VARIETAL REACTION TO DEFICIT IRRIGATION

by
Mark W. Martin and David E. Miller

Irrigation Costs Increasing, Maybe Some Varieties Require Less:

As the cost of water and pumping energy continues to increase and their availability decreases it becomes important to be prudent in the use of these resources. Excessive amounts of water are often applied to potatoes, particularly by Russet Burbank growers, since this variety responds positively to high irrigation rates. High irrigation rates may not be needed with other varieties. Each potato variety probably has its own irrigation needs, so it is important in the early evaluation of new or potential new varieties to expose them to several irrigation rates, rather than just to those adapted to Russet Burbank.

A Method of Measuring Varietal Irrigation Needs:

A single line-source technique has been developed that makes it possible to apply a wide range of irrigation rates on a relatively small area. A single line of sprinklers is set up with heads at half the usual spacing of about 15 ft apart. We use Rainbird #30 heads with 3/16 inch range and 3/32 inch spreader nozzles, operating at about 50 psi. Rows are planted parallel to the line. The highest irrigation rate is at the line source and application rates decrease linearly with distance to zero on about the 16th row from the line. Each row thus receives a different irrigation rate. Rates less than that required to replace estimated evapotranspiration is termed "deficit irrigation".

By harvesting each row and measuring yield, grade and quality, it is possible to determine optimum irrigation rates for a variety. Initial screening for drought resistant potato clones can also be accomplished by planting perpendicular rather than parallel to the line source. Of course, soil type and weather patterns have a large bearing on optimum irrigation rates and plant response to irrigation rates.

Deficit Irrigation Studies on 4 Varieties in 1979:

By studying deficit irrigation effects on potatoes since 1976 we developed the necessary background information to conduct a larger-scale irrigation experiment in 1979 using the single-line-source technique. This study involved 4 replications of 4 varieties grown on each of 2 soil types, sand and fine sandy loam, and exposed to 7 water levels ranging from 100% to 0% replacement of estimated evapotranspiration (ET). Every other row was planted to the Norgold variety to provide minimal but uniform competition to all varieties. Thus, on each side of the line-source there were 7 rows of each test variety alternated with 9 rows of Norgold. The test varieties were Russet Burbank, Butte, Lemhi (formerly Dash-1) and Nooksack. Plots were 37 feet long. Water was applied daily to replace the estimated ET of the previous day next to the line. ET was estimated as 95% of the loss from a nearby evaporation pan. Actual application rates were measured with water catch cans placed in the plots at intervals out from the line source. Early in the season irrigation lines had been placed on the outside edges at each location to provide uniform irrigation rates to all rows until early summer when the plants started setting tubers. These outside lines were then turned off and during the last 2 months of the growing season only the center line was used for irrigation.

During the 2-month test period on sand near Paterson, Wa. about 23 inches of water was applied to the row of each variety nearest the irrigation line. About 20 inches was applied to the next row of each variety, 16 inches to the 3rd row, 13 inches to the 4th row, 10 inches to the 5th row, 7 inches to the 6th row and 2 inches to the 7th row. Since the 6th and 7th rows at this location did not produce marketable tubers, they were not harvested. On loam soil near Prosser, Wa. about 17 inches of water was applied to the row of each variety nearest to the irrigation line during the 2-month period. About 15 inches were applied to the 2nd row,

13 inches to the 3rd row, 10 inches to the 4th row, 8 inches to the 5th row, 6 inches to the 6th row and 3 inches to the 7th row. All 7 rows at this location had marketable tubers and were harvested. The tubers from each plot at both locations were graded by fresh market standards, the specific gravity and incidences of external and internal tuber defects were noted. Samples from each plot were placed in a commercial storage and used to make french fries.

