SOIL MOISTURE LEVELS EFFECT ON THE PERFORMANCE OF POTATO 
(Solanum tuberosum L.) CULTIVARS

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ABSTRACT Plants subjected to soil matric potential (SMP) of 25 centibars (cb) had the highest marketable (222.33 g/2 plants); net assimilation rate at 25, 50 and 65 days after planting (DAP); and leaf area index (LAI) at 50 and 65 DAP. Plants subjected to 50/cb had a reduction of 24% marketable yield with highest percentage of second growth tubers (3.93%). Plants subjected to 75/cb had poor performance with a 50% reduction of marketable yield and higher maturity period by 4 days, and increased percentage of dumbbell tubers. Among the cultivars, Agria and Recolta produced high marketable yield 10.27 t/ha and 10.31 t/ha, respectively). These cultivars are early maturing with high net assimilation rate, the characteristics of drought resistant cultivars. Agria has a mechanism of curling leaves aside from drooping and shedding of leaves to conserve water under drought. Cultivars Agria and Recolta subjected to 25 and 50/cb produced comparatively high marketable yield in each SMP level. Igorota subjected to all SMP levels had no marketable yield. Baraka subjected to 50 and 75/cb had the highest percentage formation of second growth and dumbbell tubers. All cultivars subjected to 75/cb had high dry matter content of tubers (25%). Positive significant correlations were observed on LAI at 50 DAP, marketable yield, and percentage second growth to total yield.

INTRODUCTION

Benguet and Mt. Province, which is regarded as the potato capital of the country, has a total area of 10,960 hectares planted to potato annually (DA-CAR et al., 2005) that suffer from lack of irrigation water during dry season. Potato (Solanum tuberosum L.) needs moderate soil moisture and that irrigation should be done whenever 50% of the available soil moisture is depleted to obtain a desirable yield (Alipit, 1980; ICPRE and UI-CALS, 2002). Further, the most sensitive stage of growth are during stolonization, tuber setting and enlargement (Kee et al., 1994; DA-AFIS and BPI, 1998; ICPRE and UI-CALS, 2002) and moisture stress (75% depletion of available soil moisture) prior to irrigation results to high incidence of growth cracks and knobby second growth in potato tubers (Alipit, 1980).

The search for potential cultivars that are high yielding under low moisture condition is necessary to sustain production. The study, therefore aimed to determine the effects of soil moisture on the growth and development of potato, evaluate the performance of potato cultivars, determine the interaction effect of soil moisture and cultivar on the performance of the crop, and determine the relationship of characters to yield.

MATERIALS AND METHODS

Environmental Site Conditions

The study was conducted under a tunnel type greenhouse at the Bureau of Plant Industry, Guisad, Baguio City from May to August, 2007. The potted soil was clay loam with a pH of 6.0, 0.15 % nitrogen, 90 ppm phosphorus and 200 ppm potassium.
Soil Moisture Levels Effect on The Performance of Potato

Experimental Design and Treatments

The study was laid out in a split plot design with three replications. The treatments were as follows:

Main Plot: Soil Matric Potential (S)  
S_1 – 25/cb  
S_2 – 50/cb  
S_3 – 75/cb  

Subplot: Cultivars (C)  
C_1. Agria  
C_2. Baraka  
C_3. Franzi  
C_4. Igorota (check)  
C_5. Recolta

Crop Establishment

Tuber seeds were planted individually in 10” diameter plastic pots filled with eight kg clay loam soil, after which two kg was added at hilling-up three weeks after planting. Chicken manure was applied basally at the rate of 4 t/ha (40 g/pot), and triple 14 at 140-140-140 kg N-P_2O_5-K_2O/ha (10 g/pot) in split application at planting time and hilling-up. Spraying was done every two weeks while hand weeding as needed during the cropping period.

Soil Moisture Level Imposition

All treatments were watered regularly and evenly by measuring the amount of water twice a week up to four weeks until crop establishment. Soil matric potential (SMP) was measured through the use of Irrometer (model S) with a unit in centibars (cb), an instrument that operates on the tensiometer principle, installed one month after planting. From the initial reading of 20/cb (soil is saturated), watering was withheld until SMP dropped to 25, 50 and 75/cb then watering was done; this was repeated for several cycles up to one week before harvesting.

