Catch cans laid out in a large warehouse to measure uniformity of low-flow sprinkler systems.

Evaluation of low-flow sprinklers

Steven E. C. Post □ Donald E. Peck □ Robert A. Brendler
Nicholas J. Sakovich □ Lee Waddle

Low-flow sprinklers were first introduced into the United States from South Africa via Florida during the early 1970s. These sprinklers were first used in the avocado groves of southern California in the mid-1970s and have since been installed in citrus and, to a lesser extent, vineyards throughout the state.

Low-flow sprinklers are characterized by: (1) operating pressure less than 35 pounds per square inch (psi), (2) discharge of 5 to 60 gallons per hour (gph), and (3) throw diameter from 5 to 15 feet. Low-flow sprinklers may also have a spinning device or cap to disperse the water. Unlike standard impact sprinklers, low-flow sprinklers are usually placed in the field so that there is no overlap in their throw patterns. The term low-flow is preferred to micro-, mini- or low-volume sprinklers, because the discharge or flow from them implies a rate rather than a volume or size of head.

Evaluating application uniformity for overlapping sprinklers involves placing catch cans at certain distances in a square matrix around the sprinkler head. A square matrix is used for overlapping sprinklers, because each can represents an equal unit area of soil surface. This equal spacing removes surface area from any application uniformity calculation. The depth of water caught in each can is then measured and is used to calculate uniformity.

The highest uniformity value possible is 100 percent; that is, there is no deviation in depth of water caught among the catch cans. An even or flat application pattern results in a uniform wetting front within the soil profile. A uniform wetting front recharges the soil profile uniformly and thus minimizes soil-water availability as the limiting factor in crop production.

There are two main indexes used to describe application uniformity for overlapping sprinklers: Christiansen's uniformity coefficient (CU) and Merriam and Keller's distribution uniformity (DU). For nonoverlapping sprinklers, there is only one published method known for evaluation: Merriam and Keller's distribution characteristic (DC).

We conducted tests on the sensitivity of the geometric arrangement of cans, can numbers, and data analysis for evaluating application uniformity by nonoverlapping sprinklers. Twelve catch can patterns and three uniformity procedures were evaluated for nonoverlapping, low-flow, spinner sprinklers.

Evaluation procedure

The sprinkler tests took place in a large warehouse during the summer of 1984. In the catch can test, we used three low-flow sprinkler heads from six manufacturers. The sprinkler heads were selected on the basis of their discharge rates, which ranged from 7 to 17.3 gph at an operating pressure of 20 psi (table 1). Catch cans were placed in a 20- by 20-foot matrix on 1-foot grid intervals for each of the three heads evaluated. The heads were 8 to 10 inches above the upper lip of the catch cans, which were 2.8 inches in diameter and 2.1 inches high. We ran the tests for one hour and measured the volume of water.

We used all three methods (CU, DU, DC) to analyze the 12 catch can patterns, which were: entire catch can pattern (1) and each of the four quarters (2-5); and each radial leg, running diagonally through each quarter section (6-9), entire diagonals consisting of two opposite radial legs (10-11), and both diagonals (12) (fig. 1).

TABLE 1. Low-flow sprinklers used in evaluation

Type	Pressure	Discharge rate
	psi	*gal/hr*
Rainbird Green Spinner	20	17.3
Solcoor Yellow Spinner	20	7.9
Single Arm Hardie	20	7.0
Double Arm Hardie	20	9.8
Single Arm Irridelco	20	10.3
Olson Blue Spinner	20	8.6

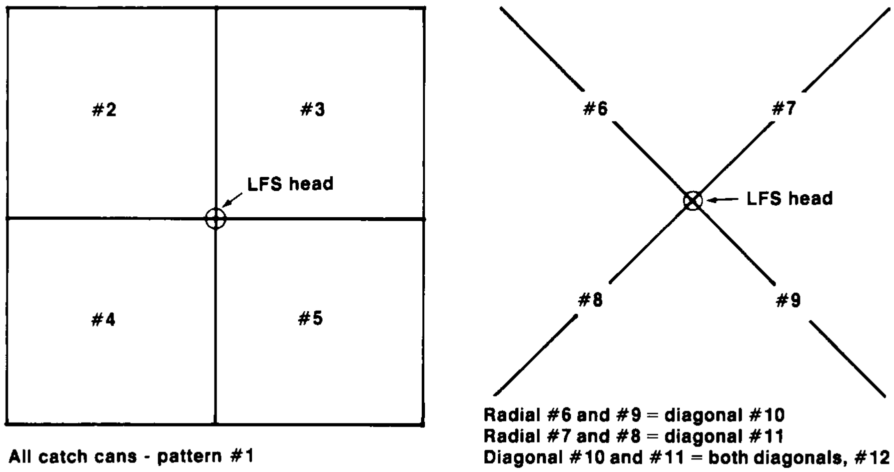

Fig. 1. Catch-can patterns used to determine uniformity of low-flow sprinklers.

