Abstract

SHETTY, NISCHIT VASANTH. Evaluation of the cucumber germplasm collection for fruit yield and quality. Under the direction of Todd Craig Wehner.

Breeding for improved yield in cucumber (*Cucumis sativus* L.) has been one of the important objectives of cucumber breeding. Although the average yield of cucumber has increased by 100% over the last four decades, yield progress has remained flat in the past two decades. Thus, it is necessary to improve yield in cucumber by finding new sources of yield genes in the germplasm collection. Discovery of new sources may be difficult, however, because measurement of yield in a diverse array of cucumber cultigens is confounded by the different sex types found in cucumber.

Ethylene is a plant growth regulator known to alter sex expression in cucumber. Preliminary studies were conducted on a set of pickling and slicing cucumber cultigens differing in sex expression. Cultigens were subjected to contrasting rates of ethephon and two harvest stages under field conditions in North Carolina. Our objectives were to determine whether ethephon had an effect on fruit yield and quality in a diverse set of cucumber cultigens, and to determine whether harvesting at the 10 or 50% oversized fruit stage had an effect on the fruit yield and quality.

No differences for yield traits (total, marketable, percentage of culls) or fruit quality rating were observed between the harvest dates for both pickling and slicing cucumbers. Ethephon treatments had a significant effect on yield and fruit quality rating. Yield traits were found to differ for the different ethephon treatments based on the sex expression (monoecious, gynoecious) of the cultigens.

In the above experiment, we also measured the effects of ethephon on several vegetative and floral traits. Ethephon had an effect on most traits evaluated: days to first flower, days to 50% flower, days to first fruit set (pickles only), days to 50% fruit set

(pickles only), and fruit quality rating. However, ethephon had no significant effect on days to vine tip-over stage (five nodes), or days to first fruit set or days to 50% fruit set in slicing cucumber cultigens.

To study the effects of ethylene on the sex expression further, ethephon was applied to inbred lines of cucumber and interactions with genes for sex expression were evaluated. Inbreds used were isogenic pairs that differed for the *F* gene conditioning monoecious or gynoecious sex expression. Ethephon played an important role in improving most of the traits such as gynoecious rating, and fruit number and weight compared to the untreated control. Ethephon was effective in increasing pistillate flower number in monoecious inbreds, but had little effect on gynoecious inbreds.

Information derived from the previous studies was used to evaluate all cucumber plant introduction (PI) accessions from the USDA cucumber germplasm collection for fruit yield, earliness, and quality. All cultigens were sprayed with ethephon to convert them to gynoecious sex expression in order to make the evaluation more uniform for all cultigens regardless of their genes for sex expression. A total of 817 cultigens were tested using recommended cultural practices. Significant differences were observed among cultigens for all traits evaluated. High yielding cultigens were identified in each of the four cucumber types. In some cases, high yielding cultigens also had high early and marketable yield, and acceptable fruit quality and days to harvest.

Regression equations were developed for predicting marketable, early, and cull fruit weight in the different cucumber types. Results from our analysis showed that the fruit weight of each grade was best estimated using the fruit number of that grade (early, marketable, and cull) along with the total fruit weight and total fruit number.

Evaluation of the Cucumber Germplasm Collection for Fruit Yield and Quality

by

Nischit V. Shetty

A dissertation submitted to the Graduate Faculty of North Carolina State University in

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Dedication

This dissertation is dedicated to my parents Prafulla and Vasanth Shetty for their love, support and encouragement.

Biography

Nischit Vasanth Shetty was born in Bangalore, India on November 25, 1971 to Prafulla and Dr. K. P. Vasanth Shetty. He did his initial schooling at St. Joseph's Boys High School in Bangalore. After which he joined St. Joseph's College of Arts and Science for his Pre University Course. He enrolled for a Bachelor's Degree in Horticulture at the University of Agricultural Sciences at Bangalore in 1989. He graduated with a Bachelor's Degree in 1993. He enrolled at North Carolina State University in 1994 and studied with Dr. Todd C. Wehner. His Master of Science thesis research was on oriental trellis cucumber production for the U.S. and screening of cucumber cultigens for anthracnose caused by the pathogen *Colletotrichum orbiculare* race 1. Upon completion of his masters he enrolled on for a Ph.D. under Dr. Todd C. Wehner.

While at the Department of Horticultural Science, he was initiated into the Pi Alpha Xi honor society. He served as the Treasurer for Pi Alpha Xi during 1996 to 1997 and as its President during 1997 to 1998. In 1998, he was inducted into Gama Sigma Delta, the National Agricultural Honor Society. During his graduate studies he served as a teaching assistant in the Department of Horticultural Science and taught courses in Floriculture, Nursery Management, Greenhouse Management, Plant Propagation, and Tree and Grounds Maintenance. He was presented the Outstanding Teaching Assistant award by the Graduate School at North Carolina State University in 1996. He earned his Ph.D. in Plant Breeding from the Department of Horticulture Science in December 1999, with a dissertation on the evaluation of the cucumber germplasm collection for fruit yield and quality.

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I finally would like to thank my parents Prafulla and Vasanth Shetty, my sister Nitasha Shetty for all their help, encouragement and love over the years. Special thanks are given to my fellow graduate students and friends within the department and the university for their support and friendship these past years. I would also like to thank all my relatives for their support and encouragement.

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General Introduction

Cucumber belongs to the *Cucurbitaceae*, which is comprised of 90 genera and 750 species (Sitterly, 1972). Cucumber is thought to be one of the oldest vegetable crops, with historical records going back five thousand years. It is grown throughout the world and is the fourth most important vegetable crop after tomato, cabbage, and onion (Tatlioglu, 1993). Cucumber is the second most important vegetable crop in North Carolina after sweet potato, with a production area comprising approximately 9,716 ha (U. S. Department of Agriculture, 1997). Nationally, North Carolina was ranked third in pickling cucumber production after Michigan and Florida, and fifth in slicing cucumber production after Georgia, Florida, Michigan, and California (U.S. Department of Agriculture, 1997). The average yield of cucumber has increased 100% over the last four decades due to a combination of factors such as breeding for high yield, use of genetic resistance to disease, and improved cultural practices. Although there has been a large increase in productivity over the previous four decades, yield has reached a plateau in the last two decades. Thus, yield in cucumber needs attention from researchers. One of the methods of achieving high yield is to identify new genes for yield in the cucumber germplasm collection. The main objective of this series of experiments was to evaluate the cucumber germplasm collection for fruit yield and quality.

Measurement of yield in the diverse cucumber germplasm collection is difficult due to the presence of contrasting sex types. The most common ones are monoecious (staminate and pistillate flowers), androecious (staminate flowers only), gynoecious (pistillate flowers only), hermaphroditic (hermaphroditic flowers only), and andromonoecious (staminate and perfect flowers). The ability to modify sex expression in cucumber has been of great interest to researchers, especially since there is a correlation between number of pistillate flowers per plant and plant yield. Thus,conversion of monoecious or andromonoecious cultivars into gynoecious ones is an easy way to improve their yield.

The plant growth regulator ethylene was reported to control sex expression in cucurbits (Pratt and Goeschl, 1969). Several studies on monoecious pickling cucumber cultigens have since proven the ability of ethylene to convert monoecious cucumber lines to their gynoecious forms. A study was conducted to determine the number of applications of ethephon necessary to convert cucumber cultigens of different sex types to gynoecious sex expression. The objective was to measure the yield of cultigens in the germplasm collection regardless of sex type. We also wanted to see if there was a difference in yield when cucumber cultigens belonging to a diverse group were harvested at two different stages (10 or 50% oversize fruit). This was done primarily to provide an efficient method for evaluating yield for a screening of the cucumber germplasm collection. Therefore, the first studies involved evaluating fruit yield and quality after treatments of ethephon and harvest dates using a set of pickling and slicing cultigens chosen for their diversity of traits including sex expression (Chapters 1 and 2).

The effect of ethephon on vegetative and floral traits was studied in both pickling and slicing cultigens (Chapter 3). Based on the results of Chapters 1 and 2, further studies were conducted to examine the effect of ethephon on yield and quality traits on isogenic lines of cucumber differing in sex expression (Chapter 4).

Based on the information gathered from previous studies (Chapters 1-4), the cucumber germplasm collection was evaluated for fruit yield (total, early, marketable and cull), quality, and days to harvest. All cucumber plant introduction (PI) accessions from the USDA cucumber germplasm collection were evaluated (Chapter 5).

Results of the previous study suggested that measurement of cucumber fruit weight in small research plots involved more labor and resources than just counting the number of fruit per plot. Therefore, an efficient method of estimating the fruit weight of each grade (early, marketable, and cull) was developed using regression equations based on fruit number and total fruit weight (Chapter 6).

Chapter One

Effect of Ethephon and Time of Harvest on Fruit Yield and Quality of Pickling Cucumber

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Breeding and Germplasm Resources

Effect of Ethephon and Time of Harvest on Fruit Yield and Quality of Pickling Cucumber

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[1] Graduate research assistant and Professor, respectively. The authors gratefully acknowledge the technical assistance of Chris S. Cramer, Tammy L. Ellington, Joel Shuman and Alan Walters.

Abstract

Ethylene is a plant growth regulator known to alter sex expression in cucumber (*Cucumis sativus* L.), increasing the number of pistillate flowers when applied to monoecious plants. A set of 33 pickling cucumber cultigens differing in sex expression were subjected to 0, 1 and 2 applications of ethephon and harvest at two contrasting stages under field conditions in North Carolina. Our objectives were to determine whether ethephon had an effect on fruit yield and quality in a diverse set of cucumber and to determine whether harvesting at 10 or 50% oversized fruit stage had an effect on the fruit yield and quality. The experiment was conducted in 2 years and 2 seasons. No differences for yield traits (total, marketable, percentage of culls) or fruit quality rating were observed between the harvest dates. Therefore, one could harvest at either stage without a significant change in total yield or quality. Ethephon treatments had a significant positive effect on total yield, percentage of culls, and fruit quality rating. There was a significant difference among gynoecious cultigens for marketable yield, and a significant difference among monoecious cultigens for total yield, marketable yield, percentage of culls, and fruit quality rating. Monoecious cultigens were further analysed by subgroups, results showed that only cultigens belonging to the old monoecious subgroup differed for total yield, marketable yield, percentage of culls, and fruit quality rating.

Cucumber is thought to have originated in India (Harlan, 1975), with domestication occurring later throughout Europe. Cucumber belongs to the *Cucurbitaceae*, which is comprised of about 750 species (Sitterly, 1972). Cucumber is a monoecious, annual, herbaceous, vining plant with staminate flowers growing in clusters and pistillate flowers usually solitary. Cucumber has been changed considerably over the course of domestication. Several new forms have been developed, such as gynoecious plants, bush habit (with determinate main stem growth and shortened internodes), or types with hairless (glabrous) leaves and stems (Malepszy and Niemirowicz-Szczytt, 1991). Yield of cucumber has been improved by direct selection. The incorporation of disease resistance into cultivars (Peterson, 1975) and the use of improved cultural practices (Cargill et al., 1975) have also contributed to the improvement of yield in cucumber.

The ability to modify sex expression in cucurbits has been of great interest to scientists, especially since there is a correlation between fruit yield and the number of pistillate flowers per plant. Any treatment that would increase the formation of pistillate flowers would therefore, be beneficial in producing high yielding cucumber lines. The inheritance of sex expression resulting from distribution patterns of the three different flower types (staminate, pistillate, and perfect), therefore, plays an important role in cucumber breeding. Based on the type of flowers present, the different sex types in cucumber are monoecious (staminate and pistillate flowers), androecious (staminate flowers only), gynoecious (pistillate flowers only), hermaphroditic (perfect flowers only) and andromonoecious (staminate and perfect flowers).

Three main genes have been found to be responsible for the formation of the different sex types in cucumber: *F/f*, *M/m* and *A/a*. Additionally, several modifier genes (as well as environmental conditions) have been found to be responsible for expression of different sex types in cucumber. The *F* gene promotes gynoecious sex expression. Monoecious plants are usually recessive at the *F/f* locus. However, plants with the *F* gene do not always produce pistillate flowers. Depending on other modifier genes and environmental conditions, they can form either staminate or hermaphroditic flowers (Shifriss, 1961). Robinson et al. (1976) reported that inbreds with the *F* gene show a higher degree of gynoecy than an isogenic line recessive at the *F/f* locus. The recessive gene *m* is responsible for the development of hermaphrodite flowers (Galun, 1961, Shifriss, 1961). Sex expression of cucumber is affected by the exogenous application of certain plant growth regulators such as auxin, ethylene, and gibberellic acid. Auxin application in cucumber was also found to increase the number of pistillate flowers (Galun, 1959; Nitsch et al., 1952). Auxin treatments were reported to induce higher ethylene evolution (Shannon and De La Guardia, 1969), while ethylene lowered auxin levels (Burg et al., 1966; Rudich et al., 1972). Endogenous auxin levels were found to be higher in gynoecious cucumber lines than in monoecious ones (Rudich et al., 1972). Besides gibberellic acid, abscisic acid also regulates sex expression (Rudich et al., 1972). Gibberellins were found to induce staminate flowers in gynoecious cultivars (Mitchell and Wittwer, 1962; Peterson and Anhder, 1960). Iwahori et al. 1970 reported that although ethrel (ethephon) and gibberellins have opposing effects on sex expression are not antagonistic, but have different sites of action.

Ethylene, the plant growth regulator associated with several physiological processes in plants was first shown to alter the sex expression in cucumber by Warner and Leopold (1969) and Yang (1969). Several studies have since proved the ability of ethephon (ethrel) to alter sex expression in several members of the *Cucurbitaceae*. Robinson et al. (1968) reported that ethephon, when applied at the first and third leaf stage, greatly promoted the number of pistillate flowers in the monoecious pickling cucumber 'Wisconsin SMR 18'. McMurray and Miller (1969) reported that the most effective concentration of ethephon (2-chloroethanephosphonic acid) to convert plants of a monoecious cucumber inbred SC 23 to continuos pistillate nodes was 120 and 240 parts per million at four and two applications. The chemical was sprayed until runoff on the first true leaf (2 cm diameter). The authors also reported an increase in the yield and earliness due to the chemical treatment (McMurray and Miller, 1969). Hogue and

Heeney (1974) reported that the best treatment (highest yield and crop value) was when pickling cucumber plants were sprayed with ethephon at a concentration of 400 ppm and a plant spacing of 15 x 15 cm.

Cantliffe and Phatak (1975) reported that to obtain best yield, fruit shape, and fresh salt stock quality, ethephon should be applied twice, at a one-week interval beginning at the fourth true-leaf stage followed by a 50 to 100 ppm spray application of chlorflurenol (methyl-2-chloro-9-hydroxyfluorene-[9]-carboxylate) when 6 to 8 pistillate flowers reached anthesis. Miller et al. (1970) reported that fruit from 'Explorer' pickling cucumber when treated with ethephon and made into fresh-pack or brined pickles were shorter than the controls. Miller and Lower (1972) reported differences in shape and degree of seed development as a result of ethephon treatment on fruit of 'Chipper', 'Pixie', and 'Explorer' pickling cucumbers which were processed either as fresh-pack pickles or brinestock. However, no differences were observed between the control and the ethephon treated plants for fruit texture, flavor, external and internal color, firmness or internal defects.

Higher ethylene was produced in apices of gynoecious plants and from pistillate buds than in monoecious plant apices and staminate flower buds (Rudich, 1969). Gaseous ethylene treatment has also been reported to promote production of pistillate flowers in monoecious cucumber lines (Iwahori et al., 1970). High carbon dioxide levels, which are antagonistic to ethylene, were reported to increase the number of staminate flowers in a gynoecious cucumber line (Rudich et al., 1972). Rudich et al. (1972) reported that ethylene may promote the production of pistillate flowers either directly by reducing endogenous gibberellin levels, or by promoting the production of abscisic acid.

Differential response to ethephon was observed in monoecious cucumber cultivars, which was attributed to the genetic system controlling the gynoecious tendency in these cultivars (George, 1971). Shannon and Robinson (1978) reported that the effect of plant growth hormones was affected by genetic differences among various sex types in summer squash (*Cucurbita pepo* L.).

Temperature and daylength variations are reported to alter sex expression in cucurbits (Dhillon, 1966; Cantliffe, 1981). Increased light intensity increased staminate to pistillate ratio (Tiedjens, 1928). Tiedjens (1928) and Edmond (1931) found that low light intensity and short photoperiod favored pistillate flowering in monoecious cucumber. Atsmon and Galun (1962) reported that an interaction of short days and cool nights also favored the production of pistillate flowers. Short day conditions enhanced pistillate flower production in monoecious cucumber plants, which was attributed to increased levels of auxin. Lower and Edwards (1986) reported that high temperatures and long day conditions produced staminate flowers. Staminate flowers were also produced in gynoecious and hermaphroditic lines when grown under environmentally stressful conditions, such as high density planting (Lower and Edwards, 1986; Shifriss, 1961).

Several studies have reported on optimum stage for once-over harvest of cucumber. The objective in most of these studies was to determine the stage providing the highest once-over harvest yield, or the highest correlation between once-over and multiple-harvest yield. Miller and Hughes (1969) reported that harvesting at 14 to 31% oversized fruit (>51 mm diameter) fruit stage in a plot was found to be optimum for maximum value in once-over harvest for 'Piccadilly' and 'Southern Cross' gynoecious hybrids in North Carolina. (For slicing cucumber, oversized fruit would be >60 mm diameter). Chen et al. (1975), used a computer simulation to calculate that 10% oversized fruit stage gave the optimum yield for 'Piccadilly' hybrid under North Carolina conditions. Colwell and O'Sullivan (1981) reported that the optimum harvest stage to maximize yield for 'Femcap' and 'Greenstar' gynoecious hybrids occurred when 5 to 15% in a plot had oversized fruit.

In cucumber, fruit number was found to be more stable than fruit weight or fruit value for yield measurement in a once-over harvest in cucumber (Ells and McSay, 1981). Fruit number also was found to have higher heritability (0.17) than fruit weight (0.02) (Smith et al., 1978). Once-over harvest trials having three replications were recommended for maximum efficiency to determine which cucumber lines should be tested further in multiple-harvest trials (Wehner and Miller, 1984; Wehner, 1986). A plot size of 1.2 m x 1.5 m was found to be optimum for yield evaluation for once-over harvest of pickling cucumber harvested using paraquat (Swallow and Wehner, 1986). Wehner and Miller (1987) recommended the use of small, single-row plots without end borders rather than large, multiple-row, bordered plots. In cucumber, small-plot, single-harvest trials were found to be more efficient than large-plot, multiple-harvest trials (Wehner, 1986; Wehner, 1989; Wehner and Miller, 1984). Swallow and Wehner (1989) suggested that maximum information (1/variance) was obtained by allocating test plots of cucumber cultigens to different seasons and years instead of using different locations and replications. Field evaluation at the Clinton location was reported to be more efficient that three other locations used for testing in North Carolina (Wehner, 1987).

The objective of this experiment was to evaluate the yield of a set of pickling cucumber cultivars and breeding lines differing in sex expression when given different treatments of ethephon and harvested at two different stages.

Materials and Methods

The experiment was conducted over two years (1996 and 1997) and two seasons (spring and summer) at the Horticultural Crops Research Station in Clinton, N.C. using recommended horticultural practices as summarized by Schultheis (1990).

Cultigens used

A set of 33 pickling cucumber cultivars and breeding lines that differed in sex expression from monoecious to gynoecious was chosen for the experiment (Table 1.1). The cucumber cultigens were chosen to represent a range in sex expression, plant type, adaptations, performance levels, and release dates. Monoecious cultigens were grouped into three into three distinct subgroups: old monoecious cultigen subgroup ('Armstrong Early Cluster', Chicago Pickling', 'Early Russian', 'Green Thumb', 'Heinz Pickling', M 22, M 41, 'Model', 'National Pickling', 'Ohio MR 17', 'Picklers Special', 'Producer', ' Southern Pickler' and 'Tiny Dill'), new monoecious subgroup ('Addis', 'Chipper', 'Clinton', M 21, M 27, 'Pixie', 'Sumter' and 'Wautoma') and littleleaf subgroup (H-19, Littleleaf).

Field test

Fertilizer was incorporated before planting at a rate of 90-39-74 $kg \cdot ha^{-1}$ (N-P-K) with an additional 34 $kg \cdot ha^{-1}$ N applied at the vine tip-over stage (four to six true leaves). Seeds were planted on raised, shaped beds with centers 1.5 m apart. Plots were 1.2 m long with 1.2 m alleys at each end, and were arranged in rows 1.5 m apart. Seeds were planted on 29 April and 18 July in 1996 and 17 April and 4 August in 1997. Plots were planted with 16 seeds, and thinned to 12 plants at the first-true-leaf stage. Irrigation was applied as needed to provide a total of 25 to 40 mm per week, and a tank mix of 2.2 $kg \cdot ha^{-1}$ of naptalam (2-[(1-naphthalenylamino) carbonyl] benzoic acid) and 4.4 $kg \cdot ha^{-1}$ of bensulide (O,O-bis(1-methylethyl) S-[2-[(phenylsulfonyl) amino] ethyl] phosphorodithioate) was applied preplant for weed control. The field was surrounded by border rows for uniform competition and were planted with the pickling cucumber cultivar 'Sumter'.

Ethephon application

The ethephon (2-chloroethyl phosphonic acid) treatments involved spraying zero, one, or two application per plot, with the first application at the first to second true leaf stage, approximately one month after planting (20 May and 1 August in 1996 and 22 May and 21 August in 1997). A Solo backpack sprayer at 100 to 140 kPa (15 to 20 psi) was used to spray the ethephon on the leaves and stems until run-off. The second application was made one week after the first (30 May and 8 August in 1996, and 29 May and 28 August in 1997). Ethephon was prepared using Florel [3.9% ethephon (2-chloroethyl phosphonic acid)] (Southern Agricultural Insecticides, Inc., Palmetto, FL 34220) at the rate of 2.5 ml/l for a concentration of 21%.

Harvest

The experiment involved two harvest dates (10% oversized fruit and 50% oversized fruit). Plots were harvested once-over when it reached the proper harvest stage. Plots were harvested starting 18 June and 26 August in 1996, and 23 June and 23 September in 1997 for the spring and summer seasons, respectively. Plots were checked thrice every week for oversized fruits. Only plots which reached the right harvest stage (10% oversized fruit and 50% oversized fruit) were harvested.

Data collection

Data were collected as plot means, and consisted of number of total, early, and cull fruit per plot. Early yield was the number of oversized fruit (>51 mm diameter) at harvest. The number of marketable fruit was calculated as total minus cull. The percentage of culls was computed as 100 x cull fruit number / total fruit number. Fruit quality was rated mainly on shape and marketability, but color was also considered. Fruit quality was rated on a 1 to 9 scale (1-3 = poor, 4-6 = intermediate, 7-9 = excellent).

Data analysis

The experiment was a split-split plot in a randomized complete block design with two replications. The two years and two seasons were considered to be four random environments to simplify the statistical analysis. Environment were assaigned to main plots, harvest time (10% oversized fruit vs. 50% oversized fruit) was assaigned to subplot, ethephon applications was the sub-sub plot and cultigens were assaigned to sub-sub-sub plots. Environments and cultigens were considered to be random effects, while harvest and ethephon were considered as fixed effects. Plots with a stand count (plant number) of less than 50% were eliminated from the statistical analysis and plots with stand count ranging from 50 to 80% were corrected using the formula: corrected yield = (total yield/

stand) x 10 according to the method of Cramer and Wehner (1998). Data were analyzed using the General Linear Models and Random procedures of the Statistical Analysis System SAS 6.12 (SAS Institute, Inc., Cary, N.C.).

Results and Discussion

The data for the experiment were analyzed first using the four environments, the two harvest treatments, the three ethephon treatments, the two sex types (monoecious and gynoecious), and the 33 cultigens (Table 1.2 and 1.3). This analysis showed that the four environments were not significantly different from each other for the fruit yield and quality traits evaluated in this study. The two harvest treatments (10 and 50% oversized fruit stages) also were found to be non-significant for fruit yield and quality.

Ethephon treatments had a significant effect on total fruit, percentage of culls, and fruit quality rating (Table 1.2 and 1.3). We observed a significant positive difference between no ethephon, and one or two ethephon applications for fruit yield (total yield and percentage of culls) and quality rating. Total yield and percentage of culls increased for all cultigens evaluated in this study with increasing ethephon, averaged over all environments and harvests. The fruit quality rating tended to decrease with increasing ethephon (Table 1.9). Based on our results, one application of ethephon was optimum to convert a diverse array of pickling cucumber cultigens for evaluation of fruit yield and quality. The recommendation is based on the fact that there was no difference statistically between one and two ethephon applications for yield. One ethephon application was also found to be optimum for percentage of culls and fruit quality rating, since two ethephon applications resulted in higher percentage culls and lower fruit quality rating (Table 1.8). These results agree with the findings of Shetty and Wehner (2000) who recommended one spray of ethephon for conversion of sex types for pickling and slicing cucumber cultigens. They observed that increased applications of ethephon increased the number of days to first flowering, 50% flowering, first fruit set, and 50%

fruit set. The results also agree with the conclusions of El-Bakry et al. (1978) who recommended one application of ethephon for improved plant height, number of leaves per plant, and fruit yield on the cucumber cultivar 'Beit Alpha'.

When the data were analyzed by sex type (monoecious and gynoecious) (Tables 1.4 and 1.5), we observed that ethephon had an effect on total, marketable, percentage of culls and fruit quality rating for monoecious cultigens (Table 1.4). However, the effect of ethephon on gynoecious cultigens was only on the fruit quality rating (Table 1.4). Cultigens differed significantly for all traits evaluated in the study (Table 1.3). Total yield differed considerably between the two sex types. The interaction of sex, environment, and ethephon was found to be significant for total yield (Table 1.2). This indicated that cultigens differed in yield depending on sex expression. We were interested in determining which of the two sex types had the larger effect on yield. Therefore, we analyzed the data by sex (monoecious and gynoecious) for the traits evaluated. Gynoecious cultigens differed only for marketable yield (Table 1.4) while monoecious cultigens differed for total, marketable, percentage of culls, and fruit quality rating (Table 1.5). Gynoecious cultigens differed in the four environments tested for total and marketable yield based on significant interaction of cultigen X environment (Table 1.4). Monoecious cultigens, however were found to differ for all traits (total, marketable, percentage of culls and fruit quality ratings) with the exception of early yield (Tables 1.5).

We wanted to further examine the source of variation within cultigens belonging to the monoecious group so we analyzed the data by grouping the cultigens. The data analysis revealed that there were no differences between the environments and the two harvest dates for the three subgroups. The old monoecious cultigens differed for total yield, marketable yield, and fruit quality rating over the three ethephon treatments, while the new monoecious cultigens differed only for total yield. Cultigens belonging to the old monoecious group differed for total and marketable yield, percentage of culls, and fruit quality rating. However, there was no difference in fruit yield and quality traits for the cultigens belonging to the new monoecious and the littleleaf groups (Tables 1.6, 1.7, and 1.8).

When the monoecious cultigens were analyzed by subgroup to study the interaction of cultigens and environment (Table 1.5), the old monoecious subgroup differed for percentage of culls and fruit quality rating, while cultigens belonging to the new monoecious subgroup differed only for marketable yield in the four environments (Tables 1.6, 1.7, and 1.8).

The other interactions of cultigens with environment, harvest, ethephon, environment and harvest, environment and ethephon, ethephon and harvest and environment, harvest and ethephon were all non-significant (Table 1.3). All interactions of cultigen within the two groups were non-significant with the exception of the interaction of cultigen with environment and harvest for the monoecious sex type (Tables 1.4 and 1.5). The source of this variation was from cultigens belonging to the old monoecious subgroup, since the interaction was found to be significant (Table 1.6).

Total yield

In general, the gynoecious cultigens performed better during 1996 as compared to 1997. The cultigens with the highest yield over all the four environments in the gynoecious group were 'Napoleon', 'Regal', and 'Calypso' (Table 1.10).

Since the interaction of sex type with environment and ethephon was significant (Table 1.2), we reported cultigen means within sex type averaged over harvest (Table 1.11). Ethephon applications increased the total yield of monoecious cucumber cultigens in all seasons except for summer, 1997. Ethephon applications also improved yield of gynoecious cultigens with the exception of summer, 1996. Thus, ethephon improved the yield of gynoecious as well as monoecious cultigens (Table 1.11).

Early yield

Early yield did not differ between the two sex types (Table 1.2). Although cultigens in the monoecious cucumber group differed in their performance of early yields in the four environments, cultigens within the three subgroups of monoecious cucumber also did not differ for early yield (Tables 1.5, 1.6, 1.7, and 1.8). Therefore, we decided to report early yield averaged over cultigen (in the gynoecious group and the three subgroups of monoecious cucumber) and over the two harvests, ethephon, and environments for early yields. Mean early yield for the gynoecious group and the littleleaf, new monoecious and old monoecious subgroups were 32, 17, 26 and 27 thousand fruit/ha, respectively. Cultigens belonging to the littleleaf subgroup had the lowest percentage (17%) of early fruit in total yield. This is typical of cultigens belonging to the littleleaf plant type, which typically produce higher yields, but produce it late in the season. The littleleaf cultigens evaluated in the study took the longest of all cultigens to reach harvest stage. Cultigens belonging to the other group/subgroups had on an average of 30% early fruit.

Marketable yield

Marketable yield differed among cultigens within sex types. The cultigens also varied in performance over the four environments (Tables 1.4 and 1.5). Analysis of cultigens within the three subgroups of the monoecious group showed that the cultigens within the old monoecious subgroup differed in marketable yield (Tables 1.6 and 1.7). Therefore, we decided to report the performance of cultigens in the gynoecious and old monoecious groups for marketable yield. The interaction of cultigen with environment was significant ($p < 0.01$) for the cultigens within the gynoecious subgroup and the new monoecious subgroup. We therefore decided to report the yield in the four environments. Since cultigens in the littleleaf and new monoecious subgroup were not significantly different, we report the average marketable yield for the cultigens averaged over the four environments (Table 1.8).

Cultigens with the highest marketable yield in the gynoecious group were 'Napoleon', 'Calypso', Gy 4, and 'Regal'. Old monoecious cultigens with the highest marketable yield were 'Southern Pickler', 'Early Russian', 'Armstrong Early Cluster', and M 22 for the old monoecious subgroup. In general, cultigens belonging to the gynoecious group had the highest marketable yield followed by cultigens in the littleleaf, new monoecious and old monoecious subgroups. (Table 1.12).

Percentage of culls in harvest

Cultigens in the gynoecious group did not differ significantly for percentage of culls (Table 1.4), although cultigens in the monoecious group did (Table 1.5). When the three subgroups within the monoecious group were studied, only cultigens belonging to the old monoecious subgroup differed in their performance for percentage of culls (Table 1.6). There was no interaction of cultigens in the gynoecious group and the new monoecious and littleleaf subgroups with environments (Tables 1.4, 1.7, and 1.8).

Therefore, we reported the percentage of culls averaged over environments, harvest, ethephon, and all the cultigens in the gynoecious group, the new monoecious subgroup, and the littleleaf subgroup (Table 1.13). All cultigens in the old monoecious subgroup averaged over harvest and ethephon with their performance in the different environments are reported since they were significant (Table 1.6). In general, cultigens in the old monoecious subgroup had higher percentage of culls during the summers of both years. Cultigens belonging to the littleleaf subgroup had the lowest percentage of culls followed by cultigens in the new monoecious, gynoecious group, and old monoecious groups, respectively. The cultigens with the lowest percentage of culls in the old monoecious subgroup were M 22, M 41, 'Chicago Pickling', 'Southern Pickler', and 'Armstrong Early Cluster'.

Fruit quality

Fruit quality rating differed among cultigens belonging to the monoecious sex type. Cultigens also varied in fruit quality rating over the four environments (Table 1.5). Upon further analysis, it was observed that only cultigen and the interaction of cultigen and environment belonging to the old monoecious subgroup differed in performance for fruit quality rating (Table 1.6). Therefore, we reported fruit quality averaged over environment, harvest, ethephon, and all the cultigens in the gynoecious group, the new monoecious subgroup, and littleleaf subgroup. Old monoecious cultigens averaged over harvest and ethephon treatments in the different environments are reported individually (Table 1.14). The littleleaf cultigens 'H-19' and 'Little John' had the best fruit quality among the 33 cultigens evaluated in the study. The cultigens belonging to the new monoecious group followed by the gynoecious group had the best rating for fruit quality. Cultigens in the old monoecious subgroup had the lowest fruit quality rating. Cultigens with the best fruit quality among the old monoecious group were M 22, 'Heinz Pickling', 'Model', and 'Southern Pickler' (Table 1.14).

Total and marketable yields were higher in summer, 1996 and spring, 1997 when averaged over all cultigens, while spring, 1996 and summer, 1997 had a higher percentage of early and cull fruit. Fruit quality rating was higher in spring, 1996 and summer, 1997.

In summary, there was no difference between harvests for yield (total, marketable, and percentage of culls) and fruit quality traits, indicating that one could harvest at either stages without affecting fruit yield and quality. Ethephon had a larger affect than harvest date for total yield, percentage of culls, and fruit quality (Table 1.2 and 1.3). This is consistent with the results of McMurray and Miller (1969), Hogue and Heeney (1974), Cantliffe and Phatak (1975) who reported that ethephon improved yield in pickling cucumber.

However, since no difference was observed between one and two ethephon applications, we concluded that one application was optimum for converting the sex expression of a diverse array of pickling cucumber cultigens. Ethephon had a positive effect on total yield on pickling cultigens (Table 1.11), the two sex types also were found to differ for total yield (Table 1.2). When the data were further analyzed by sex type, gynoecious cultigens differed significantly for marketable yield, while monoecious cultigens differed significantly for total yield, marketable yield, percentage of culls, and fruit quality rating (Tables 1.4 and 1.5). Within the monoecious cultigens only cultigens belonging to the old monoecious subgroup differed for total yield, marketable yield, percentage of culls, and fruit quality (Tables 1.6, 1.7, and 1.8).

Further research is needed to determine whether monoecious cultivars sprayed with ethephon have similar yield when they are converted to gynoecious sex expression by backcrossing the *F* gene into them.

Literature Cited

Atsmon, D. and E. Galun. 1962. Physiology of sex in *Cucumis sativus* (L.) leaf age patterns and sexual differentiation of floral buds. Ann. Bot 26: 137-146.

Burg, S. P. and E. A. Burg. 1966. The interaction between auxin and ethylene and its role in plant growth. Proc. Nat. Acad. Sci. U.S.A. 55: 262-269.

Cantliffe, D. J. 1981. Alteration of sex expression in cucumber due to changes in temperature, light intensity and photoperiod. J. Amer. Soc. Hort. Sci. 106: 133-136.

Cantliffe, D. J. and S. C. Phatak. 1975. Use of ethephon and chlorflurenol in a once-over pickling cucumber production system. J. Amer. Soc. Hort. Sci. 100: 264-267.

Cargill, B. F., D. E. Marshall and J. H. Levin. 1975. Harvesting cucumbers mechanically. Mich. State Univ. Ext. Bull. 859.

Chen, L. H., C. H. Miller and R. S. Sowell. 1975. Simulation models for harvesting of pickling cucumbers. J. Amer. Soc. Hort. Sci. 100: 176-179.

Colwell, H. T. M. and J. O'Sullivan. 1981. Economics of harvest timing for once over harvesting of cucumbers. J. Amer. Soc. Hort. Sci. 106: 163-167.

Cramer, C. S. and T. C. Wehner. 1998. Stand correction methods for cucumber fruit yield. Cucurbit Genet. Coop. Rpt. 21: 18-20.

Dhillon, H. S. 1966. Sex expression and sex determination in Cucurbitaceae. Indian J. Agr. Sci. 53: 437-441.

Edmond, J. B. 1931. Seasonal variation of sex expression of certain cucumber varieties. Proc. Amer. Soc. Hort. Sci. 27: 329-332.

El-Bakry, A. M., H. M. Goma, A. F. Omran and E. T. El-Kholy. 1978. Effects of yield and fruit quality of cucumber. Annals of Agric. Sc., Moshtohor 10: 127-132.

Ells, J. E. and A. E. McSay. 1981. Yield comparisons of pickling cucumber cultivar trials for once-over harvesting. HortScience 16: 187-189.

Galun, E. 1959. The role of auxin in the sex expression of the cucumber. Physiol. Plant 12: 48-61.

Galun, E. 1961. Study of the inheritance of sex expression. The inheritance of major genes with modifying genetic and non-genetic factors. Genetica 32: 134.

George, W. L. Jr. 1971. Influence of genetic background on sex conversion by 2-chloroethanephosphonic acid in monoecious cucumbers. J. Amer. Soc. Hort. Sci. 96: 152-154.

Harlan, J. R. 1975. Crops and man. Am. Soc. Agron., Crop Sci. Soc. Am., Madison, WI.

Hogue, E. J. and H. B. Heeney. 1974. Ethephon and high density plantings increase yield of pickling cucumbers. HortScience 9: 72-74.

Iwahori, S., J. N. Lyons and O.E. Smith. 1970. Sex expression in cucumber as affected by 2-chloroethanephosphonic acid, ethylene and growth regulators. Plant Physiol. 46: 412-415.