General Effects of Deficit Irrigation on Sand:

On sand we started irrigating with the single line alone on June 21 and the effect of deficit irrigation soon became evident. By early August most plants had died at lower irrigation rates. At harvest, on August 21, it was evident that any degree of deficit irrigation was detrimental to all 4 varieties. The total yield, yield of U.S. No. 1's, tuber size and specific gravity were all markedly reduced. The incidence of 2nd growth was increased by deficit irrigation. We were surprised to find very little hollow heart, but other internal defects such as heat necrosis and blackspot bruising were quite prevelant, especially at 100% estimated ET. Reducing irrigation rates apparently made these varieties less susceptible to bruising and internal disorders.

Deficit irrigation seemed to have little effect on processability of the resulting tubers. Color and texture of french fries were about the same at all irrigation rates, although there was a tendency for less reducing sugar and a lighter fry color at the highest and lowest irrigation rates. We were surprised that the marked depressing effect that deficit irrigation had on specific gravity on sand did not express itself in more inferior french fries at lower irrigation rates.

In summary, reducing irrigation rates from 100% estimated ET on sand was harmful, causing reduced production, grade, tuber size and specific gravity, increased incidence of external defects, but decreased internal defects and bruising. The color of french fries from this location was definitely inferior to that from the location with loam soil.

General Effects of Deficit Irrigation on Loam Soil:

The difference in results obtained on sand and loam soil was dramatic. Plants on the latter showed very little evidence of water stress throughout the 2-month test period of July 6 to September 6, even in the outside rows which received essentially no irrigation during this entire period. Total yield was reduced very little until irrigation rates of 50% estimated ET or lower were reached. Even with no irrigation during this period the yield reduction was only 20 to 40%.

As irrigation rates were lowered to 50% estimated ET the tuber size, % and yield of U.S. No. 1's actually increased and then dropped off somewhat at more severe irrigation deficits. In contrast to results on sand, the specific gravity on loam soil increased as irrigation rates were reduced. In general, external defects such as growth cracking and 2nd growth were most prevelant at the 100% rate and least prevelant at the 50% rate. In loam soil hollow heart occurred in some varieties at the 70% to 100% rates and there was a high incidence of internal necrosis at the highest and lowest irrigation rates. The incidence of internal defects decreased as irrigation rates were lowered from the 100% to the 50% rate.

In summary, reducing irrigation rates to 50% estimated ET on loam soil was generally beneficial, causing increased tuber size, yield of U.S. No. 1's, and specific gravity, and reduced growth cracking, 2nd growth and other external defects and reduced hollow heart, internal necrosis and other internal disorders. With daily irrigation, the surface of the loam soil became very wet at the higher rates and probably caused poor soil aeration, with resulting detrimental effects on plant and tuber growth.

Differential Varietal Response to Deficit Irrigation:

Russet Burbank:

At higher irrigation rates on sand Russet Burbank was the highest yielding; however, its yield was the most severely affected by deficit irrigation, so it yielded less than the others at low irrigation rates. There was little reduction in % or yield of U.S. No. 1's or specific gravity until irrigation was reduced to the 75% rate; however, at rates lower than this there was a sharp decline in these important characteristics. Russet Burbank had many more external defects and much lower % U.S. No. 1's than the other 3 varieties at all irrigation levels. At the 75% to 100% rate there was much roughness and malformation and as the irrigation rates were reduced below the 75% rate there was a sharp increase in 2nd growth. Russet Burbank had tuber size somewhat larger than Lemhi and Butte but much smaller than Nooksack and it had few marketable tubers larger than 10 oz. No hollow heart was found in Russet Burbank at this location but there was a high incidence of internal necrosis and blackspot bruising at the 100% rate. The french fry color of Russet Burbank was fair at this location but not very uniform.

On loam soil the total yield of Russet Burbank decreased with distance from the center line but much less drastic than on sand. Yield reduction was only about 30% even on rows most distant from the lines. The % of U.S. No. 1's was very low for this variety at all irrigation levels, but was lowest at the high and low irrigation rates. At high irrigation rates there was much growth cracking and 2nd growth. Average tuber size was again somewhat larger than Lemhi and Butte but much smaller than Nooksack, with the largest tubers being produced at irrigation rates of the 50% to 70% rate. Specific gravity of Russet Burbank stayed fairly constant at all irrigation rates on loam soil, ranging from 1.075 to 1.078. Again very little hollow heart occurred in Russet Burbank but incidence of internal necrosis was high, especially at high and low irrigation rates. The french fry color was somewhat better at this location but still not very uniform.

