Demonstration of New Planter Technology for Improved Water and Nitrogen Use Efficiency in Irrigated Potato Production

by

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Project Summary
In 2007, Western Ag Research LLC received a 3-year USDA National Conservation Innovation Grant to promote an innovative method of planting multiple rows of potatoes into elevated, flat beds instead of planting potatoes in the traditional ridged-row (hill) system that has been used for more than 200 years. One of the project goals was to demonstrate that enhanced spacing in flat beds results in greater production per acre with less water. The other goals were to conserve land, water, and nitrogen by planting potatoes in elevated beds, instead of the traditional ridged-row system.

The new innovative method of planting potatoes on elevated, flat beds was introduced to more than 20 farmers and used on more than 10,000 acres. The bed planting method has shown to reduce sprinkler irrigation requirements by 10 to 15% as compared to ridged-row planting. The reduction in water requirements by 10 to 15% was evaluated in on-farm studies using sophisticated soil moisture monitors by Campbell Scientific. The water savings in the bed system was also evaluated and confirmed in replicated trials at the USDA ARS Northwest Irrigation and Soils Research Laboratory located in Kimberly, Idaho under the direction of Dr. Bradley King.

Participating farmers reported returns for potatoes grown in both the bed planting and ridged-row systems. In 2007 and 2008, yields were 18 hundred-weight (cwt) per acre greater in the bed system as compared to potatoes grown in ridged rows. The beds also saved an average of 0.9 acre-inches of water in 2007-2008. In 2009, the yield difference between beds and ridged rows was around 25 cwt per acre, with a water savings of 1.5 acre-inches. An acre-inch is about 27,000 gallons of water per acre. This equates to approximately 5.5 million gallons of water saved on a typical 136 acre field.

The end result of this project was technology transfer of a new planting method that conserves water, land, and nitrogen in potato production. Several farmers have purchased their own potato bed planters and have converted to this method. The goal of this CIG project was to field test the new planters on 10,000 acres, during the three-year project period (2007-2010). The total acres planted into beds actually exceeded 20,000 acres. The investment farmers have made in purchasing their own bed planters and converting to bed planting has exceeded $700,000. Western Ag Research LLC achieved all of its goals identified in the USDA's CIG.

Key Words: potato bed planters, ridged rows, water conservation, nitrogen conservation, land conservation

The CIG Project (2007-2010)

This CIG project began in 2007 with the building of four potato bed planters using funds provided by the USDA CIG grant. The cost of designing, manufacturing, and maintaining four potato bed planters during the project period was $285,488 or about 66% of the budget. Another 14% of the budget was used in transporting the planters from farm-to-farm, and also from tractor rentals to farmers.

The practice of planting potatoes in ridged rows spans more than 200 years in the United States and was developed in areas where all of the moisture for crop production was received through rainfall. Potato yields decline drastically when soil moisture levels are 65% of field capacity or less. Therefore, potato crops are considered high water users. However, potatoes are also sensitive to too much moisture, especially if delivered at the wrong time. A rainfall event late in the season could spell disaster for a potato crop, where if too much rain occurred, tuber-rot in the field could destroy all or large portions of the potato crop. Hence, the ridged-row system was developed for drainage and crop protection.

In the ridged-row system, if excessive rainfall occurred, the majority of the moisture would run to the bottom of the hills, called a furrow. By draining into the furrow, the potatoes that are housed in the hill are protected from the excessive and untimely moisture event.

In the 1900s, potato production moved from the rainfall areas of New York, Pennsylvania, and the Carolinas to the more arid environments of Idaho, Washington, Oregon, and Colorado. With the advent of sprinkler irrigation in the 1950s, potato production moved to the arid West, which now produces more than 70% of all potatoes in the United States. The move occurred because moisture events could be controlled with irrigation systems. Thus, the potato crop in the arid West, using sprinkler irrigation, has had higher yields, less tuber rot, and better quality as compared to rain-fed areas.

When the majority of acres devoted to potatoes moved from rainfall areas to arid areas, the way potatoes received moisture changed. The way potatoes were planted, however, did not change. The ridged-row system of planting potatoes was also adopted in the arid West. While in general the ridged-row system works in the arid West, Western Ag Research advocated for changing the planting method to conserve water. In theory and observation, planting potatoes into an elevated bed conserves water without negatively affecting yield.

Planting potatoes in elevated beds conserves more water than in ridged rows. This is primarily due to beds having less furrow space than ridged rows, thus less drainage. The furrow is located below where the majority of the roots are located. The furrow also collects water and allows for drainage. The deeper water drains vertically in the furrow from the root zone, the less water that is available for crop use. By reducing the furrow area, as is done with elevated beds, the loss of water from drainage is also reduced and water is conserved.

