The Effect of Phosphorus and Soil Moisture Levels on Yield and Processing Quality of ‘Centennial’ Sweet Potatoes

H. L. Hammett
Louisiana State University Sweet Potato Research Center, Chase, LA 71324
R. J. Constantin
Southeast Horticulture Station, RFD 2, Box 71, Hammond, LA 70401
L. G. Jones
Department of Horticulture, Louisiana State University, Baton Rouge, LA 70803
Travis P. Hernandez
Louisiana State University Sweet Potato Research Center, Chase, LA 71324

Abstract. ‘Centennial’ sweet potatoes (Ipomoea batatas (L.) Lam.) did not respond to increasing levels of P over an 8 year period probably due to the low soil pH and relatively high native P levels. Increasing the available soil moisture to above 25% resulted in a 3.4 MT/ha increase in yield of marketable roots over that obtained with natural rainfall but increasing the available moisture had no influence on yield. The P rate had no effect on dry matter and/or carotenoid content, firmness and splitting of processed roots. Protein content as percent of dry weight was reduced with increased P rate. Increasing the available soil moisture resulted in lower dry matter, protein, and carotenoid contents but had no influence on fiber content, firmness, or splitting.

The sweet potato producing areas of Louisiana receive an average annual rainfall of 130 to 145 cm. Evenly distributed throughout the year, this rainfall would provide adequate moisture for most crops grown in the state but distribution is often very erratic. The sweet potato is generally considered to be moderately drought-tolerant, due in part to its extensive root system and low plant growth habit. The crop can survive prolonged dry periods and low plant growth habit. The crop can survive prolonged dry periods and following adequate rainfall, still produce profitable yields. However, during most growing seasons, there is normally periods when supplementary irrigation may enhance crop yield.

Lambeth (12) reported that irrigation to 50% available moisture on a Lintonia fine sandy loam increased yields of sweet potato roots 67% as compared to irrigation to 25% available moisture. In contrast, Jones (11) found that maintaining available moisture levels greater than 20% did not increase the yield of sweet potatoes. Bowers et al. (1) obtained increased yields when available soil moisture was maintained above 50% as compared to above 20% available moisture and non-irrigated plots but reported (3) no response above 20% available moisture on a Ruston fine sandy loam. Lana and Peterson (13) reported the best yield at 50% available moisture on a Buckner coarse sand.

Jones et al. (9) obtained a positive yield response to fertilizer in only 5 of 14 years. In a series of tests spanning 10 years at 5 locations, a measurable response to P was obtained only when the level of soil P did not exceed 30 kg/ha (10). Peterson (14) found a difference among cultivars in response to both level of irrigation and fertilization rate. Hammett and Hurt (6) in a 3 year study with ‘Centennial’ and ‘Goldrush’ sweet potatoes reported no cultivar difference in response to fertilizers; the application of more than 30 kg P and 56 kg K/ha did not improve yield on a Lintonia silt loam.

Kattan et al. (8) found high levels of irrigation, 50% available moisture or greater increased enzymatic discoloration in canned sweet potatoes. Constantin et al. (4, 10) reported that root P concentration was negatively associated with firmness and protein content and the application of irrigation water adversely affected dry matter, flesh color and protein content but there were no differences in response between 25% and 50% available moisture.

Long-term sweet potato irrigation studies have been conducted at the Sweet Potato Research Center, beginning in 1964 (4, 7). Data reported in this paper were collected during the 8 year period of 1972–79.

Materials and Methods

P levels (0, 15, 30, 45, and 60 kg/ha), and 3 moisture levels, (natural rainfall, moisture maintained above 25% available, and maintained above 50% of available) were studied in a split-plot, randomized block design experiment. The N and K were applied at 33.6 and 56 kg/ha respectively. Main plots were soil moisture levels and P rates were the sub-plots. Sub-plots were 3 rows, each 1.2 m wide and 12.1 m long, with data recorded only from the center row of each sub-plot. The soil was an Olivier silt loam with a pH of 5.1 and contained 0.78–0.84% organic matter and 69 ppm extractable P.

