The Effects of Matched Precipitation Rate Nozzles on Distribution Uniformity

Brent Q. Mecham

Northern Colorado Water Conservancy District
Loveland, Colorado

The introduction of matched precipitation rate nozzles has changed the way we design lawn sprinkler systems. It has made it possible to combine heads with different patterns onto a single zone and it has worked wonderfully well for pop-up spray heads. In fact it would be difficult to purchase nozzles for spray heads any other way than MPR. Since it worked so well for spray heads, we have attempted to do the same thing with rotor heads and have the same advantage of creating irrigation zones based upon area instead of the coverage pattern of the head. This has greatly simplified the installation of sprinkler systems. Manufacturers have been successful in designing nozzles that are capable of spraying a small amount of water over a long distance. The pattern of coverage of the nozzle is unique and is quickly changed if the radius of throw is adjusted. The uniformity of distribution changes greatly and when the flow is doubled the distribution profile changes as well. Sometimes the compatibility of nozzles that have different flow rates does not translate into a uniform distribution of water when installed although the design would indicate such. This paper will discuss and show that the nozzle combination for best distribution uniformity is not always using MPR nozzles. In the interest of water conservation, the distribution uniformity within a sprinkler system has as much impact upon water resources as does the use of MPR nozzles.

<u>Matched Precipitation Rate Nozzles</u>

A zone or system that uses heads and nozzles that have a similar precipitation rate is said to have "matched precipitation rate". In order to really achieve MPR the spacing of the heads needs to be consistent. Flow rates need to be based upon area of coverage and the hydraulics of the piping needs to deliver the water at a fairly uniform pressure to each head. For example, if Quarter heads spray 1 gpm, then Half heads need to spray 2 gpm because it is covering twice the area of the Quarter head. A general rule of thumb is: as the spray arc doubles, then the flow rate should double. The concept of MPR nozzles works very well with pop-up spray heads, but it is more challenging to use this concept with rotor heads.

One of the difficulties, is referring to the manufacturer's catalogue and noticing that if you select a nozzle for the Quarter heads that it will spray water a maximum distance and has a certain precipitation rate. Basic understanding says that for the Half heads you will need a nozzle that will spray twice as much water. But then you notice that it has a much greater radius of throw and a precipitation rate that does not match that of the Quarter head. You can then go on and do the same for Full circle heads, getting the proper flow but coverage area and precipitation rate does not match. So at first glance it appears that you have matched flow but not matched precipitation rate. Recently, some manufacturers provide only the flow rate and maximum radius of coverage and not a precipitation rate.

By using the following formula, you can begin to select nozzles that will have close to matched precipitation rates based upon flow and spacing of the sprinkler heads. The formula can be found in the back of the Hunter catalogue. The formula is:

$$\textbf{PR (in./hr.)} = \frac{\textbf{GPM (for any arc)} \times 34{,}650}{\textbf{Degree of arc} \times \textbf{Head spacing (ft)} \times \textbf{Row spacing (ft)}}$$

Enclosed are a few tables using the above formula that will show precipitation rates for various nozzles at certain head spacing. It then becomes easier to select nozzles for the various arcs of coverage. This formula can then be used with any manufacturer of sprinkler heads and nozzles using the spacing of the heads (either design or actual) to determine more accurately the precipitation rate. By matching precipitation for Quarter, Half and Full heads you can select the proper nozzles to achieve “matched precipitation rate”.

Because the flow rate is higher, the radius of throw increases. So as you attempt to match the flow, you then have to consider what the spacing between heads will be. Most manufacturers recommend that the radius of throw not be reduced more than 25% using the radius adjustment screw. At the same time it is not prudent to design based upon the maximum distance of throw. So if you choose spacing less than maximum, you will be forced to use the radius adjustment screw to get the head to spray the water in the desired area. But as soon as you use the radius adjustment screw, you will distort the stream of water, which will then change the distribution profile of the nozzle. Most sprinkler zones have more than one head, and it becomes very difficult to adjust each head exactly the same, therefore there will be considerable variation within the sprinkler zone. Changing the radius will change the area of coverage which changes the precipitation rate and the uniformity of distribution.

Distribution Uniformity

Since most sprinkler systems apply water to the soil by spraying it through the air, the distribution of the water must be fairly uniform to avoid excessively wet or dry areas in the landscape. One way of measuring the uniformity of coverage is using a statistical parameter called the distribution uniformity (DU). The DU depends upon the spacing of sprinklers and the distribution profile of the sprinkler equipment. Quality of design, installation, and maintenance of the sprinkler equipment impact the DU. Water pressure, wind direction and speed also impact the DU. One way to evaluate the effectiveness of coverage of a sprinkler or sprinkler zone is to do a catch-can test and compare the readings of the average to the average of the lowest 25% of the readings. This is the lowest quarter distribution uniformity and is a way to evaluate how well a sprinkler zone is performing. The method that is taught by the Irrigation Association for Landscape Irrigation Auditing was used to gather the data used in this paper.

