Spacing and Pattern Effects on DU_{LQ} of Spray Nozzles

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Introduction

One of the current Turf and Landscape Best Management Practices published by the Irrigation Association states that the lower-quarter distribution uniformity (DULQ) should be a minimum of 55% for pop-up spray heads. In a paper presented in 2004 at the Irrigation Association technical conference entitled “A Summary Report of Performance Evaluations on Lawn Sprinkler Systems” by the author of this paper, shows that the average DULQ for pop-up spray heads from more than 6600 sprinkler system audits to be less than the desired minimum DULQ of 55%. The purpose of this paper was to explore how individual nozzles apply water compared to the intended area of coverage and how mixing the different arcs together in a sprinkler zone with different spacings and patterns will affect how evenly water is applied or the distribution uniformity.

The study procedures

To facilitate the study, the work was done on an asphalt test pad with ready access to a water source. The study has two aspects. One is to look at how an individual nozzle will perform compared to the anticipated or expected area of coverage. The spray nozzle was attached to a stand that included a water meter and a pressure regulator. These tests were conducted by connecting to the city water supply which averaged 60-65 psi static pressure. A one-inch rubber hose was used to connect the sprinkler stand to the water source to minimize friction losses when doing the tests. The nozzle was mounted on the stand to be four inches above the surface of the test pad, or approximately the height that the nozzle would be if mounted on a four-inch pop-up spray body. The sprinkler nozzle would be turned on for approximately 20 seconds to wet the pavement sufficiently to see the pattern but not long enough so that there would be run-off to distort the pattern of coverage when a photograph was taken, usually from a ten foot tall ladder oriented to see the coverage compared to the chalked out-line that the nozzle was to spray. This was done for full circle, half circle and quarter circle patterns. The nozzles were purchased off of the shelf from local distributors.

The other aspect was to look at how well the nozzles would work together in a sprinkler zone that was built on the test pad. The “sprinkler zone” was created to measure how evenly the sprinklers applied water to the test area. Catch cans were laid in a grid format four to six feet apart depending on the spacing of the nozzles being tested. Tests that included catch can data were for areas that measured 30 x 75 for 15 foot radius nozzles, 24 x 72 for 12 foot radius nozzles. Square, triangle and equilateral triangle patters were measured. Operating pressures were at 30 psi as the preferred operating pressure for spray nozzles and at 45 psi which seems to be the typical

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operating pressures found in most residential audits. The nozzles were attached to shrub adapters which were attached to fixed risers so that the nozzles were slightly above the top of the catch cans on the test pad as seen in the following photograph. The water source is raw water that is pumped via a variable frequency drive pump that can deliver up to 80 gpm at 80 psi. A water connection for this study consisted of an 1.5 inch ball valve, 1.5 inch pipe connect to 1.5 inch Badger compound meter and a 1.5 inch electric valve with a pressure regulator and pressure gauge. Pressure gauges were also attached just below the spray nozzle to monitor operating pressures. All tests were conducted utilizing the Irrigation Association guidelines for auditing, that is the wind speed average is less than five miles per hour and a minimum of 24 catch devices were used to measure uniformity and precipitation rate.

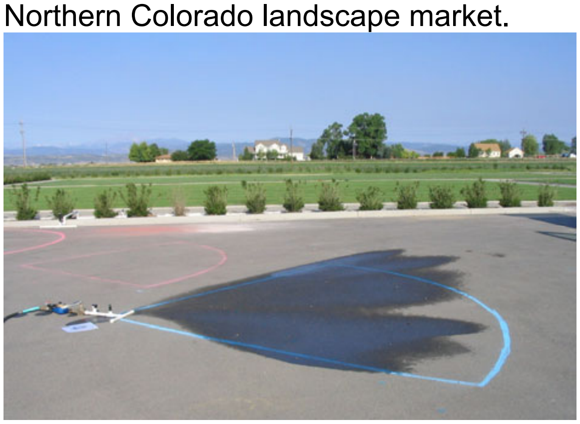

Technicians Rachel Waite and Tessa Berry gather data. A Windtronic anemometer is used to monitor wind speed during the test. It will show current speed, average wind and maximum gust during the test time. Most tests were done with an average wind speed less than three miles per hour to minimize the impact of wind on readings.

