

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.^Z

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

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.^Z

Breeding program	No. of programs	Fruit type	Wide rows	Multiple rows	Trace vines	Train vines	Use barriers
University	4	3	3	2	2	1	0
Seed Co.	10	6	3	3	5	5	1
Combined	14	9	6	5	7	6	1

^Z 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 than 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.

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