

# Breeding for Yield in Watermelon - A Review

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The United States the fourth largest producer of watermelon in the world after China, Turkey, and Iran (5). Yields are highest in China and United States and somewhat lower in the other major producing countries. Watermelon is a major vegetable crop in the U.S. The total area has changed from 76 thousand hectare in 1998 to 65 thousand hectares in 2007 (19). However, production has increased from 1.7 million Mg in 1998 to 1.9 million Mg in 2007 (14). At present, the total value of watermelon production in the United States is \$476 million. Over 80% of the watermelon production is concentrated in Arizona, Florida, Georgia, Texas, California, and North Carolina, where the temperatures are warmer and the growing season is longer than states located in northern latitudes (10).

Planned improvement in watermelon was started in the late 19<sup>th</sup> century in both the public and private sectors (13). In 1954, C.F. Andrus released 'Charleston Gray' with elongate fruit, gray rind, and red flesh. In 1970, C.V. Hall developed 'Allsweet' with similar resistance to 'Charleston Gray', but higher in quality. 'Allsweet' had elongate fruit shape and rind with wide, dark green stripes. J. M. Crall released 'Dixielee', an alternative to 'Allsweet' for its different fruit type and superior quality, and 'Minilee' and 'Mickylee', the first ice-box (< 5.5 kg/fruit) cultivars adapted to southeastern U.S. Cultivars that dominated the market in the mid 20<sup>th</sup> century were open-pollinated ones such as Charleston Gray, Jubilee, Crimson Sweet, and Sugar Baby. By the end of 20<sup>th</sup> century, hybrids had replaced open-pollinated cultivars for the commercial market. 'Sangria' was the first hybrid developed by T.V. Williams of Rogers NK (now Syngenta) in 1985. The most important change in the watermelon industry is the production of seedless cultivars. O.J. Eigsti released the first seedless watermelon, 'Tri-X-313', in 1962. However, seedless watermelon did not become commercially important until the 1990s due to poor fertility of tetraploid parents used in triploid hybrid seed production. In the U.S., three quarters of the total production is seedless (20), and 'Tri-X-313' is still popular. A recent advance in watermelon breeding was the introduction of mini watermelons that are seedless in the early 21<sup>st</sup> century. Xingping Zhang developed the first cultivars, sold under the PureHeart™ brand in the U.S. and Solinda™ brand in Europe (13). These watermelons became popular because of their good flavor, crisp texture, and small size.

The yield goal for growers is to harvest at least one load per hectare (51 Mg/ha). Hybrids became popular in 1950s and 1960s. Heterosis is not a big factor in yield for cucurbit crops. Thus, increases in yield cannot be attributed to hybrids over open-pollinated cultivars. Nevertheless, researchers have recorded heterosis in very specific crosses. Some studies reported 10% advantage of the hybrid over the high parent (4, 2). Misra et al. (14) observed that the parents having high per se performance did not always produce hybrids with high hybrid vigor. Gusmini and Wehner (8) reported 22% more fruit yield in F<sub>1</sub> than the best parent. Heterosis up to 47.55 % on per plant fruit yield was reported by in Sel-B x Shipper by Bansal et al. (1). However, they also recorded negative heterosis for fruit yield in some of the crosses. Souza et al. (17) recorded 26 to 41 % mid-parent heterosis for fruit weight in triploid watermelon hybrids. Heterosis might have contributed to yield increase in specific cultivars. In general, the small amount of heterosis for yield in watermelon makes it unnecessary to develop hybrid cultivars, since inbred lines would have similar performance (21). However, hybrids are popular in the seed industry because they provide both protection of the parental lines for intellectual property rights as well as novel traits, such as seedless triploid cultivars. Currently, growers have cultivars of both types available, diploid (seeded) and triploid (seedless) hybrids. Those include the popular diploid hybrids 'Sangria', 'Royal Sweet', 'Fiesta', 'Mardi Gras', and 'Regency' and the popular triploid hybrids 'Tri-X-313', 'Summer Sweet 5244', 'Millionaire', 'Genesis', and 'Tri-X-Shadow' (18).

Numerous yield trials are run each year in the U.S. to evaluate new watermelon hybrids for use as cultivars, but often there are few differences among the entries (7). The question arises as to whether that is due to a lack of genetic diversity for yield in watermelon, or just among the elite, new experimental entries. In the U.S., genetic diversity among watermelon cultivars is narrow because most of them have been derived from just a few original germplasm sources, which includes 'Allsweet'. Gusmini and Wehner (7) tested a diverse set of obsolete inbred cultivars that do not trace to 'Allsweet' type and found that cultivars differed in yield from 36.6 Mg.ha<sup>-1</sup> in Calsweet to 114.2 Mg.ha<sup>-1</sup> in Mountain Hoosier. This indicates that genetic variation for yield does exist in the germplasm pool made up of diploid inbred cultivars. Since sources of high yield have been identified, it

is important to develop populations using the high yielding cultivars and then use those populations to produce even higher yield.

Currently consumers prefer to have a choice of watermelon fruits from a variety of sizes. Fruit size is a component of yield in cultivated watermelon that is reported as fruit weight, ranging from 1 to 100 kg. Fruit sizes in watermelon are classified as icebox (<5.5 kg), small or pee-wee (5.5-8 kg), medium (8.1-11 kg), large (11.1-14.5 kg), and giant (>14.5 kg) (12). Significant additive, dominant, and epistatic effects have been reported for fruit size, where dominance and dominance-by-dominance effect was largest (16). Brar and Nandpuri (3) found considerable heterosis for fruit size due to partial dominance and overdominance. Gusmini and Wehner (9) recorded low to intermediate estimates of broad- and narrow-sense heritability for fruit size (0.41 and 0.59, respectively).

Yield is a complex quantitative trait, and such traits are typically controlled by many genes, each often having a small effect. In order to improve such traits, it is important to get estimates of heritability, number of genes and gene action. There are several published estimates of broad-sense heritability for yield in watermelon, which are easy to calculate (6, 15). However, in order to develop new inbred lines from segregating populations, it is important to estimate narrow-sense heritability in those populations. Kumar (11) estimated 4-12% estimates of narrow-sense heritability in two watermelon populations indicating complex genetic control of yield. Yield being low heritability trait, selection using single-plant hills would not be effective. A breeding scheme allowing maximum recombination would be useful, and recurrent selection for high yield should be effective.

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