Field Tests

Naming of manufacturers and their products does not constitute an endorsement, but rather helps in explaining some of the applications. These are individual tests and cannot be used as a basis to make a decision of what should be done at another site with different conditions. It is meant for the reader to think about how this information could be applied in their particular circumstance.

The first field study involves trying to achieve as high of distribution uniformity on a turf site where uniform coverage is needed to facilitate a water quality study. This site is also used for teaching and training. The site has been divided in half with each sprinkler zone being identical. One zone uses Rainbird R-50 heads with Rain-curtain nozzles and the other zone uses the Hardie XL head. Each sprinkler zone has 17 heads, quarters, half and full circle heads all connected to cover an area of 60 feet by 120 feet. Operating or working pressure is about 45 psi. The piping has been designed so that velocity won't exceed 5 feet per second and the zone is center-fed. Flow is measured by a 1 _" meter. The heads are spaced 30 feet apart and triangle spacing was used. All heads are properly installed, adjusted and maintained. The original nozzle selection was based upon matched flow rates and is the first combination listed in each table.

Rainbird R-50 Time & water to apply .50 inch of water

Nozzles	PR	DU	GPM	Run Time	Gallons
Q=1.5, H=3.0, F=6.0	.61	.77	56.7	63 minutes	3,572
Q=1.5, H=2.0, F=6.0	.66	.70	49.7	65 minutes	3,280
Q=0, H=3.0, F=6.0	.51	.69	50.2	86 minutes	4,367
Q=3.0, H=3.0, F=3.0	.53	.74	44.5	77 minutes	3,471
Q=1.5, H=3.0, F=3.0	.56	.78	45.0	69 minutes	3,105

Hardie XL Time & water to apply .50 inch of water

Nozzles	PR	DU	GPM	Run Time	Gallons
Q=1, H=3, F=5	.49	.61	45.5	101 minutes	4,596
Q=1, H=4, F=6	.55	.71	48.0	77 minutes	3,696
Q=1, H=3, F=6	.50	.66	47.4	92 minutes	4,361
Q=3, H=3, F=3	.49	.67	45.2	92 minutes	4,158
Q=1, H=4, F=4	.50	.63	42.6	96 minutes	4,090

In each zone, the first combination of nozzles is the preferred combination for MPR but not necessarily the best for uniformity and ultimately for conserving water. In this circumstance the Rainbird heads performed best with the Half and Full heads using the same nozzle. For the Hardie zone the standard flow nozzles performed better than the low flow nozzles as originally installed. As a note; it takes a lot of time to change all the nozzles and get them adjusted as well as the time it takes to perform an audit to verify if the changes are helping.

The second field test involves trying to improve uniformity on small zones of residential or light commercial rotors. Each plot is 30 feet by 60 feet. The heads are spaced 30 feet apart using a square spacing pattern. The water source is a _" tap with a 5/8" residential meter. Desired flow rate is not more than 12 gpm. Each zone is center fed with velocity less than 5 feet per second. Operating pressure is @45-50 psi.
The manufacturers and heads used in this comparative study are listed alphabetically:

Hardie XL	Nelson 6000	Weathermatic Turbo 3
Hunter PGP	Rainbird R-50	
K Rain K-2	Toro S 700	

The results from the audits are shown in the following table. The heads and manufacturers are listed by letter and do not necessarily correlate with the above list. The purpose is to show the effects of nozzles upon uniformity rather than trying to compare manufacturers heads or specific nozzles. Rather the interesting issue is to consider how nozzles impact DU. Improved DU will mean the potential to conserve water.

	MPR Nozzles				**Changed Nozzles**			
Head	**PR**	**DU**	**GPM**		**PR**	**DU**	**GPM**	Nozzle
A	.59	.78	13.6		.51	.68	12.1	1.5
B	.52	.69	11.4		.63	.69	13.1	3
C	.63	.62	11.9		.66	.41	14.0	6
D	.61	.69	12.0		.64	.65	13.3	6
E	.56	.69	12.0		.49	.77	12.1	6
F	.49	.57	11.1		.59	.67	12.1	2
G	.41	.66	9.9		.58	.71	12.2	2

As can be seen, there isn't any rule of thumb that could be applied. Some zones improved dramatically when all the nozzles were changed to be the same, other remained the same . So for now it is a trial or error or best guess effort. Further study needs to be made to see which nozzles combinations will yield the best results.

There is available a few computer programs that can create densograms of the designed sprinkler system. These work very well in being able to see the results of nozzle combinations without getting wet or leaving the office, but the limiting factor is the data base is very small and is available only for a few nozzles at selected operating pressures and radius of throw. Another source is to go to the manufacturer to see what detailed information they have. All nozzles and heads can operate over a wide range of pressures and flows, but each nozzle has an optimum performance range. This information is known, but not necessarily easy to obtain.