Lower, R. L., and M. D. Edwards. 1986. Cucumber Breeding. In: Breeding vegetable crops. Basset, M.J. (ed.), pp. 173-207. AVI Publishing Co., Westport, Connecticut.

Malepszy, S. and K. Niemirowicz-Szczytt. 1991. Sex determination in cucumber (*Cucumis sativus*) as a model system for molecular biology. Plant Science 39-47.

McMurray, A. L. and C. H. Miller. 1969. The effect of 2-chloroethanephosphonic acid (ethrel) on the sex expression and yields of *Cucumis sativus*. J. Amer. Soc. Hort. Sci. 94: 400-402.

Miller, C. H. and G. R. Hughes. 1969. Harvest indices for pickling cucumbers in once-over harvest systems. J. Amer. Soc. Hort. Sci. 94: 485-487.

Miller, C. H., R. L. Lower and H. P. Fleming. 1970. Evaluation of pickles from cucumber plants treated with 2-chloroethylphosphonic acid. HortScience 5: 434-435.

Miller, C. H., and R. L. Lower. 1972. Effect of ethephon on fresh-pack and brined cucumbers. HortScience 7: 418-420.

Mitchell, W. D. and S. H. Wittwer. 1962. Chemical regulation of flower sex expression and vegetative growth in *Cucumis sativus* L. Science 136: 880-881.

Nitsch, J. P., E. B. Kurz, Jr., J. L. Liverman, and F. W. Went. 1952. The development if sex expression in cucurbit flowers. American J. Bot. 39: 32-43.

Peterson, C. E. 1975. Plant introductions in the improvement of vegetable cultivars. HortScience 10: 575-579.

Peterson, C. E., and L. D. Anhder. 1960. Induction of staminate flowers on gynoecious cucumbers with gibberellin A. Science 131: 1673-1679

Robinson, R. W., S. Shannon, and M. D. de la Guardia. 1968. Regulation of sex expression in the cucumber. BioScience 19: 141-142.

Robinson, R. W., H. M. Munger, T. W. Whitaker and G. W. Bohn. 1976. Genes of Cucurbitaceae. HortScience 11: 554-568.

Rudich, J., A. H. Halevy, and N. Kedar. 1969. Increase in femaleness of three cucurbits by treatment with Ethrel, an ethylene releasing compound. Planta 86: 69-76.

Rudich, J., A. H. Halevy, and N. Kedar. 1972. The levels of phytohormones in monoecious and gynoecious cucumbers as affected by photoperiod and ethephon. Plant Physiol. 50: 585-590.

SAS Institute. 1989. SAS/STAT User's guide, Release 6.12 edition. SAS Institute Inc., Cary, NC.

Schultheis, J. R. 1990. Pickling cucumbers. North Carolina State Agr. Ext. Hort. Inform. Leaflet No. 14-A.

Shannon, S. and M. D. De La Guardia. 1969. Sex expression and the production of ethylene induced by auxin in the cucumber (*Cucumis sativus* L.). Nature 223: 186.

Shannon, S. and R. W. Robinson. 1978. Genetic differences in sex-expression and responses to ethephon in summer squash (*Cucurbita pepo* L.). Cucurbits Genetic Coop. 1: 33.

Shetty, N. V. and Wehner, T. C. 2000. Effects of ethephon on vegetative and floral traits in cucumbers. Euphytica (in review).

Shifriss, O. 1961. Sex control in cucumbers. J. Hered. 52: 5.

Sitterly, W. R. 1972. Breeding for disease resistance in cucurbits. Ann. Rev. Phytopathology 10: 471.

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

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size for measurement of yield in multiple and once over harvest trials of pickling and fresh market cucumbers. Euphytica 35: 493-501.

Swallow, W. H. and T. C. Wehner. 1989. Optimum allocation of plots to years, seasons, locations, and replications, and its applications to once-over harvest cucumber trials. Euphytica 43: 59-68.

Tiedjens, V. A. 1928. Sex-ratios in cucumber flowers affected by different conditions of soil and light. J. Agr. Res. 36;721-746.

Warner, H. L. and A. C. Leopold. 1969. Ethylene evolution from 2-chloroethylphosphonic acid. Plant Physiology 44: 156-158.

Wehner, T. C. 1986. Efficiency of 3 single-harvest tests for evaluation of yield in pickling cucumber. Euphytica 35: 493-501.

Wehner, T. C. 1987. Value of 12 season-location combinations for cucumber yield trials in North Carolina. Cucurbit Genet. Coop. Rpt. 6: 38-39.

Wehner, T. C. 1989. Breeding for improved yield in cucumber. Plant Breed. Rev. (Ed.) J. Janick. Vol. 6: 323-359.

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: 659-664.

Wehner, T. C. and C. H. Miller. 1987. Optimum plant density for multiple-harvest yield of determinate cucumbers. Cucurbit Genet. Coop. Rpt. 10: 29-30.

Yang, S. F. 1969. Ethylene evolution from 2-chloroethylnephosphonic acid. Plant Physiology 44: 1203-1204.

Table 1.1. List of Pickling cucumber cultigens used in the study.

Cultigens	Seed source	Sex[z]	Cultigens	Seed source	Sex[z]
Addis	NC State Univ.	M	M 22	NC State Univ.	M
Armstrong Early Cluster	Sunseeds	M	M 27	NC State Univ.	M
			M 41	NC State Univ.	M
Calypso	NC State Univ.	G	Model	Associated Seed	M
Chicago Pickling	Northrup-King	M	MSU 713-5	Michigan State	G
Chipper	Clemson Univ	M	Napoleon	Sunseeds	G
Clinton	NC State Univ.	M	National Pickling	NSSL	M
Double Yield	Harris Moran	M			
Early Russian	NSSL	M	Ohio MR 17	Heinz and Ohio	M
Green Thumb	Harris	M	Picklers Special	Wyoming(NSSL)	M
Gy 1	NC State Univ.	G	Pixie	Clemson Univ.	M
Gy 3	Clemson Univ.	G	Producer	Associated	M
Gy 4	NC State Univ.	G	Regal	NC State Univ.	G
Gy 5	NC State Univ.	G	Southern Pickler	Arkansas AES	M
H-19	NC State Univ.	M	Sumter	Clemson Univ.	M
Heinz Pickling	Burpee (NSSL)	M	Tiny Dill NHTD)	New Hampshire	M
Little John	Univ. Arkansas	M	Wautoma	Wis.-USDA	M
M 21	Univ. Arkansas	M			

[z] M=Monoecious, G=Gynoecious

Table 1.2. Mean squares for traits evaluated in study by sex type.

		Yield				
				Market	%	Fruit
Source of variation	df	Total	Early	-able	cull	quality
Environment	3	22040	23064	16065	440	17.4
Error A	4	1950	60	1533	222	6.3
Harvest	1	4456	987	880	825	1.6
Harvest X Environment	3	5780	1600	8320	1444	2.9
Error B	4	3510	1695	2823	437	2.0
Ethephon	2	16231*	202	3367	1796*	35**
Ethephon X Environment	6	4113	1661	3169	196	2.7
Ethephon X Harvest	2	249	137	201	231	1.3
Ethephon X Environment X Harvest	6	779	408	788	319	1.1
Error C	16	3318	505	2819	314	2.1
Sex	1	21813**	7289	13351	0.04	113
Sex X Environment	3	1391	2541	1913	126	1.0
Sex X Harvest	1	1021	1191	26	353	0.2
Sex X Ethephon	2	7729	123	5058	59	3.1
Sex X Environment X Harvest	3	270	282	534	530	0.2
Sex X Environment X Ethephon	6	4076*	183	2747	111	1.2
Sex X Ethephon X Harvest	2	1268	946	514	62	0.8
Sex X Environment X Harvest X Ethephon	6	338	634	713	239	0.2
Error D	1171	1054	340	934	196	2.2

Table 1.3. Mean squares for traits evaluated in study by cultigens.

		Yield				
				Market	%	Fruit
Source of variation	df	Total	Early	-able	cull	quality
Environment	3	18842	16061	14660	195	11.5
Error A	4	1522	131	1509	321	4.7
Harvest	1	4377	1485	891	705	3.0
Harvest X Environment	3	6770	1871	8638	715	2.7
Error B	4	2413	1335	2125	247	1.8
Ethephon	2	24430*	864	6984	1956*	26**
Ethephon X Environment	6	2732	1966	2318	208	1.3
Ethephon X Harvest	2	6	148	133	132	0.7
Ethephon X Environment X Harvest	6	1812	372	1176	177	2.2
Error C	16	2367	300	2055	214	1.1
Cultigen	32	5415**	1131*	5300**	1124**	44**
Cultigen X Environment	86	2385**	720**	2190**	375**	1.8**
Cultigen X Harvest	32	518	217	478	113	0.8
Cultigen X Ethephon	64	886	352	782	146	0.9
Cultigen X Environment X Harvest	76	1205*	337*	900	166	0.8
Cultigen X Environment X Ethephon	161	954	258	740	159	0.9
Cultigen X Ethephon X Harvest	62	801	291	700	183	0.9
Cultigen X Environment X Harvest X Ethephon	138	855	242	752	159	0.9
Errror D	540	755	307	648	147	0.9

**, * significance at 1% and 5% respectively

Table 1.4. Mean squares for traits evaluated in study for gynoecious cucumber cultigens.

		Yield				
Source of variation	df	Total	Early	Market -able	% cull	Fruit quality
Environment	3	9697	11510	10320	390	4.9
Error A	4	502	375	475	121	2.0
Harvest	1	2960	75	208	854	0.0
Harvest X Environment	3	781	184	1778	802	0.9
Error B	4	153	273	402	225	2.1
Ethephon	2	3159	40	589	534	12.5*
Ethephon X Environment	6	4545*	803	3283*	151	1.2
Ethephon X Harvest	2	309	550	378	5	0.2
Ethephon X Environment X Harvest	6	309	463	660	259	0.7
Error C	16	1286	260	1312	138	1.3
Cultigen	7	4341	1526	6358*	1180	27.6
Cultigen X Environment	19	1797*	790	1270*	104	1.1
Cultigen X Harvest	7	328	350	468	115	0.6
Cultigen X Ethephon	14	682	255	549	82	0.4
Cultigen X Environment X Harvest	17	580	417	398	75	1.2
Cultigen X Environment X Ethephon	37	547	224	513	120	0.6
Cultigen X Ethephon X Harvest	14	472	177	626	161	0.5
Cultigen X Environment X Harvest X Ethephon	32	419	363	345	88	0.6
Error D	123	522	320	453	119	0.7

**, * significance at 1% and 5% respectively

Table 1.5. Mean squares for traits evaluated in study for monoecious cucumber cultigens (all groups).

Source of variation	df	Yield: Total	Yield: Early	Yield: Market -able	% cull	Fruit quality
Environment	3	10225	8045	6701	168	8.9
Error A	4	1936	281	1917	309	2.9
Harvest	1	2191	2776	809	161	3.4
Harvest X Environment	3	6558	1963	7172	326	1.9
Error B	4	3552	1120	2937	95	0.8
Ethephon	2	23513*	1156	9178*	1407*	15.4*
Ethephon X Environment	6	2764	1236	1845	123	0.7
Ethephon X Harvest	2	120	755	41	201	0.5
Ethephon X Environment X Harvest	6	2121	334	1466	97	1.9
Error C	16	1563	323	1400	301	0.9
Cultigen	24	4790*	714	4454*	1120**	45**
Cultigen X Environment	64	2588*	579*	2418**	459	1.9**
Cultigen X Harvest	24	558	137	477	79	0.7
Cultigen X Ethephon	48	775	380	727	174	0.9
Cultigen X Environment X Harvest	56	1431*	286	1066	181	0.7
Cultigen X Environment X Ethephon	118	897	270	709	179	1.0
Cultigen X Ethephon X Harvest	46	937	244	767	195	1.0
Cultigen X Environment X Harvest X Ethephon	100	995	195	858	178	0.8
Error D	393	829	303	697	153	0.9

**, * significance at 1% and 5% respectively

Table 1.6. Mean squares for traits evaluated in study for old monoecious cucumber cultigens.

		Yield				
Source of variation	df	Total	Early	Market -able	% cull	Fruit quality
Environment	3	7696	9597	2702	840	8.1
Error A	4	879	461	1159	224	2.9
Harvest	1	3271	987	1017	167	2.5
Harvest X Environment	3	7163	1420	6871	315	1.1
Error B	4	3110	1045	1894	110	1.6
Ethephon	2	16836*	2545	7355*	487	8.7*
Ethephon X Environment	6	1293	852*	705	44	0.4
Ethephon X Harvest	2	457	661	314	296	0.6
Ethephon X Environment X Harvest	6	708	58	525	122	1.3
Error C	16	1117	293	726	302	1.2
Cultigen	14	6756	570	5771*	1432**	21**
Cultigen X Environment	36	2142	482	1943	485*	2**
Cultigen X Harvest	14	692	135	490	105	0.7
Cultigen X Ethephon	28	680	365	664	209	0.8
Cultigen X Environment X Harvest	31	1589*	355	1130	200	0.9
Cultigen X Environment X Ethephon	65	1163	264	892	242	1.1
Cultigen X Ethephon X Harvest	26	860	263	725	248	1.1
Cultigen X Environment X Harvest X Ethephon	56	907	190	855	192	0.7
Error D	211	810	311	706	175	0.7

**, * significance at 1% and 5% respectively

Table 1.7. Mean squares for traits evaluated in study for new monoecious cucumber cultigens.

Source of variation	df	Yield Total	Yield Early	Yield Market-able	% cull	Fruit quality
Environment	3	8539	1665	7921	498	4.9
Error A	4	3090	170	2292	143	2.0
Harvest	1	349	1834	455	13	0.0
Harvest X Environment	3	1605	732	2091	309	0.9
Error B	4	1731	524	2089	173	2.1
Ethephon	2	11330*	65	6029	1372	12.5
Ethephon X Environment	6	1260	544	1404	203	1.2
Ethephon X Harvest	2	437	662	416	108	0.2
Ethephon X Environment X Harvest	6	2161	656	1298	305	0.7
Error C	16	1281	314	1122	158	1.3
Cultigen	7	2492	709	2420	607	27
Cultigen X Environment	21	1621	368	1555*	237	1.1
Cultigen X Harvest	7	657	150	717	43	0.6
Cultigen X Ethephon	14	431	383	254	100	0.4
Cultigen X Environment X Harvest	19	722	194	658	168	1.2
Cultigen X Environment X Ethephon	40	450	293	341	85	0.6
Cultigen X Ethephon X Harvest	14	1003	244	830	76	0.5
Cultigen X Environment X Harvest X Ethephon	33	575	150	464	158	0.5
Error D	123	522	320	453	119	0.6

**, * significance at 1% and 5% respectively

Table 1.8. Mean squares for traits evaluated in study for littleleaf cucumber cultigens.

Source of variation	df	Yield Total	Yield Early	Yield Market -able	% cull	Fruit quality
Environment	3	10160	469	10885	1017	1.0
Error A	4	804	36	775	50	0.7
Harvest	1	611	25	732	10	0.1
Harvest X Environment	3	3270	2	2598	41	0.5
Error B	4	1625	37	1963	142	0.3
Ethephon	2	2861	422	2227	5	1.8
Ethephon X Environment	6	1989	379	1733	53	0.4
Ethephon X Harvest	2	767	141	468	73	0.4
Ethephon X Environment X Harvest	6	4492	616	3931	50	0.1
Error C	16	1447	131	1219	58	0.3
Cultigen	1	71	0.2	204	108	0.4
Cultigen X Environment	1	1053	2	1553	30	0.2
Cultigen X Harvest	1	14	331	9	3	0.4
Cultigen X Ethephon	2	1830	100	2278	198	0.3
Cultigen X Environment X Harvest	1	0.3	158	0.5	24	0.7
Cultigen X Environment X Ethephon	2	877	37	1729	241	1.1
Cultigen X Ethephon X Harvest	2	1506	8	799	303	0.1
Cultigen X Environment X Harvest X Ethephon	2	99	260	139	17	0.3
Error D	6	509	252	512	151	0.8

**, * significance at 1% and 5% respectively

Table 1.9. Performance of total yield (1000 fruit/ha), percentage of culls, and fruit quality averaged over cultigens tested in four environments and two harvests in 1996 to 1997.

Trait	Mean yield	Ethephon 0	Ethephon 1	Ethephon 2
Total yield	95	85	98	102
Percentage of culls	20	17	19	22
Fruit quality	6.0	6.3	6.0	5.6

Table 1.10. Total yield (1000 fruit/ha) for cultigens evaluated in the study averaged over harvests and ethephon treatments during 1996 to 1997. (Cultigens ranked by mean yield over the four environments)

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Gynoecious Group					
Napoleon	119	136	145	99	98
Calypso	109	118	129	95	95
Regal	104	116	130	85	84
Gy 4	99	98	116	93	89
Gy 3	94	93	116	78	90
MSU 713-5	92	104	81	-	-
Gy 1	92	97	100	79	91
Gy 5	89	79	84	107	89
Monoecious Group					
Littleleaf Subgroup					
Little John	94	114	73	.	.
H-19	90	95	82	136	48
New Monoecious Subgroup					
M 21	104	120	117	95	82
Pixie	99	89	114	110	82
Clinton	97	96	123	80	90
M 27	96	90	88	124	83
Addis	92	83	117	83	86

Table 1.10. Contd.

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Wautoma	94	88	107	97	86
Sumter	85	89	111	78	63
Mean	93	89	107	95	81
Old Monoecious Subgroup					
Early Russian	112	139	105	94	110
Southern Pickler	109	111	134	108	84
ArmstrongEarlyClstr	103	100	112	133	68
M 22	96	95	103	95	91
Green Thumb	96	101	90	87	108
Producer	88	102	130	62	60
Ohio MR 17	88	90	85	.	.
Chicago Pickling	87	81	94	.	.
National Pickling	87	96	99	73	81
Heinz Pickling	81	77	82	71	92
Chipper	79	61	82	81	79
Model	75	82	82	70	65
M 41	74	67	94	53	78
Double Yield	74	80	80	46	.
Tiny Dill (NHTD)	71	95	52	87	51
PicklersSpecial	71	79	70	58	76

Table 1.10. Contd.

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Mean	82	94	94	80	80
Mean	92	96	101	88	82
Std. Dev.	21	19	22	22	15
CV	22	19	22	25	18

[z] Yield averaged over 2 harvests, 3 ethephon treatments and 2 replications

Table 1.11. Total yield performance based on sex expression (1000 fruit/ha) evaluated in the study averaged over harvests and cultigens during 1996 to 1997.

			Total yield^{Z}	
Year	Season	Ethephon	Gynoecious^{X}	Monoecious^{Y}
1996	Spring	0	90	78
		1	101	106
		2	127	104
	Summer	0	124	83
		1	112	107
		2	104	107
1997	Spring	0	87	73
		1	79	94
		2	104	95
	Summer	0	88	79
		1	91	79
		2	95	83

^{Z} Yield averaged over 2 harvests and 2 reps

^{Y} 24 cultigens

^{X} 8 cultigens

Table 1.12. Performance of marketable yield (1000 fruit/ha) of cultigens evaluated in study averaged over harvests and ethephon treatments during 1996 to 1997 (ranked by average marketable yield over four environments).

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Gynoecious Group					
Napoleon	100	114	125	78	82
Calypso	92	100	116	76	78
Gy 4	85	85	102	80	74
Regal	81	83	112	66	64
Gy 1	79	82	87	68	80
Gy 3	73	76	91	58	69
Gy 5	65	59	67	80	54
MSU 713-5	61	64	58	-	-
Monoecious Group					
Littleleaf subgroup					
Little John	80	98	61	.	.
H-19	78	78	76	127	32
Mean	79	88	69	127	32
New Monoecious Subgroup					
Clinton	84	80	105	64	84
M 21	84	97	103	82	55
M 27	84	77	76	112	73

Table 1.12. continued.

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Pixie	84	67	101	94	73
Addis	77	74	98	66	72
Old Monoecious Subgroup[x]					
Southern Pickler	90	89	111	87	72
Early Russian	88	109	74	77	91
Armstrong Early Cluster	83	71	84	116	62
M 22	83	79	94	79	82
Green Thumb	80	83	71	76	89
Producer	75	93	106	51	48
Chicago Pickling	74	68	79	.	.
Ohio MR 17	68	74	62	.	.
National Pickling	67	71	73	59	65
Heinz Pickling	64	69	54	54	79
M 41	61	58	86	42	56
Model	54	57	58	53	49
Picklers Special	54	65	53	41	56
Double Yield	49	50	58	38	.
Tiny Dill (NHTD)	47	69	31	70	19

Table 1.12. continued.

Cultigen	Mean yield	1996 Spring[Z]	1996 Summer[Z]	1997 Spring[Z]	1997 Summer[Z]
Mean	74	76	82	72	66
Std. Dev.	20	16	22	21	17
CV	27	21	27	30	25

[Z] Yield averaged over 2 harvests, 3 ethephon treatments and 2 replications

[Y] Yield averaged over 2 harvests, 3 ethephon treatments, 4 environments, 2 cultigens and 2 replications

[X] Yield averaged over 2 harvests, 3 ethephon treatments, 4 environments and 2 replications

Table 1.13. Percentage of culls for cultigens evaluated in study averaged over harvests and ethephon treatments during 1996 to 1997 (ranked by average yield over four environments).

Cultigen	Mean % cull fruit	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Gynoecious Group					
Gy 4	14	16	12	14	16
Gy 1	14	16	13	15	13
Calypso	16	16	9	20	17
Napoleon	17	17	14	21	16
Regal	22	28	14	23	23
Gy 3	23	22	22	26	24
Gy 5	27	24	20	25	38
MSU 713-5	34	37	31	.	.
Mean	21	22	17	21	21
Monoecious Group					
Littleleaf Subgroup					
Little John	15	14	15	.	.
H-19	17	17	8	7	35
Mean	16	15	11	7	35

Table 1.13. continued.

Cultigen	Mean % cull fruit	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
New Monoecious Subgroup					
M 27	13	15	14	11	13
Clinton	14	17	13	18	6
Pixie	17	24	12	18	13
Addis	15	10	16	20	15
M 21	20	20	13	16	33
Sumter	22	22	13	32	22
Wautoma	22	26	23	29	12
Mean	18	19	16	21	16
Old Monoecious Subgroup					
M 22	13	14	9	18	10
M 41	16	13	12	20	20
Chicago Pickling	17	16	17	-	-
Southern Pickler	18	21	18	19	14
Armstrong Early Cluster	19	30	25	14	9
Green Thumb	19	21	22	12	20
Producer	20	18	16	19	26
Chipper	20	22	20	21	18

Table 1.13. continued.

Cultigen	Mean % cull fruit	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
National Pickling	21	26	26	19	13
Ohio MR 17	21	21	21	.	.
Heinz Pickling	22	10	40	22	16
Early Russian	23	30	29	17	16
Picklers Special	23	15	25	26	27
Double Yield	25	37	20	17	-
Model	26	28	30	23	24
Tiny Dill (NHTD)	42	30	52	22	64
Mean	20	21	19	19	21
Std. Dev.	8	7	9	5	12
CV	42	33	48	28	57

[z] Yield averaged over 2 harvests, 3 ethephon treatments and 2 replications

Table 1.14. Fruit quality rating for cultigens evaluated in study averaged over harvests and ethephon treatments during 1996 to 1997 (ranked by average yield over four environments).

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Gynoecious Group					
Napoleon	7.1	7.2	6.7	7.1	7.5
Regal	6.9	7.3	7	6.7	6.5
Calypso	6.8	7.3	6.8	6	7.2
Gy 1	6.5	6.6	6.4	6.3	6.8
Gy 4	6.5	6.3	6.7	6.5	6.5
Gy 3	6	6.3	5.6	5.5	6.5
Gy 5	5.2	5.6	5.4	4.2	5.4
Mean	6.4	6.7	6.4	6.0	6.6
Monoecious Group					
Littleleaf Subgroup					
H-19	7.3	7.4	7.3	7.6	6.8
Little John	7.2	7.3	7.1	.	.
Mean	7.3	7.4	7.2	7.6	6.8
New Monoecious Subgroup					
M 27	7.0	6.8	6.4	8	6.9

Table 1.14. Continued.

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Clinton	6.9	6.9	6.3	6.8	7.5
Wautoma	6.8	6.5	6.4	7	7.4
Addis	6.8	7.3	6.6	6.5	7
Pixie	6.8	7.3	6.2	6.8	6.8
M 21	6.4	6.6	6.2	6.8	6.1
Sumter	6.4	6.4	6.5	6.1	6.7
Mean	6.7	6.8	6.4	6.9	6.9
Old Monoecious Subgroup					
M 22	6.5	7.0	6.4	6.0	6.6
Heinz Pickling	5.8	8.0	6.0	4.7	4.4
Model	5.6	5.2	4.9	6.2	6.1
M 41	5.5	6.5	5.7	4.1	5.7
Southern Pickler	5.4	5.2	5.3	5.2	5.9
Green Thumb	5.2	5.6	4.8	4.9	5.6
Chicago Pickling	4.9	5.1	4.7	.	.
Producer	4.6	4.3	4.6	4.3	5.3
Ohio MR	4.5	4.6	4.8	4.3	-
Picklers Special	4.5	4.3	3.9	4.8	4.7

Table 1.14. Continued.

Cultigen	Mean yield	1996 Spring[Z]	1996 Summer[Z]	1997 Spring[Z]	1997 Summer[Z]
Tiny Dill (NHTD)	4.5	5.1	4.1	4.6	4.3
Double Yield	4.3	5.5	4.3	3.0	-
National Pickling	4.0	3.7	3.8	3.8	4.5
Early Russian	3.4	2.9	2.8	3.9	4.1
Armstrong Early Cluster	3.2	3.1	2.9	2.9	4.0
Mean	5.8	6.0	5.5	5.6	6.0
Std. Dev.	1.3	1.4	1.2	1.4	1.1
CV	22	23	22	24	18

[Z] Yield averaged over 2 harvests, 3 ethephon treatments and 2 replications

[Y] Yield averaged over 2 harvests, 3 ethephon treatments, 2 replications, 4 environments and cultigens

Chapter Two

Effect of Ethephon and Harvest on Slicing Cucumber Yield and Quality

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Breeding and Germplasm Resources

Effect of Ethephon and Time of Harvest on Slicing Cucumber Fruit Yield and Quality

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Abstract

The plant growth regulator ethephon affects sex expression in cucurbits by producing more pistillate flowers. Our objective in this experiment was to determine whether ethephon affected fruit yield and quality in a diverse set of slicing cucumber cultigens. In addition, we were interested to determine whether harvesting cucumber at the 10 or 50% oversize fruit stage had an effect on fruit yield and quality under field conditions in North Carolina. The experiment was conducted over two years and two seasons (four environments). We observed no significant differences among the four environments for traits evaluated in the study. Harvest and ethephon, the two main treatment effects, did not alter the traits evaluated. Fruit yield and quality traits were affected by the sex expression of the cultigens evaluated. When the role of sex expression was examined further, it was revealed that gynoecious cultigens did not differ for fruit yield and quality rating, while monoecious cultigens differed for total yield, marketable yield, and fruit quality. Analysis of the subgroups within the monoecious group revealed that cultigens belonging to the old monoecious subgroup differed for fruit quality, while cultigens belonging to the new monoecious subgroup differed for early fruit yield and quality. Cultigens varied in performance in the four environments for early yield (old monoecious and trellis and middle-eastern subgroup) and fruit quality (old and new monoecious subgroups).

Cucumber (*Cucumis sativus* L.) belongs to the *Cucurbitaceae,* which is comprised of about 750 species. Botanically, cucumber is an annual, herbaceous vine with a pepo type fruit. It is monoecious, with staminate flowers in clusters, and solitary pistillate flowers.

The three flower types found in cucumber are staminate, pistillate and perfect, and the five sex types are monoecious (staminate and pistillate flowers), androecious (staminate flowers only), gynoecious (pistillate flowers only), hermaphroditic (hermaphroditic flowers only), and andromonoecious (staminate and perfect flowers).

Wild type cucumber is probably monoecious or andromonoecious, but cultivars range from androecious (mostly staminate flowers) to gynoecious (all pistillate flowers) in sex expression. Three genes controlling sex expression have been reported: *F/f*, *M/m*, and *A/a*. Gynoecious inbred lines have the genotype *FF MM*, while monoecious inbreds are *FF mm*. Several modifier genes (as well as environmental conditions) have been reported to affect sex expression as well. Plants of *FF* genotype do not necessarily produce all pistillate flowers; modifier genes and environmental conditions can result in staminate or perfect flowers (Shifriss, 1961). Robinson et al. (1976) reported that an inbred of genotype *FF* had a higher degree of gynoecy than an isogenic line of genotype *ff*. The genotype *mm* causes the development of perfect flowers (Galun, 1961; Shifriss, 1961).

The ability to modify sex expression in cucumber has been of great interest to researchers, especially since there is a correlation between number of pistillate flowers per plant and plant yield. Thus, conversion of monoecious or andromonoecious cultivars into gynoecious ones is an easy way to improve their yield.

Several plant growth regulators alter sex expression in cucumber. Auxins increase the number of pistillate flowers (Galun, 1959; Heslop-Harrison, 1957; Nitsch et al., 1952), and gibberellins increase the number of staminate flowers (Galun, 1959; Peterson and Anhder, 1960; Rudich et al., 1972). Endogenous auxin levels were found to be higher in gynoecious cucumber lines than in monoecious ones (Rudich et al., 1972).

Ethylene is a plant growth regulator associated with developmental and physiological processes in plants including accelerated senescence and ripening of fruit. Ethylene also has been reported to control sex expression in cucurbits (Pratt and Goeschl, 1969). The ethylene-releasing property of ethephon (2-chloroethylphosphonic acid) was first reported by Warner and Leopold (1969) and Yang (1969). Higher ethylene was reported to be produced in apices of gynoecious plants and pistillate buds than in apices and buds of monoecious plants (Rudich, 1969). Rudich et al. (1972) reported that ethylene may promote the production of pistillate flowers directly by reducing endogenous gibberellic acid levels or by promoting the production of abscisic acid. Differential response to ethephon was observed in monoecious cucumber cultivars and was attributed to the genetic system controlling the gynoecious tendency in these cultivars (George, 1971). The total fruit number was higher when plants were treated with ethephon just before flowering than when treated at the seedling stage. Ethephon treatment also reduced the percentage fruit set in monoecious cucumber cultivars (Karchi and Govers, 1972). Gaseous ethylene treatment has also been reported to promote production of pistillate flowers in monoecious cucumber lines (Iwahori et al., 1970).

Sex expression in cucurbits is also influenced by environmental conditions such as temperature and daylength (Dhillon, 1966; Cantliffe, 1981). Increased light intensity was reported to increase staminate: pistillate ratio (Tiedjens, 1928). Short day conditions were found to enhance pistillate flower production in monoecious cucumber lines and was attributed to increased auxin levels (Rudich et al., 1972). Lower and Edwards (1986) reported that a higher number of staminate flowers were produced under high-temperature and long day conditions. Staminate flowers developed in gynoecious and hermaphroditic lines when grown under environmentally stressful conditions such as high density plantings (Lower and Edwards, 1986; Shifriss, 1961).

A range of 5 to 31% oversized fruit was recommended as the optimum harvest stage for yield as fruit weight or value in pickling cucumbers (Chen et al., 1975; Colwell and

O'Sullivan, 1981; Miller and Hughes, 1969). However, no such studies have been carried out for slicing cucumber. We were interested in determining the optimum harvest stage for slicing cucumber for use in evaluating the cucumber germplasm collection for yield. Measurement of cucumber yield as fruit number rather than fruit weight or value provided the most stable measure of yield in a once-over harvest system (Ells and McSay, 1981). Fruit number had higher heritability (0.17) making selection progress easier compared to fruit weight (0.02) (Smith et al., 1978). Two to three replications of a once-over harvest trial in early selection stages provided greatest efficiency for measuring yield of cucumber lines where yield was to be measured using multiple-harvest trials in later stages (Wehner, 1986; Wehner and Miller, 1984).

A plot size of 1.2 x 1.5 m was optimum for yield evaluation for once-over harvest of pickling cucumber (Swallow and Wehner, 1986). Wehner and Miller (1987) recommended the use of small, single-row plots without end-borders rather than large, multiple-row, bordered plots. Small-plot, single harvest trials were more efficient than large-plot, multiple harvest trials, which required more time and labor (Wehner, 1986; Wehner, 1989; Wehner and Miller, 1984). Swallow and Wehner (1989) reported that maximum information (1/variance) was obtained by allocating test plots of cucumber lines to different seasons and years instead of using different locations and replications. Finally, field plots at the Clinton location provided better data for yield evaluation than three other locations in North Carolina (Wehner, 1987).

The objective of this experiment was to measure yield of a set of slicing cucumber cultigens (chosen to differ in sex expression, plant type, and other traits) subjected to different ethephon and harvest stage treatments under field conditions in North Carolina. Ultimately, the results of this study were used to develop a method for evaluation of the U.S.D.A. cucumber germplasm collection for yield.

Materials and Methods

The experiment was conducted over two years (1996 and 1997) and two seasons (spring and summer) at the Horticultural Crops Research Station in Clinton, N.C. using recommended horticultural practices as summarized by Schultheis (1990).

Cultigens used

A set of 33 slicing cucumber lines that ranged in sex expression from monoecious to gynoecious were chosen (Table 2.1). Cultigens were chosen to represent the range of traits found in slicing cultivars. The monoecious cultigens were further divided into three subgroups: new monoecious, old monoecious, and middle-eastern and trellis subgroups. The 11 old monoecious cultigens were 'Arlington White Spine', 'Ashley', 'Cubit', 'Davis Perfect', 'Dublin', 'Early Michigan', 'Everbearing', 'Longfellow', 'Marketer', 'Polaris', and 'Straight 8'. The 9 new monoecious cultigens were 'Fletcher', 'Marketmore 76', 'Medalist', 'Pacer', 'Poinsett 76', 'Redlands Long White', 'Slice', and 'Tablegreen 72 M'. The three middle-eastern (Beit Alpha) and trellis cultigens were 'Coolgreen', 'Supergreen', and 'Yangzhou Greenskin' (only the last was an oriental trellis cultivar).

Field test

Fertilizer was incorporated before planting at a rate of 90-39-74 $kg \cdot ha^{-1}$ (N-P-K) with an additional 34 $kg \cdot ha^{-1}$ N applied at the vine tip-over stage (four to six true leaves). Seeds were planted on raised, shaped beds with centers 1.5 m apart. Plots were 1.2 m long with 1.2 m alleys at each end, and were arranged in rows 1.5 m apart. Seeds were planted on 29 April and 18 July in 1996 and 17 April and 4 August in 1997. Plots were planted with 16 seeds, and thinned to 12 plants at the first-true-leaf stage. Irrigation was applied as needed to provide a total of 25 to 40 mm per week, and a tank mix of 2.2 $kg \cdot ha^{-1}$ of naptalam (2-[(1-naphthalenylamino) carbonyl] benzoic acid) and 4.4 $kg \cdot ha^{-1}$ of bensulide (O,O-bis(1-methylethyl) S-[2-[(phenylsulfonyl) amino] ethyl] phosphorodithioate) was applied preplant for weed control. The field was surrounded by 'Poinsett 76' planted in border rows and end plots for uniform competition, and to provide an additional pollen source for fruit development.

Ethephon application

The ethephon (2-chloroethyl phosphonic acid) treatments involved spraying plants with zero, one, or two application of ethephon. The first application was at the first to second true leaf stage, approximately one month after planting (20 May and 1 August in 1996, and 22 May and 21 August in 1997). A Solo backpack sprayer at 100 to 140 kPa (15 to 20 psi) was used to apply the treatments, and was sprayed onto the leaves until run-off. The second application was one week after the first (30 May and 8 August in 1996, and 29 May and 28 August in 1997). Ethephon was prepared using Florel [3.9% ethephon (2-chloroethyl phosphonic acid)] (Southern Agricultural Insecticides, Inc. Palmetto, FL 34220) at the rate of 2.5 ml/l for a concentration of 21%.

In addition to the ethephon treatments, the experiment involved two harvest dates (10 and 50% oversized fruit). Plots were harvested once-over beginning 18 June and 26 August in 1996, and 23 June and 23 September in 1997.

Data collection

Data were collected as plot means, and consisted of number of total, early, and cull fruit per plot. Early fruit were the number of oversized (>60 mm diameter) at harvest. The number of marketable fruit was calculated as total - culls. The percentage of culls was calculated as 100 x cull fruit number / total fruit number. Fruit quality was rated mainly on shape and marketability, but color was also considered. Fruit quality was rated on a 1 to 9 scale (1-3 = poor, 4-6 = intermediate, 7-9 = excellent).

Data analysis

The experiment was a split plot in a randomized complete block design with two replications. Environment were assaigned to main plots, harvest time (10% oversized fruit vs. 50% oversized fruit) was assaigned to subplot, ethephon applications was the sub-sub plot and cultigens were assaigned to sub-sub-sub plots. For statistical analysis, we considered years and seasons as four environments, with environments and cultigens as random effects, and harvest and ethephon as fixed effects. Data were analyzed using the General Linear Models and Random procedures of the Statistical Analysis System SAS 6.12 (SAS Institute, Inc., Cary, N.C.).

