Irrigating with Booms vs. Big Guns in Northwestern Washington

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS003E

Introduction

Irrigation in northwestern Washington is done on a supplemental basis. Although there have been years in the past when farmers did not use their irrigation equipment (e.g., the 1996 growing season), this is becoming less frequent. WSU Skagit County Extension agriculture statistics indicate a rise in supplemental irrigation in western Washington with what is referred to as a traveling, or reel big gun system (Photo 1). This system of irrigation is effective at supplying water to crops but does so inefficiently. High pressures are required to propel the water long distances, making it highly vulnerable to wind drift and evaporation. Tests show that big gun systems also have poor distribution uniformity compared to other irrigation systems (Hoffman et al., 2007).

Irrigation efficiency and distribution uniformity are important because they can lead to improved crop yields, crop uniformity and quality, and more accurate fertigation or chemigation. These improvements can in turn lower the input costs for irrigated specialty crops in northwestern Washington such as high value vegetable seed crops and small fruit and potato production while addressing environmental concerns for conserving water and energy.

Recently manufacturers have adapted the reel big gun to a boom system (Photo 2). Similar to a reel big gun, a boom system is mounted on a traveling cart that is slowly reeled in towards the reel. However, booms (supported pipes) are cantilevered over both sides of the cart and sprinklers are spaced along the length of the pipe to evenly distribute water over the soil similar to center pivot or linear-move irrigation systems. Because of the different mode of operation, a boom system operates at lower pressures and the water travels less distance through the air than with a big gun. This should make a boom irrigation system 1) more efficient since less water is evaporated as it travels to the soil surface, and 2) better at distribution uniformity since the water is less susceptible to wind redistribution.

This publication represents WSU Extension's efforts to document the benefits and drawbacks of typical big gun irrigation systems and the new boom-type irrigation system by comparing their respective water application efficiency and costs as applied to potato production in northwestern Washington.

Photo 1. A big gun irrigation system in operation.

Photo 2. A boom irrigation system in operation.

Materials and Methods

Evaluations were performed on two big gun systems and two boom systems in potato fields in northwestern Washington using standard procedures (Merriam and Keller, 1978). For each system evaluation, a line of catch cans was placed at equal intervals ahead of the traveling sprinkler perpendicular to its path in an un-irrigated area of the field. The cans were placed on the top of the bed of every third row in line with the plants. Each can's position in relation to the center line of the traveling sprinkler's path was noted. The cans were placed as level as possible and the plant canopy was laid down away from the can if it was likely to interfere with the trajectory of the sprinkler drops as they traveled from the sprinklers to the catch cans. The system was allowed to pass completely over the row of cans until water was no longer being caught in the cans. The volume of caught water and can position were then measured and recorded for each can. This volume was converted into an application depth using the cross-sectional area of the can opening.

The travel speed of the sprinkler was measured using a long survey tape, marked beginning and ending locations, and a timer. This measured speed was compared with the travel speed information on the reel controller as a back-up check. The pressure was noted at the sprinklers, reel, and if possible, the pump. Wind conditions were also recorded. The water flow rate going into the reel was measured using a portable transit time ultrasonic flow meter. The catch depth, spacing between the cans, and travel speed of the carts were used to calculate the water application rate at the soil surface. This was then divided by the measured inflow rate to calculate irrigation application efficiency[1].

The catch depths from the border cans were added to simulate overlap from previous and subsequent pulls. These catch depths are ordered and the average of the lowest 25% was divided by the overall average catch to give the distribution uniformity of the low quarter (DU_{LQ})[2].

[1]Application efficiency is the percentage of water leaving the nozzle that makes it to the ground to be stored in the soil (assuming no runoff).

[2]DU_{LQ} is a number between zero and one that reflects how evenly the irrigation system applies water. The lower the DU_{LQ}, the more water must be applied to adequately irrigate all areas of a field to compensate for some areas receiving inadequate water.

