Influence of Seed Size and Density on the Performance of Direct Seedling Transplants from Hybrid True Potato Seed

M.D. Upadhya and R. Cabello

The genotype by environment interactions affecting the quantity and quality of hybrid true potato seed (TPS) were evaluated. Sixteen cross combinations were tested to select parental lines and cross combinations for stability for berry and TPS characteristics across environments. CIP facilities in Peru, La Molina (coastal plains at 280 m) and Huancayo (highland valley at 3285 m), permit hybridization and TPS production in two environments within a year. In La Molina, the winter season’s short photoperiod was artificially extended to 16 hours to promote blooming. In Huancayo, the photoperiod during summer is adequate to promote profuse blooming. The effects of seed size and density strongly suggest a high correlation between seed size and yield. Therefore, in the selection of hybrid TPS combinations, parental lines that give a higher proportion of large (1.6 mm) seeds should be selected for field trials in the development of TPS for use in potato (Solanum tuberosum L.) production.

Studies conducted by CIP and collaborating national agricultural research systems on the economics of potato production from TPS have shown that crops raised from direct seedling transplants give the highest cash returns (Khatana et al., 1996). Therefore, CIP efforts have been directed toward the production of hybrid TPS families that will give high tuber yields when a crop is raised through directly transplanted seedlings. Studies have also shown considerable variability in the proportion of different fractions based on size and embryo structure in a sample of hybrid TPS produced under different agroclimates and production protocols (Upadhya et al., 1984). Furthermore, the proportion of different fractions is also affected by the genotypes and nutrition of the maternal parents (Upadhya et al., 1984, 1985; Thakur, 1987; Pallais and Espinola, 1992; Thakur and Upadhya, 1994).

Thakur (1987), Bhatt et al. (1988, 1989), and Thakur and Upadhya (1994) showed that TPS size affected germination, seedling vigor, and final yield of the seedling transplanted crop. Large seeds (1.6 mm) gave higher germination, produced more vigorous seedlings, and gave significantly higher tuber yield than small (<1.4 mm) seeds. Studies done at CIP also indicate that high density TPS gives higher germination and more vigorous seedlings (R. Falcon and N. Pallais, CIP, Lima, Peru, 1999, pers. comm.). Dayal et al. (1984) showed positive phenotypic and genotypic correlations of 1000 TPS weight with total tuber yield, harvest index, and other plant characteristics in their study on 76 hybrid TPS families grown as seedling transplants. However, field studies have not been conducted to establish higher yield potential of high-density compared to low-density seeds.
Therefore, we evaluated the performance of different fractions of hybrid TPS based on size and density with respect to seedling emergence nine days after sowing, plant vigor 45 days after transplanting, and the final yield of the crop. The data presented and discussed in this paper highlight the importance of TPS size and weight on the field performance of a hybrid TPS family.

**Materials and Methods**

The hybrid TPS of the cross Serrana x TS-5 produced at Huancayo in 1998 were stored in moisture-proof containers at 4.5% moisture at 30°C for one year for the release of dormancy. Germination was tested at 27°C following the procedure standardized at CIP (Pallais and Falcon, 1997). The germination of this lot was >95% in seven days. The lot was separated into three seed sizes of >1.6 mm, 1.6–1.4 mm, and 1.4–1.27 mm using sieves with round holes. Each size lot was then separated into high- and low-density classes using a continuous air system separator (CAS, Hoffman, Inc., Albany, NY, USA) at 40.23 CFM/m. These procedures allowed the TPS lot to be separated into six grades, three sizes of two densities each.

Seedlings were raised from the six grades and transplanted in the field following the procedure detailed by Upadhya and Cabello (1997). Data on emergence nine days after sowing were recorded. The trial was laid out in a randomized block design with four replications in La Molina during the winter season in 1999 (May to August). Data on plant vigor were taken 45 days after transplanting. The haulms were cut 90 days after transplanting and the tubers were harvested 15 days later. Data were recorded from each plot on total tuber yield and marketable yield (tubers >5 cm). Data analysis was done using the SAS (1989).

**Results and Discussion**

Analysis of the data showed that the interaction between seed size and density for the characters studied were non-significant (Table 1), hence the data were analyzed individually for seed size and density classes. The results of the analysis for the effect of seed density and seed size on the characters are presented in Tables 2a and 2b. Seed density seems to have some effect on emergence but does not affect plant vigor and total and marketable yields (Table 2a). Seed size, however, significantly affected emergence and total and marketable yields (Table 2b). Plant vigor does not seem to be affected by seed size or density at 45 days after transplanting. There is a highly significant correlation between seed size and emergence (r = 0.78, P <0.01) and between seed size and marketable yield (r = 0.44, P <0.01), but only a significant correlation between seed size and total yield (r = 0.50, P <0.05). No significant correlation was found between seed size and plant vigor (r = 0.38, P >0.05), or between seed size and plant uniformity (r = 0.22, P >0.05).