Conclusion

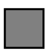
Matched precipitation rate nozzles do not translate to best distribution uniformity. Improving DU most definitely is a key water conservation practice. DU is affected by so many different things that close attention needs to be paid to the design, the proper installation and adjustment of the sprinkler head and then to have a high level of maintenance. If anyone of these areas is weak, it will affect the others. All nozzles and heads have optimum performance requirements including flow, and operating pressures. Much of the data available is for the performance of a nozzle at maximum radius of throw. As soon as you begin to change the radius of throw to fit a given situation, you immediately impact the distribution profile of the nozzle. Sometimes, it is changed so much, that the combination of a lot of adjusted heads hurts the distribution uniformity. When that happens, consider changing to a different combination of nozzles to improve uniformity. But before making those changes, consider the impacts upon the hydraulics of the sprinkler system or zone. It is recommended to look for combinations that will have a flow rate less than what has been designed, but also considering the spacing of the heads to make sure that they are not farther apart than the maximum throw of the nozzles being considered for installation. Because nozzles perform differently at certain pressures or in different spacing patterns it can't be assumed that if a nozzle combination works well at 30 psi that it will be the best combination at 50 psi. Finally, it is recommended to perform an audit to verify that the nozzle changes and combinations have really improved the performance of the sprinkler zone or system. The goal is to help improve the performance to conserve water.

Example
Nozzle Selector
Matched Precipitation Rate

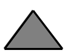
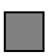
ROTOR HEAD
Pressure 40 psi

Nozzle	1	2	3	4	5	6	7	8	9	10	11	12
GPM	0.6	0.8	1.0	1.4	1.8	2.4	3.0	3.7	4.9	6.0	8.0	11.4
Maximum Radius	29’	30’	31’	33’	36’	38’	40’	40’	43’	45’	46’	46’

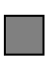
25 oc spacing

		1	2	3	4	5	6	7	8	9	10	11	12
	Q	0.43	0.57	0.71	1.00	1.28	1.71	2.13	2.63	3.49	4.27	5.69	8.11
	**H**	0.21	0.28	0.36	0.50	0.64	0.85	1.07	1.32	1.74	2.13	2.85	4.05
	F	0..11	0.14	0.18	0.25	0.32	0.43	0.53	0.66	0.87	1.07	1.42	2.03
	Q	0.37	0.49	0.62	0.86	1.11	1.48	1.85	2.28	3.02	3.70	4.93	7.02
	**H**	0.18	0.25	0.31	0.43	0.55	0.74	0.92	1.14	1.51	1.85	2.46	3.51
	F	0.09	0.12	0.15	0.22	0.28	0.37	0.46	0.57	0.75	0.92	1.23	1.76

30 oc spacing

		1	2	3	4	5	6	7	8	9	10	11	12
	Q	0.30	0.40	0.49	0.69	0.89	1.19	1.48	1.83	2.42	2.96	3.95	5.63
	**H**	0.15	0.20	0.25	0.35	0.44	0.59	0.74	0.91	1.21	1.48	1.96	2.82
	F	0.07	0.10	0.12	0.17	0.22	0.30	0.37	0.46	0.61	0.74	0.99	1.41
	Q	0.26	0.34	0.43	0.60	0.77	1.03	1.28	1.58	2.10	2.57	3.42	4.88
	**H**	0.13	0.17	0.21	0.30	0.39	0.51	0.64	0.79	1.05	1.28	1.71	2.44
	F	0.06	0.09	0.11	0.15	0.19	0.26	0.32	0.40	0.52	0.64	0.86	1.22

40 oc spacing

		1	2	3	4	5	6	7	8	9	10	11	12
	Q	0.17	0.22	0.28	0.39	0.50	0.67	1.09	1.34	1.78	2.18	2.90	4.14
	**H**	0.08	0.11	0.14	0.19	0.25	0.33	0.54	0.67	0.89	1.09	1.45	2.07
	F	0.04	0.06	0.07	0.10	0.13	0.17	0.27	0.34	0.44	0.54	0.73	1.03
	Q	0.19	0.25	0.31	0.44	0.57	0.75	0.94	1.16	1.54	1.89	2.51	3.58
	**H**	0.09	0.13	0.16	0.22	0.28	0.38	0.47	0.58	0.77	0.94	1.26	1.79
	F	0.05	0.06	0.08	0.11	0.14	0.19	0.24	0.29	0.39	0.47	0.63	0.90

Nozzles in shaded areas are not recommended.

To select nozzle combinations select the nozzles in the various arcs that have similar precipitation rates to achieve MPR. The MPR does not guarantee highest uniformity.