Results

Big Gun Evaluation 1

This experiment was performed on a Bauer reel and gun. During the experiment, a wind speed of about 10 mph out of the northwest was estimated. The big gun was pulled from the south towards the north across rows oriented north-south. The pressure at the pump was 140 psi. Because the reel was run by a hydraulic drive, the pressure was reduced across the drive and the pressure at the nozzle was 100 psi. Potatoes were grown on 36-inch centers and irrigated at 90 rows per pull for a total irrigation width of 270 feet per pull. The depth of water caught in each can at various distances from the center line is shown in Figure 1.

During the evaluation, the wind had a large effect on the uniformity and efficiency of the big gun. The wind was likely responsible for not only distorting the pattern to one side, but also tightening the pattern so that the outer edges didn't receive as much water as they should have. If the exact same application pattern occurred for every pull, the overlap strategy of 90 rows would result in the pattern shown in Figure 2. An improved overlap strategy of irrigating only 65 rows per pass is shown in Figure 3. This overlap strategy would give a much better water distribution uniformity. In general, narrowing the distance between passes assures good irrigation uniformity regardless of the wind condition. This would result in improved yields and crop quality. The efficiency of this system was estimated at **58%**. In other words, 58% of the water that left the nozzle made it to the soil surface.

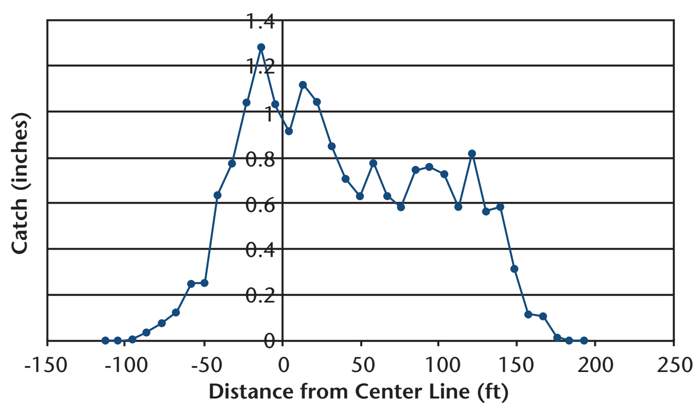

Figure 1. The catch of Big Gun 1 at various distances from the center line.

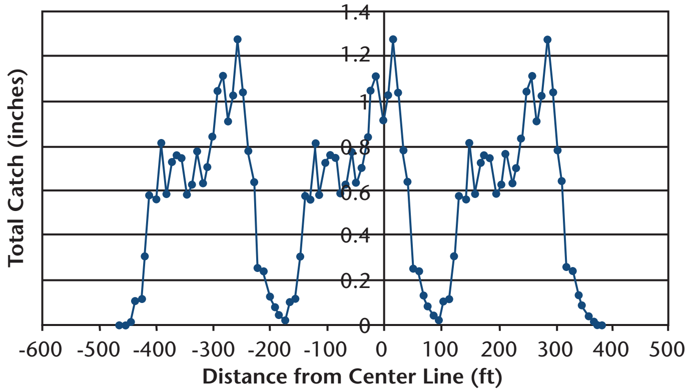

Figure 2. Three current overlapping pulls of Big Gun 1 if the exact pattern is replicated with 90-row spacing, resulting in a DU_{LQ} of 0.20.

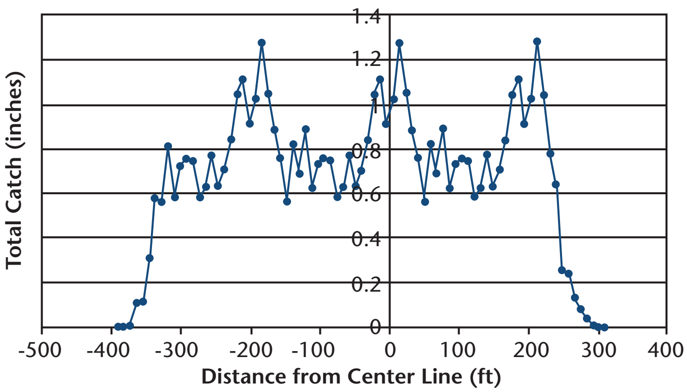

Figure 3. Three improved overlapping pulls of Big Gun 1 if the exact pattern is replicated on a 65-row spacing, resulting in a DU_{LQ} of 0.75.

