Lowering Average Application Rate (AAR) Expands Potential of Center Pivots

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Abstract: *Technical advancements have eliminated the single greatest limitation of Center Pivots. According to Dr. Brad King "The main disadvantage of Center Pivot irrigation systems is the high water application rates under their outer spans to compensate for the increased rate of travel." In lowering the AAR on the last third of any Center Pivot by installing 15' Boombacks on every outlet in opposing directions, Center Pivots are now a viable option for any soil type.*

AAR is an often misunderstood concept. Even seasoned irrigators may think the speed of rotation can effect AAR. We have created an innovative learning program with custom animation that simplifies this complex concept.

We have incorporated research on AAR by Dr. Howard Neibling and on runoff by Dr. Troy Peters. We also include the experience of two of the nation's largest growers in California who now use Center Pivots where they believed it impossible, reducing water usage by 33% and increasing yields by 37%.

This presentation brings together university research, real world farm data and modern teaching techniques to explain how using Boombacks to lower AAR will expand the use of Center Pivots to what was previously thought unsuitable land - such as tight soils, hilly ground or on any soil with a low infiltration rate.

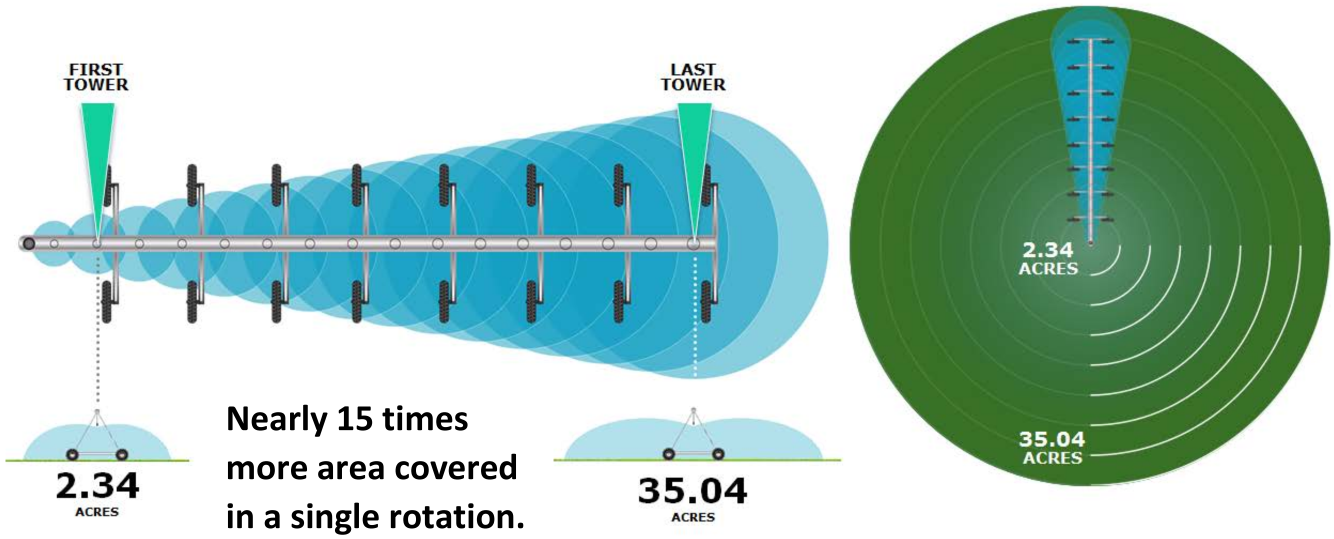
Keywords: Boomback, Boombacks, Boom, Booms, Offset, Offsets, Center Pivots, Pivots, Average Application Rate, Sprinklers, Efficiency, Reducing Waste, Reducing Pollution, Conservation, Conserving Water, Optimal Performance, Energy Savings, Wetted Footprint, Water Savings, Increased Yields, Increased Crop Quality, Increased Crop Uniformity, Runoff Eliminated, Increased Soak Time.

Introduction: In 1997 Bradley King and Dennis Kincaid with the University of Idaho published a paper entitled ***Optimal Performance from Center Pivot Sprinkler Systems***. In this paper they stated, *"The main disadvantage of Center Pivot irrigation systems is the high water application rates under their outer spans to compensate for the increased rate of travel."*

On a ¼ mile pivot, with 180 foot spans, the last tower travels eight times faster than the first tower. Sprinkler packages are designed with incrementally increasing nozzle sizes to compensate for the increasing rate of travel and the increased area of coverage.