Fertilizer was applied to each sub-plot between May 15 and 25 of each year, and plots were then ridged in rows about 30 cm high. One week later, ‘Centennial’ plants (25 to 30 cm long) were transplanted 30.4 cm apart on the rows. Alachlor4, (2-chlor 2,
6-diethyl-N-(methoxymethyl) acetalanilide), was sprayed at 2.24 kg (active ingredient)/ha on a 40.5 cm band in the row center for weed control, and about 1.5 cm of irrigation water was applied the same day by overhead sprinklers to activate the herbicide and insure plant survival. Stand counts were made 7 days later, and any missing plants were replaced.

Bouyoucos blocks were imbedded at 15 and 30 cm depths in each row at random locations in the irrigated plots, and the available moisture was determined using a Delmhorst KS-1 moisture meter. The 3 readings at the same depth within a sub-plot were averaged to determine moisture availability within the sub-plot. Soil moisture was maintained at the appropriate level by use of flood (furrow) irrigation. Records were kept of moisture available for crop utilization in each plot and was determined as natural rainfall + irrigation water applied.

About mid-October of each year roots were harvested, graded into No. 1 (5.5-9 cm in diameter and 9-18 cm long), No. 2 (4.5-5 and 9-11 cm diameter and not over 23 cm long) and cull roots (sound roots that did not meet the above sizes or where misshapen or damaged), and weighed.

After harvest roots from the No. 1 grade and No. 2 grade were brought to Baton Rouge for analysis and canning. Ten roots of No. 1 size from each plot were cut longitudinally, one-half was used for carotenoid analysis and one-half for dry matter determinations. Duplicate 10 to 12 g samples of grated tissue were dried for 24 hr at 80°C in a forced-air oven for dry matter determinations. Dried samples were ground to pass through a 40-mesh screen in a Wiley mill, and were analyzed for fiber and crude protein content according to A.O.A.C. procedures (1) by the L.S.U. Feeds and Fertilizer Laboratory.

Carotenoid pigments content (flesh color) was determined on grated sweet potato tissue using 0.1 g duplicate samples per plot homogenized with 10 ml of hexane in a tube homogenizer, filtered and optical density of the filtrate determined at 440 m|x with a spectrophotometer. Carotenoid content was determined by comparison to a beta-carotene standard curve. Carotenoid content of canned sweet potatoes was determined as for fresh potatoes, with the exception that benzene was used as the solvent. Duplicate samples from each plot were analyzed.

No. 2 grade roots were processed 1 to 2 days after harvest. Standard canning procedures were followed: lye peeling in 10% NaOH at 102–104°C, washing, trimming and filling into cans (size 303 x 406, enamel lined) with hot 30% sucrose syrup, exhausting to a center can temperature of 82°C (about 3.5 min), sealing and retorting for 35 min at 115.5°C. After water cooling, the canned samples were stored 2–3 months before evaluation for carotenoid content, firmness and percent split roots. Eight cans of sweet potatoes from each plot were processed.

Firmness of the canned product was determined by use of an FTC shear press with recorder, utilizing a 1134 kg proving ring, 200 g of roots in a 10-prong standard shear cell and a 30 second stroke. Four determinations were made per replication.

Roots from 4 cans were examined for splitting. Data were recorded on number of roots slightly and severely split. Severely split roots were those that were judged split enough to have fallen apart during transit.

Results and Discussion

Rainfall and supplementary irrigation applied for the 4 months of the growing season (June through September) of each year from 1972 through 1979 is presented in Fig. 1. Plots maintained at natural rainfall moisture had an average of 36.1 cm of water available for crop utilization. Plots maintained at 25 and 50% available moisture had an average of 49.1 and 55.4 cm of water available for crop utilization, respectively.

There were no yield differences due to P levels. There was a strong consistent trend that indicated 45 kg/ha of P was the best treatment, but the differences were not statistically significant. The absence of a response to P may have been due to soil pH (5.1) which resulted in rapid conversion of the available P to insoluble Fe and Mn phosphates. Iron, Al, and Mn are relatively abundant in area soils, and toxicity symptoms have been noted in adjacent fields. Also, soils in this area are considered high in P (native and applied). Soil tests revealed an extractable P of 69 ppm in the test area. The P results are in close agreement with other studies (5, 6, 9, 10, 13 and 14). No consistent differences were reported from application of more than 30 kg/ha P when soil P exceeded 60 ppm.