Data

1. Meteorological data. Temperature (°C) inside the greenhouse and sunshine duration (hr) were obtained during the cropping period.

2. Net Assimilation Rate (NAR). NAR was taken at 35, 50 and 65 DAP (Gardner, 1985).

\[ \text{NAR (g/cm}^2/\text{day)} = \frac{\ln \left( \frac{\text{Total dry wt}_2}{\text{Total dry wt}_1} \right)}{(\text{Time}_2 - \text{Time}_1) \left( \text{Leaf area}_2 - \text{Leaf area}_1 \right)} \]

3. Leaf area index (LAI). LAI was observed at 35, 50 and 65 DAP using the formula:

\[ \text{LAI} = \frac{\text{Leaf area} \left( \text{cm}^2 \right)}{\text{Ground area} \left( \text{cm}^2 \right)} \]

4. Marketable yield (kg/plot). During harvest, quality tubers were classified by sizes and weighed.

5. Tuber Disorders. Percentage sprouted, dumbbell and second growth tubers were observed separately. These were taken using a common formula:

\[ \text{Specific tuber defect (\%)} = \frac{\text{No. of specific tuber defect}}{\text{No. of tuber samples}} \times 100 \]

6. Dry matter Content. Dry matter content was obtained using the formula:

\[ \text{DMC (\%)} = 100 - \frac{\text{\% Moisture Content}}{\text{\% Moisture Content}} \times 100 \]

Where: MC (\%) = \frac{\text{Fresh Wt. - Oven Dry Wt.}}{\text{Fresh Wt.}} \times 100

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RESULTS AND DISCUSSION

Meteorological Data

The greenhouse air temperature during the growing period ranged from 11.0 to 40.0 °C, and sunshine duration was 65.9 to 141.5 hours (Table 1). The temperature range observed was within the requirement of potato however, maximum temperatures were too high that greatly affected the yield and favored haulm growth of some cultivars. The optimum daily temperature of 18 to 20 °C and night temperatures of 10 to 15 °C are necessary for tuber initiation (FAO, 2001) while Zaag (1992) stressed that long sunshine duration helps in the production of assimilates.

Table 1. Meteorological data from May to August, 2007

<table>
<thead>
<tr>
<th>Month</th>
<th>Greenhouse Air Temp (°C)</th>
<th>Sunshine Duration (Hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>May</td>
<td>11.0</td>
<td>39.0</td>
</tr>
<tr>
<td>June</td>
<td>14.0</td>
<td>40.0</td>
</tr>
<tr>
<td>July</td>
<td>14.0</td>
<td>39.0</td>
</tr>
<tr>
<td>August</td>
<td>14.0</td>
<td>37.0</td>
</tr>
</tbody>
</table>

Net Assimilation Rate

Soil Matric Potential (SMP) Effect

Net assimilation rate (NAR) of plants at all SMP levels was increased from 35, 50 up to 65 DAP ranging from 3.17 to 5.70 g/cm²/15 days, which means that even there is severe water deficit, dry matter is produced gradually (Table 2).

Cultivar Differences

Cultivars Agria, Franzi and Recolta had increased NAR due to the production of tubers. Cultivars Baraka and Igorota had increased NAR from 35 to 50 DAP but decreased at 65 DAP because these cultivars produced vigorous lateral shoots more than the tubers. NAR decreases in more than 50 day old leaves since photosynthesis decreases (Zaag, 1992).

Interaction Effect

Cultivars Agria, Franzi and Recolta subjected to all SMP levels had increased NAR from 35 to 50 up to 65 DAP. Likewise, cultivars Baraka and Igorota subjected to all SMP levels had increased NAR from 35 to 50 DAP but decreased at 65 DAP. During the early phase, linear relationship of leaf area and plant weight is assumed but not for latter phases, as growth rate of leaf area may exceed dry matter or vice versa (Gardner, et al., 1985).

Leaf Area Index

SMP Effect

LAI of plants subjected to 25, 50 and 65/cb increased from 35 to 50 DAP but decreased at 65 DAP (Table 2). Results of studies show that water deficit reduces leaf area or foliage growth (Zaag, 1992) and leaf area index (Lahlou et al., 2003).