Results of individual nozzles coverage

Individual nozzles were attached to the test stand and allowed to run for a very short duration to see how the coverage compared to the anticipated coverage we have often assumed. As a designer, I have almost always thought that the radius of the nozzle meant that it would spray as far as it was indicated, that is a 15 foot radius nozzle would throw the water 15 feet from the nozzle. I have also assumed that the pattern of coverage would be quite close to the arc as shown in the manufacturer's catalog, that is a quarter, half and full spray would have patterns of coverage as indicated:

Arc	Pressure PSI	Pattern
90°	20	Q
	25	
	30	
	35	
	40	
180°	20	H
	25	
	30	
	35	
	40	
360°	20	F
	25	
	30	
	35	
	40	

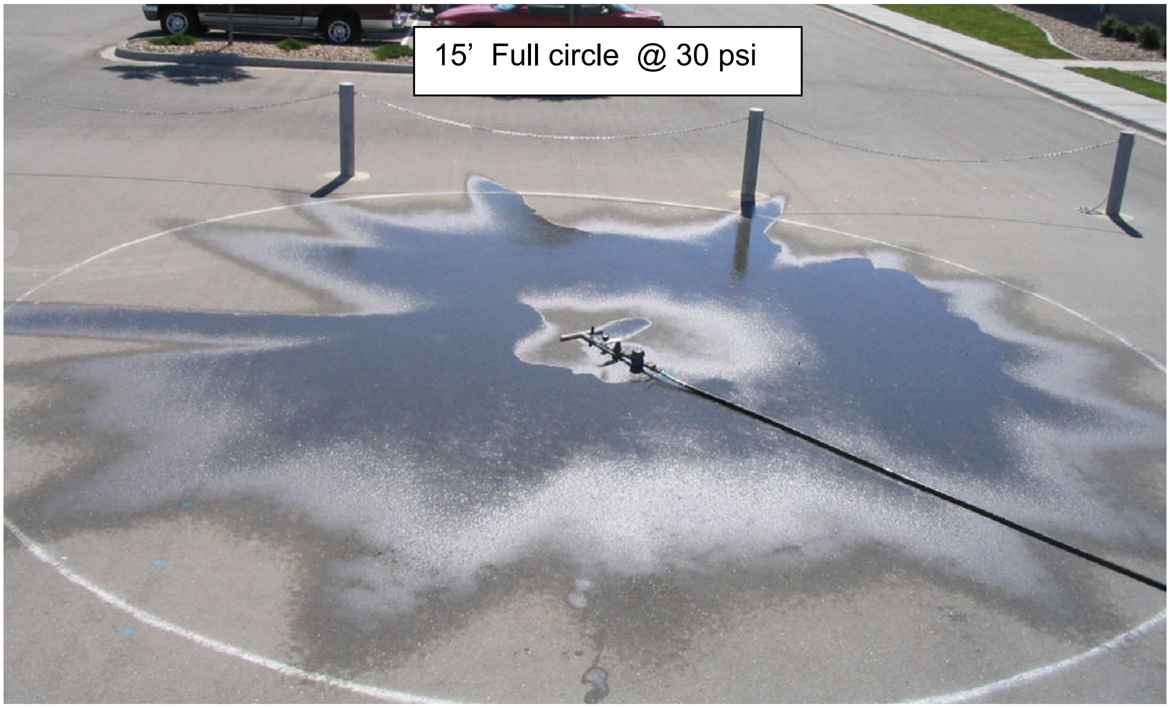
The following photographs are of nozzles selected at random from off of the shelf at local distributors. The study selected those nozzle most often sold and installed in the Northern Colorado landscape market.

