Abstract

NEPPL, GRANT P. Efficient trialing methods for watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai). (Under the direction of Dr. Todd C. Wehner)

Researchers interested in evaluating watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) cultivars for yield use multiple-row plots to simulate the monoculture system growers use, or single-row plots to save on land, labor, and seeds. We were interested in whether there is a significant interaction of border with center row when diverse cultivars are planted in adjacent rows. Charleston Gray, Crimson Sweet, and Sugar Baby were chosen to represent long, medium, and short vined cultivars, respectively. Cultivars were planted in three-row plots with all nine combinations of the three represented in border and center rows. Each cultivar combination of center row and border rows represented one treatment. The experiment was a randomized complete block with nine plot treatments, two locations (Kinston, Clinton), and three replications. Vine length was measured during the season, and fruit were graded (marketable and cull), counted and weighed at four harvests. Results showed that Charleston Gray had the longest vines, followed by Crimson Sweet and Sugar Baby. In the analysis of variance, the largest effects (F ratio size) on yield were from cultivar, location, and the interaction of the two. The smallest effects were due to the interaction of center with border row, although center by border interactions were significant (5% level) in some cases. Therefore, researchers interested in running trials with many cultivars and small seed quantities can obtain good data using single-row plots. However, there is a small (but significant) interaction of center with border in some cases, so testing at the final stage should be with trials having multiple-row plots or grouping cultivars by vine length. Cultivars having extreme plant types (dwarf vines for example) should be tested in separate trials.

One of the most expensive stages of breeding is field testing. This encourages breeders and researchers to make efficient use of limited land, labor and seed in order to maximize information obtained while minimizing the costs of trialing. We were interested in whether smaller single-row plots could be used that would effectively be able to achieve and predict yields obtained from plots with larger dimensions when diverse cultivars were evaluated. The 13 cultivars Allsweet, Fiesta, Regency, Starbrite, Sultan, Florida Favorite, Charleston Gray, Hopi Red Flesh, Crimson Sweet, Jubilee, Navajo Sweet, New Hampshire Midget, and Sugar Baby were used to represent a wide range in yield. Cultivars were planted in single-row plots of three different plot lengths (7.3 m, 3.7 m, and 2.4 m) with all cultivars represented in each plot size. Each combination of cultivar and plot size represented one treatment. The experiment was a randomized complete block with 39 plot treatments, two locations (Kinston and Clinton) and three replications. Fruit were graded (marketable and cull), counted and weighed at five harvests. Analysis of variance indicated the largest effects (F ratio size) on plot yields were from location, plot size and cultivar. The smallest effects were due to the interactions of location with plot size, and cultivar by location by plot size. A location by cultivar interaction was also present, but F ratios were small indicating a small effect. Yields from 7.3 m and 3.7 m plots were consistently no different from each other. Regression analysis of 2.4 m and 3.7 m plots in prediction of 7.3 m plot yields showed 3.7 m plots to have higher R^2 (0.90), lower mean square error, lower standard deviations and a lower coefficient of variation than was found for 2.4 m plots. Therefore, researchers interested in maximizing information obtained while minimizing costs in trials with many cultivars can obtain data representative of large 7.3 m plots using 3.7 m plots. However, alleys separating 7.3 m and 3.7 m plots required a yield correction to compensate for the extra growing space allotted to these plots.

Efficient Trialing Methods for Watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai)

by

Grant Neppl

A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of

Master of Science

Horticultural Science

Raleigh

2001

Approved by:

Todd C. Wehner, Ph.D. Chairperson, Advisory Committee	Trudy MacKay, Ph.D.
Jonathan R. Schultheis, Ph.D.	William H. Swallow, Ph.D.

Dedication

This thesis signifies the culmination of two life enriching years of work toward further understanding plant breeding. There were many difficult forks in the road during which I questioned how much I really knew. Sensing my frustration, those dear to me never gave up on my efforts. It is through the many supportive voices around me that I found the strength to look at frustrations from a different approach and continue on. I would therefore like the dedicate this thesis to all those who held their breath during the tough times and cheered me on during the good times. Namely, I would like to dedicate this to my parents, my family, loved ones and friends. Thank you for believing in me.

Biography

Grant P, Neppl was born on June 21, 1976 to Roger and Jennifer Neppl in Denver, CO. He has one sister, Heather, who is married to Tom Smith and has two children, Bailey and Chloe. Grant spent most of his childhood in Evergreen, CO with a brief move to Newnan, GA during his junior year of high school. He attended Clear Creek High School in Idaho Springs, CO from 1991-1993, Newnan High School from 1993-1994 and Clear Creek High School from 1994-1995. Grant graduated as a Varsity athlete in track and cross country, and as salutatorian of his class.

Fall of 1995 he enrolled in Colorado State University to obtain a Bachelor of Science degree in Crop Science. While attending Colorado State, Grant held the office of treasurer and chair of the chili bean fundraising committee for the Agronomy Club. He received numerous scholarships including the Helen M. Faris Agronomy Scholarship from 1995-1998, the Wayne and Joyce Keim Scholarship for 1998-1999, and the D. W. Scotty Roberston Award in 1999. Grant spent two consecutive summer internships (1997, 1998) with Seedex Inc., a sugarbeet seed breeding company located in Longmont, CO. Under the direction of Shaoke Wang, he gained experience in the process of seed breeding and some of the genetics behind it.

With directional leadership from his father, Grant started his own carpet cleaning business for rental cars in 1996. In May of 1999 Grant graduated from Colorado State University with a B.S. degree in Crop Science with honors.

Upon his acceptance into North Carolina State University's Master's degree program, he sold his carpet cleaning business to his brother in law. His pursuit was to obtain a Master's degree in Horticultural Plant Breeding. Grant studied under Dr. Todd Wehner working on watermelon. His research involved determining the need for border rows in research plots as well as the most efficient plot size for maximizing information obtained from yield trials. Under a research assistantship, Grant gained further plant breeding experience working at the cucurbit research greenhouses. There, he performed cross pollination and seed increases for both watermelon and cucumber. While at NC State, Grant was initiated into the honor society of Pi Alpha Xi. As a member, he volunteered at the society's spring and fall fundraising plant sales. He later became a member of the SR-ASHS (Southern Region American Society for Horticultural Science). Grant was also the 2000-2001 recipient of the Foil McLaughlin Fellowship Award.

Grant would eventually like to perform scientific research in the area of plant breeding as a junior breeder or a research technician. A few of his hobbies are running, camping, trekking, archery, leather working, medieval reenacting and gardening. He hopes to be able to return to the mountains of Colorado some day.

Acknowledgments

I would like to thank Dr. Todd C. Wehner for his guidance, computer advice, and mentoring. Sincerest thanks are given to my committee members for their guidance and encouragement. In addition, I would also like to thank Sandy Donaghy for her SAS expertise in solving many stumbling blocks in analyzing my data. Thanks to Mr. Jimmy Prince and the entire Clinton field station for their hard work and cooperation. Thanks as well to Mr. Randy Herring and the entire Kinston field station crew for their expert field care, cooperation and hard work. I would especially like to thank the members of the cucurbit research group: Tammy L. Ellington, Julia Jenkins, Nihat Guner, Ronghao Song, Jiahua Xie, and Louis Jackson for their assistance in the field and greenhouse and for their friendship.

I would also like to thank my fellow graduate students and many friends within the department and university for their words of encouragement and kindness. Special thanks to professors and teachers for you challenged me to become a better teacher, scientist, student and a person. Rachel Rosenblum also deserves a deep hearted thank you. You kept me sane and helped me to relax once in a while. Finally, I would like to thank my parents Roger and Jennifer Neppl and Heather, Tom, Bailey and Chloe Smith for their patience, support and love.

Table of Contents

List of Tables

General Introduction

Plot layout, in terms of cultivar placement and plot size, are crucial considerations in the stages of plant breeding. Resources available to the plant breeder are limited. Field trials are conducted to obtain the maximum amount of information while minimizing both costs and trialing errors. There are usually limited quantities of seeds of each experimental line, accession or cultivar. Although larger plots provide more information through larger sample sizes, limited seed encourages the use of small plots. Despite the ability to evaluate greater numbers of breeding lines, smaller plots are affected more so by competition effects and consequent yield bias from different cultivars in adjacent plots than large plots.

As early as 1917, border competition was being documented along with ways of avoiding it (Arny, 1922). Christidis (1931) later summarized border competition. He noted that competition between plants exists in some cases; the effects (when present) were limited to one row on either side of a plot, and competition effects were negligible when cultivars similar in growth habit and morphology were grown in adjacent plots.

The use of border rows is recommended for crops such as sugarbeet (*Beta vulgaris*) (Deming and Brewbaker, 1934), rice (*Oryza sativa*) (Zimmermann, 1980), field bean (*Vicia faba*) (Costa and Zimmermann, 1998; Kempton and Lockwood, 1984), soybean (*Glycine max*) (Evans and Lewin, 1986; Gedge et al., 1977; Monzan et al., 1972; Probst, 1943), red clover (*Trifolium pratense*), alfalfa (*Medicago sativa*) (Hollowell and Heusinkveld, 1933), and the small grains; oat (*Avena sativa*), barley (*Hordeum vulgare*), and winter and spring wheat (*Triticum aestivum*) (Hulbert and Remsberg, 1927; Down, 1942). Studies of border competition in wheat and barley have shown mixed results on whether border row use is warranted due to the existence of border effects and the lack of the effect being significant in altering plot yields in some cases (Kramer et al., 1982; Romani et al., 1993; Stringfield, 1927). Maize (*Zea mays*) studies have also noted a lack of significance in border row effects (Bowman, 1989; Silva et al., 1991). Upward and downward biasing of yield due to competition has been noted in field bean (Kempton and Lockwood, 1984); potato (*Solanum tuberosum*) (Thornton, 1987); triticale (*Triticosecale 'Lasko'*) (Kempton et al., 1986); and wheat (Austin and Blackwell, 1980; Clarke et al., 1998; Fasoula, 1990; May and Morrison, 1986). The biasing effect on yield due to different competing abilities of adjacent cultivars can be associated with plant architecture. In wheat, yields are reduced 0.34% for every centimeter increase in height of adjacent plots (Clarke et al., 1998).

Plot size is another method of maximizing information obtained from breeding trials through minimizing variance between treatments. Increasing plot sizes will tend to reduce variability in a decreasing manner since larger plots will have a greater chance of spanning different soil environments (Zhang et al., 1994). However, since a significant component of variability comes from levels of soil heterogeneity, long plots are recommended more so than square ones to account for soil variation (Christidis, 1931; Smith, 1938). Long plots have a better random chance of being unaffected by patches of different soil fertility than square plots while they can also be oriented parallel to gradual fertility changes easier than square plots.

At the other extreme when considering plot size, single-plant plots can be used. Small plots are efficient for some crops and traits, and can provide good data while permitting maximum replication (including years, planting dates, and locations) without using excessive amounts of seed (Wehner, 1987). This is especially true in the early stages of breeding or with quantitative traits with low h^2 (<25%) such as yield. Longer plots should be used in advanced trialing stages when more accurate information is needed.

Research on other crops has demonstrated the value of small, single-row plots of about 1.5 m, up to multiple-row plots with as many as six rows. Although few researchers recommend single-plant plots for evaluating yield, small (1.5 m long) plots are recommended for early generation testing of pickling cucumbers (Swallow and Wehner, 1986; Wehner, 1986; Wehner, 1988; Wehner and Swallow, 1984). Large pickling cucumber plots are recommended for advanced trials (Wehner, 1986) to provide good data and sufficient fruit for evaluation (Smith and Lower, 1978), with an optimum around 6 m long for multiple harvest trials (Swallow and Wehner, 1986). In rye (*Secale cereale*), small plots are recommended based on high heritabilities achieved from yield selection compared to single plant plots (Rattunde et al., 1991). On the other hand, spring wheat uses large, multiple row plots, making border effects that become more pronounced as plot size decreases become negligible (Kramer et al., 1982). Proso millet (*Panicum miliaceum*) is also planted in multiple row plots to decrease border effects without designated border rows being harvested (Nelson, 1981).

No studies to date have looked at border effects in watermelon. Research on cucumber indicated that multiple-row plots were not needed due to non-significant interaction of center row with border rows of different genotype (Wehner, 1984; Wehner, 1988; Wehner and Miller, 1990). Plot size for the best prediction of larger plot yields using the smallest plot size possible has also not been studied in watermelon. Among U.S. breeders, small single-row plots of about 15 plants per plot are used (Neppl and Wehner, 2001a).

The objectives of this research were to 1) determine whether a border effect for the use of different watermelon vine length cultivars was present; 2) verify the vine lengths of the cultivars used in the border competition experiment; 3) begin studies of small plots for measuring yield.

Chapter One: Interaction of Border and Center Rows in Watermelon Yield Trials

(In the format appropriate for submission to the Journal of the American Society for Horticultural Science)

For: Journal of ASHS
Genetics and Breeding

Interaction of Border and Center Rows in Watermelon Yield Trials

Grant P. Neppl, Todd C. Wehner, and Jonathan R. Schultheis[1]

Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695-7609

Additional index words. Cucurbitaceae, *Citrullus lanatus*, border competition, vegetable breeding

---

Received for publication ____________________. The research reported herein was funded in part by the North Carolina Agricultural Research Service. Use of trade names in this publication does not imply endorsement by the NCARS or the products named, nor criticism of similar ones not mentioned.

[1] Graduate research assistant, professor, and associate professor, respectively. The authors gratefully acknowledge the technical assistance of Tammy L. Ellington.

For: Journal of ASHS
Genetics and Breeding

Interaction of Border and Center Rows in Watermelon Yield Trials

Additional index words. Cucurbitaceae, *Citrullus lanatus*, border competition, vegetable breeding

Abstract

Researchers interested in evaluating watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) cultivars for yield often use multiple-row plots to simulate the monoculture system growers use, or single-row plots to save on land, labor, and seeds. An important question is whether there is significant interaction of border with center row when diverse cultivars are planted in adjacent rows. 'Charleston Gray', 'Crimson Sweet', and 'Sugar Baby' were chosen to represent long, medium, and short vined cultivars, respectively based on recommendations from watermelon researchers in the U.S. Cultivars were planted in three-row plots with all nine combinations of the three represented in border and center rows. The experiment was a randomized complete block with the nine border by center plot combinations, two locations (Kinston, Clinton), and three replications at each location. Vine length was measured during the season, and fruit were graded (marketable and cull), counted and weighed from four harvests. Results showed that 'Charleston Gray' did in fact have the longest vines, followed by 'Crimson Sweet' and 'Sugar Baby'. In the analysis of variance, the largest effects (F ratio) on yield were from cultivar, location, and the interaction of the two. The smallest effects were border row and the interaction of center with border row. Center by border interactions were significant (5% level) in some cases, but were usually small and non-significant. Therefore, researchers interested in running trials with

many cultivars and small seed quantities can obtain good data using single-row plots. However, there is a small (but significant) interaction of center with border in some cases, so testing at the final stage should be with trials having multiple-row plots or with cultivars grouped by vine length. Additional research is needed to determine the effect of cultivars having extreme plant types, for example dwarf cultivars in bordering rows with long-vined cultivars.

Introduction

Watermelon (*Citrullus lanatus* (Thunb.) Matsum & Nakai) is the primary edible and cultivated species of *Citrullus*, a genus that consists of five species. Watermelon originated in tropical Africa with the first recorded cultivation in ancient Egypt. It is now grown throughout the world, particularly in regions suited to this thermophilic species. The main watermelon producing areas of the United States are in the south, primarily Florida, Texas, Georgia, and California. U.S. production in 1999 was 1.9 million megagrams (Mg) with a value of $268 million dollars (U.S. Department of Agriculture, 2000).

Watermelon breeding consists of crossing two or more parents of interest, selection, stabilization, (usually by self-pollination), production of potential cultivars, (diploid or triploid inbreds or hybrids), and field testing in the locations of interest. One of the most expensive stages is field testing. Therefore, watermelon breeders are interested in optimizing their field testing methods to provide the most information for the lowest cost. Multiple-row plots provide conditions similar to the monoculture production system that growers will use. On the other hand, single-row plots permit more experimental cultigens to be tested and/or more replications, while requiring fewer seeds per plot. Since seed supply, land, labor, and funding are limiting, breeders are interested to know whether multiple-row plots are necessary for proper testing of experimental cultigens.

One potential biasing effect on yields of a single-row plot is the competition between plants of adjacent plots. Arny (1922) showed that border rows could be harvested along with the center rows of the plot in small grains if the alleys between plots were planted with winter wheat sown in the spring. Cropped alleys provided competition to the plants at each end of the plot, eliminating the yield inflation that normally occurred. Christidis (1931) later summarized border competition. He noted that competition between plants exists in some cases; the effects (when present) were limited to one row on either side of a plot, and competition effects were negligible when cultivars similar in growth habit and morphology were grown in adjacent plots.

If there is no border competition, single-row plots would be the most efficient trialing method. Should significant border competition exist, steps should be taken to eliminate the effects from the trials. Two methods have been proposed to do that. The first, proposed by David et al. (1996) is to allocate cultivars in field layouts so plots are grouped to include cultivars having similar competition effects. This allows for competition effects on yield to be effectively ignored in later statistical analysis. A second method allows competition to occur, but compensates for biased yield effects through the use of designated border rows, which are not included in the measurement of plot yield. In this study, we refer to border rows as those rows on the edge of each plot, not the guard rows on the outside of the entire experiment. Regardless of whether multiple-row plots are used, the entire experiment usually should be surrounded by guard rows and end plots for many crop species (Wehner, 1987).

The use of border rows is recommended for crops such as sugarbeet (*Beta vulgaris*) (Deming and Brewbaker, 1934), rice (*Oryza sativa*) (Zimmermann, 1980), field bean (*Vicia faba*) (Costa and Zimmermann, 1998; Kempton and Lockwood, 1984), soybean (*Glycine max*) (Evans and Lewin, 1986; Gedge et al., 1977; Monzan et al., 1972; Probst, 1943), red clover (*Trifolium pratense*), and alfalfa (*Medicago sativa*) (Hollowell and Heusinkveld, 1933), and the small grains oat (*Avena sativa*), barley (*Hordeum vulgare*), winter and spring wheat (*Triticum aestivum*) (Hulbert and Remsberg, 1927; Down, 1942). Studies of border competition in wheat and barley have shown mixed results on whether border row use is warranted due to the existence of border effects and the lack of the effect being significant in altering plot yields in some cases (Kramer et al., 1982; Romani et al., 1993; Stringfield, 1927). Maize (*Zea mays*) studies have also shown a lack of significance in border row effects (Bowman, 1989; Silva et al., 1991). Over or under exaggeration of yield due to competition has been noted in field bean (Kempton and Lockwood, 1984); potato (*Solanum tuberosum*) (Thornton, 1987); triticale (*Triticosecale 'Lasko'*) (Kempton et al., 1986); and wheat (Austin and Blackwell 1980; Clarke et al., 1998; Fasoula, 1990; May and Morrison, 1986). The biasing effect on yield due to different competing abilities of adjacent cultivars can be associated with plant architecture. In wheat, yields are reduced 0.34% for every centimeter increase in height of adjacent plots (Clarke et al., 1998).

No studies to date have evaluated border effects in watermelon. Research on another cucurbit, cucumber, indicated that multiple-row plots were not needed due to non-significant interaction of center row with border rows of a different genotype (Wehner, 1984; Wehner, 1988; Wehner and Miller, 1990).

The objectives of this study were to determine whether border effects were present in the field using three watermelon cultivars differing in vine length. Since cultivars differing in vine length were used, we also measured vine length and canopy size of different cultivars.

Materials and Methods

The experiment was conducted during the summer season of 2000 at the Cunningham Research Station in Kinston and the Horticultural Crops Research Station in Clinton, North Carolina. Hereafter, locations will be referred to as Kinston and Clinton, respectively.

Experiment design

The experiment was a randomized complete block with two locations, three replications at each location, and nine border-center row combinations of the three cultivars. Location was the whole plot and border-center treatment was the sub-plot. Replication (block) was nested within location. Each plot (treatment combination) consisted of three rows such that all possible combinations of center row with left and right border rows (of the same cultivar but not necessarily the same as the center row) could be obtained.

Weak plants were replaced with transplants 4 to 14 days after transplanting to assure that all plots had 12 plants. At harvest, all plots had the required 12 plants. Rows were covered with black plastic mulch and irrigated using plastic drip tape. Plastic mulch was 1.25 mil. at Kinston and 1.5 mil. at Clinton. Drip tape was 8 mil. manufactured by Roberts Irrigation Products Inc. (San Marcos, California) at Kinston and 8 mil. Streamline 80 manufactured by Netafim (Fresno, California) at Clinton. Individual rows of each plot were 7.3 m long, on 3.0 m centers with 0.6 m between hills, and 2.4 m alleys at each end of the plot.

Cultivars used

Three cultivars were evaluated based on recommended extremes of vine length gathered from a survey of public and private breeders in the U.S. Cultivars used were 'Charleston Gray' (long vine), 'Crimson Sweet' (medium-length vine) and 'Sugar Baby' (short vine). Seeds of 'Sugar Baby' were obtained from N.C. State University seed increase lots, 'Crimson Sweet' from Hollar and Co. (Rocky Ford, Colorado), and 'Charleston Gray' from Willhite Seed Inc. (Poolville, Texas). Seeds (except 'Sugar Baby', which were fermented after increase at N.C. State Univ.) were acid washed prior to planting to eliminate bacterial fruit blotch causing organisms. Fermenting seed will also eliminate bacterial fruit blotch causing bacteria. Acid treatment consisted of placing seeds into 1% hydrochloric acid (HCl) for 15 minutes. Seeds were then rinsed in tap water for six minutes and dried.