In summary, on sand, Russet Burbank yields were best at the highest irrigation rates, but external and internal disorders were more prevelent at these rates. On loam soil Russet Burbank performed best at the 50% to 70% rates. Russet Burbank was more severely affected by irrigation deficits or surpluses than the other 3 varieties and was much inferior to the others in roughness and grade.

Lemhi:

On sand, Lemhi yielded less than Russet Burbank at high irrigation rates but more at lower rates. Its yields of U.S. No. 1's and % over 10 oz. were much superior to Russet Burbank at all irrigation rates, although the average tuber size was somewhat smaller. Lemhi had more tubers under 4 oz. than Russet Burbank but much less 2nd growth and other tuber malformations. The specific gravity of Lemhi decreased from 1.090 to 1.076 as irrigation rates decreased from the 100% to 40% rate but was about 4 points higher than Russet Burbank at all irrigation rates. Though it sometimes gets hollow heart, Lemhi produced no hollow heart at any irrigation rate in this test on sand. However, the incidence of other internal defects such as blackspot and discolored blotches was higher in Lemhi than in the other 3 varieties, especially at higher irrigation rates. Its french fry color from this location was quite dark but more uniform than Russet Burbank.

On loam soil Lemhi yielded less than Russet Burbank at higher irrigation rates but the yield was affected very little by irrigation deficits. Its yield was almost the same over the full range of 100% to 0% estimated ET, having only 18% less yield at the 0% than the 100% rate. The yields of U.S. No. 1's and tubers over 10 oz. increased as irrigation rates decreased from 100% down to 50% estimated ET but then dropped off rapidly because of an increase in tubers with pear shape and those under 4 oz. The specific gravity of Lemhi was about 2 points lower than Russet Burbank at higher irrigation rates but it increased from

1.075 to 1.081, or 6 points higher than Russet Burbank, as irrigation rates were decreased from the 70% to 0% rates. Compared to Russet Burbank, Lemhi had more pear shape and other malformations but much less 2nd growth cracking, so it had a much higher % of tubers free of external defects. Lemhi was much better than the other 3 varieties in its freedom from internal necrosis and other internal defects at this location. However, its weakness toward hollow heart was expressed, especially at higher irrigation rates, with 26% of the tubers expressing hollow heart at the highest irrigation rate, 23% at the next highest and 9% at the 3rd highest irrigation rate. Lemhi produced much lighter colored french fries than the other 3 varieties at this location and much lighter fries at this location than it did at the location with sandy soil.

In summary, at high irrigation rates Lemhi produced lower yields than Russet Burbank at both locations but was less affected by deficit irrigation, so outyielded Russet Burbank at lower irrigation rates. It had far less external defects than Russet Burbank at both locations, so had a much higher yield of U.S. No. 1's and a much larger proportion of U.S. No. 1's over 10 oz. The specific gravity of Lemhi was higher than that of Russet Burbank at all irrigation rates at both locations, except for the high rates on loam soil. It's specific gravity was reduced by deficit irrigation on sand but improved by deficit irrigation on loam soil. At both locations high irrigation rates caused serious internal defects in Lemhi. Only fair french fries were obtained from Lemhi tubers grown in sand but those grown on loam soil produced excellent fries.