Results and Discussion

Among environments fruit yield and did not differ significantly. Fruit quality however differed considerably between the four enviornments tested (Table 2.3). Harvest and ethephon also did not have a significant effect on the traits evaluated. However, total yield, marketable yield, and fruit quality rating were significantly different between the two sex groups (monoecious and gynoecious) of cultigens. Early yield had a significant interaction for sex types and environment, and for harvest. While the fruit quality rating differed over environment for sex expression. There were significant differences among cultigens for total and marketable yield, percentage of culls, and fruit quality rating. There were significant differences among cultigens over environments for all the traits evaluated (Table 2.3).

Cultigens were analyzed by sex type (monoecious or gynoecious) to determine the contribution of each to the total yield, marketable yield, and fruit quality rating. The 11 gynoecious cultigens (Table 2.1) did not differ significantly for any of the traits evaluated (Table 2.4). However, the 22 monoecious cultigens differed significantly for total yield, marketable yield, and fruit quality rating (Table 2.5). The 22 monoecious cultigens also were significant for fruit quality rating over environment. There was a significant interaction observed between the 22 monoecious cultigens in the four environments, and the two harvest dates for total, early, and marketable yields (Table 2.5).

When the analysis was conducted based on the three subgroups, we observed that cultigens belonging to the old monoecious subgroup differed for fruit quality (Table 2.6) while cultigens belonging to the new monoecious subgroup differed for early yield and fruit quality (Table 2.7). Cultigens differed significantly over environment for early yield (old monoecious and trellis/middle-eastern subgroup) and fruit quality (old and new monoecious subgroups) (Tables 2.6, 2.7 and 2.8). Interactions were significant for cultigen within the old monoecious subgroup with environment and harvest for total and marketable yield (Table 2.6).

The mean squares from Tables 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 and 2.8 are summarized in Table 2.9, showing that total yield, marketable yield, and fruit quality rating differences between the two sex types were due mostly to the monoecious group. Also, within the monoecious group, cultigens belonging to the new and old monoecious subgroups contributed most of the differences observed. Cultigens within the three subgroups did not differ for total yield. However, since yields of the three subgroups were different, this explains the significance of total yield for the monoecious group and non-significance of the subgroups in Table 2.9. All cultigens within the monoecious subgroups had an influence in contributing to the differences for fruit quality rating among environments. The interaction of sex with environment and harvest could also be attributed to differences among cultigens within the monoecious group (Table 2.9).

Since no differences were observed among gynoecious cultigens for the traits evaluated, we report the yield and quality traits averaged over all treatments (harvest and ethephon) and the 11 cultigens belonging to the gynoecious sex type.

Total yield was averaged over ethephon and harvest treatments and as well as over all cultigens, since cultigen and cultigen interactions with other treatments were not statistically significant for the new monoecious or trellis/middle-eastern subgroups (Tables 2.7 and 2.8). Total yield of all cultigens belonging to the old monoecious subgroup in the four environments and the two harvests are reported since cultigens and cultigen interaction with harvest and environment were found to be statistically significant (Table 2.6). Cultigens belonging to the gynoecious group had the highest total yield followed by cultigens in the trellis/middle-eastern subgroup. The cultigens with the highest total yields in the old monoecious subgroups were 'Dublin' and 'Ashley' (Table 2.10).

Cultigens (new monoecious subgroup) and the interaction of cultigen with environment (old monoecious and trellis/middle-eastern subgroups) effects were significant for early yield. Therefore, we report cultigen means averaged over environments, harvests, and ethephon applications for cultigens belonging to the new monoecious subgroup. Early yield averaged over harvest and ethephon treatment in the four environments are reported for cultigens belonging to the old monoecious and trellis/middle-eastern subgroups (Tables 2.6, 2.7, and 2.8).

When early yield was averaged over cultigen and environment for the cultigen groups and subgroups studied, cultigens with gynoecious sex expression had the highest early yield (28,000 fruit/ha) compared to the subgroups within monoecious sex type which had early yields of 23,000 fruit/ha. The cultigens with the highest early yields averaged over all environments under the new monoecious subgroups were 'Redlands Long White' and 'Slice'. 'Everbearing' (a cultigen of the old monoecious subgroup) had the highest early yield when averaged over all environments (Table 2.11).

Marketable yield was averaged over all cultigens of the new monoecious and trellis/middle-eastern subgroups since no statistical difference were observed for cultigens and their interactions with the other treatments. Marketable yield was significant for cultigens of the old monoecious subgroup for the four environments and two harvest treatments (Tables 2.6, 2.7 and 2.8). Cultigens belonging to the gynoecious group had the highest marketable yield. Cultigens of the new monoecious and the trellis/middle-eastern subgroups did not differ significantly for marketable yield. In general, cultigens in the old monoecious group had higher yield during the spring season compared to the summer season in both years. The cultigens with the highest total yields in the old monoecious subgroups were 'Dublin' and 'Ashley' (Table 2.12).

There were no differences in percentage of culls in harvest among cultigens belonging to any of the groups or subgroups studied in the experiment. Therefore, we report the mean percentage of culls averaged over all cultigens. Since the interaction of cultigen and environment was significant for the new monoecious subgroup, we report the percent of culled fruit for cultigens in each environment. The mean percentage of culls over all the cultigens was 26. Cultigens in the gynoecious sex type had the lowest percentage of culls (22%) followed by cultigens in the new monoecious subgroup (24%), trellis/middle-eastern subgroup (28%) and old monoecious subgroup (30%).

Fruit quality rating varied among cultigens belonging to the new and old monoecious groups. Rating also was found to differ over environment. Therefore, fruit quality rating was reported for all cultigens within the subgroups in all environments studied in the experiment, while the average rating over all cultigens was reported for the trellis/middle-eastern subgroup (since the interaction of cultigen and the four environments were found to be non-significant) (Tables 2. 6, 2.7, and 2.8).

Cultigens in the gynoecious group had the highest fruit quality rating, and those in the old monoecious subgroup had the lowest. Cultigens with the highest fruit quality rating in the new monoecious subgroup were 'Medalist', 'Marketmore 76', and 'Poinsett 76'; and in the old monoecious subgroup were 'Polaris', 'Ashley', and 'Dublin' (Table 2.13).

In summary, harvest did not produce a significant effect on the traits evaluated in the study. This result was similar to the results for pickling cucumber (Shetty and Wehner, 2000). Ethephon, the other main treatment effect, also had no significant effect on the traits evaluated. This is contrary to the results reported by McMurray and Miller (1969), Hogue and Heeney (1974), and Cantliffe and Phatak (1975), who reported that ethephon improved fruit yield in pickling cucumber cultivars. Ethephon was also found to affect the yield and quality traits evaluated in a study of pickling cucumber (Shetty and Wehner, 2000).

Yield and quality traits were affected by the sex expression of the cultigens evaluated. When the role of sex expression was further examined, we found that gynoecious cultigens were not significantly different for fruit yield and quality rating, while monoecious cultigens were significantly different for total yield, marketable yield, and fruit quality.

Literature Cited

Burg, S. P. and E. A. Burg. 1966. The interaction between auxin and ethylene and its role in plant growth. Proc. Nat. Acad. Sci. U.S.A. 55: 262-269.

Cantliffe, D. J. 1981. Alteration of sex expression in cucumber due to changes in temperature, light intensity and photoperiod. J. Amer. Soc. Hort. Sci. 106: 133-136.

Chen, L. H., C. H. Miller and R. S. Sowell. 1975. Simulation models for harvesting of pickling cucumbers. J. Amer. Soc. Hort. Sci. 100: 176-179.

Colwell, H. T. M. and J. O'Sullivan. 1981. Economics of harvest timing for once over harvesting of cucumbers. J. Amer. Soc. Hort. Sci. 106: 163-167.

Dhillon, H. S. 1966. Sex expression and sex determination in Cucurbitaceae. Indian J. Agr. Sci. 53: 437-441.

Ells, J. E. and A. E. McSay. 1981. Yield comparisons of pickling cucumber cultivar trials for once-over harvesting. HortScience 16: 187-189.

Galun, E. 1959. The role of auxin in the sex expression of the cucumber. Physiol. Plant 12: 48-61.

Galun, E. 1961. Study of the inheritance of sex expression. The inheritance of major genes with modifying genetic and non-genetic factors. Genetica 32: 134.

George, W. L. Jr. 1971. Influence of genetic background on sex conversion by 2-chloroethanephosphonic acid in monoecious cucumbers. J. Amer. Soc. Hort. Sci. 96: 152-154.

Heslop-Harrison, J. 1957. The experimental modification of sex expression in flowering plants. Biol. Rev. 32: 38-90.

Iwahori, S., J. N. Lyons and O.E. Smith. 1970. Sex expression in cucumber as affected by 2-chloroethanephosphonic acid, ethylene and growth regulators. Plant Physiol. 46: 412-415.

Karchi, Z and A. Govers. 1972. Effects of ethephon on vegetative and flowering behaviour in cucumber (*Cucumis sativus* L.). J. Amer. Soc. Hort. Sci. 95: 357-360.

Lower, R. L., and M. D. Edwards. 1986. Cucumber Breeding. In: Breeding vegetable crops. Basset, M.J. (ed.), pp. 173-207. AVI Publishing Co., Westport, Connecticut.

Malepszy, S. and K. Niemirowicz-Szczytt. 1991. Sex determination in cucumber (*Cucumis sativus*) as a model system for molecular biology. Plant Science 39-47.

McMurray, A. L. and C. H. Miller. 1968. Cucumber sex expression modified by 2-chloroethanephosphonic acid. Science 162: 1396-397.

Miller, C. H. and G. R. Hughes. 1969. Harvest indices for pickling cucumbers in once-over harvest systems. J. Amer. Soc. Hort. Sci. 94: 485-487.

Nitsch, J. P., E. B. Kurz, Jr., J. L. Liverman, and F. W. Went. 1952. The development if sex expression in cucurbit flowers. American J. Bot. 39: 32-43.

Peterson, C. E. and L. D. Anhder. 1960. Induction of staminate flowers in gynoecious cucumber with GA_3. Science 131: 1673-1674.

Robinson, R. W., S. Shannon, and M. D. de la Guardia. 1968. Regulation of sex expression in the cucumber. BioScience 19: 141-142.

Robinson, R. W., H. M. Munger, T. W. Whitaker and G. W. Bohn. 1976. Genes of Cucurbitaceae. HortScience 11: 554-568.

Rudich, J., A. H. Halevy, and N. Kedar. 1969. Increase in femaleness of three cucurbits by treatment with Ethrel, an ethylene releasing compound. Planta 86: 69-76.

Rudich, J., A. H. Halevy, and N. Kedar. 1972. The levels of phytohormones in monoecious and gynoecious cucumbers as affected by photoperiod and ethephon. Plant Physiol. 50: 585-590.

Shannon, S. and M. D. De La Guardia. 1969. Sex expression and the production of ethylene induced by auxin in the cucumber (*Cucumis sativus* L.). Nature 223: 186.

Shannon, S. and R. W. Robinson. 1978. Genetic differences in sex-expression and responses to ethephon in summer squash (*Cucurbita pepo* L.). Cucurbits Genetic Coop. 1: 33.

Shetty, N.V. and T. C. Wehner. 2000. Effects of ethephon and harvest treatments on pickling cucumber yield and quality. Crop Science (in review)

Shifriss, O. 1961. Sex control in cucumbers. J. Hered. 52: 5.

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: 92-94.

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size for measurement of yield in multiple and once over harvest trials of pickling and fresh market cucumbers. Euphytica 35: 493-501.

Swallow, W. H. and T. C. Wehner. 1989. Optimum allocation of plots to years, seasons, locations, and replications, and its applications to once-over harvest cucumber trials. Euphytica 43: 59-68.

Tiedjens, V. A. 1928. Sex-ratios in cucumber flowers affected by different conditions of soil and light. J. Agr. Res. 36;721-746.

Wehner, T. C. 1986. Efficiency of 3 single-harvest tests for evaluation of yield in pickling cucumber. Euphytica 35: 493-501.

Wehner, T. C. 1987. Value of 12 season-location combinations for cucumber yield trials in North Carolina. Cucurbit Genet. Coop. Rpt. 6: 38-39.

Wehner, T. C. 1989. Breeding for improved yield in cucumber. Plant Breed. Rev. (Ed.) J. Janick. Vol. 6: 323-359.

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: 659-664.

Wehner, T. C. and C. H. Miller. 1987. Optimum plant density for multiple-harvest yield of determinate cucumbers. Cucurbit Genet. Coop. Rpt. 10: 29-30.

Table 2.1. List of slicing cucumber cultigens used in the study.

Cultigens	Seed source	Sex[z]	Cultigens	Seed source	Sex[z]
Arlington			Medalist	Harris Moran	M
White Spine	NSSL	M	Pacer	Harris Moran	M
Ashley	Clemson Univ.	M	Poinsett 76	Cornell Univ.	M
Coolgreen	Asgrow Seed	M	Poinsett 83F	Cornell Univ.	G
Cubit	Associated Seed	M	Polaris	Clemson Univ.	M
Dasher II	Petoseed	G	Raider	Harris Moran	G
Davis Perfect	NSSL	M	Redlands		
Daytona	Petoseed	G	Long White	New World Seeds	M
Dublin	NSSL	M	Slice	Clemson Univ.	M
Early Michigan	NSSL	M	Sprint 440	Asgrow	G
Everbearing	NSSL	M	Straight 8	NSSL	M
Fletcher	NC State Univ.	M	Striker	Asgrow	G
Gy 57u	Cornell Univ.	G	Super Green	Harris Moran	M
Indy	Petoseed	G	Tablegreen 72 M	Cornell Univ.	M
Lightening	Asgrow	G	Thunder	Asgrow	G
Longfellow	NSSL	M	Verino	Sluis & Groot	M
Marketer	Associated Seed	M	Yangzhou Green		
Marketmore 76	Cornell Univ.	M	Skin	Yangzhou, PRC	M

[z] M=Monoecious, G=Gynoecious

Table 2.2. Mean squares for traits evaluated in study based on sex expression.

		Yield				
				Market	%	Fruit
Source of variation	df	Total	Early	-able	cull	quality
Environment	3	7745	12390	4804	9872	28
Error A	4	1850	403	3015	704	0.6
Harvest	1	391	23457	2039	1506	1.1
Harvest X Environment	3	401	11043	3710	4846	0.5
Error B	4	1824	2975	1437	187	0.3
Ethephon	2	5363	368	1301	592	1.7
Ethephon X Environment	6	1896	159	2727	580	0.9
Ethephon X Harvest	2	1589	180	316	294	0.2
Ethephon X Environment X Harvest	6	1948	257	1350	124	0.9
Error C	16	912	166	797	228	0.7
Sex	1	41241**	3493*	47412**	7205	442**
Sex X Environment	3	2117	598	2874	1545	6.1*
Sex X Harvest	1	19	965	445	154	1.9
Sex X Ethephon	2	3511*	110	1435	173	0.8
Sex X Environment X Harvest	3	421	1458**	720	597	0.5
Sex X Environment X Ethephon	6	421	290	614	148	0.7
Sex X Ethephon X Harvest	2	352	185	208	214	0.8
Sex X Environment X Harvest X Ethephon	6	553	83	510	141	0.7
Error D	1152	811	234	705	225	1.4

Table 2.3. Mean squares for traits evaluated in study based on cultigens.

Source of variation	df	Yield Total	Yield Early	Yield Market -able	% cull	Fruit quality
Environment	3	4266	8386	7095	11870	34**
Error A	4	1626	200	3147	807	1.3
Harvest	1	205	20226	459	361	1.0
Harvest X Environment	3	288	9928	3857	4904	1.2
Error B	4	1774	2146	1444	94	0.7
Ethephon	2	6598	387	1544	933	1.4
Ethephon X Environment	6	1679	232	1896	403	1.4
Ethephon X Harvest	2	1375	134	214	351	0.2
Ethephon X Environment X Harvest	6	1376	303	1155	212	0.6
Error C	16	699	208	746	228	0.9
Cultigen	31	4351**	985	4508**	999**	30**
Cultigen X Environment	87	1616**	551*	1500**	466**	2.5**
Cultigen X Harvest	31	669	426	725	244	0.6
Cultigen X Ethephon	62	810	259	564	150	0.7
Cultigen X Environment X Harvest	73	946**	355**	883**	252	0.7
Cultigen X Environment X Ethephon	155	633	212*	458	154	0.6
Cultigen X Ethephon X Harvest	61	565	126	444	157	0.6
Cultigen X Environment X Harvest X Ethephon	132	537	161	455	188	0.7
Error D	516	590	146	521	192	0.7

**, * significance at 1% and 5% respectively

Table 2.4. Mean squares for traits evaluated in study for gynoecious cucumber cultigens.

		Yield				
Source of variation	df	Total	Early	Market -able	% cull	Fruit quality
Environment	3	3666	4115	672	1606	6.7
Error A	4	656	80	1661	491	0.9
Harvest	1	727	10511	1712	498	0.2
Harvest X Environment	3	376	6636	815	865	0.3
Error B	4	445	1168	514	110	0.8
Ethephon	2	82	371	147	101	0.9
Ethephon X Environment	6	1075	211	1442	206	0.6
Ethephon X Harvest	2	320	294	4	346	0.5
Ethephon X Environment X Harvest	6	589	244	432	186	0.9
Error C	16	613	279	501	139	0.6
Cultigen	10	2089	465	2241	397	4.5
Cultigen X Environment	28	1826	467	1559	153	0.9
Cultigen X Harvest	10	304	486	320	102	0.6
Cultigen X Ethephon	20	532	310	349	160	0.9
Cultigen X Environment X Harvest	25	796	293	855	166	0.9
Cultigen X Environment X Ethephon	51	584	254	338	110	0.6
Cultigen X Ethephon X Harvest	19	528	90	393	104	0.7
Cultigen X Environment X Harvest X Ethephon	46	469	160	508	138	0.7
Error D	175	543	145	454	138	0.8

**, * significance at 1% and 5% respectively

Table 2.5. Mean squares for traits evaluated in study for monoecious cucumber cultigens.

Source of variation	df	Yield Total	Yield Early	Yield Market -able	% cull	Fruit quality
Environment	3	2637	4775	8850	11212	31**
Error A	4	1007	124	1605	397	1.2
Harvest	1	35	9583	11	45	1.8
Harvest X Environment	3	336	4856	3593	4233*	0.9
Error B	4	1627	1175	1265	98	0.8
Ethephon	2	8497*	90	2263	1098	0.8
Ethephon X Environment	6	1270	288	1164	337	1.4
Ethephon X Harvest	2	1011	12	247	119	0.1
Ethephon X Environment X Harvest	6	1290	183	1204	189	0.5
Error C	16	680	112	528	186	1.1
Cultigen	21	3670*	1159	3621*	1054	24**
Cultigen X Environment	59	1513	579	1409	553	3.1**
Cultigen X Harvest	21	853	340	911	301	0.6
Cultigen X Ethephon	42	787	231	588	141	0.7
Cultigen X Environment X Harvest	52	1058*	316*	889*	282	0.7
Cultigen X Environment X Ethephon	104	652	178	492	175	0.6
Cultigen X Ethephon X Harvest	42	584	145	471	184	0.5
Cultigen X Environment X Harvest X Ethephon	86	562	163	420	224	0.7
Error D	317	625	145	576	230	0.7

**, * significance at 1% and 5% respectively

Table 2.6. Mean squares for traits evaluated in study for old monoecious cucumber cultigens.

		Yield				
Source of variation	df	Total	Early	Market -able	% cull	Fruit quality
Environment	3	2297	1325	4986	4803	16
Error A	4	849	78	891	338	0.4
Harvest	1	22	3740	96	66	0.2
Harvest X Environment	3	249	3097	870	1298	2.1
Error B	4	691	72	108	340	0.1
Ethephon	2	2904*	66	743	657	1.6
Ethephon X Environment	6	444	210	533	176	0.6
Ethephon X Harvest	2	1094	20	276	74	1.0
Ethephon X Environment X Harvest	6	849	41	688	235	0.6
Error C	15	594	75	484	120	0.6
Cultigen	10	3647	588	5035	1459	9.4*
Cultigen X Environment	26	678	611*	652	372	2.5*
Cultigen X Harvest	10	606	434	772	329	1.0
Cultigen X Ethephon	20	750	246	583	137	0.5
Cultigen X Environment X Harvest	18	1250*	149	984*	359	0.4
Cultigen X Environment X Ethephon	43	776	212	572	176	0.6
Cultigen X Ethephon X Harvest	20	271	114	309	206	0.6
Cultigen X Environment X Harvest X Ethephon	28	533	170	339	257	0.6
Error D	119	616	149	613	292	0.8

**, * significance at 1% and 5% respectively

Table 2.7. Mean squares for traits evaluated in study for new monoecious cucumber cultigens.

		Yield				
Source of variation	df	Total	Early	Market -able	% cull	Fruit quality
Environment	3	491	2736	4471	6851	16*
Error A	4	1351	259	1493	243	0.6
Harvest	1	174	4872	480	110	2.8
Harvest X Environment	3	1374	1984	2582	2579	0.1
Error B	4	1980	1137	1829	87	1.0
Ethephon	2	4684	44	2127	190	0.9
Ethephon X Environment	6	1679	113	730	311	0.5
Ethephon X Harvest	2	515	10	164	316	0.7
Ethephon X Environment X Harvest	6	147	182	418	262	0.3
Error C	16	629	160	543	250	0.8
Cultigen	7	5646	1997*	3192	66	27**
Cultigen X Environment	21	1846	608	1672	716	2.6**
Cultigen X Harvest	7	1041	220	903	180	0.3
Cultigen X Ethephon	14	900	358	762	159	0.5
Cultigen X Environment X Harvest	18	926	342	860	255	0.6
Cultigen X Environment X Ethephon	37	566	248	500	150	0.5
Cultigen X Ethephon X Harvest	14	1117	225	644	127	0.4
Cultigen X Environment X Harvest X Ethephon	33	720	188	527	181	0.6
Error D	117	707	143	584	203	0.6

**, * significance at 1% and 5% respectively

Table 2.8. Mean squares for traits evaluated in study for trellis and middle-eastern cucumber cultigens.

		Yield				
Source of variation	df	Total	Early	Market -able	% cull	Fruit quality
Environment	3	4049	1341	1170	997	2.6
Error A	4	234	61	328	123	1.4
Harvest	1	70	902	340	485	0.1
Harvest X Environment	3	72	1397	806	912	0.5
Error B	4	682	430	806	331	1.2
Ethephon	2	3607	509	1552	172	1.8
Ethephon X Environment	6	371	33	249	142	0.9
Ethephon X Harvest	2	651	84	991	554	1.3
Ethephon X Environment X Harvest	6	735	189	1081	303	1.5
Error C	15	432	152	722	183	0.9
Cultigen	2	600	249	399	164	5.2
Cultigen X Environment	6	3971	706*	4347	712	6.2
Cultigen X Harvest	2	196	417	630	134	0.02
Cultigen X Ethephon	4	258	5	216	226	0.3
Cultigen X Environment X Harvest	6	961	96	1223	387	1.6
Cultigen X Environment X Ethephon	12	477	68	549	222	0.8
Cultigen X Ethephon X Harvest	4	649	188	894	288	0.03
Cultigen X Environment X Harvest X Ethephon	12	585	66	483	256	1.0
Error D	35	418	121	403	154	0.7

**, * significance at 1% and 5% respectively

Table 2.9. Summary of mean squares from Tables 2.2, 2.3, 2.4, 2.5, 2.6, and 2.7.

Variable	Yield Total	Yield Early	Yield Market -able	% cull	Fruit quality
Sex	**	ns	**	ns	**
Gynoecious cultigens	ns	ns	ns	ns	ns
Monoecious cultigens	*	ns	*	ns	**
Old Monoecious	ns	ns	ns	ns	*
New Monoecious	ns	ns	*	ns	*
Trellis and Middle-eastern	ns	ns	ns	ns	ns
Sex X Environment	ns	ns	ns	ns	*
Gynoecious cultigens	ns	ns	ns	ns	ns
Monoecious cultigens	ns	ns	ns	ns	**
Old Monoecious	ns	*	ns	ns	*
New Monoecious	ns	ns	ns	ns	**
Trellis and Middle-eastern	ns	*	ns	ns	ns
Sex X Environment X Harvest	ns	**	ns	ns	ns
Gynoecious cultigens	ns	ns	ns	ns	ns
Monoecious cultigens	ns	*	*	*	ns
Old Monoecious	ns	*	ns	*	ns
New Monoecious	ns	ns	ns	ns	ns
Trellis and Middle-eastern	ns	ns	ns	ns	ns

**, * significance at 1% and 5% respectively

Table 2.10. Performance of total yield (1000 fruit/ha) of cultigens evaluated in study averaged over ethephon treatments during 1996 to 1997.

	1996	1996				1997	1997			
	1996	Spring		Summer		1997	Spring		Summer	
	mean	Harvest				mean	Harvest			
Cultigen	yield	10%[z]	50%[z]	10%[z]	50%[z]	yield	10%[z]	50%[z]	10%[z]	50%[z]
Monoecious Subgroups										
New Monoecious										
Fletcher	87	111	101	79	67	84	76	77	83	98
Marketmore 76	69	62	96	46	62	72	90	99	32	67
Medalist	76	60	73	55	71	87	65	123	63	96
Pacer	57	51	61	37	61	62	65	77	63	43
Poinsett 76	90	85	87	100	85	92	72	75	132	87
Redlands Long White	89	98	83	105	92	81	62	104	78	.
Slice	86	94	94	86	93	80	72	72	100	75
Tablegreen 72 M	62	75	57	58	72	59	58	60	72	47
Trellis & MiddleEastern										
Coolgreen	81	105	86	61	67	82	78	73	89	88
Super Green	87	102	131	83	86	74	78	74	73	69
Yangzhou Green Skin	94	95	89	132	110	81	71	66	77	108
Old Monoecious										
Dublin	110	91	122	136	90	98	111	84	80	115
Ashley	94	92	101	98	87	94	104	85	-	93
Everbearing	81	104	75	74	72	78	83	73	-	-
Cubit	80	88	92	90	49	45	45	-	-	-
Early Michigan	80	81	81	77	-	89	71	107	-	-
Straight 8	80	101	74	77	70	63	66	51	72	64

Table 2.10. Contd.

Cultigen	1996 mean yield	1996 Spring Harvest 10%[z]	1996 Spring Harvest 50%[z]	1996 Summer Harvest 10%[z]	1996 Summer Harvest 50%[z]	1997 mean yield	1997 Spring Harvest 10%[z]	1997 Spring Harvest 50%[z]	1997 Summer Harvest 10%[z]	1997 Summer Harvest 50%[z]
Polaris	77	-	54	74	102	75	70	70	80	81
Arlington White Spine	75	74	96	55	-	65	72	69	81	37
Davis Perfect	72	84	74	66	66	78	73	58	93	89
Longfellow	65	56	78	69	58	73	76	62	75	81
Marketer	58	71	60	41	61	129	-	129	-	-
Gynoecious Sex type										
Daytona	109	104	83	119	121	112	79	124	149	95
Dasher II	103	120	112	101	96	98	91	97	103	102
Verino	98	.	.	.	.	98	114	97	.	84
Indy	94	100	92	101	114	86	77	85	78	107
Striker	93	95	90	81	87	97	94	94	96	105
Sprint 440	92	117	111	97	100	101	68	56	94	96
Lightning	91	108	101	102	106	78	80	77	68	85
Raider	91	96	78	76	72	93	108	90	97	108
Poinsett 83F	90	86	108	95	62	77	86	.	100	.
Thunder	86	91	97	117	94	72	74	71	74	67
Gy 57u	85	116	106	81	99	69	70	71	66	70
Mean	86	91	89	83	82	82	78	82	84	84
Std. Dev.	20	18	18	25	18	19	15	20	22	20
CV	23	20	21	29	23	24	20	24	26	24

[z] Yield averaged over 3 ethephon treatments and 2 replications

Table 2.11. Performance of early yield (1000 fruit/ha) of cultigens evaluated in study averaged over ethephon and harvest treatments during 1996 to 1997.

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Monoecious Subgroups					
New Monoecious					
Redlands Long White	36	31	71	12	38
Slice	34	10	27	13	56
Fletcher	24	11	18	19	25
Tablegreen 72 M	24	6	34	7	26
Medalist	21	0	16	5	25
Poinsett 76	20	4	16	7	38
Marketmore 76	14	3	9	3	16
Pacer	13	1	5	2	13
Old Monoecious					
Everbearing	34	48	24	31	-
Davis Perfect	28	14	24	28	49
Ashley	27	12	27	28	43
Longfellow	25	14	19	27	43
Dublin	24	10	27	30	29
Straight 8	23	22	20	24	24
Arlington White Spine	21	23	13	25	22
Marketer	18	12	10	32	-

Table 2.11. continued.

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Polaris	18	0	29	10	33
Cubit	17	8	20	22	-
Early Michigan	15	15	15	14	-
Trellis & MiddleEastern					
Super Green	24	23	14	37	24
Yangzhou Green Skin	20	10	18	19	32
Coolgreen	21	11	15	18	40
Gynoecious Group					
Verino	37	.	.	.	.
Striker	32	11	17	11	36
Daytona	30	13	23	11	56
Indy	30	19	13	10	67
Sprint 440	30	21	32	9	63
Raider	29	15	14	8	37
Lightning	28	22	20	5	43
Dasher II	25	14	13	11	35
Thunder	25	15	11	6	42
Gy 57u	23	21	20	14	38
Poinsett 83F	17	4	18	8	11

Table 2.11. continued.

Cultigen	Mean yield	1996 Spring[z]	1996 Summer[z]	1997 Spring[z]	1997 Summer[z]
Mean	19	17	22	26	34
Std. Dev.	15	12	10	9	13
CV	78	73	47	32	38

[z] Yield averaged over 2 harvests, 3 ethephon treatments and 2 replications

Table 2.12. Performance of marketable yield (1000 fruit/ha) of cultigens evaluated in study averaged over ethephon treatments during 1996 to 1997.

Cultigen	1996 mean yield	1996 Spring Harvest 10%[z]	1996 Spring Harvest 50%[z]	1996 Summer Harvest 10%[z]	1996 Summer Harvest 50%[z]	1997 mean yield	1997 Spring Harvest 10%[z]	1997 Spring Harvest 50%[z]	1997 Summer Harvest 10%[z]	1997 Summer Harvest 50%[z]
Monoecious Subgroups										
New Monoecious										
Fletcher	65	65	79	88	52	64	62	61	64	68
Marketmore 76	59	56	49	89	28	62	75	85	32	57
Medalist	61	51	30	73	43	70	53	106	45	76
Pacer	46	41	43	53	18	50	56	70	44	31
Poinsett 76	70	67	50	79	85	73	58	65	104	67
Redlands Long White	67	66	65	60	80	67	52	89	59	.
Slice	63	64	65	77	65	62	58	59	78	52
Tablegreen 72 M	47	47	61	49	41	47	46	48	59	34
Trellis & MiddleEastern										
Coolgreen	61	54	73	44	40	68	65	56	71	79
Super Green	63	71	79	114	62	54	61	59	53	43
Yangzhou Green Skin	64	67	59	67	10	60	52	47	66	77
Old Monoecious										
Dublin	86	75	102	101	54	84	98	81	65	94
Ashley	78	66	82	81	61	79	96	73	-	67
Early Michigan	59	47	61	49	-	77	60	94	-	-
Marketer	58	66	53	25	30	118	-	118	-	-

Everbearing	57	70	43	60	46	63	59	67	-	-

Cultigen	1996 mean yield	1996 Spring Harvest 10%[z]	1996 Spring Harvest 50%[z]	1996 Summer Harvest 10%[z]	1996 Summer Harvest 50%[z]	1997 mean yield	1997 Spring Harvest 10%[z]	1997 Spring Harvest 50%[z]	1997 Summer Harvest 10%[z]	1997 Summer Harvest 50%[z]
Straight 8	55	84	57	58	41	40	50	39	36	34
Polaris	51	.	32	54	60	55	52	57	57	54
Arlington White Spine	50	40	73	34	-	48	58	54	48	33
Cubit	48	70	84	63	27	22	22	-	-	-
Davis Perfect	47	53	45	48	29	51	55	39	54	54
Longfellow	41	31	64	39	22	42	50	47	33	36
Gynoecious Sex type										
Daytona	89	85	83	68	99	92	65	110	124	70
Dasher II	81	81	88	84	84	81	75	85	83	80
Verino	77	.	.	.	.	77	96	80	.	56
Striker	75	69	63	76	61	81	79	82	80	85
Indy	74	77	78	69	84	71	69	67	60	88
Raider	73	66	70	53	49	79	95	71	75	74
Poinsett 83F	67	64	60	92	77	69	54	.	85	.
Lightning	69	74	85	82	76	63	64	63	59	65
Sprint 440	69	75	94	95	73	62	55	48	79	65
Thunder	66	72	69	73	102	60	62	58	66	55
Gy 57u	58	66	90	76	66	50	53	61	43	44
Mean	63	66	71	63	52	64	63	69	64	61
Std. Dev.	21	17	19	23	20	19	16	20	21	18

CV	33	26	27	37	38	29	26	29	33	30

Z Yield averaged over 3 ethephon treatments and 2 replications

Table 2.13. Fruit quality rating for cultigens evaluated in study averaged over harvests and ethephon treatments during 1996 to 1997 (ranked by average quality over four environments).

	Mean	1996		1997	
Cultigen	yield	Spring[Z]	Summer[Z]	Spring[Z]	Summer[Z]
Monoecious Subgroups					
New Monoecious					
Medalist	7.2	7.7	6.8	7.2	7.3
Poinsett 76	7.0	6.8	7.2	7.1	7.2
Marketmore 76	6.9	7.8	5.8	7.3	6.7
Pacer	6.8	7.8	5.3	7.2	6.8
Slice	6.7	6.8	6.5	6.0	7.4
Tablegreen 72 M	6.6	7.0	6.1	6.2	7.0
Fletcher	5.4	5.6	4.3	5.2	6.3
Redlands Long White	4.7	4.5	4.1	4.3	6.0
Old Monoecious					
Polaris	6.3	8.0	5.2	6.3	5.7
Ashley	6.2	6.4	5.3	6.4	6.7
Dublin	5.9	6.1	5.6	6.0	6.0
Marketer	5.7	5.7	4.4	7.0	-

Cubit	5.5	6.4	5.0	5.0	-
Early Michigan	5.5	5.3	4.3	6.9	-

Table 2.13. continued

	Mean	1996		1997	
Cultigen	yield	Spring^z	Summer^z	Spring^z	Summer^z
Longfellow	5.0	5.3	4.3	4.9	5.7
Davis Perfect	4.8	5.2	4.2	4.7	5.2
Straight 8	4.8	5.3	4.3	4.7	5.0
Arlington White Spine	4.6	4.8	4.3	4.1	5.2
Everbearing	4.4	3.7	3.6	6.0	-
Trellis & MiddleEastern					
Super Green	6.7	6.8	6.3	7.6	6.1
Coolgreen	6.6	7	6.2	6.4	7
Yangzhou Green Skin	6.1	6.8	6.6	5	5.9
Gynoecious Group					
Daytona	7.6	7.8	7.8	7.3	7.5
Indy	7.5	8	7.6	7.1	7.5
Dasher II	7.4	7.7	6.9	7.7	7.3
Thunder	7.4	7.4	7.3	7.6	7.4
Lightning	7.3	7.5	7.3	7	7.3
Raider	7.3	7.8	7.1	7.3	7

Striker	7.2	7.3	7.1	6.9	7.7
Sprint 440	7.1	7.5	7	6.5	7.5

Table 2.13. continued

	Mean	1996		1997	
Cultigen	yield	Spring[z]	Summer[z]	Spring[z]	Summer[z]
Verino	6.9	.	.	6.8	7
Gy 57u	6.5	7.1	6	6.2	6.6
Poinsett 83F	6.5	7.1	5.9	5	8
Mean	6.3	6.6	5.8	6.3	6.7
Std. Dev.	1.1	1.1	1.2	1.1	0.8
CV	18	17	21	17	12

[z] Yield averaged over 2 harvests, 3 ethephon treatments and 2 replications

Chapter Three

Effects of Ethephon on Vegetative and Floral Traits in Diverse Cucumber Cultivars

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Effects of Ethephon on Vegetative and Floral Traits in Diverse Cucumber Cultivars

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Abstract

Ethylene is a plant growth regulator associated with important developmental processes in plants, including the control of sex expression in cucurbits. Ethephon promotes gynoecious flowering in cucumber and may be useful for evaluation of yield in monoecious breeding lines that are being considered for use in the production of gynoecious hybrids or breeding populations. Ethephon was used to treat a diverse set of gynoecious and monoecious cucumber for evaluation of vegetative and floral traits under field conditions. The experiment was conducted in North Carolina in 1996 during two production seasons using 66 diverse cucumber cultigens (33 pickling and 33 slicing) and three ethephon treatments. Differences between the spring and summer seasons were significant, as were differences among cultigens for all the traits evaluated with the exception of days to produce 50% flower set in pickling cucumber cultigens. Cucumber growth was faster in the summer than in spring season due to the greater heat units per day. Ethephon had an effect on most traits evaluated: days to first flower set in a plot, days to 50% flower set in a plot, days to first fruit set (pickles only), days to 50% fruit set (pickles only), and fruit quality rating. However, ethephon had no significant effect on days to vine tip-over stage (five nodes), or days to first fruit set and 50% fruit set in slicing cucumber cultigens.