Flats were seeded on 21 March 2000 and 28 March 2000 to be transplanted at Kinston and Clinton experiment stations, respectively. A third set of transplants was seeded on 4 April as insurance for loss of a previous set, but was not used in the experiment. All transplants were grown in the research greenhouses at North Carolina State University. Transplants were taken to cold frames for seven days before transplanting on 17 and 24 April 2000 for Kinston and Clinton, respectively.

Scotts Professional® water soluble 20N-16.6P-8.8K fertilizer was applied to transplants in the greenhouse and under cold frames at a concentration of 28.35 grams of fertilizer per 3.79 liters of concentrate. Fertilizer was applied once per week using a brass siphon mixer (Miracle-Gro Siphonex) from Scotts Miracle-Gro Products Inc., Port Washington, NY 11050 generating a dilution rate of 16:1. Hand brushing was used three times per day while transplants were in the greenhouse to limit stem elongation. Each brushing, the flattened palm of the hand was lightly moved across the tops of the transplants in a random manner across each flat so that plants were brushed approximately three times per brushing. Seedlings were transplanted at Kinston on 25 April 2000 and at Clinton on 1 May 2000.

Cultural practices

The experiment was conducted using recommended horticultural practices (Sanders, 1999). Plots were on raised plastic mulch beds. Soil at Kinston was a Norfolk sandy loam. Soil at Clinton was Orangeburg loamy sand.

Kinston field preparation included soil incorporation of a 10N-16.6P-8.8K fertilizer applied at 336.4 $kg \cdot ha^{-1}$ and the fumigant Telone C-17 (1,3-Dichloropropene + chloropicrin) applied at a rate of 59.8 $L \cdot ha^{-1}$ on 6 April 2000. At transplanting completion on 27 April 2000, 20N-16.6P-8.8K fertilizer and 29.57 ml of Diazinon (Diethyl 2-Isopropyl-4-Methyl-6-Pyrimidyl Thionophosphate) were applied per 189.25 liters of transplant water after transplanting. Application rates were less than 5.6 $kg \cdot ha^{-1}$ or a water diluted equivalent of a 1N-0.83P-0.44K fertilizer. Further fertilizer, fungicide, insecticide and herbicide applications made throughout the growing season can be found in Appendix Table 3.4. Fertilizers applied after planting were injected into the drip tape irrigation system.

Field preparation at Clinton included the soil incorporation of a 10N-8.3P-4.4K fertilizer applied at 560.7 $kg{\cdot}ha^{-1}$ and Telone C-35 (1,3-Dichloropropene + chloropicrin) fumigant applied at 168.2 $kg{\cdot}ha^{-1}$ on 29 March 2000. Fertilizer application for the remainder of the growing season consisted of 224.3 $kg{\cdot}ha^{-1}$ of 13.5N-0P-19.8K and 112.1 $kg{\cdot}ha^{-1}$ of calcium along with 15.5N-0P-0K applied on 22 May, 30 May, and 7 June 2000. Only 13.5N-0P-19.8K was applied on 14 June and 23 June 2000. Gramoxone (1,1'-Dimethyl-4,4'-bipyridinium dichloride) was applied to plastic mulch edges on 23 May 2000 using a backpack sprayer. Further fertilizer, fungicide, insecticide and herbicide applications made throughout the growing season can be found in Appendix Table 3.5. Fertilizers applied after planting were injected into the drip tape irrigation system.

Data collection and analysis

Plots had a total of four harvests beginning 27 June 2000 at Kinston and 6 July 2000 at Clinton. Each location was harvested once per week on non-overlapping days. Vine tracing was used when the plot of origin for a fruit was in question. Only fruit from the center row of each three-row plot were harvested. Fruit were determined as ripe after checking fruit in the border rows for sugar content, a dried tendril nearest that fruit, light colored groundspot, and the sound of the fruit when thumped. Individual cull and marketable fruit were weighed (nearest 0.1 kg) for each plot. Numbers of cull and marketable fruit were also recorded. Yield was calculated as total or marketable fruit weight ($Mg{\cdot}ha^{-1}$) or number ($thousands{\cdot}ha^{-1}$) after summing plot yields over the four harvests.

Vine size, as an indication of row width coverage by canopy, was rated on a scale of 1 to 9, where 1-3=small vines, 4-6=medium sized vines, 7-9=large vines. Ratings were taken based on average canopy of the entire harvested center row of each plot.

Data were collected on individual fruit, and analyzed as plot means summed over harvest. Data were analyzed using the ANOVA, Correlation and Means procedures of SAS (SAS Institute, Cary, NC).

Vine Length

Vine length was measured in plots adjacent to the main experiment using the same cultivars. The experiment was a randomized complete block with two locations, three replications per location, and three cultivars, with a total of 18 single-row plots. Location was the whole plot and cultivar was the sub-plot. Replication (block) was nested within location. Plots were planted using the same row spacing as described above for the border competition study. At harvest, all plots had the required 12 plants.

Three measurements of vine length (in mm) were taken beginning at first fruit set for each location and every other week thereafter. The first vine length was taken on 31 May 2000 at Kinston and 8 June at Clinton. Measurements two and three were taken on 12 and 27 June for Kinston, and 22 June and 6 July for Clinton, respectively. First fruit set was when fruit were softball size. For each measurement, plants three, seven and eleven in a plot were used. The same vine of each plant was used throughout the experiment unless the growing tip had been damaged. In that event, a neighboring plant within the plot was used. Vine length was measured from the base of each plant to the growing point. A main vine was measured, one of those extending furthest from the crown. Data were analyzed using the ANOVA, Correlation and Means procedures of the Statistical Analysis System (SAS Institute, Cary, NC).

Results

Border competition

Analysis of variance (Table 1.1 and Table 1.2), showed that location and center row main effects were large and significant or highly significant for most traits. Border effects and border by center row interaction were small and non-significant for all traits.

At the Kinston and Clinton research stations, 'Charleston Gray' yielded 52.8 to 108.4 $Mg \cdot ha^{-1}$ when planted in both border and center rows representing monoculture conditions (Table 1.3). 'Charleston Gray' treatments having 'Crimson Sweet' borders yielded from 65.4 to 103.5 $Mg \cdot ha^{-1}$, while those with 'Sugar Baby' borders ranged from 56.4 to 99.3 $Mg \cdot ha^{-1}$. Treatments with a 'Crimson Sweet' center and either 'Charleston Gray', 'Crimson Sweet', or 'Sugar Baby' borders, yielded 53.9 to 90.0, 53.3 to 90.3, and 57.6 to 108.2 $Mg \cdot ha^{-1}$, respectively. 'Sugar Baby' centers yielded 31.6 to 37.1, 37.8 to 40.8, and 24.4 to 34.5 $Mg \cdot ha^{-1}$ when grown with 'Charleston Gray', 'Crimson Sweet', and 'Sugar Baby' borders, respectively.

There was a high correlation (r=0.99) between total and marketable fruit weight (Table 1.3), so we presented data only for total yield. Marketable yield data is presented in the appendix. There was a high correlation (r=0.84) between total yield and marketable weight per fruit indicating that large-fruited cultivars had higher yields than small-fruited ones. A high correlation (r=0.80) was also found between total fruit weight and total fruit number.

Kinston had higher yield (total or marketable fruit weight or number) for every center and border treatment combination except for 'Sugar Baby' in the center row (Table 1.3, Appendix Table 3.3). Yield differences among locations for 'Sugar Baby' were not significant. A single significant difference in percentage of culls occurred for 'Charleston Gray' centers with 'Crimson Sweet' in the border rows at Clinton. This treatment produced a higher percentage of culls. Marketable weight per fruit was also significantly higher at

Kinston in the treatments having 'Crimson Sweet' as the center with 'Sugar Baby' as the border than at Clinton. Despite the above yield trends, F ratios for a location by border by center interaction were not significant for any trait including percentage of culls (Table 1.3, Appendix Table 3.3).

Comparison of treatments within each location revealed few differences (Table 1.3 and Appendix Table 3.3). At Kinston, 'Crimson Sweet' centers with 'Sugar Baby' borders had significantly higher total fruit weight and number than 'Crimson Sweet' centers with either 'Charleston Gray' or 'Crimson Sweet' borders. Additionally, plots with a 'Sugar Baby' center and 'Crimson Sweet' border also produced significantly more fruit than 'Sugar Baby' centers with 'Sugar Baby' borders. Treatment differences for percentage of culls occurred at the Clinton location only (Table 1.3, Appendix Table 3.3). 'Charleston Gray' centers with 'Crimson Sweet' borders had a significantly higher percentage of culls than treatments having a 'Charleston Gray' center and either a 'Charleston Gray' or 'Sugar Baby' border. For total fruit number, Clinton plots having 'Charleston Gray' in the center row with 'Crimson Sweet' in the border had higher numbers of fruit than 'Charleston Gray' centers with 'Charleston Gray' borders. No marketable weight per fruit differences between treatments was found in either location.

Despite a high correlation (r=0.99) between total fruit weight and marketable fruit weight, several different marketable yield trends were found within each location as shown in Appendix Table 3.3. Like Kinston total fruit weight in Table 1.3, 'Crimson Sweet' centers with 'Sugar Baby' borders at Kinston had significantly higher marketable fruit weight than 'Crimson Sweet' centers with either 'Charleston Gray' or 'Crimson Sweet' borders. For marketable fruit number at Kinston, 'Charleston Gray' centers with 'Charleston Gray' borders had significantly higher numbers of fruit than 'Charleston Gray' centers with 'Sugar Baby' borders. 'Crimson Sweet' centers with 'Sugar Baby' borders produced higher numbers of marketable fruit than 'Crimson Sweet' centers with either 'Charleston Gray' or

'Crimson Sweet' borders. Additionally, 'Sugar Baby' centers with 'Crimson Sweet' borders had significantly higher marketable fruit number than 'Sugar Baby' centers with 'Sugar Baby' borders.

At the Clinton location, only percentage of culls and marketable fruit number had treatment differences with respect to treatments having a common center (Appendix Table 3.3). For percentage of culls, 'Charleston Gray' centers with 'Crimson Sweet' borders produced a higher percentage of culls than 'Charleston Gray' centers with either 'Charleston Gray' or 'Sugar Baby' borders. Marketable fruit number was significantly higher in treatments of 'Sugar Baby' centers with 'Crimson Sweet' borders compared to 'Sugar Baby' centers with 'Sugar Baby' borders.

Data were analyzed using means over locations to show general trends. Total fruit weight and total fruit number had a correlation of 0.80 that was highly significant (Table 1.3). Within common center treatments for total fruit weight (Appendix Table 3.1), only 'Crimson Sweet' centered plots had highest yields in the treatment having a small vined cultivar ('Sugar Baby') as the border. For total fruit number, treatments having a 'Crimson Sweet' center with a 'Sugar Baby' border produced a greater total number of fruit than when planted with either a 'Charleston Gray' or 'Sugar Baby' in the border. 'Sugar Baby' centers with 'Crimson Sweet' had a significantly higher total number of fruit than 'Sugar Baby' with itself in the border. Center by border interaction was significant for total and marketable fruit weight and highly significant for total and marketable fruit number. There was a high correlation (r=0.99) between total and marketable fruit weight, so the same yield trends appeared for marketable fruit weight and number (Appendix Table 3.2).

In terms of percentage of culls combined over locations, an F ratio of 1.6 (Appendix Table 3.1 and Table 3.2) was not significant for a center by border interaction. A center by border interaction was also not significant for marketable weight per fruit. The treatment with 'Charleston Gray' as the center and 'Crimson Sweet' as the border had the highest percentage of culls compared to the same center cultivar having 'Sugar Baby' as the border. Weights per fruit were similar regardless of which border cultivar was planted with a common center cultivar. No other trend was seen for this trait for the experimental treatments (Appendix Table 3.1 and Table 3.2).

Vine length

Vine length measurements and vine size (canopy coverage) rating were taken to confirm the relative vine sizes of the three cultivars used in this study. According to analysis of variance (Table 1.2 and 1.4), the main effect of location was highly significant for vine size, vine length measurement two, measurement three, and average vine length, but not for vine length measurement one. Location by cultivar interaction was significant at the 5% level for vine length measurement one, measurement three, and average vine length. Cultivar was significant or highly significant for vine size, vine length measurement two, measurement three, and average vine length.

Vine size at Kinston ranged from 5.3 for 'Sugar Baby' to 8.4 for 'Charleston Gray' (Table 1.5). Clinton vine size ranged from 3.1 for 'Sugar Baby' to 6.9 for 'Charleston Gray'. Location by cultivar interaction was not significant for vine size.

Average vine lengths over the course of the growing season (Table 1.5) did have a significant location by cultivar interaction. 'Charleston Gray' and 'Sugar Baby' vines were significantly longer at Kinston than at Clinton, although there were no significant differences in average vine length for 'Crimson Sweet' when compared between locations.

Between locations tested, 'Crimson Sweet' vines were significantly longer at Clinton while vines of 'Sugar Baby' were longer at Kinston after five weeks of growth (Table 1.5). From seven weeks of growth onward until the last vine length measurement, vine length differences stabilized with 'Charleston Gray' and 'Sugar Baby' vines being significantly longer at Kinston. 'Crimson Sweet' vine length showed no difference between location after seven and nine weeks of growth. Vine length rankings also varied between locations with

'Charleston Gray' the longest vined cultivar at Kinston while 'Crimson Sweet' and 'Charleston Gray' had similar vine lengths (longest vined) at Clinton.

Within each location, a number of vine differences were found (Table 1.5). Vine size rating at the Kinston location revealed 'Charleston Gray' and 'Crimson Sweet' had a significantly larger canopy than 'Sugar Baby'. Vine lengths averaged over the entire growing season showed a reversed trend with 'Charleston Gray' having a significantly longer vine than either 'Crimson Sweet' or 'Sugar Baby'. For the initial vine length measurement after five weeks of growth, 'Charleston Gray' and 'Sugar Baby' were significantly longer than 'Crimson Sweet'. However, from seven weeks of growth onward, only 'Charleston Gray' maintained greater vine length than either 'Crimson Sweet' or 'Sugar Baby'.

Vine growth measurements within the Clinton location were similar to those for Kinston (Table 1.5). Vine size ratings again showed that 'Charleston Gray' and 'Crimson Sweet' had significantly more row width covered by canopy than 'Sugar Baby'. Vine lengths averaged over the entire growing season mirrored vine size results with 'Charleston Gray' and 'Crimson Sweet' having significantly longer vines than 'Sugar Baby'. After five weeks of growth, 'Crimson Sweet' had a significantly longer vine than 'Sugar Baby', but was no different from 'Charleston Gray'. At seven weeks of growth, 'Charleston Gray' and 'Crimson Sweet' had significantly longer vines than 'Sugar Baby'. At the last measurement of vine length after about nine weeks of growth, 'Crimson Sweet' still had a significantly longer vine than 'Sugar Baby', but remained no different from 'Charleston Gray'.

For vine size rating averaged over locations, 'Charleston Gray' and 'Crimson Sweet' were significantly larger (more row width covered by canopy) than 'Sugar Baby', but were not significantly different from each other (Table 1.5). Average vine length over locations had significant cultivar row effects as 'Charleston Gray' was longer than both 'Crimson

Sweet' and 'Sugar Baby'. However, 'Crimson Sweet' and 'Sugar Baby' did not differ significantly in average vine length.

After five weeks of growth, vine lengths of all three cultivars showed no differences (Table 1.5). Between weeks seven and nine, length rankings did not change, with 'Charleston Gray' being the longest cultivar and 'Sugar Baby' the shortest. At week seven, 'Charleston Gray' and 'Crimson Sweet' were longer than 'Sugar Baby'. However, at week nine, only 'Charleston Gray' remained longer than 'Sugar Baby'. Vine size rating was negatively correlated with vine length at week five ($r=-0.01$), but was positively correlated with vine length at week seven ($r=0.68$) and nine ($r=0.60$).

Discussion

Higher total and marketable fruit weight and number were produced at Kinston for 'Charleston Gray' and 'Crimson Sweet' in every treatment where these cultivars were planted in the center row. Higher yields at Kinston may be due to better soils, timing of fertilizer application, and better overall field maintenance at that location. Although N, P, and K were applied at higher rates at Clinton than at Kinston, a longer time elapsed before any subsequent fertilizer application (Appendix Table 3.4 and Table 3.5). Since fertilizer was applied during transplanting and through drip irrigation less than a week after transplanting at Kinston, transplants were able to establish themselves much faster than at Clinton. Transplants at Clinton had no fertilizer added until three weeks after transplanting, and the fertilizer in the soil had been placed about one month before transplanting, likely leading to some fertilizer loss.

Plots at Kinston were better maintained compared with Clinton, which had higher weed competition. Disease and insect incidence was lower at Kinston. The few leaf samples found with problems were diagnosed as anthracnose, wind, and spray damage. Several fruit and tissue samples from Clinton resulted in the identification of gummy stem blight as well as spider mites, thrips and leaf miners. Less biotic stress at Kinston probably resulted in more vine and fruit production than was possible by plants at Clinton.

Christidis (1931) summarized border competition noting that competition between plants exists in some cases, that the effects (when present) were limited to one row on either side of a plot, and that competition effects were negligible when cultivars similar in growth habit and morphology were grown in adjacent plots. In our study, we found some support that border competition may affect total and marketable fruit weight and number.

Numerous studies conducted on watermelon have manipulated plants and row spacing along with plant densities. Spacings studied ranged from 0.6 to 3.7 m in row and 1.5 to 4.5 m between rows. Our study used 0.6 m within row spacing and 3.0 m between row spacing. Generally, researchers have reported that as spacing increased, yields decreased while weight per fruit increased (Bracy and Parish, 1994; Brinen et al., 1979a; 1979b; Elmstrom and Crall, 1985; Gilreath et al., 1987; NeSmith, 1993). This is usually a linear response to spacing, however, one exception was a study by Singh and Naik (1989). They found decreased yields with increased plant spacing. As spacing decreased or plant populations rose, a reverse of the above trend has been found. Generally, researchers report that more fruit were produced with smaller spacing, although each fruit had less biomass (Duthie et al., 1999a; Duthie et al., 1999b; Elmstrom and Crall, 1985; Gilreath et al., 1987; NeSmith, 1993).

The same trend of increased yield with decreased spacing or increased population density was also found for other cucurbits such as squash (Dweikat, and Kostewicz, 1989; Mulkey and Talbot, 1993), pumpkin (Reiners and Riggs, 1997), muskmelon (Maynard and Scott, 1998; Paris et al., 1988), round gourd (Kanwar et al., 1994), and cucumber (Chambliss and Turner, 1972; Nerson, 1998). However, on a per plant basis, increased density and thus competition in cucumber resulted in lower mean fruit number per plant. Fruit weight per plant was shown to decrease with increasing density (Bach and Hruska, 1981; Delaney et al., 1983; Schultheis et al., 1997b; Staub et al., 1992; Widders and Price, 1989).

The above effects on fruit yield result from competition from neighboring plants. Since our study made no use of different plot sizes, the differences in vine length and canopy we observed may have produced similar yield effects to spacing or plant density adjustments. When grown next to each other for the same length of time, long vining cultivars such as 'Charleston Gray' must grow faster and have a higher competing ability than short vined cultivars such as 'Sugar Baby'. Since, more soil would be covered by large vined cultivars at a faster rate, the effects on other cultivars would be similar to increased planting densities or reduced spacing in terms of sheer biomass involved. The only difference between 'Charleston Gray' and 'Crimson Sweet' was that 'Charleston Gray' had a greater canopy ground coverage at Kinston. This would lead to increased shading of 'Crimson Sweet' borders than with itself as a border. We expected higher total fruit weight for 'Charleston Gray' bordered by either 'Crimson Sweet' or 'Sugar Baby' to result from longer vine lengths and greater canopy, but found no total fruit weight differences between 'Charleston Gray' centers and different borders. Higher total fruit weight for 'Crimson Sweet' centers with 'Sugar Baby' borders at Kinston were likely due to competition effects resulting from canopy differences. Since 'Crimson Sweet' has greater canopy coverage than 'Sugar Baby' even though average vine length was not different, 'Crimson Sweet' was still able to out-compete 'Sugar Baby' borders resulting in higher total yields.

Differences found in vine traits may also account for yield differences seen in total and marketable fruit number and marketable weight per fruit. When 'Charleston Gray' was grown with 'Crimson Sweet' in the border rows, more total fruit per hectare was produced at Clinton, but this was compensated for by a large increase in percentage of culls produced. 'Crimson Sweet' centers and 'Sugar Baby' borders also produced significantly more total and marketable fruit per hectare at Kinston than when it was bordered by 'Charleston Gray' or itself. 'Crimson Sweet', like 'Charleston Gray' also had a larger canopy so that it could have harvested more solar radiation to support more fruit with higher weight per fruit.

The effects of competition from adjacent large vined cultivars or alterations in plant density/spacing can be manifested in how vine growth and consequential fruit production changes. When plants interact with each other whether due to spacing or physical growth habit such as vine length, environmental factors such as light, water and nutrients become limiting. A plant having a lower competing ability produces less leaf area per plant or slower fruit development when competition against it is high such as with high plant densities in cucumber (Schultheis et al., 1997b). A source/sink imbalance is then created in which an out-competed plant cannot maximize the capture of solar radiation. Consequently, not as many flowers are able to support fruit and so either fewer fruit set or are smaller in size. This could be a possible explanation for the higher total fruit weights found for "Crimson Sweet' when grown with 'Sugar Baby' as a border. However, we did not measure leaf area of border and center cultivars in this study.

Not all of our findings can be explained through differences in competing ability. Yield results for treatments having a 'Sugar Baby' center do not fit what would be expected in relation to competing ability. Instead of having the highest total yield when bordered by itself, yields were visually the lowest. 'Sugar Baby' also produced more total numbers of fruit per hectare when bordered by 'Crimson Sweet', a cultivar with a higher competing ability.