Simmonds (1963) reported higher germination percentages (85–90%) for large and medium seeds compared with small seeds (60–65%). Dayal et al. (1984) showed that the 1000 TPS weight in a hybrid TPS family was positively correlated with total yield. Later, Thakur and Upadhya (1994) reported a highly significant effect of seed size on seedling emergence and growth in nursery beds. Seedlings grown from large seeds had higher survival and total tuber yield. The higher yield was due to the production of more tubers and higher yield/plant. They also showed that seed size had a positive but non-significant relationship with average tuber weight and marketable yield. In the present study, however, there was a significant effect of seed size on marketable yield. This could be due to the fact that Thakur and Upadhya (1994) studied the effect of seed size in the open pollinated TPS of TPS-2, whereas the present study used the hybrid TPS family from Serrana x TS-5. This difference could be due to the effect of hybrid vigor.
The higher seedling emergence, growth, and yield potential associated with large seeds compared with small seeds could be attributed to their larger storage reserves and biochemical composition. Seed size and protein content have been shown to be related to seedling vigor in wheat and beans (Ries, 1971; Lowe and Ries, 1972; Lowe et al., 1972).

Upadhya et al. (1984) and Thakur (1987) reported higher contents of carbohydrates and soluble proteins in large rather than small hybrid TPS. Bhatt et al (1989) reported a positive correlation between 100 seed weight and contents of total proteins, total lipids, and phospholipids, as well as germination percentage and velocity. Based on these earlier reports and the present investigation, seed size is an important quality trait of TPS that could be used as a basis to assess the productivity of a hybrid TPS family. This criterion is being regularly used at CIP to evaluate hybrid TPS families by determining the proportion of large seeds (> 1.6 mm). Also, male and female parental lines are routinely evaluated for their potential to produce hybrid TPS with a higher proportion of large seeds. Parental lines showing high combining ability and stability for a high proportion of large seeds are preferentially selected for field trials through direct seedling transplants to assess their production potential.

**Conclusions**

The present study suggests a strong correlation between seed size and yield.

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**Table 1.** ANOVA for seed density and size on seedling emergency, plant vigor, total yield, and marketable yield as seedling transplant crop of Serrana x TS-5 hybrid TPS family at la Molina, 1999.

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>Emergence DAS 9 days</th>
<th>Plant vigor</th>
<th>Total yield (t/ha)</th>
<th>Marketable yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSD 0.05</td>
<td>Density(D) *</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Size(S) **</td>
<td>ns</td>
<td>ns</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>D x S ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>CV% 2.9</td>
<td>9.0</td>
<td>9.50</td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>

Notes: * = significant at 0.05; ** = significant at 0.01; ns = not significant.

**Table 2a.** Comparison of seed density on seedling emergence, plant vigour, total and marketable yield in Serrana x TS-5 hybrid TPS family as seedling transplant crop at la Molina, 1999.

<table>
<thead>
<tr>
<th>Density</th>
<th>Emergence at 9 days (%)</th>
<th>Vigor 45 DAT</th>
<th>Total yield t/ha</th>
<th>Marketable tubers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 91.5a</td>
<td>7.6a</td>
<td>17.61a</td>
<td>80a</td>
<td></td>
</tr>
<tr>
<td>D2 88.2b</td>
<td>7.5a</td>
<td>16.77a</td>
<td>79a</td>
<td></td>
</tr>
<tr>
<td>CV% 2.9</td>
<td>9.0</td>
<td>9.50</td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Duncan at P= 0.01. D1= High density; DAT= Days after transplant; D2= Low density; Vigor: 1= Poor, 9= Excellent.

**Table 2b.** Comparison of seed size on seedling emergence, plant vigour, total and marketable yield in Serrana x TS-5 hybrid TPS family as seedling transplant crop at la Molina, 1999.

<table>
<thead>
<tr>
<th>Seed size</th>
<th>Emergence at 9 days (%)</th>
<th>Vigor 45 DAT</th>
<th>Total yield t/ha</th>
<th>Marketable tubers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 94.4a</td>
<td>8.0a</td>
<td>19.2a</td>
<td>81.0a</td>
<td></td>
</tr>
<tr>
<td>S2 91.8a</td>
<td>7.4a</td>
<td>16.8b</td>
<td>79.3b</td>
<td></td>
</tr>
<tr>
<td>S3 84.3b</td>
<td>7.2a</td>
<td>16.0b</td>
<td>78.6b</td>
<td></td>
</tr>
<tr>
<td>CV% 2.9</td>
<td>9.0</td>
<td>9.50</td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Duncan at P = 0.01.

S1: > 1.6 mm; S2: 1.6-1.4 mm; S3: 1.4-1.27 mm.

DAT= Days after transplant; Vigor: 1= Poor, 9= Excellent.
Therefore, in the selection of hybrid TPS combinations, parental lines that give higher proportions of large seeds (1.6 mm) should be selected for field trials.

References


