Standardization of plant density and intra-row spacing to maximize seed size tubers in two potato cultivars (*Solanum tuberosum*) grown in northern hills

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ABSTRACT

To overcome the problem of oversize tubers, three planting densities (80000, 100000 and 133333 plants/ha) were evaluated at 25, 20 and 15 cm intra-row and 50 cm inter-row spacing, in two late blight resistant potato (*Solanum tuberosum* L.) cultivars, viz. Kufri Himalini and Kufri Girdhari during the *kharif* season under hill conditions. At the maximum plant density (133333 plants/ha) obtained with closer spacing (50 × 15 cm), the proportion of extra large (>150 g) tubers was reduced from 23.5 to 12.4% in cv. Kufri Himalini and from 17.4 to 10.4% in cv. Kufri Girdhari. Besides, an increase in the proportion of seed size (20-80 g) tubers from 33.6 to 43.9% was also recorded. The yield of extra-large tubers (>150g) came down from 43 to 30% along with 10% increase in the yield of seed size (20-80 g) tubers.

Key words: Ground cover, Plant density, Plant vigour, Potato, Seed size, Tubers

Optimizing plant density and seed size is the most important issue of potato production due to its direct effect on seed cost, plant development, yield and quality of the crop. Seed constitutes a major and important input in potato (*Solanum tuberosum* L.) cultivation; non-availability of quality seeds has been reported to be a major factor for low potato productivity in India (Rana et al. 2013). On account of vegetative propagation, the requirement of seed potatoes (tubers) is voluminous and accounts for 40-50% of the total production cost (Kushwah and Singh 2008, Sharma and Singh 2010). The production cost may still be higher in the high hills, where, a major proportion of the potato harvest falls in large and extra-large grades on account of long crop season coupled with long day conditions (Sharma and Kumar 2014). Small tubers compared to large ones are highly preferred by the farmers to reduce the seed costs (Horton, 1987). Small tubers are known to reduce the seed requirement by ~50% and consequently, decline the cost of cultivation by about 25% (Arsenault et al. 2001).

Late blight is one of the major diseases in the hilly areas, where potato is grown mainly during *kharif* season. To circumvent the problem, development of late blight resistant cultivars is an important approach which also saves the cost of chemicals. On these lines, the ICAR-Central Potato Research Institute, Shimla released two late blight resistant cultivars, viz. Kufri Himalini and Kufri Girdhari during the years 2007 and 2011, respectively. Both the cultivars besides being resistant to late blight have high yield potential over the existing cultivars of potato in the region (Joseph et al. 2007, 2011).

Being resistant to late blight, these cultivars are becoming popular amongst the farmers of the hilly areas (Sharma and Pandey 2015). Although, the cultivar Kufri Himalini is performing well in all the potato growing regions of India, due to the longer crop duration in the high hills, a major proportion of the produce falls in large and extra-large grades (Sharma and Pandey 2015). Such, large-sized tubers are not preferred either for seed or for table purpose. Keeping in view the problem of over-sized tubers with late blight resistant cultivars in the hills, an attempt was made to improve the proportion of seed size tubers through the manipulation of planting density/crop geometry.

MATERIALS AND METHODS

A field study was conducted in split plot design with three replications during the *kharif* seasons of 2013 and 2014 at ICAR-Central Potato Research Station, Kufri (Fagu Unit), Shimla, which is located at 2700 m above mean sea level. Seed tubers (40-60 g) of potato cultivars Kufri Himalini and Kufri Girdhari collected from last season (Sept. harvest) were planted at three plant densities, viz., 80000 (D1), 100000 (D2) and 133333 (D3) plants/ha, representing the intra-row spacing of 25, 20 and 15 cm,
PLANT DENSITY AND INTRA-ROW SPACING IN POTATO

respectively. Row-to-row spacing was kept uniform at 50 cm. The recommended inter and intra row spacing for the hills are 50-60 × 20cm. In both the years of study, planting was done on 29 April in 3×3 m plots. The recommended doses of fertilizers for the region, i.e. 120 Kg N, 100 Kg each of P and K were applied for raising the crop. Full dose of P as single super phosphate, K as muriate of potash and 80% N as calcium ammonium nitrate (CAN) were applied at the time of planting. The remaining dose of N (20%) was applied as CAN at the time of earthing up after 50 days after planting (DAP). Standard package of practices was followed for raising a good seed potato crop. Data was collected on frequency of plant emergence (%) at 35 and 50 DAP, whereas, plant height (cm), number of shoots and compound leaves per plant was recorded at 75 DAP. Ground cover (%) was estimated at 60, 75, 90 and 105 DAP with the help of a 50×50 cm grid with 100 equal compartments at two locations in each plot as described by Burstall and Harris (1983). Haulms were cut after 120 DAP and fresh weight was recorded. At harvest, the produce was graded in to four grades, viz., under-size tubers (<20 g), seed-size tubers (20-80 g), large-size (80-150 g) and extra-large tubers (>150 g). Data were recorded on the number and weight (yield) of total and graded tubers. The data was statistically analyzed by following the standard procedures (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Plant emergence