Results obtained for 'Sugar Baby' treatments might be better understood if competition is broken down to its component types. One study breaks competition into three types; auto-, allo-,and nil-competition (Fasoula, 1990). Auto-competition results when genetically identical genotypes compete equally for environmental resources. In our study, this type of competition would be in treatments having the same center and border cultivars. Allo-competition occurs among dissimilar genotypes in which resources are shared unequally. Finally, nil-competition is the absence of competition where every plant can exploit resources according to its genetic potential (Fasoula, 1990). The same study, using bread wheat found a negative correlation between yielding and competing ability that was speculated to pertain to all crops in general rather than specific to this study. This correlation would fit the data seen for higher yields in mixed treatments with 'Sugar Baby' centers and either 'Charleston Gray' or 'Crimson Sweet' in the border than in pure stands of 'Sugar Baby'. Additionally, our study has shown that 'Sugar Baby' has less of a competing ability than either 'Charleston Gray' or 'Crimson Sweet' with its smaller vine length and less canopy ground coverage.

Other likely causes for higher 'Sugar Baby' yields when bordered by 'Crimson Sweet' as opposed to 'Sugar Baby' as the border could be due to differences in insect pollinator visitation, pollen competition among cultivars or differences in root mass. None of these effects were studied in this experiment, but could provide further explanation if studied using the cultivars evaluated here. A study performed on watermelon noted that floral attributes such as pollen production, nectar volume and sugar content of nectar were important in determining the number of honeybee visits and consequently fruit yield. Flower diameter was not found to influence bee visitation. No difference in the volumes of nectar produced was found between watermelon cultivars of which 'Sugar Baby' was one cultivar tested. However, differences in both nectar sugar content and pollen amounts were found (Wolf et al., 1999). Related studies have found multiple bee visits resulted in three times more fruit produced than in unvisited plots in cucumber (Gingras et al., 1999) and reduced fruit abortion in watermelon (Stanghellini et al., 1997). It is possible that 'Crimson Sweet' produces more pollen than 'Sugar Baby' and has a higher sugar content in its nectar. This may attract more bees which would then visit adjacent 'Sugar Baby' flowers once food sources on 'Crimson Sweet' were depleted to cause overall higher yields than in plots having all three rows as 'Sugar Baby'.

If more pollen were produced by 'Crimson Sweet' followed by increased bee visitation, more 'Crimson Sweet' pollen would be deposited on female flowers. In the case of 'Sugar Baby' yield, 'Crimson Sweet' pollen from adjacent rows may out-compete 'Sugar Baby' pollen resulting in more successful fruit set. In a study using different pollenizers including 'Crimson Sweet' in the production of seedless watermelon, 'Crimson Sweet' produced greater numbers of large (>7.3 kg) seedless fruit than with the other pollenizers 'Fiesta' and 'Royal Sweet' (Fiacchino and Walters, 2000).

Although not studied on a cultivar basis, differences in root mass and distribution could also be a contributing factor in altering 'Sugar Baby' yields. In general, watermelon produce shallow, but extensive root systems not penetrating much below 60 cm in the soil (Nonnecke, 1989; Whitaker and Davis, 1962). In one study, researchers evaluated the rooting distribution of watermelon grown either as direct seeded or transplanted onto plastic mulch. They found that direct-seeded plants developed vigorous, extended tap roots, while transplants tended to lack a deep tap root and produced more extensive lateral root systems near the soil surface (Elmstrom, 1973). Differences in root competition for nutrients may explain further the small border by center interaction seen in our experiment as well as the yield trend for 'Sugar Baby' when grown with either itself as a border or 'Crimson Sweet'. No research to date has documented rooting distribution based on cultivar, but would be useful in explaining cultivar interactions to a greater extent.

Cucumber is the only cucurbit for which competing ability, competition and their relation to the need for plot borders has been extensively studied. Studies of end border effects found that unbordered plot ends results in yield inflation of 5 to 21% per plot. However, overall rankings of cultivars were not affected so that unbordered plots could be used for trials where only relative yield performance is desired (Wehner, 1984; Wehner, 1988). When mixtures of cucumber cultivars having different plant architecture (vine length, determinate vs. indeterminate, gynoecious hybrid vs. inbred, and early vs. late) and consequently competing ability were studied, those cultivars with the higher competing ability (i.e. early, long vine) had higher yields as their component in the mixture increased up to pure stands (Schultheis et al., 1997a). Another study specifically on border row effects used contrasting plant architecture of determinate vs. indeterminate, tall vs. dwarf, and gynoecious vs. monoecious to determine border effects. Long vined borders did have a tendency to reduce center row yields, but the effects were not significant in enough of the treatments to warrant the used of border rows in trialing plots (Wehner and Miller, 1990). Although our experiment showed a small center by border interaction, the overall ranking of cultivars was not affected. Typical high yielding cultivars Charleston Gray and Crimson Sweet had consistently higher total fruit weights compared to 'Sugar Baby' in all center border combinations.

Border studies in other crops have resulted in recommendations that plots have some type of end border. Yields for crops in plots without end borders have been found to produce increased yields in soybean of 16% (Monzon et al., 1972; Probst, 1943), common bean (Costa and Zimmermann, 1998) and unirrigated rice (Zimmermann, 1980). Studies performed specifically on border row effects for other crops have consistently found border intergenotypic effects when adjacent plants differ in plant architecture and consequently competing ability. Suggestion of the need for bordered plots varies, but border effects have been found for soybean (Evans and Lewin, 1986, Gedge et al., 1977; Monzon et al., 1972,), red clover and alfalfa (Hollowell and Heusinkveld, 1933), field bean (Costa and Zimmermann, 1998; Kempton and Lockwood, 1984), sugarbeet (Demming and Brewbaker, 1934), the small grains oat, barley, winter wheat, spring wheat, and triticale (Austin and Blackwell, 1980; Clarke et al., 1998; Down, 1942; Hulbert and Remsburg, 1927; Kempton et al., 1986; May and Morrison, 1986; Romani et al., 1993), potato (Thornton, 1987), and unirrigated rice (Zimmermann, 1980).

To reduce yield bias in watermelon, several options exist for the layout of plots. Plots may be planted as multiple rows, with wide spacing between plots, alleys between plots may be cropped, or plots may be grouped according to competing ability. When plots consist of multiple rows, two harvesting choices become available. One method would be to harvest only inner rows of a plot so that the yield bias of the outside rows is eliminated. Referred to as the net plot by Kramer, et al. (1982), this harvest method has drawbacks limiting its usefulness. When border rows are discarded, trials have a reduced sample area making random effects more important. Net plots have also been shown to result in a higher coefficient of variation (CV) in both proso millet (Nelson, 1981) and spring wheat (Kramer et al., 1982). Instead, the same study on wheat suggests that harvesting of gross or total plots when in multiple rows is the better choice. A greater sampled area results in lower CVs and higher heritability, while making the border effects insignificant. Unfortunately, the use of border rows will greatly increase the overall size of a trial. Spacing between plots could also be increased. This would reduce intergenotypic competition between plots, but again greatly increases the size of a trial. Wider row spacing also has the potential of introducing bias due to different genotypic reactions to increased spacing.

Perhaps the best concept for controlling intergenotypic competition and resulting border effects would be to group cultivars according to competing ability. As proposed by David, et al. (1996), cultivars could be allocated into three groups having different competing abilities. The first and last groupings would show the largest difference in competing ability such that randomization would be restricted. This would ensure that these two groupings would not be placed adjacent to one another. Competition could then be effectively ignored with greater confidence in statistical analysis of the trial. Grouping cultivars by vine length may be difficult to apply for watermelon. A study conducted on a wide range of watermelon cultivars found standard-type cultivar vine lengths ranging from 2.8 m to 7.4 m. Bush-type cultivars, although shorter vined on average (1.2 m to 2.7 m), were not different from the vine lengths of some standard cultivars (Neppl and Wehner, 2001b). This finding was bush-type cultivar specific. One major concern with the grouping concept is the possible introduction of cultivar estimate bias due to plot heterogeneity which would need to be addressed in the restricted randomization (David et al., 1996).

Producers are generally not interested in an individual plant's performance; rather, their goal is to increase marketable yields per unit of land area. Plant breeders, while trying to mirror the environment in a grower's field are restricted by the need to evaluate as many lines as accurately as possible in order to reduce trialing costs. Yield bias may then result depending on the competing ability of cultivars in adjacent plots. In relation to competition effects for watermelon, our findings enable the use of single-row plots, which allow for accurate data to be gathered. A small (but significant) interaction of center with border was found in some cases. Therefore, testing at later breeding stages would benefit from conducting trials with multiple row plots or grouping cultivars according to vine length. Cultivars having extreme plant architecture (dwarf vines for example) should be tested in separate trials to eliminate all yield bias due to competition. Further study of border competition using more extremes of plant architecture such as dwarf or citron cultivars may help further refine which cultivars may be grown adjacent to one another without significant yield bias. From the vine length side experiment, we found breeder concepts of vine length ranking for the cultivars used to be accurate. 'Charleston Gray' was the longest vining cultivar used while 'Sugar Baby' was the shortest. Vine lengths of 'Crimson Sweet' were often no different from 'Charleston Gray' as occurred at Clinton or not so different from 'Sugar Baby' as occurred at Kinston. Additional investigation of pollen transfer, pollen competition, and root distribution may also further explain the anomalous high yields for 'Sugar Baby" when bordered by 'Crimson Sweet'.

Literature Cited

Arny, A. C. 1922. Border effect and ways of avoiding it. Agron. J. 14(7):265-278.

Austin, R. B. and R. D. Blackwell. 1980. Edge and neighbor effects in cereal yield trials. J. Agric. Sci., Camb. 94:731-734.

Bach, C. E. and A. J. Hruska. 1981. Effects of plant density on the growth, reproduction and survivorship of cucumbers in monocultures and polycultures. Journal of Applied Ecology. 18:929-943.

Bowman, D. T. 1989. Plot configuration in corn yield trials. Crop Science. 29:1202-1206.

Bracy, R. and R. Parish. 1994. Row number, not plant spacing affects melon production. Louisiana Agriculture. 37(4):29.

Brinen, G. E., S. J. Locascio, and G. W. Elmstrom. 1979a. Plant arrangement for increased watermelon yield. Proceedings of the Florida State Horticultural Society 92:80-82.

Brinen, G. E., S. J. Locascio and G. W. Elmstrom. 1979b. Plant and row spacing, mulch and fertilizer rate effects on watermelon production. J. Amer. Soc. Hort. Sci. 104(6):724-726.

Chambliss, O. L. and J. L. Turner. 1972. High density plantings give higher production of cucumbers, southern peas. Highlights Agric. Res. Ala. Agric. Exp. Station 19(3):10-11.

Christidis, B. G. 1931. The importance of the shape of plots in field experimentation. Journal of Agricultural Science 2:14-37.

Clarke, F. R., R. J. Baker, and R. M. DePauw. 1998. Interplot interference distorts yield estimates in spring wheat. Crop Science 38:62-66.

Costa, J. G. C. S. and F. J. P. Zimmermann. 1998. Experimental plot border effect on yield and plant height of common bean (in Portuguese). Pesq. Agropec. Bras., Brasilia 33(8):1297-1304.

David, O., R. A. Kempton, and I. M. Nevison. 1996. Designs for controlling interplot competition in variety trials. Journal of Agricultural Science. 127:285-288.

Delaney, K. E., R. L. Lower, and M. D. Edwards. 1983. Effect of within row spacing on mature fruit yield of three *Cucumis sativus* var. *hardwickii* derivatives and a gynoecious inbred of *Cucumis sativus*. Cucurbit Genetics Cooperative Report 6:3-4.

Deming, G. W. and H. E. Brewbaker. 1934. Border effect in sugarbeets. J. Amer. Soc. Agron. 26(7):615-619.

Down, E. E. 1942. Plot technique studies with small grains. J. Amer. Soc. Agron. 34(5):472-481.

Duthie, J. A., B. W. Roberts, J. V. Edelson, and J. W. Shrefler. 1999a. Plant density-dependent variation in density, frequency, and size of watermelon fruits. Crop Science. 39:412-417.

Duthie, J. A., J. W. Shrefler, B. W. Roberts, and J. V. Edelson. 1999b. Plant density-dependent variation in marketable yield, fruit biomass, and marketable fraction in watermelon. Crop Science. 39:406-412.

Dweikat, I. M. and S. R. Kostewicz. 1989. Row arrangement, plant spacing, and nitrogen rate effects on zucchini squash yield. HortScience 24(1):86-88.

Elmstrom, G. W. 1973. Watermelon root development affected by direct seeding and transplanting. HortScience. 8(2):134-136.

Elmstrom, G. W. and J. M. Crall. 1985. "Icebox" watermelons for Florida: cultivar and spacing evaluations. Proc. Fla. State Hort. Soc. 98:276-278.

Evans, L. S. and K. F. Lewin. 1986. Effects of limited border and harvest rows and interplanting cultivars on yields of field-grown soybeans. J. Agronomy and Crop Science. 156:206-212.

Fasoula, D. A. 1990. Correlations between auto-, allo-, and nil-competition and their implications in plant breeding. Euphytica. 50:57-62.

Feher, T. 1993. Watermelon. p.295-315. In: Kalloo, G. and B. O. Bergh (eds.). Genetic improvement of vegetable crops. Pergamon Press Ltd., Tarrytown, New York.

Fiacchino, D. C. and S. A. Walters. 2000. Influence of diploid pollenizers on seedless watermelon yield and quality. HortScience. 35(3):430 (Abstr.).

Gedge, D. L., W. R. Fehr, and A. K. Walker. 1977. Intergenotypic competition between rows and within blends of soybeans. Crop Science. 17:787-790.

Gilreath, P. R., R. L. Brown, and D. N. Maynard. 1987. Icebox watermelon fruit size and yield as influenced by plant population. Proc. Fla. State Hort. Soc. 100:210-213.

Gingras, D., J. Gingras, and D. De. Oliveira. 1999. Visits of honeybees (Hymenoptera: Apidae) and their effects on cucumber yields in the field. Horticultural Entomology. 92(2):435-438.

Hollowell, E. A. and D. Heusinkveld. 1933. Border effect studies of red clover and alfalfa. J. Amer. Soc Agron. 25(12):779-789.

Hulbert, H. W. and J. D. Remsberg. 1927. Influence of border rows in variety tests of small grains. J. Amer. Soc. Agron. 19(7):585-589.

Kanwar, J. S., D. S. Khurana, and B. Singh. 1994. Effect of nutrients and plant-population density on yield and quality or round gourd (*Citrullus lanatus* var. *fistulosus*). Indian Journal of Agricultural Sciences 64(11):765-767.

Kempton, R. A., R. S. Gregory, W. G. Hughes, and P. J. Stoehr. 1986. The effect of interplot competition on yield assessment in triticale trials. Euphytica 35:257-265.

Kempton, R. A. and G. Lockwood. 1984. Inter-plot competition in variety trials of field beans (*Vicia faba* L.). J. Agric. Sci., Camb. 103:293-302.

Kramer, J. W. Van Ooijen, and C. J. T. Spitters. 1982. Selection for yield in small plots of spring wheat. Euphytica. 31:549-564.

May, K. W. and R. J. Morrison. 1986. Effect of different plot borders on grain yields in barley and wheat. Can. J. Plant Sci. 66:45-51.

Maynard, E. T. and W. D. Scott. 1998. Plant spacing affects yield of 'Superstar' muskmelon. HortScience 33(1):52-54.

Monzon, D., J. J. Pacheco G., and O. Martinez R. 1972. Effectos de competencia y de bordura en ensayos de variedades. I. soya. Agronomia Tropical. 22:67-74.

Mulkey, W. A. and T. P. Talbot. 1993. Varieties, planting dates, and spacing for high yield zucchini summer squash. Louisiana Agriculture. 36(1):17-19.

Nelson, L. A. 1981. Yield variability in proso millet due to plot size. Agron. J. 73:23-25.

Neppl, G.P. and T.C. Wehner. 2001b. Vine length of a diverse set of watermelon cultivars. Cucurbit Genetics Cooperative Report 24: in press.

Nerson, H. 1998. Responses of "little leaf" vs. normal cucumber to planting density and chlorflurenol. HortScience. 35(5):816-818.

NeSmith, D. S. 1993. Plant spacing influences watermelon yield and yield components. HortScience. 28(9):885-887.

Nonnecke, I. B. L. 1989. Vegetable production. p.541-550. Van Nostrand Reinhold. New York, New York.

Paris, H. S., H. Nerson, Y. Burger, M. Edelstein, Z. Karchi, T. G. McCollum, and D. J. Cantliffe. 1988. Synchrony of yield of melons as affected by plant type and density. Journal of Horticultural Science. 63(1):141-147.

Probst, A. H. 1943. Border effect in soybean nursery plots. J. Amer. Soc. Agron. 35:662-666.

Reiners, S. and D. I. M. Riggs. 1997. Plant spacing and variety affect pumpkin yield and fruit size, but supplemental nitrogen does not. HortScience. 32(6):1037-1039.

Romani, M., B. Borghi, R. Alberici, G. Delogu, J. Hesselbach, and F. Salamini. 1993. Intergenotypic competition and border effect in bread wheat and barley. Euphytica. 69:19-31.

Sanders, D. C. (ed.). 1999. Watermelon. p.115-118. 1999 North Carolina commercial vegetable recommendations. North Carolina Cooperative Extension Service, Raleigh North Carolina.

Schultheis, J. R., T. C. Wehner, and S. A. Walters. 1997a. Mixtures of cucumber cultigens affect yield in a multiple-harvest system. HortScience. 32(6):1024-1027.

Schultheis, J. R., T. C. Wehner, and S. A. Walters. 1997b. Optimum planting density and harvest stage for little-leaf and normal-leaf cucumbers for once-over harvest. Canadian Journal of Plant Science. 78(2):333-340.

Silva, P. S. L., P. G. de Souza, and E. E. Montenegro. 1991. Plot-end border effect of irrigated maize (in Portuguese). Revista Ceres 38(216):101-107.

Singh, R. V. and L. B. Naik. 1989. Response of watermelon (*Citrullus lanatus* Thumbs. Mansf.) to plant density, nitrogen and phosphorus fertilization. Indian Journal of Horticulture. 46(1):80-83.

Stanghellini, M. S., J. T. Ambrose, and J. R. Schultheis. 1997. The effects of honey bee and bumble bee pollination on fruit set and abortion of cucumber and watermelon. American Bee Journal. 137(5):386-391.

Staub, J. E., L. D. Knerr, and H. J. Hopen. 1992. Plant density and herbicides affect cucumber productivity. J. Amer. Soc. Hort. Sci. 117(1):48-53.

Stringfield, G. H. 1927. Intervarietal competition among small grains. J. Amer. Soc. Agron. 19(11):971-983.

Thornton, R. E. 1987. Comparison of single row vs. three row plots for cultivar evaluation. American Potato Journal. 64(1):461 (Abstr.).

U. S. Department of Agriculture. 2000. Agricultural statistics. U. S. Government Printing Office, Washington D. C. p. IX22-IX23.

Wehner, T. C. 1984. Effect of end borders on plot yield on once-over harvested pickling and fresh-market cucumbers. Cucurbit Genetics Cooperative Report. 7:31-32.

Wehner, T. C. 1987. Efficient methods for testing vegetable cultivars. HortScience. 22(6):1220-1223.

Wehner, T. C. 1988. Effect of end-border condition on small-plot yield of cucumber. Euphytica 38:113-119.

Wehner, T. C. and C. H. Miller. 1990. Yield of cucumbers in multiple-harvest trials with dissimilar genotypes in border rows. HortScience. 25(1):106-108.

Whitaker, W. and Davis, G. N. 1962. Cucurbits. Interscience Publishers Inc., New York, New York.

Widders, I. E., and H. C. Price. 1989. Effects of plant density on growth and biomass partitioning in pickling cucumbers. J. Amer. Soc. Hort. Sci. 114(5):751-755.

Wolf, S., Y. Lensky, and N. Paldi. 1999. Genetic variability in flower attractiveness to honeybees (*Apis mellifera* L.) within the genus *Citrullus*. HortScience. 34(5):860-863.

Zimmermann, F. J. P. 1980. Border effect in experimental plots of unirrigated rice (in Portuguese). Pesq. Agropec. Bras., Brasilia 15(3):297-300.

Table 1.1. Analysis of variance for total yield for watermelon trials using three-row plots tested at two locations (Kinston and Clinton).[z]

		Mean squares for total yield			
Source of variation	df	Fruit wt. (Mg·ha^{-1})	Fruit no. (th·ha^{-1})	Wt./fruit (kg)	Culls (%)
Location	1	12962.939**	90.588**	23.066*	9.386
Replication(Loc.)	4	102.381	0.912	2.746	122.942
Center	2	11706.020**	13.628**	119.114**	828.293**
Border	2	38.156	1.210	0.401	91.586
Border X Center	4	207.619	2.985	0.517	90.851
Location X Center	2	2099.583**	11.290**	3.757	79.802
Location X Border	2	87.657	0.279	0.601	119.155
Location X Border X Center	4	75.317	1.385	0.517	48.077
Error	32	72.742	0.715	1.144	58.131

[z] Analyses performed for mean yields.

**,* = F ratio significant at 0.01 or 0.05 level of significance, respectively.

Table 1.2. Analysis of variance for marketable yield for watermelon trials using three-row plots tested at two locations (Kinston and Clinton).[z]

		Mean squares for marketable yield			
Source of variation	df	Fruit wt. ($Mg\cdot ha^{-1}$)	Fruit no. ($th\cdot ha^{-1}$)	Wt./fruit (kg)	Vine size
Location	1	11013.534**	72.959**	19.511*	32.667**
Replication(Loc.)	4	142.484	0.473	2.163	0.981
Center	2	8967.897**	1.478	135.829**	58.741**
Border	2	23.953	0.417	0.376	4.796
Border X Center	4	246.527	3.722	0.110	0.491
Location X Center	2	1825.043**	7.977**	3.526	2.000
Location X Border	2	90.958	1.087	1.192	1.500
Location X Border X Center	4	63.058	1.333	0.243	1.083
Error	32	71.374	0.737	1.571	1.794

[z] Analyses performed for mean yields.