Cultivar Differences

Cultivar Baraka had increased LAI at 35, 50 up to 65 DAP because it produced vigorous lateral shoots while the other four cultivars increased from 35 to 50 DAP but decreased at 65 DAP (Table 2). The decrease in LAI of the four cultivars was due to the shedding of leaves. A
LAI of 3 to 5 is necessary for maximum dry matter production for most cultivated vegetable crops (Gardner et al., 1985).

**Interaction Effect**

Cultivars Baraka and Igorota subjected to 25/cb and Baraka subjected to 50/cb had increased LAI due to the development of vigorous lateral shoots. Other treatments had increased LAI from 35 to 50 DAP but eventually decreased at 65 DAP primarily due to shedding of leaves and the production of smaller leaves in the later stages as a result of water deficit.

**Marketable Yield**

**SMP Effect**

Highest marketable yield was obtained from plants subjected to 25/cb at 222.33 g/2 plants (11.12 t/ha). It was observed that plants subjected to 50 and 75/cb had reduced marketable yield by 24% and 53%, respectively. Limited soil moisture on potato decreases yield by 24-33% (Karafyllidis et al., 1996) while Lahlou et al. (2003) observed a decrease of 11-53%.

**Cultivar Differences**

Comparatively high marketable yield was produced by Recolta at 343.67 g/2 plants (10.31 t/ha) and Agria at 342.22 g/2 plants (10.27 t/ha) while Igorota had no marketable yield. Cultivar Franz produced 18 g/2 plants and Baraka had 121.67 g/2 plants. Taligan (2004) found that Agria produces the highest marketable and total yields among 10 varieties in drought condition under greenhouse.

**Interaction Effect**

Cultivars Recolta and Agria subjected to 25/cb produced comparatively high marketable yield. This indicated that both cultivars can resist water deficit under greenhouse conditions. Igorota subjected to 25, 50 and 75 cb and Franz subjected to 75 cb had no marketable yields.

The test cultivars subjected to the different soil moisture levels have low yield because of high temperature inside the greenhouse that favored haulm growth, short sunshine duration, and low light intensity due to cloudy atmosphere during the cropping period. Further, the crop was planted during the long day periods (May-August). AVRDC (1990) cited that tuberization in potato is favored by short days.

**Tuber Disorders**

**SMP Effect**

Plants subjected to 25/cb produced the highest percentage of sprouted tubers, at 75/cb dumbbell tubers, and at 50/cb second growth tubers. Fluctuating moisture supply causes tuber malformations (FAO, 2001; Ferreria, 2002; ICPRE and UI-CALS, 2002; Zaag, 1992; MFAI, 2006; Alipit, 1980). Moreover, Alipit (1980) and Zaag (1992) pointed that high temperature and drought breaks the dormancy of tubers resulting in sprouting and second growth.

**Cultivar Differences**

Cultivar Agria produced the highest percentage sprouted tubers. On dumbbell and second growth, Baraka had the highest percentage. FAO (2001) reported that water deficit in the early part of yield formation increases the occurrence of spindled tubers, which is more noticeable in cylindrical than round tuber varieties.
Interaction Effect

Cultivar Agria subjected to 50/cb gave the highest percentage sprouted tubers (10%). Other treatment combinations had 1.77 to 8% sprouted tubers. On dumbbell tubers, Baraka subjected to 75/cb registered the highest percentage (22.77%). On second growth, Baraka subjected to 50 and 25/cb had higher percentage of 16.43 and 12.57%, respectively, while Franzi and Igorota in all SMP levels had none.

Dry Matter Content (DMC)

SMP Effect

Plants subjected to 75/cb produced tubers with the highest tuber DMC (25.55%) while tubers from plants subjected to 25/cb had the lowest DMC (23.94%). Dry soil conditions in the later growth stages increases specific gravity or DMC and sugar content of tubers (ICPRE and UI-CALS, 2002; Nadler and Heuer, 1995).

Cultivar Differences

Recolta (26.41%), Igorota (25.67%) and Baraka (25.25%) had similarly high tuber DMC while Agria (23.82%) and Franzi (22.71%) had comparatively lower DMC. However, DMC of all the cultivars were within the processing requirement (20-25%). Variety is a great factor which influences the tuber DMC and sugar content of tubers (OSU, 1997).

