 psi were similar at 30 and 33 foot distances between lateral pipes. The SPACE program predicted a small reduction in uniformity at distances between pipes of more than 33 feet (Table 2). Using the data from Figure 2 (wind speeds between 6 and 7 mph), the SPACE program also predicted similar distribution uniformities for nozzle pressures of 40 psi and 60 psi for distances between lateral pipes ranging from 30 to 40 feet (results not shown).

Energy costs to pump water increased as nozzle pressure increased by 20 psi. For an electrically driven pump, the difference in energy costs between 40 and 60 psi may range from $7 to $12 per acre-ft of water pumped depending on the price of electricity (Table 3). Similarly for diesel driven pumps, an increase of pressure of 20 psi could increase pumping costs from $16 to $26 per acre-ft of water pumped (Table 4).

Summary

Our tests demonstrated that for typical spacings used for solid-set sprinkler pipe on cool season vegetables of 30 feet × 30 feet or 30 feet × 33 feet, increasing nozzle pressure from 40 psi to 60 psi did not improve distribution uniformity. However, energy costs for pumping at higher pressures were increased by $7 to $26 per acre-foot of water depending on the energy source (electric *vs* diesel) and price of energy. Also, the amount of water applied per hour increased by about 18% by raising the pressure from 40 to 60 psi. On soils where water tends to infiltrates slowly, the higher application rate of water could also increase tail water run-off.

Table 1. Flow rates for varying pressures and nozzle sizes on 20JH sprinkler heads. Values determined by Rainbird, Inc.

	---------------- nozzle size ----------------			
Nozzle pressure	7/64"	1/8"	9/64"	5/32"
psi	---------------- gpm ------------------			
35	2.05	2.68	3.39	4.19
40	2.19	2.86	3.62	4.47
45	2.32	3.03	3.84	4.73
50	2.45	3.20	4.05	5.00
55	2.57	3.35	4.24	5.23
60	2.68	3.50	4.43	5.47

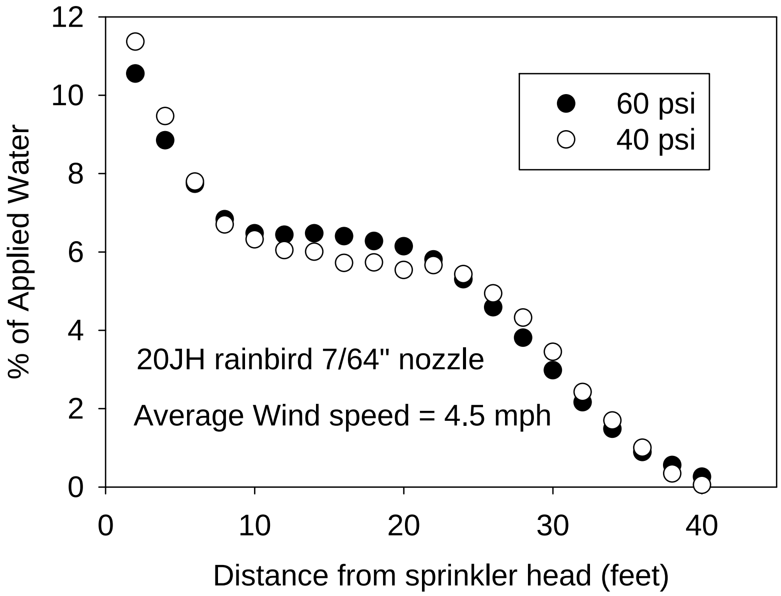

Figure 1. Average distribution of water from a rainbird 20JH sprinkler head with a 7/64 inch diameter nozzle at pressures of 60 and 40 psi and average wind speeds of 4.5 mph.

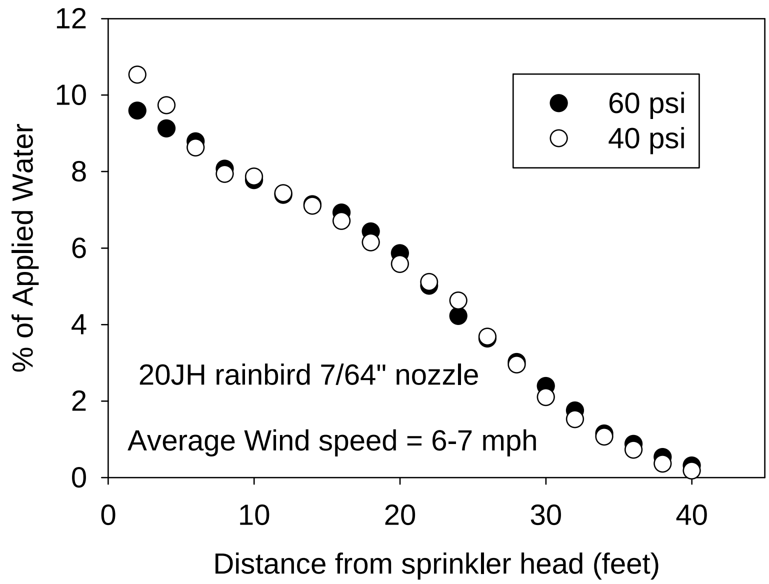

Figure 2. Average distribution of water from a rainbird 20JH sprinkler head with a 7/64 inch diameter nozzle at pressures of 60 and 40 psi and average wind speeds of 6 to 7 mph.

Table 2. Estimated distribution uniformity and scheduling coefficients for 20JH Rainbird sprinkler heads with a 7/64 inch diameter nozzle at pressures of 40 and 60 psi and varying lateral spacings. Spacing between heads on lateral lines is 30 feet and riser height is 18 inches.

Spacing between lateral lines	Distribution Uniformity (lowest quarter)	Scheduling Coefficient (5%)
feet	%	
-------------Nozzle pressure = 60 psi --------------		
30.0	94	1.1
33.3	90	1.1
36.7	87	1.2
40.0	88	1.2
-------------Nozzle pressure = 40 psi --------------		
30.0	94	1.1
33.3	88	1.2
36.7	83	1.3
40.0	83	1.3

Table 3. Estimated electrical energy costs for pumping water and pressuring overhead sprinklers to 40 and 60 psi.

	Pumping Costs for Sprinklers[1]		
	Pressure at nozzle		
Energy Cost Rate	40 psi	60 psi	Difference
$/kWhr	------- $/acre-ft ----------		
0.10	33.5	40.8	7.3
0.12	40.2	48.9	8.7
0.14	46.9	57.1	10.2
0.16	53.6	65.2	11.6

1. 120 ft operating depth for well, 90% efficiency motor, 72% efficiency pump

Table 4. Estimated diesel energy costs for pumping water and pressuring overhead sprinklers to 40 and 60 psi.

	Pumping Costs for Sprinklers[1]		
	Pressure at nozzle		
Energy Cost Rate	40 psi	60 psi	Difference
$/gal	------- $/acre-ft ----------		
2.50	73.7	89.7	16.0
3.00	88.4	107.6	19.2
3.50	103.1	125.5	22.4
4.00	117.9	143.4	25.5

1. 120 ft operating depth for well, 25% efficiency engine, 72% efficiency pump