**,* = F ratio significant at 0.01 or 0.05 level of significance, respectively.

Table 1.3. Yield of three watermelon cultivars as the center row of a three-row plot having different or the same borders separated by location.[z]

Cultivar Center	Border	Total yield ($Mg \cdot ha^{-1}$)	Culls (%)	Total yield ($th \cdot ha^{-1}$)	Wt/frt (kg)
Clinton					
Charleston Gray	Charleston Gray	52.8	17.4	6.0	9.3
	Crimson Sweet	65.4	30.2	7.6	8.6
	Sugar Baby	56.4	6.1	7.0	8.3
Crimson Sweet	Charleston Gray	53.9	5.3	6.1	9.2
	Crimson Sweet	53.3	6.4	6.3	8.8
	Sugar Baby	57.6	1.1	6.7	8.4
Sugar Baby	Charleston Gray	31.6	2.2	6.9	4.8
	Crimson Sweet	37.8	0.0	7.3	5.1
	Sugar Baby	24.4	1.4	6.0	4.3

continued next page

Table 1.3 (continued).

Cultivar Center	Border	Total yield (Mg·ha^{-1})	Culls (%)	Total yield (th·ha^{-1})	Wt/frt (kg)
Kinston					
Charleston Gray	Charleston Gray	108.4	11.2	11.4	9.9
	Crimson Sweet	103.5	13.7	11.2	10.3
	Sugar Baby	99.3	12.0	10.2	10.6
Crimson Sweet	Charleston Gray	90.0	2.8	8.5	10.8
	Crimson Sweet	90.3	6.4	8.7	10.6
	Sugar Baby	108.2	6.0	10.5	10.6
Sugar Baby	Charleston Gray	37.1	2.8	7.6	4.9
	Crimson Sweet	40.8	2.2	8.4	4.9
	Sugar Baby	34.5	5.6	6.9	5.0
LSD (5%)		14.2	12.7	1.4	2.1
F ratio (loc X border X center)		1.0ns	0.8ns	1.9ns	0.2ns

Correlation (total vs. marketable yield) = 0.99**

Correlation (total vs. marketable wt/frt) = 0.84**

Correlation (total vs. total fruit number) = 0.80**

---

[z] Data are means of 2 locations and 3 replications of 12 plants/plot summed over 4 harvests.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 1.4. Analysis of variance for vine length for watermelon using single-row plots and three cultivars tested at two locations (Kinston and Clinton).[z]

Source of variation	df	Mean squares for vine length Length 1	Length 2	Length 3	Average length
Location	1	0.004	0.992**	5.567**	1.300**
Replication(Loc.)	4	0.017	0.015	0.063	0.010
Cultivar	2	0.013	0.776*	0.953*	0.399*
Location X Cultivar	2	0.146*	0.347	1.264*	0.466*
Error	8	0.022	0.093	0.194	0.059

[z] Analyses performed for mean vine lengths.

**,* = F ratio significant at 0.01 or 0.05 level of significance, respectively.

Table 1.5. Vine length and size (as a function of canopy ground coverage) of three watermelon cultivars having no border row.[z]

Cultivar Center	Size rating	Vine length (m) Week 5	 Week 7	 Week 9	 Average
Clinton					
Charleston Gray	6.9	2.0	3.0	3.0	2.7
Crimson Sweet	6.4	2.2	3.1	3.3	2.9
Sugar Baby	3.1	1.9	2.3	2.4	2.2
Mean	5.5	2.0	2.8	2.9	2.6
Kinston					
Charleston Gray	8.4	2.2	3.8	4.8	3.6
Crimson Sweet	7.3	1.9	3.0	3.4	2.8
Sugar Baby	5.3	2.2	3.0	3.8	3.0
LSD (5%)	1.3	0.3	0.6	0.8	0.5
Mean	7.0	2.1	3.3	4.0	3.1
F ratio (loc X cultivar)	1.1ns	6.7*	3.8ns	6.5*	7.9*

continued next page

Table 1.5 (continued).

Cultivar Center	Size rating	Vine length (m) Week 5	 Week 7	 Week 9	 Average
Location mean					
Charleston Gray	7.7	2.1	3.4	3.9	3.1
Crimson Sweet	6.9	2.0	3.1	3.4	2.8
Sugar Baby	4.2	2.1	2.7	3.1	2.6
LSD (5%)	0.9	0.2	0.4	0.6	0.3
Mean	6.3	2.1	3.0	3.5	2.9
F ratio (cultivar)	32.7**	0.6ns	8.4*	4.9*	6.8*

Correlation (rating vs. week 5) = -0.01ns

Correlation (rating vs. week 7) = 0.68**

Correlation (rating vs. week 9) = 0.60**

---

[z] Data are means of 2 locations and 3 replications of 3 plants/plot (vine size rating is also averaged over 3 border row treatments).

*,** Indicates correlations significant at the 5 and 1% levels, respectively.

Chapter Two: Efficient Selection Methods for Watermelon

(In the format appropriate for submission to the Journal of the American Society for Horticultural Science)

For: Journal of ASHS
Genetics and Breeding

Efficient Selection Methods for Watermelon

Grant Neppl, Todd C. Wehner, and Jonathan R. Schultheis[1]

Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695-7609

Additional index words. Cucurbitaceae, *Citrullus lanatus*, optimum trial, vegetable breeding

---

Received for publication ____________________. The research reported herein was funded in part by the North Carolina Agricultural Research Service. Use of trade names in this publication does not imply endorsement by the NCARS or the products named, nor criticism of similar ones not mentioned.

[1] Graduate research assistant, professor, and associate professor, respectively. The authors gratefully acknowledge the technical assistance of Tammy L. Ellington.

For: Journal of ASHS
Genetics and Breeding

Efficient Selection Methods for Watermelon

Additional index words. Cucurbitaceae, *Citrullus lanatus*, optimum trial, vegetable breeding, plot size

Abstract

Breeders and researchers interested in evaluating watermelon (*Citrullus lanatus* (Thunb.) Matsum & Nakai) cultivars for desired traits must make efficient use of limited land, labor and seed to maximize information obtained while minimizing costs of trialing. We were interested in whether smaller single-row plots could be used that would effectively achieve and predict yields obtained from plots with larger dimensions when large numbers of diverse cultivars were evaluated. The cultivars Allsweet, Fiesta, Regency, Starbrite, Sultan, Florida Favorite, Charleston Gray, Hopi Red Flesh, Crimson Sweet, Jubilee, Navajo Sweet, New Hampshire Midget, and Sugar Baby were used to represent a wide range in yield. Cultivars were planted in single-row plots of three different plot lengths (7.3 m, 3.7 m, and 2.4 m) with all cultivars represented in each plot size. Each combination of cultivar and plot size represented one treatment. The experiment was a randomized complete block with 39 plot treatments, two locations (Kinston and Clinton) and three replications per location. Fruit were graded (marketable and cull), counted and weighed at five harvests. Analysis of variance indicated the largest effects (F ratio size) on plot yields were from location, plot size and cultivar. The smallest effects were due to the interaction of location by plot size and cultivar by location by plot size. A genotype by environment interaction was also present, but its effect was small. Yields from the 7.3 m and 3.7 m plots were consistently no

different from each other. Regression analysis of the 2.4 m and 3.7 m plots in prediction of 7.3 m plot yields showed the 3.7 m plots to have higher R^2 (0.90), lower mean square error, lower standard deviations and a lower coefficient of variation than was found for the 2.4 m plots. Therefore, researchers interested in maximizing information obtained while minimizing costs in trials with many cultivars can obtain data representative of large 7.3 m plots using 3.7 m plots. However, alleys separating the 7.3 m and 3.7 m plots required a yield correction to compensate for the extra growing space allotted to these plots.

Introduction

The main watermelon (*Citrullus lanatus* (Thunb.) Matsum & Nakai) producing areas in the United States are in the southern states, primarily, Florida, Texas, Georgia, and California. North Carolina production ranks 7th in the nation (National Watermelon Promotion Board, 2001). Conducting field trials is one of the most expensive stages of breeding. Therefore, breeders are interested in obtaining the maximum amount of information while reducing trialing error and minimizing costs in terms of land, labor, and seed.

Maximizing the amount of information gained from selection for yield is achieved by minimizing variation among treatments. Smith (1938) proposed an empirical law relating the variance of yield on plot size that also took soil heterogeneity into account. Based on Smith’s law, Binns (1982) proposed equivalent formulas demonstrating that the more homogeneous plots are within a block, the smaller the variance between treatments.

Plot shape can be used to influence the level of homogeneity within a plot and help improve gain from selection. Increasing plot size tends to reduce variability (Zhang et al., 1994). One significant component of plot variability is soil heterogeneity. A field having a wide range in mineral and soil characteristics is more likely to induce plot variation when plants in the plot are exposed to these differences. That will be especially true as plots become larger through use of multiple rows or increased plot length. Consequently, long plots are recommended rather than square ones to minimize soil variation across a field when plots are oriented parallel with zones of different soil characteristics (Christidis, 1931; Smith, 1938).

Instead of long or multiple-row plots, single-plant plots would permit the use of more replications. Wehner (1987) proposed that small plot size be used for early stages of breeding or with quantitative traits like yield having low h^2 (<25%). Large plots could be used in advanced breeding stages when more resources are spent to test fewer cultivars and experimental lines.

Determination of the most efficient plot size for gathering accurate information has not been done for watermelon. Research on other crops has demonstrated the value of small, single-row plots of about 1.5 m up to multiple-row plots of about six rows. Single-plant (hill) plots have generally not been recommended for evaluating yield. Small 1.5 m plots are recommended in early generation testing of pickling cucumbers (*Cucumis sativus*) (Swallow and Wehner, 1986; Wehner, 1986; Wehner, 1988; Wehner and Swallow 1984). Large plots have also been recommended for cucumber since selection in smaller plots has failed to accurately reflect yield (Wehner, 1986) or the minimum number of plants needed to bear fruit for evaluation (Smith and Lower, 1978). Cucumber plots 6 m long are recommended for multiple harvest trials (Swallow and Wehner, 1986). In rye (*Secale cereale*), small plots have been recommended rather than single plant plots because of the very low heritability for yield achieved through selection from single plant plots (Rattunde et al., 1991). On the other hand, spring wheat (*Triticum aestivum*) trials often have large multiple-row plots to remove border effects (Kramer et al., 1982). Proso millet (*Panicum miliaceum*) is also planted in multiple-row plots to decrease border effects without designated border rows being harvested (Nelson, 1981). Chaves and Filho (1992) recommended larger plots in the range of 1 to 5 m since yield gain was noted to increase with plot size. In sweetpotato (*Ipomoea batatas*), no significant reduction in variance or error was found when plot size was increased. However, smaller plot size increased experimental accuracy when combined with increased number of replications (Vallejo and Mendoza, 1992).

Although plot size has not been studied in watermelon, the use of small, single-row plots with about 15 plants per plot is frequently used among U.S. breeders (Neppl and Wehner, 2001a). The objective of this study was to determine the most efficient plot size to use for evaluation of yield in watermelon. This was done using the ability of a plot to predict yield in large plots using a diverse sample of cultivars.

Materials and Methods

The experiment was conducted during the summer of 2000 at the Cunningham Research Station in Kinston and the Horticultural Crops Research Station in Clinton, North Carolina. Hereafter, locations will be referred to as Kinston and Clinton, respectively.

Experiment design

The experiment was a randomized complete block with three replications per location. Location was the whole plot, plot size was the sub-plot and cultivar was the sub-sub-plot. Replication (block) was nested within location. There were two locations (Kinston, Clinton), three plot sizes (7.3, 3.7, or 2.4 m long), and thirteen cultivars, for a total of 234 plots.

Weak plants were replaced with transplants 4 to 14 days after transplanting to assure that all plots had 12, six or one plant depending on plot size. All plots had the required number of plants at harvest except for two 7.3 m plots and two 3.7 m plots (with 11 and 5 plants each, respectively). Rows were covered with black plastic mulch and irrigated using plastic drip tape. Plastic mulch was 1.25 mil. at Kinston and 1.5 mil. at Clinton. Drip tape was 8 mil. manufactured by Roberts Irrigation Products Inc. (San Marcos, California) at

Kinston and 8 mil. Streamline 80 manufactured by Netafim (Fresno, California) at Clinton. Each plot consisted of a single-row of 12 plants (7.3 m), 6 plants (3.7 m), or 1 plant (2.4 m). Rows were 3 m apart, with plants spaced at 0.6 m apart, and 2.4 m alleys between plots.

Cultivars used

Thirteen watermelon cultivars differing in yield, earliness, fruit quality and disease resistance were chosen to provide a wide range in traits. Cultivars used were Allsweet (elongate fruit, wide stripe), Charleston Gray (elongate fruit, solid gray), Crimson Sweet (round, medium stripe), Fiesta (elongate fruit, wide stripe), Florida Favorite (elongate fruit, narrow stripe), Hopi Red Flesh (round, light solid), Jubilee (elongate, narrow stripe), Navajo Sweet (round, intermittent stripe), New Hampshire Midget (round, solid gray), Regency (blocky fruit, wide stripe), Starbrite (elongate fruit, narrow stripe), Sugar Baby (round, dark solid), and Sultan (blocky fruit, wide stripe). Seeds of 'Crimson Sweet', 'Florida Favorite', 'Hopi Red Flesh', 'Navajo Sweet', and 'Sugar Baby' were obtained from North Carolina State University, that had been increased in isolation in 1997 to 1999. All other seeds were obtained from commercial companies, with 'Allsweet', 'Charleston Gray', 'Jubilee', and 'New Hampshire Midget' from Hollar & Company (Rocky Ford, Colorado) and 'Fiesta' from Syngenta Seeds Inc. (Boise, Idaho). Seeds of 'Regency 'and 'Starbrite' were obtained from Seminis Vegetable Seeds (Tifton, Georgia). 'Sultan' was obtained from the Harris Moran Seed Company (Modesto, California). All seeds were acid treated prior to planting except those from N.C. State University, which were fermented after seed increase. Either fermenting seed or acid washing will eliminate bacterial fruit blotch causing bacteria. Acid treatment consisted of placing seeds into a 1% Hydrochloric acid (HCl) bath for 15 minutes. Seeds were then rinsed in tap water for six minutes and dried.

Flats were seeded on 21 April and 28 April 2000 for transplanting at Kinston and Clinton, respectively. A third set of transplants was seeded 4 April as insurance if something happened to one of the other sets, but was not used in the experiment.

Transplants were grown in the NC State University research greenhouses. Transplants were hardened in cold frames for seven days before transplanting on 17 and 24 April 2000 for Kinston and Clinton, respectively.

Scotts Professional® water-soluble 20N-16.6P-8.8K fertilizer was applied to transplants in the greenhouse and under cold frames at a concentration of 28.35 grams of fertilizer per 3.79 liters of concentrate. Fertilizer was applied once per week using a brass siphon mixer (Miracle-Gro Siphonex) from Scotts Miracle-Gro Products Inc. Port Washington, NY 11050 generating a dilution rate of 16:1. Hand brushing was used three times per day while transplants were in the greenhouse to limit stem elongation. Each brushing, the flattened palm of the hand was lightly moved across the tops of the transplants in a random manner across each flat so that plants were brushed approximately three times per brushing. Plants were transplanted at Kinston on 25 April and at Clinton on 1 May 2000.

Cultural practices

The experiment was conducted using recommended horticultural practices (Sanders, 1999). All plots were on raised plastic mulch beds. Soil at Kinston was a Norfolk sandy loam, and soil at Clinton was an Orangeburg loamy sand.

Kinston field preparation included soil incorporation of a 10N-16.6P-8.8K fertilizer applied at 336.4 $kg{\cdot}ha^{-1}$ and the fumigant Telone C-17 (1,3-Dichloropropene + chloropicrin) applied at a rate of 59.8 $L{\cdot}ha^{-1}$ on 6 April 2000. At transplanting on 27 April 2000, 20N-16.6P-8.8K fertilizer and 29.57 ml of Diazinon (Diethyl 2- Isopropyl-4-Methyl-6-Pyrimidyl Thionophosphate) was applied per 189.25 liters of transplant water. Application rates were less than 5.6 $kg{\cdot}ha^{-1}$ or a water diluted equivalent of a 1N-0.83P-0.44K fertilizer. Other fertilizer, fungicide, insecticide and herbicide applications made throughout the growing season can be found in Appendix Table 3.4. Fertilizers applied after planting were injected into the drip tape irrigation system.

Field preparation at Clinton included the soil incorporation of a 10N-8.3P-4.4K fertilizer applied at 560.7 kg·ha^{-1} and Telone C-35 (1,3-Dichloropropene + chloropicrin) fumigant applied at 168.2 kg·ha^{-1} on 29 March 2000. Fertilizer application for the remainder of the growing season consisted of 224.3 kg·ha^{-1} of 13.5N-0P-19.8K and 112.1 kg·ha^{-1} of calcium along with 15.5N-0P-0K applied on 22 May, 30 May, and 7 June 2000. Only 13.5N-0P-19.8K was applied on 14 and 23 June 2000. Gramoxone (1,1'-Dimethyl-4,4'-bipyridinium dichloride) was applied to plastic mulch edges on 23 May 2000 using a backpack sprayer. Further fertilizer, fungicide, insecticide and herbicide applications made throughout the growing season can be found in Appendix Table 3.5. Fertilizers applied after planting were injected into the drip tape irrigation system.

Data collection and analysis

Plots had a total of five harvests beginning 27 June 2000 at Kinston and 6 July 2000 at Clinton. Harvesting continued at one week intervals for each location on non-overlapping days. Fruit were determined to be ready to harvest by testing sugar content, as well as looking for indicators such as a dried tendril at the fruit node, a light colored ground spot and a dull sound when the rind was thumped. Vine tracing was used when the plot origin of a fruit was in question. Marketable and cull fruit were counted and weighed (0.1 kg) for each plot.

Data were analyzed using plot size as a factor and as a variable using the ANOVA, Correlation and Means procedures of SAS (SAS Institute, Cary, NC). The 7.3 m and 3.7 m plots had a yield correction for calculation of plot yields in megagrams per hectare for each plot size. Calculation of true plot yields used the plot size, which was under the assumption that vines grew halfway into the alleys separating the plots. Since alleys were 2.4 m, the assumption increased the 7.3 m and 3.7 m plots by 1.2 m each.

Results

Location was significant for total and marketable fruit weight and number, and marketable weight per fruit, but not for percentage of culls (Table 2.1 and Table 2.2). There was significant (but small) cultivar by location (genotype by environment) interaction for total and marketable fruit weight and number, and marketable weight per fruit, but not for percentage of culls. Plot size was significant for all traits (Tables 2.1, 2.2, 2.5 and Appendix Table 3.8). In the ANOVA, cultivar was significant for total and marketable fruit weight and number, marketable weight per fruit, and percentage of culls (Table 2.1 and Table 2.2).

Yield trends found were similar over cultivars evaluated. Consequently, yield trends will be presented with regard to typical high ('Fiesta'), medium ('Sultan'), and low ('Sugar Baby') yielding cultivars. Total fruit weight was much higher at Kinston for all cultivars evaluated, but not for all plot sizes (Table 2.3). Low yielding cultivars had the only occurrence where 2.4 m and 3.7 m plot total fruit weight was no different between locations. The 7.3 m plots of 'Sugar Baby' had higher total fruit weight at Kinston than respective low yielding cultivars at Clinton. No clear trend for differences in percentage of culls and weight per fruit among all 13 cultivars and the two locations tested was found (Table 2.3 and Appendix Table 3.6). Total fruit number showed a higher trend in the 3.7 m plots and 7.3 m plots across the range in yields as shown by the cultivars Fiesta, Sultan, and Sugar Baby at Kinston compared to the same cultivars and plot sizes at Clinton (Table 2.3).

Within each location, more total yield differences were found between plot sizes of various cultivars at Kinston than at Clinton (Table 2.3). The 7.3 m and 3.7 m plots of 'Fiesta', 'Sultan' , and 'Sugar Baby' evaluated at Kinston had higher total fruit weight and fruit number than in the 2.4 m plots. For marketable weight per fruit at Kinston, fruit were larger from the 2.4 m plots of 'Sultan' compared to the 3.7 m and 7. 3 m plots. No clear weight per fruit trend was found regarding both high and low yielding cultivars. Although a few plot sizes and cultivars showed significantly higher percentages of culls, no clear trend was found (Table 2.3 and Appendix Table 3.6).

At the Clinton location, yields were not significantly different between plot sizes regardless of yield grouping for the traits total fruit weight and percentage of culls (Table 2.3 and appendix Table 3.6). More total fruit were produced in 'Sultan' 3.7 m and 7.3 m plots compared to the 2.4 m plots. The 7.3 m plots of 'Sugar Baby' also produced higher numbers of fruit than both the 3.7 m and 2.4 m plots. No significant differences in total fruit number was found for plots sizes having high yielding cultivars. Marketable weight per fruit, depending on the cultivar, had higher weight per fruit in the 2.4 m plots (Table 2.3 and Appendix Table 3.6). However, this was not a consistent trend for each grouping of cultivars based on overall yield.

The cultivar by location by plot size interaction was not significant for total and marketable fruit weight and percentage of culls (Table 2.3 and Appendix Table 3.6). However, the interaction was highly significant for total and marketable fruit number and marketable weight per fruit.

Table 2.4 presents mean yields combined over both locations. None of the cultivars had significant total fruit weight yield differences between the 3.7 m and 7.3 m plots although yields tended to be higher than in the 2.4 m plots regardless of yield group. Percentage of culls was not significantly different between plot sizes for most cultivars when grouped by yield (Table 2.4 and Appendix Table 3.7). For most of the cultivars evaluated in each yield grouping, higher total fruit numbers were obtained in the larger plot sizes than in the 2.4 m plots. Marketable weight per fruit was significantly higher in the 2.4 m plots of 'Sultan' compared to either the 3.7 m or 7.3 m plots. Only scattered significant differences were found for marketable weight per fruit in high and low yielding cultivar plots of 'Fiesta' and 'Sugar Baby', respectively.