The frequency of plant emergence (%) after 35 and 50 DAP was found to be similar between both the cultivars (Table 1). However, at 35 DAP, plant emergence showed a decreasing trend with the increasing plant density. With the advancement of time (at 50 days crop) the effect of planting density on plant emergence was over, and it was almost same in all the treatments.

Ground cover

At 60 DAP, ground cover was significantly affected by the plant density but was same between the two cultivars (Table 1, 2). With the increase in plant density, a gradual increase in the ground cover was recorded, which could be attributed to more number of plants per unit area.

A similar observation was also reported by Midmore (1988), Singh et al. (1997) and Zamil et al. (2010). At 75 and 90 DAP, ground cover reached to the maximum (99.9%) and was almost same and statistically non-significant among the treatments as well as between the two cultivars (data for ground cover at 75 DAP not provided). At 105 DAP, the ground cover followed a trend just opposite to the one noticed at 60 DAP, i.e. a gradual decline in the ground cover with increasing plant density. However, at this stage, the ground cover was found to be significantly higher in Kufri Girdhari (99.1%) than Kufri Himalini (94.5%).

Plant growth parameters

Plant height was significantly affected by plant density but not by the genotype (Table 3). Increasing plant density resulted in a gradual increase in plant height. Such a significant increase could be attributed to increased competition among the stems for light and space as already reported by earlier workers (Singh et al. 1993, Singh et al. 1997).

Number of stems and compound leaves per plant showed a gradual and significant decrease with the increasing

<table>
<thead>
<tr>
<th>Variety</th>
<th>Frequency of germination (%)</th>
<th>35 DAP</th>
<th>50 DAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>K. Himalini</td>
<td></td>
<td>D1 99.9</td>
<td>D2 97.2</td>
</tr>
<tr>
<td>K. Girdhari</td>
<td></td>
<td>D1 99.4</td>
<td>D2 99.0</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>99.7</td>
<td>98.1</td>
</tr>
</tbody>
</table>

CD(P=0.05)

Cultivar (A) NS
Spacing (B) 0.8 NS
Factor (B) at same level of A 1.6 1.2
Factor (A) at same level of B 1.6 1.0

<table>
<thead>
<tr>
<th>Variety</th>
<th>Ground cover (%)</th>
<th>60 DAP</th>
<th>90 DAP</th>
<th>105 DAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>K. Himalini</td>
<td></td>
<td>D1 75.6</td>
<td>D2 77.8</td>
<td>D3 81.0</td>
</tr>
<tr>
<td>K. Girdhari</td>
<td></td>
<td>D1 75.8</td>
<td>D2 77.4</td>
<td>D3 80.6</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>75.6</td>
<td>77.8</td>
<td>81.0</td>
</tr>
</tbody>
</table>

CD (P=0.05)

Cultivar (A) NS
Spacing (B) 1.1 NS
Factor (B) at same level of A NS
Factor (A) at same level of B NS

Table 1 Effect of varying intra-row spacings on % germination of potato

Table 2 Ground cover (%) in potato cultivars as affected by varying plant densities

0.7
1.1
1.7
1.4
Number of stems between the cultivars was found to be almost same but the compound leaves per plant were higher in Kufri Girdhari (35.1) than Kufri Himalini (28.2) (Table 3). Reduction in number of leaves and stems per plant with increasing plant population can be attributed to the availability of limited space for the proper development of plant (Lal et al. 1981, Khurana and Pandita 1982). Reduction in plant vigour (stems and leaves) may also be due to lack of space on account of increasing plant population and thus posing a barrier for plant development (Kushwah 1989, Singh et al. 1997).