Interaction Effect

Recolta and Igorota subjected to 75/cb were noted with the highest dry matter content of 27.15 and 26.62%, respectively, which are higher than the processing requirement. The lowest DMC was recorded from Franzi subjected to 25/cb at 22.19%. According to IAC (1989), dry matter content higher than 25% is no longer recommended for chips because the resulting product becomes too hard.

Correlation Analyses

Positive significant correlations were observed in leaf area index (LAI) at 50 DAP, marketable yield, and percent second growth to total yield (Table 3). As the characters increased, there was an increase in total yield. According to Tacio and Tad-awan (2005), marketable yield has a significant correlation with total yield. This corroborates with the findings of Nadler and Heuer (1995) and ICPRE and UI-CALS (2002) that there is a direct correlation between increasing drought and reduction in yield. There were no significant correlations of other characters to total yield.
Table 2. Net assimilation rate (NAR), leaf area index (LAI), marketable yield, tuber disorders and dry matter content of tubers as affected by SMP and cultivar

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Net Assimilation Rate</th>
<th>Leaf Area Index</th>
<th>Yield</th>
<th>% Tuber Disorders</th>
<th>DM C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NAR 35 DAP</td>
<td>NAR 50 DAP</td>
<td>NAR 65 DAP</td>
<td>LAI 35 DAP</td>
<td>LAI 50 DAP</td>
</tr>
<tr>
<td>SMP (S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/cb</td>
<td>3.54a</td>
<td>5.30a</td>
<td>5.71a</td>
<td>2.29b</td>
<td>4.21a</td>
</tr>
<tr>
<td>50/cb</td>
<td>3.18b</td>
<td>4.41b</td>
<td>4.70b</td>
<td>2.41a</td>
<td>3.64b</td>
</tr>
<tr>
<td>75/cb</td>
<td>3.24b</td>
<td>3.85c</td>
<td>4.34c</td>
<td>2.40b</td>
<td>3.49b</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agria</td>
<td>3.27c</td>
<td>4.31c</td>
<td>5.52a</td>
<td>2.32c</td>
<td>3.73b</td>
</tr>
<tr>
<td>Baraka</td>
<td>4.52a</td>
<td>5.90a</td>
<td>4.91c</td>
<td>2.87b</td>
<td>4.39b</td>
</tr>
<tr>
<td>Franz</td>
<td>2.33d</td>
<td>3.06d</td>
<td>3.31f</td>
<td>1.61d</td>
<td>2.43c</td>
</tr>
<tr>
<td>Igorota</td>
<td>2.64d</td>
<td>4.63d</td>
<td>3.99dd</td>
<td>3.35a</td>
<td>3.82b</td>
</tr>
<tr>
<td>Recolta</td>
<td>3.81l</td>
<td>4.70b</td>
<td>6.86e</td>
<td>1.69d</td>
<td>4.51c</td>
</tr>
<tr>
<td>S X C</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CV – S (%)</td>
<td>2.58</td>
<td>3.95</td>
<td>1.94</td>
<td>8.50</td>
<td>3.85</td>
</tr>
<tr>
<td>CV – C (%)</td>
<td>6.36</td>
<td>4.13</td>
<td>2.67</td>
<td>4.97</td>
<td>3.78</td>
</tr>
</tbody>
</table>

* Means with the same letter in a column are not significantly different at 5% level by DMRT.

Table 3. Correlation coefficients of net assimilation rate, leaf area index, marketable yield, tuber disorders and dry matter content of tubers to total yield (R=1.000)

