RESEARCH PROPOSAL
NATIONAL WATERMELON ASSOCIATION

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Title:
Location and Variety Affects on Yield and Hollow Heart in Watermelon (Search for High and Stable Fruit Yield and Quality) - Year 2

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Executive Summary:

Watermelon is an important crop to growers in the southern U.S. Growers see value in traits such as yield, earliness, hollow heart resistance, and percentage marketable fruit because that is how payment is calculated. We have been studying these traits extensively over the last few years, and have made significant progress in learning how to improve them with selection. The next step needed is to learn how to keep yield and quality high over diverse environments. That trait is referred to as stability. We propose to study the stability of fruit yield and quality by using high and low performing varieties in locations ranging from North Carolina and South Carolina in the east to Georgia, Florida and Texas in the south to California in the west. The study will be difficult, requiring the cooperation of scientists from many institutions. When the study is completed, we will be able to describe which varieties to use for breeding both high performance and high stability for fruit yield and quality, and which locations to use for developing those varieties. In the first year of the study, we observed differences in the stability of fruit yield and quality over the 7 locations. The varieties having the highest yield were Starbrite, AU-Jubilant and Stone Mountain. However, those with the highest yield stability were Sugar Baby, Fiesta, Minilee and Quetzali. We need to run the study in 2010 and 2011 to measure the effect of years, and to determine the consistency of the location effects.

Situation:
Watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) is a major vegetable crop in the U.S., with production increasing from 1.2 million tons in 1980 to 2.1 million tons in 1995 (Picha and Motsenbocker, 1997). Production increased from 2.64 billion lbs in 1980 to 6.16 billion lbs in 2007 (USDA, 2009). In the last century, new varieties have been developed with high fruit quality, excellent shipping characteristics, and disease resistance. Uniform hybrids, seedless triploids, high sugar content, dark red flesh, 20 lb picnic watermelons, and 7 lb mini watermelons are innovations that have met with success. However, yield has remained about the same over the years in the

varieties that have been developed. Gains in yield (tons/acre) have resulted primarily from improvements in pest management, fertilization, and irrigation.

Watermelon breeders test for yield and quality during the development of new varieties, but it is difficult to make significant progress for yield and quality. Proper evaluation requires replicated plots with multiple hills per plot, and there are many traits besides yield that are important to select for during variety development. Most watermelon breeders in the U.S. run field trials using 1-row or 3-row plots 30 to 50 ft long with 10 to 20 plants per plot harvested 1 to 3 times (Neppl and Wehner, 2001).

In previous studies to optimize the measurement of yield and quality in field trials, a 6-plant plot 12 ft long was more efficient than a single-plant hill 8 ft long, or a 12-plant plot 24 ft long (Neppl, 2001). In addition, 3-row plots were not necessary to reduce competition from different varieties in bordering rows (Neppl et al, 2003). Also, in a series of diverse varieties tested in three North Carolina environments, there were large and significant differences in yield (Gusmini and Wehner, 2005).

Now that efficient testing methods have been developed, high yielding lines have been identified, and the heritability of yield has been estimated, the next step is to evaluate the stability of yield and quality over environments. Stability is a way of looking at the importance of genotype x environment interaction for yield and quality in watermelon. We are asking the question of whether varieties perform the same over different environments, and which environments give us the best measure of yield and quality when testing varieties.

Yield of watermelon depends on the number of fruit per plant, fruit size (the weight per fruit), and fruit marketability. Inheritance of fruit size has been reported as a polygenic trait (approximately 25 genes involved) (Poole and Grimball, 1945). Fruit shape is a qualitative trait, with a single, incompletely dominant gene involved, resulting in fruit that are elongate (*OO*), oval (*Oo*), or round (*oo*) (Poole and Grimball, 1945; Porter, 1937; Weetman, 1937). Fruit marketability depends on traits like fruit surface, skin color and durability, flesh color and rind pattern. A single gene controls furrowed fruit surface (*f*), which is recessive to smooth (*F*) (Poole, 1944) and explosive rind (*e*), that causes the fruit rind to burst or split when cut (Porter, 1937). Guner and Wehner (2004) reported thirteen genes that affect the color of the fruit skin or flesh. A single gene determines the intensity of green color of the fruit skin, with solid light green (g) skin color recessive to solid dark green (Weetman, 1937). Weetman (1937) also reported the greenish white mottling of the fruit skin is controlled by the single recessive gene (*m*), resulting in gray types, such as 'Iowa Belle' and 'Charleston Gray'. Golden yellow mature fruit rind color is inherited by a single recessive gene *go* (Barham, 1956).

Watermelon flesh color is inherited by several genes that produces an array of flesh colors including red, orange, salmon yellow, canary yellow and white. Genes responsible for flesh color are *B* (yellow) (Shimotsuma, 1963), *C* (canary yellow) (Poole, 1944), *y* (salmon yellow) (Porter, 1937) and y^o (orange) (Henderson, 1989 and Henderson et al., 1998).