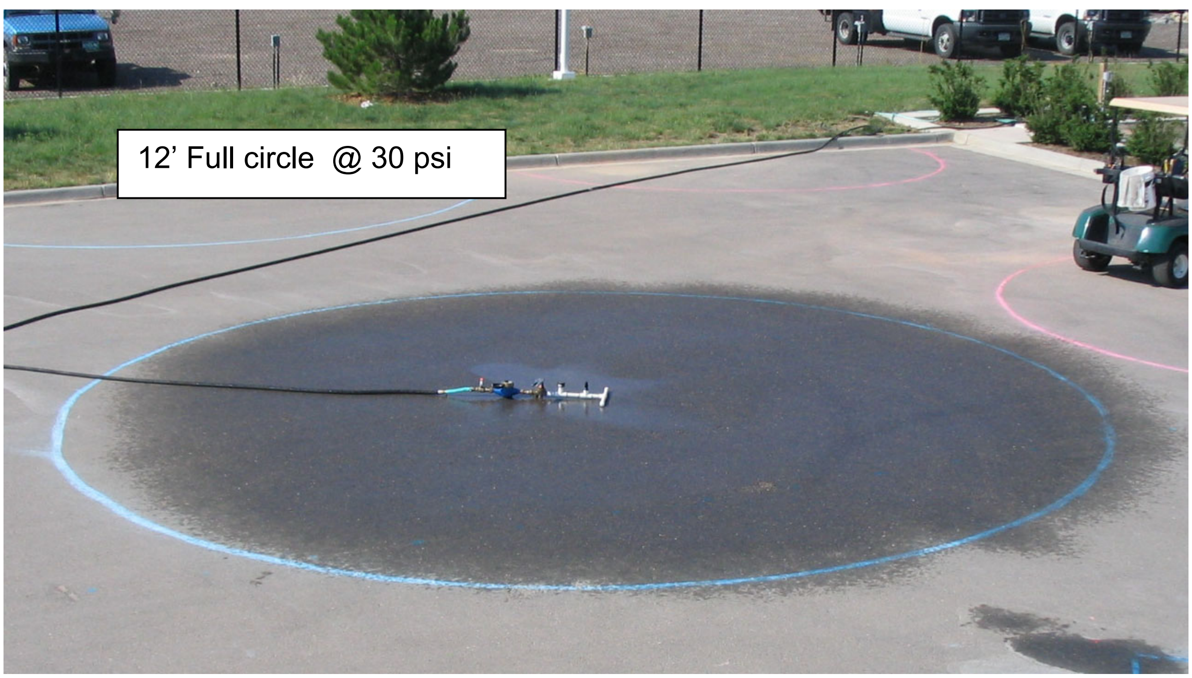


Photographs of nozzles that were tested on the asphalt pad. The photos show more than can be explained even by a catch can test.

Nozzles are not manufactured equally, and most likely one batch of nozzles will not perform exactly the same as another because of molding issues. The challenge is to understand how they perform individually and then compensate for individual performance when put together in a sprinkler zone. A few of the nozzles had excellent coverage for the pattern intended, but most were not as good as would have been expected.

The study looked at individual nozzles for 10’, 12’, 15’ radii in fixed pattern as well as adjustable or variable arc patterns.


15’ Full circle @ 30 psi


12’ Full circle @ 30 psi

Same nozzle at two different operating pressures. As we know pressure will affect distribution uniformity. It is usually assumed that a higher pressure will affect it adversely, but as these photos show, that may not necessarily be the case.

Results of catch can audits

In most landscapes, pop-up spray heads are often used for small turf areas that usually have curves or irregular shapes. This makes it challenging to design a sprinkler zone that will water the area properly and very efficiently, meaning it will have a very even application of water. This study focused primarily on a nearly “ideal” arrangement of sprinkler heads where regular spacing could be achieved. Zones were created using fixed arc and also considered using all variable or adjustable arc nozzles for all patterns. The tests were only done one time at each pressure. Wind speed was measured during each test which was typically five minutes long. The catch cans were placed in a grid pattern so that on the 15’ radius nozzle with an area of 30 x 75 feet there were 90 catchments which is nearly twice the minimum number if done “at the head” and “half-way between the head” method as taught in the certified landscape irrigation auditor training. Catch-can audits were done for square spacing, triangle spacing and equilateral triangle spacing for the 15’ radius nozzles and 12’ radius nozzles. The tests were conducted at 30 psi which is typically considered the preferred pressure and at 45 psi. 86 catch-can tests were completed.

For the 15’ radius nozzles at 30 psi, the highest DU measured was 76% on square spacing and the lowest DU was 39% on a variable arc nozzle at equilateral triangle spacing. At 45 psi operating pressure the results were the same as for the 30 psi tests.

For the 12’ radius nozzles at 30 psi, the highest DU measured was 78% on equilateral triangle spacing with a variable arc nozzle and the lowest DU was 29% on an a variable arc nozzle on square spacing. At 45 psi the highest DU was 71% on both a fixed nozzle and a variable arc nozzle from two different manufacturers on equilateral triangle spacing and the lowest DU_{LQ} of 32% on a variable arc nozzle.