There were differences among years and among water treatments within years. With the exception of the 1978 season, all plots that received supplementary irrigation produced higher yields than those that received only natural rainfall. The difference was consistent among grades with about 6 MT/ha difference in yield due to irrigation. There was no yield difference between plots maintained above 25% and those above 50% available moisture.

About half of the 1978 season's rainfall occurred during September, with most of it concentrated between September 12 and 16. This resulted in excessive rotting of the roots, which was much more severe in the higher moisture plots. Some rotting of roots was experienced in the high moisture plots each year but not of the magnitude of that during 1978.

The 20-year average rainfall for the 4 months of the growing season is 35.8 cm. The average for the 8 years of this test was 36.1 cm (Table 1). Very high yields were recorded in 1979 from all plots. Rainfall was above normal for the season and distribution was better than that experienced in most years. This resulted in some upward skewing of the data, but it appeared relatively uniform across grades and treatments.

The results of these tests indicated that sweet potatoes benefited from irrigation in most years; however, there was no advantage in maintaining soil moisture levels greater than 25% available moisture. An average of 13 cm of water was required to maintain soil moisture above 25% available, and this resulted in a yield in-

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (MT/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. 1's</td>
</tr>
<tr>
<td>P rate (kg/ha)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>12.9</td>
</tr>
<tr>
<td>15</td>
<td>13.9</td>
</tr>
<tr>
<td>30</td>
<td>14.0</td>
</tr>
<tr>
<td>45</td>
<td>14.3</td>
</tr>
<tr>
<td>60</td>
<td>13.9</td>
</tr>
<tr>
<td>Moisture level (cm)</td>
<td></td>
</tr>
<tr>
<td>36.1</td>
<td>11.7 b</td>
</tr>
<tr>
<td>49.1</td>
<td>15.1 a</td>
</tr>
<tr>
<td>55.6</td>
<td>14.6 a</td>
</tr>
</tbody>
</table>

*Water available 8 yr average rainfall for growing season, June - Sept.
**Water available rainfall plus irrigation for growing season, June - Sept., 25% available moisture.
*50% available moisture.
**Mean separation within column by Duncan's multiple followed by the same range test, 1% level.

Table 1. Yield of 'Centennial' sweet potatoes as influenced by moisture and P, average for 8 years, 1972 - 79.

### Table 2. Main effects of P rate on quality of sweet potatoes, 1972-79.

<table>
<thead>
<tr>
<th>P rate (kg/ha)</th>
<th>Dry matter (%)</th>
<th>Firmness²</th>
<th>Carotenoids (mg/100 g)</th>
<th>Protein (%)</th>
<th>Crude fiber (%)</th>
<th>Splits (%)y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>26.8</td>
<td>67.2</td>
<td>10.2</td>
<td>6.1</td>
<td>5.35</td>
<td>1.43</td>
</tr>
<tr>
<td>15</td>
<td>26.9</td>
<td>65.9</td>
<td>10.6</td>
<td>6.3</td>
<td>5.23</td>
<td>1.40</td>
</tr>
<tr>
<td>30</td>
<td>27.0</td>
<td>65.0</td>
<td>10.5</td>
<td>6.3</td>
<td>5.13</td>
<td>1.38</td>
</tr>
<tr>
<td>45</td>
<td>26.7</td>
<td>64.8</td>
<td>10.3</td>
<td>6.2</td>
<td>5.15</td>
<td>1.39</td>
</tr>
<tr>
<td>60</td>
<td>27.0</td>
<td>70.8</td>
<td>10.5</td>
<td>6.1</td>
<td>5.05</td>
<td>1.36</td>
</tr>
</tbody>
</table>

Significance

<table>
<thead>
<tr>
<th>(1%)</th>
<th>NS</th>
<th>NS</th>
<th>NS</th>
<th>NS</th>
<th>L**</th>
<th>NS</th>
<th>NS</th>
<th>NS</th>
<th>NS</th>
</tr>
</thead>
</table>

CV (%) 2.9 29.9 10.4 17.0 5.2 10.2 2.9 7.5 58.1 53.5

²Force (kg) required to shear a 200 g sample of canned sweet potatoes with a shear press.

yRoots that have split or cracked in the can. Severe splits are roots that have been judged to have fallen apart during transit.