The plant growth regulator ethylene has been associated with several developmental processes, including accelerated senescence in plant species, ripening of fruit in climacteric species, and control of sex expression in cucurbits (Pratt and Goeschl, 1969). The ethylene-releasing property of ethephon (2-chloroethylphosphonic acid) was first reported by Warner and Leopold (1969) and Yang (1969). Several studies have since proved the ability of ethephon to alter sex expression in several species of the *Cucurbitaceae*. Ethephon was applied either at the seedling stage (Iwahori et al., 1969; Rudich et al., 1969), at pre-flowering stage (Karchi, 1970; Karchi and Govers, 1972), or as a pre-sowing seed treatment (Sadhu and Das, 1978) for successful altering of sex expression of cucumber. The effect of ethylene was similar to that of auxin. Exogenous application of auxin is known to increase ethylene production in cucumber (Shannon and De LaGuardia, 1969), while ethylene lowers the auxin levels (Rudich et al., 1972). Rudich et al. (1972) reported that ethylene may promote the production of pistillate flowers, either directly, or by reducing endogenous gibberellin levels, or by promoting the production of abscisic acid. High carbon dioxide level is antagonistic to ethylene, and increased the number of staminate flowers in a gynoecious cucumber cultivar.

Miller et al. (1969) reported that ethephon was responsible for stunting in a study which involved 21 vegetable cultivars representing eight botanical families. The stunting was permanent in some vegetables (pea and eggplant), but was temporary in others (carrot, parsley, onion, radish and broccoli). The degree and duration of stunting varied with cultivar and ethephon concentration. Arora et al. (1985) reported that application of ethephon at 100 mg/liter to luffa sponge gourd (*Luffa aegyptiaca* Mill.) or 250 mg/liter to summer squash (*Cucurbita pepo* L.) was effective in increasing branches per plant, lowering the staminate: pistillate ratio, increasing the fruit set, and producing higher yields compared to the untreated controls.

Ethephon treatment at the seedling stage of monoecious and gynoecious cucumber cultivars resulted in the increased production of lateral branches and nodes, especially on lateral branches. Total fruit number increased when plants were treated with ethephon before flowering rather than at seedling stage. Preflowering application of 150 ppm ethephon on monoecious cultivars, and 250 to 350 ppm on gynoecious cultivars resulted in higher fruit number. Ethephon treatments were also found to lower the percentage of fruit set in monoecious cucumber cultivars (Karchi and Govers, 1972).

Hogue and Heeney (1974) reported that the treatment producing the highest fruit weight and value was pickling cucumber sprayed with ethephon (2-chloroethanephosphonic acid) at a concentration of 400 ppm and a plant spacing of 15 x 15 cm. Cantliffe and Phatak (1975) reported that optimum yield, fruit shape and fresh salt stock quality were obtained when ethephon was applied twice, one week apart commencing at the fourth true-leaf stage followed by a 50 to 100 ppm application of chlorflurenol (methyl-2-chloro-9-hydroxyfluorene-[9]-carboxylate) when 6 to 8 pistillate flowers had reached anthesis. Lower et al. (1970) reported that slight checks in plant growth were observed when ethephon was applied twice at 48 hr intervals to plants having one to six true leaves. However, plant growth (lateral branches, plant height) and number of pistillate flowers open, was severely checked when ethephon was sprayed on plants with 8, 10, or 12 true leaves.

Miller et al. (1970) reported that ethephon treatment of plants of the pickling cucumber cultivar 'Explorer' resulted in fresh-pack pickles and brinestock that were shorter than those from untreated controls. Miller and Lower (1972) reported differences in shape and degree of seed development as a result of ethephon treatment on fruit of pickling cucumber cultivars 'Chipper', 'Pixie', and 'Explorer' which were processed either as fresh-pack or brinestock pickles. However, no differences were observed between the control and the ethephon-treated plants for fruit texture, flavor, external color, internal color, firmness, or internal defects.

A plot size of 1.2 x 1.5 m was found to be optimum for yield evaluation for once-over harvest of pickling cucumber harvested using paraquat (Swallow and Wehner, 1986;

Wehner, 1989). Wehner and Miller (1987) recommended the use of small, single-row plots without end borders rather than large, multiple-row, bordered plots. Swallow and Wehner (1989) suggested that maximum information (1/variance) was obtained by allocating test plots of cucumber cultigens to different seasons and years instead of using different locations and replications. Field evaluation at the Clinton location was reported to be more efficient than three other locations tested in North Carolina (Wehner, 1987). The objective of this experiment was to test a set of pickling and slicing cucumber cultivars which differed in their sex expression for differences in vegetative and floral traits when subjected to treatments of different rates of ethephon under field conditions in North Carolina.

Materials and Methods

The experiment was conducted in 1996 during two seasons (spring and summer) at the Horticultural Crops Research Station in Clinton, N.C. using recommended horticultural practices as summarized by Schultheis (1990).

Cultigens used

A set of 66 (33 pickling and 33 slicing) cucumber cultivars and breeding lines (hereafter referred to as cultigens) was chosen for their diversity of sex expression, disease resistance, adaptation, and other horticultural traits. The cucumber cultigens were selected to represent the entire range of sex expression observed in cucumber with the exception of hermaphroditic sex expression.

Field test

Fertilizer was incorporated before planting at a rate of 90-39-74 $kg \cdot ha^{-1}$ (N-P-K) with an additional 34 $kg \cdot ha^{-1}$ N applied at the vine tip-over stage (four to six true leaves). Seeds were planted on raised, shaped beds with centers 1.5 m apart. Seeds were planted on 29 April and 18 July in 1996. Plots 1.2 m long were seeded with 16 seeds, and later thinned to 12 plants at the first true leaf stage. Irrigation was applied when needed to provide a total of 25 to 40 mm per week, and a tank mix of 2.2 kg·ha^{-1} of naptalam (2-[(1-naphthalenylamino) carbonyl] benzoic acid) and 4.4 kg·ha^{-1} of bensulide (O,O-bis(1-methylethyl) S-[2-[(phenylsulfonyl) amino] ethyl] phosphorodithioate) was applied preplant for weed control. Plots were 1.2 m long with 1.2 m alleys at each end and were arranged in rows 1.5 m apart. The field was surrounded by border rows for uniform competition. The cultivars used around the pickling and slicing cucumber were 'Sumter' and 'Poinsett 76', respectively.

Ethephon application

The ethephon (2-chloroethyl phosphonic acid) treatments involved spraying zero, one, or two applications of ethephon. The cucumber plants were sprayed at the first to second true leaf stage approximately a month after planting (20 May and 1 August in 1996). A Solo backpack sprayer at 100 to 140 kPa (15 to 20 psi) was used to apply ethephon to the leaves and stems until run-off.

The second spray of ethephon was applied one week after the first (30 May and 8 August in 1996). Ethephon was prepared using Florel [3.9% ethephon (2-chloroethyl phosphonic acid)] (Southern Agricultural Insecticides, Inc. Palmetto, FL 34220) at the rate of 2.5 ml/l for a concentration of 21%.

Data collection

Data were collected as plot means and consisted of number of days to produce the first five nodes, number of days to first flower, number of days to 50% flowering, number of days to first fruit set, number of days for 50% fruit set, and fruit quality rating. Fruit quality was rated mainly on shape and marketability, but color was also considered. Fruit quality was rated on a 1 to 9 scale (1-3 = poor, 4-6 = intermediate, 7-9 = excellent).

Data analysis

The experiment was a split plot in a randomized complete block design with four replications. Each crop (pickles and slicers) was run as a separate experiment. Season (spring, summer) was whole plot, ethephon (0, 1, or 2 applications) was sub-plot, and the 33 cultigens were sub-sub plot. Season and ethephon were considered as a fixed factor while the cultigens were considered as random factors for the statistical analysis. Data were analyzed using the General Linear Models, Correlation and Random procedures of SAS 6.12 (SAS Institute, Inc., Cary, NC).

Results and Discussion

Seasonal differences were highly significant for all traits evaluated in the study. Cultigens (pickling and slicing) differed significantly for all traits (Table 3.1).

Days to five nodes

Ethephon had no effect in delaying or enhancing the number of days to produce the first five nodes on either pickling or slicing cucumber cultigens. The ethephon treatments were applied at the first true leaf stage. However, we observed significant differences among cultigens (pickling and slicing) in producing the first five nodes (range of 8 days for pickles and 6 to 8 days in slicers). (Tables 3.1, 3.2, 3.4, and 3.5)

In general, cultigens took fewer days in summer to produce the first five nodes as compared to the spring season (nine fewer days for pickles and six fewer days for slicers on average during the summer season). The likely reason was the high temperatures prevalent during the summer season, which enhanced the growth and development of the plants (Tables 3.1, 3.2, 3.4, and 3.5).

Days to first flower set

Ethephon had a significant effect on the number of days to first flower in both pickling and slicing cucumber (Tables 3.1 and 3.2). Significant differences were observed among cultigens (pickling and slicing) between ethephon and no ethephon applications and between one and two ethephon applications for the number of days to first flower (Table 3.3). In general, it took more days to produce first flowers with increasing number of ethephon applications. It required an average of three days more for flowers to appear on plots treated with two ethephon applications than for no ethephon (Tables 3.4 and 3.5).

Therefore, ethephon delayed the formation of first flower set, and the delay increased with increased ethephon applications. The number of days to first flower set was earlier by an average of ten days during the summer season compared to the spring season. Cultigens ranged for number of days (five to eight) to first flower depending on the treatment combination (Tables 3.1, 3.2, 3.4, and 3.5). Iwahori et al. (1970) reported that the number of days to anthesis of female flowers increased when ethephon was applied at later stages of growth from the cotyledon to the third true leaf stage.

Days to 50% flower set

No differences were observed between the 33 pickling cultigens for the number of days it took to produce 50% flower set (Table3.1 and 3.6). However, slicing cucumber cultigens, and their performance in the three environments were found to be significant (Table 3.2). Cultigens reached 50% flower stage 10 days faster in the summer season than in the spring. Differences among cultigens were significant for days to 50% flowering, with a range of 4 to 8 days (Tables 3.6 and 3.7). There was a significant difference between no ethephon and ethephon treatments and between one and two ethephon treatments for days to 50% flowering (Table 3.3). This was similar to the findings of Lower et al. (1970) who reported that ethephon application at the second true leaf stage significantly reduced the number of days required for 20 pistillate flowers to open from 17 days (unsprayed control) to 11 days.

Days to first fruit set and 50% fruit set

In the summer season, cultigens reached first fruit set and 50% fruit set 10 days earlier than in the spring season. Ethephon had a significant effect on first fruit set and 50% fruit set in pickling cucumber cultigens, but had no effect in slicing cucumber cultigens (Tables 3.1 and 3.2). The number of days to first fruit set and 50% fruit set among pickling cucumber cultigens also was significantly different between the ethephon and no ethephon treatment and between the one vs. two ethephon treatments (Tables 3.3, 3.6, 3.7, and 3.8). The number of days the 33 pickling cucumber cultigens took to produce the first fruit set and 50% fruit set ranged from 7 to 10 days and 6 to 9 days (Tables 3.6 and 3.8). The range of days the 33 slicing cucumber cultigens took to produce the first fruit set and 50% fruit set was reduced by about 5 days during the summer season as compared to the spring (Table 3.7).

Fruit quality

Ethephon had a significant effect on fruit quality rating. There were significant differences between the ethephon and no ethephon treatments for both pickling and slicing cucumber cultigens (Table 3.3). However, differences were significant only between one and two ethephon applications for pickling cucumber cultigens, and no differences between one and two applications for slicing cucumber cultigens. The fruit quality rating was higher in the spring season than in the summer. Cultigen means for fruit quality rating ranged from 2.0 to 6.8 on the 1 to 9 scale (Tables 3.1, 3.2, 3.7, and 3.8).

When the data were reanalyzed with cultigens grouped by crop and sex expression (monoecious pickles, gynoecious pickles, monoecious slicers, and gynoecious slicers), it was clear that ethephon had a larger effect on monoecious than gynoecious cultigens. In general, the groups showed significant differences for all traits between the spring and summer seasons, with the exception of quality rating for gynoecious pickling cultigens. Ethephon also had a large, significant effect on most traits across all the groups, with the exception of days to five nodes (all groups), fruit quality (monoecious pickling and slicing cultigens), days to first fruit set (slicing monoecious and gynoecious cultigens), and days to 50% fruit set (slicing monoecious and gynoecious cultigens). Cultigens within each group differed significantly for the traits evaluated in the study(data not shown), with the exception of days to 50% flowering (pickling gynoecious cultigens), days to first fruit set (pickling gynoecious cultigens), and fruit quality rating (pickling monoecious cultigens).

Based on the results of our experiment, we propose a growth model for pickling and slicing cucumber cultigens based on the effects of ethephon and the environment observed in the study (Fig. 1, 2, 3, and 4). Cucumber cultigens (pickling and slicing) took 10 days less to reach each of the stages measured in the study in the summer than in the spring season. The application of ethephon had an effect on most of the traits that were evaluated in the study, with the exception of days to five nodes in pickling and slicing cucumber cultigens, days to produce first fruit in slicing cucumber cultigens, and days to 50% fruit in slicing cucumber cultigens. There were significant differences between ethephon to no ethephon treatments, as well as between one and two ethephon applications for all the traits responding to ethephon (as described above). The exception was fruit quality rating, where there were no differences between one and two ethephon applications for slicing cucumber cultigens (Table 3.3).

For measurement of once-over harvest yield in cultigens differing in sex expression, we recommend one application of ethephon for conversion to gynoecious expression of pickling and slicing cucumber cultigens. Additional applications of ethephon tended to increase the number of days to reach the desired growth stage [first flower, 50% flower (both pickles and slicers), first fruit set, and 50% fruit set (pickles only)] (Table 3.3 and Fig. 3.1, 3.2, 3.3, and 3.4). In addition, one ethephon application resulted in a higher fruit quality rating than if a second one were used. Application of more than one treatment of ethephon was found to be either significant at the 5% level (pickling cucumber) or was non-significant (slicing cucumber) for the fruit quality ratings (Table 3.3). This recommendation is also supported by El-Bakry et al. (1978), who reported that one application of ethephon was found to significantly increase plant height, number of leaves per plant, and fruit yield as compared to two applications of ethephon in a cucumber cultivar 'Beit-Alpha'.

Literature Cited

Arora, S. K., M. L. Pandita, P. S. Partap and A. S. Sidhu. 1985. Effect of ethephon, gibberellic acid, and maleic hydrazide on vegetative growth, flowering, and fruiting of cucurbitaceous crops. J. Amer. Soc. Hort. Sci. 110: 442-445.

Cantliffe, D. J. and S. C. Phatak. 1975. Use of ethephon and chlorflurenol in a once-over pickling cucumber production system. J. Amer. Soc. Hort. Sci. 100: 264-267.

El-Bakry, A. M., H. M. Goma, A. F. Omran and E. T. El-kholy. 1978. Effects of yield and fruit quality of cucumber. Annals of Agric. Sc., Moshtohor 10: 127-132.

Hogue, E. J. and H. B. Heeney. 1974. Ethephon and high density plantings increase yield of pickling cucumbers. HortScience 9: 72-74.

Iwahori, S., J. N. Lyons and O.E. Smith. 1970. Sex expression in cucumber as affected by 2-chloroethanephosphonic acid, ethylene and growth regulators. Plant Physiol. 46: 412-415.

Karchi, Z. 1970. Effects of 2-chloroethanephosphonic acid on flower types and flowering sequences in muskmelon. J. Amer. Soc. Hort. Sci. 95: 515-518.

Karchi, Z and A. Govers. 1972. Effects of ethephon on vegetative and flowering behaviour in cucumber (*Cucumis sativus* L.). J. Amer. Soc. Hort. Sci. 95: 357-360.

Lower, R. L., C. H. Miller, F. H. Baker, and C. L. Combs. Effects of 2-chloroethylphosphonic acid treatment at various stages of cucumber development. HortScience 5: 433-434.

Miller, C. H., R. L. Lower and A. L. McMurray. 1969. Some effects of ethrel (2-chloroethanephosphonic acid) on vegetable crops. HortScience 4: 248-249.

Miller, C. H., R. L. Lower and H. P. Fleming. 1970. Evaluation of pickles from cucumber plants treated with 2-chloroethylphosphonic acid. HortScience 5: 434-435.

Miller, C. H., and R. L. Lower. 1972. Effect of ethephon on fresh-pack and brined cucumbers. HortScience 7: 418-420.

Pratt, H. K. and J. D. Goeschl. 1969. Physiological roles of ethylene in plants. Annual Review of Plant Physiology 20: 541-584.

Rudich, J., A. H. Halevy, and N. Kedar. 1969. Increase in femaleness of three cucurbits by treatment with Ethrel, an ethylene releasing compound. Planta 86: 69-76.

Rudich, J., A. H. Halevy, and N. Kedar. 1972. The levels of phytohormones in monoecious and gynoecious cucumbers as affected by photoperiod and ethephon. Plant Physiol. 50: 585-590.

Sadhu, M. K. and P. C. Das. 1978. Effect of ethrel (ethephon) on the growth, flowering and fruiting of three cucurbits. J. Hort Science 53: 1-4.

SAS Institute. 1989. SAS/STAT User's guide, Release 6.12 edition. SAS Institute Inc., Cary, NC.

Schultheis, J. R. 1990. Pickling cucumbers. North Carolina State Agr. Ext. Hort. Inform. Leaflet No. 14-A.

Shannon, S. and M. D. De La Guardia. 1969. Sex expression and the production of ethylene induced by auxin in the cucumber (*Cucumis sativus* L.). Nature 223: 186.

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size for measurement of yield in multiple and once over harvest trials of pickling and fresh market cucumbers. Euphytica 35: 493-501.

Swallow, W. H. and T. C. Wehner. 1989. Optimum allocation of plots to years, seasons, locations, and replications, and its applications to once-over harvest cucumber trials. Euphytica 43: 59-68.

Warner, H. L. and A. C. Leopold. 1969. Ethylene evolution from 2-chloroethylphosphonic acid. Plant Physiology 44: 156-158.

Wehner, T. C. 1987. Value of 12 season-location combinations for cucumber yield trials in North Carolina. Cucurbit Genet. Coop. Rpt. 6: 38-39.

Wehner, T. C. 1989. Breeding for improved yield in cucumber. Plant Breed. Rev. (Ed.) J. Janick. Vol. 6: 323-359.

Wehner, T. C. and C. H. Miller. 1987. Optimum plant density for multiple-harvest yield of determinate cucumbers. Cucurbit Genet. Coop. Rpt. 10: 29-30.

Yang, S. F. 1969. Ethylene evolution from 2-chloroethylnephosphonic acid. Plant Physiology 44: 1203-1204.

Table 3.1. Mean squares for traits evaluated in pickling cucumber study.

Source of variation	df	Days - 5 node	Days- 1st flower	Days-50% flower	Days- 1stfruit	Days-50% fruit	Fruit quality
Season	1	397.4**	864.4**	2154.9**	16598.9**	2044.8**	46.4*
Block	3	0.3	0.1	0.1	41.3	30.7	13.9
ErrorA	3	4.6	7.0	2.9	0.2	1.6	0.4
Ethephon	2	0.7	118.5**	16.9**	51.2**	29.5**	6.6*
Ethephon x Season	2	0.5	0.5	3.7	2.3	14.8**	0.1
Ethephon X Block	6	0.6	1.8	2.1	2.4	0.7	0.7
Error B	6	3.2	1.7	1.6	0.9	1.2	3.
Cultigen	32	7.7**	10.7**	5.2	17.5**	14.2**	39.4**
Cultigen X Season	32	1.8*	2.9**	1.1	1.5	1.5	1.0
Cultigen X Block	96	0.9	1.1	0.8	1.0	1.3	0.9
Cultigen X Ethephon	64	0.9	1.7**	1.1	1.8*	1.2	1.2
Cultigen X Ethephon X Block	190	1.0	0.9	0.7	1.0	1.0	1.0
Cultigen X Ethephon X Season	62	0.9	1.1	0.9	1.2	0.8	1.1
Cultigen X Block X Season	92	1.00	1.0	0.8	1.00	1.0	1.0
Error C	158	5.6	2.4	2.6	4.4	3.7	0.9

**, * significance at 1% and 5%

Table 3.2. Mean squares for traits evaluated in slicing cucumber study.

Source of variation	df	Days - 5 node	Days-1st flower	Days-50% flower	Days-1stfruit	Days-50% fruit	Fruit quality
Season	1	218.8**	6473.0**	2432.2**	940.8**	833.9**	46.9**
Block	3	0.8	10.1	1.6	0.7	77.0	0.5
ErrorA	3	5.4	0.9	4.4*	3.	2.7	2.9
Ethephon	2	0.2	30.5**	18.9**	5.0	1.2	10.4*
Ethephon x Season	2	2.9	2.5	3.4	2.1	1.2	0.2
Ethephon X Block	6	2.5	0.5	0.9	2.6	2.0	0.5
Error B	6	1.3	4.3*	4.6*	1.2	2.6	0.8
Cultigen	32	5.4**	11.5**	10.4**	8.0**	8.4**	41.3**
Cultigen X Season	31	2.2**	0.8*	2.6**	5.3**	3.9**	2.6*
Cultigen X Block	93	1.0	1.1	1.1	0.8	1.4	1.0
Cultigen X Ethephon	62	1.0	1.4	1.0	1.7	1.3	0.9
Cultigen X Ethephon X Block	181	0.8	1.0	1.2	1.0	1.4	1.0
Cultigen X Ethephon X Season	62	0.9	1.4	1.6	1.0	1.2	0.9
Cultigen X Block X Season	86	0.8	1.0	1.5	1.0	1.3	0.8
Error C	155	5.0	2.6	2.0	4.6	4.2	0.7

**, * significance at 1% and 5%

Table 3.3. Contrasts for ethephon treatments.

Source of variation	Days to fifth node	Days - 1st flower	Days-50% flower	Days - 1st fruit	Days - 50%	Fruit quality
Pickles						
Ethephon vs. No Ethephon	0.2	127.7**	16.6**	13.3**	19.4**	15.2**
1 vs. 2 Ethephon	1.27	151.8**	33.7**	64.2**	46.0**	5.0*
Slicers						
Ethephon vs. No Ethephon	0.1	75.0**	60.3**	2.3	1.6	7.3**
1 vs. 2 Ethephon Treatment	0.0	105.1**	48.2**	8.2	5.5	0.1

**, * significance at 1% and 5%

Table 3.4. Days to appearence of fifth node averaged over both harvests and ethephon applications (0, 1, and 2), and days to first flower set averaged over both harvests for picklingcultigens in 1996.

	First five nodes		First flower set					
			Spring			Summer		
Cultigen	Spring	Summer	0	1	2	0	1	2
Addis	30	21	40	40	41	28	29	31
Armstrong Early Cluster	29	21	36	35	37	27	28	29
Calypso	28	19	37	37	41	27	29	31
Chicago Pickling	28	22	40	41	42	28	29	31
Chipper	33	24	40	41	43	30	29	34
Clinton	29	21	37	40	41	28	28	30
Double Yield	30	25	38	43	45	29	31	34
Early Russian	29	20	36	36	40	27	27	32
Green Thumb	30	22	40	41	41	28	28	30
Gy 1	28	19	36	37	40	29	29	28
Gy 3	29	21	39	38	42	28	29	32
Gy 4	31	21	39	39	43	30	30	34
Gy 5	31	22	41	39	41	29	29	33
H-19	30	18	37	40	40	28	31	31
Heinz Pickling	34	23	41	43	45	31	32	33
Little John	30	18	39	41	40	29	34	33
M 21	32	22	40	41	41	28	28	30

Table 3.4. continued.

Cultigen	First five nodes Spring	First five nodes Summer	First flower set Spring 0	First flower set Spring 1	First flower set Spring 2	First flower set Summer 0	First flower set Summer 1	First flower set Summer 2
M 22	31	23	40	41	41	29	30	33
M 27	32	24	38	37	40	27	28	29
M 41	32	24	40	41	43	29	30	32
MSU 713-5	27	19	36	36	42	28	28	30
Model	29	20	37	38	41	27	28	31
Napoleon	30	22	38	38	39	28	29	30
National Pickling	28	22	38	40	40	28	28	31
Ohio MR 17	28	22	39	40	43	28	29	32
Picklers Special	30	22	39	39	42	28	29	32
Pixie	30	22	38	40	43	29	29	33
Producer	29	18	37	37	41	28	28	32
Regal	27	20	38	38	40	28	28	31
Southern Pickler	30	21	36	36	43	27	28	30
Sumter	30	22	39	41	41	28	28	30
Tiny Dill (NHTD)	32	23	40	41	42	28	27	31
Wautoma	30	22	39	42	42	30	30	33
Mean	30	21	38	39	41	28	29	31
Range	8	8	5	8	8	5	6	5.
CV	6	10	4	5	4	4	5	5
Std Dev	2	2	1	2	2	1	1	1

Table 3.5. Days to appearence of fifth node averaged over both harvests and ethephon applications and days to first flower set averaged over both harvests for slicing cultignes in 1996.

	First five nodes		First flower set					
			Spring			Summer		
Cultigen	Spring	Summer	0	1	2	0	1	2
Arlington White Spine	30	25	42	42	43	29	29	34
Ashley	30	24	41	41	43	31	28	33
Coolgreen	29	20	38	37	39	28	29	33
Cubit	30	25	42	43	42	34	30	33
Dasher II	28	23	38	38	42	28	29	31
Davis Perfect	29	22	38	40	42	28	28	33
Daytona	28	23	38	39	42	28	29	31
Dublin	31	22	41	42	43	29	32	32
Early Michigan	30	21	40	41	42	28	29	34
Everbearing	28	24	41	41	42	28	29	31
Fletcher	29	21	41	39	42	28	29	31
Gy 57u	29	21	38	39	42	29	30	32
Indy	28	21	38	38	42	28	29	31
Lightning	28	22	38	39	41	28	29	29
Longfellow	29	24	42	41	42	28	31	34
Marketer	31	24	42	43	44	33	32	34
Marketmore 76	29	23	42	42	43	29	29	33

Table 3.5. continued.

	First five nodes		First flower set					
			Spring			Summer		
Cultigen	Spring	Summer	0	1	2	0	1	2
Medalist	31	25	42	42	43	32	33	34
Pacer	32	24	42	44	44	31	32	34
Poinsett 76	31	24	42	44	42	29	28	31
Poinsett 83F	30	26	41	41	42	31	32	33
Polaris	34	25	44	43	43	32	34	34
Raider	29	24	41	40	42	29	29	33
Redlands Long White	28	24	42	42	42	31	29	31
Slice	28	22	41	40	42	29	29	31
Sprint 440	28	24	39	40	42	28	30	31
Straight 8	29	23	40	39	42	28	30	33
Striker	29	23	41	42	43	28	29	33
Super Green	28	24	36	36	40	28	29	32
Tablegreen 72 M	30	22	41	43	42	31	31	33
Thunder	28	21	38	40	40	28	28	29
Verino	-	26	-	-	-	-	26	-
Yangzhou Green Skin	28	22	40	42	42	29	29	32
Mean	29	23	40	41	42	29	30	32
Range	6	8	8	8	6.	6	8	5
CV	5	8	5	5	3	6	6	5
Std Dev	2	2	2	2	1	2	2	1

Table 3.6. Days to fifty percent flower set and first fruit set for pickling cucumber cultigens averaged over both harvests in 1996.

	50 % flower set						First fruit set					
	Spring			Summer			Spring			Summer		
	Ethephon			Ethephon			Ethephon			Ethephon		
Cultigen	0	1	2	0	1	2	0	1	2	0	1	2
Addis	45	46	45	33	34	35	46	47	45	33	34	36
Armstrong Early Cluster	44	44	44	31	33	34	47	42	48	37	34	35
Calypso	44	43	44	33	35	35	42	43	44	31	31	35
Chicago Pickling	45	44	45	34	34	36	47	48	47	34	36	37
Chipper	45	45	46	34	35	36	51	47	48	36	35	38
Clinton	44	45	43	33	33	35	45	46	47	32	34	36
Double Yield	47	48	48	34	35	36	50	52	52	40	38	39
Early Russian	44	45	45	32	32	34	45	47	47	35	34	37
Green Thumb	44	45	44	33	33	35	46	48	48	36	36	37
Gy 1	45	44	45	34	33	34	42	43	46	32	32	36
Gy 3	45	43	45	34	35	35	42	41	46	33	33	36
Gy 4	46	43	46	35	33	36	42	41	45	33	33	36
Gy 5	44	44	45	35	34	34	44	43	44	31	33	35
H-19	45	48	47	32	37	37	51	49	50	40	40	40
Heinz Pickling	47	47	48	36	34	36	48	50	50	37	36	38
Little John	46	49	48	34	38	41	50	51	50	41	41	41
M 21	45	45	45	33	33	35	43	45	45	34	33	35
M 22	45	44	46	34	34	35	52	47	50	34	35	39

Table 3.6. continued.

	50 % flower set						First fruit set					
	Spring			Summer			Spring			Summer		
	Ethephon			Ethephon			Ethephon			Ethephon		
Cultigen	0	1	2	0	1	2	0	1	2	0	1	2
M 27	45	43	44	32	33	34	47	44	47	34	33	36
M 41	46	44	47	34	35	35	45	42	48	35	34	36
MSU 713-5	45	44	45	33	34	34	43	42	47	32	33	35
Model	45	44	45	33	33	34	44	46	47	35	33	35
Napoleon	44	44	45	34	34	34	43	42	45	32	34	34
National Pickling	44	45	46	33	34	35	44	46	46	34	33	36
Ohio MR 17	44	44	46	34	34	35	47	46	49	36	36	36
Picklers Special	44	46	47	34	31	35	48	47	46	37	35	38
Pixie	45	45	46	35	34	35	48	46	47	34	34	37
Producer	45	45	45	33	33	36	44	47	46	33	34	37
Regal	43	42	44	34	34	34	42	41	44	33	30	35
Southern Pickler	44	44	45	33	33	35	42	43	48	32	33	37
Sumter	44	45	45	34	33	35	47	44	48	35	34	37
Tiny Dill (NHTD)	44	44	45	33	33	37	46	47	49	39	38	40
Wautoma	45	46	45	35	35	35	48	49	46	39	37	38
Mean	45	45	45	33	34	35	46	45	47	35	34	37
Range	4	7	5	5	6	7	10	11	8	10	10	7
CV	2	3	3	3	4	4	6	6	4	8	6	5
Std Dev	1	1	1	1	1	1	3	3	2	3	2	2

Table 3.7. Days to fifty percent flower set, first fruit set, 50% fruit set, and fruit quality in slicing cultigens in 1996.

	50 % flower set						Fruit set				Quality			
	Spring			Summer			First		50 %		Spg		Smr	
	Ethephon			Ethephon									Ethephon	
Cultigen	0	1	2	0	1	2	Spg	Smr	Spg	Smr	0	1&2	0	1&2
ArlingtonWhiteSpine	49	49	49	34	34	38	55	43	60	47	5.3	4.7	5.0	3.8
Ashley	48	47	49	36	34	36	51	42	57	49	6.5	6.3	5.8	5.0
Coolgreen	47	47	46	34	34	39	52	43	55	50	7.0	7.1	5.8	6.4
Cubit	48	49	50	37	36	37	53	42	60	49	6.5	6.3	4.0	5.0
Dasher II	45	46	47	34	35	36	49	42	56	49	8.0	7.5	6.8	7.0
Davis Perfect	47	49	48	34	34	37	54	42	56	47	5.3	5.2	4.3	4.2
Daytona	47	47	47	34	34	36	49	42	55	49	8.0	7.7	8.0	7.7
Dublin	49	49	49	34	35	36	53	42	58	48	6.8	5.8	6.0	5.3
Early Michigan	48	47	49	33	34	38	54	43	60	47	5.3	5.4	4.5	4.3
Everbearing	47	48	49	34	34	36	52	42	56	47	4.0	3.6	3.5	3.7
Fletcher	47	48	48	34	34	35	52	43	56	48	6.3	5.3	4.8	4.2
Gy 57u	46	46	48	35	36	36	50	42	55	48	7.5	6.9	6.3	5.9
Indy	45	45	48	34	35	36	49	42	54	49	8.0	8.0	8.0	7.4
Lightning	44	44	45	34	34	34	47	41	53	48	7.5	7.5	7.3	7.4
Longfellow	49	48	49	33	35	40	55	42	58	49	5.5	5.2	4.5	4.2
Marketer	48	51	50	36	36	39	54	42	59	50	6.7	5.3	4.8	4.2
Marketmore 76	48	49	50	34	34	38	54	43	60	50	7.5	8.0	5.8	5.9
Medalist	49	49	49	36	38	39	54	42	59	49	8.0	7.6	6.8	6.8

Table 3.7. continued.

	50 % flower set						Fruit set				Quality			
	Spring			Summer			First		50 %		Spg		Smr	
	Ethephon			Ethephon							Ethephon			
Cultigen	0	1	2	0	1	2	Spg	Smr	Spg	Smr	0	1&2	0	1&2
Pacer	49	52	51	37	37	37	55	43	60	50	8.0	7.8	5.0	5.5
Poinsett 76	48	49	48	33	34	36	54	43	61	49	6.8	6.8	8.0	6.8
Poinsett 83F	48	50	48	36	36	38	51	42	57	49	7.0	7.2	6.0	6.1
Polaris	49	49	50	36	38	39	56	44	59	49	6.5	7.0	5.0	5.7
Raider	47	46	48	34	34	37	49	42	55	50	8.0	7.7	7.5	6.9
Redlands LongWhite	48	48	47	35	36	36	53	42	55	47	5.8	4.3	4.3	4.1
Slice	47	47	47	34	34	36	51	43	56	49	7.3	6.7	6.5	6.5
Sprint 440	45	47	47	33	35	36	49	42	54	48	7.5	7.4	7.0	7.0
Straight 8	48	47	49	34	34	37	53	43	57	49	5.5	5.3	4.3	4.3
Striker	49	49	49	34	36	37	53	43	57	50	7.5	7.3	7.0	7.2
Super Green	45	45	46	34	35	37	47	43	56	49	6.8	6.9	6.5	6.2
Tablegreen 72 M	49	49	50	35	37	38	55	42	58	49	7.0	7.1	6.3	6.1
Thunder	45	47	47	34	34	34	49	41	54	48	7.8	7.3	7.5	7.3
Verino	-	-	-	-	33	-	-	42	-	46	-	-	-	-
Yangzhou Green Skin	46	48	48	34	34	37	50	41	56	49	6.3	7.2	6.8	6.6
Mean	47	48	48	34	35	37	52	42	57	48	6.8	6.5	5.9	5.7
Range	5	8	6	5	5	6	10	4	9	5	4.0	4.6	4.5	4.2
CV	3	3	3	3	3	4	5	2	4	3	15	19	22	23
Std Dev	1	2	1	1	1	1	2	1	2	1	1.0	1.2	1.3	1.3

Table 3.8. Days to fifty percent fruit set and fruit quality rating for pickling cucumber cultigens averaged over both harvests in 1996.

	50 % fruit set						Fruit quality					
	Spring			Summer			Spring			Summer		
	Ethephon			Ethephon			Ethephon			Ethephon		
Cultigen	0	1	2	0	1	2	0	1	2	0	1	2
Addis	52	52	52	42	44	46	8.5	7.0	6.5	6.8	6.3	6.8
Armstrong Early Cluster	52	53	53	45	42	44	3.8	3.0	2.8	2.8	2.8	3.3
Calypso	51	51	52	39	41	43	7.5	8.3	6.3	7.3	6.8	6.5
Chicago Pickling	53	53	52	43	43	47	5.5	5.5	4.3	4.8	5.0	4.3
Chipper	56	55	54	42	44	45	7.0	6.7	5.8	6.3	7.0	6.0
Clinton	52	52	52	40	42	44	7.5	6.8	6.5	6.3	6.3	6.5
Double Yield	52	60	57	47	47	47	7.0	5.8	4.0	4.3	4.5	3.8
Early Russian	53	52	54	44	43	45	2.8	2.8	3.3	3.3	2.5	2.8
Green Thumb	53	52	52	43	44	46	5.8	5.8	5.3	5.0	4.8	4.5
Gy 1	51	51	52	41	41	45	6.8	7.0	6.0	7.0	7.0	6.0
Gy 3	51	51	53	39	40	43	6.3	6.5	6.3	6.5	5.0	5.3
Gy 4	51	51	52	41	42	45	7.0	5.7	6.0	6.5	6.8	6.8
Gy 5	52	51	53	42	42	44	5.5	5.7	5.8	6.0	5.5	4.8
H-19	57	57	57	48	47	47	8.0	7.0	7.3	7.5	7.3	7.3
Heinz Pickling	52	52	56	47	47	46	8.0	2.0	6.3	6.3	6.5	6.3
Little John	58	58	57	48	47	48	7.7	7.3	6.7	7.5	6.8	7.5
M 21	52	52	54	42	43	44	6.8	6.3	6.8	6.8	6.3	5.5
M 22	58	56	52	43	43	46	7.5	5.0	8.0	7.0	5.0	7.3

Table 3.8. continued.

