EFFECT OF IRRIGATION SCHEDULING ON TUBER YIELD OF POTATO UNDER DIFFERENT CROP ESTABLISHMENT METHODS

Sanjeev Ahuja1, Khurana D.S.2 and Kulbir Singh2

1Krishi Vigyan Kendra, Ropar (Punjab) 140001, India
2Department of Vegetable Science, Punjab Agricultural University, Ludhiana 141004, India

*Author for Correspondence

ABSTRACT
A field investigation was conducted to find out the optimal irrigation schedule under different crop establishment methods in sandy loam soil in North-Western plains of India during 2012-13 and 2013-14. The experiment comprised of climatic and soil matric potential based irrigation treatments: I1: IW/CPE: 1.00, I2: IW/CPE: 1.25, I3: IW/CPE: 1.50, I4: S35D20 and I5: control (farmers practice). These treatments were compared under furrow-ridge (M1) and furrow-bed planting (M2) system. The experiment was conducted in split plot design and it was replicated thrice. The ridge-furrow planting method proved better than bed-furrow system in terms of marketable tuber yield, large and medium sized tuber yield and average tuber weight. Treatment I4 recorded more than twice increase in irrigation water use efficiency as compared to control as well as enhanced the graded and marketable tuber yield as compared to all other treatments under ridge-furrow planting system. The results suggest that scheduling irrigation based on soil matric potential at -35 kPa measured at soil depth of 20 cm under ridge-furrow irrigation system is a better option under the North-Western plains of India.

Keywords: Potato, Irrigation Scheduling

INTRODUCTION
Potato is a major food crop in the world with an estimated production of 368.1 million tonnes (Anonymous, 2013). India is the second largest producer of potatoes after China with a production of 45.3 million tonnes from an area of 1.99 million ha (CPRI, 2013). In the Indian state of Punjab (North-Western India) the area and production under potato has witnessed five and eight times increase, respectively in the last fifty years with present production of about 2 million tonnes (CPRI, 2013).

The ridge-furrow planting system which use furrow irrigation method is mostly adopted for potato planting in the North Indian plains. In the prevailing method of furrow irrigation, most of the irrigation water infiltrate down the root zone area without its proper absorption by the roots. Bed planting has been found beneficial for improving yield and water use efficiency in potato (Fisher, 1995; Sidhu et al., 2005; Harms and Konschuh 2010; Singh et al., 2010; Qasim et al., 2013). Varying geometries of ridge planting has been studied by various scientists for improving the tuber yield and quality (Singh et al., 2010; Bombik et al., 2013; Singh and Sood, 2013; Vitos, 2013).

Keeping in view the increasing demand of water and area under potato crop especially in the Indo-Gangetic plains of India, there is a need for evaluating accurate irrigation schedule to improve irrigation water use and energy use efficiency (Gulati and Singh, 2011). Scheduling of irrigation in any crop depends upon soil type, crop variety, methods of planting as well as location. In India, pan evaporation based irrigation schedule has been recommended for potato cultivation by Directorate of All India coordinated project for research on water management. But more recently, Medici et al., (2014) has suggested that soil water tension is a good technique for scheduling irrigation to the different crops which needs further studies. This technique requires simple instrument like tensiometer for irrigation scheduling. A preliminary study conducted by the authors (unpublished) has established scheduling of irrigation at SWT of 35 kPa for higher yield and better tuber quality under furrow-ridge irrigation system for sandy-loam soils in the North-Western Indian plains. Further study was planned to compare the SMP based irrigation schedule with the pan evaporation based irrigation scheduling under the two crop establishment methods of ridge-furrow and bed-furrow planting system.
Considering all these factors, this study was undertaken with the objective to find out the best irrigation schedule for maximizing tuber yield, and quality under different crop establishment methods in the North-Western plains of India.