A computer program was written to calculate all three indices. We determined the application uniformity value for each of the three indices from those cans in the appropriate area, leg, or diagonal (table 2). The coefficient of variation was also calculated as a means of expressing the standard deviation relative to the mean. The data in table 2 represent the average of three sprinkler heads from each manufacturer.

Results and discussion

Water distribution in relation to the sprinkler head is important in deciding the uniformity of the catch can pattern. The average catch can patterns taken from both diagonal patterns show that four of the six sprinklers had distinct "doughnut" patterns — a decrease then increase in depth of applied water with distance from the sprinkler head (fig. 2). This pattern for overlapping sprinklers is undesirable and is usually associated with pressures less than the manufacturer's specifications.

The variation among coefficients from different portions of the entire pattern and by the three application uniformity procedures is considerable (table 2). This variation possibly reflects the sensitivity of the various procedures to can number or catch can pattern.

Generally, the coefficient of uniformity produced a higher value while the distribution uniformity or distribution characteristic produced a lower value. The CU values were generally highest in the quarter patterns, while the DU and DC were higher in the other three patterns. In addition, as the number of cans representing a given pattern decreased, the coefficient of variation increased. This relationship indicated a decrease in the ability to estimate the true application uniformity as the number of observations or cans decreased.

We evaluated the relationship or sensitivity between can number, geometric arrangement, and application uniformity procedure for all six sprinklers. We assumed that the entire catch can pattern represented the "true" uniformity because of the high density (225) and close spacing (1-foot intervals) of cans. The average and variation about the average or standard deviation(s) of the absolute deviation from the entire pattern were calculated for the three application uniformity procedures, the coefficient of variation, and the four patterns (table 3). The absolute deviation from the entire catch can pattern was used, because the smaller the deviation, the more representative that pattern would be of the entire pattern.

The quarter pattern standard deviation, when averaged over the application uniformity procedure, was 3.9, or 63 per-

TABLE 2. Application uniformity coefficients and coefficients of variation (as a percentage) for six 360-degree, low-flow, spinner sprinklers and 12 catch-can patterns