	50 % fruit set						Fruit quality					
	Spring			Summer			Spring			Summer		
	Ethephon			Ethephon			Ethephon			Ethephon		
Cultigen	0	1	2	0	1	2	0	1	2	0	1	2
M 27	54	52	54	43	42	47	6.5	7.5	6.3	7.0	6.0	6.3
M 41	54	51	56	42	43	45	6.7	5.7	6.3	6.3	5.3	5.5
MSU 713-5	51	51	52	41	41	43	4.5	3.8	4.3	3.8	5.0	3.8
Model	52	51	53	44	44	46	6.3	4.8	5.0	5.0	4.8	5.0
Napoleon	51	51	52	41	43	44	7.5	7.0	7.0	7.0	7.0	6.0
National Pickling	51	52	52	42	42	42	3.5	3.8	3.8	3.5	4.5	3.3
Ohio MR 17	52	52	54	44	45	46	5.0	5.0	4.5	5.0	3.0	4.0
Picklers Special	55	53	53	44	43	45	5.0	4.0	4.0	4.3	4.0	3.5
Pixie	52	52	54	41	43	45	8.0	6.8	6.5	6.3	6.5	5.8
Producer	53	51	52	44	42	47	4.3	4.0	4.3	6.0	3.8	4.0
Regal	51	51	51	39	39	44	7.5	7.5	6.8	7.5	6.8	6.8
Southern Pickler	51	51	54	39	42	45	5.8	5.8	4.0	6.3	5.0	4.5
Sumter	52	52	52	42	42	43	7.0	6.3	6.0	7.0	6.5	6.0
Tiny Dill (NHTD)	54	54	54	47	46	48	5.5	5.0	4.8	4.5	5.0	3.3
Wautoma	55	53	53	46	43	46	6.3	7.0	6.3	6.3	6.5	6.5
Mean	53	52	53	43	43	45	6.3	5.7	5.5	5.9	5.5	5.3
Range	8	9	6	9	8	6	5.8	6.3	5.3	4.8	4.8	4.8
CV	4.	4	3	6	5	3	23	27	23	23	24	26
Std Dev	2	2	2	3	2	1	1	1	1	1	1	1

Figure 3.1. Effects of ethephon on pickling cucumber cultigens during spring 1996 based on mean values for cultigens evaluated in the study.

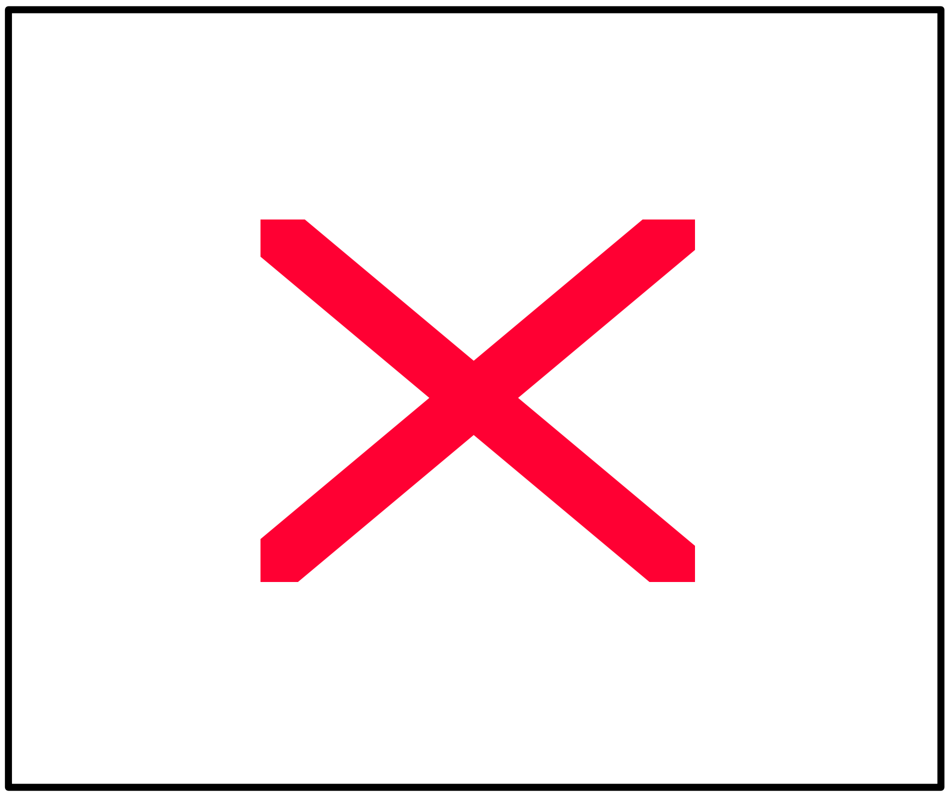


Figure 3.2. Effects of ethephon on pickling cucumber cultigens during summer 1996 based on mean values for cultigens evaluated in the study.

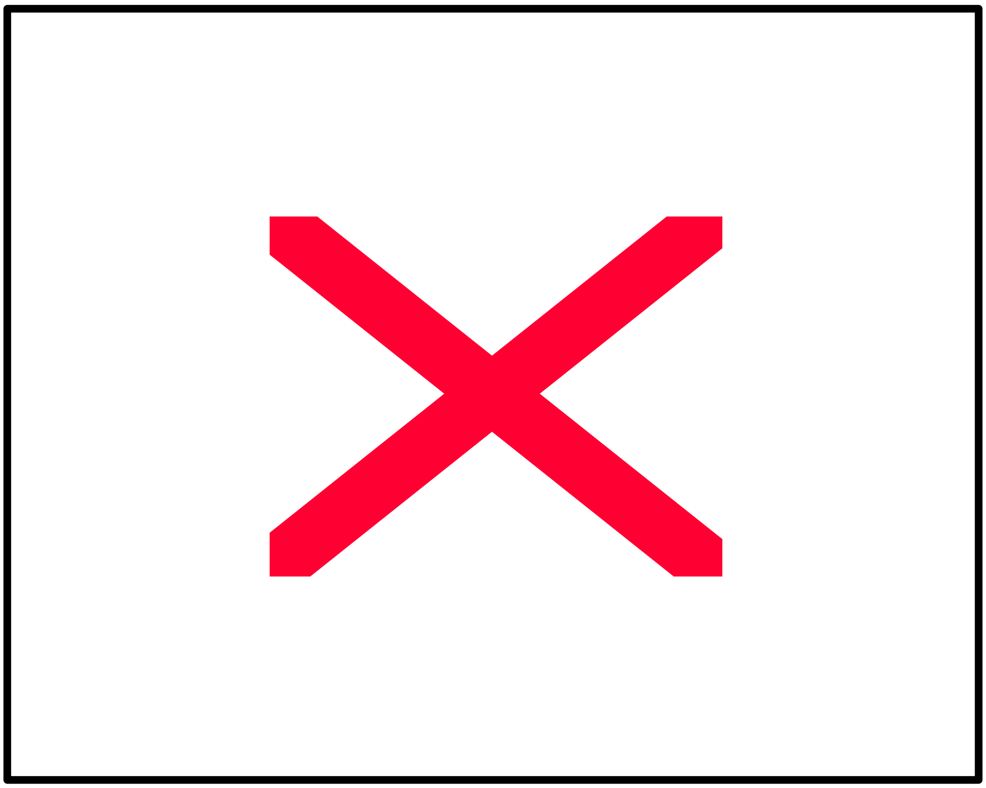


Figure 3.3. Effects of ethephon on slicing cucumber cultigens during Spring 1996 based on mean values for cultigens evaluated in the study.

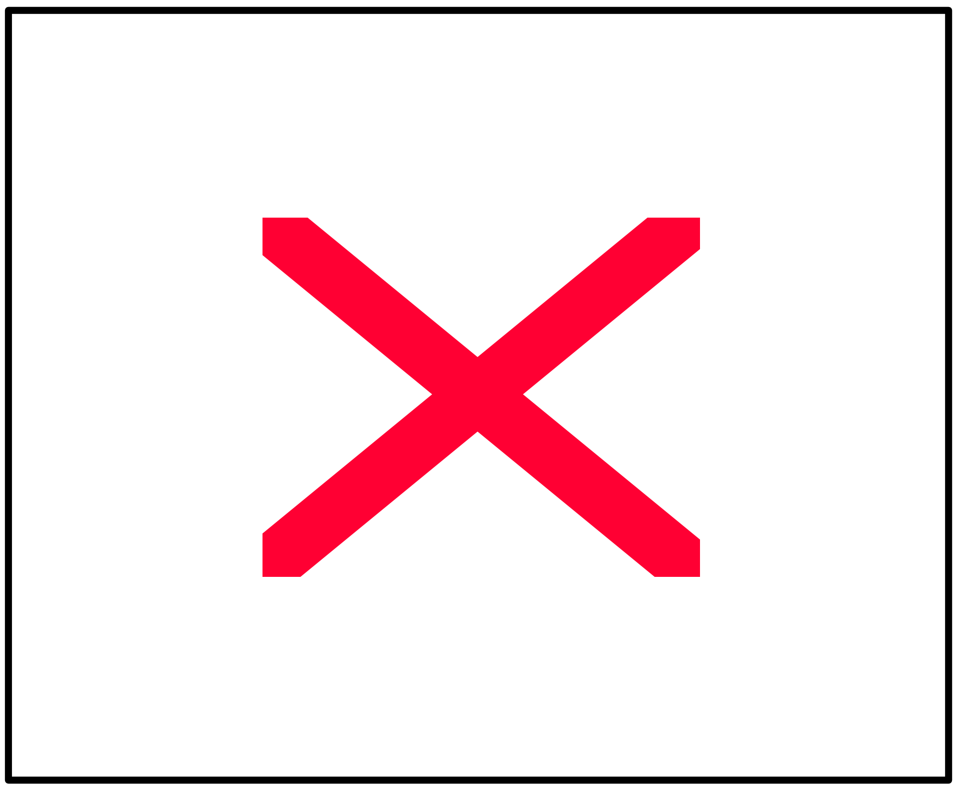
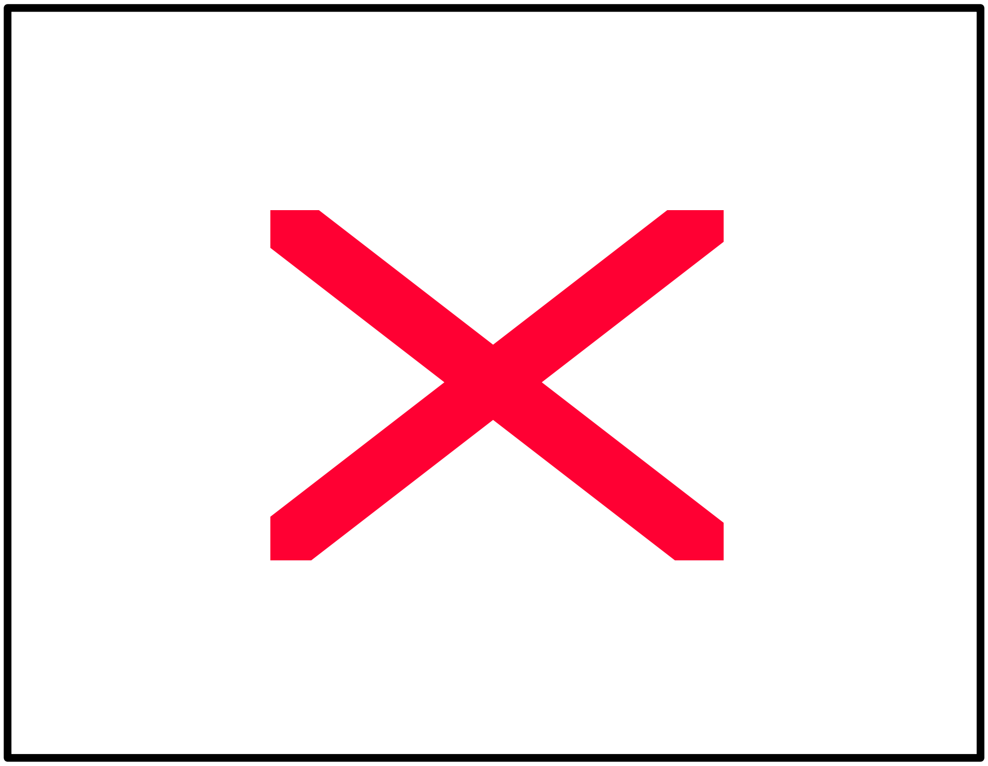


Figure 3.4. Effects of ethephon on slicing cucumber cultigens during Summer 1996 based on mean values for cultigens evaluated in the study.



Chapter Four

Effect of Ethephon on Isogenic Lines of Cucumber for Gynoecious Sex Expression

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

For: Scientia Horticulturae

Breeding and germplasm resources

Effect of Ethephon on Isogenic lines of Cucumber for Gynoecious Sex Expression

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Additional index words. *Cucumis sativus*, Cucurbitaceae, vegetable breeding

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Abstract

Ethephon (2-chloroethyl phosphonic acid) was applied to inbred lines of cucumber to determine its interaction with genes for sex expression. Ethephon treatments involved spraying zero, one, or two applications on plants at the first to second true leaf stage. Inbreds were isogenic pairs that differed for the *F* gene conditions sex expression (monoecious vs gynoecious) in cucumber. The application of ethephon improved most traits: gynoecious rating, fruit number (total, early, and marketable) and fruit weight (total, early, and marketable), compared to the unsprayed control in the study. Ethephon was effective in increasing pistillate flower number on monoecious inbreds, but had little effect on gynoecious inbreds. However, ethephon had no effect on the number and weight of culled fruit, or on fruit quality rating.

Cucumber (*Cucumis sativus* L.) is an unusual crop plants in terms of sex expression. The basic sex types that have been reported in cucumber are: monoecious (bearing staminate and pistillate flowers on the same plant), gynoecious (producing only pistillate flowers), gynomonoecious (pistillate and perfect flowers), andromonoecious (staminate and perfect flowers), hermaphroditic (only perfect flowers), trimonoecious (staminate, pistillate, and perfect flowers) and androecious (only staminate flowers). The wild type was probably monoecious or andromonoecious. (Robinson et al., 1976). Monoecious plants usually have staminate flowers followed by a mixture of staminate and pistillate flowers and finally pistillate flowers. However, there are differences among monoecious cucumber cultivars for ratio of staminate to pistillate flowers. Gynoecious cucumber cultivars have predominantly pistillate flowers and few staminate flowers (Shifriss, 1961).

Shifriss (1961) reported that sex expression in cucumber during plant growth and development is controlled by three groups of hereditary factors. First, several qualitative genes (*G, g*) determine the kind of flower to produce. All cucumber plants are known to have the genetic potential to produce staminate flowers. The monoecious genotype carries the *G* gene for pistillate flowers, and the andromonoecious genotype carries the *g* gene for perfect flowers. Secondly, a set of polygenes is thought to govern the accumulation or depletion of an unknown substrate. The levels of this substrate are thought to control the genes for the different kinds of flowers. Third, the gene *Acr* (*F*) is thought to enhance the rate of physiological processes controlled by the polygenes. Environmental factors (daylength, light intensity, and temperature) also play a role in sex expression (Nitsch et al., 1952; Tiedjens, 1928). The above non-genetic factors may affect the substrate, which is thought to control the genes for the different kinds of flowers. Therefore, Shifriss (1961) proposed that monoecious and andromonoecious genotypes differentiate staminate flowers early in the plant growth and development. Later, they differentiate pistillate (*G*) or perfect (*g*) flowers. The final phase of flowering is strictly pistillate or hermaphroditic.

There is a wide range in staminate:pistillate flower ratio among monoecious cucumber cultivars. A series of polygenes is thought to determine the rate of sex conversion, which in turn, controls the formation of staminate flowers. The gene *F* was found to be responsible for gynoecy, with monoecious plants homozygous recessive. Robinson et al. (1976) reported that inbred lines with genotype *FF* were more gynoecious than isogenic inbreds with genotype *ff*.

Ethylene is a plant growth regulator that is associated with accelerated senescence in plants, ripening of fruis, and control of sex expression in cucurbits (Pratt and Goeschl, 1969). The ethylene-releasing property of ethephon (2-chloroethylphosphonic acid) was first reported by Warner and Leopold (1969) and Yang (1969). Several studies have since demonstrated the ability of ethephon to alter sex expression in species of the *Cucurbitaceae*. Ethephon was effective in altering sex expression in cucumber when applied at the seedling stage (Iwahori et al., 1969; Rudich et al., 1969), as a pre-flowering spray (Karchi, 1970; Karchi and Govers, 1972), or as a pre-sowing seed treatment (Sadhu and Das, 1978).

Ethylene has an effect similar to that of auxin. Exogenous application of auxin increases ethylene production in cucumber plants (Shannon and De LaGuardia, 1969), while ethylene is known to lower the auxin levels (Burg et al., 1966; Rudich et al., 1972). Rudich et al. (1972) indicated that ethylene may promote the production of pistillate flowers either directly or by reducing endogenous gibberellic acid and auxin levels, or by promoting the production of abscisic acid. High carbon dioxide levels are antagonistic to ethylene, and were reported to increase the number of staminate flowers in a gynoecious cucumber line. Higher ethylene was produced in pistillate flower buds and in apices of gynoecious plants than from staminate flower buds or apices of monoecious plants (Rudich, 1969).

McMurray and Miller (1968) reported that the application of 2-chloroethanephosphonic acid to seedlings of the monoecious cucumber inbred, SC 23, produced an average of 19 pistillate nodes in sequence, starting at the base of the plant. Plant yield (total fruit number) was higher when they were treated with ethephon before flowering than at seedling stage. Preflowering application of 150 ppm ethephon to monoecious cultivars and 250 to 350 ppm to gynoecious cultivars resulted in higher fruit numbers than the controls. Ethephon treatments also decreased the percentage fruit set in monoecious cucumber cultivars (Karchi and Govers, 1972).

Hogue and Heeney (1974) reported that the treatment that produced the highest fruit weight and value was when pickling cucumber plants were sprayed with ethephon at a concentration of 400 ppm and a plant spacing of 15 x 15 cm. Cantliffe and Phatak (1975) reported that best yield, fruit shape, and fresh salt stock quality were obtained by the following combinations: ethephon should be applied twice at one week intervals commencing at the fourth true-leaf stage, followed by a 50 to 100 ppm application of chlorflurenol (methyl-2-chloro-9-hydroxyfluorene-[9]-carboxylate) when 6 to 8 pistillate flowers have reached anthesis.

In cucumber, fruit number was found to be more stable than fruit weight or fruit value for yield measurement in once-over harvest of cucumber (Ells and McSay, 1981). Fruit number had a higher heritability (0.17) than fruit weight (0.02) (Smith and Lower, 1978), making selection for number more efficient than weight. Once-over harvest trials having three replications was recommended for maximum efficiency to determine which cucumber lines should be tested further in multiple-harvest trials (Wehner and Miller, 1984; Wehner, 1986). A plot size of 1.2 m x 1.5 m was found to be optimum for yield evaluation for once-over harvest trials of pickling cucumber (Swallow and Wehner, 1986). Wehner and Miller (1987) recommended the use of small, single-row plots without end borders rather than large, multiple-row, bordered plots for efficient evaluation of yield. In cucumber, small-plot, single-harvest trials were found to be more efficient than large-plot, multiple-harvest trials (Wehner, 1986; Wehner, 1989; Wehner and Miller, 1984). Swallow and Wehner (1989) suggested that maximum information (1/variance) was obtained by allocating test plots of cucumber cultigens to different seasons and years instead of locations and replications. Field evaluation at the Clinton location was reported to be more efficient than three other locations tested in North Carolina (Wehner, 1987).

The objective of this experiment was to test a set of monoecious and gynoecious cucumber inbreds that were near-isogenic for differences in sex expression and yield when treated with different rates of ethephon.

Materials and Methods

The experiment was conducted in 1998 during two seasons (spring and summer) at the Horticultural Crops Research Station in Clinton, N.C. using recommended horticultural practices as summarized by Schultheis (1990).

Cultigens used

Three sets of near isogenic cucumber lines differing in sex expression (monoecious vs. gynoecious) were chosen for the experiment: 'Tablegreen 72M', 'Tablegreen 68F', 'Marketmore 76M', 'Marketmore 80F', SR 551M, and SR 551F. The cultigens were developed by Dr. Henry Munger at Cornell University. The monoecious and the gynoecious lines were designated with the suffix M and F, respectively.

Cultural practices

Fertilizer was incorporated before planting at a rate of 90-39-74 $kg \cdot ha^{-1}$ (N-P-K) with an additional 34 $kg \cdot ha^{-1}$ N applied at the vine tip-over stage (four to six true leaves). Seeds were planted on raised, shaped beds with centers 1.5 m apart. Plots 1.2 m long were seeded with 16 seeds, and later thinned to 12 plants at the first true leaf stage. Irrigation was applied when needed to provide a total of 25 to 40 mm per week, and a tank mix of 2.2 $kg \cdot ha^{-1}$ of naptalam (2-[(1-naphthalenylamino) carbonyl] benzoic acid) and 4.4 $kg \cdot ha^{-1}$ of bensulide (O,O-bis(1-methylethyl) S-[2-[(phenylsulfonyl) amino] ethyl] phosphorodithioate) was applied preplant for weed control. Plots were 1.2 m long with 1.2 m alleys at each end, and were arranged in rows 1.5 m apart. 'Sumter' pollenzier was planted in side border rows and in end plots to provide competition to the outside plots in each field.

Ethephon application

The ethephon (2-chloroethyl phosphonic acid) treatments involved spraying zero, one, or two applications on cucumber plants at the first to second true leaf stage. A Solo backpack sprayer at 100 to 140 kPa (15 to 20 psi) was used to spray the ethephon onto leaves until run-off. The second application was made one week after the first. Ethephon was prepared using Florel [3.9% ethephon (2-chloroethyl phosphonic acid)] (Southern Agricultural Insecticides, Inc. Palmetto, FL 34220) at the rate of 2.5 ml/l for a concentration of 21%.

Data collection

Data were collected as plot means, and included a gynoecious rating, a fruit quality rating, and number and weight of total, early, and cull fruit per plot. Early fruit were the number of oversized at harvest. The number of marketable fruit was calculated as total minus cull fruit. Gynoecious rating was on a 1 to 9 scale (1-3 = androecious, 4-6 = monoecious, 7-9 = gynoecious). Fruit quality was rated mainly on shape and marketability, but color was also considered. Fruit quality was rated on a 1 to 9 scale (1-3 = poor, 4-6 = intermediate, 7-9 = exellent). Fruit number per plot was converted to thousands/ha, and fruit weight was converted to Mg/ha.

Data analysis

The experiment was a randomized complete block design with four replications in a 3x6 factorial arrangement (ethephon and cultigen). Whole plot was season (spring and summer). Data were analyzed using the General Linear Models and Correlation procedures of the Statistical Analysis System 6.12 (SAS Institute, Inc., Cary, NC).

Results and Discussion

There were significant differences between spring and summer seasons for total and marketable fruit number, and for total, marketable, and cull fruit weight. The six cultigens evaluated in the study were significantly different for all the traits evaluated, except for total and early fruit number and weight. Ethephon applications had an effect on most of the traits: gynoecious rating, fruit number (total, early, and marketable), and fruit weight (total, early, and marketable). However, ethephon had no significant effect on the number and weight of culled fruit and on fruit quality rating in the study (Tables 4.1 and 4.2).

Gynoecious rating

The gynoecious rating with no ethephon treatment (control) matched the reported sex expression of the cultigens. We observed that cultigen SR 551F, reportedly gynoecious, did not differ from SR 551M for gynoecious rating in both seasons. However, the remaining cultigens behaved according to their intended sex expression designations i.e., 'Tablegreen 72M' and 'Marketmore 76M' had lower gynoecious rating (lower percentage of pistillate flowers), while 'Tablegreen 68F' and 'Marketmore 80F' had higher gynoecious rating (higher percentage of pistillate flowers).

In general, ethephon converted monoecious cucumber inbreds into gynoecious ones. 'Tablegreen 72M' and 'Marketmore 76M' produced more pistillate flowers with increased ethephon applications. This result is not consistent with the results of George (1971), who reported that ethephon did not significantly improve the sex expression of 'Marketmore'. Possible explanations for the difference could be the environment used, or seed source of 'Marketmore' tested in the studies. SR 551M produced more pistillate flowers with two applications of ethephon, but tended to produce a lower percentage of pistillate flowers than the control when treated with one ethephon application during both the seasons. As expected, ethephon did not improve significantly the gynoecious rating for the gynoecious cucumber cultigens evaluated in the study (Table 4.3).

Total yield

Ethephon improved total yield (fruit number) of cucumber cultigens evaluated in this study. Total fruit number increased with ethephon application in both monoecious and gynoecious cucumber cultigens. This was in agreement with El-Bakry et al. (1978) who reported that ethephon applied to the cucumber cultivar 'Beit Alpha' increased total fruit weight and numbers per plot. In our study, the only exception was 'Marketmore 76M' during the summer season, where it was observed that total fruit number decreased with ethephon application. A possible explanation may be that high summer temperature, daylength, and light intensity may have caused some reversion of pistillate to staminate flowers.

The increased production of staminate flowers in monoecious cucumber has been reported with increasing temperature, photoperiod, and light intensity by Cantliffe (1981). He further reported that temperature had a bigger influence on sex expression than light intensity or photoperiod. Tiedjens (1928) and Edmond (1931) found that pistillate flowering in monoecious cucumber was favored by low light intensity and short photoperiod. Atsmon and Galun (1962) reported that the combination of short days and cool nights favored the production of pistillate flowers. Lower and Edwards (1986) found that staminate flower production was favored by high temperature and long daylength. In our study, ethephon had a larger effect on monoecious cucumber inbreds than on their gynoecious isoline, with increased fruit yield as ethephon was increased. That is probably due to the larger increase in pistillate flower number in monoecious inbreds than in their gynoecious isolines. SR 551F was supposed to be gynoecious, but did not differ in gynoecious rating from SR 551M, the monoecious isoline. SR 551M varied in yield response to ethephon over the two seasons. Ethepon had minimal effect on the total fruit number in the spring season but had a large effect in the summer (Table 4.3). Ethephon treatment resulted in increased total fruit weight. In general, total fruit weight increased with increasing ethephon, with highest weight at two applications. With ethephon treatment, monoecious cucumber inbreds increased more in total fruit weight than their gynoecious isolines. The only exception was 'Marketmore 76M' during the summer season, where no difference was observed in ethephon treatments. The other exception to the above generalization regarding the better performance of monoecious vs. gynoecious inbreds was SR 551F. Fruit weight of SR 551F increased with ethephon treatment, with two ethephon applications producing fruit weights nearly four times the control (ethephon spray 0). The SR 551F seed lot we used may not have been as gynoecious as the original (Table 4.3).

Marketable and cull yield

Ethephon had a significant effect on the marketable fruit number and weight of cultigens evaluated in the study. There was a difference for ethephon vs. the control but not between one and two ethephon applications. In general, marketable fruit number was lower with ethephon than with the control and during the summer than in the spring season. However, marketable weight was unaffected or was slightly increased (Table 4.4).

There was no significant effect of ethephon on cull fruit weight among the inbreds evaluated. However, cull fruit weight was higher in the summer than in the spring season, probably due to the higher temperature and moisture stress (Table 4.4).

Early yield

There was no significant difference between seasons for early fruit number, early fruit weight, cull fruit number, and fruit quality rating (Tables 4.1 and 4.2).

Ethephon had a significant effect on early fruit number and weight (Tables 4.1 and 4.2). Early fruit number and weight increased with ethephon application (Table 4.5). However, cull fruit number and fruit quality rating were not affected by the number of ethephon applications. Cultigens were significantly different for cull number and fruit quality (Tables 4.1 and 4.2). SR 551F produced a third fewer culls than the monoecious isoline SR 551M. Also, the gynoecious inbred 'Tablegreen 68F' produced significantly fewer cull fruit than its monoecious isoline. However, there were no significant differences between 'Marketmore 76M' and 'Marketmore 80F' for cull fruit number. Fruit quality was found to differ significantly between the two isogenic lines of SR 551 and 'Tablegreen', but was not different for the 'Marketmore' isolines.

Summary

In general, ethephon played an important role in most of the traits evaluated in the study. Ethephon made significant changes in the monoecious cucumber inbreds, but had little effect on the gynoecious isolines. This was reflected in the increased gynoecious ratings with increased ethephon applications, but mainly for the monoecious isolines. Yield (total and early fruit number and weight) increased with increased ethephon applications.

The increase in total fruit number with increased ethephon applications was common to both monoecious and gynoecious cucumber isolines. However, the rate of increase in total fruit weight with ethephon applications was greater among monoecious cucumber cultigens than gynoecious cultigens evaluated in the study. Marketable fruit number and weight was found to differ significantly between the control and ethephon applications. However, ethephon had no effect on cull fruit number, fruit weight, and fruit quality rating for the six cultigens evaluated.

Literature Cited

Atsmon, D. and E. Galun. 1962. Physiology of sex in Cucumis sativus (L.) leaf age patterns and sexual differentiation of floral buds. Ann. Bot 26: 137-146.

Burg, S. P. and E. A. Burg. 1966. The interaction between auxin and ethylene and its role in plant growth. Proc. Nat. Acad. Sci. U.S.A. 55: 262-269.

Cantliffe, D. J. 1981. Alteration of sex expression in cucumber due to changes in temperature, light intensity and photoperiod. J. Amer. Soc. Hort. Sci. 106: 133-136.

Cantliffe, D. J. and S. C. Phatak. 1975. Use of ethephon and chlorflurenol in a once-over pickling cucumber production system. J. Amer. Soc. Hort. Sci. 100: 264-267.

Edmond, J. B. 1931. Seasonal variation of sex expression of certain cucumber varieties. Proc. Amer. Soc. Hort. Sci. 27: 329-332.

El-Bakry, A. M., H. M. Goma, A. F. Omran and E. T. El-kholy. 1978. Effects of yield and fruit quality of cucumber. Annals of Agric. Sc. Moshtohor 10: 127-132.

Ells, J. E. and A. E. McSay. 1981. Yield comparisons of pickling cucumber cultivar trials for once-over harvesting. HortScience 16: 187-189.

George, W. L. Jr. 1971. Influence of genetic background on sex conversion by 2-chloroethanephosphonic acid in monoecious cucumbers. J. Amer. Soc. Hort. Sci. 96: 152-154.

Hogue, E. J. and H. B. Heeney. 1974. Ethephon and high density plantings increase yield of pickling cucumbers. HortScience 9: 72-74.

Iwahori, S., J. N. Lyons and O.E. Smith. 1970. Sex expression in cucumber as affected by 2-chloroethanephosphonic acid, ethylene and growth regulators. Plant Physiol. 46: 412-415.

Karchi, Z. 1970. Effects of 2-chloroethanephosphonic acid on flower types and flowering sequences in muskmelon. J. Amer. Soc. Hort. Sci. 95: 515-518.

Karchi, Z and A. Govers. 1972. Effects of ethephon on vegetative and flowering behaviour in cucumber (*Cucumis sativus* L.). J. Amer. Soc. Hort. Sci. 95: 357-360.

Lower, R. L., and M. D. Edwards. 1986. Cucumber Breeding. In: Breeding vegetable crops. Basset, M.J. (ed.), pp. 173-207. AVI Publishing Co., Westport, Connecticut.

McMurray, A. L. and C. H. Miller. 1968. Cucumber sex expression modified by 2-chloroethanephosphonic acid. Science 162: 1396-1397.

Nitsch, J. P., E. B. Kurz, Jr., J. L. Liverman, and F. W. Went. 1952. The development if sex expression in cucurbit flowers. American J. Bot. 39: 32-43.

Pratt, H. K. and J. D. Goeschl. 1969. Physiological roles of ethylene in plants. Annual Review of Plant Physiology 20: 541-584.

Robinson, R. W., H. M. Munger, T. W. Whitaker and G. W. Bohn. 1976. Genes of Cucurbitaceae. HortScience 11: 554-568.

Rudich, J., A. H. Halevy, and N. Kedar. 1969. Increase in femaleness of three cucurbits by treatment with Ethrel, an ethylene releasing compound. Planta 86: 69-76.

Rudich, J., A. H. Halevy, and N. Kedar. 1972. The levels of phytohormones in monoecious and gynoecious cucumbers as affected by photoperiod and ethephon. Plant Physiol. 50: 585-590.

Sadhu, M. K. and P. C. Das. 1978. Effect of ethrel (ethephon) on the growth, flowering and fruiting of three cucurbits. J. Hort Science 53: 1-4.

SAS Institute. 1989. SAS/STAT User's guide, Release 6.12 edition. SAS Institute Inc., Cary, NC.

Schultheis, J. R. 1990. Pickling cucumbers. North Carolina State Agr. Ext. Hort. Inform. Leaflet No. 14-A.

Shannon, S. and M. D. De La Guardia. 1969. Sex expression and the production of ethylene induced by auxin in the cucumber (*Cucumis sativus* L.). Nature 223: 186.

Shifriss, O. 1961. Sex control in cucumbers. J. Hered. 52:5.

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

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size for measurement of yield in multiple and once over harvest trials of pickling and fresh market cucumbers. Euphytica 35: 493-501.

Swallow, W. H. and T. C. Wehner. 1989. Optimum allocation of plots to years, seasons, locations, and replications, and its applications to once-over harvest cucumber trials. Euphytica 43: 59-68.

Tiedjens, V. A. 1928. Sex-ratios in cucumber flowers affected by different conditions of soil and light. J. Agr. Res. 36: 721-746.

Warner, H. L. and A. C. Leopold. 1969. Ethylene evolution from 2-chloroethylphosphonic acid. Plant Physiology 44: 156-158.

Wehner, T. C. 1986. Efficiency of 3 single-harvest tests for evaluation of yield in pickling cucumber. Euphytica 35: 493-501.

Wehner, T. C. 1987. Value of 12 season-location combinations for cucumber yield trials in North Carolina. Cucurbit Genet. Coop. Rpt. 6: 38-39.

Wehner, T. C. 1989. Breeding for improved yield in cucumber. Plant Breed. Rev. (Ed.) J. Janick. Vol. 6: 323-359.

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: 659-664.

Wehner, T. C. and C. H. Miller. 1987. Optimum plant density for multiple-harvest yield of determinate cucumbers. Cucurbit Genet. Coop. Rpt. 10: 29-30.

Yang, S. F. 1969. Ethylene evolution from 2-chloroethylnephosphonic acid. Plant Physiology 44: 1203-1204.

Table 4.1. Mean squares for traits evaluated in study.

Source of Variation	df	Gynoecious rating	Fruit number Total	Early	Marketable	Cull
Season	1	0.01	6.58*	0.33	22.30**	2.54
Rep (Season)	6	2.12	0.36	0.80	0.25	0.87
Cultigen	7	3.72*	0.92	1.07	9.50**	4.60*
Ethephon	2	4.41*	6.63*	10.14**	0.91*	2.48
Cultigen X Ethephon	14	4.95**	1.83	3.22**	0.79	1.14
Season X Ethephon	2	0.31	0.31	0.38	0.13	0.98
Cultigen X Season	6	3.66**	0.90	0.67	0.52	1.63
Cultigen X Season X Ethephon	12	0.66	1.40	0.85	0.40	1.66
Error	122	1.1	742	437	185	136

**, * significance at 1% and 5% respectively

Table 4.2. Mean squares for traits evaluated in study.