MATERIALS AND METHODS

Site, Climate and Soil

The investigation was undertaken on a typic Ustipsamment soil at Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana (Punjab) India for two potato growing seasons (October to January) in 2012-13 and 2013-14. The climate of Ludhiana is subtropical; semi-arid with an annual rainfall of 755 mm. Major part of the annual rainfall is received during June to September known as monsoon. Soil type was sandy loam with composition of 71 % sand, 19% silt and 10% clay. The experimental site in 2012 has: pH 7.9, electrical conductivity: 0.24 dS m⁻¹, organic C 3.5 g kg⁻¹, 0.5 M NaHCO₃ extractable P (Olsen et al., 1954) 8.0 mg kg⁻¹ and K (Pratt, 1965) 172.5 mg kg⁻¹, and in the year 2013 these values were pH: 7.8, EC: 0.21 dS m⁻¹, OC: 3.5 g kg⁻¹, extractable P: 7.75 mg kg⁻¹ and K: 171.0 mg kg⁻¹. The details of other physical characteristics observed before planting the crop at experimental sites are shown in table 1.

Table 1: Physical characteristics of soil during the year 2012 and 2013

<table>
<thead>
<tr>
<th>Soil depth (cm)</th>
<th>Bulk density (g cm⁻³)</th>
<th>Saturated conductivity (cm hr⁻¹)</th>
<th>Unsaturated conductivity (cm hr⁻¹)</th>
<th>Infiltration rate (cm hr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15</td>
<td>1.36</td>
<td>1.33</td>
<td>310.0</td>
<td>312.0</td>
</tr>
<tr>
<td>15-30</td>
<td>1.50</td>
<td>1.48</td>
<td>140.0</td>
<td>145.0</td>
</tr>
<tr>
<td>30-45</td>
<td>1.63</td>
<td>1.64</td>
<td>144.0</td>
<td>140.0</td>
</tr>
<tr>
<td>45-60</td>
<td>1.69</td>
<td>1.70</td>
<td>115.0</td>
<td>120.0</td>
</tr>
</tbody>
</table>

Field Experiment Design

The experiments were conducted in split plot design with four replications. There were two main plots comprising ridge-furrow (M₁) and bed-furrow (M₂) planting systems. The treatments under sub-plots consisted of five irrigation levels: I₁; IWCP (Irrigation water to cumulative pan evaporation) ratio 1.0, I₂; IWCP ratio 1.25, I₃; IWCP ratio 1.5, I₄, S₅D₉₀ (Maintaining suction ‘S’ of 35 kPa by installing tensiometer at soil depth ‘D’ of 20 cm) and I₅; control (farmers practice in the region). Each ridge was spaced at 60 cm from another ridge and it was followed by a furrow in ridge-furrow planting system. Beds with 85 cm top and 120 cm bottom width were prepared each followed by a furrow under bed-furrow planting method. Ridge-furrow and bed-furrow plots were prepared using semi-automatic potato planter and bed planter respectively, and planting was done manually. Plots measuring 10.0 m × 5.2 m (gross plot size) comprising eight ridges and four beds under bed-furrow each followed by a furrow under bed planting method of planting were prepared. Two rows of potatoes were planted on each bed. Two metre wide border was kept between two adjacent plots as well from irrigation channel to prevent unwanted water seepage. Disease free tubers of Kufri Pukhraj were planted 20 cm apart on top of the ridges. A performa was prepared and filled after polling and personal interviews with the farmers for collecting information regarding crop and irrigation management practices followed by them before finalizing irrigation scheduling for control treatment.

Crop Management

Pre-sprouted seed tubers weighing approximately 45g each were planted at the spacing of 60×20 cm under ridge-furrow and 45×27 cm on the bed (equivalent to a maintaining equal plant density of 8.33 plants m⁻²) on 18th October 2012 and 15th October 2013. Planting was done in the dry soil for control plot and in pre-irrigated soil for all other treatments during both the years. All plants emerged 19 and 21 days...
after planting during the first and second years respectively. Standard crop management practices as per the recommendations of PAU, Ludhiana were followed for raising successful crop. Potato vines were dehaulled 90 days after planting and tubers were lifted 15 days after dehauling for hardening of tubers. The tubers were harvested on 31 January 2013 and 28 January 2014. The yield parameters were recorded at the time of harvest.