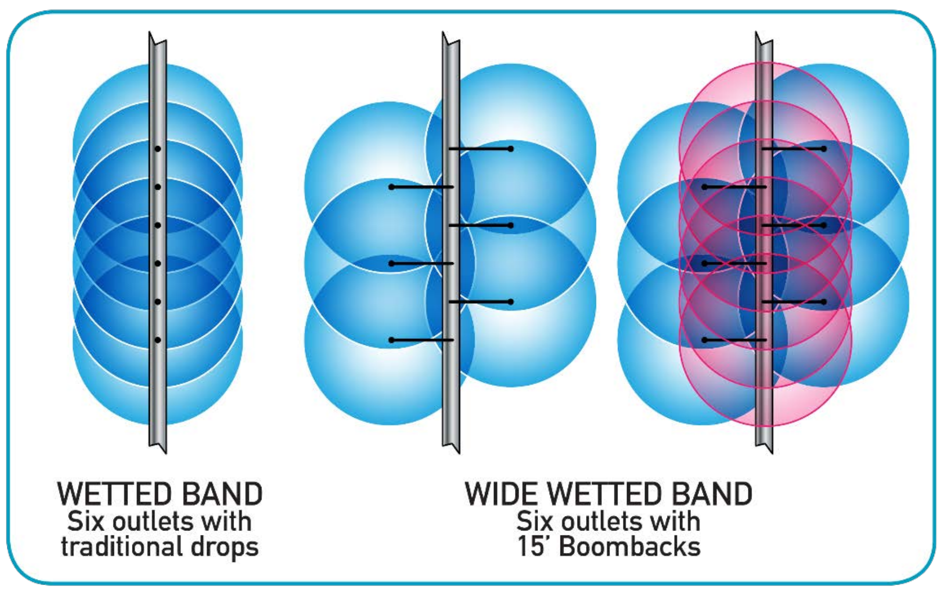
That speed difference translates into 2.35 feet per minute at the first tower and 18.8 feet per minute on the last. In the same amount of time, the first tower is covering just 2.34 acres compared to 35.04 acres on the last tower, nearly 15 time more area covered in a single revolution.

Pivot Rotation Speed and Area Covered:



In that same paper King and Kincaid determined *“Application rates under the outer spans of the standard quarter-mile-long low pressure center pivot normally exceed infiltration rate and result in runoff.”*

But they did not just identify a problem. They recommended a solution. *“The application rate of low pressure spray sprinklers can be reduced by using offset booms on alternate sides of the center pivot lateral.”*



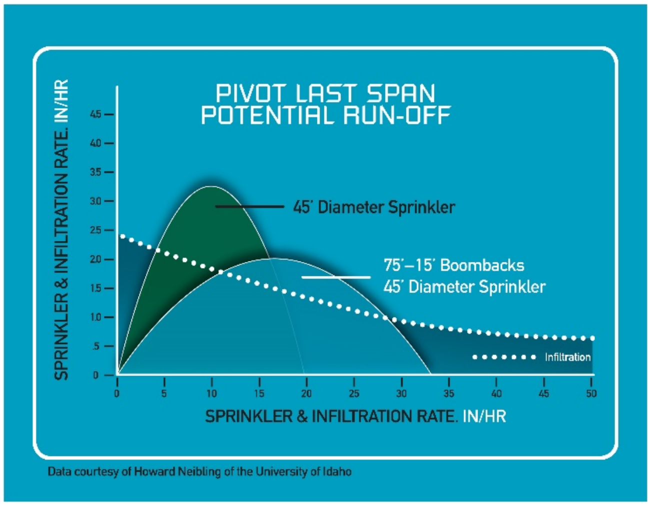
Boombacks, sometimes called offset booms, are add-on accessories for Pivots or Linears to re-locate or offset the sprinkler 15’ away from the center line of the span.

Innovative Boom Technology, putting Boombacks on every outlet – alternating in opposing directions - on roughly the last third of a pivot, can eliminate runoff and greatly reduce the occurrence of soil sealing - also known as crusting.

Spreading out the sprinklers using Boombacks, *even with the larger nozzle sizes*, can lower the *Average Application Rate* and decrease the *Application Intensity*.

Changing from drops to Boombacks gains a 66% increase in wetted footprint. You do not change the *amount of water* you are putting on, but you do change the *amount of time* it takes to put that water on.

