The Irrigation of Potatoes

By F. S. Harris.

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THE IRRIGATION OF POTATOES

By F. S. Harris*

Introduction

Very few field crops yield as large returns to the acre as do potatoes during favorable years, and but few crops are as greatly affected in quality and yield by soil and seasonal conditions. The potato is particularly sensitive to soil moisture. For this reason yields under irrigation, where the moisture can be controlled, are usually much higher than where the moisture supply is irregular.

The almost universal use of potatoes makes the crop one of the most important and one that contributes greatly to the national food supply in times of shortage of other foods. The amount of human food that can be produced on an acre is greater than for the cereals, and where necessary, potatoes may be in part substituted for cereals in the human food ration. This makes the crop an important one, not only to supply regular demands, but as an emergency crop to restore a shortage that might arise in the national food supply.

The expense of producing the crop is rather high, consequently potatoes should not be planted under unfavorable soil and moisture conditions; poor land should be reserved for cheaper crops. Likewise the crop should be irrigated when the water is needed even if some other crop has to be sacrificed.

It becomes important, therefore, to learn as nearly as possible the exact moisture needs of the crop. Soil and climatic conditions will greatly vary irrigation practice, but it is believed that the experiments reported in this bulletin will throw considerable light on the moisture requirements of potatoes. The ways of meeting these needs under various conditions can then be determined for each locality.

Literature Review

Since the irrigation of potatoes has been investigated under

*The author wishes to acknowledge his indebtedness to his assistants, A. E. Bowman, H. W. Stucki, H. J. Maughan and D. W. Pittman, for faithfulness in connection with field and laboratory work, and to N. I. Butt for assistance in preparing the material for publication.
almost every climatic and soil condition of the world, the literature is varied, and in some cases contradictory. From work in Wisconsin, King\textsuperscript{a} found irrigation to lessen injury to potatoes due to tip burn. Water applied to every row proved better than that applied to alternate rows. The quality\textsuperscript{b} of the tubers was not affected, but the percentage of large potatoes was increased by irrigation.

McClatchie\textsuperscript{c}, in Arizona, found it possible to store in the soil before planting at least half the water needed to produce an early crop of potatoes. The first irrigation after planting did not need to be given for about two months if moisture conditions were favorable at planting time and cultivation was practiced. A total of 18 to 24 inches of water during the irrigating season, used in applications of about five inches, was ample for most potato soils. Cultivation gave very good returns, especially where the amount of water to be used was small. A tendency for a rank growth of tops and a deficiency in tubers was noticed after very early irrigation. "The less water the crop received and the

\begin{itemize}
\end{itemize}
more thoroughly it was cultivated the better was the quality of the tubers.''

A report of the practices in the Greeley, Colorado, section showing that it was preferable to delay irrigation until the vines shaded the ground and the plants were in bloom if the vines did not show signs of suffering for water before this time. A check in growth after irrigation had begun was far more injurious than a pinching of the plant for moisture before the first application was used. The condition of the soil and crop should determine the frequency and number of irrigations.

Grubb states that with thorough cultivation potatoes planted the first of May seldom need irrigating before July, although the best way of knowing the time to water is to observe the color of the foliage. Irrigation should be frequent enough to maintain a rapid growth during the irrigating season, but about 50 to 60 days prior to harvest it should stop.

Better yields were secured at the Wyoming Station with the irrigation water applied three times during the season than with 1, 2, or 4 applications. Earlier experiments indicate 16.3 inches to be the best amount both for total yield of tubers per acre and per inch of water.

According to Bennett of Colorado, potatoes grown on old potato land required 4.41 inches less total water than the 22.51 inches required by this crop when grown on an old alfalfa patch, and the crop ripened earlier and gave a larger yield when grown on the old potato soil.

German experiments indicate a short irrigation season (51 days) to be more efficient than a longer one. Irrigation increased the percentage of large potatoes and the starch content of the crop.

At the Gooding sub-station, on a rather impervious loam

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soil, Martin\textsuperscript{j} reports better results from irrigation six times than from three or five times when the total amount of water used was 24.6 inches. Farrell\textsuperscript{k}, at the same place, records yields of 72, 146, and 131 bushels for irrigation of 10.44, 17.88, and 24.6 inches of water, respectively. Later, Welch\textsuperscript{l} found that less water was needed and larger yields with a higher percentage of marketable tubers resulted when the first irrigation was given at the time the tubers were forming rather than when the plants were four or five inches high or when the tubers were about the size of an egg. About 21 inches of water applied in four irrigations after the tubers began to form, produced the largest yield of marketable potatoes, although eight inches gave the largest marketable yield per inch of water. Soggy tubers inferior in

Fig. 2. Potato Digging Machine. The Area of Potatoes That Can Be Raised by a Farmer Will Be Greatly Increased by the Use of Harvesting Machinery.