Irrigation Treatments

Good quality irrigation water (EC: 0.5 dS m$^{-1}$) was given to facilitate the rooting and establishment of the crop for its complete emergence and for this purpose all plots received 5 cm of pre-plant irrigation water except control plots. The control plots received 11 and 9 cm and other plots received 5 and 4 cm post-plant irrigation water under ridge-furrow and bed-furrow planting system, respectively for proper establishment of the crop (Table 2).

After these common irrigations, rest irrigations were applied as per the treatment schedule. However, the control treatment received first irrigation 10 days after complete emergence and remaining irrigations at an interval of 12 days. Additional irrigation was given to control plots during the days when there were chances of frost occurrence. Only rainfall exceeding 5 mm within 25 hr was considered effective and included in the calculations for total water use.

Dial vacuum gauge tensiometers were installed at 20 cm depth on the ridge (from the top surface of the ridge) between two plants in the middle potato row of each I$_i$ plot. Monitoring of tensiometers was started regularly for SMP reading after the complete emergence of the crop. The readings were observed daily between 8.00 a.m. and 9.30 a.m. and irrigation was applied thereafter as per requirement of the treatment. The irrigation schedule under I$_i$ to I$_3$ treatment plots was followed as per the targeted IW: CPE ratios.

Data Collection

At tuber harvest, 50 plants from each plot were harvested by randomly selecting middle three rows of potatoes; the tubers were picked manually, counted, graded based on the tuber weight and weighed to determine average tuber weight, graded and marketable tuber yield. The four grades were selected based on tuber weight i.e. large (>100 g), medium (≥ 75g), small (≥ 50g) and smaller (≥ 50g).

The irrigation water use efficiency (WUE$_i$) was computed based on the marketable tuber yield by using the following formula $WUE_i = \frac{\text{Marketable tuber yield (Kg/ha)}}{\text{Total irrigation water (mm)}}$ where, Total irrigation water = water given to various treatments through irrigation.

Meteorological Data

Meteorological data were recorded at meteorological station situated nearby the experimental site. Weekly average temperature, relative humidity, sunshine and total rainfall and evaporation during the potato growing period from October, 15 to January, 31 in 2012-13 and 2013-14 seasons, respectively were recorded (Figure 1 & Figure 2).

Data Analysis

Two years data were subjected to analysis of variance (ANOVA) (Gomez and Gomez, 2010) based on PROC GLM (SAS software 9.1). Duncan’s multiple range tests at p=0.05 was applied to compare the means of different treatments.
Figure 1: Maximum and Minimum temperature (°C) (a), average humidity percent and total rainfall (mm) (b), sunshine (Hrs) and Evaporation (mm) (c) during 2012-2013.
Figure 2: Maximum and Minimum temperature (°C) (a), average humidity percent and total rainfall (mm) (b), sunshine (Hrs) and Evaporation (mm) (c) during 2013-2014.
Total rainfall was not uniformly distributed and was lower than the normal range during 2012-13 potato growing season [Figure 1 (a to c)].

There were two events of rainfall above 5 mm measuring 25.6 mm of water in the IIIrd week of December (17.2 mm) and IIIrd week of January (8.2 mm). But the rainfall that occurred in IIIrd week of January was not considered for further calculations as this event occurred when the crop had approached maturity.

During the 2013-14 potato growing period, there were three effective events of rainfall above 5 mm measuring in total 48.5 mm water [Figure 2 (a to c)]. One event of rainfall (12 mm) occurred in the 1st week of November and second event (10.4 mm) occurred in last week of December. The rainfall that occurred in the IIInd and IIIrd week of January (26.1 mm) were not of much use as crop was approaching near maturity and the same was not considered for doing further calculations.

**RESULTS AND DISCUSSION**

**Irrigation Water and Irrigation Water Use Efficiency**

It was observed that approximately 10 % lower water volume was utilized under bed planting than that of ridge planting during both the years (Table 2). Highest irrigation water was used under the control during both the years and methods.