	Low-flow sprinkler, index, and variation*											
	Rainbird Green Spinner				Solcoor Yellow Spinner				Single Arm Hardie			
Pattern	CU	DU	DC	CV	CU	DU	DC	CV	CU	DU	DC	CV
Entire	58.70	35.50	45.60	68.80	34.10	15.60	37.30	97.10	44.60	30.20	43.70	67.60
Quarter 1	50.50	26.60	48.50	73.20	32.60	14.20	37.00	101.80	44.80	29.80	39.10	63.40
Quarter 2	59.10	30.00	54.60	57.30	33.30	17.50	38.20	107.40	53.90	34.80	53.10	54.00
Quarter 3	63.80	48.60	39.00	63.50	34.70	13.90	40.30	97.00	40.30	31.30	34.60	70.50
Quarter 4	57.10	43.00	24.40	75.50	37.20	17.10	40.50	82.00	50.40	37.20	45.70	66.10
Radial 1	31.60	4.60	22.20	105.20	22.60	17.60	28.60	99.60	41.10	21.10	57.10	68.20
Radial 2	46.10	27.10	37.50	78.60	11.80	18.00	28.60	110.90	52.50	30.50	55.60	54.80
Radial 3	33.40	28.50	30.00	110.80	32.10	25.70	28.60	90.40	34.20	29.80	44.40	71.00
Radial 4	33.60	26.40	33.30	88.30	42.50	23.90	42.90	72.80	48.50	25.20	44.40	79.20
Diagonal 1	31.40	21.90	27.80	93.80	32.90	20.50	35.70	87.50	44.80	19.50	43.80	86.90
Diagonal 2	38.80	28.00	27.80	96.10	22.00	21.50	28.60	97.10	42.40	30.60	55.60	62.80
Both diag.	34.90	22.70	25.00	93.70	27.60	17.90	32.10	92.40	44.00	24.70	52.90	73.10
	Double Arm Hardie				Single Arm Irradelco				Olson Blue Spinner			
Pattern	CU	DU	DC	CV	CU	DU	DC	CV	CU	DU	DC	CV
Entire	59.80	48.90	45.30	50.50	54.70	42.70	32.20	121.70	56.50	28.40	50.30	60.80
Quarter 1	55.40	45.90	40.50	58.70	51.20	42.90	16.00	114.00	56.10	33.60	48.60	55.80
Quarter 2	64.70	54.70	46.90	40.00	64.90	50.40	39.70	83.00	64.70	40.70	53.70	52.70
Quarter 3	54.10	44.00	42.90	56.70	61.70	53.40	24.00	98.30	50.60	22.50	56.50	60.70
Quarter 4	67.90	54.80	53.00	36.90	53.90	41.70	20.00	146.30	53.30	24.20	52.10	72.90
Radial 1	39.80	27.10	37.50	87.20	2.60	24.70	28.60	146.80	64.00	51.00	50.00	53.10
Radial 2	63.70	61.00	42.90	41.80	20.10	34.30	14.30	124.90	47.50	25.60	25.00	76.50
Radial 3	51.70	43.30	37.50	70.20	15.80	34.80	28.60	130.90	54.80	25.80	42.90	74.90
Radial 4	60.40	50.90	57.10	44.30	-7.80	26.30	14.30	167.10	37.00	23.80	28.60	96.10
Diagonal 1	50.70	35.30	46.70	78.80	-2.80	19.10	14.30	168.90	49.40	27.80	30.80	78.00
Diagonal 2	57.20	48.30	40.00	57.80	15.30	32.90	21.40	126.40	46.90	25.40	33.30	76.90
Both diag.	53.90	41.30	43.30	68.30	5.70	24.00	21.40	152.50	47.80	26.40	32.10	76.50

* CU = Christiansen's coefficient of uniformity; DU = Merriam and Keller's distribution uniformity; DC = Merriam and Keller's distribution characteristic; CV = coefficient of variation.

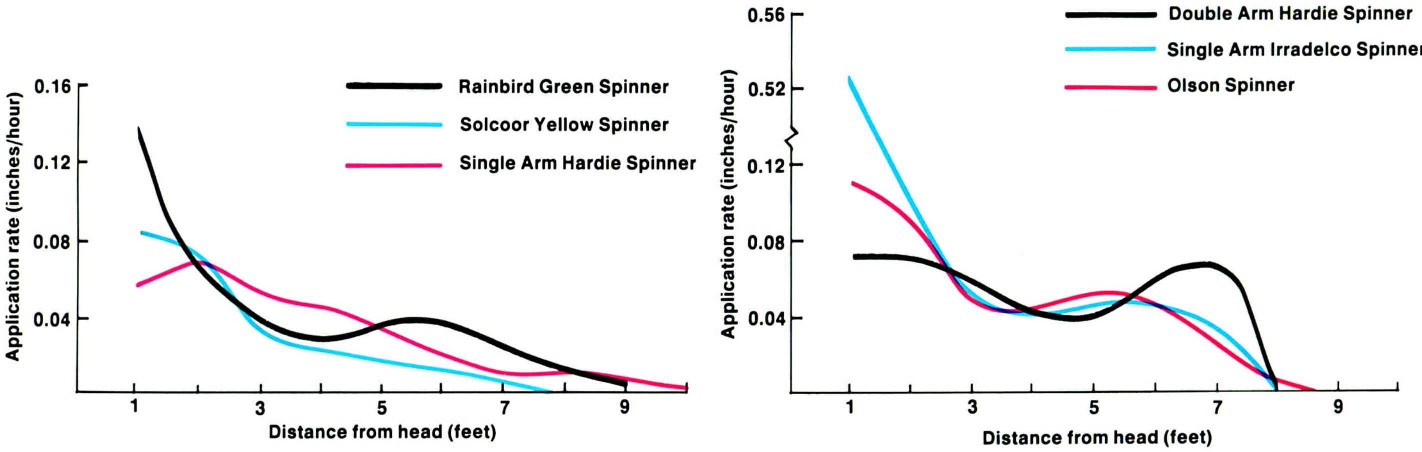

Fig. 2. Variation in uniformity of water application of six different low-flow sprinklers.