Source of Variation	df	Fruit weight Total	Early	Marketable	Fruit Cull	quality
Season	1	48.13**	1.39	30.91**	68.58**	0.01
Error A	6	0.63	0.79	0.83	0.43	2.81
Cultigen	7	2.77	1.68	18.60**	3.69*	41.62**
Ethephon	2	10.20**	5.90*	4.10*	3.11	1.36
Cultigen X Ethephon	14	1.10	3.83**	0.40	0.71	1.06
Season X Ethephon	2	1.90	0.83	0.18	1.88	0.99
Cultigen X Season	6	0.39	0.68	1.17	0.87	0.02
Cultigen X Season X Ethephon	6	1.01	0.62	0.55	1.15	0.35
Error	122	0.9	0.2	0.1	0.6	0.6

**, * significance at 1% and 5% respectively

Table 4.3. Gynoecious rating and total yield (fruit number and weight) in 1998. (fruit numbers in thousands/Ha, fruit weight in Mg/Ha)

	Gynoecious rating			Total number[Z]			Total weight[Y]		
	Ethephon			Ethephon			Ethephon		
Cultigen	0	1	2	0	1	2	0	1	2
Spring									
SR 551M	6.0	5.5	7.8	70	68	77	1.3	1.0	1.5
SR 551F	5.5	6.3	7.8	33	56	82	0.4	0.9	1.6
Tablegreen 72M	5.0	7.0	8.3	39	88	81	1.1	2.3	2.0
Tablegreen 68F	8.0	8.8	8.3	64	69	69	1.3	1.1	1.6
Marketmore 76M	5.8	5.8	6.5	45	84	75	0.8	1.8	1.4
Marketmore 80F	9.0	8.3	8.5	94	55	114	1.9	0.9	1.9
Mean	*6.4*	*6.9*	*7.8*	*56*	*70.1*	*83.2*	*1.1*	*1.3*	*1.6*
SD	*2.0*	*1.6*	*1.1*	*34*	*20*	*33.1*	*79*	*0.6*	*0.6*
CV	*31*	*24*	*14*	*6*	*29*	*40*	*1.0*	*47*	*39*
Summer									
SR 551M	5.5	3.8	7.5	57	75	119	1.4	2.4	3.2
SR 551F	5.8	6.8	7.3	30	75	83	0.8	1.8	2.3
Tablegreen 72M	4.8	6.8	8.8	50	106	119	1.8	3.3	3.3
Tablegreen 68F	6.0	7.8	8.3	.	.	.	.	.	.
Marketmore 76M	7.3	7.3	7.8	89	78	79	2.3	2.2	2.5
Marketmore 80F	9.0	8.8	8.5	69	76	94	1.5	2.3	3.0
Mean	*6.4*	*6.8*	*8.0*	*62.4*	*82.7*	*100.5*	*1.7*	*2.4*	*2.9*
SD	*1.9*	*1.7*	*0.9*	*29.5*	*26.1*	*28.6*	*0.9*	*1.0*	*1.0*
CV	*30*	*25*	*11*	*47*	*32*	*28*	*52*	*39*	*33*

Table 4.4. Marketable fruit number, marketable and cull fruit weight in 1998. (fruit numbers in thousands/Ha, fruit weight in Mg/Ha)

	Marketable number			Marketable weight			Cull weight
	Ethephon			Ethephon			Ethephon
Cultigen	0	1	2	0	1	2	Average
Spring							
SR 551M	24	15	9	0.2	0.1	0.1	0.7
SR 551F	21	24	31	0.2	0.2	0.2	0.4
Tablegreen 72M	10	9	9	0.1	0.1	0.1	0.8
Tablegreen 68F	16	27	14	0.1	0.2	0.1	0.6
Marketmore 76M	21	29	23	0.1	0.2	0.2	0.6
Marketmore 80F	47	32	36	0.2	0.3	0.3	0.7
Mean	*22*	*22.5*	*20.4*	*0.1*	*0.2*	*0.2*	0.6
SD	*20*	*14.5*	*15.6*	*0.1*	*0.1*	*0.2*	0.5
CV	*91*	*64*	*76*	*99*	*66*	*90*	75.0
Summer							
SR 551M	32	21	24	0.2	0.2	0.2	1.6
SR 551F	22	26	40	0.2	0.5	0.4	0.7
Tablegreen 72M	21	19	14	0.2	0.2	0.2	1.5
Tablegreen 68F	.	.	.	.	.	.	.
Marketmore 76M	48	34	29	0.5	0.5	0.4	1.4
Marketmore 80F	46	37	35	0.4	0.5	0.4	1.3
Mean	*35.1*	*27.5*	*27.1*	*0.3*	*0.4*	*0.3*	*1.3*
SD	*17.3*	*12.2*	*16.9*	*0.2*	*0.2*	*0.2*	0.8
CV	*49*	*44*	*63*	*58*	*48*	*53*	56.3

Table 4.5. Yield performance (Early, cull fruit number and early fruit weight) and fruit quality averaged over both seasons in1998. (fruit numbers in thousands/Ha, fruit weight in Mg/Ha)

	Early number			Early weight			Cull	Fruit
	Ethephon			Ethephon			number[z]	Quality[z]
Cultigen	0	1	2	0	1	2	Ethephon	Ethephon
SR 551M	20	35	48	0.28	0.47	0.63	22.0	4.5
SR 551F	8	33	34	0.14	0.61	0.64	7.3	6.8
Tablegreen 72M	10	61	65	0.21	1.38	1.39	21.7	5.9
Tablegreen 68F	33	23	42	0.59	0.44	0.78	15.7	4.9
Marketmore 76M	19	34	35	0.35	0.65	0.66	15.0	7.1
Marketmore 80F	16	14	53	0.38	0.28	1.04	16.7	7.1
Mean	*17*	*35*	*47*	*0.30*	*0.50*	*0.90*	16.7	*6.1*
SD	*13*	*22*	*23*	*0.20*	*0.40*	*0.50*	11.9	*1.3*
CV	*80*	*65*	*49*	*81*	*75*	*56*	71.3	*22*

[z] Average of 3 ethephon spray treatments

Chapter Five

Screening the Cucumber Germplasm Collection for Fruit Yield and Quality

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(In the format appropriate for submission to the Journal

of the American Society for Horticultural Science)

For: Crop Science

Breeding and germplasm resources

Screening the Cucumber Germplasm Collection for Fruit Yield and Quality

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Abstract

All cucumber plant introduction (PI) accessions from the USDA-ARS cucumber germplasm collection along with check cultivars (hereafter collectively referred to as cultigens) were evaluated for yield, fruit quality rating, and days to harvest in small plots harvested once at Clinton, North Carolina. All cultigens were treated with ethephon to convert them to gynoecious sex expression in order to make the evaluation more uniform for all cultigens. A total of 817 cultigens (including 7 checks) was tested in the field for total, early, and marketable yield (number and weight), fruit quality rating, and days to harvest. The crop was grown using recommended cultural practices. Highly significant differences were observed among cultigens for all traits evaluated in the study. The cultigens with the highest total yield in terms of total fruit weight among the pickling cucumber cultigens evaluated in the study were PI 209065, PI 326598, PI 137848, PI 285610, and PI 264666. Nine slicing cultigens had more total fruit weight than the standard slicing check 'Sprint 440'. Of the nine, four cultigens (PI 234517, PI 118279, PI 304085, and PI 512614) had higher yield in terms of total fruit number. There were 229 middle-eastern (Beit Alpha) cultigens that had higher yield than the check (WI 2757) used in the study. The cultigens with the highest yield (fruit weight) were PI 167050, PI 163213, PI 532519, PI 211978, PI 357864, PI 183231, and PI 211117. Cultigens with the highest fruit yield based on total fruit weight in the trellis type were PI 264228, PI 478366, PI 390262, PI 532524, PI 390267, and PI 532520. The USDA-ARS collection also exhibited a wide range in diversity for marketable fruit number, fruit weight, percentage of culled fruit at harvest, fruit quality and

days to harvest. High yielding cultigens identified in the study could be used to develop high yielding cultivars.

Cucumber (*Cucumis sativus* L.) is thought to have originated in India or China (Harlan, 1975), with domestication occurring later throughout Europe. Cucumber is a member of the Cucurbitaceae which comprises 90 genera and 750 species (Sitterly, 1972). Cucumber is thought to be one of the oldest vegetable crops, being grown for at least five thousand years. Cucumber is a thermophilic and frost-susceptible crop, growing best at temperatures above 20 C. The crop is grown throughout the world and is the fourth most important vegetable crop after tomato, cabbage, and onion (Tatlioglu, 1993).
Cucumber is grown as a number of different types, and is used as either a fresh or processed vegetable. Some of the types of cucumber grown throughout the world are American pickling, European pickling, American slicing (fresh market), European greenhouse (parthenocarpic), oriental trellis, middle-eastern (Beit Alpha), and schalgurken. The different types of cucumber differ based on the type of use (fresh market or processed), fruit length, diameter, color, color uniformity, skin thickness, and skin surface protrusions. In the United States, 17, 264 ha were planted to pickling cucumber with a total production of 615,310 Mg of fruit during 1998 (U.S. Department of Agriculture, 1998). The total area and production of slicing cucumber for 1997 was 9,760 ha with a production of 202,514 Mg (U.S. Department of Agriculture, 1998). Cucumber is the second most important vegetable crop in North Carolina after sweetpotato, with a production area of approximately 9,717 ha (U.S. Department of Agriculture, 1997). Nationally, North Carolina was ranked third in pickling cucumber production after Michigan and Florida, and fifth in slicing cucumber production after Georgia, Florida,

Michigan, and California during 1997, respectively (U.S. Department of Agriculture, 1997).

Breeding for yield in cucumber has been one of the important objectives of many cucumber breeding programs since the 1900's (Wehner, 1989). Yield of pickling cucumber has been improved by breeding for disease resistance (Peterson, 1975), as well as through improved cultural practices (Cargill et al., 1975). Increased yield of cucumber cultivars also has been due to the improvement of qualitative traits such as gynoecious sex expression, improved fruit color (improved percentage marketable fruit), and direct yield improvement (Wehner, 1989).

The USDA average yield of pickling cucumber in the United States over the last forty years (USDA Statistics 1959-1998) has increased by 100% over the last four decades due improved breeding for high yields, disease resistance, and improved cultural practices . Although there was a sharp increase in the productivity over the first two decades, there has been a plateau in the yield over the last two decades. (Fig. 1) There is a need to improve productivity further. One method is to find new sources of diverse high yielding germplasm in the cucumber germplasm and employ them in a breeding program for high yield.

We are evaluating yield in cucumber using a three-stage process: first, testing of all available plant introduction accessions, cultivars, and breeding lines (hereafter collectively referred to as cultigens) using combining ability with a gynoecious tester; second, testing of all available cultigens for yield *per se*; and third, evaluation of the best cultigens using larger trials with multiple harvests, seasons, and years.

Measurement of the yield of a large and diverse set of cucumber cultigens is costly. Previous research has provided some guidelines for the design of efficient yield trials. Fruit number was found to be a more stable measure of productivity than fruit weight or value in a once-over harvest trial for cucumber (Ells and McSay, 1981). Fruit number was more highly heritable (0.17) than fruit weight (0.02) (Smith and Lower, 1978). Single-plant evaluation of yield was poorly correlated with multiple-harvest yield in replicated field trials indicating the necessity for testing in row plots (Wehner, 1986; Wehner and Miller, 1984). In addition, greenhouse evaluation for yield based on fruit number on single plants was not correlated (r=0.09 to 0.15) with yield in two field locations (Nerson et al., 1987).

Once-over harvest trials having three replications were recommended for maximum efficiency to determine which cucumber lines should be tested further in multiple-harvest trials (Wehner and Miller, 1984; Wehner, 1986). A plot size of 1.2 x 1.5 m was found to be optimum for yield evaluation for once-over harvest of pickling cucumber cultigens harvested using paraquat (Swallow and Wehner, 1986). In cucumber, small-plot, single-harvest trials were found to be more efficient than large-plot, multiple-harvest trials (Wehner, 1986; Wehner, 1989; Wehner and Miller, 1987). Wehner et al. (1984) recommended the use of paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) to defoliate plots for efficient yield measurement in once-over harvest trials.

Swallow and Wehner (1989) suggested that maximum information (1/variance) was obtained by allocating test plots of cucumber cultigens to different seasons and years rather than locations and replications. However, use of locations and replications was found to be less expensive than seasons and years. Field evaluation at the Clinton location was more efficient than three other North Carolina locations tested (Wehner, 1987a).

Miller and Hughes (1969) reported that harvesting at 14 to 31% oversized fruit (>51 mm diameter for pickling cucumber and >60 mm diameter for fresh market cucumber) stage in a plot was found to be optimum for maximum value in once-over harvest for 'Piccadilly' and 'Southern Cross' gynoecious hybrids in North Carolina. Chen et al. (1975) used a computer simulation and reported that plots harvested at 10% oversized fruit stage gave an optimum yield for 'Piccadilly' hybrid under North Carolina conditions. Colwell and O'Sullivan (1981) reported that the optimum harvest stage to maximize yield for 'Femcap' and 'Greenstar' gynoecious hybrids occurred when 5 to 15% in a plot had oversized fruit. Studies conducted by the authors on a diverse array of pickling and slicing cucumber cultigens revealed that there was no effect on fruit yield and quality traits (with the exception of early yield of pickling type) between harvesting cucumber when fruit in a plot reached 10 or 50% oversized fruit stage (Shetty and Wehner, 2000a, 2000b).

Ethylene is a plant growth regulator associated with several developmental and physiological processes including accelerated senescence in plants, ripening of fruit, and sex expression in cucurbits (Pratt and Goeschl, 1969). The ethylene-releasing property of ethephon (2-chloroethylphosphonic acid) was first reported by Warner and Leopold (1969) and Yang (1969).

Cucumber plants produce three types of flowers: staminate, pistillate, and perfect. Exogenous application of ethylene is known to promote the production of pistillate flowers in monoecious cucumber lines, resulting in increased fruit yield (Cantliffe and Phatak, 1975; Hogue and Heeney, 1974; McMurray and Miller, 1969; Miller et al., 1970; Robinson et al., 1968; and Rudich et al., 1972).

The authors studied the role of ethephon on a diverse array of pickling and slicing cucumber lines differing in sex expression for yield (total, marketable, early, and percentage culled fruit) and fruit quality. Ethrel treatments (1 or 2 applications) significantly improved the total yield, percentage of culled fruit, and fruit quality traits evaluated in pickling cucumbers (Shetty and Wehner, 2000a). They observed higher total yields with ethephon application but did not observe an additional benefit beyond a single application at the first true leaf stage. Therefore, the authors recommended one application of ethephon as optimum to convert a diverse array of pickling cucumber cultigens for fruit yield and quality.

Ethrel also was found to have an effect on vegetative and floral traits (days to first flower set, days to 50% flower set, days to first fruit set, days to 50% fruit set, and fruit quality in a group of cucumber cultigens which differed in their sex expression. This study also concluded that one application of ethephon was optimum. The higher the number of ethephon applications usually tended to increase the number of days it took to reach the desired growth stage (days to first flower set, days to 50% flower set, days to first fruit set, and days to 50% fruit set) (Shetty and Wehner, 2000c). However, ethephon did not have an effect on fruit yield and quality traits on a set of slicing cucumber cultigens (Shetty and Wehner, 2000b).

Shetty and Wehner (2000d) reported that, when ethrel was sprayed on isogenic lines of cucumber differing in sex expression, ethephon improved gynoecious rating, fruit number (total, early, and marketable) and fruit weight (total, early, and marketable) compared to the unsprayed control. Ethephon was effective in increasing pistillate flower number on monoecious inbreds but had little effect on gynoecious inbreds.

The objective of this experiment was to evaluate all available cucumber cultigens in the USDA germplasm collection for fruit yield and quality under field conditions in North Carolina.

Materials and Methods

All experiments were conducted at the Horticultural Crops Research Station, Clinton, North Carolina during the spring and summer seasons of 1997 and 1998.

Cultural practices

Recommended horticultural practices (Schultheis, 1990) were used for all experiments. Fertilizer was incorporated before planting at a rate of 90-39-74 kg/ha (N-P-K), with an additional 34 kg/ha N applied at the vine tip-over stage. Curbit (ethalfluralin N-ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine) was applied for weed control. Irrigation was applied when needed for a total (irrigation plus rainfall) of 25 to 40 mm per week. 'Sumter' pollenizer was planted in side rows and end plots to provide additional pollen and border competition for the experimental plots.

No disease problems were observed. Each plot was harvested once-over when the plants had 15% oversized fruit. Although the usual index for yield evaluation for testing populations in our breeding program is 10%, we used a 15% index in this study to avoid penalizing low yielding or late-maturing cultigens.

Seeds were planted on raised, shaped beds in rows 1.5 m apart. Plots were 1.2 m long and 1.5 m wide with 1.2 m alleys at each end. Plots were planted with 16 seeds and thinned to a uniform stand of 12 plants per plot.

Cultigens evaluated

For this experiment, 817 cultigens have you defined cultigen were evaluated (810 plant introduction accessions and 7 check cultivars and breeding lines). Plant introduction accessions were obtained from the U.S.D.A. North Central Regional Plant Introduction Station, Ames Iowa. The cultigens originated in 50 different countries, with the majority from Turkey, People's Republic of China, former Yugoslavia, Iran, former USSR, Japan, India, and Spain (Table 5.1).

Ethephon application.

The ethephon (2-chloroethyl phosphonic acid) was applied at the first to second true leaf stage (approximately one month after planting). A Solo backpack sprayer at 100 to 140 kPa (15 to 20 psi) was used to spray the ethephon on the leaves until run-off. Ethephon was prepared using Florel [3.9% ethephon (2-chloroethyl phosphonic acid)] (Southern Agricultural Insecticides, Inc., Palmetto, FL 34220) at the rate of 2.5 ml/l for a concentration of 21%.

Traits measured

Data were collected as plot means, and consisted of number of total, early, and cull fruit per plot. Early fruit were the number of oversized fruit at harvest. The number of marketable fruit was calculated as total - cull. Percentage of culls was calculated as 100 x cull fruit number / total fruit number. Similar formulas were used to compute percentage of early (by weight and by number) fruit and percentage of marketable (by weight and by number) fruit. Fruit weight was recorded for all grades (early, marketable, cull, and total during the spring season of 1997. In all other environments, only total fruit weight was recorded. In those environments, early, marketable, and cull fruit weights were estimated using regression equations proposed using fruit numbers and fruit weights (Shetty and Wehner, 2000e).

Fruit quality was rated on a 1 to 9 scale (1-3 = poor, 4-6 = intermediate, 7-9 = excellent). Days to harvest and fruit quality rating were also recorded. All cultigens were grouped into one of four types: pickling, slicing, middle-eastern (Beit Alpha), and oriental trellis. Digital photographs of fruit of all cultigens used in the study were recorded.

Data analysis

The experiment was a randomized complete block design with 817 cultigens, two seasons (spring, summer), two years (1997, 1998), and three replications. The two years and two seasons were considered to be four environments to simplify the statistical analysis. Data were analyzed using GLM procedures of SAS 6.12 (SAS Institute, Inc., Cary, NC).

Yield was expressed as thousands of fruit/ha for fruit number, and Mg/ha for fruit weight to make comparisons with other studies easier.

Plots with a stand count (plant number) of less than 50% were eliminated from the statistical analysis, and plots with stand count ranging from 50 to 75% of proper stand (12 plants) were corrected using the formula: corrected yield = 12 x (total yield / stand), according to the method of Cramer and Wehner (1998).

Results and Discussion

Data collected in spring and summer seasons of 1997 and spring 1998 were excellent. However, poor stand establishment conditions occurred in summer 1998. Good data were obtained for 70% of the plots in one replication, and for 30% of the plots in the other two replications. Therefore, the final analysis used data from three replications in each of three environments (eliminating data for the three replications of summer 1998).

The main effect of environment was not significant for any traits except percentage marketable fruit weight (Table 5.2). There were significant differences among the 817 cultigens for fruit yield and quality, and for days to harvest. The interaction of cultigen and environment was significant for all traits, except percentage of culls. However, the effect of cultigen was much larger than that of cultigen x environment for all the traits (Table 5.2). Therefore, we presented the fruit yield and quality traits as averages over the three environments.

The 817 cultigens evaluated were grouped into four distinct categories based on the fruit type data. Fruit type was verified using digital photographs recorded for all the cultigens in the study. There were 249 pickling, 116 slicing, 265 middle-eastern (Beit Alpha types), and 187 oriental trellis cucumber cultigens (Tables 5.3, 5.4, 5.5, and 5.6).

Because some cultigens produce large numbers of fruit, but with a small fruit weight, and because breeders and growers are most interested in fruit weight, we present the data for cultigens in order by total fruit weight produced. The most interesting cultigens would be those with highest fruit weight and number within a particular fruit type. Also of interest are early and marketable fruit weight and number, percentage of culls, fruit quality rating, and days to harvest (Tables 5.3, 5.4, 5.5, and 5.6).

Total Yield:

Pickling Cucumber:

The cultigens with the highest total yield in terms of fruit weight among the pickling cucumber cultigens evaluated in the study were PI 209065, PI 326598, PI 137848, PI 285610, and PI 264666. There were 17 cultigens that produced higher total fruit weight than the check cultivar Calypso. In general, all 17 cultigens identified had higher or similar early and marketable fruit weight and number than 'Calypso'. However, fruit quality ratings were lower for the 17 cultigens. The number of days to harvest for the 17 cultigens was in general also greater than 'Calypso'. The lowest yielding cultigens in the study were PI 179921, PI 163222, PI 222986, PI 164465, and PI 481612. The five also had low fruit quality rating and high number of days to harvest (Table 5.3).

47 cultigens produced higher total fruit number than the highest yielding check 'Calypso' (pickling type). The cultigens with the highest fruit number were PI 215589, PI 344440, PI 356809, PI 370643, PI 249561, PI 209065, PI 288992, PI 179678, PI 531314, and PI 422191. PI 215589 produced a total of 267,000 fruit/ha, compared to 'Calypso', with 105,000 fruit/ha. PI 209065 (USA OH) and PI 531314 (Hungary) were the only two cultigens with both a higher fruit number and fruit weight than 'Calypso' (Table 5.3).

Slicing Cucumber:

Nine cultigens had more fruit weight than the high slicing check 'Sprint 440'. Four cultigens also had higher total fruit number than the check: PI 234517, PI 118279, PI 304085, and PI 512614. The nine cultigens were similar for early, marketable, and cull fruit weight. However, PI 118279 (Brazil) had a high number of total, early, and marketable fruit but fruit weight similar to the other eight PI accessions identified. Thus, PI 118279 had smaller fruit than the rest. The nine cultigens identified were similar for days to harvest with the exception of PI 304805 and PI 368560, which took 8 days longer. The fruit quality ratings for the nine cultigens were lower than the checks, 'Sprint 440' and 'Dasher II'.

Of the check cultivars, Sprint 440 and Dasher II had similar fruit yield, quality rating, and days to harvest. 'Sprint 440' and 'Dasher II' had the highest yields in terms of total fruit weight followed by the remaining two slicing checks used in the study 'Poinsett 76' and 'Marketmore 76' (Table 5.4).

There were 16 cultigens with a higher number of total fruit than the check cultivar, Sprint 440. However, only three cultigens (PI 118279, PI 304805, PI 561145) had higher total fruit number than 'Poinsett 76', and only five cultigens (PI 118279, PI 304805, PI 561145, PI 234517, PI 512614) were higher than 'Dasher II'. Cultigens with both high fruit weight and number were PI 118279 (Brazil), PI 234517 (USA SC), PI 304805 (USA NY), and PI 512614 (Spain). The four cultigens produced higher total, early, and marketable fruit weight and number than the check cultivars of the same type. Their percentage of cull fruit weight was higher than 'Sprint 440', but their percentage of cull fruit number was lower. Fruit quality ratings were lower than the check, and PI 234517 had the best fruit quality rating of the four. The four PI accessions had similar days to harvest. However, PI 304805 took 8 days longer than the check (Table 5.4).

Middle-Eastern (Beit Alpha) Cucumber:

WI 2757 was included as a late low yielding gynoecious inbred check. A total of 229 middle-eastern (Beit Alpha) cultigens produced higher total fruit weight than the check, WI 2757, while 32 cultigens produced higher fruit weight than the standard pickling cucumber check, 'Calypso'. The cultigens with the highest total fruit weight were PI 167050, PI 163213, PI 532519, PI 211978, PI 357864, PI 183231, and PI 211117. Nine cultigens had twice the total fruit weight of WI 2757. There were 97 cultigens with a higher fruit number than WI 2757, while 25 cultigens produced higher fruits than 'Calypso' (Table 5.5). Cultigens with highest total fruit number were PI 175693, PI 532519, PI 292010, PI 176956, PI 171601, PI 181910, PI 293923, PI 175690, PI 535881, and PI 525152. The cultigens which were ranked in the top 10% for both total fruit number and total fruit weight were PI 137856, PI 169391, PI 171601, PI 175693, PI 181755, PI 292010, PI 525152, PI 532519, PI 534540, PI 534543, and PI 535881 (Table 5.5).

Trellis Cucumber:

Cultigens with the highest total fruit weight of the trellis type were PI 264228, PI 478366, PI 390262, PI 532524, PI 390267, and PI 532520. Cultigens with high total fruit number were PI 432849, PI 264228, PI 275411, PI 532520, PI 390262, PI 489754, PI 518854, PI 478364, PI 478366, and PI 532523. Eight cultigens (PI 263085, PI 264228, PI 275411, PI 390262, PI 390267, PI 478366, PI 511820, and PI 532520) were in both lists for top 10% for fruit weight and number. (Table 5.6)

Early Yield:

Pickling Cucumber:

Pickling cultigens with the highest early fruit weight were PI 209065, PI 285610, PI 175111, PI 137848, PI 264666, PI 269481, PI 306180, PI 370019, PI 482463, PI 211728, and PI 163216. All produced more than 20 Mg/ha. Twenty-one cultigens had higher early yield than the cultivar with the highest early yield, 'Calypso'. A total of 68 cultigens had a higher percentage of early yield (by weight) than the best check cultivar, 'Sumter'. Pickling PI accessions with the highest early percentage weights were PI

211728, PI 512336, PI 175121, PI 500359, PI 344432, PI 370447, PI 163218, PI 163216, PI 212896, and PI 512607 (data not presented). Cultigens with high early fruit weight and high percentage early (by weight) compared to the best checks were PI 174160, PI 175111, PI 175121, PI 209065, PI 269481, PI 285610, PI 344432, and PI 370019. Thirty PI accessions had higher early yields (by number), and 111 PI accessions had higher percentage early fruit number than the best check, 'Calypso'. PI accessions with the highest early yields (by number) were PI 209065, PI 422191, PI 531314, PI 169397, PI 215589, PI 379278, and PI 269480. All had greater than 66 thousand fruit/ha. Cultigens with the highest percentage of early fruit were PI 500359, PI 222986, PI 370447, PI 175120, PI 175121, PI 217946, PI 512607, and PI 221440. All had over 70% of yield in numbers as early yield (data not presented). Cultigens with both high early fruit yield and percentage early fruit number compared to the checks were PI 169397, PI 209065, PI 212985, PI 263047, PI 263079, PI 269480, PI 269481, PI 326597, PI 330628, PI 370019, PI 379278, PI 390954, PI 422191, PI 458855, PI 458856, PI 504567, and PI 512620. PI 269481 was the only cultigen which had high early yield (number and weight) and had high percentage of early yield (number and weight). (Table 5.3)

Slicing Cucumber:

Seven cultigens produced higher early yield by fruit weight (PI 234517, PI 118279, PI 368560, PI 173893, PI 165499, PI 512614, and PI 512615) and by fruit number (PI 118279, PI 234517, PI 173893, PI 288996, PI 390259, PI 512614, and PI 561148) than the best check, 'Dasher II'. Forty PI accessions had a higher percentage early yield (by weight) than the best check, 'Dasher II'. Cultigens with the highest early yield were PI 338234, PI 368551, PI 368559, PI 173893, PI 368560, PI 379283, PI 250147, PI 357860, PI 561144, PI 267745, and PI 391570. Cultigens with both high early yield and high percentage early yield were PI 173893 and PI 288996. Thirteen cultigens had a higher percentage of early yield (by number) compared to the highest yielding check 'Sprint 440'. PI 118279 was the only cultigen with a high early fruit yield and percentage of early fruit compared to the high check. (Table 5.4)

Middle-Eastern (Beit Alpha) Cucumber:

There were 164 cultigens with higher early yield and percentage early yields (by weight) compared to the check WI 2757, while 32 cultigens were higher in early yield compared to the standard pickling check, 'Calypso'. Cultigens with the highest early yield and percentage early yield were PI 357849, PI 512628, PI 379287, PI 169384, PI 344433, PI 211589, PI 182188, PI 172852, PI 357859, and PI 357834. Of the cultigens with high early yield, 147 had higher early yield (by number) than the check, while 225 had a higher percentage of early yield than the high check. PI 172852 was the only cultigen common to both groups. (Table 5.5)

Trellis Cucumber:

Cultigens of the trellis type that had high early yield (by weight) and percentage early yield were PI 357837, PI 418963, PI 422167, and PI 432889. Cultigens with high early yield and percentage early yield (by number) were PI 192940, PI 193497, PI 212233, PI 264228, PI 275412, PI 432851, and PI 432889. (Table 5.6)

Marketable Yield:

Pickling Cucumber:

There were 21 pickling cultigens with marketable yields (by weight) higher than the best check, 'Calypso'. Cultigens with greater than 5 Mg/ha were PI 326598, PI 197087, PI 478367, PI 206043, PI 326596, PI 512597, PI 531312, PI 169397, PI 379278, PI 209065, PI 531309, PI 271753, and PI 531314. There were 88 cultigens with a higher percentage of marketable fruit (by weight) than the best check, 'Calypso'. Cultigens with both high marketable weight and high percentage marketable weight were PI 197087, PI 206043,

PI 271753, PI 326596, PI 326598, PI 379278, PI 478367, PI 512597, PI 531309, and PI 531312. (Table 5.3)

There were 72 and 101 cultigens with higher early yield (by number) and higher percentage early fruit number than the best check, 'Calypso' (33 thousand fruit/ha), respectively. Cultigens with high marketable fruit number were PI 215589, PI 179678, PI 288992, PI 249561, PI 267087, PI 356809, PI 205995, PI 344440, PI 292012, PI 390953 (all greater than 53 thousand fruit/ha) (data not presented). Those with high percentage marketable fruit (by number) were PI 179678, PI 215589, PI 200815, PI 164734, PI 532162, PI 288992, PI 135122, PI 267087, PI 264226, and PI 482463 (all greater than 50%) (data not presented). Pickling cultigens ranked in the top 10% category for high marketable fruit number and percentage of marketable fruit were PI 179678, PI 215589, PI 267087, and PI 288992. (Table 5.3)

Slicing Cucumber:

Eighteen cultigens produced higher marketable yields (by weight) while 11 cultigens had a higher percentage of marketable fruit yield compared to the best performing slicing cucumber check, 'Poinsett 76'. Cultigens with both high marketable yield and high percentage marketable yield compared to the checks were PI 304805, PI 369717, PI 390244, PI 504815, and PI 512598. Five cultigens (PI 504816, PI 401732, PI 304805, PI 432864, and PI 118279) had high marketable yield (by number) compared to the best check, 'Sprint 440'. Eleven cultigens (PI 481616, PI 504816, PI 432864, PI 390244, PI 401732, PI 525075, PI 561146, PI 390260, PI 512633, PI 344347, and PI 512639) had a higher percentage of marketable yield compared to high check, 'Poinsett 76' (data not presented). PI 401732, PI 432864, and PI 504816 had both high marketable yield and high percentage marketable yield compared to the best checks. (Table 5.4)

Middle-Eastern (Beit Alpha) Cucumber:

A total of 164 middle-eastern PI accessions had a higher marketable yield (weight) than the best check. Cultigens in the top 10% category that had greater than 6 Mg/ha marketable yield were PI 171601, PI 176924, PI 534543, PI 163213, PI 211117, PI 176951, PI 175693, PI 169380, and PI 344437. There were 72 cultigens with a higher percentage of marketable fruit (by weight) than the best check. Cultigens with the best performance for percentage marketable fruit weight were PI 172844, PI 176924, PI 174173, PI 357843, PI 176522, and 176951 (data not presented). PI 171601, PI 176924, PI 176951, and PI 357843 were in the top 10% group for both high marketable weight and high percentage marketable fruit (by weight). (Table 5.5)

There were 87 cultigens with a higher marketable yield (by number) than the check, WI 2757, while 76 cultigens had a high percentage of marketable fruit (by number). Cultigens in the top category for marketable yield and, which produced greater than 50,000 marketable fruit/ha, were PI 534543, PI 293923, PI 181910, PI 292010, and PI 171601. Cultigens in the top 10% for percentage of marketable fruit (by number) were PI 171604, PI 357843, PI 176924, PI 169385, PI 169380, PI 357854, and PI 169383. (Table 5.5)

Trellis Cucumber:

Cultigens with the highest yields for marketable fruit weight were PI 478366, PI 264228, PI 532524, PI 518851, PI 390262, PI 390267, PI 422167, PI 275411, PI 419182, and PI 419010 (all greater than 20 Mg/ha). PI accessions of the trellis type with high percentage of marketable fruit (by weight) were PI 192940, PI 357841, PI 390263, PI 368554, PI 267742, PI 470254, PI 357837, PI 418963, and PI 193497 (data not presented). PI accessions ranked in the top 10% for marketable fruit weight and percentage of marketable fruit were PI 264228, PI 357837, PI 422167, PI 432889, and PI 518851. PI accessions with high marketable fruit number were PI 264228, PI 275411, PI 511820, PI 518851, PI 390267, and PI 478366 (all greater than 40,000 fruit/ha). PI 368554 from Yugoslavia had 100% marketable fruit in all replications of all environments in the study. Cultigens that ranked in the top category for both marketable fruit number and percentage of marketable fruit (by number) were PI 192940, PI 193497, PI 212233, PI 264228, PI 275412, PI 432851, and PI 432889. PI 264228 and PI 432889 were in the top group for marketable fruit (number and weight) and percentage of marketable fruit (number and weight). (Table 5.6)

Cull yield:

Pickling Cucumber:

A total of 100 pickling PI accessions had a lower percentage of culled fruit (by weight) than the best check 'Calypso'. 'Calypso' had fewer culls than the other pickling check, 'Sumter', for total cull fruit weight but had the same percentage of culls (by number). There were 114 cultigens with a lower percentage of culled fruit than 'Calypso'. Cultigens which ranked in the top 10% for number and weight of culls were PI 135122, PI 175121, PI 283902, PI 289698, PI 370447, PI 504570, PI 512634, PI 512637, PI 512640, and PI 532162. (Table 5.3)

Slicing Cucumber:

Of the four slicing cultigens used as a check in the study, 'Marketmore 76' had the lowest percentage of cull fruit (by weight) followed by 'Sprint 440', 'Poinsett 76', and 'Dasher II'. Two cultigens (PI 338234 and PI 481616) had a lower percentage of culled fruit (by weight) than 'Marketmore 76'. The check cultigens with the lowest percentage culled fruit (by number) were 'Marketmore 76', 'Sprint 440', 'Dasher II', and 'Poinsett 76'. Eight cultigens (PI 390238, PI 481614, PI 250147, PI 379280, PI 368560, PI 512625, PI 338234, and PI 481616) had a lower percentage of culls (by number) than 'Marketmore 76'. (Table 5.4)

Middle-Eastern (Beit Alpha) Cucumber:

There were 214 and 89 cultigens, respectively, having a lower percentage of culls (by weight and number) than the check WI 2757. The PI accessions which were in the top 10% for lowest percentage of culled fruit (by weight and number) were PI 169385, PI 172852, PI 176924, PI 222243, PI 357843, PI 357849, and PI 512628. (Table 5.5)

Trellis Cucumber:

PI accessions with the lowest percentage of culls in the trellis type (by weight and number) were PI 192940, PI 212233, PI 255938, PI 357830, PI 368554, and PI 368555 (Table 5.6).

Fruit Quality:

In general, the PI accessions evaluated had poor fruit quality ratings compared to the standard checks used in the study. Four pickling cultigens had similar or better ratings for fruit quality: PI 422180, PI 422182, PI 506461, and PI 435947 (Table 5.3). The four slicing cucumber checks had the highest fruit quality ratings. PI 306785 from Canada was the only PI which had a similar fruit quality rating to the checks. Slicer cultigens which ranked just below the checks for fruit quality were PI 561148, PI 561145, PI 512633, PI 422192, PI 451976, and PI 406473 (Table 5.4).

There were 30 PI accessions with fruit quality ratings better than WI 2757, the middle-eastern (Beit Alpha) check. Some of the PI accessions with high fruit quality ratings were PI 535881, PI 532519, PI 525153, PI 534539, PI 534541, PI 525154, PI 422197, PI 292010, PI 525155, and PI 525165 (Table 5.5). Cultigens with the highest fruit quality ratings among the trellis type of cultigens were PI 422184, PI 255935, PI 285608, PI

422167, PI 372893, PI 356833, PI 511821, PI 255933, PI 390262, PI 508460, and PI 275410 (Table 5.6).

Days to Harvest:

There were 36 cultigens that required fewer days to harvest than 'Calypso'. The best one (PI 343452) was four days earlier than 'Calypso'. The latest one (PI 512336) required 28 days more than 'Calypso' to harvest. The earliest cultigens were PI 205995, PI 271334, PI 164816, PI 531309, PI 342950, PI 257486, PI 351139, PI 164819, PI 264226, PI 267746, PI 137848, and PI 343452 (Table 5.3). PI 176519 was the only slicing cultigen that harvested as early (55 days) as 'Marketmore 76', the earliest slicer check. The latest cultigen was PI 481616, which took 81 days to harvest (Table 5.4). There were 222 PI accessions with earlier yield than WI 2757, which took 64 days to harvest. The earliest middle-eastern (Beit Alpha) cultigen took 52 days to harvest. Some of the other cultigens which took fewer days to harvest were PI 226509, PI 175694, PI 174177, PI 344439, and PI 211975, which all took between 52 and 54 days to harvest. PI 357853 took the longest to produce fruit (77 days) (Table 5.5). The earliest of the trellis cultigens were PI 263081, PI 419183, PI 518854, PI 432849, PI 267742, and PI 275411 (Table 5.6).