Total water volume utilized varied from 2524 to 5124 m$^3$ ha$^{-1}$ during first year and 2154 to 5524 m$^3$ ha$^{-1}$ during the second year under ridge-furrow planting method. The corresponding values under bed-furrow method of planting were 2274 to 4224 and 2354 to 4274 m$^3$ ha$^{-1}$ during first and second year, respectively. Irrigation water use efficiency (WUEi) did not vary with the methods of planting.

Treatment I$_4$ recorded significantly higher WUEi among all the irrigation treatments during both the years as well as under both the planting methods.

Treatment, I$_4$ recorded 138% higher WUEi than that of control as 52% water volume was saved during the first year and the corresponding values during the second year were 167% and 60% under ridge-furrow method of planting (M$_1$).

The corresponding values for the same treatment in the second year under bed-furrow method of planting (M$_2$) were 123% & 48% and 129% & 53%. Sidhu et al., (2005) also recorded higher water use efficiency by maintaining soil matric suction of 20±2 kPa under different planting methods. The control treatment recorded lowest water use efficiency during both the years of planting because maximum irrigation water was received by these treatments.
Table 2: Irrigation water application and water use efficiency during the year 2012 and 2013

<table>
<thead>
<tr>
<th>Method of planting</th>
<th>M₁ (Ridge-furrow method)</th>
<th>M₂ (Bed-furrow method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation treatments</td>
<td>I₁</td>
<td>I₂</td>
</tr>
<tr>
<td>Irrigation application (mm)</td>
<td>23</td>
<td>19</td>
</tr>
<tr>
<td>Total water application (m³ ha⁻¹)</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>WUEi (kg ha⁻¹ mm⁻¹)</td>
<td>60.6</td>
<td>78.0</td>
</tr>
</tbody>
</table>

Column means followed by the same letter are not significantly different at p<0.05
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Table 3: Tuber yield and quality characters as affected by methods of planting and irrigation during the year 2012 and 2013

<table>
<thead>
<tr>
<th>Method of planting</th>
<th>M&lt;sub&gt;1&lt;/sub&gt; (Ridge-furrow method)</th>
<th>M&lt;sub&gt;2&lt;/sub&gt; (Bed-furrow method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation treatments</td>
<td>I&lt;sub&gt;1&lt;/sub&gt;</td>
<td>I&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Year</td>
<td>201</td>
<td>20</td>
</tr>
<tr>
<td>Avg. Tr wt (g)</td>
<td>30.9</td>
<td>31.2</td>
</tr>
<tr>
<td>Mkt. Tr yield (q/ha)</td>
<td>143.5</td>
<td>15.7</td>
</tr>
<tr>
<td>Large Tr yield (q/ha)</td>
<td>15.1</td>
<td>14.3</td>
</tr>
<tr>
<td>Med. Tr yield (q/ha)</td>
<td>24.7</td>
<td>27.2</td>
</tr>
<tr>
<td>Small Tr yield (q/ha)</td>
<td>38.6</td>
<td>41.4</td>
</tr>
<tr>
<td>Smaller Tr yield (q/ha)</td>
<td>64.6</td>
<td>68.6</td>
</tr>
</tbody>
</table>

Column means followed by the same letter are not significantly different at p<0.05

* Avg. Tr wt= Average tuber weight, Mkt. Tr yield= Marketable tuber yield, Med. Tr yield= Medium sized tuber yield
Average Tuber Weight and Marketable Tuber Yield