\textsuperscript{k} Farrell, F. D. Work at the Gooding Sub-station. Idaho Country Life, 4 (1911), No. 9, pp. 13-15, 19.

quality were produced when as much as 34 inches of water were used.

From extensive experiments and observations covering five years, Bark\textsuperscript{m} at Gooding, Idaho, concluded that the yield of potatoes tended to increase as the irrigation water applied increased from 6 to 36 inches, but since the rate of increase grew smaller with increased quantities of water, not more than 24 to 30 inches were thought advisable or profitable. He also believes that after the first application, irrigation should continue throughout the season.

Knorr\textsuperscript{n} in Nebraska observed a larger percentage of poorly shaped tubers when the crop was allowed to suffer for water between irrigations than when given usual treatment. He found the lowest yields on plats irrigated in every other row; the un-watered row being irrigated the next time, etc. He\textsuperscript{o} advises keeping the irrigation water in the furrows below the tuber bed. The potato should not be heavily irrigated before the tubers begin to set, although light applications are necessary when the vines show signs of suffering for want of water. The ground should be kept continuously wet after the first irrigation.

Powers\textsuperscript{p} believes potatoes to be one of the high-water-requiring crops, but in Oregon two irrigations maintained the uniform moisture content required for best results. Irrigating whenever the moisture content of the top foot of soil drops to 20\% and allowing 50 to 60 days without irrigation at the end of the season to hasten maturity is advised. Properly controlling the water applied decreased the percentage of culls, but did not affect the palatability nor the moisture content of the tubers. Irrigating increased the proportion of vines to potatoes.

Experiments in Nevada\textsuperscript{q} indicate that allowing potatoes

\textsuperscript{o} Knorr, F. Irrigated Field Crops in Western Nebraska. Nebr. Sta. Bul. No. 141, p. 32 (1914).
to wilt until they fail to revive at night prevents a satisfactory yield. Applications of three inches of water produced a better crop than those of 6 or 9 inches, although little difference was shown in the yield where 2, 4, or 5 three-inch irrigations were given. The highest starch content was secured with the smallest applications when the plants were never allowed to wilt, but for all three stages of wilting the 9-inch applications were best.

From experience in Colorado, Sandsten concluded that after the tubers have once set, it is necessary to irrigate often enough to keep the soil in good condition for the crop until it matures. A check in growth during this period resulted in knobby and gnarly tubers.

Because of the tendency for the soil to puddle and harden with small frequent irrigations, applying enough water to saturate the ground thoroughly at less frequent intervals is recommended. A small stream running for a long period is better than a large stream for a short time.

"Crowding" potatoes during August and the first half of September by liberal use of water generally results in watery, soggy tubers with poor keeping qualities and lacking in vigor when used as seed.

**Previous Results at Utah Station**

Results obtained in 1893 show that the largest yield of marketable potatoes was produced on the plats irrigated every eighth day and receiving a total of 14 inches of water. Large quantities of water tended to induce the plant to form more tubers than it could support.

On the gravel bench soils of the Utah Station potatoes used soil moisture more rapidly than the other common crops. Irrigation seemed to have little effect on the percentage moisture in the tubers. The percentage starch increased very regularly with increased applications of water. A few heavy irrigations produced potatoes rich in protein and poor in starch. The land

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The irrigation of potatoes receiving 40 inches of water in 7 irrigations, the largest applications coming first, produced larger yields, both total and marketable, than smaller amounts with fewer applications. The smallest yields, both total and marketable, were produced with 10 inches applied in two equal irrigations—one in the last part of June, and the other late in July. With 15 inches of water applied the percentage of marketable tubers was nearly as high as with 40 inches. Frequent small irrigations seemed to give best results. Potatoes have a higher water requirement for a pound of dry matter than oats, wheat, sugar beets, or corn. The increased yield of tubers or of dry matter decreased rapidly when more than the minimum quantities of water were used.