Boombacks increase the amount of time it takes to put on the same amount of water. It takes longer for the Boomback spray pattern to move past the same point as the traditional drop spray pattern. By using Boombacks to create a larger wetted footprint, soak time is increased. Dr. Howard Neibling created a graph to depict the advantages of Boombacks. His graph depicts infiltration rates. The dotted line is the infiltration rate of the soil. It will vary by the type of soil, but all soil types have the same basic curve. The line may be higher up on the graph for tight clay soils or lower down on the graph for looser sandy soils. The bottom of the graph represents time. As indicated, in the beginning the soil can absorb more water.



Over time the ground becomes saturated and is no longer able to absorb water at the same rate. The curve of the infiltration rate almost flattens out over time. The first arc is from a 45 foot diameter sprinkler. Anything above the dotted infiltration rate line is potential runoff. The objective is to flatten out the application curve to match the soil infiltration rate.

Typically, the first thing irrigators do when they see runoff is to speed up the pivot. What happens when you speed up the pivot? You *reduce* the amount of water being applied. You cannot control the Average Application rate by the speed of the pivot. The Average Application Rate is a constant determined by contributing factors other than the speed of the pivot. The average application rate is the same if the pivot is sitting still or moving at maximum speed. The only thing you control with the speed of the pivot is the depth of water being applied.

Speeding up the Pivot may have eliminated any runoff, but now you are not getting the root penetration or the appropriate amount of water necessary to maximize yields. On tight soils, such as clay, or hilly ground, or on any other land experiencing runoff, speeding up the Pivot is not a solution.

Using Boombacks to increase soak time also lowers application intensity, reducing the likelihood of soil sealing. A point under any traditional drop spray pattern will be watered by five different sprinklers. All sprinkler manufactures recommend a 200% overlap for optimal uniformity. The impact to the ground by five sprinklers increases application intensity and can lead to soil sealing or crusting. Using Boombacks can reduce the application intensity significantly by spreading out the sprinklers.

A Theoretical Example: Consider a ¼ mile pivot, with traditional drops moving at average speed, putting on 1.25 inches of water. Presumably, the calculations show this is the required amount of water the crop needs. If everything works correctly there is no runoff - the application rate has matched the infiltration rate of the soil.

But what if there is runoff? What if the water being applied is not being absorbed into the ground? Then the crop is distressed, not getting the root penetration required for maximum yields. In addition, runoff erodes fertile soil. It also carries fertilizer and other chemicals into the surrounding soil, polluting groundwater and streams.

By adding Boombacks to the above example, you are still applying the same amount of water, 1.25 inches, but over a longer period of time. We have increased the wetted diameter, lowered the Average Application Rate, and more closely matched the soil's infiltration rate. We increased root penetration, eliminated runoff and are poised for maximum yields. We also lowered the Instantaneous Application Rate, greatly reducing the chances of soil sealing. We are using water more effectively.

Average Application Rate is the rate at which the depth of water increases if applied uniformly throughout the wetted area.

The formula is:

$$\textbf{AAR (in./hr.)} = \frac{\textbf{(Flowrate x dfp)}}{\textbf{72 x Cov}}$$

There is one constant, 72, and three variables. 1. **Flowrate:** the system flow, gallons per minute per acre. 2. **Dfp:** distant from the pivot point in feet. 3. **cov:** the sprinkler throw diameter (coverage) in feet. It is the *Flowrate* ***times*** the *distance from the pivot* ***divided*** by 72 ***times*** the *throw diameter* of the sprinkler.

Here is a specific example. On this particular pivot we have a Flowrate of 6 gallons per minute per acre. The pivot is 1300 feet long. Using Nelson Rotators with an Orange plate and a 20 PSI regulator at 9 feet height on traditional drops, gives a 72 foot throw diameter. Doing the math, we have a 1.5 inches per hour Average Application Rate.

$$\textbf{AAR (in./hr.)} = \frac{(6 \times 1300)}{72 \times 72} = \textbf{1.5 Inches per Hour}$$