Conclusions:

The USDA cucumber germplasm collection was screened for fruit yield, earliness, and quality. Digital photographs of the germplasm collection for fruits have been recorded. Several high yielding cultigens have been identified in each of the four cucumber types. The cultigens outyielded the check cultivars in the study. The high yielding cultigens evaluated in the study should be tested in multiple-harvest trials to evaluate their performance further. High yielding cultigens identified could be used to develop breeding populations of each of the four cucumber types. These populations could be improved using recurrent selection and used in cultivar development. Finally, high-yielding cultigens with poor qualitative traits (some aspects of fruit quality) could be improved using backcross breeding.

Literature Cited

Cantliffe, D. J. and S. C. Phatak. 1975. Use of ethephon and chlorflurenol in a once-over pickling cucumber production system. J. Amer. Soc. Hort. Sci. 100: 264-267.

Cargill, B. F., D. E. Marshall and J. H. Levin. 1975. Harvesting cucumbers mechanically. Mich. State Univ. Ext. Bull. 859.

Chen, L. H., C. H. Miller and R. S. Sowell. 1975. Simulation models for harvesting of pickling cucumbers. J. Amer. Soc. Hort. Sci. 100: 176-179.

Colwell, H. T. M. and J. O'Sullivan. 1981. Economics of harvest timing for once over harvesting of cucumbers. J. Amer. Soc. Hort. Sci. 106: 163-167.

Cramer, C. S. and T. C. Wehner. 1998. Stand correction methods for cucumber fruit yield. Cucurbit Genet. Coop. Rpt. 21: 18-20.

Ells, J. E. and A. E. McSay. 1981. Yield comparisons of pickling cucumber cultivar trials for once-over harvesting. HortScience 16: 187-189.

Harlan, J. R. 1975. Crops and Man. Amer. Soc. Agron., Madison, WI.

Hogue, E. J. and H. B. Heeney. 1974. Ethephon and high density plantings increase yield of pickling cucumbers. HortScience 9: 72-74.

McMurray, A. L. and C. H. Miller. 1968. Cucumber sex expression modified by 2-chloroethanephosphonic acid. Science 162: 1396-1397.

Miller, C. H. and G. R. Hughes. 1969. Harvest indices for pickling cucumbers in once-over harvest systems. J. Amer. Soc. Hort. Sci. 94: 485-487.

Miller, C. H., R. L. Lower and H. P. Fleming. 1970. Evaluation of pickles from cucumber plants treated with 2-chloroethylphosphonic acid. HortScience 5: 434-435.

Nerson, H., H. S. Paris, Z. Karchi, A. Govers, M. Edelstein and Y. Burger. 1987. Comparison of fruit-set concentration of pickling cucumbers under greenhouse and field conditions. Cucurbit Genet. Coop. Rpt. 10: 2-3.

Peterson, C. E. 1975. Plant introductions in the improvement of vegetable cultivars. HortScience 10: 575-579.

Pratt, H. K. and J. D. Goeschl. 1969. Physiological roles of ethylene in plants. Annual Review of Plant Physiology 20: 541-584.

Robinson, R. W., S. Shannon, and M. D. de la Guardia. 1968. Regulation of sex expression in the cucumber. BioScience 19: 141-142.

Rudich, J., A. H. Halevy, and N. Kedar. 1972. The levels of phytohormones in monoecious and gynoecious cucumbers as affected by photoperiod and ethephon. Plant Physiol. 50: 585-590.

SAS Institute. 1989. SAS/STAT User's guide, Release 6.12 edition. SAS Institute Inc., Cary, NC.

Schultheis, J. R. 1990. Pickling cucumbers. N.C. State Ag. Extension. Horticulture Information Leaflet No. 14-A.

Shetty, N. V. and T. C. Wehner. 2000a. Effect of Ethrel and Harvest on Pickling Cucumber Yield and Quality. Crop Science (in review)

Shetty, N. V. and T. C. Wehner. 2000b. Effect of Ethrel and Harvest on Slicing Cucumber Yield and Quality. HortScience (in review)

Shetty, N. V. and T. C. Wehner. 2000c. Effects of ethrel on vegetative and floral traits in cucumbers. Euphytica (in review)

Shetty, N. V. and T. C. Wehner. 2000d. Effect of Ethrel on Isogenic lines of Cucumber for Gynoecious Sex Expression. Scientia Horticulturae (in review)

Shetty, N. V. and T. C. Wehner. 2000e. Efficient Estimation of Fruit Grade Weights Based on Fruit Number and Total Fruit Weight in Cucumber. HortScience (in review).

Sitterly, W. R. 1972. Breeding for disease resistance in cucurbits. Ann. Rev. Phytopathology 10: 471.

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

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size for measurement of yield in multiple and once over harvest trials of pickling and fresh market cucumbers. Euphytica 35: 493-501.

Swallow, W. H. and T. C. Wehner. 1989. Optimum allocation of plots to years, seasons, locations, and replications, and its applications to once-over harvest cucumber trials. Euphytica 43: 59-68.

Tatlioglu, T. 1993. Cucumbers. In: Genetic Improvement of vegetable crops. (Ed.) G. Kalloo and B.O. Bergh. Pergamon Press.

U. S. Department of Agriculture. 1959-98. Agricultural statistics. U. S. Government Printing Office, Washington D. C.

Warner, H. L. and A. C. Leopold. 1969. Ethylene evolution from 2-chloroethylphosphonic acid. Plant Physiology 44: 156-158.

Wehner, T. C. 1986. Efficiency of 3 single-harvest tests for evaluation of yield in pickling cucumber. Euphytica 35: 493-501.

Wehner, T. C. 1987a. Value of 12 season-location combinations for cucumber yield trials in North Carolina. Cucurbit Genet. Coop. Rpt. 6: 38-39.

Wehner, T. C. 1987b. Genotype-environment interaction for cucumber yield in 23 North Carolina environments. Cucurbit Genet. Coop. Rpt. 10: 25-26.

Wehner, T. C. 1989. Breeding for improved yield in cucumber. Plant Breed. Rev. (Ed.) J. Janick. Vol. 6: 323-359.

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: 659-664.

Wehner, T. C. and C. H. Miller. 1987. Optimum plant density for multiple-harvest yield of determinate cucumbers. Cucurbit Genet. Coop. Rpt. 10: 29-30.

Wehner, T. C., T. J. Monaco and A. R. Bonanno. 1984. Chemical defoliation of cucumber vines for simulation of once-over harvest in small-plot yield trials. HortScience 19: 671-673.

Yang, S. F. 1969. Ethylene evolution from 2-chloroethylnephosphonic acid. Plant Physiology 44: 1203-1204.

Table 5.1. Seed source for the 817 cucumber cultigens tested for fruit yield.

Seed source	Number of cultigens	Seed source	Number of cultigens
Afghanistan	15	Lebanon	4
Australia	1	Malaysia	2
Bhutan	3	Mauritius	1
Brazil	2	New Zealand	2
Burma	2	Netherlands	15
Canada	3	Oman	3
Former Czechoslovakia	29	Pakistan	7
Denmark	3	Philippines	3
Egypt	19	Poland	13
Ethiopia	2	P.R. China	111
France	6	Puerto Rico	3
Georgia	1	Spain	43
Germany	4	Sweden	4
Great Britain	2	Syria	11
Greece	1	Taiwan	10
Hong Kong	2	Thailand	2
Hungary	21	Turkey	149
India	45	Ukraine	3
Indonesia	1	USA	19
Iran	59	USSR	49
Iraq	1	Uzbekistan	4
Israel	6	Former Yugoslavia	62
Italy	3	Zambia	1
Japan.	47	Zimbabwe	2
Kenya	2		
Korea	17	Cultivars (Checks)	7

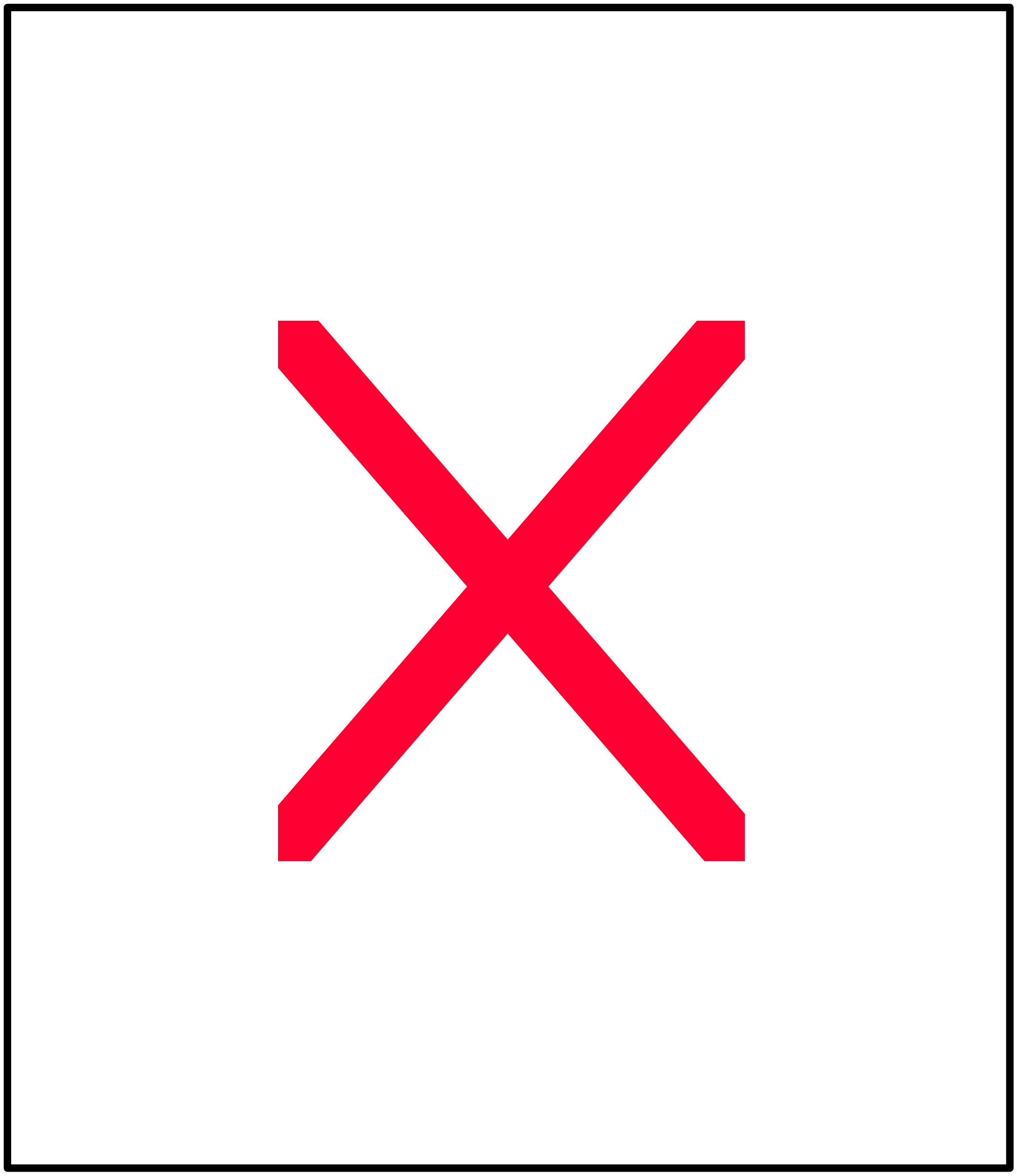

Figure 5.1. Average yields of pickling cucumber in the US from 1959 to 1998 (yield in tons/ac). (USDA Statistics 1959-1998)

Table 5.2. Mean Squares of traits evaluated in study.

Source of variation	df	Number			Percent Number			
		Total	Early	Marketable	Early	Marketable	Cull	Quality
Environment	2	1.28	1.6	1.5	1.00	1.1	0.2	2.3
Rep (Environment)	6	152	45.6	117	31	34	42	140
Cultigens	817	5.5**	2.9**	3.5**	2.1**	1.7**	2.1**	8.6**
Cultigen X Environment	1521	1.3**	1.2**	1.3**	1.2**	1.2**	1.2**	1.3**

**, * significance at 1% and 5% respectively

Table 5.2 continued.

Source of variation	df	Weight			Percent Weight			
		Total	Early	Marketable	Early	Marketable	Cull	Harvest date
Environment	2	0.8	0.8	2.1	3.8	56.2**	3.5	2.2
Rep (Environment)	6	147	132	52	50	7	76	1115
Cultigens	817	2.3**	1.9**	1.7**	3.1**	1.6**	3.02**	8.7**
Cultigen X Environment	1521	1.3**	1.3**	1.1**	1.31**	1.2**	1.03	1.4**

**, * significance at 1% and 5% respectively

Table 5.3. Yield, quality and harvest traits for 249 pickling cucumber cultigens evaluated during 1997-98 at Clinton, NC. (weight in Mg/ha; number in '000 fruit/ha)

		Total		Early		Marketable		% Cull		Qua-	Hvst
Cultigen	Source	wt	no.	wt	no.	wt	no.	wt	no.	lity	date
PI 209065	USA OH	33	146	24	92	5	19	6	20	5.7	57
PI 326598	Hungary	30	92	16	52	1	31	5	10	6.8	64
PI 137848	Iran	30	123	22	65	5	36	7	20	5.0	52
PI 285610	Poland	29	80	23	48	5	21	4	17	5.9	61
PI 264666	Germany	29	84	21	45	5	18	9	25	5.9	58
PI 175111	India	28	73	22	40	4	19	5	19	3.8	55
PI 169397	Turkey	28	116	20	69	6	27	7	16	5.4	55
PI 306180	Poland	28	85	21	44	5	24	7	19	5.7	61
PI 379278	Yugoslavia	27	104	20	67	6	28	7	11	5.4	59
PI 426169	Philippines	27	89	20	50	5	18	8	22	4.7	56
PI 370019	India	26	99	20	65	4	16	8	19	3.1	56
PI 531314	Hungary	26	135	18	72	5	35	13	22	5.3	58
PI 269481	Pakistan	26	99	21	66	3	20	6	15	2.9	58
PI 326597	Hungary	26	102	19	58	4	25	10	18	7.1	63
PI 174160	Turkey	26	73	20	39	5	22	4	18	6.0	60
Calypso	USA	26	105	18	55	5	33	7	16	7.4	55
PI 264665	Germany	25	75	19	50	4	9	8	22	6.0	59
PI 206043	USA PR	25	105	17	39	7	50	5	14	6.9	63
PI 379285	Yugoslavia	25	81	19	40	4	17	9	28	5.1	60
PI 163216	India	25	50	20	31	3	8	4	19	5.0	78
PI 482463	Zimbabwe	25	21	20	11	4	10	3	0	6.0	73
PI 326596	Hungary	25	117	16	50	6	45	5	16	6.5	57
PI 504567	USSR	24	109	18	63	4	27	6	15	6.4	58
PI 176517	Turkey	24	106	17	52	4	36	8	17	5.0	57
PI 326595	Hungary	24	110	17	50	5	41	8	19	6.2	58
PI 285604	Poland	24	78	18	47	3	15	8	20	5.5	57

Table 5.3. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 458855	USSR	24	83	17	56	4	15	9	16	3.3	61
PI 422169	Czech Rep.	23	70	18	35	4	24	6	16	5.8	60
PI 267746	India	23	81	17	47	4	22	6	15	4.3	52
PI 271328	India	23	110	17	57	4	44	7	10	3.1	59
PI 344432	Iran	23	90	19	48	3	27	5	17	3.1	61
PI 271753	Netherlands	23	118	14	51	5	42	17	23	5.5	59
PI 422172	Czech Rep.	23	117	16	60	4	40	9	18	6.1	58
PI 422198	Czech Rep.	23	99	16	53	5	30	9	19	5.1	57
PI 164819	India	23	104	16	55	4	29	6	16	3.5	53
PI 211728	Afghanistan	22	61	20	38	1	7	3	24	4.3	61
PI 175121	India	22	45	19	35	3	10	4	0	4.2	60
PI 324239	Sweden	22	102	16	49	4	36	8	18	5.3	59
PI 271334	India	22	90	16	51	4	21	10	23	3.4	54
PI 422168	Czech Rep.	22	122	15	60	4	34	12	23	5.8	56
PI 343451	USSR	22	90	16	53	4	9	9	26	5.5	57
PI 164816	India	22	113	15	47	5	38	10	24	4.0	54
PI 288993	Hungary	22	69	17	41	3	12	7	25	5.6	63
PI 269482	Pakistan	22	84	16	47	3	23	9	19	3.7	61
PI 507874	Hungary	22	93	15	41	5	31	8	21	5.6	57
PI 269480	Pakistan	21	108	16	66	3	32	8	12	2.6	58
PI 197087	India	21	62	13	31	8	28	6	6	5.1	70
PI 289698	Australia	21	99	17	52	3	38	5	8	2.9	69
PI 212985	India	21	107	16	64	4	21	11	23	3.8	55
PI 531309	Hungary	21	115	13	39	5	41	10	33	6.6	54
PI 285603	Poland	21	82	15	37	4	22	12	29	5.1	57
PI 357846	Yugoslavia	21	77	15	42	4	23	7	16	5.0	58

Table 5.3. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Qua-lity	Hvst date
PI 288994	Hungary	21	98	15	45	4	38	8	18	5.4	58
PI 458856	USSR	21	94	16	55	3	19	10	21	3.4	60
PI 422183	Czech Rep.	21	114	14	45	5	52	6	13	6.0	60
PI 512620	Spain	21	89	16	58	3	18	5	15	5.4	59
PI 288990	Hungary	21	67	16	37	3	21	6	11	7.0	67
PI 178886	Turkey	21	108	15	56	3	28	11	22	5.6	54
PI 175691	Turkey	21	83	15	41	3	18	10	29	4.6	59
PI 342951	Denmark	21	111	14	47	4	46	12	17	5.4	54
PI 466922	USSR	21	123	14	48	4	31	10	33	4.4	54
PI 531312	Hungary	21	118	12	44	6	38	13	31	5.6	59
PI 288991	Hungary	20	92	14	41	4	33	10	20	4.6	58
PI 390953	USSR	20	120	14	56	5	53	8	10	4.0	62
PI 264668	Germany	20	109	13	35	5	43	12	24	5.2	55
PI 504573	India	20	63	14	33	5	27	5	20	4.0	69
PI 435946	USSR	20	112	14	48	5	52	5	10	5.5	57
PI 183056	India	20	47	16	29	1	8	14	21	5.3	76
PI 422171	Czech Rep.	20	111	14	45	4	35	14	29	5.0	57
PI 229808	Canada	20	65	16	36	2	18	7	17	5.6	60
PI 478367	PR China	20	77	12	29	7	35	12	28	4.4	64
PI 177359	Turkey	20	100	15	47	3	33	7	16	5.7	57
PI 263079	USSR	20	93	14	61	4	20	6	12	6.0	56
PI 512600	Spain	20	103	14	41	4	39	9	25	5.4	56
PI 257486	PR China	20	87	15	49	3	25	7	15	4.1	54
PI 512596	Spain	20	90	13	33	4	41	9	19	5.1	60
PI 506461	Ukraine	20	102	13	46	5	48	5	8	7.6	60
PI 212896	India	20	70	16	48	2	15	6	11	4.1	64
PI 326594	Hungary	19	78	15	42	2	22	10	14	6.4	57
PI 422182	Czech Rep.	19	88	14	51	4	25	9	13	7.7	56

Table 5.3. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
Sumter	USA	19	98	15	47	3	28	7	21	7.2	58
PI 506462	Ukraine	19	80	13	51	4	19	6	12	4.6	56
PI 504566	USSR	19	86	13	38	3	33	11	19	5.1	58
PI 209066	USA OH	20	70	15	41	4	22	4	13	5.5	65
PI 262990	Netherlands	19	89	14	43	4	32	8	16	5.2	63
PI 390954	USSR	19	88	14	55	3	15	11	22	4.3	54
PI 422180	Czech Rep.	19	85	13	40	4	37	6	8	7.8	57
PI 267086	USSR	19	82	13	48	5	24	6	11	6.6	57
PI 458846	USSR	19	80	14	51	3	16	7	19	3.8	60
PI 531313	Hungary	19	99	13	38	3	30	15	32	5.4	61
PI 422190	Czech Rep.	19	92	14	47	3	26	9	21	5.4	57
PI 531308	Hungary	19	92	13	37	3	36	12	22	5.0	59
PI 512599	Spain	19	72	14	37	3	20	11	20	4.9	57
PI 211984	Iran	19	49	14	29	3	13	4	17	3.9	61
PI 172842	Turkey	19	60	14	34	3	16	5	15	4.9	57
PI 401734	Puerto Rico	19	92	12	35	5	41	10	18	6.0	63
PI 209064	USA OH	19	74	14	40	3	20	7	19	5.6	58
PI 531310	Hungary	19	95	13	47	3	22	8	28	5.3	61
PI 264227	France	19	78	13	33	4	23	8	28	5.6	60
PI 368558	Yugoslavia	19	91	14	45	3	33	10	15	5.6	56
PI 263078	USSR	19	83	14	42	4	31	7	15	3.3	58
PI 193496	Ethiopia	18	84	14	49	3	23	7	14	5.4	58
PI 263047	USSR	18	116	14	65	3	39	5	13	4.5	58
PI 264667	Germany	18	98	13	50	4	28	9	19	5.1	56
PI 330628	Pakistan	18	97	13	60	4	27	6	11	1.9	62
PI 532161	Oman	18	108	13	43	3	32	6	30	4.0	66
PI 263080	USSR	18	99	12	46	4	35	9	14	3.9	54
PI 435947	USSR	18	107	13	49	3	44	5	10	7.4	58

Table 5.3. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 422218	Israel	18	102	12	36	3	34	12	29	5.9	58
PI 204690	Turkey	18	91	13	45	3	26	7	22	5.0	58
PI 283899	Czech Rep.	18	72	13	41	3	21	5	14	5.3	57
PI 283900	Czech Rep.	18	78	13	44	3	19	9	16	4.3	58
PI 390951	Georgia	18	72	14	41	2	20	9	16	4.9	57
PI 392292	USSR	18	94	12	32	4	43	6	20	6.1	57
PI 458853	USSR	18	69	13	40	4	22	7	10	4.0	62
PI 204567	Turkey	18	93	13	51	3	22	12	21	5.6	55
PI 206953	Turkey	18	54	13	26	3	14	7	26	4.7	66
PI 504571	USA	18	91	12	50	4	20	8	25	5.1	56
PI 422174	Czech Rep.	18	102	12	32	4	44	10	28	5.3	59
PI 512603	Spain	18	89	13	51	3	20	10	21	5.3	55
PI 422185	Netherlands	18	100	13	34	3	43	8	22	5.8	59
PI 512631	Spain	18	38	16	25	3	7	11	18	5.5	67
PI 504561	USSR	17	92	12	42	3	25	12	25	5.0	55
PI 267088	USSR	17	82	13	51	3	19	8	17	3.4	60
PI 540416	Uzbekistan	17	99	11	50	4	33	12	20	3.7	62
PI 263048	USSR	17	80	13	49	3	17	6	16	3.5	60
PI 512638	Spain	17	71	12	41	4	15	6	21	5.8	58
PI 512636	Spain	17	63	12	24	3	29	7	17	5.2	63
PI 507875	Hungary	17	69	12	37	3	16	10	25	4.7	59
PI 506465	Ukraine	17	99	12	54	3	28	11	19	4.9	57
PI 506464	USSR	17	80	12	47	3	27	6	8	4.9	60
PI 422170	Czech Rep.	17	93	12	40	3	39	8	17	6.0	58
PI 173892	India	17	49	12	32	3	13	6	7	4.7	64
PI 271754	Netherlands	17	66	13	36	3	18	6	20	5.8	62
PI 339243	Turkey	17	71	11	29	3	22	13	25	5.2	57
PI 233932	Canada	17	89	12	46	3	32	12	14	5.4	55

Table 5.3. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 561147	USA-New York	17	77	13	41	3	21	5	26	5.1	61
PI 506463	USSR	17	104	10	37	4	33	11	32	5.3	55
PI 458851	USSR	17	89	12	44	3	25	11	21	2.9	58
PI 263046	USSR	17	63	12	33	3	17	7	21	3.6	61
PI 422199	Netherlands	17	108	11	45	3	39	12	25	5.0	59
PI 308915	USSR	17	109	10	35	5	51	9	17	5.5	69
PI 209068	USA OH	17	79	13	40	2	29	5	13	5.1	58
PI 458848	USSR	17	76	13	48	2	8	9	25	3.3	60
PI 422181	Czech Rep.	16	51	12	29	3	14	5	15	6.0	61
PI 370450	Yugoslavia	16	60	12	38	3	16	4	12	5.6	58
PI 249562	Thailand	16	44	12	19	3	14	3	18	5.5	72
PI 356809	USSR	16	165	12	58	3	63	9	29	3.0	54
PI 176516	Turkey	16	58	10	31	4	15	9	21	5.0	60
PI 215589	India	16	267	11	67	3	83	10	10	4.5	67
PI 285605	Poland	16	83	11	34	3	33	7	17	5.1	56
PI 288992	Hungary	16	143	10	46	4	75	7	15	3.9	55
PI 354952	Denmark	16	78	11	35	2	20	12	32	5.1	59
PI 209069	USA OH	16	63	11	33	3	20	7	17	5.6	59
PI 246930	Afghanistan	16	72	13	48	2	14	6	13	4.2	59
PI 502331	Uzbekistan	16	95	11	44	3	37	7	14	3.6	59
PI 422189	Czech Rep.	16	80	11	30	4	36	5	19	5.1	61
PI 458852	USSR	16	100	11	40	3	38	9	21	3.6	55
PI 285606	Poland	16	72	11	30	4	29	6	14	5.9	57
PI 512602	Spain	16	72	10	28	3	28	14	23	5.0	63
PI 422188	Czech Rep.	16	70	11	38	3	19	7	21	6.1	59
PI 163218	India	16	61	12	31	2	13	4	15	4.6	68
PI 466921	USSR	16	87	11	36	3	16	14	39	4.9	55
PI 217644	India	15	59	11	32	3	18	9	13	3.2	59

Table 5.3. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 507876	Hungary	15	82	11	39	3	25	6	21	5.4	57
PI 512607	Spain	15	39	13	30	1	3	11	16	5.6	63
PI 422179	Czech Rep.	15	81	10	25	4	36	9	23	5.9	59
PI 422186	Czech Rep.	15	96	11	32	2	40	10	25	4.9	58
PI 357852	Yugoslavia	15	64	10	26	3	19	7	26	5.0	61
PI 370643	USSR	15	156	9	55	4	49	8	32	3.8	55
PI 220338	Afghanistan	15	71	10	32	3	23	10	21	4.7	56
PI 458850	USSR	15	83	10	43	3	25	13	16	3.6	56
PI 200818	Burma	15	66	10	35	3	21	10	13	5.4	61
PI 458849	USSR	15	84	11	42	3	22	10	22	3.3	55
PI 292012	Israel	15	120	10	54	3	57	5	10	3.8	58
PI 343452	USSR	15	69	11	45	2	16	8	11	5.3	52
PI 221440	Afghanistan	15	58	11	36	2	17	8	8	4.2	61
PI 207476	Afghanistan	15	55	11	36	2	11	8	15	4.2	61
PI 357850	Yugoslavia	15	49	12	24	3	20	9	15	5.8	60
PI 217946	Pakistan	15	42	12	31	2	5	6	15	3.8	65
PI 173889	India	14	78	10	35	3	37	5	6	5.2	61
PI 390253	Japan	14	84	11	41	2	28	8	21	3.0	55
PI 422176	Czech Rep.	14	115	9	30	3	48	11	30	5.4	57
PI 264226	France	14	93	8	33	4	43	12	17	6.0	52
PI 422173	Czech Rep.	14	90	9	34	3	30	15	28	5.6	58
PI 512644	Spain	14	53	11	26	2	13	8	31	5.1	59
PI 535880	Poland	14	90	11	46	3	36	11	15	4.0	58
PI 197088	India	14	69	11	46	2	17	5	8	2.4	64
PI 280096	USSR	14	95	9	47	4	36	10	14	4.5	63
PI 249550	Iran	14	58	10	27	2	15	7	26	4.5	61
PI 283902	Czech Rep.	14	54	11	29	2	20	5	9	7.0	55
PI 164734	India	14	46	12	19	3	24	6	8	5.0	69

Table 5.3. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Qua-lity	Hvst date
PI 458845	USSR	14	65	10	36	2	18	6	15	3.9	60
PI 504565	USSR	14	62	10	41	2	11	9	15	3.6	62
PI 342950	Denmark	14	108	9	46	4	44	8	19	4.0	54
PI 169400	Turkey	13	43	11	23	3	14	6	10	4.7	66
PI 212599	Afghanistan	13	60	9	33	3	14	15	24	4.3	59
PI 504569	India	13	45	10	27	2	8	6	31	2.9	67
PI 532162	Oman	13	87	7	43	5	40	4	2	5.3	72
PI 220791	Afghanistan	13	80	9	42	3	27	8	14	4.3	60
PI 205996	Sweden	13	57	10	27	2	18	9	21	5.1	60
PI 205995	Sweden	13	116	9	45	4	60	5	8	3.2	54
PI 261608	Spain	13	44	10	24	2	11	4	14	5.9	67
PI 249561	Thailand	13	148	9	62	4	68	5	15	2.7	54
PI 370022	India	13	43	10	23	2	10	5	20	3.9	57
PI 370447	Yugoslavia	13	28	11	21	2	5	5	6	5.4	66
PI 306179	Poland	13	86	9	25	2	32	11	34	3.0	58
PI 351139	USSR	13	129	9	58	3	35	10	27	2.6	53
PI 135122	N. Zealand	13	80	10	47	2	23	2	9	2.0	77
PI 285607	Poland	13	70	9	33	3	25	12	17	5.9	57
PI 197085	India	13	57	9	32	2	15	10	22	1.9	60
PI 164679	India	13	42	9	32	2	8	14	17	3.8	76
PI 390261	Japan	13	74	8	33	3	30	9	14	2.9	64
PI 344440	Iran	13	170	7	58	3	57	14	35	2.4	58
PI 512601	Spain	13	34	10	20	2	6	6	31	6.0	67
PI 209067	USA OH	12	66	8	35	3	16	12	26	5.3	56
PI 357855	Yugoslavia	12	66	9	35	2	16	10	22	4.9	57
PI 458847	USSR	12	65	8	35	2	24	8	12	3.1	61
PI 512640	Spain	12	46	9	23	2	19	4	8	5.7	62
PI 512604	Spain	12	34	9	17	2	13	5	11	5.4	67

Table 5.3. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 175120	India	12	35	9	26	2	2	5	9	4.2	71
PI 271327	India	12	31	9	16	2	10	5	17	4.0	68
PI 135123	N. Zealand	12	82	8	35	2	20	8	25	3.0	66
PI 163223	India	12	50	9	15	2	23	5	20	4.0	71
PI 165509	India	11	100	8	55	2	35	8	11	2.2	59
PI 512626	Spain	11	69	8	33	2	25	8	15	5.3	59
PI 265887	Netherlands	11	32	8	18	2	12	8	7	5.7	68
PI 197086	India	11	70	8	43	2	26	5	2	1.9	61
PI 308916	USSR	11	85	6	25	3	41	9	25	4.5	59
PI 512635	Spain	10	28	8	11	2	8	10	34	4.7	73
PI 222720	Iran	10	33	8	21	1	6	7	20	3.5	59
PI 200815	Burma	10	68	7	34	3	31	7	5	5.6	75
PI 532160	Oman	10	36	8	17	2	12	5	17	5.3	76
PI 512637	Spain	10	37	7	19	2	15	4	9	5.5	67
PI 504570	India	10	89	7	45	2	43	5	2	2.3	61
PI 500359	Zambia	10	14	10	12	1	0	5	8	4.5	73
PI 222987	Iran	10	45	7	22	1	17	6	14	5.2	60
PI 267087	USSR	9	120	5	44	3	63	3	12	2.6	55
PI 179678	India	9	137	5	42	3	96	5	0	2.0	80
PI 512336	Hong Kong	9	14	9	12	0	1	5	13	4.8	83
PI 357857	Yugoslavia	9	8	9	3	1	3	35	38	5.7	73
PI 512634	Spain	9	23	7	11	3	10	3	4	6.0	76
PI 179921	India	8	27	7	13	1	11	6	21	4.6	75
PI 163222	India	8	26	6	15	1	7	8	14	4.1	72
PI 222986	Iran	7	18	5	11	1	3	10	8	5.5	64
PI 164465	India	4	15	3	6	1	2	7	48	3.8	78
PI 481612	Bhutan	3	12	3	5	0	6	4	17	3.2	80

Table 5.3. continued.