In 1903 the conclusions from work on the gravel loam bench land were that 15 inches of water when applied in six irrigations gave nearly 2½ times as many potatoes as when used in two applications. Few heavy irrigations tend to produce small potatoes, while frequent small applications increase the percentage of marketable potatoes and the starch content, especially when rather large amounts of water are used.

On the Greenville soil, which is the same as that used in the experiment reported in the present bulletin, Widtsoe and McLaughlin found potatoes to exhaust the soil less thoroughly of moisture either during the irrigating season or at harvest time than any other common crop. The rate of loss during a definite period was greater for wheat and oats than for potatoes, but because of the longer growing period for the latter, it required more total water. Potatoes required less water during the early and late periods of growth than during the middle ones when growth was most rapid.

Widtsoe found 67 per cent of the dry matter of potatoes produced by an irrigation of 7.5 inches of water to be due to the natural precipitation. The yield of dry matter increased with the water applied until 30 inches were used, after which there was a diminution until 60 inches were applied. Increasing the water from 5 to 60 inches decreased the yield of dry

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matter per inch of water from 462 to 76 pounds. The amount of water to produce a pound of dry matter increased with the amount of water given the plants.

It was found\(^x\) that part of the yield of potatoes was due to the water applied prior to the planting of the crop. With an application of 7.5 inches to be used during the irrigating season, water added at high water period (June 8) was better than that given earlier. Young plants were found\(^y\) to be more wasteful of water than those nearly mature. During every period of growth, large quantities of water seemed to decrease the proportion of leaves and of stems and to increase the proportion of tubers. Heavy irrigations tended to decrease the proportion of leaves to stems. The water applied influenced the moisture content of the different parts of the potato but little.

**Description of the Experiment**

The experimental work reported in this bulletin was conducted on the Greenville Experiment Farm two miles north of Logan, Utah. The soil, which is a well-drained uniform clay loam to great depth, has been described in detail in Utah Station Bulletin No. 115. The land was manured every year and was plowed in the fall except one year when fall storms made it necessary to wait until spring. The land was planted alternately to beets and potatoes. The soil will hold about 22 percent of moisture as a maximum under field conditions. The plats were 30 by 58.08 feet, which gives one-twenty-fifth of an acre each, exclusive of a seven-foot space between plats.

The water was measured by means of a Cippoletti weir and taken to the land in wooden flumes, where it was added to the potatoes by the flooding method. All the water was retained on the plats by banks around the edges. To a number of plats water was added each week during the growing season, but the time of applying water to most of the plats depended on the stage of development of the plants.

The potato plant was divided into four stages as follows:

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THE IRRIGATION OF POTATOES

First, when the vines were four inches high; second, when tubers began to form; third, when the potatoes were in full bloom; and, fourth, when the potatoes were nearly—but not quite—ripe.

A five-inch irrigation was used as a standard at these stages. An application of this amount was given at each stage, at each two stages, at each three stages, and at all four stages, thus giving quite a number of different combinations. It is possible, therefore, from the results obtained, to determine which stages are best when either one, two, or three irrigations are used.

In the weekly irrigations one plat received 1 inch, another 2½ inches, another 5 inches, and another 7½ inches of water each week during the regular irrigation season.

The experiment was begun in 1912 and carried through 1913, 1914, 1915, and 1916, giving five years' results. Conditions during these years were made as uniform as possible in every respect. The record of precipitation during the first four years is given in Utah Station Bulletin No. 146. It averaged a little less than 18 inches in a year. Peerless potatoes were used the first four years; Utah No. 1 was the variety used in 1916.

Fig. 3. Field in Which the Experiment Was Conducted.
Yield of Crop

The yield of tubers and vines on plats receiving different quantities of irrigation water weekly is given in Figure 4, which shows that the greatest yield of tubers was obtained with one inch of water weekly, or a total of 12.8 inches for the season in addition to the natural precipitation. This treatment gave an average yield of 337.1 bushels to the acre for five years. Reference to the Appendix shows that in 1912 a yield of 557 bushels to the acre was produced, while in 1915 the yield was only 103.7 bushels. During this year the yields for all treatments were only about one-fourth normal.

When 7½ inches weekly, or a total of 96 inches, were applied the yield of tubers was less than where no irrigation water was given. The weight of air-dry vines, however, for the high irrigation, averaged nearly double those for the no-irrigation. The figure makes it very clear that where irrigation water is applied each week, one inch is better than a larger quantity, and that as much as 5 inches a week is altogether too much.