At 120 DAP, increasing plant density resulted in a significant decrease in the weight of haulms/plant (Table 4). Significant reduction in weight of haulms with increase in plant population has also been reported by Zamil et al. (2010), and which could be attributed to the increasing competition between plants as space is the major limitation in the development of plant under increased plant densities. Between the cultivars, the haulms weight/plant was found to be higher in Kufri Girdhari (205.3 g/m²) than Kufri Himalini (132.8 g/m²). More weight of haulms in Kufri Girdhari could be attributed to the higher ground coverage in this cultivar for the longer period of time (up to 105 DAP and beyond).

Among the cultivars, total potato yield was more in Kufri Himalini than Kufri Girdhari. Higher tuber yields in Kufri Himalini than Kufri Girdhari have also been reported by the breeders of these cultivars (Joseph et al. 2007 and 2011) as well as by Sharma and Pandey (2015). Higher total tuber yield in Kufri Himalini than Kufri Girdhari can be attributed to the fact that the full yield potential of Kufri Girdhari might not have been exploited at the time of cutting the haulms at 120 days of crop age, as indicated by the higher green mass (haulms weight). Increasing the crop duration further, i.e. beyond 120 days in table crop may further increase the yields in Kufri Girdhari.

Proportion of different grades of tubers
Increasing plant density resulted in a gradual and significant reduction in the proportion of extra-large (>150 g) tubers, while increasing the proportion of seed size (20-80 g) tubers. The proportion of large (80-150 g) and under-size (<20 g) tubers was found to be unaffected by the varying plant densities. Between the two cultivars, the proportion

### Table 3 Plant growth parameters of potato as affected by the varying plant densities at 75 DAP

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plant height (cm) Mean</th>
<th>Number of shoots/ plant Mean</th>
<th>No. of leaves/ plant Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D1 D2 D3</td>
<td>D1 D2 D3</td>
<td>D1 D2 D3</td>
</tr>
<tr>
<td>K. Himalini</td>
<td>63.4 64.5 71.5 66.5</td>
<td>2.5 2.1 2.3 2.3</td>
<td>31.6 29.4 23.7 28.2</td>
</tr>
<tr>
<td>K. Girdhari</td>
<td>61.7 65.2 75.2 67.4</td>
<td>2.7 2.3 2.3 2.5</td>
<td>38.0 37.0 30.1 35.1</td>
</tr>
<tr>
<td>Mean</td>
<td>62.5 64.9 73.3</td>
<td>2.6 2.2 2.3</td>
<td>34.8 33.2 26.9</td>
</tr>
</tbody>
</table>

*CD (P=0.05)*

| Cultivar (A) | NS | NS | 0.5 |
| Spacing (B)  | 1.9 | 0.1 | 1.0 |
| Factor (B) at same level of A | 2.8 | NS | NS |
| Factor (A) at same level of B | 2.4 | NS | NS |

### Table 4 Production behaviour of potato as affected by varying intra-row spacing

<table>
<thead>
<tr>
<th>Variety</th>
<th>Haulms weight (g/m²) Mean</th>
<th>Total number of tubers (’,000/ha) Mean</th>
<th>Total yield (tonnes/ha) Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D1 D2 D3</td>
<td>D1 D2 D3</td>
<td>D1 D2 D3</td>
</tr>
<tr>
<td>K. Himalini</td>
<td>155.8 135.3 107.3 132.8</td>
<td>438 471 504 471</td>
<td>40.5 39.9 40.1 40.2</td>
</tr>
<tr>
<td>K. Girdhari</td>
<td>272.1 181.6 162.3 205.3</td>
<td>422 473 501 465</td>
<td>37.3 36.5 34.9 36.2</td>
</tr>
<tr>
<td>Mean</td>
<td>213.9 158.5 134.8</td>
<td>430 472 503</td>
<td>38.9 38.2 37.5</td>
</tr>
</tbody>
</table>

*CD (P=0.05)*

| Cultivar (A) | 4.5 | NS | 0.5 |
| Spacing (B)  | 1.7 | 0.6 | 0.2 |
| Factor (B) at same level of A | 3.8 | 11 | 0.5 |
| Factor (A) at same level of B | 4.7 | 11 | 0.5 |
PLANT DENSITY AND INTRA-ROW SPACING IN POTATO

February 2019

123

CD (P=0.05) >150g 80-150g 20-80g <20g Cultivar (A) 2.7 1.5 1.5 NS Spacing (B) 1.2 1.1 1.3 0.5 Factor (B) at same level of A NS 2.0 2.2 NS Factor (A) at same level of B NS 1.9 2.0 NS

Fig 2 Proportion of potato yield in different grades

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