Photos 1-3 show how potatoes are planted in beds and ridged rows. In photo 1, the current technology of planting potatoes in ridged rows is shown on the right, with valleys (furrows) and hills. The furrow is the water storage and drainage areas. The hill is where potatoes are housed. In the ridged-row planting method, a furrow is next to every hill throughout the field. The bed concept is shown on the left, where furrows are located only on the outside of the elevated bed. By using the elevated-bed method, three furrow spaces are eliminated for every 12 foot width in the field. With the elimination of furrow space, both water and land are conserved.

Photo 1: Elevated beds on left; ridged rows on right.

Photo 2: Potatoes planted into elevated beds.

Photo 3: Potatoes planted in ridged-rows.

Photo 4: A vertical section of a potato plant in a ridged row. The root system is located primarily in the hill with much less root volume in the furrow.

Photo 5: Ridge-rows on the left; elevated beds on the right.

The concept of planting potatoes into elevated beds was shown to more than 200 farmers at our seminars and workshops in 2007. Out of the 200 farmers that learned about converting from ridged-rows to elevated beds, more than 20 used the technology between 2007 and 2010. All of the farmers that planted potatoes in beds in 2007 and 2008 are still using the technology, as of 2010. Use of the bed planting technology is growing at a slow but steady pace and could encompass 30,000 acres by 2015, if the current growth trend continues. If bed planted acres reach 30,000 acres by 2015, this would represent 10% of all potato fields raised in Idaho.

Western Ag Research will continue to work closely with farmers to assist them in successfully adopting bed planting. When this project began, there were only two potato bed planters built by Harriston or Spudnik in the United States. Both of the planters were owned by Western Ag Research. As of completion of this project on June 30, 2010, we know of at least 16 bed planters that have been developed according to our protocols. The cash value of the additional bed planters is approximately $720,000.

Original Project Objectives

The overall project goal was to promote producer adoption of bed-planted potatoes in sprinkler irrigated potato production to conserve land, water, and nitrogen. The specific objectives of the CIG project were the following:

1. Build four potato bed planters for producers to use and evaluate bed planting on their own farms.
2. Evaluate water savings and nitrate leaching associated with potato bed planting.
3. Compare the economics of hill- and bed-planted potatoes using on-farm data.
4. Achieve 10,000 acres of potatoes planted in beds during the three-year project.
5. Transfer this technology by having farmers buy bed planters and use them on their farms.

All of the project objectives have been achieved. The four potato bed-planters *(Objective #1)* were built and used on 23 farms during 2007 through 2010. In-field studies on more than 10,000 acres and replicated trials at the USDA ARS in Kimberly showed water conservation *(Objective #2)* for potatoes planted in elevated beds. From the data collected so far, it appears that fields planted into elevated beds require 10 to 15% less water for the same yield as achieved by planting in ridged-rows.

Nitrogen conservation *(Objective #2)* was found in potatoes grown in beds in the replicated trials in Kimberly, but was not so clear in the in-field studies. The replicated trials in Kimberly showed that the elevated beds utilized both water and nitrogen more efficiently than the ridged-row system. Nitrogen management in fields planted with beds is similar to fields planted with ridged-rows. Farmers did not deviate much from their normal nitrogen fertilizer programs. The soil N tests were too close between beds and ridged-rows to show any statistical differences in nitrogen conservation. The evidence for nitrogen conservation from farmer's fields came from the fact that most bedded fields yielded slightly higher with the same amount of fertilizer nitrogen applied.

The economics *(Objective #3)* of planting in beds versus ridged-rows was shown through the participating potato farmers' actual returns. According to their USDA grades and returns, bed-planted potatoes returned higher revenues per acre as compared to potatoes grown in ridged-rows in more than 70% of the comparisons from 2007 through 2009. The 2010 potato harvest data will not be known until after harvest this October.

Objective #4 was accomplished and exceeded. We planned to have 10,000 acres planted with beds during the project period of 2007 to 2010. The exact acres planted with beds are unknown because several farmers that were not involved in the project purchased their own bed planters, and we have no verification of their acres that were planted into beds. So far, we have estimated that about 20,000 acres have been planted into beds as of June 30, 2010. The 20,000 acres includes project fields and non-project fields.