![Figure 4. Yield of Potato Tubers and Vines on Plats Receiving Different Quantities of Irrigation Water Weekly. Average for Five Years.](image-url)
Figure 5 gives the yield of tubers and air-dry vines when irrigations of 5 inches each were applied at different stages in the growth of the plant. The lowest yield of tubers was obtained when the land was watered after the potatoes were planted and before the vines were up. The water applied at this time was worse than wasted.

The best single stage for irrigation was the third, when the plants were in full bloom.

Upon comparing Figures 4 and 5, it will be noted that neither 10, 15, nor 20 inches applied in two, three, or four irrigations of five inches each, gave results as good as 12.8 inches when given regularly in weekly irrigations of one inch each.

A study of the results shown in the two figures brings out the importance of a regular supply of moisture during the growing season rather than a large amount at any particular time. The relative unimportance of the very early and the very late water in comparison with that during the middle period of growth in the potato is also emphasized.

Late water as well as large quantities increased the relative growth of vines.

The total quantity of water required by potatoes is not large if it is properly distributed, but any break in the regular
Fig. 6. Average Weight of Tubers and Average Number of Tubers Per Hill on Plats Receiving Different Quantities of Irrigation Water Weekly. Results for Five Years.

Fig. 7. Average Weight of Tubers and Average Number of Tubers Per Hill on Plats Receiving Various Quantities of Water at Different Stages. Results for Five Years.
supply of moisture after its application is once begun seems to be particularly destructive of good yields.

**Size of Tubers**

The average size of tubers resulting from the various treatments is shown in Figures 6 and 7. Where the water was applied weekly the largest tubers grew with one inch each week. Both 5 and 7½ inches weekly produced smaller tubers than where no irrigation water was used. Figure 8 shows that as a rule the late irrigations tended to produce the larger potatoes. The tubers on plats receiving water at the third and fourth stages, and those on plats watered at all four stages averaged just the same size and were larger than for any other treatment.

**Number of Tubers in a Hill**

The average number of tubers in a hill is also shown in Figures 6 and 7, which make clear that high yield does not necessarily mean a large number of tubers in each hill. The most potatoes in a hill were found with 2½ inches of water weekly, and even 5 inches weekly gave a larger number of potatoes than one inch weekly, which, it will be remembered, was the treatment giving the highest yield.

Figure 7 seems to indicate that the earlier irrigations are the ones that are most able to increase the number of tubers in each hill.

**Weight of Hill**

Figures 8 and 9 give the average weight of the hills, which was determined by weighing 100 average hills from each plat. While these results are not so reliable as those for total yield, yet they have some interest. Of the weekly irrigations, 1-inch and 2½-inch were about equal, but there was a rapid decrease in the weight of hills as the amount of water was increased. As with total yield, the third stage was found most effective in increasing the size of hills; in fact, the yield per acre and the average weight of the hills are, naturally, very closely related.

**Height of Vines**

The average height of vines, expressed in inches, is also shown in Figures 8 and 9, which bring out the fact that height is much more uniform for the various treatments than is the
Fig. 8. Weight of the Average Hill and Average Height of Vines on Plats Receiving Different Quantities of Irrigation Water Weekly. Results for Five Years.

Fig. 9. Weight of the Average Hill and Average Height of Vines on Plats Receiving Different Quantities of Irrigation Water at Various Stages. Results for Five Years.
weight of tubers in the hill. All the irrigation treatments produced vines that were higher than those produced with no irrigation. Where 7½ inches of water were applied weekly the vines were nearly as high as those with but one inch weekly, while the yield of tubers was less than half as much. This makes clear the fact that a comparison of the vines is very little indication of the relative value of different irrigation treatments.

During the growth of the potatoes a very great difference in color of vines was noted for the different methods of irrigation, and it was observed that color was one of the best methods of finding the moisture needs of the potato plant.

Summary

1. This bulletin reports the results of a five years' experiment on the irrigation of potatoes at the Greenville Experimental Farm.

2. Important literature on the subject is reviewed.

3. The highest yield of potatoes was produced where small regular irrigations were given.

4. One inch weekly, or a total of 12.8 inches during the season, gave a higher yield than any other treatment.

5. When as much as 96 inches of water were applied the yield was less than where no water was given.

6. Watering the land after planting the potatoes and before the plants were up, reduced the yield below that where no irrigation was given.