The cultivar by plot size interaction was not significant for total and marketable fruit weight (Table 2.4 and Appendix Table 3.7), while a highly significant interaction was found for marketable weight per fruit. The same interaction was significant at the 5% level for percentage of culls and total fruit number. A correlation between total yield and marketable yield of r=0.93 (significant at 1%) indicated that the response for each was similar. Correlation between total fruit weight and total fruit number was much lower (r=0.38), but was still significant at the 1% level.

Marketable yield by location was similar to the means for total yield over location shown in Table 2.3 (Appendix Table 3.6). No treatment produced higher yields at Clinton compared to Kinston. Marketable fruit weight for most cultivars in each yield grouping at Kinston was significantly higher when compared to the same treatments at Clinton. Marketable fruit number at Kinston for 'Fiesta' produced higher numbers of fruit in the 7.3 m plots compared to the 2.4 m plots. The 3.7 m plots of the same yield grouping were not as consistent for higher numbers of fruit than in the 2.4 m plots. Plots of 'Sultan' (mid-yielding) and 'Sugar Baby' (low-yielding) produced greater numbers of fruit in the 7.3 m plots compared to 2.4 plots, but the trend occurred for slightly more than half of the cultivars in this grouping.

Within the Kinston location, the 7.3 m and 3.7 m plots of 'Sultan' produced higher marketable fruit weight and number than the 2.4 m plots (Appendix Table 3.6). Among the low yielding cultivars, the 7.3 m plots consistently had higher marketable fruit weight and number than the 2.4 m plots. No consistently higher yields were found between plots sizes of the high yielding cultivars for either marketable fruit weight or number. However, fewer marketable yield differences were found within the Clinton location than were found at Kinston (Appendix Table 3.6). Although some plot sizes significantly varied in marketable yields, differences were not consistent within high, medium, and low yielding groups for marketable fruit weight and number.

Marketable yield data combined over both locations showed marketable fruit weight in both the 7.3 m or 3.7 m plots of 'Sultan' to be significantly higher than in the 2.4 m plots for most of the cultivars making up this yield group (Appendix Table 3.7). The 7.3 m plots of 'Sugar Baby' produced higher marketable fruit weight than 2.4 plots. Among the high yielding cultivars, a consistent trend for higher yields in either the 7.3 m or 3.7 m plots was not found. Results for marketable fruit number in Appendix Table 3.7 were similar to marketable fruit weight except for the low yielding cultivars where both the 7.3 m and 3.7 m plots produced significantly higher numbers of fruit than in the 2.4 m plots. The only occurrence where yields differed between the 3.7 m and 7.3 m plots occurred in marketable fruit weight for the cultivar 'Charleston Gray'.

Mean total yields grouped by plot size can be found in Table 2.5 and Appendix Table 3.8. The 2.4 m plots produced less total fruit weight (44.9 $Mg \cdot ha^{-1}$) than the 7.3 m plots (60.0 $Mg \cdot ha^{-1}$) (Table 2.5). Similar to yield trends among separate cultivars, 7.3 m plot and 3.7 m plot total fruit weights were not different from each other. Percentage of culls and marketable weight per fruit were similar across the different plot sizes (Table 2.5 and Appendix Table 3.8). For total and marketable fruit number, the 2.4 m plots produced fewer fruit than both the 3.7 m and 7.3 m plots. Fewer marketable fruit were produced in 2.4 m plots compared with both the 3.7 m and 7.3 m plots. Plot size significantly influenced total fruit weight, total fruit number, marketable fruit weight, marketable fruit number, and marketable weight per fruit. Percentage of culls also had a significant plot size effect, but only at the 5% level.

Yield data were also analyzed for repeatability for each location and replication of the experiment (Table 2.6). Correlations between locations were highly positive and significant at the 1% level, with r=0.81 for total fruit weight (r=0.86 for fruit number) and r=0.76 for marketable fruit weight (r=0.80 for fruit number).

Correlations between replications for the same traits were also highly positive and significant at the 1% level, but marketable yield correlations were not as high as those for total yield (Table 2.6). Correlations between replication one and replication two were r=0.78 for both total fruit weight and number. Marketable fruit weight had a correlation of r=0.69 between replication one and replication two while that for marketable fruit number was r=0.70. Correlations between replication one and replication three were slightly different. A correlation of r=0.77 was found for total fruit weight and r=0.87 for total fruit number. Marketable fruit weight had a slightly lower correlation (r=0.65) than replication one versus replication two while the correlation for marketable fruit number was higher (r=0.76). Replication two compared to replication three produced correlations of r=0.77 for both total and marketable fruit weight. Total fruit number had a correlation of r=0.85 while the correlation for marketable fruit number was r=0.83.

Standard deviations of yields for the plot sizes evaluated are noted in Table 2.9 and Appendix Table 3.11 as a second measure of repeatability. Of the three plot sizes (2.4 m, 3.7 m, 7.3 m) standard deviations for the 2.4 m plots were higher than the 7.3 m and 3.7 m plots for total fruit weight, total fruit number and marketable weight per fruit. Standard deviations were 12.1, 2.0 and 1.4 for total fruit weight, total fruit number and marketable weight per fruit, respectively. The 3.7 m and 7.3 m plots had similar standard deviations for total fruit number (1.3, 1.5, respectively) and marketable weight per fruit (0.9, 0.8, respectively). Standard deviations for total fruit weight, although lower than the standard deviation found for the 2.4 m plots were much higher than what was obtained with the 3.7 m and 7.3 m plots for the other variables (standard deviations of 7.2 and 9.8, respectively).

Standard deviation for marketable yield traits mirrored those for total yields (Appendix Table 3.11). The 2.4 m plots had the highest standard deviations and consequently error for marketable fruit weight (14.5) and marketable fruit number (2.2). A standard deviation of 1.2 was obtained for marketable fruit number from both the 3.7 m and

7.3 m plots. Marketable fruit weight standard deviations, like those for total fruit weight, were quite different, having deviations of 7.3 and 9.2 for the 3.7 m and 7.3 m plots, respectively.

Mean yield data for each cultivar was used to generate yield rankings from highest to lowest yielding based on plot size. Table 2.7 and Appendix Table 3.9 show yield rankings separated by each location tested. The 7.3 m plots were used as a standard yield ranking giving the highest yielding cultivar rank=1 and the lowest rank=13. At the Kinston location, if the top six cultivars identified in the 7.3 m plots for total fruit weight were grown in the 3.7 m plots, four of the top six yielding cultivars would be correctly identified while the 2.4 m plots also would identify four of the top six (Table 2.7). For the Clinton location, the 3.7 m plots would be able to correctly identify four of the top six yielding cultivars. The 2.4 m plots would have identified five of the top six. Using the same criteria of taking the top six cultivars identified in the 7.3 m plots, marketable yield rankings according to location are presented in Appendix Table 3.9. At Kinston, the 3.7 m plots would have identified five of the top six cultivars while the 2.4 m plots would have identified four of the top six. For the Clinton location, using either the 3.7 m or 2.4 m plots would each have correctly identified three of the top six yielding cultivars.

In terms of the ability of identifying the lowest yielding cultivars, total yields using 3.7 m plots at Kinston would have correctly revealed three of the lowest six yielding cultivars while the 2.4 m plots would have found four of the lowest six (Table 2.7). At Clinton, the 3.7 m plots would be able to reveal four of the lowest six while the 2.4 m plots would correctly reveal all six of the lowest yielding cultivars that the 7.3 m plots would identify. In Appendix Table 3.9 for marketable yield, the 3.7 m plots at Kinston would identify four of the lowest six while the 2.4 m plots would have revealed five of the lowest six yielding cultivars. At the Clinton location, the 3.7 m plots would be able to determine four of the lowest six and the 2.4 m plots would identify four of the lowest six as well.

When rankings were determined over both locations combined, those corresponding to total yield mirrored the identifying ability of top yielders at Clinton and the low yielding cultivars at Kinston (Table 2.8). The 3.7 m plots were able to identify four of the top six yielding cultivars found in the 7.3 m plots while the 2.4 m plots identified five of the top six. For identification of the lowest yielding cultivars, the 3.7 m plots could identify three of the lowest six and the 2.4 m plots were able to find four of the lowest six. Under marketable yield rankings, the 3.7 m plots in Appendix Table 3.10 were able to identify four of the top six yielding cultivars and three of the lowest six. Use of the 2.4 m plots were able to identify four of the top six yielding and four of the six lowest for marketable yield.

Output from regression analysis for fruit yields of the 3.7 m and 2.4 m plots regressed onto 7.3 m plots can be found in Table 2.10 and Appendix Table 3.12. For all independent variables in the equations from Table 2.10 and Appendix Table 3.12, p-values for parameter estimate t-tests showed the traits to be significantly different from zero and thus different from corresponding traits in the 7.3 m plots (data not shown). As shown in Table 2.10, R^2 for regression lines using 3.7 m plots were higher than those for the 2.4 m plots. R^2s found were 0.90 using total fruit weight in the 3.7 m plots, 0.90 for total fruit number in the 3.7 m plots, 0.76 for total fruit weight in 2.4 m plots, and 0.72 for total fruit number in 2.4 m plots. The same trend was also found for R^2 using marketable fruit weights and number of fruit per hectare for regression onto 7.3 m plots (Appendix Table 3.12). In addition to larger amounts of variation being explained by regression models using 3.7 m plots data, mean square errors demonstrated a lower trend for the 3.7 m plot data than for the 2.4 m plot data (data not shown). Line intercepts of regression models were 2.65 using total fruit weight from the 3.7 m plot data, 1.67 using total fruit number per hectare for the 3.7 m plot data, 10.89 for total weight for the 2.4 m plot data, and 3.30 for total fruit number per hectare for the 2.4 m plot data. These findings coupled with the 3.7 m plot data having lower parameter estimates than the 2.4 m plots of 0.96 (total fruit weight

3.7 m), 1.09 (total fruit weight 2.4 m), 0.85 (total fruit number per hectare 3.7 m), and 0.94 (total fruit number per hectare 2.4 m) indicated that the 3.7 m plot yields contributed more in predicting yields in the 7.3 m plots than did the 2.4 m plots. Coefficients of variation in this table were lower for prediction equations using the 3.7 m plot data whether for total fruit weight or total fruit number than for the 2.4 m plot data. Coefficients of variation were CV=12.01 and CV=18.14 for the 3.7 m and 2.4 m plot total fruit weights, respectively (Table 2.10). The same trends for lower intercepts, parameter estimates, and coefficients of variation of the 3.7 m marketable yield data were also found (Appendix Table 3.12). The only exception was a slightly higher parameter estimate of 0.85 for marketable fruit number in the 3.7 m plots versus 0.82 for the 2.4 m plots. The difference was small enough to lack any significant effect.

Discussion

Higher yields at Kinston may be due to better soils, timing of fertilizer application, and better overall field maintenance at that location. This could also be an explanation for the highly significant location effects seen. Although N, P, and K were applied at higher rates at Clinton than at Kinston, a longer time elapsed before any subsequent fertilizer application. Since fertilizer was applied during transplanting and through drip irrigation less than a week after transplanting at Kinston, transplants were able to establish themselves much faster than at Clinton. Transplants at Clinton had no fertilizer added until three weeks after transplanting, and were transplanted into beds having been fertilized about one month earlier. Fertilizing this far in advance of a crop gave plenty of time for nutrients to leach, volatilize and otherwise transform into forms unavailable to the transplants.

Plots at Kinston were better maintained compared with Clinton, which had higher weed pressure. Disease and insect incidence was lower at Kinston. The few leaves found with problems were diagnosed to be anthracnose, wind or spray damage. Several fruit and tissue samples from Clinton resulted in identification of gummy stem blight and heavy insect infestations of spider mites, thrips and leaf miners. Less biotic stress at Kinston would probably resulted in more vine and fruit production than was possible by plants at Clinton.

As a consequence of the slightly poorer performance of the 3.7 m plots only when cultivars were ranked according to yield, breeders of watermelon and other cucurbits should not be too hasty in altering plot sizes. Instead, breeding goals should be re-evaluated noting variable heritabilities, correlations, expected genetic advance, genetic variation and breeding methods used just to name a few. All of the above may or may not influence what plot size should be used to ensure a great enough sample size that sufficient breeding progress can be made.

Important traits for watermelon have been studied in numerous experiments. High broad sense heritabilities when data were pooled have been found for the traits 100 seed weight (h^2=0.89), average fruit weight (h^2=0.60), yield per vine (h^2=0.59), seeds per fruit (h^2=0.58), fruit shape index, rind thickness, total soluble solids, total water-soluble sugars, and vitamin C content (Crajendran and Thamburaj, 1994; Gill and Kumar, 1986). In addition, phenotypic coefficients of variation have been noted at 88.34% for the trait yield per vine. The highest genotypic coefficient of variation was 67.60% for yield per vine (Crajendran and Thamburaj, 1994). Only total soluble solids have shown a narrow range of phenotypic variation (Gill and Kumar, 1986). These same two studies also found estimates of genetic advance to be highest for the traits yield per vine (106.57%), sex ratio (87.56%), 100 seed weight (79.00%), average fruit weight (71.76%), number of seeds per fruit (69.87%), and rind thickness (41.13%) (Crajendran and Thamburaj, 1994; Gill and Kumar, 1986). It should be noted as well that the two studies had significant genotype by season interactions that may alter quality trait expression.

In determining selection indices for watermelon, high heritabilities coupled with high estimates of genetic advance for the previously mentioned traits show promise for improvement through selection. However, some negative correlations between traits have been documented. While fruit per plant and yield per plant have positive correlations, fruit per plant and fruit size have a negative one (Feher, 1993; Partap et al., 1984). Negative correlations have also been found between flesh weight and nodes of first female flower, flesh weight versus seeds per kilogram of flesh and 100 seed weight versus total soluble solids (Sidhu and Brar, 1981). In the same study, strong positive correlations were found for 100 seed weight with yield and flesh weight with days to maturity. Consequently, Sidhu and Brar (1981) suggested maximum selection weighting should be given to flesh weight, number of nodes of first female flower, 100 seed weight, and weight of fruit.

Research involving the related cucurbit cucumber has also noted the positive effects of high heritabilities and variances in selection of better cultivars. In a study using elite, medium and wide genetically based populations, wide based populations showed the widest variation. Heritabilities for total, marketable, and early yield ranged from 0.18 to 0.25, 0.12 to 0.22 and 0.03 to 0.20 for elite, medium and wide base populations, respectively (Strefeler and Wehner, 1986). This wide base population having large additive variance for all traits studied (total yield, marketable yield, early yield, percentage of culls, shape, color, seed cell size, and overall performance) had the highest predicted means after 11 cycles of full-sib family selection for all traits except for fruit shape and overall performance (Strefeler and Wehner, 1986). Various other cucumber studies noted expected progress to be slow for low heritability traits unless associated genetic variances can be increased (Serquen et al., 1997; Smith et al., 1978). Without the increase, plot sizes would have to be increased making the process more expensive in terms of time, labor, and land to achieve acceptable rates of genetic advance.

During the course of a breeding program, plot size is generally restricted only in early breeding stages. Early segregating generations may generate few seed such that testing may only be done in single hill plots or very small plots. Traits with high narrow sense heritability (greater than 50%) can effectively be tested with single plant hills in early generations while low heritability traits (less than 25%) such as yield, which was measured in this experiment, would be better evaluated in small plots associated with intermediate or later testing stages (Wehner, 1987). During intermediate testing stages, information is often collected from large numbers of lines. This can rapidly use up limited land and labor thus encouraging a reduction in plot size without reducing information gained whenever possible. Single plant hills or small unbordered plots have been suggested as sufficient for gathering relative performance data during intermediate trialing stages (Wehner, 1987). In the final stages of testing, large quantities of seed are generally available and accurate information is desired from a few existing lines. At this stage, medium to large plots are used sometimes having border rows.

Results from this experiment indicated that 3.7 m plots provide yield information just as well as 7.3 m plots. We found a plot size main effect to be significant at the 5% level for all yield traits considered. The 2.4 m plots over all cultivars had the lowest total yields with 44.9 $\mathrm{Mg{\cdot}ha^{-1}}$ compared to 60.0 $\mathrm{Mg{\cdot}ha^{-1}}$ for the 7.3 m plots. Whether separated by cultivar or not, a consistent trend was found demonstrating no significant yield differences between the 3.7 m and 7.3 m plots (Table 2.5 and Appendix 3.13). Differences between the 2.4 m plots and 7.3 m plots as well as between the 2.4 m plots and 3.7 m plots appeared more frequently. In addition, the 2.4 m plots over all cultivars tended to produce fewer fruit per hectare than both the 3.7 m and 7.3 m plots. These findings may best be applied to either intermediate or final testing stages. Use in intermediate stages would allow more breeding lines to be evaluated in a given amount of land without sacrificing precision of the information gained.

Altering plots to increase the accuracy of data may be accomplished in two ways. The first, plot shape, is through the use of either rectangular or square blocks. Use of rectangular blocks generally increases variability within and decreases variability among blocks. This can be advantageous where within plot variability is not of interest. When blocks are desired that are as uniform as possible, square blocks can be used. Square blocks cover the smallest field area thus reducing soil heterogeneity effects. Variability within blocks will also be reduced while increasing that among blocks.

This experiment, except for the 2.4 m plots, was run using rectangular plots in the 3.7 m and 7.3 m single row plots. Concern arises in the use of rectangular plots that border competition from adjacent rows, which may bias plot yields. Competition, according to Fasoula (1990) may be divided into auto-competition, allo-competition, and nil-competition. Auto competition occurs when genetically identical genotypes compete evenly for resources to suppress yield in an even fashion. Allo-competition results when different genotypes compete in a dissimilar manner for resources resulting in uneven yield bias. The third competition type, nil-competition, is the complete absence of competition. Our evaluation of 13 different cultivars covering a wide range of yields, 'Hope Red Flesh' versus 'New Hampshire Midget' and growth habits, 'Charleston Gray' versus 'Sugar Baby' is representative of possible allo-competition effects. Cultivars were not grouped according to growth habit such as vine lengths. A negative correlation between yield and competing ability is speculated as being general in nature across all crops (Fasoula, 1990). Fortunately, a previous study on border competition effects did find competition bias based on growth types, but the interactions did not change rankings of high versus low yielding cultivars (Neppl, 2001).

A sure way to remove competition bias would be to use either well bordered plots or unbordered plots with careful cultivar choice and plot layout. Large plots, while providing more information also increase the cost per unit of information when border rows are used.

Border rows provide auto-competition within the plot to eliminate yield bias while providing competition to outside rows of other plots. The extra rows are then discarded to eliminate any potential yield bias resulting in the harvest of net plots. Use of net plots allows for a smaller sample area while making random effects more important and lowering heritability. Large plots on the contrary provide greater sample area thus decreasing the coefficient of variation (Kramer et al., 1982). Trials run in unbordered plots may be more of a necessity rather than choice due to limited seed or propagule availability. Unbordered plots can reduce yield bias through grouping cultivars having similar competing ability or using alleys to separate plots.

A second way of altering plots, changing plot size, also serves to improve the precision and repeatability of a trial. Determining the optimum plot size of a trial or experiment is similar to what this experiment attempted to accomplish. Using optimum plot size succeeds in minimizing the cost per unit of information gained or as Swallow and Wehner (1986) explain for experimental design, "information is the reciprocal of variance". No matter what the plot size of a trial is, the more homogeneous plots are in a block, correlation between plots increases while variance decreases for treatment comparisons (Binns, 1982). H. Fairfield Smith combined the above effects into an empirical law stating that the variance of yield V_X on a plot size X is inversely proportional to a power of X: $V_X = V_1/X^b$ (Smith, 1938). The power of X is a measure of the heterogeneity in a field and usually must be estimated. Through a measure of intrablock correlation obtained from ANOVA of a randomized-block experiment, Lin and Binns (1984) have established a set of rules for estimating the level of heterogeneity. Their rules state that:

If the intrablock correlation is >0.5, incomplete block designs or reduced plot size in order to increases replication should be used. If the intrablock correlation is <0.1, increases in plot sizes would be effective. Finally, if the intrablock correlation is between 0.1 and 0.5, a combination of increasing plot size and decreasing the number of plots per block would be useful (Lin and Binns, 1984).

A study conducted by Swallow and Wehner (1986) referred to the above parameter (b) as being more an index of the degree of correlation between neighboring plots than a measure of soil heterogeneity. Consequently, like Lin and Binns' conclusions, when neighboring plots are highly intercorrelated (i.e. small b), increasing plot size will not result in much of a benefit. However, if b is large, plots that are smaller than optimum will also be cost inefficient (Swallow and Wehner, 1986).

In terms of repeatability, 3.7 m plots were found to be more repeatable than 2.4 m plots along with high correlations for total fruit weight yield between the two locations. Standard deviations for the 2.4 m plots were also higher (12.1) for total fruit weight than for both the 7.3 m plots (9.8) and 3.7 m plots (7.2). In addition, a cultivar by location (genotype by environment) interaction was found to be significant for total fruit weight at the 1% level. The interaction was slight, indicating that some other factor or lack of a factor could be contributing to the 3.7 m plots producing better representative yields of the 7.3 m plots than the 2.4 m plots did.

When selecting a field site, it is advantageous that soil heterogeneity be minimized. It is understood that soil heterogeneity can be a significant cause of experimental error. Soil heterogeneity can exist in two main forms. The first, patched heterogeneity, is manifested in patches of ground within a field that are either higher or lower in fertility than surrounding ground. Since the patches occur at random across a field, the shape of a plot will have little effect on reducing heterogeneity's influence. Instead, it is suggested that plot size not be altered and to use increased replication so that any soil effects are reduced through averaging replication data. Additionally, long plots have a better random chance of being unaffected in this soil situation (Christidis, 1931).