Big Gun Evaluation 2

This evaluation was done on a Rainstar reel (Model E51) and a Bauer gun. However, the application rate was set high on this gun such that too much water was caught in the cans, resulting in a large amount of splash-out and overflow. A similar evaluation on a big gun done earlier in the year by Tom Walters (Horticulture Specialist at the Northwestern Washington Research and Extension Center) resulted in a DU_{LQ} of 0.73 for the overlapping portions.

Boom Evaluation 1

A Bauer Rainstar reel (Model E31) and Bauer boom were used in this evaluation. The reel was driven by a small gasoline engine. The system pressure was 58 psi at the pump and 45 psi at the reel, regulated at the boom nozzles to 20 psi. Instead of just one row of cans, two rows were used to improve the accuracy of the catch estimates. The results are shown in Figure 4 and the application pattern that would result from the overlap strategy is demonstrated in Figure 5.

The grower found plugging in the pressure regulators, which was apparent from the evaluation data indicating low catches next to the center line. A low catch followed by a high catch was also observed at the ends of the boom. The grower subsequently changed the nozzle configuration at the ends of the booms to decrease the over-application at the ends and improve the uniformity underneath the ends. Figure 6 gives the potential application efficiency and uniformity of this system after these two minor issues were corrected. The efficiency of this system was estimated at **86%.**

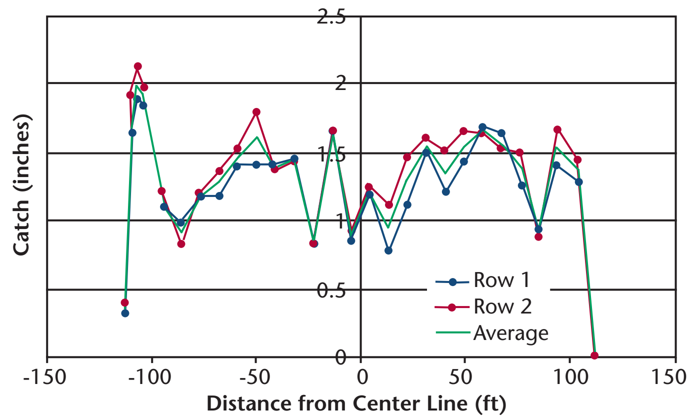

Figure 4. The catch of Boom 1 at various distances from the center line.

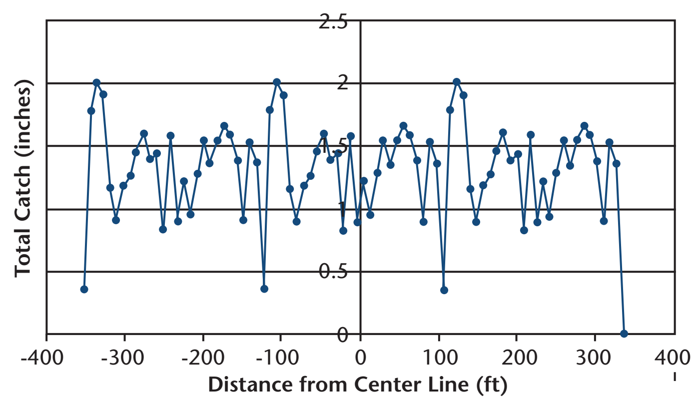

Figure 5. Three improved overlapping pulls of Boom 1 if the exact pattern is replicated on a 76-row spacing, resulting in a DU_{LQ} of 0.64.