<table>
<thead>
<tr>
<th>Character</th>
<th>Correlation Coefficient</th>
<th>Significance</th>
<th>Character</th>
<th>Correlation Coefficient</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net assimilation rate at 35 DAP</td>
<td>0.1566</td>
<td>R=0.4548</td>
<td>ns</td>
<td>Marketable yield</td>
<td>0.9790</td>
</tr>
<tr>
<td>Net assimilation rate at 50 DAP</td>
<td>-0.1895</td>
<td>R=0.3642</td>
<td>ns</td>
<td>% Sprouted tubers</td>
<td>0.1840</td>
</tr>
<tr>
<td>Net assimilation rate at 65 DAP</td>
<td>-0.0722</td>
<td>R=0.7316</td>
<td>ns</td>
<td>% Dumbell tubers</td>
<td>0.1044</td>
</tr>
<tr>
<td>Leaf area index at 35 DAP</td>
<td>0.0693</td>
<td>R=0.7421</td>
<td>ns</td>
<td>% Second growth</td>
<td>0.3193</td>
</tr>
<tr>
<td>Leaf area index at 50 DAP</td>
<td>0.2555</td>
<td>R=0.2177</td>
<td>*</td>
<td>% Dry matter content</td>
<td>0.2329</td>
</tr>
<tr>
<td>Leaf area index at 65 DAP</td>
<td>0.1589</td>
<td>R=0.4480</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 5% level of significance

SUMMARY

Five processing potato cultivars Agria, Baraka, Franzi, Igorota, and Recolta were subjected to soil matric potentials of 25, 50 and 75/cb under greenhouse condition to determine the effect of soil moisture on the growth and development of potato, evaluate the performance of potato cultivars, determine the interaction effect of soil moisture and cultivar on the performance of the crop, and determine the relationship of characters to yield.

Soil Matric Potential (SMP) Effect

SMP of 25/cb effected the highest marketable yield. Plants exhibited the lowest net assimilation rate (NAR) and leaf area index (LAI) at 50 and 65 DAP; and late maturity. Further,
highest percentage sprouted tubers, lowest dumbbell tubers, second growth, and dry matter content of tubers were observed.

SMP of 50/cb effected the lowest NAR at 35 DAP, reduced marketable yield by 24%, and highest percent second growth. SMP of 75/cb reduced marketable yield by 53%. Plants subjected to 75/cb had higher percentage of second growth tubers (3.00%) but highest dumbbell tubers, and tuber dry matter content (DMC). Moreover, plants exhibited lower NAR, LAI at 50 and 65 DAP, and earliest maturity of plants.

**Cultivar Differences**

Among the cultivars, Agria and Recolta could be considered tolerant to water deficit due to their high marketable yield, NAR and early maturity. Agria is short and has a mechanism of curling leaves aside from drooping and shedding to lessen transpiration when subjected to water deficit conditions. Other cultivars had poor performance in most of the characters observed.

**Interaction Effect**

Agria and Recolta subjected to 25/cb had produced comparatively high marketable yield while Igorota in all SMP levels had no marketable yield. Other treatments had poor performance in most of the characters observed.

**Correlation of Characters**

LAI at 50 DAP, marketable yield, and percentage second growth had positive significant correlations. There were no significant correlations of other characters with total yield.

**CONCLUSIONS**

Based on the results, the following conclusions are drawn:

1. Potato plants subjected to soil matric potential of 25/cb prior to irrigation had better physiological, growth, and yield performance.
2. Soil matric potential of 50 and 75/cb had negative effects on the physiological, growth, and yield performance of the five potato cultivars, caused tuber disorders and effected high dry matter content of tubers.
3. Cultivars Agria and Recolta had high marketable yield and net assimilation rate, and early maturity. Agria has a mechanism of curling of leaves.
5. Cultivars Agria and Recolta subjected to 25/cb had high marketable yield.
6. Cultivar Baraka subjected to 50 and 75/cb produced high percentage of tuber disorders and Igorota subjected to varying soil matric potential levels did not produce marketable tubers.
7. The five cultivars subjected to 75/cb produced tubers with high dry matter content.
8. Leaf area index at 50 DAP, marketable yield, and percentage second growth have positive significant correlations with total yield.

**RECOMMENDATIONS**

Considering the findings in the study, the following are recommended:

1. Irrigation of potato particularly cultivars Agria and Recolta should be done whenever the soil matric potential reaches 25/cb to attain better growth performance, higher yield and dry matter content, and lesser tuber disorders.
2. When water is a limiting factor, irrigation could be done at soil matric potential of 50/cb and water deficit-resistant cultivars such as Agria and Recolta are to be planted.

3. Other cultivars could be tested to determine their reactions to soil moisture levels in the open field.

LITERATURE CITED