When averaging the results for each of the tests, the 15’ square spacing had the highest overall average of all of the different 15’ nozzles tested at nearly 64% while the 12’ nozzles on equilateral triangle spacing averaged just over 64% DU_{LQ}.

The average of all of the tests conducted showed that the DU_{LQ} at 30 psi was slightly better than the tests done at 45 psi, 57.25% compared to 55.6%. As an overall average

Perhaps of more significance is the change in precipitation rate when systems are operating at a higher pressure. For both the 15’ and 12’ radius nozzles, the average increase in flow was 17.8%. This has a significant impact on the amount of water applied to a landscape. Most schedules are probably created assuming the preferred operating pressure, but the actual operating pressure is more, therefore more water is applied than is intended which means scheduled run times could be shorted by an equal amount. The variation was quite large in some of the lines of nozzles and others it was minimized because the nozzles included a pressure compensating disc that can minimize the effect of pressure on flow. However if the pressure compensating device is removed, then the increase in flow becomes significant. In most of the audits, the net precipitation rate was less than the catalog stated value. Perhaps part of this is due to the fact that the nozzles do not throw the water as far as expected, but at the same time frequently the gross precipitation rate calculated based upon water meter readings is higher than the catalog flow.

One last test was done to more represent the real world of spray head design. An amoeba shaped lawn area was outlined and a sprinkler zone designed to apply water to the target area. The test was done utilizing a single manufacturer of nozzle and mostly utilizing mostly 12' radius throw nozzles. In one area a 15 foot nozzle was included to make sure that there was adequate coverage. The heads were place @12' apart around the perimeter edge and the middles filled in with full circle patterns. After the fixed arc nozzles were tested at various pressures, the heads were "tilted" to represent what is most often seen in the real world. Nothing sever, but enough that the pattern of coverage would be changed. Finally, a variable arc nozzle was selected to see what the results would be if they were used on all heads versus the fixed arc nozzles. The following results were measured

	60 psi 12' Fixed Arc	45 psi 12' Fixed Arc	30 psi 12' Fixed Arc	30 psi 12' Fixed Arc Tilted Heads	30 psi 12' Variable Arc
DU_{LQ}	53%	58%	62%	52%	43%
Precip.Rate	2.17 in/hr	1.91 in/hr	1.70 in/hr	1.66 in/hr	1.93 in/hr

Conclusion

Since only one test was done with each nozzle or head layout, spacing and pressure it is hard to make any real conclusions that could be used decisively. A number of tests need to be conducted to have some averages that can smooth out some of the anomalies that happen when doing snap-shot audits of sprinkler performance. Based upon visual observations; 15' nozzles were not as adversely affected by the increased operating pressure as were the 12' nozzles. This seems to make sense since the orifice is smaller and so increased pressure would change the droplet size. At 60 psi, the misting of the nozzle was significant. Square spacing or equilateral triangle spacing definitely improved distribution uniformity over triangle space which stretches the head spacing because of the geometry of the area. There is not a definite conclusion that equilateral triangle spacing is better than square spacing, in fact from the few tests conducted, it would probably indicate just the opposite. Square spacing tends to be easier to design with and if the distribution uniformity is not adversely affected, this helps with the design and installation of sprinkler systems. The testing of individual nozzles to see the true pattern of coverage has been the most enlightening. To see where the water is actually applied compared to the catalog picture of coverage may help to improve the designs. Frequently many irrigation managers are frustrated with the dry edges that occur or dry spots near corners. From the photo images it is now easier to see why they dry up because in many instances there is very little water falling in those locations. The problem seems to be shared by all of the manufacturers and additional work on nozzle design and coverage will greatly assist in creating more efficient irrigation systems. As nozzles improve, this could be a solution to improve existing sprinkler systems that have already been designed and installed correctly.

Lastly with the many irregular shapes that exist in most landscapes to make them aesthetically pleasing, but very difficult to water efficiently I think the current BMP of 55% DU_{LQ} for pop-up spray heads is reasonable. More water will be saved by having the spray heads operate at the preferred operating pressure of 30 psi with the proper run times programmed into the controller than by trying to raise the bar for higher uniformity for difficult areas to irrigate.

Special thanks to Ron Boyd, Tessa Berry and Rachel Waite for assistance in doing the audits and gathering the data.