The Problem:
The usefulness of high performance varieties of watermelon in a breeding program depends upon the stability of their performance for fruit yield and quality across diverse environments. The development of varieties that are stable in their performance in a wide range of environments is a major goal of breeding programs. The environment directly influences gene expression. Therefore, variety performance depends on the environment (Kang, 1998).

A variety is considered to be more stable if it has little change in yield and quality from one environment to another (Arshad et al., 2003). The measure yield and quality of each variety in each test environment is the result of an environment main effect (E), a genotype main effect (G), and the genotype x environment (GxE) interaction (Yan and Kang, 2003). Inconsistent responses of variety to environment factors such as temperature, soil moisture, soil type, or fertility level from location to location and year to year are a function of GxE interactions (Rao et al., 2002). The term GxE interaction commonly refers to failure of genotype to achieve the same relative performance in different environments (Baker, 1988). This approach leads to higher heritability of traits because of increased efficiency of predictable gains of traits under selection, which ensures rapid progress in breeding programs (Egesi et al., 2007). Thus, identification of traits that contribute to fruit yield and quality, and a knowledge of GxE interactions and stability are important for breeding new varieties with improved adaptation to environment (Rao et al., 2002).

Objectives:
The objective of this research is to: 1) measure the stability for yield and quality in a diverse array of varieties that differ for yield, fruit size, adaptation and resistance; 2) identify varieties having high stability for fruit yield and quality for use in breeding; and 3) identify locations that are representative and effective for the testing of fruit yield and quality.

Methods:
Forty watermelon varieties will be used: 20 high- and 20 low-yielding, based on previous testing. The varieties represent a diverse set of materials, and include new vs old releases, small vs large fruit, round vs elongate shape, striped vs solid rind, resistant vs susceptible to disease, eastern and western adapted, and inbred vs hybrid type. All the 40 watermelon varieties will be grown in 3 years (2009, 2010, 2011) and 7 locations (Kinston NC, Clinton NC, Charleston SC, Cordele GA, Quincy FL, College Station TX, and Woodland CA). A randomized complete block design will be used with 4 replications in each year and at each location. Field trials will be run in rows 7 to 10 ft apart using 6-plant plots that are 12 ft long. Plants will be transplanted onto raised beds covered with black plastic mulch, and watered with drip irrigation. Each variety will be harvested 2-5 times.

The varieties to be used are as follows:
01 Mountain Hoosier
02 Hopi Red Flesh
03 Early Arizona
04 Starbrite F_1
05 Stone Mountain
06 Stars-N-Stripes F_1
07 AU-Jubilant
08 Calhoun Gray
09 Big Crimson
10 Legacy F_1
11 Yellow Crimson
12 Charleston Gray
13 Tom Watson
14 King & Queen
15 Desert King
16 Jubilee
17 Sangria F_1
18 Navajo Sweet
19 Tri-X-313
20 Millionaire
21 Mickylee
22 Crimson Sweet
23 Allsweet
24 Black Diamond
25 Carolina Cross #183
26 Georgia Rattlesnake
27 Sugarlee
28 Graybelle
29 Congo
30 Early Canada
31 Quetzali
32 NC Giant
33 Fiesta F1
34 Peacock WR-60
35 Sweet Princess
36 Golden Midget
37 Sugar Baby
38 Tendersweet OF
39 Minilee
40 Calsweet

The following traits will be measured on all plots at each location and each year: marketable fruit yield (lbs/A), marketable fruit number (thousand/A), marketable fruit size (lbs/fruit), % marketable fruit, early yield (% of yield in harvest 1), sugar content (°brix), and hollow heart severity (standard rating). A method of regression analysis was developed by Finlay and Wilkinson (1963), and Eberhart and Russell (1966) for determining the stability of individual varieties. Analysis of variance will be conducted using SAS (SAS Institute, 1996) to determine the effect of environment (E), year (Y), location (L), Genotype (G), GxL, GxY, GxLxY on watermelon fruit yield and quality.

Correlation coefficients between pairs of environments will be computed using SAS (SAS Institute, 1996) to determine the value of each environment for testing watermelon varieties for fruit yield and quality. Environments will be grouped using cluster analysis. The most efficient environments from each cluster will be identified for future testing of varieties.

Industry Value:
The most stable variety across all locations will be identified based on having high fruit yield and quality, a regression coefficient close to 1.0, and deviation from regression close to 0 (Eberhart and Russell, 1966). High performing varieties that are stable over environments will be made available to industry, and locations that are representative and effective for yield testing will be identified.