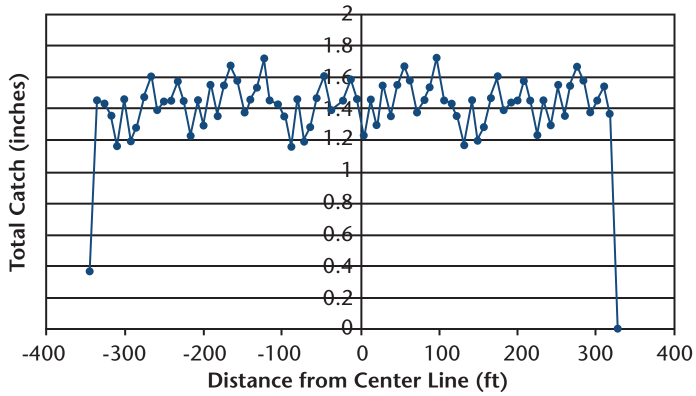

Figure 6. An improved overlap strategy for Boom 1 with 72-row spacing and with the fixing of plugged nozzles, resulting in a DU_{LQ} of 0.88.

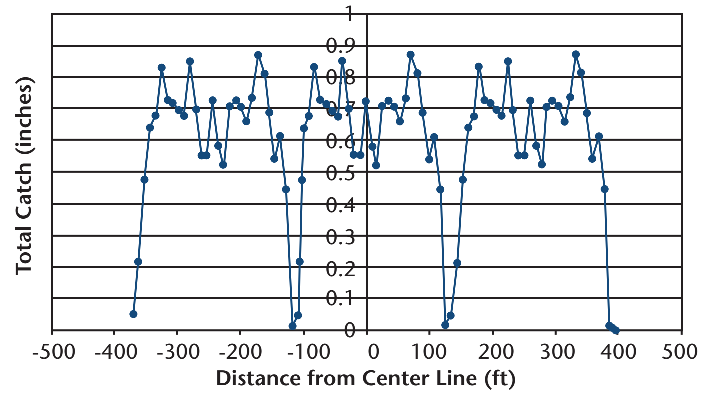

Figure 8. Three improved overlapping pulls of Boom 2 if the exact pattern is replicated on a 90-row spacing, resulting in a DU_{LQ} of 0.53.

Boom Evaluation 2

This evaluation was performed on a Greenseeker reel and Briggs boom. The reel was driven by a small gasoline engine. Pressure at the pump was 100 psi (much more than necessary), which was regulated at the boom nozzles to 20 psi. The catch can results are shown in Figure 7 and the overlap strategy used at the time of evaluation would give the application pattern in Figure 8. Figure 9 gives the potential application efficiency and uniformity of this system on a 78-row spacing. The efficiency of this system was estimated at 85%.

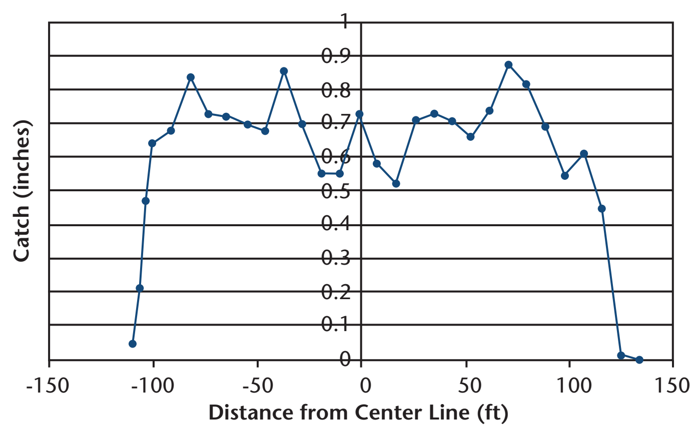

Figure 7. The catch of Boom 2 at various distances from the center line.