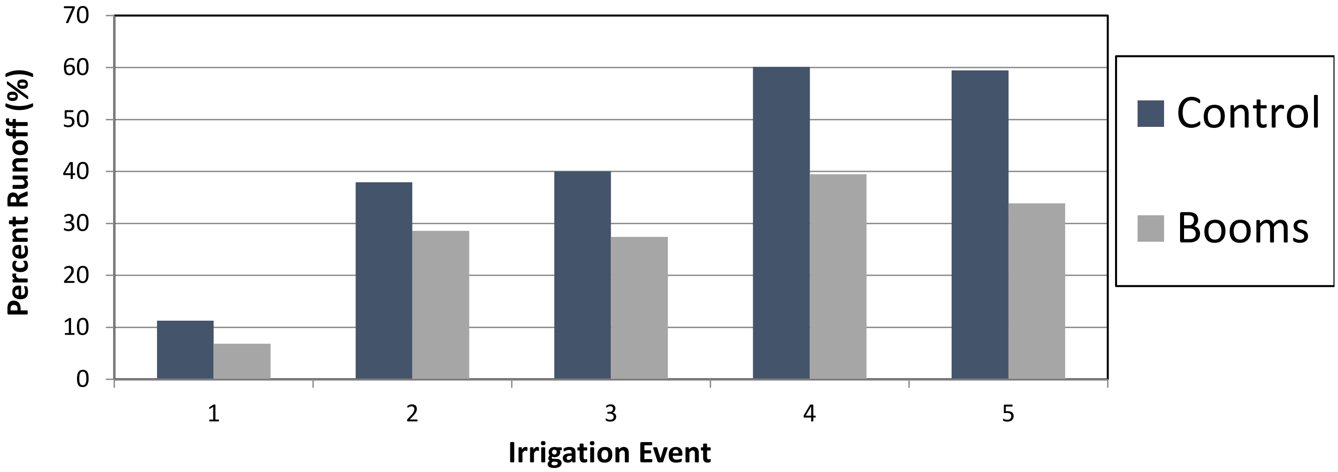
Here is that same example with 15' Boombacks. We still have the 6 gpm/acre and the 1300 feet from pivot point, but now we have a wider wetted band. Because of the 15' Boombacks, we have increased the throw diameter by 30 feet. So, instead of the 72 feet, the throw diameter is now 102 feet.

$$\textbf{AAR (in./hr.)} = \frac{(6 \times 1300)}{72 \times 102} = \textbf{1 Inch per Hour}$$

We now have an Average Application Rate of 1 inch per hour, a 33% decrease.

We've lowered the Average Application Rate and the Instantaneous Application Rate. We've increased the soak time, eliminated runoff, and reduced the chances of soil sealing.

A 2014 study by Dr. Troy Peters of Washington State University (WSU) at Prosser, Washington: **Efficacy of Boom Systems in controlling runoff under center pivots and linear move irrigation systems,** looked at how much Boombacks reduce runoff compared to traditional drops. The study does not look at yields or crop quality. For this particular study, Dr. Peters quantified how much runoff is actually reduced by using Boombacks.



The numbers on the bottom of the chart depict the irrigation event. The dark blue bar represents runoff from traditional drops. The light gray represents runoff from Boombacks. For this study, WSU overwatered until they had some runoff to measure from both systems so that they could compare the difference. The first event yielded a 4% reduction using Boombacks. Referring back to the graph representing soil absorption rates, you will recall that when the ground is dry it can absorb more water. Once they reached the 5th event, the reduction in runoff by using Boombacks had already jumped to a significant 24%.

Dr. Peters' study was published and is available online at the ASABE Technical Library, Volume 30, Issue 5 of *Applied Engineering in Agriculture*.

Real World Results: A large grower in California wanted to germinate carrots seeds with a pivot. The application rate required was too high for the ground to absorb - especially at the end of the pivot. They installed Boombacks on every outlet in opposing directions on the last third of a Pivot. Over a three year period, the solution was so effective they installed several more pivots. After the first three years, an interview with the grower revealed valuable results. Here is what they had to say.

"We have compiled data on all the different ways of irrigating, Pivots, Pivots with Boombacks, Handlines, Wheelines, Drip and Flood. We determined using Pivots with Boombacks is more than a solution for carrot germination. We are now putting the water into the ground more efficiently and reaping the benefits."

- 33% Water Savings
- 37% Increase In Yields
- Increase Crop Quality
- Increase Crop Uniformity
- Runoff Practically Eliminated

"The 33% water savings is coming from the eliminated runoff. We are now achieving deeper root penetration. All the listed benefits are generated by a more efficient use of water. When compared head to head, Pivots with Boombacks are by far the most economical way to irrigate."

Conclusion: There is now the possibility to utilize the advantages of Center Pivots in areas and on soils previously thought unsuitable for this type of irrigation.

The primary need for the expanded use of Center Pivots is the dissemination of the results of these studies and the real world experience of successful and innovative growers.

A lower Average Application Rate produces an increase in yields, improved crop quality and uniformity - all while conserving water.

Using Boombacks to lower the Average Application Rate (AAR) increases the potential for Center Pivots, including areas with a low infiltration rate or anywhere runoff is a problem.

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