---

**Fig. 1.** Rainfall and irrigation, monthly totals, in cm for June to September during 1972 to 1979 at Chase, La.
creased by 6.7 MT/ha (total) or about 0.5 MT/cm of water applied. Irrigation resulted in a 25% increase in yield of marketable roots. These results disagree with Bowers et al. (3), Lambeth (12), Lana (13) and Peterson (14), but their studies involved different cultivars in soils with a high content of sand. They reported yield increases when soil moisture was increased to 50% or above. Bowers et al. (2), Jones (11) and Constantin et al. (4), working with heavier soils, found no increased benefit from maintaining soil moisture above 25%. The latter findings coincide closely with the results of this study.

Varying rates of P from 0–60 kg/ha had little influence on quality of sweet potatoes (Table 2). P fertilization had no influence on dry matter content, carotenoid content (flesh color) of either fresh or processed roots, firmness of canned roots, or percentage of split or severely split canned roots. Protein content (percent fresh weight) was not altered by P rate; however on a dry weight basis, protein content was reduced by increasing soil-applied P. These results are similar to data obtained in an earlier study (10). There were significant interactions between year and irrigation and irrigation and P.

Fiber content (dry weight basis) was affected by P rates, but effects were not consistent. On a fresh weight basis, P had no influence on fiber content.

All quality measurements evaluated varied significantly from year to year. For example, dry matter content varied from a low of 24.9% in 1972 to a high of 28.6% in 1979. Protein content varied from a low of 8.5% (dry weight basis) in 1976, 1978, 1979 to a high of 28.8% in 1979. The response of sweet potatoes to fertilizer phosphorous and potassium was related to levels of these elements available in the soil. La. Agr. Expt. Sta. Bui. 704.

Irrigation had more influence on quality of sweet potatoes than P levels (Table 3). Irrigation reduced sweet potato dry matter content over natural rainfall. Maintaining soil moisture at 25% or 50% available moisture resulted in the same dry matter content. Irrigation levels reduced carotenoid content of both fresh and processed roots. Roots from plots receiving the most moisture had the lowest carotenoid content (flesh color). Roots from the natural rainfall plots (non-irrigated) had the highest protein content, both on a fresh and dry wt basis.

Added irrigation had no influence on fiber content, firmness, or splitting of canned roots.

Table 3. Main effects of irrigation on quality of sweet potatoes, 1972-79.

<table>
<thead>
<tr>
<th>Irrigation levels</th>
<th>Dry matter (%)</th>
<th>Protein (%)</th>
<th>Carotenoids (mg/100 g)</th>
<th>Splits (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
<td>Processed</td>
<td>Fresh</td>
<td>Processed</td>
</tr>
<tr>
<td>Natural rainfall</td>
<td>27.2 a</td>
<td>68.8 a</td>
<td>11.0 a</td>
<td>6.9 a</td>
</tr>
<tr>
<td>25% available</td>
<td>26.7 b</td>
<td>65.2 a</td>
<td>10.2 b</td>
<td>5.9 b</td>
</tr>
<tr>
<td>50% available</td>
<td>26.7 b</td>
<td>66.2 a</td>
<td>10.0 b</td>
<td>5.8 b</td>
</tr>
</tbody>
</table>

*Mean separation in columns by Duncan's multiple range test, 1% level.

<table>
<thead>
<tr>
<th>Protein (％)</th>
<th>Crude fiber (%)</th>
<th>Splits (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry wt</td>
<td>Fresh wt</td>
<td>Dry wt</td>
</tr>
<tr>
<td>2.87 a</td>
<td>0.78 a</td>
<td>2.92 a</td>
</tr>
<tr>
<td>57.0 a</td>
<td>21.2 a</td>
<td>56.8 a</td>
</tr>
</tbody>
</table>

*Mean separation in columns by Duncan's multiple range test, 1% level.

<table>
<thead>
<tr>
<th>Force (kg) required to shear a 200 g sample of canned sweet potatoes with a shear press.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roots that have split or cracked in the can. Severe splits are roots that have been judged to have fallen apart during transit.</td>
</tr>
</tbody>
</table>

**Literature Cited**