Objective #5 was to have farmers adopt this technology and move from planting in ridged-rows to planting potatoes in elevated beds. This objective was accomplished and will continue. Farmers are trying the new technology and some have already pursued it further by purchasing their own potato bed planters. Western Ag Research predicted that by the end of this project there would be an additional one or two bed planters sold. Instead, there are at least 16 potato bed planters now in existence.

The technology transfer also has had a 'boost' by the endorsement of Potandon LLC. Potandon is a marketing group that markets and sells more than 25% of all fresh potato sales in Idaho. Potandon has endorsed use of bed planting on their specialty varieties that they contract and sell. Western Ag Research will continue work with USDA ARS in Kimberly and technology transfer to farmers after completion of this project.

The Evidence of Water and Nitrogen Conservation

The best evidence for water and nitrogen conservation came from replicated trials at the USDA NWISRL in Kimberly under the direction of Dr. Bradley A. King. The beds produced a higher yield on the lower water and nitrogen application rates. The highest yield variance between the beds and ridged rows was at irrigation levels at 70% of water requirements, or ETs.

At 30% deficit irrigation (70% of ET), the beds produced an average yield of 40 cwt per acre higher than the ridged-rows at all three fertilize nitrogen application levels.

Table 1: The average yield for Russet Norkotah potatoes in 2006 and 2007 using different N and irrigation levels in beds and ridged-rows. Data from the USDA ARS NWIRSL study in Kimberly.

Irrigation	**100 lb N/acre**			**200 lb N/acre**			**300 lb N/acre**		
% of ET	Rows	5 Row Bed	7 Row Bed	Rows	5 Row Bed	7 Row Bed	Rows	5 Row Bed	7 Row Bed
70%	317	364	376	321	369	391	324	356	376
85%	392	436	440	393	404	428	384	403	410
100%	424	436	469	406	428	444	412	437	447

The Financial Expenditures of USDA CIG Awarded Funds

Western Ag Research LLC was awarded an USDA CIG grant of $508,000 to build four potato bed planters and evaluate them for potato production and water conservation. We utilized $433,502.96 of the funds and have $74,497.04 of unused funds that will be released back to USDA.

The following is an accounting of the $433,502.96 that was used in this project.

1. Lockwood Potato Planters (Rexburg, Idaho)……..$193,501.37
2. Spudnik Potato Planters (Blackfoot, Idaho)…… 66,512.88
3. RockyMountain Machinery-John Deere (Blackfoot, ID) 59,164.20
4. Western Laboratories (Parma, Idaho)…… 39,527.00
5. Campbell Scientific (Logan, Utah)…… 28,987.24
6. Ray Butt—Field Technician (Pingree, Idaho)…….. 21,878.38
7. Valley Equipment and Irrigation (Blackfoot, Idaho)……. 9,473.63
8. Jennifer Miller, PhD—Professional Writer (Boise, Idaho). 4,500.00
9. InterMountain Press—Booklet Publisher (Boise, Idaho)….3,339.00
10. Sarah King—Laborer of irrigation manf. (Logan, Utah)…. 1,935.00

11. Dr. Richard Wall, Electrical Engineer Univ. of Idaho……. 1,400.00
12. All other vendors (solar panels, electronics, rain gauges)… 3,284.26

Total: $433,502.96

Conclusions and the Future of Planting Potatoes into Beds

The bed planting system for potatoes has been shown to conserve water, land, and nitrogen fertilizer without negatively impacting yield or the farmer's returns. Yield data from on-farm field studies and also from replicated trials at the USDA have shown that beds have equal or better yields with less water and nitrogen inputs.

Further adoption of bed planting by farmers will depend upon the yields and over-all farm-gate returns. If potatoes planted in beds make money, then farmers will adopt the planting system. So far, the beds have done well and growth of this technology should not be hindered by economics of purchasing a potato planter designed for beds instead of the conventional ridged-row system.

The most important environmental benefit of bed planting is water conservation. Less water is wasted in the bed planting system because the furrow area is eliminated. Farmers do have to learn how to manage their irrigation differently in a bed system as compared to ridged rows. Further adoption of bed planting will also depend on farmers' abilities to successfully understand how to manage irrigation in bed-planted potato fields.

The success and failure of potato bed planting will depend on yields and irrigation management. Irrigation management of beds and soil water profiles after irrigation in beds will be crucial to the understanding and future success of bed planting. Western Ag Research will continue working with Dr. Bradley King at USDA ARS NWISRL on soil moisture and irrigation research as it relates to beds versus ridged-rows. So far, as of this writing, two research papers related to bed planting have been submitted to peer-reviewed journals. I have included the rough-draft of both research reports on beds.