Survey of Watermelon Trialing Methods Used by Breeders in the United States

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Introduction. We are in the process of developing efficient trialing methods for the breeding of watermelon (Citrullus lanatus (Thunb.) Matsum. & Nakai). Efficient methods will provide maximum information for the resources used (6). Research in cucumber (Cucumis sativus L.) has provided information on optimum plot size (1, 3), multiple- vs. single-row plots (9), plot-end border effects (7), testing methods (5, 8, 10), and proper allocation of plots into replications, locations, seasons and years (4). However, little research has been done in watermelon on efficient trialing methods. It is also useful to have estimates of genetic variances, heritabilities, and genetic correlations for the important quantitative traits when designing optimum trialing methods (2).

Plot sizes used for watermelon trials range from single-plant hills with a low density of plants/ha to multiple-row plots of 0.1 ha in size. Small plots or hills can be used to evaluate many accessions, families, breeding lines, experimental hybrids, and cultivars (hereafter referred to collectively as cultigens). On the other hand, large plots provide data typical of production fields, with monoculture conditions, standard plant density, and a representative sampling of field variability. The optimum plot size is calculated using information about field variability, resources required, and number of cultigens that can be evaluated.

The objective of this study was to survey watermelon breeders in the U.S. to determine the methods being used for yield trials in the public and private sector.

Methods. Survey questions were sent to breeders with significant responsibilities for watermelon breeding in land grant universities and seed companies in the U.S.

One set of questions inquired about the layout of plots for use in preliminary and advanced evaluations of cultigens. Information was requested on the number of cultigens tested, row spacing, plot length, plants per plot, number of harvests, and number of replications used. A second set of questions focused on the methods used to identify the fruit associated with each plot at harvest. Questions were asked whether or not fruit type, wide row spacing, single- or multiple-row plots, vine tracing, vine training, and physical barriers were used.

Answers were summarized for public and private breeders. Means and ranges were used to summarize the important data, including plot length, row width, number of rows per plot, number of plants per row, number of harvests per plot, number of replications per trial, and number of cultigens evaluated.

Results. Many watermelon breeders use a three-stage system of trialing to test cultigens being developed in their programs: preliminary, intermediate, and advanced (data not shown). Cultigens being evaluated are generally direct-seeded or transplanted into the field plots.

The mean number of cultigens tested per trial for the breeders surveyed was 27 for public and 21.1 for private breeders (Table 1), with a range of 6 to 60. An average of 1.3 rows per plot and a mean plot length of 9.5 were found, along with 9.6 plants per row for public breeders. Breeders in the private sector used an average of 1.3 rows per plot, mean plot lengths of 15.8 and 19.1 plants per row. The mean number of plants per row also resulted from a wide range of responses (6 to 50). This range should not be surprising as the common spacing between plants within the row was 0.6 to 1.2 m, with a mean of 1 m for each breeding sector. Row widths had a mean of 2.9 m for public and 2.6 m for private breeders. Mean number of harvests ranged between 3.4 and 1.1 per season for public and private breeders respectively. Public breeders used an average of 4.0 replications and private breeders used 1.8.
Table 1. Description of trial layouts for watermelon breeding programs in the U.S.\textsuperscript{x}

<table>
<thead>
<tr>
<th>Breeding program</th>
<th>Total no. of programs</th>
<th>Statistic</th>
<th>Plot length (m)</th>
<th>Row width (m)</th>
<th>Rows /plot (no.)</th>
<th>Plants /row (no.)</th>
<th>Crop harvests (no.)</th>
<th>Trial reps (no.)</th>
<th>Cultigens /trial (no.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td>4</td>
<td>Mean</td>
<td>9.5</td>
<td>2.9</td>
<td>1.3</td>
<td>9.6</td>
<td>3.4</td>
<td>4.0</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>6.1</td>
<td>2.7</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>12.2</td>
<td>3.1</td>
<td>2</td>
<td>12.5</td>
<td>4</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>Seed Co.</td>
<td>9</td>
<td>Mean</td>
<td>15.8</td>
<td>2.6</td>
<td>1.3</td>
<td>19.1</td>
<td>1.1</td>
<td>1.8</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>8.2</td>
<td>1.5</td>
<td>1</td>
<td>6.5</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>45.8</td>
<td>3.7</td>
<td>3</td>
<td>50</td>
<td>1.5</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Combined</td>
<td>13</td>
<td>Mean</td>
<td>12.8</td>
<td>2.7</td>
<td>1</td>
<td>14</td>
<td>2</td>
<td>3</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 2. Number of trials in watermelon breeding programs in the U.S. that use six different methods for separating the fruit in adjacent rows.\textsuperscript{x}