cent less than the other three patterns, and it also had the lowest coefficient of variation. The standard deviation based on CU for the quarter pattern was 16 and 65 percent less than the standard deviation for the quarter pattern DU or DC, respectively. Therefore, the quarter pattern contributed the least to this standard deviation value of 3.9. With either the radial leg, diagonal, or both diagonal patterns, the opposite trend was observed. The standard deviation of the DU and DC procedure was 38 and 48 percent less, respectively, than for the CU in these three catch can patterns. This implies a closer approximation of the entire pattern using the DU or DC procedure based on a radial leg, diagonal, or both diagonal patterns. The standard deviation for the three application uniformity procedures was averaged over the four catch can patterns. Under these circumstances, the CU had the highest value. The standard deviation for the quarter pattern, however, was much less than for the other three patterns, that is, 3.1 versus 16.3 to 18.1.

The radial, diagonal, and two-diagonal patterns had 48, 40, and 24 fewer cans than the quarter pattern. Their standard deviation was essentially the same — that is, 6.5 to 7.8 — while the coefficient of variation for the two-diagonal pattern was three points less. Because the standard deviation for the three patterns remained almost constant, regardless of can number, the geometric pattern played a greater role in estimating the entire pattern than can number. Therefore, the radial leg pattern with eight cans can give as good an estimate of the entire pattern as the two-diagonal pattern with 32 cans.

TABLE 3. Number of observations (n), mean ($\bar{x}$), and standard deviation(s) for the deviations from the entire catch-can pattern of the four major catch-can patterns, coefficent of variation (CV), and three application uniformity (AU) procedures

Pattern	CU	DU	DC	CV	Average across AU method*
Quarter					
n	24.0	24.0	24.0	24.0	24.0
$\bar{x}$	4.3	5.0	6.1	9.9	5.1
s	3.1	3.7	5.1	8.8	3.9
Radial					
n	24.0	24.0	24.0	24.0	24.0
$\bar{x}$	17.4	9.1	10.2	17.1	12.2
s	16.3	7.8	7.2	13.3	10.4
Diagonal					
n	12.0	12.0	12.0	12.0	12.0
$\bar{x}$	15.7	7.8	10.8	17.2	11.4
s	17.7	6.9	7.3	13.3	10.6
Both diagonals					
n	6.0	6.0	6.0	6.0	6.0
$\bar{x}$	15.8	8.2	11.0	16.5	11.7
s	18.1	6.5	7.2	10.4	10.6
Average across patterns					
$\bar{x}$	13.3	7.5	9.5	15.2	
s	13.8	6.2	6.7	11.5	

*Based on AU procedure only.

Conclusion

The results from this catch can study on nonoverlapping sprinklers indicates that application uniformity values are much lower than from overlapping sprinklers, regardless of procedure or geometry of can pattern. It was shown that the quarter pattern with 56 catch cans, placed 1-foot intervals, and Christiansen's uniformity coefficient (CU) best represented the "true" application uniformity. Therefore, when estimating uniformity based on Christiansen's CU, catch cans should be placed in a square matrix pattern over one quarter of the throw area and with the apex of the matrix at a 45-degree angle to the low-flow sprinkler arm.

The Merriam and Keller distribution uniformity (DU) or distribution characteristic (DC) procedures were found to represent the entire pattern fairly well when based on either a radial leg with eight cans, a diagonal pattern with 16 cans, or a pattern of both diagonals with 32 cans. The geometric arrangement was of greater significance than the number of catch cans in estimating the "true" uniformity.

The last question, from a crop production standpoint, that should be addressed to complete an evaluation of this nature is the application uniformity value that best indicates a poor versus a good sprinkler distribution pattern. This question cannot be addressed until consideration is given to the relationship between a given uniformity value and the lowest wetted root volume that minimizes plant stress and deep percolation.

Steven E. C. Post is Area Soil and Water Specialist, Cooperative Extension, University of California, Riverside; Donald E. Peck is Water Resources Manager, Rancho California Water District; Robert A. Brendler and Nicholas J. Sakovich are Farm Advisors, UC Cooperative Extension, Ventura County; and Lee Waddle is Water Resource Technician, Rancho California Water District.