Nooksack:

On sand Nooksack was adversely affected by all levels of deficit irrigation in total yield, yield of U.S. No. 1's, % over 10 oz. and average tuber size. The total yield of Nooksack was lower than yields of the other 3 varieties but its % and yield of U.S. No. 1's, tuber size and % over 10 oz. were far superior to the others. The specific gravity of Nooksack was 1.090 at the 100% to 75% rate but went down to 1.078 as irrigation rates were lowered to the 40% rate. Its specific gravity was about 6 points higher than Russet Burbank at all levels of irrigation at this location. The % of tubers with 2nd growth and the presence of external and internal defects in general was lower in Nooksack than in any of the other 3 varieties. It followed the pattern of the other varieties at this location, however, in having more internal defects at the highest irrigation rate. The french fries from Nooksack grown at this location had only fair color but good uniformity of color.

On loam soil Nooksack compared more favorably in total yield with the other varieties, being 2nd only to Russet Burbank, and again its % and yield of U.S. No. 1's, average tuber size, % over 10 oz., and specific gravity were far superior to the other 3 varieties, except at the highest irrigation rate. On this soil type excess irrigation had a particularly bad affect on Nooksack, causing bad growth cracking, roughness and internal disorders and lowered specific gravity. Nooksack expressed excellent tolerance to deficit irrigation in that it improved in almost every regard as irrigation rates were lowered from the 70% to 30% rates. In fact it was not hurt much by reducing irrigation rates to 0. Other than the growth cracking at high irrigation rates, which was about equal to that on Russet Burbank, it had very few external defects. It did have 16% hollow heart at the 70% rate and 10% hollow heart at the 100% rate which is unusual, because Nooksack seldom has this defect. It also had a rather large amount of internal necrosis, about equivalent to Russet Burbank, at all irrigation rates. In general, though it had less internal defects than any of the other 3 varieties. The Nooksack french fries from this location were superior to those of Russet Burbank in both color and uniformity of color but were not quite as good as those from Lemhi.

In summary, Nooksack appeared to be a very drought tolerant variety with lower overall yielding capacity than Russet Burbank but much superior in % and yield of U.S. No. 1's, tuber size, specific gravity and freedom from external and internal defects, except at higher irrigation rates on loam soil, where it showed very little advantage over Russet Burbank. Nooksack actually looked best at deficit irrigation rates of 30% to 70% estimated ET on loam

soil and was adversely affected by rates higher than this. It produced excellent french fries when grown on heavier soil but fried quite dark when grown on sand.

Butte:

When grown on sand the total yield of Butte was lower than Russet Burbank or Lemhi but like Lemhi, was not as severely affected as Russet Burbank by reducing irrigation rates to the 75% rate. Butte produced a much smaller % and yield of U.S. No. 1's than Lemhi or Nooksack but more than Russet Burbank. The tuber size of Butte was smaller than those of the other 3 lines with a resulting higher % under 4 oz. and lower % over 10 oz. The specific gravity of Butte stayed quite constant under deficit irrigation, ranging from 1.089 at the 100% rate down to 1.084 at the 40% rate. This was a much different reaction than the other 3 varieties which dropped 12 to 14 specific gravity points under deficit irrigation at this location. Butte had very few external or internal defects at any of the irrigation rates, ranking close to Nooksack in this regard. Butte tubers from this location produced very dark, unacceptable colored french fries.

On loam soil Butte produced much lower yields than the other 3 varieties. Because of a very high proportion of tubers under 4 oz., it produced a low % and yield of U.S. No. 1's, not much higher than the very rough Russet Burbank variety. Tuber size was small at all irrigation rates but was best at the 50% rate. Specific gravity of Butte was again quite constant at all irrigation rates, ranging from 1.077 at the 100% rate up to 1.080 with no irrigation, averaging about 3 points higher than Russet Burbank but about 6 points less than Nooksack. Butte had very little growth cracking or 2nd growth but had a weakness toward pear shape and other types of malformation. It expressed very little hollow heart and was exceeded only by Lemhi in freedom from internal disorders. At this location it did express some internal necrosis and other defects, especially at lower irrigation rates. It again had much darker fries than the other 3 varieties.

In summary, Butte had smaller tubers and lower yields than the other 3 varieties and produced darker colored fries even though it's specific gravity was uniformly high over a wide range of irrigation rates. It was relatively free of external and internal defects.