The second form of soil heterogeneity is a gradual change in fertility across a field. In this situation, Zhang, et al. (1994) have found that plots laid out in the same direction as the change in heterogeneity (i.e. parallel) are more efficient at reducing variability. In support of the 3.7 m plots having less variability by means of a lower standard deviation compared to the 2.4 m plots, other researchers have noted that long narrow plots tend to have on average less variability than square plots (Christidis, 1931; Smith, 1938; Zhang et al., 1994). Through a blank experiment on small plots of wheat, Smith (1938) concluded that plots of single plants comprising "test area" were unlikely to be efficient in a gain of accuracy relative to soil heterogeneity effects. Instead, for an increase in plot size, a proportional decrease in variability was found.

Reduced variability in longer plots for this experiment was manifested in the fact that all of the 7.3 m and 3.7 m plot total yields were not significantly different from each other. The 2.4 m plots seemed to show variability based on cultivar since only the cultivars Fiesta, Starbrite, Jubilee, Allsweet, Navajo Sweet, Sultan, and Sugar Baby plots were significantly lower yielding than either the 3.7 m or 7.3 m plots. We also found that the 3.7 m plots by means of regression analysis are better at predicting yields in the larger 7.3 m plots than the 2.4 m plots were. Similar results in support of small plot use and rejection of single plant plots in prediction of yield have been found in cucumber (Smith and Lower, 1978; Wehner, 1986; Wehner and Miller, 1984). Mid-size plots of maize (*Zea mays L.*) consisting of 15 to 20 plants in three to four square meter plots were also more efficient in discriminating yield traits than one square meter plots with five plants (Chaves and Filho, 1992). However, not all studies have found supporting results for smaller plots sizes rather than plots with very few plants. One study using rye, while noting higher heritabilities from small plots than from single plant plots, also found expression of grain yield to be basically the same among different plot sizes despite differences in competition (Rattunde et al., 1991). In sweetpotato trials, increases in plot size or number of replications did not individually contribute to reduced experimental error, but results pointed toward a combination of the two in achieving desired reductions (Vallejo and Mendoza, 1992).

From regression analysis of using the 3.7 m and 2.4 m plots to predict 7.3 m plot yields, we found R^2 for the 3.7 m plots to explain more of the variation seen (R^2=0.90) than the 2.4 m plots (R^2=0.76) for total yields. Additionally, the 3.7 m plots showed a lower trend in mean square error. The 3.7 m plot data also produced lower parameter estimates for regression lines than the 2.4 m plots. This indicates that 3.7 m plot yields have a higher contribution at predicting yields than would be found in the 2.4 m plots. Further support for the use of small 3.7 m plots was found from the smaller coefficient of variation obtained from using the 3.7 m data as a predictor of 7.3 m plot yields. Research on proso millet and maize indicated that as plot size and harvest size increased, CV tended to decrease whether or not a plot had a border (Chaves, and Filho, 1992; Nelson, 1981). Since the coefficient of variation is a measure of the variability of values relative to the mean, our low standard deviations found for the 3.7 m plots as well as the low CVs demonstrates that 3.7 m plot yields are much more stable in terms of yield than 2.4 m plots and therefore a better predictor of larger plot yields.

The minimum plot size for any experiment is a single plant while the maximum depends upon the amount of resources available. The question then becomes what size of plot can best be used to minimize resources used while maximizing the information obtained from a trial. The conclusion of this experiment is that 3.7 m plots would be the best plot size to use. Data gathered has shown the use of this plot size provides a large enough sample of material to accurately predict the same yields in trials run with larger plots. Use of 2.4 m plots provides only one plant from which selections can be made. This extreme of size also results in higher error variances. The 3.7 m plots possessed lower errors and fairly consistent yields mirroring those of the 7.3 m plots over the range in cultivars examined. Further study of plot size effects using even more extremes of cultivars such as citron or bush-type watermelon may prove useful. Since this experiment used 2.4 m alleys between the 3.7 m and 7.3 m plots, each of those plots had an additional 2.4 m of growing space. We corrected for this extra space, but for further support, it may be helpful to run the experiment without alleys and see if the same conclusions would be reached. Additionally, yield rankings due to plot size were quite similar between the 2.4 m and 3.7 m plots. In some cases, 3.7 m appeared to be at a disadvantage in identifying top yielding cultivars. Consequently this aspect of plot size should be explored further.

Literature Cited

Binns, M. R. 1982. The choice of plot size in randomized block experiments. J. Amer. Soc. Hort. Sci. 107(1):17-19.

Chaves, L. J. and J. B. de M. Filho. 1992. Plot size for progeny selection in maize (*Zea maize L.*). Theor. Appl. Genet. 84:963-970.

Crajendran, P. and S. Thamburaj. 1994. Genetic variability in biometrical traits in watermelon (*Citrullus lanatus*). Indian Journal of Agricultural Science. 64(1):5-8.

Christidis, B. G. 1931. The importance of the shape of plots in field experimentation. Journal of Agricultural Science. 2:14-37.

Fasoula, D. A. 1990. Correlations between auto-, allo-, and nil-competition and their implications in plant breeding. Euphytica. 50:57-62.

Feher, T. 1993. Watermelon. p.295-315. In Kalloo, G. and B. O. Bergh (eds.). Genetic improvement of vegetable crops. Pergamon Press Ltd., Tarrytown, New York.

Gill, B. S. and J. C. Kumar. 1986. Variability in genetic stock and heritable components in watermelon. J. Res. Punjab Agric. Univ. 23(4):583-588.

Kramer, J. W., J. W. Van Ooijen, and C. J. T. Spitters. 1982. Selection for yield in small plots of spring wheat. Euphytica. 31:549-564.

Lin, C. S. and M. R. Binns. 1984. Working rules for determining the plot size and numbers of plots per block in field experiments. J. Agric. Sci., Camb. 103:11-15.

National Watermelon Promotion Board. 2001. "Fields of green." National Watermelon Promotion Board. http://www.watermelon.org/ (7 March 2001).

Nelson, L. A. 1981. Yield variability in proso millet due to plot size. Agron. J. 73:23-25.

Neppl, G. P. 2001. Chapter 1: Interaction of border and center rows in watermelon yield trials. MS Thesis, Dept. of Horticulture, North Carolina State Univ., Raleigh.

Neppl, G.P. and T.C. Wehner. 2001a. Survey of watermelon trialing methods in the U.S. Cucurbit Genetics Cooperative Report 24: in press.

Partap, P. S., N. Mehrotra, R. N. Vashistha, and M. L. Pandita. 1984. Biparental crossing in watermelon (*Citrullus lanatus* (Thunb.) Mansf.). Genetica Agraria 38(4):379-385.

Rattunde, H. F. W., T. Miedaner, and H. H. Geiger. 1991. Biometrical analysis of alternative plot types for selection in rye. Euphytica. 57:141-150.

Sanders, D. C. (ed.). 1999. Watermelon. p.115-118. 1999 North Carolina commercial vegetable recommendations. North Carolina Cooperative Extension Service, Raleigh North Carolina.

Serquen, F. C., J. Bacher, and J. E. Staub. 1997. Genetic analysis of yield components in cucumber at low plant density. J. Amer. Soc. Hort. Sci. 122(4):522-528.

Sidhu, A. S. and J. S. Brar. 1981. Correlation and path coefficient analysis for yield, quality and earliness in watermelon [*Citrullus lanatus* (Thunb.) Mansf.]. Indian J. Agric. Res. 15(1):33-37.

Smith, H. F. 1938. An empirical law describing heterogeneity in the yields of agricultural crops. Journal of Agricultural Science. 28:1-23.

Smith, O. S. and R. L. Lower. 1978. Field plot techniques for selecting increased once-over harvest yields in pickling cucumbers. J. Amer. Soc. Hort. Sci. 103(1):92-94.

Smith, O. S., R. L. Lower, and R. H. Moll. 1978. Estimates of heritabilities and variance components in pickling cucumber. J. Amer. Soc. Hort. Sci. 103(2):222-225.

Strefeler, M. S. and T. C. Wehner. 1986. Estimates of heritabilities and genetic variances of three yield and five quality traits in three fresh-market cucumber populations. J. Amer. Soc. Hort. Sci. 111(4):599-605.

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size determination and its application to cucumber yield trials. Euphytica. 35:421-432.

Vallejo, R. L. and H. A. Mendoza. 1992. Plot technique studies on sweetpotato yield trials. J. Amer. Soc. Hort. Sci. 117(3):508-511.

Wehner, T. C. 1986. Efficiency of three single-harvest tests for evaluation of yield in pickling cucumber. Euphytica. 35:493-501.

Wehner, T. C. 1987. Efficient methods for testing vegetable cultivars. HortScience. 22(6):1220-1223.

Wehner, T. C. 1988. Effect of end-border condition on small-plot yield of cucumber. Euphytica 38:113-119.

Wehner, T. C. and C. H. Miller. 1984. Efficiency of single-harvest methods for measurement of yield in fresh-market cucumbers. J. Amer. Soc. Hort. Sci. 109(5):659-664.

Wehner, T. C. and W. H. Swallow. 1984. Optimum plot size for once-over harvest of pickling and fresh-market cucumbers. Cucurbit Genetics Cooperative Report. 7:35.

Zhang, R., A. W. Warrick, and D. E. Myers. 1994. Heterogeneity, plot shape effect and optimum plot size. Geoderma. 62:183-197.

Table 2.1. Analysis of variance for total yield for watermelon with plot size as a factor using three plot sizes (7.3m, 3.7m, and 2.4m) and thirteen cultivars tested at two locations (Kinston and Clinton).[z]

Source of variation	df	Mean squares for total yield Fruit wt. ($Mg\cdot ha^{-1}$)	Fruit no. ($th\cdot ha^{-1}$)	Wt./fruit (kg)	Culls (%)
Location	1	43299.987**	562.6759**	49.505**	9.868
Replication(Loc.)	4	279.884	2.991	1.460	20.288
Size	2	5739.181**	197.894**	19.001**	354.868*
Location X Size	2	846.818	6.772	0.783	23.775
Rep. X Size(Loc.)	8	389.424	8.842	1.692	68.360
Cultivar	12	3102.784**	185.802**	137.466**	496.287**
Cultivar X Size	24	107.909	4.416*	3.890**	88.361*
Cultivar X Loc.	12	468.951**	16.006**	2.498*	58.339
Cultivar X Loc. X Size	24	101.300	5.687**	3.083**	65.315
Error	144	98.066	2.604	1.181	46.295

[z] Analyses performed for mean yields (plot size as a variable values were not as useful).

**,* = F ratio significant at 0.01 or 0.05 level of significance, respectively.

Table 2.2. Analysis of variance for marketable yield for watermelon with plot size as a factor using three plot sizes (7.3m, 3.7m, and 2.4m) and thirteen cultivars tested at two locations (Kinston and Clinton).[z]

Source of variation	df	Mean squares for marketable yield Fruit wt. ($Mg·ha^{-1}$)	Fruit no. ($th·ha^{-1}$)	wt./fruit (kg)
Location	1	35498.818**	416.772**	52.937**
Replication(Loc.)	4	393.270	4.585	1.256
Size	2	4713.958**	140.374**	16.172**
Location X Size	2	722.837	4.533	0.427
Rep. X Size(Loc.)	8	504.098	8.940	1.752
Cultivar	12	2266.254**	111.821**	147.733**
Cultivar X Size	24	152.0678	4.210*	3.589**
Cultivar X Loc.	12	421.216**	6.494**	2.747**
Cultivar X Loc. X Size	24	121.678	6.065**	2.503**
Error	144	115.922	2.568	1.156

[z] Analyses performed for mean yields (plot size as a variable values were not as useful).

**,* = F ratio significant at 0.01 or 0.05 level of significance, respectively.

Table 2.3. Yield of 13 watermelon cultivars tested in three plot sizes and two locations.[z]

Cultivar	Plot size (m)	Total yield ($Mg\cdot ha^{-1}$)	Culls (%)	Total yield ($th\cdot ha^{-1}$)	Wt/Frt (kg)
Clinton					
Hopi Red Flesh	2.4	49.4	8.9	8.5	6.4
	3.7	62.4	9.2	14.3	5.0
	7.3	50.8	35.5	11.5	5.4
Starbrite	2.4	35.9	3.3	3.6	10.4
	3.7	45.1	5.7	5.4	9.5
	7.3	49.3	2.0	5.9	8.7
Fiesta	2.4	40.5	0.0	4.9	8.3
	3.7	49.5	7.4	6.1	8.3
	7.3	50.7	4.0	6.6	7.8
Regency	2.4	45.0	0.0	4.9	9.3
	3.7	47.8	0.7	5.9	8.1
	7.3	46.4	1.8	5.2	9.1
Jubilee	2.4	44.8	10.0	4.0	11.6
	3.7	54.3	10.1	5.0	11.1
	7.3	50.5	16.2	5.7	9.0

continued next page

Table 2.3 (continued).

Cultivar	Plot size (m)	Total yield ($Mg\cdot ha^{-1}$)	Culls (%)	Total yield ($th\cdot ha^{-1}$)	Wt/Frt (kg)
Charleston Gray	2.4	36.9	8.9	4.5	9.8
	3.7	44.8	12.0	6.3	7.8
	7.3	54.2	3.5	7.1	7.8
Allsweet	2.4	48.3	6.7	5.4	9.9
	3.7	46.4	3.2	4.8	9.7
	7.3	45.8	18.1	5.2	9.5
Florida Favorite	2.4	28.2	2.2	4.9	5.9
	3.7	45.7	2.3	8.2	6.2
	7.3	36.2	8.3	5.9	6.6
Navajo Sweet	2.4	32.9	8.0	6.3	5.6
	3.7	48.7	3.8	9.0	5.5
	7.3	45.6	11.5	9.1	5.3
Sultan	2.4	29.8	0.0	2.2	13.9
	3.7	42.4	11.1	4.8	9.7
	7.3	41.7	5.4	5.2	8.7
Crimson Sweet	2.4	32.6	2.2	4.5	6.7
	3.7	45.8	5.6	5.6	9.4
	7.3	44.9	8.8	5.4	8.9

continued next page

Table 2.3 (continued).

Cultivar	Plot size (m)	Total yield (Mg·ha^{-1})	Culls (%)	Total yield (th·ha^{-1})	Wt/Frt (kg)
Sugar Baby	2.4	21.8	0.0	4.5	4.9
	3.7	28.5	0.0	5.9	4.9
	7.3	31.0	1.0	7.7	4.1
NH Midget	2.4	8.9	0.0	5.8	1.5
	3.7	20.9	2.4	14.0	1.5
	7.3	22.1	2.3	14.2	1.5
Kinston					
Hopi Red Flesh	2.4	82.7	19.7	16.1	5.9
	3.7	97.8	27.1	20.8	5.1
	7.3	91.5	26.5	20.7	4.9
Starbrite	2.4	75.4	0.0	6.7	11.7
	3.7	95.2	2.8	8.4	11.9
	7.3	93.8	5.3	9.4	10.5
Fiesta	2.4	69.1	0.0	6.7	10.1
	3.7	90.9	6.8	10.4	9.1
	7.3	94.2	3.1	10.0	9.1

continued next page

Table 2.3 (continued).

Cultivar	Plot size (m)	Total yield (Mg·ha^{-1})	Culls (%)	Total yield (th·ha^{-1})	Wt/Frt (kg)
Regency	2.4	67.1	2.2	6.7	10.0
	3.7	76.6	0.0	7.9	10.5
	7.3	84.3	2.4	9.2	9.8
Jubilee	2.4	43.3	10.0	4.9	9.0
	3.7	74.8	9.7	6.3	12.4
	7.3	82.5	5.9	7.4	12.2
Charleston Gray	2.4	60.4	8.3	5.8	11.1
	3.7	69.2	4.4	6.6	10.4
	7.3	81.1	7.9	9.2	9.2
Allsweet	2.4	46.3	0.0	3.6	13.3
	3.7	85.6	5.6	8.8	10.9
	7.3	73.9	22.7	8.6	9.6
Florida Favorite	2.4	62.0	17.8	7.2	10.1
	3.7	82.1	2.9	11.5	6.8
	7.3	75.1	11.0	11.2	7.0
Navajo Sweet	2.4	44.3	0.0	6.7	6.8
	3.7	79.1	3.3	12.4	6.0
	7.3	75.8	0.0	12.9	5.7

continued next page

Table 2.3 (continued).

Cultivar	Plot size (m)	Total yield ($Mg \cdot ha^{-1}$)	Culls (%)	Total yield ($th \cdot ha^{-1}$)	Wt/Frt (kg)
Sultan	2.4	52.0	3.3	4.5	12.6
	3.7	79.5	1.5	7.5	10.8
	7.3	82.4	9.8	9.0	9.5
Crimson Sweet	2.4	54.5	0.0	6.3	9.3
	3.7	60.9	13.3	5.7	10.0
	7.3	77.9	2.8	8.6	10.1
Sugar Baby	2.4	23.3	0.0	5.4	4.0
	3.7	41.2	5.6	8.6	4.8
	7.3	49.5	2.4	10.8	4.5
NH Midget	2.4	31.9	3.3	17.5	2.0
	3.7	32.5	3.2	18.5	1.8
	7.3	28.0	7.4	16.6	1.9
LSD (5%)		15.8	10.9	2.6	1.7
F ratio (cultivar X loc X plot size)		1.0ns	1.4ns	2.2**	2.2**
Correlation (Total yield Clinton vs. Kinston) = 0.81**					

[z] Data are means of 3 replications summed over 5 harvests. Cultivars are listed in descending order from highest to lowest yield averaged over all plot sizes and locations.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 2.4. Yield of 13 watermelon cultivars using three plot sizes tested at two locations.[z]

Cultivar	Plot size (m)	Total yield ($Mg\cdot ha^{-1}$)	Culls (%)	Total yield ($th\cdot ha^{-1}$)	Wt/Frt (kg)
Hopi Red Flesh	2.4	66.0	14.3	12.3	6.1
	3.7	80.1	18.2	17.6	5.1
	7.3	71.2	31.0	16.1	5.1
Starbrite	2.4	55.6	1.7	5.2	11.0
	3.7	70.1	4.3	6.9	10.7
	7.3	71.6	3.6	7.7	9.6
Fiesta	2.4	54.8	0.0	5.8	9.2
	3.7	70.2	7.1	8.2	8.7
	7.3	72.4	3.6	8.3	8.5
Regency	2.4	56.1	1.1	5.8	9.7
	3.7	62.2	0.4	6.9	9.3
	7.3	65.3	2.1	7.2	9.5

continued next page

Table 2.4 (continued).

Cultivar	Plot size (m)	Total yield ($Mg{\cdot}ha^{-1}$)	Culls (%)	Total yield ($th{\cdot}ha^{-1}$)	Wt/Frt (kg)
Jubilee	2.4	44.1	10.0	4.5	10.5
	3.7	64.6	9.9	5.6	11.7
	7.3	66.5	11.1	6.6	10.6
Charleston Gray	2.4	48.6	8.6	5.2	10.5
	3.7	57.0	8.2	6.5	9.1
	7.3	67.6	5.7	8.1	8.5
Allsweet	2.4	47.3	3.3	4.5	11.6
	3.7	66.0	4.4	6.8	10.3
	7.3	59.8	20.4	6.9	9.6
Florida Favorite	2.4	45.1	10.0	6.1	8.0
	3.7	63.9	2.6	9.9	6.5
	7.3	55.7	9.6	8.6	6.8
Navajo Sweet	2.4	38.6	4.0	6.5	6.2
	3.7	63.9	3.6	10.7	5.8
	7.3	60.7	5.7	11.0	5.5
Sultan	2.4	40.9	1.7	3.4	13.2
	3.7	60.9	6.3	6.2	10.3
	7.3	62.0	7.6	7.1	9.1

continued next page

Table 2.4 (continued).

Cultivar	Plot size (m)	Total yield ($Mg \cdot ha^{-1}$)	Culls (%)	Total yield ($th \cdot ha^{-1}$)	Wt/Frt (kg)
Crimson Sweet	2.4	43.5	1.1	5.4	8.0
	3.7	53.3	9.4	5.6	9.7
	7.3	61.4	5.8	7.0	9.5
Sugar Baby	2.4	22.5	0.0	4.9	4.5
	3.7	34.9	2.8	7.3	4.8
	7.3	40.3	1.7	9.2	4.3
NH Midget	2.4	20.4	1.7	11.7	1.7
	3.7	26.7	2.8	16.2	1.7
	7.3	25.0	4.9	15.4	1.7
LSD (5%)		11.2	7.7	1.8	1.2
Mean		54.8	6.4	8.1	8.0
F ratio (cultivar X plot size)		1.1ns	1.9*	1.7*	3.1**

Correlation (Total yield vs. Marketable yield) = 0.93**

Correlation (Total yield vs. Total thousands of fruit) = 0.38**

---

[z] Data are means of 3 replications and two locations summed over 5 harvests. Cultivars are listed in descending order from highest to lowest yield averaged over all plot sizes and locations.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 2.5. Mean yield of three plot sizes using 13 watermelon cultivars tested at two locations.[z]

Plot size (m)	Total yield ($Mg \cdot ha^{-1}$)	Culls (%)	Total yield ($th \cdot ha^{-1}$)	Wt/Frt (kg)
2.4	44.9	4.4	6.2	8.5
3.7	59.5	6.2	8.8	8.0
7.3	60.0	8.7	9.2	7.5
LSD (5%)	11.2	7.7	1.8	1.2
F ratio (plot size)	14.7**	5.2*	22.4**	9.2**

[z] Data are means of 3 replications, two locations, and 13 cultivars summed over 5 harvests.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 2.6. Correlations of three trialing plot sizes tested at two locations.[z]

Location and replication	Total yield ($Mg{\cdot}ha^{-1}$)	Market yield ($Mg{\cdot}ha^{-1}$)	Total yield ($th{\cdot}ha^{-1}$)	Market yield ($th{\cdot}ha^{-1}$)
Location				
Clinton vs. Kinston	0.81**	0.76**	0.86**	0.80**
Replication				
1 vs. 2	0.80**	0.69**	0.80**	0.70**
1 vs. 3	0.77**	0.65**	0.87**	0.76**
2 vs. 3	0.77**	0.77**	0.85**	0.83**

[z] Data are correlations of 3 replications summed over 5 harvests.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 2.7. Yield rankings from highest to lowest of 13 watermelon cultivars using three plot sizes separated by two locations tested.^{z}

Cultivar	Total yield (7.3 m)	Total yield (3.7 m)	Total yield (2.4 m)
Clinton			
Charleston Gray	1	10	6
Hopi Red Flesh	2	1	1
Fiesta	3	3	5
Jubilee	4	2	4
Starbrite	5	9	7
Regency	6	5	3
Allsweet	7	6	2
Navajo Sweet	8	4	8
Crimson Sweet	9	7	9
Sultan	10	11	10
Florida Favorite	11	8	11
Sugar Baby	12	12	12
NH Midget	13	13	13

continued next page

Table 2.7 (continued).