<table>
<thead>
<tr>
<th>Breeding program</th>
<th>No. of programs</th>
<th>Fruit type</th>
<th>Wide rows</th>
<th>Multiple rows</th>
<th>Trace vines</th>
<th>Train vines</th>
<th>Use barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Seed Co.</td>
<td>10</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Combined</td>
<td>14</td>
<td>9</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

\textsuperscript{x} Fruit type=cultigens with different fruit type are planted in adjacent rows; wide rows=wider rows are used for trials than are standard for growers; multiple rows=multiple rows per plot are used; trace vines=vines are traced from the fruit to its proper row; train vines=train vines for each row to keep from growing into adjacent row; use barrier=use barrier (for example, netting) to keep vines from each row in its assigned area.

Although plot spacings were not uniform over breeding programs, often breeders do not have total control over the management of their trials. Preliminary and intermediate trials are conducted on plots solely controlled by the breeder. However, advanced trials and some intermediate ones must be conducted off site using cooperating growers. Due to the high volume of plant material being evaluated for future release, breeders use the plant spacing of the cooperating growers.

From the data, smaller plots were commonly used with a limited number of cultigens being evaluated. This observation holds for each sector of plant breeders. Public and private breeders tended to use similar plot layouts. However, public breeders consistently used higher numbers of harvests and trial replications than their private counterparts. The use of smaller plots allows for more material to be tested on a smaller land area. One advantage of this method is the reduction of soil heterogeneity commonly found to affect the yields of large plots. Loss of information due to the use of small plots is compensated by the use of multiple locations and seasons (4). U.S. watermelon breeders commonly use close to ten locations and multiple seasons (data not shown).

One major problem of watermelon trials is to identify fruit belonging to adjacent rows. The majority of public breeders did this using a combination of wide row spacing and cultivars having different fruit type

assigned to adjacent plots (Table 2). About half of
the private breeders used the combination of different
fruit type, vine tracing and vine training (data not
shown). Different fruit types in adjacent plots in the
same row offered an additional advantage when vine
overlap occurred in the alleys of multiple-row plots.
The other methods were used at about the same
frequency in the two sectors.

Use of a physical barrier was the least applied
method of controlling vine growth or reducing fruit
mix-up at harvest for public and private breeders. Survey responses for the use of vine tracing indicated
its necessity especially when there was preference for
allowing vines in a trial to grow undisturbed. Some
breeders noted that vine growth and fruit set were
altered when vines were trained or otherwise
disturbed before harvest. Breeders also noted
occasional problems with vine overlap within alleys
at the ends of plots. However, responses indicated
that vine overlap in general was a less significant
problem in the western part of the U.S.

Conclusions. From this survey, we found the use of
small plot sizes consisting of one to three rows per
plot, few replications with multiple locations, low
numbers of plants per plot, and one to two harvests to
be commonly used in trials of U.S. private
watermelon breeders. U.S. public watermelon
breeders were found to use small plot sizes with one
to two rows per plot, more replications, multiple
locations, lower numbers of plants per plot then
private breeders and multiple harvests. Although the
use of small plots allows for more efficient use of
space and labor resources, there is increased risk of
border effect producing biased plot yields. To date,
no research has been done regarding the need for
border rows in plots of watermelon. Vine training
methods found in this survey serve to reduce error
while at the same time reduce border effect without
adjusting row number. Adjusting the numbers or
rows to create an artificial border could prove costly
in terms of monetary costs, numbers of lines
evaluated, and labor. The information found here
will be used in future studies to make trialing
procedures more efficient at maximizing the
information gained while minimizing the use of
resources.

Literature Cited

techniques for selecting increased once-over
harvest yields in pickling cucumbers. J. Amer.
Hort. Sci. 103: 92-94.

Estimates of heritabilities and genetic variances
of three yield and five quality traits in three
fresh-market cucumber populations. J. Amer.

Optimum plot size determination and its
application to cucumber yield trials. Euphytica
35: 421-432.

Optimum allocation of plots to years, seasons,
locations, and replications, and its application to
once-over-harvest cucumber trials. Euphytica
43: 59-68.

5. Wehner, T. C. 1986. Efficiency of 3 single-
harvest trials for evaluation of yield in pickling

testing vegetable cultivars. HortScience 22:
1220-1223.

condition on small-plot yield of cucumber.
Euphytica 38: 113-119.

Efficiency of single-harvest methods for
measurement of yield in fresh-market cucumbers.

cucumbers in multiple-harvest trials with
dissimilar genotypes in border rows.

10. Wehner, T. C., T. J. Monaco, and A. R. Bonanno.
1984. Chemical defoliation of cucumber vines
for simulation of once-over harvest in small-plot