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Center Pivot Sprinkler
Instantaneous Application Area, Droplet Size and Soil Infiltration

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Objective:

Provoke thought, research and the development of improved methodology in analyzing the effects of sprinkler system application intensity as it pertains to instantaneous uniformity and droplet size. Promote the development of standards and procedures in the quantification of system application efficiency and potential soil property degradation.

Note: For the purpose of this presentation, the term sprinkler is often used to refer to any type of water emission device used in center pivot irrigation (impact-driven sprinkler, fixed-plate spray nozzles, moving-plate applicators, etc).

Intro:

The modeling of sprinkler application patterns provides valuable information necessary in designing irrigation systems that will uniformly apply our valuable water resource. Good designers rely on this information to help determine the optimum spacing, elevation and operating pressure of a selected sprinkler. The most commonly used model is arguably the single ray profile which can be described as the "fingerprint" of a sprinkler's performance at a specified pressure, flow rate and elevation. Our industry has benefited greatly from software packages currently being used to calculate system application uniformity and/or estimate potential run-off. These applications depend heavily on the single ray profile model.

While the quantification of system application uniformity is achieved with reasonable accuracy through conventional analytical methods, the ability to accurately predict application efficiency and the potential negative effects a system design may have on soil structure remains elusive. Scientists and irrigators have hypothesized on many ideas and concepts that could lead to great improvements in this area yet improved procedures and firm solutions have not yet solidified.

The remainder of this presentation will focus on some ideas that have improved our understanding of the interface between the irrigation system and the soil or crop. An isolated look at what occurs at the critical moment water is delivered to the soil and the benefits and detriments in the process. Without standardized methods of quantifying many of the sprinkler application aspects being discussed, observations and comparisons must be based on relativity.

Conventional methods and thought:

Application Intensity or Instantaneous Application Rate:

The term IAR (Instantaneous Application Rate) has been used for several years in discussions relating to the system-to-soil interface, most frequently when considering potential detrimental effects to the soil such as structural degradation, surface compaction and run-off. Application Intensity may be a better term as there has been some confusion in our industry between the definitions of System Application Rate and Instantaneous Application Rate.

It is generally understood that the term System Application Rate (can be stated in GPM/Acre) is the total system flow rate divided by the entire wetted area of the system.

SAR = System Flow / Total Area of Coverage

Example: A center pivot system with a flow rate of 750 gpm and a length of 1,300 ft equipped with sprinklers (fixed-plate spray nozzles) having an average wetted diameter of 80 ft. Total area of coverage in acres is calculated by 1,300 ft multiplied by 40 ft and the product divided by 43,560 ft^2 per acre.

SAR = 750 gpm / 1.2 Acres = 625 GPM/Acre

In the estimation of how the system's application may impact the soil, using SAR can be characterized as a two dimensional view of the system-to-soil interface where a three dimensional view, using IAR, could provide additional detail for a more accurate analysis. With SAR as our only gauge for application intensity, we are making two very errant assumptions. First we are assuming that the total wetted area is receiving a perfectly uniform application and secondly that this uniform application is instantaneous and continuous in time.

-Assumption #1 – Total Uniformity

The single ray profile model again proves useful in revealing that the different types of sprinklers available today have varying application rates at varying distances from the sprinkler location out to the edge of the wetted area. While some sprinkler types do have a more even distribution profile than others, none of them offer perfect uniformity throughout the profile.

Duly noted: This is not to say that a sprinkler distributing an uneven profile is necessarily bad. When properly selected, spaced and designed, many sprinklers that individually produce an uneven profile have very good distribution uniformity as a collective package on a mechanical move system. These types of sprinklers may offer other advantages over those with more even profiles such as application efficiency and/or low pressure operation.