Cultivar	Total yield (7.3 m)	Total yield (3.7 m)	Total yield (2.4 m)
Kinston			
Fiesta	1	3	3
Starbrite	2	2	2
Hopi Red Flesh	3	1	1
Regency	4	8	4
Jubilee	5	9	11
Sultan	6	6	8
Charleston Gray	7	10	6
Crimson Sweet	8	11	7
Navajo Sweet	9	7	10
Florida Favorite	10	5	5
Allsweet	11	4	9
Sugar Baby	12	12	13
NH Midget	13	13	12

[z] Data are means of 3 replications summed over 5 harvests ranked in order of yield.

Table 2.8. Yield rankings from highest to lowest of 13 watermelon cultivars using three plot sizes tested at two locations.[z]

Cultivar	Total yield (7.3 m)	Total yield (3.7 m)	Total yield (2.4 m)
Fiesta	1	2	4
Starbrite	2	3	3
Hopi Red Flesh	3	1	1
Charleston Gray	4	10	5
Jubilee	5	5	8
Regency	6	8	2
Sultan	7	9	10
Crimson Sweet	8	11	9
Navajo Sweet	9	6	11
Allsweet	10	4	6
Florida Favorite	11	7	7
Sugar Baby	12	12	12
NH Midget	13	13	13

[z] Data are means of 3 replications and two locations summed over 5 harvests ranked in order of yield.

Table 2.9. Standard deviations of three plot sizes using 13 watermelon cultivars tested at two locations.[z]

Plot size	Total yield ($Mg \cdot ha^{-1}$)	Total yield ($th \cdot ha^{-1}$)	Wt/Frt (kg)
2.4	12.1	2.0	1.4
3.7	7.2	1.3	0.9
7.3	9.8	1.5	0.8

[z] Data are standard deviations from ANOVA output of 3 replications summed over 5 harvests.

Table 2.10. Predicted regression equations for total weight in 7.3 m plots (TW73) based on total weight 3.7 m' plots (TW37), total weight 2.4 m plots (TW24), total fruit number 3.7 m plots (TN37), and total fruit number 2.4 m plots (TN24).[z]

Equation	CV	R^2	Inter-cept	Total weight 3.7 m	Total weight 2.4 m	Total number 3.7 m	Total number 2.4 m
TW73=2.65+0.96(TW37)	12.01	0.90	2.65	0.96	-	-	-
TW73=10.89+1.09(TW24)	18.14	0.76	10.89	-	1.09	-	-
TN73=1.67+0.85(TN37)	13.26	0.90	1.67	-	-	0.85	-
TN73=3.30+0.94(TN24)	22.36	0.72	3.30	-	-	-	0.94

[z] Regression calculations made with plot weights in $Mg \cdot ha^{-1}$ and fruit numbers in thousands$\cdot ha^{-1}$.

General References

Arny, A. C. 1922. Border effect and ways of avoiding it. Agron. J. 14(7):265-278.

Austin, R. B. and R. D. Blackwell. 1980. Edge and neighbor effects in cereal yield trials. J. Agric. Sci., Camb. 94:731-734.

Bach, C. E. and A. J. Hruska. 1981. Effects of plant density on the growth, reproduction and survivorship of cucumbers in monocultures and polycultures. Journal of Applied Ecology. 18:929-943.

Binns, M. R. 1982. The choice of plot size in randomized block experiments. J. Amer. Soc. Hort. Sci. 107(1):17-19.

Bowman, D. T. 1989. Plot configuration in corn yield trials. Crop Science. 29:1202-1206.

Bracy, R. and R. Parish. 1994. Row number, not plant spacing affects melon production. Louisiana Agriculture. 37(4):29.

Brinen, G. E., S. J. Locascio, and G. W. Elmstrom. 1979a. Plant arrangement for increased watermelon yield. Proceedings of the Florida State Horticultural Society 92:80-82.

Brinen, G. E., S. J. Locascio and G. W. Elmstrom. 1979b. Plant and row spacing, mulch and fertilizer rate effects on watermelon production. J. Amer. Soc. Hort. Sci. 104(6):724-726.

Chambliss, O. L. and J. L. Turner. 1972. High density plantings give higher production of cucumbers, southern peas. Highlights Agric. Res. Ala. Agric. Exp. Station 19(3):10-11.

Chaves, L. J. and J. B. de M. Filho. 1992. Plot size for progeny selection in maize (*Zea maize L.*). Theor. Appl. Genet. 84:963-970.

Christidis, B. G. 1931. The importance of the shape of plots in field experimentation. Journal of Agricultural Science. 2:14-37.

Clarke, F. R., R. J. Baker, and R. M. DePauw. 1998. Interplot interference distorts yield estimates in spring wheat. Crop Science 38:62-66.

Costa, J. G. C. S. and F. J. P. Zimmermann. 1998. Experimental plot border effect on yield and plant height of common bean (in Portuguese). Pesq. Agropec. Bras., Brasilia 33(8):1297-1304.

Crajendran, P. and S. Thamburaj. 1994. Genetic variability in biometrical traits in watermelon (*Citrullus lanatus*). Indian Journal of Agricultural Science. 64(1):5-8.

David, O., R. A. Kempton, and I. M. Nevison. 1996. Designs for controlling interplot competition in variety trials. Journal of Agricultural Science. 127:285-288.

Delaney, K. E., R. L. Lower, and M. D. Edwards. 1983. Effect of within row spacing on mature fruit yield of three *Cucumis sativus* var. *hardwickii* derivatives and a gynoecious inbred of *Cucumis sativus*. Cucurbit Genetics Cooperative Report 6:3-4.

Deming, G. W. and H. E. Brewbaker. 1934. Border effect in sugarbeets. J. Amer. Soc. Agron. 26(7):615-619.

Down, E. E. 1942. Plot technique studies with small grains. J. Amer. Soc. Agron. 34(5):472-481.

Duthie, J. A., B. W. Roberts, J. V. Edelson, and J. W. Shrefler. 1999a. Plant density-dependent variation in density, frequency, and size of watermelon fruits. Crop Science. 39:412-417.

Duthie, J. A., J. W. Shrefler, B. W. Roberts, and J. V. Edelson. 1999b. Plant density-dependent variation in marketable yield, fruit biomass, and marketable fraction in watermelon. Crop Science. 39:406-412.

Dweikat, I. M. and S. R. Kostewicz. 1989. Row arrangement, plant spacing, and nitrogen rate effects on zucchini squash yield. HortScience 24(1):86-88.

Elmstrom, G. W. 1973. Watermelon root development affected by direct seeding and transplanting. HortScience. 8(2):134-136.

Elmstrom, G. W. and J. M. Crall. 1985. "Icebox" watermelons for Florida: cultivar and spacing evaluations. Proc. Fla. State Hort. Soc. 98:276-278.

Evans, L. S. and K. F. Lewin. 1986. Effects of limited border and harvest rows and interplanting cultivars on yields of field-grown soybeans. J. Agronomy and Crop Science. 156:206-212.

Fasoula, D. A. 1990. Correlations between auto-, allo-, and nil-competition and their implications in plant breeding. Euphytica. 50:57-62.

Feher, T. 1993. Watermelon. p.295-315. In: Kalloo, G. and B. O. Bergh (eds.). Genetic improvement of vegetable crops. Pergamon Press Ltd., Tarrytown, New York.

Fiacchino, D. C. and S. A. Walters. 2000. Influence of diploid pollenizers on seedless watermelon yield and quality. HortScience. 35(3):430 (Abstr.).

Gedge, D. L., W. R. Fehr, and A. K. Walker. 1977. Intergenotypic competition between rows and within blends of soybeans. Crop Science. 17:787-790.

Gill, B. S. and J. C. Kumar. 1986. Variability in genetic stock and heritable components in watermelon. J. Res. Punjab Agric. Univ. 23(4):583-588.

Gilreath, P. R., R. L. Brown, and D. N. Maynard. 1987. Icebox watermelon fruit size and yield as influenced by plant population. Proc. Fla. State Hort. Soc. 100:210-213.

Gingras, D., J. Gingras, and D. De. Oliveira. 1999. Visits of honeybees (Hymenoptera: Apidae) and their effects on cucumber yields in the field. Horticultural Entomology. 92(2):435-438.

Hollowell, E. A. and D. Heusinkveld. 1933. Border effect studies of red clover and alfalfa. J. Amer. Soc Agron. 25(12):779-789.

Hulbert, H. W. and J. D. Remsberg. 1927. Influence of border rows in variety tests of small grains. J. Amer. Soc. Agron. 19(7):585-589.

Kanwar, J. S., D. S. Khurana, and B. Singh. 1994. Effect of nutrients and plant-population density on yield and quality or round gourd (*Citrullus lanatus* var. *fistulosus*). Indian Journal of Agricultural Sciences 64(11):765-767.

Kempton, R. A. and G. Lockwood. 1984. Inter-plot competition in variety trials of field beans (*Vicia faba* L.). J. Agric. Sci., Camb. 103:293-302.

Kempton, R. A., R. S. Gregory, W. G. Hughes, and P. J. Stoehr. 1986. The effect of interplot competition on yield assessment in triticale trials. Euphytica 35:257-265.

Kramer, J. W. Van Ooijen, and C. J. T. Spitters. 1982. Selection for yield in small plots of spring wheat. Euphytica. 31:549-564.

Lin, C. S. and M. R. Binns. 1984. Working rules for determining the plot size and numbers of plots per block in field experiments. J. Agric. Sci., Camb. 103:11-15.

May, K. W. and R. J. Morrison. 1986. Effect of different plot borders on grain yields in barley and wheat. Can. J. Plant Sci. 66:45-51.

Maynard, E. T. and W. D. Scott. 1998. Plant spacing affects yield of 'Superstar' muskmelon. HortScience 33(1):52-54.

Monzon, D., J. J. Pacheco G., and O. Martinez R. 1972. Effectos de competencia y de bordura en ensayos de variedades. I. soya. Agronomia Tropical. 22:67-74.

Mulkey, W. A. and T. P. Talbot. 1993. Varieties, planting dates, and spacing for high yield zucchini summer squash. Louisiana Agriculture. 36(1):17-19.

National Watermelon Promotion Board. 2001. "Fields of green." National Watermelon Promotion Board. http://www.watermelon.org/ (7 March 2001).

Nelson, L. A. 1981. Yield variability in proso millet due to plot size. Agron. J. 73:23-25.

Neppl, G. P. 2001. Chapter 1: Interaction of border and center rows in watermelon yield trials. MS Thesis, Dept. of Horticulture, North Carolina State Univ., Raleigh.

Neppl, G.P. and T.C. Wehner. 2001a. Survey of watermelon trialing methods in the U.S. Cucurbit Genetics Cooperative Report 24: in press

Neppl, G.P. and T.C. Wehner. 2001b. Vine length of a diverse set of watermelon cultivars. Cucurbit Genetics Cooperative Report 24: in press.

Nerson, H. 1998. Responses of "little leaf" vs. normal cucumber to planting density and chlorflurenol. HortScience. 35(5):816-818.

NeSmith, D. S. 1993. Plant spacing influences watermelon yield and yield components. HortScience. 28(9):885-887.

Nonnecke, I. B. L. 1989. Vegetable production. p.541-550. Van Nostrand Reinhold. New York, New York.

Paris, H. S., H. Nerson, Y. Burger, M. Edelstein, Z. Karchi, T. G. McCollum, and D. J. Cantliffe. 1988. Synchrony of yield of melons as affected by plant type and density. Journal of Horticultural Science. 63(1):141-147.

Partap, P. S., N. Mehrotra, R. N. Vashistha, and M. L. Pandita. 1984. Biparental crossing in watermelon (*Citrullus lanatus* (Thunb.) Mansf.). Genetica Agraria. 38(4):379-385.

Probst, A. H. 1943. Border effect in soybean nursery plots. J. Amer. Soc. Agron. 35:662-666.

Rattunde, H. F. W., T. Miedaner, and H. H. Geiger. 1991. Biometrical analysis of alternative plot types for selection in rye. Euphytica. 57:141-150.

Reiners, S. and D. I. M. Riggs. 1997. Plant spacing and variety affect pumpkin yield and fruit size, but supplemental nitrogen does not. HortScience. 32(6):1037-1039.

Romani, M., B. Borghi, R. Alberici, G. Delogu, J. Hesselbach, and F. Salamini. 1993. Intergenotypic competition and border effect in bread wheat and barley. Euphytica. 69:19-31.

Sanders, D. C. (ed.). 1999. Watermelon. p.115-118. 1999 North Carolina commercial vegetable recommendations. North Carlolina Coopperative Extension Service, Raleigh North Carolina.

Schultheis, J. R., T. C. Wehner, and S. A. Walters. 1997a. Mixtures of cucumber cultigens affect yield in a multiple-harvest system. HortScience. 32(6):1024-1027.

Schultheis, J. R., T. C. Wehner, and S. A. Walters. 1997b. Optimum planting density and harvest stage for little-leaf and normal-leaf cucumbers for once-over harvest. Canadian Journal of Plant Science. 78(2):333-340.

Serquen, F. C., J. Bacher, and J. E. Staub. 1997. Genetic analysis of yield components in cucumber at low plant density. J. Amer. Soc. Hort. Sci. 122(4):522-528.

Sidhu, A. S. and J. S. Brar. 1981. Correlation and path coefficient analysis for yield, quality and earliness in watermelon [*Citrullus lanatus* (Thunb.) Mansf.]. Indian J. Agric. Res. 15(1):33-37.

Silva, P. S. L., P. G. de Souza, and E. E. Montenegro. 1991. Plot-end border effect of irrigated maize (in Portuguese). Revista Ceres 38(216):101-107.

Singh, R. V. and L. B. Naik. 1989. Response of watermelon (*Citrullus lanatus* Thumbs. Mansf.) to plant density, nitrogen and phosphorus fertilization. Indian Journal of Horticulture. 46(1):80-83.

Smith, H. F. 1938. An empirical law describing heterogeneity in the yields of agricultural crops. Journal of Agricultural Science. 28:1-23.

Smith, O. S. and R. L. Lower. 1978. Field plot techniques for selecting increased once-over harvest yields in pickling cucumbers. J. Amer. Soc. Hort. Sci. 103(1):92-94.

Smith, O. S., R. L. Lower, and R. H. Moll. 1978. Estimates of heritabilities and variance components in pickling cucumber. J. Amer. Soc. Hort. Sci. 103(2):222-225.

Stanghellini, M. S., J. T. Ambrose, and J. R. Schultheis. 1997. The effects of honey bee and bumble bee pollination on fruit set and abortion of cucumber and watermelon. American Bee Journal. 137(5):386-391.

Staub, J. E., L. D. Knerr, and H. J. Hopen. 1992. Plant density and herbicides affect cucumber productivity. J. Amer. Soc. Hort. Sci. 117(1):48-53.

Strefeler, M. S. and T. C. Wehner. 1986. Estimates of heritabilities and genetic variances of three yield and five quality traits in three fresh-market cucumber populations. J. Amer. Soc. Hort. Sci. 111(4):599-605.

Stringfield, G. H. 1927. Intervarietal competition among small grains. J. Amer. Soc. Agron. 19(11):971-983.

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size determination and its application to cucumber yield trials. Euphytica. 35:421-432.

Thornton, R. E. 1987. Comparison of single row vs. three row plots for cultivar evaluation. American Potato Journal. 64(1):461 (Abstr.).

U. S. Department of Agriculture. 2000. Agricultural statistics. U. S. Government Printing Office, Washington D. C. p. IX22-IX23.

Vallejo, R. L. and H. A. Mendoza. 1992. Plot technique studies on sweetpotato yield trials. J. Amer. Soc. Hort. Sci. 117(3):508-511.

Wehner, T. C. 1984. Effect of end borders on plot yield on once-over harvested pickling and fresh-market cucumbers. Cucurbit Genetics Cooperative Report. 7:31-32.

Wehner, T. C. 1986. Efficiency of three single-harvest tests for evaluation of yield in pickling cucumber. Euphytica. 35:493-501.

Wehner, T. C. 1987. Efficient methods for testing vegetable cultivars. HortScience. 22(6):1220-1223.

Wehner, T. C. 1988. Effect of end-border condition on small-plot yield of cucumber. Euphytica 38:113-119.

Wehner, T. C. and C. H. Miller. 1984. Efficiency of single-harvest methods for measurement of yield in fresh-market cucumbers. J. Amer. Soc. Hort. Sci. 109(5):659-664.

Wehner, T. C. and C. H. Miller. 1990. Yield of cucumbers in multiple-harvest trials with dissimilar genotypes in border rows. HortScience. 25(1):106-108.

Wehner, T. C. and W. H. Swallow. 1984. Optimum plot size for once-over harvest of pickling and fresh-market cucumbers. Cucurbit Genetics Cooperative Report. 7:35.

Whitaker, W. and Davis, G. N. 1962. Cucurbits. Interscience Publishers Inc., New York, New York.

Widders, I. E., and H. C. Price. 1989. Effects of plant density on growth and biomass partitioning in pickling cucumbers. J. Amer. Soc. Hort. Sci. 114(5):751-755.

Wolf, S., Y. Lensky, and N. Paldi. 1999. Genetic variability in flower attractiveness to honeybees (*Apis mellifera L.*) within the genus *Citrullus*. HortScience. 34(5):860-863.

Zhang, R., A. W. Warrick, and D. E. Myers. 1994. Heterogeneity, plot shape effect and optimum plot size. Geoderma. 62:183-197.

Zimmermann, F. J. P. 1980. Border effect in experimental plots of unirrigated rice (in Portuguese). Pesq. Agropec. Bras., Brasilia 15(3):297-300.

Appendix Tables

Table 3.1. Yield of three watermelon cultivars as the center row of a three-row plot having different or the same borders.[z]

Cultivar Center	Border	Total yield ($Mg \cdot ha^{-1}$)	Culls (%)	Total yield ($th \cdot ha^{-1}$)	Wt/Frt (kg)
Charleston Gray	Charleston Gray	80.6	14.3	8.7	9.6
	Crimson Sweet	84.5	21.9	9.4	9.5
	Sugar Baby	77.9	9.1	8.6	9.4
Crimson Sweet	Charleston Gray	72.0	4.0	7.3	10.0
	Crimson Sweet	71.8	6.4	7.5	9.7
	Sugar Baby	82.9	3.6	8.6	9.5
Sugar Baby	Charleston Gray	34.3	2.5	7.2	4.9
	Crimson Sweet	39.3	1.1	7.8	5.0
	Sugar Baby	29.4	3.5	6.4	4.7
LSD (5%)		10.0	9.0	1.0	1.5
Mean		63.6	7.4	8.0	8.0
F ratio (center X border)		2.8*	1.6ns	4.2**	0.07ns

[z] Data are means of 2 locations and 3 replications of 12 plants/plot summed over 4 harvests.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 3.2. Marketable yield of three watermelon cultivars as the center row of a three-row plot having different or the same borders.[z]

Cultivar Center	Border	Marketable yield ($Mg{\cdot}ha^{-1}$)	Culls (%)	TotMkyield ($th{\cdot}ha^{-1}$)	MkWt/Frt (kg)
Charleston Gray	Charleston Gray	71.7	14.3	7.5	9.6
	Crimson Sweet	75.8	21.9	7.8	9.5
	Sugar Baby	70.7	9.1	7.4	9.4
Crimson Sweet	Charleston Gray	69.3	4.0	6.9	10.0
	Crimson Sweet	66.8	6.4	6.8	9.7
	Sugar Baby	80.2	3.6	8.2	9.5
Sugar Baby	Charleston Gray	33.8	2.5	7.1	4.9
	Crimson Sweet	39.0	1.1	7.8	5.0
	Sugar Baby	28.5	3.5	6.2	4.7
LSD (5%)		10.0	9.0	1.0	1.5
Mean		59.5	7.4	7.3	8.0
F ratio (border X center)		3.5*	1.6ns	5.1**	0.7ns

[z] Data are means of 2 locations and 3 replications of 12 plants/plot summed over 4 harvests.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 3.3. Marketable yield of three watermelon cultivars as the center row of a three-row plot having different or the same borders separated by location.[z]

Cultivar Center	Border	Marketable yield ($Mg\cdot ha^{-1}$)	Culls (%)	TotMK yield ($th\cdot ha^{-1}$)	MKWt/Frt (kg)
Clinton					
Charleston Gray	Charleston Gray	46.6	17.4	5.1	9.3
	Crimson Sweet	59.9	30.2	6.4	8.6
	Sugar Baby	53.4	6.1	6.4	8.3
Crimson Sweet	Charleston Gray	49.1	5.3	5.4	9.2
	Crimson Sweet	48.8	6.4	5.5	8.8
	Sugar Baby	56.3	1.1	6.6	8.4
Sugar Baby	Charleston Gray	31.3	2.2	6.7	4.8
	Crimson Sweet	37.8	0.0	7.3	5.1
	Sugar Baby	24.1	1.4	5.8	4.3

continued next page

Table 3.3 (continued).