Duration:
This is the end of the first year of a three year study. Research would be conducted from February 2009 through October 2011. View of the plots in North Carolina in 2009:

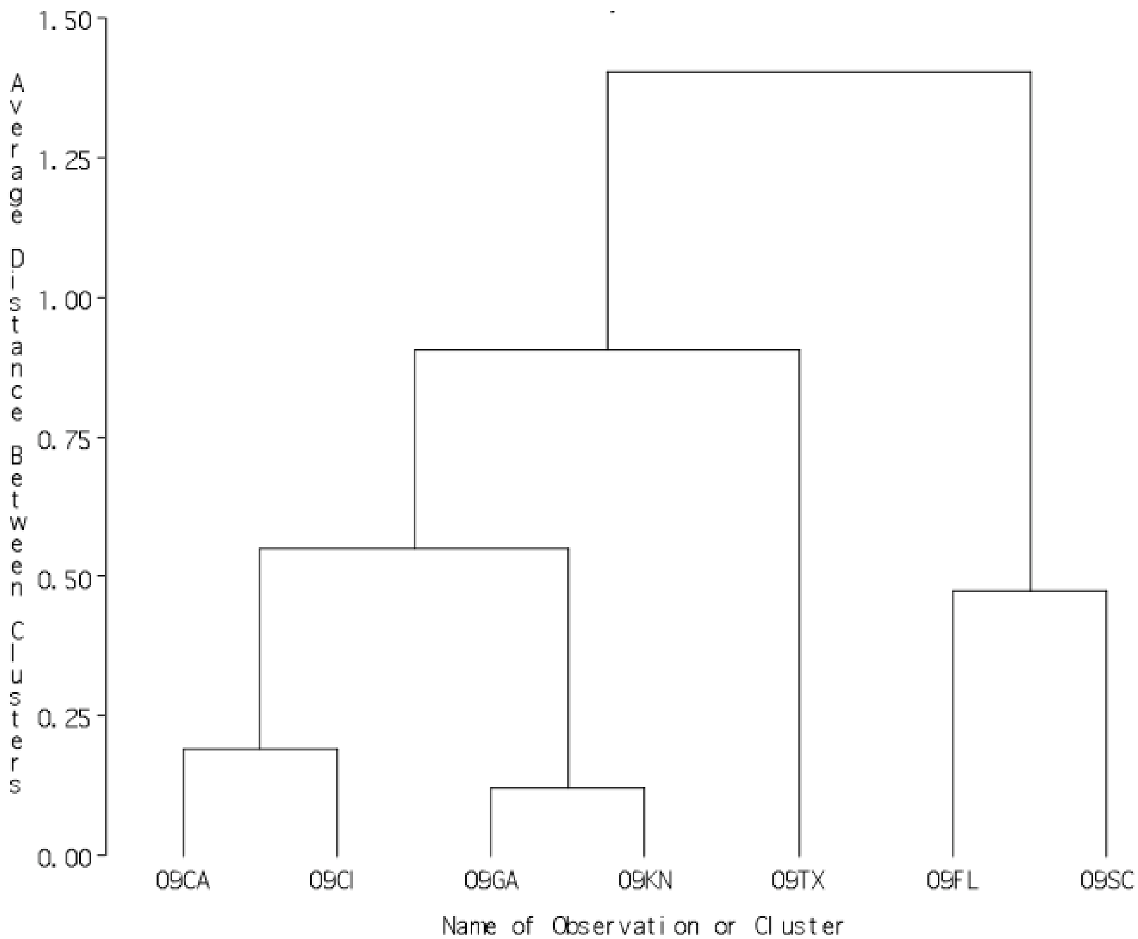
Results:
This is a progress report for the first year of a three-year study. Therefore, we do not have any information on the effect of different years on watermelon fruit yield and quality. However, we have two major conclusions: 1)

varieties differ in yield and quality, and 2) locations differ in their value for testing the varieties. For each variety, we measured performance, response, and stability. Performance is the average over locations for the one year. Response is the improvement in performance as the environment gets better. Stability is the amount of predictability over changing environments. Some specific findings (based on one year only) are given below.

Performance (over locations in one year): The varieties having the highest yield were Starbrite, AU-Jubilant and Stone Mountain. Those with the earliest maturity were Golden Midget, Carolina Cross and Stone Mountain. Those with the most hollow heart were Early Canada, Tendersweet Orange Flesh and Mountain Hoosier. Those with resistance to hollow heart were King & Queen, Calsweet, Peacock WR-60 and Mickylee. Those with the highest sugars were Stars-N-Stripes, Sugarlee and Regency.

Stability (over locations in one year): The varieties having the highest yield stability were Sugar Baby, Fiesta, Minilee and Quetzali. Those with the highest stability for earliness were Hopi Red Flesh, Allsweet and Early Arizona. Those with stability for resistance to hollow heart were King & Queen, Peacock WR-60, Mickylee and Calsweet. Those with stability for high sugars were Mountain Hoosier, Allsweet and Early Canada.

The **locations** that produced the highest yield over all the varieties were Florida and South Carolina. California and Texas had the lowest yield. Locations that gave similar results could be combined for efficiency to use only 4 instead of 7 locations as follows: California (instead of Clinton NC), Kinston NC (instead of Georgia), Texas, and Florida (instead of South Carolina). See the cluster diagram below:



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