The analysis of data revealed that average tuber weight was significantly higher under ridge-furrow (M1) in comparison to the bed-furrow planting method during the second year. It was significantly higher for I3, I4 and I5 under M1 and I4 treatment under M2 method of planting during both the years and for I3 treatment under M2 during the second year. The treatments I3, I4 and I5 under M1 method of planting have received higher amount of irrigation water which may probably have resulted in better moisture content in the root zone for better growth and development of tubers. Similarly, the treatment I4 under bed-furrow method of planting may have received optimum soil moisture for the better tuber development. Singh and Sood (2013) also obtained higher average tuber weight in the traditional ridge-furrow planting as compared to the raised bed planting. The method of planting significantly affected the marketable tuber yield which was significantly higher under M1 i.e. ridge-furrow planting method as compared to M2, method of planting. The lower marketable tuber yield under bed planted crop may be due to moisture stress in the vicinity of the root zone area as the plantation was near the centre of beds. Sidhu et al., (2005) also reported lower tuber yield under 90 cm wide beds as compared to the 60 cm wide beds. In our study also bed width on the top was 85 cm. However, our finding is in contrary to the results of Qasim et al., (2013), who had reported higher tuber yield under wide beds as compared to the ridge planted crop. Among the various irrigation treatments, marketable tuber yield was significantly higher for I4 treatment under both the planting methods and years and this treatment were statistically at par with I3 treatment during the second year. Treatment I4 recorded 13.1% and 12.6% higher tuber yield than that of control under ridge-furrow planting system during first and second years, respectively and the corresponding values under bed-furrow planting method were 15.4% and 8.3%. The treatment I4 under M2 method of planting also recorded significantly higher marketable tuber yield which was statistically at par with I3 treatment during the second year. The recording of higher marketable tuber yield under ridge-furrow planting method evidenced the advantage of this method over the bed-furrow planting. The irrigation treatments which registered higher marketable tuber yield may probably have received the proper amount of irrigation water for keeping optimum soil moisture in the root zone for higher production of healthy tubers.

Graded Tuber Yield

Graded tuber yield was significantly affected by method of planting except for small size tubers during both the years and smaller size tubers for first year. Among the two methods, ridge-furrow planting method (M1) recorded significantly higher tuber yield for large and medium sized tubers during both the years. However, M2 showed significantly higher tuber yield for smaller sized tubers during the second year. Among different irrigation treatments, I4 treatment during both the years and I3 and I5 during the first year under M1 method of planting recorded significantly higher large sized tuber yield. Under M2 method of planting, I4 recorded significantly higher large sized tuber yield and treatments, I3 and I5 for second year were statistically at par with I4. Treatment, I4 recorded significantly higher medium and small sized tuber yield both under M1 and M2 methods during two years. Under M2 method of planting, I5 treatment recorded significantly higher medium and small sized tuber yield during the second year. Medium sized tubers yield for I3 treatment during second year under M2 was also significantly higher. It is evident that the I3, I4 and I5 treatments recorded higher large and medium sized tuber yield which indicates that under these treatment, tubers gathered higher biomass. It may probably because of proper moisture in the root zone which may have resulted in better growth and development of tubers. Similarly, Singh and Sood (2013) and Singh et al., (2010) also recorded higher tuber yield of large sized (>75g) tubers under conventional ridge-furrow system as compared to raised bed planting. In our study, medium size tubers were >75g, thus our results were similar to earlier findings. All the irrigation treatments under M1 recorded statistically at par values of smaller sized tuber yield during both the years. Similarly smaller sized tuber yield was statistically at par for all the irrigation treatments under M2 method of planting during the first year.

The advantage of ridge-furrow planting method over bed-furrow planting method in terms of marketable tuber yield, large and medium sized tuber yield and water use efficiency supported the relevance of ridge-
furrow planting system over that of bed-furrow planting method. Singh and Sood (2013) also reported that raised bed planting of double and triple row planting of potato is non advantageous as compared to conventional ridge planting under furrow irrigation method. In conclusion, higher graded and marketable tuber yield and average tuber weight under ridge-furrow planting method was recorded as compared to bed-furrow planting method. About three time’s higher irrigation water use efficiency was recorded by I₄ treatment as compared to the control (farmers practice) along with saving of 48 to 60% irrigation water. This suggests that irrigation scheduling based on soil matric potential by following ridge-furrow irrigation system is a better criterion in our conditions than that of climatic based irrigation scheduling. Thus, irrigation scheduling by fixing -35 kPa SMP at soil depth of 20 cm form top of the ridge is the best treatment under our conditions.

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