Cultivar Center	Border	Marketable yield (Mg·ha^{-1})	Culls (%)	TotMK yield (th·ha^{-1})	MKWt/Frt (kg)
Kinston					
Charleston Gray	Charleston Gray	96.9	11.2	10.0	9.9
	Crimson Sweet	91.7	13.7	9.3	10.3
	Sugar Baby	87.9	12.0	8.4	10.6
Crimson Sweet	Charleston Gray	89.5	2.8	8.4	10.8
	Crimson Sweet	84.8	6.4	8.1	10.6
	Sugar Baby	104.2	6.0	9.9	10.6
Sugar Baby	Charleston Gray	36.3	2.8	7.5	4.9
	Crimson Sweet	40.3	2.2	8.2	4.9
	Sugar Baby	32.8	5.6	6.6	5.0
LSD (5%)		14.1	12.7	1.4	2.1
F ratio (loc X border X center)		0.9ns	0.8ns	1.8ns	0.2ns

[z] Data are means of 2 locations and 3 replications of 12 plants/plot summed over 4 harvests.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 3.4. Chemical and fertilizer applications for three cultivars of watermelon planted in three-row plots having the same or different borders at Kinston.[z]

Date	Operation	Rate	Compound	Application Method
4/6/00	fertilize	336.41 kg·ha^{-1}	10N-16.6P-8.8K	pre-plant incorporated
4/7/00	fumigant	59.83 L·ha^{-1}	telone c-17	mulched acre rate
4/27/00	fertilize	< 5.61 kg·ha^{-1}	20N-16.6P-8.8K	transplant water (<1N-0.83P-0.44K)
4/27/00	plant			
5/1/00	fertilize	39.25 kg·ha^{-1}	34N-0P-0K	week long (drip)
5/3/00	fungicide	3.50 L·ha^{-1}	tenn cop 5e	
5/3/00	insecticide	0.58 L·ha^{-1}	dimethoate 4ec	
5/8/00	fertilize	125.59 kg·ha^{-1}	34N-0P-0K	week long (drip)
5/11/00	fungicide	2.24 kg·ha^{-1}	manzate 200	
5/11/00	herbicide	3.50 L·ha^{-1}	curbit ec	row middles hooded sprayer
5/11/00	herbicide	2.34 L·ha^{-1}	gramoxone	row middles hooded sprayer
5/11/00	insecticide	0.70 L·ha^{-1}	asana xl	
5/15/00	fertilize	31.40 kg·ha^{-1}	13.5N-0P-19.8K	week long (drip)
5/18/00	fungicide	2.24 kg·ha^{-1}	manzate 200	

continued next page

Table 3.4 (continued).

Date	Operation	Rate	Compound	Application Method
5/18/00	insecticide	0.70 L·ha^{-1}	asana xl	
5/18/00	insecticide	0.58 L·ha^{-1}	dimethoate 4ec	
5/22/00	fertilize	31.40 kg·ha^{-1}	13.5N-0P-19.8K	week long (drip)
5/25/00	fungicide	2.24 kg·ha^{-1}	ridomil / bravo	
5/25/00	insecticide	0.70 L·ha^{-1}	asana xl	
5/29/00	fertilize	31.40 kg·ha^{-1}	13.5N-0P-19.8K	week long (drip)
6/1/00	fungicide	0.80 L·ha^{-1}	quadris	
6/1/00	insecticide	0.58 L·ha^{-1}	ambush	
6/5/00	fertilize	31.40 kg·ha^{-1}	13.5N-0P-19.8K	week long (drip)
6/9/00	fungicide	2.24 kg·ha^{-1}	ridomil / bravo	
6/9/00	insecticide	0.70 L·ha^{-1}	asana xl	
6/12/00	fertilize	56.07 kg·ha^{-1}	13.5N-0P-19.8K	week long (drip)
6/15/00	fungicide	0.80 L·ha^{-1}	quadris	
6/15/00	insecticide	0.58 L·ha^{-1}	ambush	
6/19/00	fertilize	56.07 kg·ha^{-1}	13.5N-0P-19.8K	week long (drip)
6/24/00	fungicide	2.24 kg·ha^{-1}	ridomil / bravo	
6/24/00	insecticide	0.70 L·ha^{-1}	asana xl	
6/26/00	fertilize	56.07 kg·ha^{-1}	13.5N-0P-19.8K	week long (drip)

continued next page

Table 3.4 (continued).

Date	Operation	Rate	Compound	Application Method
6/30/00	fungicide	0.29 $L \cdot ha^{-1}$	bayleton	
6/30/00	fungicide	3.50 $L \cdot ha^{-1}$	bravo wethr stik	
6/30/00	insecticide	0.58 $L \cdot ha^{-1}$	ambush	
7/7/00	fungicide	2.24 $kg \cdot ha^{-1}$	ridomil / bravo	
7/7/00	insecticide	0.70 $L \cdot ha^{-1}$	asana xl	
7/14/00	fungicide	2.24 $kg \cdot ha^{-1}$	dithane df	
7/14/00	insecticide	0.58 $L \cdot ha^{-1}$	ambush	
7/24/00	fungicide	2.24 $kg \cdot ha^{-1}$	dithane df	
7/24/00	insecticide	0.58 $L \cdot ha^{-1}$	ambush	
7/27/00	fungicide	0.22 $L \cdot ha^{-1}$	bayleton	
7/27/00	fungicide	3.50 $L \cdot ha^{-1}$	manex	
7/27/00	insecticide	0.70 $L \cdot ha^{-1}$	asana xl	
8/3/00	fungicide	2.24 $kg \cdot ha^{-1}$	dithane df	
8/3/00	insecticide	0.70 $L \cdot ha^{-1}$	asana xl	
8/8/00	herbicide	4.67 $L \cdot ha^{-1}$	round up	burn down end of test
Fertilizer	season totals (117N-50.6P-79.2K)			

[z] Data are operation, compounds, and rates applied at the Cunningham Research Station in Kinston North Carolina.

Table 3.5. Chemical and fertilizer applications for three cultivars of watermelon planted in single-row and three-row plots having the same or different borders at Clinton.[z]

Date	Operation	Rate	Compound
03/29/00	fertilizer	560.69 $kg{\cdot}ha^{-1}$	10N-8.3P-4.4K
03/29/00	fumigant	168.21 $kg{\cdot}ha^{-1}$	telone c-35
05/01/00	plant		
05/09/00	fungicide	2.34 $L{\cdot}ha^{-1}$	bravo weather stik
05/09/00	insecticide	2.34 $L{\cdot}ha^{-1}$	sevin xlr 4ec
05/23/00	fungicide	3.36 $kg{\cdot}ha^{-1}$	aliette wdg
05/23/00	fungicide	0.34 $kg{\cdot}ha^{-1}$	benlate 50wp
05/23/00	herbicide	spot	gramoxone extra 2.5l
05/23/00	insecticide	1.40 $kg{\cdot}ha^{-1}$	sevin 80w
05/31/00	insecticide	0.58 $L{\cdot}ha^{-1}$	asana xl .66ec
05/31/00	fungicide	0.88 $L{\cdot}ha^{-1}$	quadris
06/08/00	fungicide	2.34 $L{\cdot}ha^{-1}$	bravo weather stik
06/08/00	insecticide	2.34 $L{\cdot}ha^{-1}$	thiodan 3ec
06/15/00	insecticide	0.58 $L{\cdot}ha^{-1}$	asana xl .66ec
06/15/00	fungicide	0.88 $L{\cdot}ha^{-1}$	quadris
06/22/00	insecticide	2.34 $L{\cdot}ha^{-1}$	phaser 3ec

continued next page

Table 3.5 (continued).

Date	Operation	Rate	Compound
06/23/00	fungicide	2.34 L·ha^{-1}	bravo weather stik
06/30/00	insecticide	0.58 L·ha^{-1}	asana xl .66ec
06/30/00	fungicide	0.88 L·ha^{-1}	quadris
07/07/00	insecticide	0.58 L·ha^{-1}	asana xl .66ec
07/07/00	fungicide	2.34 L·ha^{-1}	bravo weather stik
07/14/00	fungicide	2.34 L·ha^{-1}	bravo weather stik
07/14/00	insecticide	1.17 L·ha^{-1}	kelthane 4f
07/14/00	insecticide	2.34 L·ha^{-1}	phaser 3ec
08/07/00	fungicide	2.34 L·ha^{-1}	bravo weather stik
08/07/00	insecticide	1.40 kg·ha^{-1}	sevin 80w
08/10/00	herbicide	3.50 L·ha^{-1}	gramoxone extra 2.5l

[z] Data are operation, compounds, and rates applied at the Horticultural Crops Research Station in Clinton North Carolina.

Table 3.6. Marketable yield of 13 watermelon cultivars tested in three plot sizes and two locations.[z]

Cultivar	Plot size(m)	Market yield ($Mg\cdot ha^{-1}$)	Culls (%)	Market yield ($th\cdot ha^{-1}$)	Market Wt/Frt (kg)
Clinton					
Hopi Red Flesh	2.4	37.2	8.9	5.8	6.4
	3.7	47.5	9.2	9.3	5.0
	7.3	28.2	35.5	5.5	5.4
Starbrite	2.4	32.8	3.3	3.1	10.4
	3.7	42.5	5.7	4.8	9.5
	7.3	46.8	2.0	5.5	8.7
Fiesta	2.4	40.5	0.0	4.9	8.3
	3.7	48.0	7.4	5.7	8.3
	7.3	48.4	4.0	6.2	7.8
Regency	2.4	45.0	0.0	4.9	9.3
	3.7	46.9	0.7	5.7	8.1
	7.3	45.1	1.8	4.9	9.1
Jubilee	2.4	37.3	10.0	3.1	11.6
	3.7	45.7	10.1	4.1	11.1
	7.3	40.6	16.2	4.4	9.0

continued next page

Table 3.6 (continued).

Cultivar	Plot size(m)	Market yield (Mg·ha^{-1})	Culls (%)	Market yield (th·ha^{-1})	Market Wt/Frt (kg)
Charleston Gray	2.4	30.4	8.9	3.1	9.8
	3.7	37.8	12.0	4.8	7.8
	7.3	52.0	3.5	6.5	7.8
Allsweet	2.4	42.6	6.7	4.5	9.9
	3.7	43.2	3.2	4.3	9.7
	7.3	40.4	18.1	4.1	9.5
Florida Favorite	2.4	26.6	2.2	4.5	5.9
	3.7	42.2	2.3	7.4	6.2
	7.3	32.6	8.3	5.0	6.6
Navajo Sweet	2.4	30.3	8.0	5.4	5.6
	3.7	47.8	3.8	8.6	5.5
	7.3	44.3	11.5	8.4	5.3
Sultan	2.4	29.8	0.0	2.2	13.9
	3.7	35.5	11.1	3.6	9.7
	7.3	38.1	5.4	4.6	8.7
Crimson Sweet	2.4	29.0	2.2	4.0	6.7
	3.7	43.0	5.6	4.8	9.4
	7.3	42.3	8.8	5.0	8.9

continued next page

Table 3.6 (continued).

Cultivar	Plot size(m)	Market yield (Mg·ha^{-1})	Culls (%)	Market yield (th·ha^{-1})	Market Wt/Frt (kg)
Sugar Baby	2.4	21.8	0.0	4.5	4.9
	3.7	28.5	0.0	5.9	4.9
	7.3	30.5	1.0	7.6	4.1
NH Midget	2.4	8.9	0.0	5.8	1.5
	3.7	20.5	2.4	13.6	1.5
	7.3	21.4	2.3	13.9	1.5
Kinston					
Hopi Red Flesh	2.4	54.8	19.7	9.4	5.9
	3.7	59.2	27.1	11.3	5.1
	7.3	63.0	26.5	12.9	4.9
Starbrite	2.4	75.4	0.0	6.7	11.7
	3.7	93.1	2.8	8.1	11.9
	7.3	88.8	5.3	8.5	10.5
Fiesta	2.4	69.1	0.0	6.7	10.1
	3.7	84.0	6.8	9.3	9.1
	7.3	87.8	3.1	9.0	9.1

continued next page

Table 3.6 (continued).

Cultivar	Plot size(m)	Market yield $(Mg\cdot ha^{-1})$	Culls (%)	Market yield $(th\cdot ha^{-1})$	Market Wt/Frt (kg)
Regency	2.4	65.1	2.2	6.3	10.0
	3.7	76.6	0.0	7.9	10.5
	7.3	80.3	2.4	8.5	9.8
Jubilee	2.4	29.0	10.0	3.1	9.0
	3.7	69.1	9.7	5.6	12.4
	7.3	71.9	5.9	6.3	12.2
Charleston Gray	2.4	53.6	8.3	4.9	11.1
	3.7	63.7	4.4	5.9	10.4
	7.3	74.1	7.9	8.0	9.2
Allsweet	2.4	46.3	0.0	3.6	13.3
	3.7	76.8	5.6	7.5	10.9
	7.3	57.0	22.7	5.9	9.6
Florida Favorite	2.4	47.8	17.8	5.4	10.1
	3.7	74.6	2.9	10.4	6.8
	7.3	64.0	11.0	9.3	7.0
Navajo Sweet	2.4	44.3	0.0	6.7	6.8
	3.7	78.7	3.3	12.2	6.0
	7.3	75.8	0.0	12.9	5.7

continued next page

Table 3.6 (continued).

Cultivar	Plot size(m)	Market yield ($Mg·ha^{-1}$)	Culls (%)	Market yield ($th·ha^{-1}$)	Market Wt/Frt (kg)
Sultan	2.4	48.5	3.3	4.0	12.6
	3.7	76.4	1.5	7.0	10.8
	7.3	78.5	9.8	8.2	9.5
Crimson Sweet	2.4	54.5	0.0	6.3	9.3
	3.7	56.9	13.3	5.2	10.0
	7.3	75.1	2.8	8.2	10.1
Sugar Baby	2.4	23.3	0.0	5.4	4.0
	3.7	39.9	5.6	8.2	4.8
	7.3	48.0	2.4	10.4	4.5
NH Midget	2.4	31.1	3.3	17.0	2.0
	3.7	30.4	3.2	17.0	1.8
	7.3	26.3	7.4	15.4	1.9
LSD (5%)		17.2	10.9	2.6	1.7
F ratio (cultivar X loc X plot size)		1.1ns	1.4ns	2.4**	2.2**

[z] Data are means of 3 replications summed over 5 harvests and three replications. Cultivars are listed in descending order from highest to lowest yield averaged over all plot sizes and locations.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 3.7. Marketable yield of 13 watermelon cultivars using 3 plot sizes tested at 2 locations.[z]

Cultivar	Plot size(m)	Market yield (Mg·ha^{-1})	Culls (%)	TotMK yield (th·ha^{-1})	MK Wt/Frt (kg)
Hopi Red Flesh	2.4	46.0	14.3	7.6	6.1
	3.7	53.3	18.2	10.3	5.1
	7.3	45.6	31.0	9.2	5.1
Starbrite	2.4	54.1	1.7	4.9	11.0
	3.7	67.8	4.3	6.5	10.7
	7.3	67.8	3.6	7.0	9.6
Fiesta	2.4	54.8	0.0	5.8	9.2
	3.7	66.0	7.1	7.5	8.7
	7.3	68.1	3.6	7.6	8.5
Regency	2.4	55.1	1.1	5.6	9.7
	3.7	61.8	0.4	6.8	9.3
	7.3	62.7	2.1	6.7	9.5
Jubilee	2.4	33.1	10.0	3.1	10.5
	3.7	57.4	9.9	4.8	11.7
	7.3	56.3	11.1	5.3	10.6

continued next page

Table 3.7 (continued).

Cultivar	Plot size(m)	Market yield (Mg·ha^{-1})	Culls (%)	TotMK yield (th·ha^{-1})	MK Wt/Frt (kg)
Charleston Gray	2.4	42.0	8.6	4.0	10.5
	3.7	50.8	8.2	5.4	9.1
	7.3	63.0	5.7	7.2	8.5
Allsweet	2.4	44.4	3.3	4.0	11.6
	3.7	60.0	4.4	5.9	10.3
	7.3	48.7	20.4	5.0	9.6
Florida Favorite	2.4	37.2	10.0	4.9	8.0
	3.7	58.4	2.6	8.9	6.5
	7.3	48.3	9.6	7.2	6.8
Navajo Sweet	2.4	37.3	4.0	6.1	6.2
	3.7	63.2	3.6	10.4	5.8
	7.3	60.1	5.7	10.6	5.5
Sultan	2.4	39.1	1.7	3.1	13.2
	3.7	56.0	6.3	5.3	10.3
	7.3	58.3	7.6	6.4	9.1

continued next page

Table 3.7 (continued).

Cultivar	Plot size(m)	Market yield (Mg·ha^{-1})	Culls (%)	TotMK yield (th·ha^{-1})	MK Wt/Frt (kg)
Crimson Sweet	2.4	41.7	1.1	5.2	8.0
	3.7	50.0	9.4	5.0	9.7
	7.3	58.7	5.8	6.6	9.5
Sugar Baby	2.4	22.5	0.0	4.9	4.5
	3.7	34.2	2.8	7.1	4.8
	7.3	39.3	1.7	9.0	4.3
NH Midget	2.4	20.0	1.7	11.4	1.7
	3.7	25.4	2.8	15.3	1.7
	7.3	23.9	4.9	14.6	1.7
LSD (5%)		12.2	7.7	1.8	1.2
Mean		49.6	6.4	7.0	8.0
F ratio (cultivar X plot size)		1.3ns	1.9*	1.6*	3.1**

[z] Data are means of 3 replications summed over 5 harvests, three replications, and two locations. Cultivars are listed in descending order from highest to lowest yield averaged over all plot sizes and locations.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 3.8. Mean marketable yield of three plot sizes using 13 watermelon cultivars tested at two locations.[z]

Plot size	Marketable yield ($Mg \cdot ha^{-1}$)	Culls (%)	Marketable yield ($th \cdot ha^{-1}$)	MKWt/Frt (kg)
2.4	40.6	4.4	5.4	8.5
3.7	54.2	6.2	7.6	8.0
7.3	53.9	8.7	7.9	7.5
LSD (5%)	12.2	7.7	1.8	1.2
F ratio (plot size)	9.4**	5.2*	15.7**	9.2**

[z] Data are means of 3 replications, two locations, and 13 cultivars summed over 5 harvests.

ns,*,** Indicates correlations not significant, or significant at the 5 and 1% levels, respectively.

Table 3.9. Marketable yield rankings from highest to lowest of 13 watermelon cultivars using three plot sizes separated by locations tested.^{z}

Cultivar	Marketable yield (7.3 m)	Marketable yield (3.7 m)	Marketable yield (8')
Clinton			
Charleston Gray	1	10	7
Fiesta	2	1	3
Starbrite	3	8	6
Regency	4	4	1
Navajo Sweet	5	2	8
Crimson Sweet	6	7	10
Jubilee	7	5	4
Allsweet	8	6	2
Sultan	9	11	9
Florida Favorite	10	9	11
Sugar Baby	11	12	12
Hopi Red Flesh	12	3	5
NH Midget	13	13	13

continued next page

Table 3.9 (continued).

Cultivar	Marketable yield (7.3 m)	Marketable yield (3.7 m)	Marketable yield (8')
Kinston			
Starbrite	1	1	1
Fiesta	2	2	2
Regency	3	5	3
Sultan	4	6	7
Navajo Sweet	5	3	10
Crimson Sweet	6	11	5
Charleston Gray	7	9	6
Jubilee	8	8	12
Florida Favorite	9	7	8
Hopi Red Flesh	10	10	4
Allsweet	11	4	9
Sugar Baby	12	12	13
NH Midget	13	13	11

[z] Data are means of 3 replications summed over 5 harvests ranked in order of yield.

Table 3.10. Marketable yield rankings from highest to lowest of 13 watermelon cultivars using 3 plot sizes tested at two locations.[z]

Cultivar	Marketable yield (7.3 m)	Marketable yield (3.7 m)	Marketable yield (8')
Fiesta	1	2	2
Starbrite	2	1	3
Charleston Gray	3	10	6
Regency	4	4	1
Navajo Sweet	5	3	9
Crimson Sweet	6	11	7
Sultan	7	8	8
Jubilee	8	7	11
Allsweet	9	5	5
Florida Favorite	10	6	10
Hopi Red Flesh	11	9	4
Sugar Baby	12	12	12
NH Midget	13	13	13

[z] Data are means of 3 replications and two locations summed over 5 harvests ranked in order of yield.

Table 3.11. Marketable standard deviations of three plot sizes using 13 watermelon cultivars tested at 2 locations.[z]

Plot size	Marketable yield ($Mg \cdot ha^{-1}$)	Tot.Market yield ($th \cdot ha^{-1}$)	Market Wt/Frt (kg)
2.4	14.5	2.2	1.4
3.7	7.3	1.2	0.9
7.3	9.2	1.2	0.8

[z] Data are standard deviations from ANOVA output of 3 replications summed over 5 harvests.

Table 3.12. Predicted regression equations for Total market weight in 7.3 m plots (MW73) based on total market weight 3.7 m plots (MW37), total market weight 2.4 m plots (MW24), market fruit number 3.7 m plots (MN37), and market fruit number 2.4 m plots (MN24).[z]

Equation	CV	R^2	Intercept	Market weight 3.7 m	Market weight 2.4 m	Market number 3.7 m	Market number 2.4 m
MW73=2.73+0.94(MW37)	16.15	0.82	2.73	0.94	-	-	-
MW73=10.94+1.06(MW24)	21.82	0.67	10.94	-	1.06	-	-
MN73=1.42+0.85(MN37)	18.39	0.79	1.42	-	-	0.85	-
MN73=3.40+0.82(MN24)	36.20	0.57	3.40	-	-	-	0.82

[z] Regression calculations made with plot weights in Mg·ha^{-1} and fruit numbers in thousands·ha^{-1}.