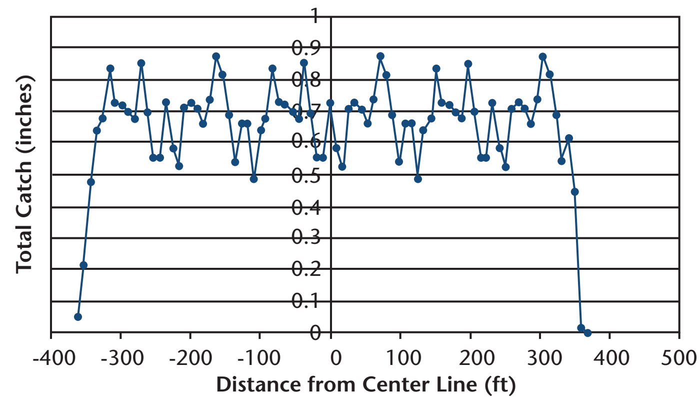

Figure 9. An improved overlap strategy for Boom 2 of 78-row spacing, resulting in a DU_{LQ} of 0.81.

Summary of Results

The key results for each of the irrigation evaluations are summarized for comparison in Table 1, in addition to the DU_{LQ} that would have been possible with optimal overlap and functional nozzles.

Table 1. Summarized results for all tested irrigation systems.

	Big Gun 1	Big Gun 2	Boom 1	Boom 2
Efficiency (%)	58	60	86	85
Evaluation DU_{LQ}	0.20	0.57	0.64	0.53
Possible DU_{LQ}	0.75	0.86	0.88	0.81
Pump Pressure (psi)	150	130	55	100
Pressure Possible (psi)	150	130	55	35

The efficiency and distribution uniformity numbers for the big gun and boom system evaluations are consistent with what was expected. A typical efficiency for a big gun irrigation system is about 60%. Since their water application method is essentially the same as a center pivot, the booms were expected to have efficiencies in the same range as a center pivot (80–85%). Indeed, the results indicate that 42% more usable irrigation water is delivered to the soil with a boom system compared to a big gun.

Although under ideal conditions the distribution uniformity of both systems was comparable, the big guns were much more susceptible to poor uniformity due to high wind conditions than the booms were. It was also interesting to note that uniformity was significantly improved with either system by increasing the overlap by just a few rows. This is equivalent to one or two extra pulls per field.

Economic Comparisons

Acquisition of a boom cart costs significantly more than a big gun cart, but there are potential long-term cost savings since booms are more efficient by operating at lower pressure and delivering more water to soil. Energy costs are directly related to pressure and flow rate. For example, if the pressure is cut in half, the energy costs can also be cut in half (assuming that the pump is changed so that equivalent pumping plant efficiencies can be obtained). Not only will this result in lower seasonal energy bills, but it will require less expensive pumps (lower horse power). Pump horsepower can be further reduced since less water must be pumped per unit area irrigated due to higher application efficiency of the boom system.

An analysis was done to compare the potential costs of both a big gun and a boom system with both electric and diesel pumping plants for a typical grower in northwestern Washington. The following assumptions were made for both systems:

- water lift from the water source to the pump of 20 ft
- flow rate of 350 gpm
- 100 acres are irrigated per system
- seasonal irrigation requirement of 6 inches
- power transmission efficiency from motor to pump of 95%
- water pump efficiency of 80%
- electrical motor efficiency of 85%, diesel motor efficiency of 33%

2007 electric power rates were used from Puget Sound Energy. These were 5.74 cents per kilowatt-hour (KWH) for consumption less than 20,000 KWH and 5.08 cents/KWH for consumption exceeding 20,000 KWH. In the most extreme case, only 38 kilowatts (kW) was demanded, which is less than the 50 kW cutoff for a demand charge so no demand charges were applied. Diesel was assumed to cost $2.90/gallon and have 130,500 British thermal units (BTUs) of energy/gallon.

A big gun system was assumed to require 150 psi at the pump to adequately operate with 60% application efficiency compared to a boom at 50 psi and 85% application efficiency. The results are given in Table 2.

Table 2. Comparison of typical annual energy costs for big gun and boom systems in Skagit and Whatcom counties.

	Electric		Diesel	
	Big gun	Boom	Big gun	Boom
Energy Cost per Season	$2,585	$723	$9,435	$2,462
Cost per acre-inch	$2.59	$1.02	$9.44	$3.49
Required Motor Size (hp)	43	16	43	16

Given the assumptions outlined above, running a boom system instead of a big gun results in a *total season energy savings* of **$662** with an electric pumping plant and **$5,773** with a diesel pumping plant.