-Assumption #2 – Instantaneous Application

As mentioned before, a standard for measuring a sprinkler's instantaneous application area has not yet been determined. This is the most important factor to analyze when considering an irrigation system's potential impact on soil and is the greater contributor, of the two assumptions, to an inaccurate analysis based on the SAR formula. Even without a standard, comparing different sprinklers through observation has proven useful. Focusing on application intensity, an observer can look at the relativity among various sprinklers in the total surface area of soil that is being impacted at any given second of the sprinkler's operation. How much surface area of the soil is being wetted instantaneously?

It is easier at this point to explain the difference between SAR and IAR, and the two dimensional versus three dimensional view concept. Referencing the previous example of the SAR calculation we can modify the formula to an IAR calculation.

IAR = System Flow / Instantaneous Area of Coverage

The difficulty comes in quantifying the "Instantaneous Area of Coverage" without a standard method of testing and quantification. At this point we must default to estimates via observation. For the purpose of this example, it is reasonably safe to say that a fixed-plate spray nozzle providing a 40 ft diameter of coverage is instantaneously applying water to only 25% or less of the total area that it covers. Allowing this assumption through observation, we would adjust our Total Area of Coverage accordingly, producing an IAR calculation as follows.

IAR = 750 gpm / 0.3 Acres = 2500 GPM/Acre

The potential impact a system's application may have on the soil surface becomes much more apparent when we are seeing a more accurate picture, in this case we might say a magnitude of four times more accurate. It is important to again mention that there are many aspects to consider in evaluating a sprinkler package. Spray nozzles inherently have a greater application intensity than some other devices but when applied in the proper areas can offer benefits that lower intensity sprinklers may not.

The concept of lowering application intensity is not new and can also be further achieved in various ways of opening up the total sprinkler package wetted area through specialized mounting hardware such as "boom-backs" and truss-rod mounting systems. With the growing recognition of the benefits in lower application intensity, our industry needs to support this movement through research and further development. Standardized methodology and procedures that could incorporate an "Application Intensity" factor into new or existing formulation of estimating run-off potential or soil structure degradation is necessary for truly accurate forecasting.

-Intensity and Droplet Size:

Droplet size is another common topic when irrigators discuss potential soil structure degradation. The physical truth of *energy equals mass multiplied by velocity²* has held up too long to argue. Yet even with this strong physical understanding, field observations have sometimes shown that soil structure degradation occurs with small droplets when larger droplets have lesser impact. This was difficult to explain until the application intensity issue was brought into the equation. With certain soil conditions it has been demonstrated that smaller droplets delivered at high intensity have a much greater negative impact on soil structure than larger droplets at low intensity. Research in the area of what specific soil characteristics contribute to a soil being either more droplet size sensitive or more application intensity sensitive would bring tremendous insight to sprinkler selection and design.

-Benefits of maximizing droplet size:

When maximizing sprinkler system efficiency, a great rule of thumb regarding droplet size is to select a sprinkler and pressure that generate the largest droplet possible without adverse effects on the soil or crop. This rule of thumb covers three major design points:

1) Promotes efficiency by minimizing wind drift and evaporative loss.
2) Larger droplets are generally associated with lower operating pressures. Lowering system operating pressure has become a very successful strategy in conserving energy and enhancing profitability.
3) Design spacing and elevation are typically selected through single ray profile analysis. Industry standards and repeatability dictate that the data for these profiles be gathered in no-wind conditions. Larger drops contribute to better "pattern integrity" which means the performance illustrated in a single ray profile will be closer to field conditions with a wind element. System application uniformity is likely to be negatively affected if a pattern does not have strong integrity.

Conclusion:

Sprinkler technology has advanced greatly over recent years resulting in an ability to yield very high performance in uniformity and efficiency while reaping the benefits of energy savings through lower system operating pressures. Focusing on performance aspects such as application intensity and droplet size are critical in providing solutions to ongoing center pivot irrigation concerns such as surface soil compaction, run-off and wheel tracking. Further research and support to our industry is crucial to leverage the potential of our advancing technology.