7. Where but one irrigation was applied, it gave best results if applied when the potatoes were in full bloom. The second best stage was just as tubers began to form.

8. Discontinuing irrigation during the rapid growing season, after it was once begun, decreased the yield.

9. Excessive moisture, or that applied late in the life of the plant, increased the relative production of vines.

10. The relative number of tubers per hill was increased by early irrigation, while the relative size of the tubers was influenced more by late water.
11. Height of vines was affected much less by the treatment than yield of tubers.

12. The experiment brings out the importance of an even supply of soil moisture during the middle portion of the life of the potato after the tubers begin to form, and before they begin to ripen.

(College Series No. 50.)
### APPENDIX. DETAILED DATA DURING VARIOUS YEARS

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<tbody>
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<td>1</td>
<td>1 inch weekly</td>
<td>557.0</td>
<td>413.3</td>
<td>361.0</td>
<td>103.7</td>
<td>250.4</td>
<td>337.1</td>
<td>4.26</td>
<td>4.75</td>
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<td>25 inches weekly</td>
<td>418.0</td>
<td>342.5</td>
<td>348.0</td>
<td>94.0</td>
<td>502.0</td>
<td>300.9</td>
<td>5.02</td>
<td>4.04</td>
<td>2.60</td>
<td>.58</td>
<td>1.75</td>
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<tr>
<td>3</td>
<td>5 inches weekly</td>
<td>246.0</td>
<td>150.0</td>
<td>190.0</td>
<td>83.5</td>
<td>284.8</td>
<td>190.9</td>
<td>2.06</td>
<td>3.02</td>
<td>1.69</td>
<td>.62</td>
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<td>7.5 inches weekly</td>
<td>85.0</td>
<td>43.5</td>
<td>254.0</td>
<td>74.2</td>
<td>246.4</td>
<td>104.5</td>
<td>.84</td>
<td>1.09</td>
<td>1.62</td>
<td>.62</td>
<td>1.51</td>
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<td>5</td>
<td>None</td>
<td>259.0</td>
<td>192.1</td>
<td>172.0</td>
<td>47.0</td>
<td>96.3</td>
<td>153.8</td>
<td>2.28</td>
<td>2.32</td>
<td>2.12</td>
<td>.26</td>
<td>5.43</td>
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<tr>
<td>6</td>
<td>5 in. before coming up</td>
<td>315.0</td>
<td>90.1</td>
<td>169.7</td>
<td>31.2</td>
<td>89.1</td>
<td>139.0</td>
<td>2.93</td>
<td>1.74</td>
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<td>.16</td>
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<tr>
<td>7</td>
<td>5 inches 1st stage</td>
<td>391.0</td>
<td>210.8</td>
<td>208.2</td>
<td>48.8</td>
<td>110.5</td>
<td>193.9</td>
<td>3.46</td>
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<td>5 inches 2nd stage</td>
<td>404.0</td>
<td>158.3</td>
<td>273.0</td>
<td>72.0</td>
<td>99.6</td>
<td>201.4</td>
<td>3.73</td>
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<td>.72</td>
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<td>5 inches 3rd stage</td>
<td>404.0</td>
<td>240.2</td>
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<td>149.2</td>
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<td>10</td>
<td>5 inches 4th stage</td>
<td>274.0</td>
<td>252.5</td>
<td>216.5</td>
<td>33.8</td>
<td>123.8</td>
<td>180.1</td>
<td>2.64</td>
<td>3.46</td>
<td>1.27</td>
<td>.22</td>
<td>.67</td>
<td>1.65</td>
</tr>
<tr>
<td>11</td>
<td>20 in. 5 at 1, 2, 3, 4 stages</td>
<td>566.0</td>
<td>335.0</td>
<td>340.5</td>
<td>76.9</td>
<td>268.3</td>
<td>317.3</td>
<td>4.12</td>
<td>5.23</td>
<td>1.91</td>
<td>.24</td>
<td>1.46</td>
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<tr>
<td>12</td>
<td>15 in. 5 at 2, 3, 4 stages</td>
<td>491.0</td>
<td>376.4</td>
<td>290.0</td>
<td>77.7</td>
<td>238.8</td>
<td>294.8</td>
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<tr>
<td>13</td>
<td>15 in. 5 at 1, 3, 4 stages</td>
<td>429.0</td>
<td>335.6</td>
<td>225.0</td>
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