Although a boom system has obvious pumping energy savings, it can require more labor to move than a big gun and would therefore result in higher labor costs. If an additional 30 minutes per move (interviewed growers reported 15 minutes additional time required or less) is allocated for moving a boom system 160 times per season at a skilled labor rate of $15/hour, there will be an additional labor cost of **$1,200** per season to move a boom compared to a big gun.

If energy rates are assumed to increase at 9% per year, a grower can get a 10% return on otherwise saved money (unsecured investments), and a boom system will last 15 years with no salvage value, then *the net present value of converting from a big gun to a boom* (including energy, additional labor costs, and subtracting annualized equipment costs) is **$8,473** with an electric pumping plant and **$73,905** with a diesel pumping plant. This net present value of converting to a boom should be compared to the additional cost of the cart (approximately $40,000 as of February 2010) to determine whether it is cost-effective to convert. In this scenario a grower using a diesel pump would save money in the long run, while a grower using an electrical pumping plant would not save money by converting.

These cost differences are the results of energy savings only. Factors that were not considered but would also *have very real effects on the economics of converting from a big gun to a boom type system are:*

- Return to the producer due to increased crop yields and quality that will result from better uniformity of booms (especially under windy conditions). Although very difficult to predict or quantify, these differences will likely have the greatest effect on a grower's bottom line.
- The differences in the purchase and maintenance costs of lower horsepower pumps needed for boom systems compared to big guns. For comparison, the initial cost of a 6-cylinder diesel pump that will run two big guns at 150 psi is around $28,000, while a 4-cylinder diesel pump to run two booms at 50 psi is closer to $20,000.
- Additional water and pumping costs to compensate for poor uniformity.
- More frequent repair and replacement costs to address problems with mainline and component wear and tear and failure of irrigation system components associated with higher pressures.

All of these unconsidered factors provide further economic incentives to convert from big gun carts to booms, in addition to the energy cost differences calculated above.

Practical Considerations

- While a big gun nozzle is large enough to pass most debris in an irrigation line, boom system nozzles and pressure regulators have significantly smaller orifices that plug with much smaller diameter debris. A filter will likely be needed if converting from a big gun to a boom system, depending on how clean the source water is.
- High wind conditions appear to not only push an application pattern to one direction, but also tighten it up. This means that under windy conditions, growers can improve uniformity by decreasing the spacing between pulls. Unfortunately this increases the number of pulls required to adequately irrigate a field, which is complicated by wind conditions that often change over the course of a day.
- Despite any irrigation system's inherent advantages and disadvantages, good irrigation scheduling and management have a large effect on energy cost savings and crop yield and quality.
- Saving pumping energy costs by operating sprinklers at pressures below manufacturer recommendations can result in poor irrigation uniformity, yields, crop uniformity, and crop quality, all of which hurt a grower's bottom line.
- Maximizing the spacing between pulls is attractive because it decreases labor requirements, but irrigation uniformity suffers greatly.

Conclusion

The evaluations indicated that the irrigation efficiency and uniformity of a typical boom is significantly greater than a typical big gun. Under ideal conditions and optimal spacing, boom systems have similar distribution uniformity to big gun systems. However, big guns are much more susceptible to poor uniformity in higher wind conditions. Overlap should be increased (fewer rows between pulls) under high wind conditions. In general, the uniformity of all the systems measured could be improved greatly by increasing the overlap.

The lower pressures required by a boom and subsequent water savings would likely make the transition to a boom system cost-effective due to energy savings alone for those using diesel pumping plants. Those using electric pumping plants will likely see less economic benefits due to energy savings by converting. Although any irrigation system can have very real limitations, good management of existing equipment may be even more important to good crop uniformity and quality than switching to a different system.

References

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Merriam, J.L, and J. Keller. 1978. *Farm Irrigation System Evaluation: A Guide for Management.* Utah State University, Logan, UT.

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The title photo is author Donald McMoran measuring the volume in a catch can with a boom irrigation system in the background.

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