		Total		Early		Marketable		% Cull		Qua-	Hvst
Cultigen	Source	wt	no.	wt	no.	wt	no.	wt	no.	lity	date
Mean		83	18	41	13	27	3	18	8	4.9	60
Range		446	80	232	74	350	44	100	100	8.0	63
Std Dev		45	10	26	8	27	3	17	8	1.6	9
CV		53	59	64	65	101	82	90	100	33	15

Table 5.4. Yield, quality and harvest traits for 116 slicing cucumber cultigens evaluated during 1997-98 at Clinton, NC. (weight in Mg/ha; number in '000 fruit/ha)

		Total		Early		Marketable		% Cull		Qua-	Hvst
Cultigen	Source	wt	no.	wt	no.	wt	no.	wt	no.	lity	date
PI 234517	USA SC	35	105	28	55	5	33	5	16	6.9	63
PI 118279	Brazil	35	148	27	80	5	45	7	15	5.3	57
PI 304805	USA NY	32	114	21	43	9	46	6	23	6.5	69
PI 368560	Yugoslavia	32	55	27	37	3	13	3	9	4.9	69
PI 173893	India	31	80	26	55	2	8	7	20	3.9	59
PI 512614	Spain	30	102	23	48	5	40	5	20	5.6	59
PI 512615	Spain	28	69	23	41	3	19	6	9	5.2	62
PI 165499	India	28	64	24	30	2	18	8	25	4.3	59
Sprint 440	USA	28	88	22	42	4	35	6	14	7.9	61
PI 414159	USA-HW	27	87	20	36	4	36	9	18	6.9	63
Dasher II	USA	27	101	21	43	3	37	6	20	7.8	61
PI 288238	Egypt	26	79	21	37	2	14	13	34	5.9	62
PI 288996	Hungary	26	82	20	50	4	18	9	16	4.7	60
PI 512623	Spain	26	95	20	39	3	30	9	27	5.6	60
PI 406473	Netherlands	26	94	20	40	3	25	10	29	7.0	63
PI 561145	USA-New York	26	109	17	41	5	39	10	27	7.4	65
PI 401733	Puerto Rico	25	87	18	35	5	31	9	23	5.4	62
Poinsett7	USA	25	106	19	41	4	44	6	20	7.6	64
PI 357860	Yugoslavia	25	54	21	36	2	9	4	15	5.0	66
PI 283901	Czech Rep.	25	71	19	34	3	11	19	37	4.6	61
PI 561148	USA-New York	25	95	18	47	6	34	4	16	7.4	68
PI 390246	Japan	24	65	18	29	4	20	8	25	6.0	70
PI 422177	Czech Rep.	24	85	18	43	4	25	9	21	6.4	63
PI 401732	Puerto Rico	24	98	18	31	4	53	7	15	6.4	63
PI 561144	USA Minn.	24	82	19	36	3	29	5	16	6.8	72
PI 512608	Spain	24	54	19	31	3	15	6	12	5.3	62

Table 5.4. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Qua-lity	Hvst date
PI 321006	Taiwan	24	63	19	32	2	16	7	25	7.0	62
PI 109483	Turkey	24	70	19	35	2	14	10	30	5.3	65
PI 511818	Taiwan	24	59	18	30	3	9	10	34	6.5	63
PI 483343	Korea	23	87	17	32	4	36	10	22	4.9	60
PI 451976	Japan	23	91	17	38	4	38	9	18	7.1	62
PI 267747	USA OK	22	97	16	34	4	35	11	29	4.3	56
PI 263049	USSR	22	70	17	32	3	26	12	21	5.6	60
PI 422200	Czech Rep.	22	44	20	20	2	7	7	36	5.1	70
PI 419214	Hong Kong	22	54	17	29	3	12	6	22	6.8	60
PI 357865	Yugoslavia	21	57	15	28	5	24	5	8	4.9	60
PI 512606	Spain	21	56	16	27	3	19	6	17	5.0	60
PI 512609	Spain	20	63	16	29	2	14	7	28	4.9	62
PI 561146	USA-New York	20	75	15	31	4	33	4	18	6.9	66
PI 483340	Korea	20	83	13	31	5	24	11	37	4.5	64
PI 390952	USSR	20	82	15	33	2	18	13	40	5.1	60
PI 504815	PR China	20	78	13	31	6	30	7	24	5.5	60
PI 304803	USA NY	20	67	15	30	2	24	9	22	5.0	60
PI 391570	PR China	20	63	17	34	2	19	7	16	5.4	61
PI 482464	Zimbabwe	20	66	15	36	3	22	6	13	6.7	66
PI 512605	Spain	20	60	16	31	2	22	8	17	4.9	63
PI 512598	Spain	20	43	13	19	5	21	8	12	5.8	68
PI 390251	Japan	19	71	16	31	2	25	5	23	4.6	63
PI 164284	India	19	40	17	19	2	13	5	25	4.6	71
PI 512633	Spain	19	83	14	28	3	40	6	19	7.3	65
PI 357847	Yugoslavia	19	63	15	23	3	27	6	26	5.3	63
PI 379281	Yugoslavia	19	55	16	32	2	14	5	15	6.3	63
PI 508456	Korea	19	81	14	28	3	28	10	31	4.0	61
PI 426170	Philippines	19	82	15	34	2	27	9	25	4.1	57

Table 5.4. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 418989	PR China	18	58	15	36	2	11	7	19	5.0	60
PI 358814	Malaysia	18	65	13	29	3	18	8	26	4.5	58
PI 390240	Japan	18	41	14	24	3	6	5	26	5.2	77
PI 512617	Spain	18	57	14	28	3	16	6	20	6.5	68
PI 369717	Poland	18	100	11	31	5	35	11	33	4.3	60
PI 114339	Japan	18	52	13	23	2	14	10	28	5.5	61
PI 220860	Korea	18	51	15	30	2	13	5	17	4.9	60
PI 267745	Brazil	17	56	15	24	1	17	7	27	5.9	65
PI 206952	Turkey	17	69	13	32	2	25	9	22	4.1	59
PI 511817	Taiwan	17	62	12	32	2	13	11	24	6.3	63
PI 432864	PR China	17	84	11	22	4	45	6	22	4.2	64
PI 512613	Spain	16	59	12	25	2	20	11	27	5.5	59
PI 481614	Bhutan	16	26	14	17	2	6	4	10	4.9	72
PI 504816	PR China	16	91	12	22	2	56	11	15	4.7	58
PI 504813	Japan	16	75	12	36	3	28	7	16	4.3	60
PI 508453	Korea	16	74	11	29	3	23	9	26	4.6	63
PI 390239	Japan	16	56	11	27	4	13	5	19	5.1	70
PI 306785	Canada	16	60	11	22	3	20	8	23	7.6	66
PI 357838	Yugoslavia	15	34	13	19	2	12	5	9	5.9	64
PI 176519	Turkey	15	68	12	29	2	19	15	31	5.2	55
PI 224668	Korea	15	60	10	22	3	26	13	25	4.8	63
PI 338234	Turkey	15	47	13	42	1	5	3	0	4.5	66
PI 250147	Pakistan	15	37	12	18	1	10	4	16	3.4	69
PI 279468	Japan	15	44	11	16	2	16	8	27	4.3	65
PI 370449	Yugoslavia	15	44	11	17	2	18	8	17	6.0	63
PI 379283	Yugoslavia	14	29	12	16	2	13	4	3	5.1	72
PI 391568	PR China	14	45	11	21	2	15	11	20	4.8	61
PI 512641	Spain	14	63	10	32	2	20	8	19	5.1	60

Table 5.4. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Qua-lity	Hvst date
PI 512632	Spain	14	37	12	21	1	10	7	16	5.4	67
PI 525075	Mauritius	14	55	11	10	1	26	8	20	5.3	73
PI 171611	Turkey	14	60	10	27	2	22	8	19	4.6	60
PI 390259	Japan	14	92	11	49	2	24	10	24	4.8	65
PI 390244	Japan	14	41	7	12	4	21	9	18	4.8	67
PI 344347	Turkey	13	49	10	19	2	21	6	16	4.7	58
PI 288995	Hungary	13	53	9	18	3	18	9	26	5.0	63
MM_76	USA	13	39	9	25	3	14	4	0	7.7	55
PI 390260	Japan	13	37	9	13	3	17	6	18	4.5	71
PI 285609	Poland	13	66	8	18	2	22	14	35	4.6	60
PI 512610	Spain	13	48	11	26	1	15	5	18	4.9	59
PI 227209	Japan	13	70	6	20	3	32	33	15	4.8	66
PI 390243	Japan	13	41	10	19	1	10	5	33	4.9	69
PI 512616	Spain	12	31	11	18	3	8	5	15	5.3	73
PI 358813	Malaysia	12	53	9	21	2	19	7	25	3.9	59
PI 281448	Korea	12	60	9	23	2	22	10	23	5.0	59
PI 321007	Taiwan	12	32	9	19	2	10	5	6	5.0	69
PI 512642	Spain	12	35	9	16	2	16	9	30	5.6	74
PI 368551	Yugoslavia	12	24	10	13	1	6	5	18	5.0	65
PI 532521	Japan	11	63	8	22	2	11	9	47	4.3	66
PI 512624	Spain	11	42	9	15	1	13	7	20	5.5	66
PI 163217	India	11	27	9	19	1	5	6	10	3.8	73
PI 512639	Spain	11	33	9	16	1	15	5	5	4.1	70
PI 279466	Japan	10	29	7	9	2	12	5	31	5.0	69
PI 357856	Yugoslavia	9	27	7	12	1	8	9	19	5.8	64
PI 267743	PR China	9	26	6	16	2	5	7	14	5.3	66
PI 422192	Czech Rep.	8	19	8	9	2	4	4	29	7.3	71
PI 512619	Spain	8	23	6	9	1	8	6	23	5.4	68

Table 5.4. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 390238	Japan	8	31	6	15	1	11	4	11	5.6	72
PI 321009	Taiwan	7	18	5	9	1	7	6	17	5.3	71
PI 512625	Spain	6	23	6	8	2	11	3	21	5.0	69
PI 379280	Yugoslavia	6	15	6	8	2	5	4	18	4.8	69
PI 368559	Yugoslavia	6	16	5	12	0	3	5	5	4.4	70
PI 481616	Bhutan	2	3	0	0	2	3	0	0	3.0	81
Mean		65	19	29	15	22	3	21	7	5.5	64
Range		312	102	269	84	129	30	100	78	8	59
Std Dev		38	12	21	10	21	3	17	7	1.5	9
CV		58	63	74	70	93	113	84	101	27	14

Table 5.5. Yield, quality and harvest traits for 265 middle-eastern (Beit-alpha) cucumber cultigens evaluated during 1997-98 at Clinton, NC. (weight in Mg/ha; number in '000 fruit/ha)

		Total		Early		Marketable		% Cull		Qua-	Hvst
Cultigen	Source	wt	no.	wt	no.	wt	no.	wt	no.	lity	date
PI 167050	Turkey	34	69	26	36	5	18	6	18	6.3	64
PI 163213	India	33	78	24	40	8	35	4	6	5.5	65
PI 532519	USSR	33	131	23	40	5	50	8	30	7.7	59
PI 211978	Iran	33	66	26	45	5	13	5	14	6.0	59
PI 357864	Yugoslavia	31	85	22	32	5	34	9	23	5.7	62
PI 183231	Egypt	30	99	19	53	4	20	13	25	6.2	61
PI 211117	Israel	30	97	20	44	7	39	7	13	7.0	65
PI 292010	Israel	30	127	20	49	6	55	8	21	7.3	62
PI 172852	Turkey	30	87	24	58	4	26	3	3	6.0	64
PI 169401	Turkey	29	86	22	42	4	25	6	19	7.0	63
PI 181755	Lebanon	29	111	21	52	4	42	10	19	6.3	57
PI 169385	Turkey	29	88	20	38	6	45	4	6	6.3	54
PI 167079	Turkey	28	105	21	61	4	29	7	15	6.2	60
PI 534543	Syria	28	155	17	56	8	68	13	22	6.2	56
PI 169388	Turkey	28	55	22	37	3	11	5	10	5.8	62
PI 218036	Iran	28	72	22	49	4	12	7	15	6.0	61
PI 535881	Poland	28	115	20	49	5	37	7	24	7.9	57
PI 137856	Iran	28	111	19	57	5	23	13	25	4.8	55
PI 211988	Iran	28	88	19	49	4	18	12	26	5.8	59
PI 204569	Turkey	28	92	19	49	5	25	7	20	5.5	57
PI 344437	Iran	28	78	18	38	6	21	10	25	5.9	58
PI 167134	Turkey	27	84	21	47	3	19	8	23	6.1	58
PI 175693	Turkey	27	146	17	64	7	48	9	22	5.1	55
PI 171601	Turkey	27	121	15	45	9	51	8	16	6.8	60

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 344444	Iran	27	67	20	40	4	14	7	19	6.8	61
PI 534540	Syria	27	112	18	44	6	48	9	19	7.0	60
PI 525152	Egypt	27	114	19	62	4	37	9	14	7.0	56
PI 169391	Turkey	27	110	17	50	6	38	11	19	6.4	59
PI 211983	Iran	27	70	19	40	5	20	5	16	6.8	58
PI 226461	Iran	26	105	18	51	5	31	12	22	5.3	57
PI 355053	Iran	26	65	19	31	4	16	12	29	5.7	61
PI 176956	Turkey	26	121	19	69	4	28	9	19	5.3	58
PI 534539	Syria	26	107	18	46	5	44	7	17	7.4	62
PI 288237	Egypt	26	90	19	52	5	28	7	12	7.0	60
PI 292011	Israel	26	65	18	33	4	21	10	22	6.8	65
PI 167043	India	26	79	21	53	3	14	5	9	6.0	60
PI 164951	Turkey	25	113	16	46	6	42	9	20	6.0	56
PI 525153	Egypt	25	113	16	41	5	48	12	24	7.6	60
PI 319216	Egypt	25	112	18	61	4	25	11	23	6.3	59
PI 174164	Turkey	25	88	17	41	6	28	11	16	5.2	65
PI 385967	Kenya	25	56	18	31	4	14	11	19	5.5	59
PI 176951	Turkey	25	102	15	51	7	30	13	21	6.2	55
PI 167052	Turkey	25	81	16	35	6	35	8	14	5.8	61
PI 525157	Egypt	25	96	19	59	4	27	7	11	6.4	57
PI 169390	Turkey	25	83	17	48	4	18	14	21	5.3	57
PI 525163	Italy	25	94	17	41	5	39	8	16	7.1	59
PI 169399	Turkey	25	75	19	35	4	26	5	17	4.9	60
PI 176924	Turkey	25	73	15	30	9	38	4	6	6.5	64
PI 211943	Iran	25	93	18	48	5	31	4	13	5.6	59
PI 534541	Syria	25	91	16	38	5	37	10	15	7.4	61
PI 181756	Lebanon	25	100	17	47	4	33	10	21	6.4	60
PI 344353	Turkey	25	66	19	32	4	21	5	24	5.8	57

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 525156	Egypt	24	92	17	49	4	30	8	13	6.6	57
PI 357868	Yugoslavia	24	51	18	25	3	11	9	29	5.4	62
PI 164670	India	24	60	19	36	3	14	6	21	5.4	65
PI 525152	Egypt	27	114	19	62	4	37	9	14	7.0	56
PI 169391	Turkey	27	110	17	50	6	38	11	19	6.4	59
PI 175694	Turkey	24	107	17	60	4	21	9	25	5.3	53
PI 344442	Iran	24	95	16	50	5	28	7	17	6.9	55
PI 355052	Israel	24	107	16	49	5	45	7	10	7.0	61
PI 368550	Yugoslavia	24	67	17	32	3	12	11	35	4.6	58
PI 177364	Iraq	23	90	17	46	5	27	9	17	6.2	61
PI 174167	Turkey	23	98	16	52	3	34	8	13	6.0	57
PI 176523	Turkey	23	70	17	31	4	22	10	26	6.1	60
PI 176521	Turkey	23	84	17	31	5	38	6	16	5.6	59
PI 174170	Turkey	23	98	15	40	4	40	11	20	6.8	56
PI 175695	Turkey	23	99	15	53	3	17	12	26	5.5	56
PI 211982	Iran	23	79	16	38	4	20	15	26	5.3	56
PI 177361	Turkey	23	113	16	54	4	38	11	20	5.4	55
PI 175680	Turkey	23	41	18	21	5	16	9	13	5.8	64
PI 525155	Egypt	23	89	15	28	5	45	9	19	7.2	58
PI 171600	Turkey	22	66	15	29	4	16	8	32	5.0	58
PI 167198	Turkey	22	80	16	37	4	27	7	18	5.9	60
PI 339250	Turkey	22	97	15	46	4	33	8	20	6.1	60
PI 344439	Iran	22	104	16	60	5	27	7	17	5.1	53
PI 169383	Turkey	22	89	14	30	4	42	10	18	5.3	58
PI 171602	Turkey	22	60	16	28	4	19	6	20	6.8	63
PI 525150	Egypt	22	101	16	42	4	45	7	13	6.7	59
PI 357858	Yugoslavia	22	65	16	28	4	21	7	24	5.5	62
PI 339248	Turkey	22	61	16	32	3	15	7	20	6.8	59

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Qua-lity	Hvst date
PI 206954	Turkey	22	44	17	27	3	11	5	13	5.7	64
PI 172846	Turkey	22	96	14	50	5	27	12	18	5.4	56
PI 344350	Turkey	22	101	15	49	4	27	8	24	6.1	56
PI 218199	Lebanon	22	84	16	33	3	35	9	22	6.5	62
PI 227013	Iran	22	68	16	43	3	12	5	17	4.7	62
PI 181910	Syria	22	118	13	35	5	57	12	23	6.6	57
PI 344434	Iran	22	43	16	27	4	8	5	18	5.0	65
PI 171606	Turkey	22	84	14	36	5	28	9	23	6.4	58
PI 296120	Egypt	22	74	15	24	4	35	10	21	6.7	61
PI 169353	Turkey	22	65	13	21	5	29	11	19	5.8	63
PI 172841	Turkey	21	85	15	42	4	29	8	17	5.9	56
PI 314426	USSR	21	60	15	39	4	14	8	11	5.2	61
PI 296387	Iran	21	67	15	39	3	17	9	17	5.8	56
PI 171608	Turkey	21	50	15	27	4	15	7	13	5.2	62
PI 293432	Lebanon	21	86	16	46	3	24	7	20	7.1	61
PI 164743	India	21	52	15	26	4	17	11	20	6.0	63
PI 357859	Yugoslavia	21	43	17	26	3	9	5	13	6.5	70
PI 211975	Iran	21	111	12	41	5	28	20	37	5.3	54
PI 169403	Turkey	21	78	16	39	3	26	5	12	5.8	58
PI 188749	Egypt	21	98	15	53	4	32	7	12	6.6	63
PI 176518	Turkey	21	77	16	43	3	19	12	23	5.7	58
PI 344435	Iran	21	84	14	46	5	26	8	16	5.3	60
PI 338236	Turkey	21	113	15	61	4	34	8	15	5.4	56
PI 344352	Turkey	21	45	16	24	3	12	8	25	6.0	63
PI 525151	Egypt	21	97	13	32	5	44	12	20	6.3	56
PI 164950	Turkey	21	71	15	32	4	25	8	26	5.0	64
PI 109063	PR China	21	100	13	39	5	46	11	17	4.8	55
PI 169394	Turkey	21	88	15	56	3	13	11	23	5.3	57

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 525158	Egypt	21	93	15	37	4	36	8	24	6.9	57
PI 174177	Turkey	21	55	15	41	3	8	7	10	5.7	53
PI 175696	Turkey	21	103	14	44	4	36	12	24	5.5	55
PI 525165	Italy	20	87	14	39	5	40	6	9	7.1	58
PI 172847	Turkey	20	101	12	52	6	28	10	22	6.0	55
PI 211986	Iran	20	51	15	27	3	10	6	23	6.4	62
PI 137851	Iran	20	84	15	44	4	29	6	13	6.3	56
PI 344438	Iran	20	54	15	32	3	11	7	20	6.5	66
PI 211962	Iran	20	64	15	37	3	20	5	12	5.0	58
PI 175690	Turkey	20	116	15	55	3	32	9	27	5.6	55
PI 525161	Egypt	20	84	15	40	3	34	7	12	7.1	60
PI 202801	Syria	20	68	14	35	4	20	9	20	6.3	58
PI 220171	Afghanistan	20	61	15	30	3	18	5	19	6.3	59
PI 174174	Turkey	20	79	12	40	4	22	12	21	7.0	59
PI 172845	Turkey	20	84	14	43	3	30	10	14	7.0	58
PI 211967	Iran	20	78	14	42	3	20	8	21	5.7	56
PI 169382	Turkey	20	66	14	36	3	20	5	13	6.1	59
PI 183677	Turkey	20	111	12	44	3	32	13	32	5.5	58
PI 171612	Turkey	20	58	14	33	5	17	6	14	4.8	63
PI 105263	Turkey	20	75	14	31	4	26	8	24	5.7	57
PI 169380	Turkey	19	75	11	25	4	40	10	12	5.5	61
PI 182188	Turkey	19	55	16	39	6	11	4	10	6.3	61
PI 178885	Turkey	19	54	14	22	2	23	8	15	6.1	59
PI 525159	Egypt	19	91	14	49	3	30	9	13	6.8	57
PI 169398	Turkey	19	83	13	35	3	30	8	17	5.3	56
PI 206955	Turkey	19	51	14	28	4	18	7	19	5.9	65
PI 172849	Turkey	19	78	13	35	3	24	13	26	5.4	56
PI 165506	India	19	67	14	33	4	18	5	19	5.1	60

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 263083	PR China	19	76	13	36	3	22	10	25	4.6	58
PI 175689	Turkey	19	68	15	34	3	26	7	16	6.6	64
PI 525162	Italy	19	91	12	35	3	41	10	18	7.0	56
PI 181753	Syria	19	71	13	30	5	22	12	23	6.3	61
PI 175697	Turkey	19	70	12	30	4	28	9	19	6.0	59
PI 169351	Turkey	19	60	13	22	5	23	13	27	6.7	59
PI 176524	Turkey	19	76	14	37	3	24	8	19	6.3	61
PI 169395	Turkey	19	75	13	28	3	28	8	27	5.1	62
PI 174166	Turkey	19	86	13	39	4	28	9	20	6.3	59
PI 173674	Turkey	19	64	14	39	3	11	7	19	5.1	63
PI 257494	Iran	19	80	13	35	2	30	9	18	5.5	58
PI 181942	Syria	19	92	13	40	3	33	11	22	6.6	60
PI 344348	Turkey	19	66	13	32	3	23	6	16	4.9	61
PI 169352	Turkey	19	53	13	17	4	22	4	12	6.0	65
PI 356832	Netherlands	19	49	13	23	4	16	6	17	6.0	63
PI 169334	Turkey	18	51	13	22	3	17	9	19	5.3	61
PI 274902	Great Britain	18	83	13	34	3	24	14	31	5.1	61
PI 137853	Iran	18	70	13	35	3	19	10	20	5.3	55
PI 169350	Turkey	18	58	13	23	3	16	7	30	6.0	62
PI 525154	Egypt	18	78	12	28	3	35	7	19	7.3	60
PI 179260	Turkey	18	54	15	23	4	5	6	38	6.3	64
PI 181874	Syria	18	94	13	47	2	26	11	24	5.9	56
PI 540414	Uzbekistan	18	78	10	33	3	28	9	19	5.4	60
PI 177363	Syria	18	77	13	33	5	26	11	21	6.2	55
PI 223437	Afghanistan	18	68	13	41	2	20	7	14	4.3	58
PI 222243	Iran	18	63	14	43	3	16	4	8	4.9	57
PI 222244	Iran	18	89	12	37	3	33	9	21	5.7	55
PI 204692	Turkey	18	75	12	37	3	22	13	21	6.1	56

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Qua-lity	Hvst date
PI 339244	Turkey	18	58	13	25	3	14	9	29	4.6	59
PI 176525	Turkey	18	42	13	18	3	11	12	27	6.3	64
PI 512627	Spain	18	70	12	28	2	21	13	28	4.8	59
PI 357834	Yugoslavia	18	25	14	18	2	7	5	2	6.4	71
PI 379282	Yugoslavia	18	36	14	17	2	12	9	22	5.0	70
PI 137847	Iran	17	69	13	30	3	16	11	32	5.7	59
PI 176526	Turkey	17	37	14	27	3	5	8	18	5.8	66
PI 504562	USSR	17	85	12	34	2	33	7	17	6.2	62
PI 339245	Turkey	17	70	12	26	4	28	9	24	5.3	60
PI 357863	Yugoslavia	17	58	12	30	3	20	11	17	4.3	59
PI 175686	Turkey	17	84	12	34	3	38	8	15	6.5	57
PI 169377	Turkey	17	53	12	18	4	16	5	30	5.4	63
PI 169378	Turkey	17	45	12	23	4	17	9	11	5.0	63
PI 314425	USSR	17	82	12	45	4	22	7	18	3.8	59
PI 137857	Iran	17	69	13	45	3	16	6	12	5.0	55
PI 379284	Yugoslavia	17	42	13	23	3	8	4	22	5.1	67
PI 220789	Afghanistan	17	65	13	29	3	13	12	34	4.7	64
PI 181940	Syria	17	90	11	46	2	26	10	15	6.3	57
PI 183445	India	17	83	11	27	3	37	13	25	4.7	55
PI 165046	Turkey	17	44	12	20	4	16	7	22	6.4	66
PI 171609	Turkey	17	78	12	29	3	33	6	17	4.1	62
PI 182190	Turkey	17	77	12	39	4	27	9	15	5.6	56
PI 176522	Turkey	17	67	10	29	3	29	9	17	6.8	60
PI 357854	Yugoslavia	17	52	12	13	5	26	6	25	6.0	71
PI 137846	Iran	17	77	12	45	3	15	13	25	5.4	55
PI 183224	Egypt	17	67	13	37	2	22	5	12	6.2	56
PI 169304	Turkey	17	50	12	28	2	12	8	20	5.2	61
PI 223841	Philippines	17	62	12	35	3	14	7	17	5.0	62

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 169384	Turkey	17	63	13	24	3	30	2	11	6.3	68
PI 226509	Iran	17	69	11	30	3	28	8	12	6.0	52
PI 222099	Afghanistan	17	66	13	31	3	18	8	26	4.5	57
PI 368548	Yugoslavia	17	54	12	25	2	21	6	14	4.6	62
PI 178888	Turkey	17	52	11	26	3	11	10	26	5.1	65
PI 172844	Turkey	17	69	9	36	4	24	15	15	6.2	59
PI 344443	Iran	17	51	12	29	5	10	9	22	6.3	57
PI 169381	Turkey	17	45	13	27	2	10	7	17	6.1	59
PI 344349	Turkey	16	63	12	29	3	25	6	10	4.9	60
PI 220169	Afghanistan	16	54	13	33	2	10	8	21	3.6	59
PI 176520	Turkey	16	80	12	34	3	32	9	18	5.4	56
PI 422197	Czech Rep.	16	57	11	20	3	16	12	33	7.3	70
PI 137839	Iran	16	64	11	39	4	17	7	12	5.0	59
PI 220790	Afghanistan	16	63	12	38	3	15	8	18	4.8	59
PI 167358	Turkey	16	46	11	22	4	18	13	13	6.5	61
PI 227664	Iran	16	73	12	44	3	22	7	10	6.7	55
PI 368557	Yugoslavia	16	42	14	18	2	11	6	21	5.4	67
PI 296121	Egypt	16	73	11	37	3	26	10	11	5.8	59
PI 176952	Turkey	16	45	12	18	3	18	8	25	6.6	65
PI 172838	Turkey	16	67	12	34	3	25	7	12	6.6	60
PI 222783	Iran	16	76	10	34	3	24	9	22	6.0	56
PI 137836	Iran	16	54	12	33	2	12	10	21	5.8	61
PI 251028	Afghanistan	16	56	11	32	2	11	12	17	4.3	63
PI 226510	Iran	16	86	11	38	3	30	11	20	5.5	55
PI 357843	Yugoslavia	16	60	13	27	6	33	4	0	6.0	72
PI 174172	Turkey	16	69	12	42	2	19	7	12	6.8	57
PI 211977	Iran	16	76	12	38	2	22	6	19	4.9	57
PI 176957	Turkey	16	59	11	26	3	16	12	24	6.0	59

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 222782	Iran	15	52	11	26	3	17	8	15	5.7	62
PI 175683	Turkey	15	84	11	45	2	19	10	24	5.3	55
PI 357869	Yugoslavia	15	31	12	21	2	7	6	9	6.0	63
PI 222985	Iran	15	72	11	36	3	24	12	16	5.0	55
PI 357842	Yugoslavia	15	71	10	38	3	22	10	18	4.9	56
PI 137844	Iran	15	77	10	39	3	21	9	20	5.0	56
PI 175681	Turkey	15	33	11	19	2	5	6	28	5.3	70
PI 251519	Iran	15	78	11	31	2	26	12	29	5.4	56
PI 357836	Yugoslavia	15	31	11	18	3	10	7	11	5.8	66
WI 2757	USA	15	79	10	33	3	27	7	24	6.8	64
PI 251520	Iran	15	65	10	32	3	23	9	16	5.1	56
PI 177360	Turkey	15	57	12	34	2	16	7	12	5.3	57
PI 339246	Turkey	15	51	9	19	4	22	11	20	5.6	61
PI 355055	Iran	15	57	10	32	3	13	10	20	5.6	57
PI 357861	Yugoslavia	15	41	10	24	4	14	6	6	5.8	67
PI 179263	Turkey	15	47	10	25	3	14	6	22	5.5	69
PI 512628	Spain	15	19	16	15	1	5	4	0	5.2	76
PI 164952	Turkey	14	50	9	16	4	16	9	31	6.0	61
PI 171605	Turkey	14	37	11	23	2	5	6	20	5.6	64
PI 176953	Turkey	14	49	10	27	2	9	13	24	5.6	58
PI 379286	Yugoslavia	14	29	10	17	2	11	5	3	4.9	66
PI 137835	Iran	14	77	9	35	3	30	11	15	5.3	59
PI 339241	Turkey	14	65	10	27	2	24	9	17	5.3	57
PI 109482	Turkey	14	44	10	22	2	10	12	26	6.0	61
PI 174173	Turkey	13	106	7	35	4	37	18	33	5.0	57
PI 357835	Yugoslavia	13	25	10	15	2	8	5	6	5.1	64
PI 211589	Afghanistan	13	40	10	30	2	7	5	3	5.3	65
PI 171603	Turkey	12	43	9	21	3	17	9	15	6.3	62

Table 5.5. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 175679	Turkey	12	45	9	18	2	14	8	23	5.9	68
PI 172848	Turkey	12	62	8	26	3	17	14	29	5.6	56
PI 171610	Turkey	12	49	9	28	2	9	13	26	5.6	64
PI 540415	Uzbekistan	12	51	8	25	3	21	6	6	4.7	64
PI 351140	USSR	12	49	9	13	2	17	6	25	5.6	70
PI 344445	Iran	12	84	7	27	2	25	15	35	4.7	56
PI 175688	Turkey	12	42	9	21	2	12	6	17	5.7	65
PI 248778	Iran	12	56	8	27	2	21	10	12	5.3	57
PI 172839	Turkey	11	38	8	15	2	15	8	21	6.2	66
PI 368556	Yugoslavia	11	32	8	15	2	8	7	30	5.1	67
PI 357867	Yugoslavia	11	22	8	14	2	6	6	15	6.0	73
PI 344433	Iran	11	25	9	17	1	6	5	11	5.6	70
PI 357853	Yugoslavia	10	10	10	9	2	0	7	50	3.3	77
PI 211980	Iran	9	42	6	23	2	12	13	19	5.2	59
PI 171604	Turkey	9	29	6	10	2	17	5	5	5.0	72
PI 379287	Yugoslavia	6	17	5	7	0	6	6	22	4.7	75
PI 357849	Yugoslavia	6	13	5	11	1	2	2	0	5.5	72
Mean		74	20	35	14	24	4	19	8	5.9	60
Range		421	92	145	61	245	48	100	74	8	56
Std Dev		39	11	22	9	22	3	16	7	1	8
CV		53	57	61	61	93	80	86	87	22	13

Table 5.6. Yield, quality and harvest traits for 187 trellis cucumber cultigens evaluated during 1997-98 at Clinton, NC. (weight in Mg/ha; number in '000 fruit/ha)

		Total		Early		Marketable		% Cull		Qua-	Hvst
Cultigen	Source	wt	no.	wt	no.	wt	no.	wt	no.	lity	date
PI 264228	France	40	127	24	61	7	18	13	26	5.8	62
PI 478366	PR China	40	99	26	41	6	20	12	39	6.5	67
PI 390262	Japan	36	105	21	35	6	32	17	33	7.0	66
PI 532524	Japan	34	85	23	34	5	30	14	25	6.3	67
PI 390267	Japan	34	95	21	42	6	29	15	22	6.8	64
PI 532520	USSR	33	115	18	35	8	40	19	35	6.6	66
PI 275411	Netherlands	33	116	20	48	6	39	15	24	5.3	58
PI 419010	PR China	33	80	20	36	6	24	14	27	6.1	62
PI 518851	PR China	32	89	23	45	4	18	14	28	6.3	64
PI 511820	Taiwan	32	93	18	46	6	24	22	26	6.6	61
PI 422167	Czech Rep.	32	84	21	30	5	26	11	31	7.3	66
PI 432884	PR China	31	89	19	29	7	36	14	25	6.4	69
PI 419009	PR China	31	74	16	31	7	23	21	25	6.4	66
PI 418964	PR China	31	72	19	36	5	20	15	22	5.9	67
PI 263085	PR China	31	92	19	34	4	23	18	37	4.8	61
PI 432887	PR China	30	65	18	22	5	16	17	42	6.0	68
PI 257487	PR China	30	90	17	32	6	26	17	35	6.8	61
PI 432873	PR China	30	85	17	25	5	23	22	40	6.3	70
PI 419136	PR China	30	91	17	33	5	22	21	40	6.0	62
PI 419040	PR China	30	82	16	34	5	26	26	34	5.3	65
PI 390268	Japan	30	74	20	35	3	11	18	37	5.4	67
PI 427089	PR China	29	57	19	32	5	12	18	22	5.7	64
PI 227208	Japan	29	69	18	30	5	22	17	24	6.8	63
PI 464873	PR China	29	74	17	32	3	12	27	40	6.4	63
PI 419182	PR China	29	86	20	33	3	28	17	28	5.8	64
PI 532523	Japan	29	98	16	25	6	42	17	32	6.6	62

Table 5.6. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 372893	Netherlands	29	89	17	33	5	30	18	27	7.2	68
PI 508455	Korea	29	97	16	29	5	37	22	37	6.8	59
PI 432883	PR China	29	80	18	35	6	31	13	18	6.3	69
PI 508460	Korea	29	84	18	37	4	24	16	29	7.0	62
PI 432889	PR China	29	71	19	37	3	10	14	31	5.3	66
PI 432872	PR China	28	88	18	39	4	23	15	29	6.1	65
PI 432870	PR China	28	78	17	33	5	17	16	34	5.4	61
PI 357844	Yugoslavia	28	66	18	35	4	20	15	21	5.1	60
PI 426629	Pakistan	28	45	17	26	5	13	12	13	6.4	64
PI 418962	PR China	28	85	16	33	5	24	18	35	6.2	62
PI 518849	PR China	28	75	17	30	5	20	16	32	6.3	65
PI 432886	PR China	28	80	16	35	5	29	15	20	5.9	69
PI 432869	PR China	27	85	15	29	5	18	21	39	6.3	63
PI 432875	PR China	27	85	16	36	5	25	15	26	6.0	68
PI 419135	PR China	27	83	16	35	4	15	19	39	6.8	62
PI 432885	PR China	27	92	15	27	6	26	15	37	6.4	68
PI 432865	PR China	27	89	16	31	4	29	16	31	5.9	62
PI 432855	PR China	27	91	15	35	4	25	22	35	5.7	68
PI 436608	PR China	27	72	16	29	5	21	18	33	6.8	60
PI 418963	PR China	27	76	18	37	3	14	12	31	5.9	62
PI 169319	Turkey	26	64	16	34	5	20	14	19	5.9	60
PI 489754	PR China	26	104	14	28	6	42	15	32	5.9	62
PI 432868	PR China	26	56	17	25	5	17	14	22	6.7	62
PI 432859	PR China	26	76	15	29	5	17	20	40	6.1	65
PI 390255	Japan	26	69	16	36	5	18	14	21	6.5	62
PI 436609	PR China	26	81	15	34	5	24	20	29	5.8	62
PI 212233	Japan	26	61	16	37	5	18	11	8	4.7	72
PI 275412	Netherlands	26	67	17	39	3	15	16	18	5.3	62

Table 5.6. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 511819	Taiwan	26	80	15	34	6	36	13	16	6.0	65
PI 432849	PR China	25	140	13	33	5	38	24	49	4.8	57
PI 357832	Yugoslavia	25	58	17	29	4	16	15	20	5.6	63
PI 478364	PR China	25	101	13	28	6	40	16	29	5.5	64
PI 321011	Taiwan	25	65	15	28	4	11	19	41	6.0	61
PI 508454	Korea	25	67	15	28	4	16	17	35	6.5	66
PI 432877	PR China	25	77	15	36	4	20	26	36	6.3	66
PI 483342	Korea	25	89	14	34	5	31	16	25	6.1	66
PI 212059	Greece	25	60	13	25	6	26	17	13	6.3	62
PI 432857	PR China	25	95	15	40	4	24	18	33	5.7	63
PI 518854	PR China	25	103	13	30	6	44	14	29	6.6	56
PI 419017	PR China	25	63	14	22	4	13	19	44	6.3	64
PI 483341	Korea	25	80	13	27	5	25	17	34	6.6	64
PI 356833	Great Britain	25	80	14	28	5	33	16	39	7.2	69
PI 285608	Poland	25	66	15	27	6	25	12	31	7.3	67
PI 391569	PR China	24	78	15	32	4	27	16	27	6.5	63
PI 511821	Taiwan	24	55	14	32	5	11	16	23	7.2	66
PI 357839	Yugoslavia	24	66	15	32	4	18	13	25	6.4	60
PI 275410	Netherlands	24	63	16	33	4	20	15	18	7.0	72
PI 432878	PR China	24	77	13	24	6	29	16	30	6.3	65
PI 390257	Japan	24	69	14	26	4	15	18	39	6.5	59
PI 390252	Japan	24	95	14	38	4	25	17	28	6.0	62
PI 279464	Japan	24	77	13	21	5	32	18	35	5.0	61
PI 263081	PR China	24	72	13	31	5	32	20	14	4.9	56
PI 419079	PR China	24	78	14	23	4	30	19	33	5.9	62
PI 192940	PR China	24	68	19	38	3	24	5	9	4.8	61
PI 432854	PR China	24	62	15	28	4	20	16	22	6.3	66
PI 385968	Kenya	23	87	12	28	6	26	18	37	4.9	64

Table 5.6. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 255938	Netherlands	23	62	16	24	5	29	8	13	7.0	69
PI 432850	PR China	23	82	13	26	4	26	21	37	5.3	59
PI 518852	PR China	23	82	12	27	5	30	22	34	6.4	62
PI 518853	PR China	23	74	13	28	4	26	22	28	5.7	63
PI 419108	PR China	23	72	13	33	5	27	16	18	6.3	60
PI 227210	Japan	23	65	14	30	4	12	16	33	5.2	63
PI 390263	Japan	23	55	18	26	3	17	8	24	5.4	64
PI 508459	Korea	23	92	12	33	4	27	24	36	5.6	61
PI 427090	PR China	23	74	14	27	4	15	15	43	6.6	60
PI 432852	PR China	23	74	15	35	4	26	13	19	5.5	64
PI 390250	Japan	22	76	14	26	5	27	12	34	4.9	63
PI 321010	Taiwan	22	72	14	23	4	26	17	31	5.1	61
PI 432867	PR China	22	50	15	20	3	11	15	36	6.6	65
PI 419078	PR China	22	75	15	38	3	25	14	16	6.3	60
PI 518848	PR China	22	83	12	28	4	29	19	36	6.3	60
PI 390247	Japan	22	74	12	22	5	36	15	21	6.9	63
PI 489753	PR China	22	49	13	19	3	17	17	23	6.1	71
PI 193497	Ethiopia	22	72	16	39	3	13	12	26	4.9	63
PI 478365	PR China	22	55	14	25	4	13	15	30	6.7	65
PI 390241	Japan	22	63	14	30	4	22	14	15	6.3	66
PI 390266	Japan	22	56	13	27	4	11	18	29	6.3	67
PI 432848	PR China	22	71	13	27	4	21	16	28	5.8	63
PI 432876	PR China	22	66	12	28	4	16	18	26	6.4	68
PI 432858	PR China	22	60	12	20	4	20	19	33	6.4	64
PI 092806	PR China	22	74	12	35	5	24	16	19	4.5	60
PI 179259	Turkey	22	56	14	29	4	17	17	20	5.5	62
PI 432881	PR China	22	78	12	24	4	31	19	32	6.1	69
PI 357837	Yugoslavia	22	46	19	26	2	7	13	24	6.3	65

Table 5.6. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 432851	PR China	22	62	13	36	4	18	16	16	5.8	70
PI 532522	Japan	21	74	12	28	5	20	15	36	6.3	62
PI 432891	PR China	21	66	12	29	4	17	17	32	5.9	66
PI 374694	Japan	21	73	11	26	4	16	23	46	5.8	66
PI 518853	PR China	23	74	13	28	4	26	22	28	5.7	63
PI 419183	PR China	21	79	12	20	4	30	17	38	5.7	56
PI 432856	PR China	21	64	11	27	4	20	22	23	5.9	61
PI 432879	PR China	21	72	11	25	7	33	11	23	5.4	69
PI 357840	Yugoslavia	21	64	14	27	4	26	13	18	5.8	66
PI 432893	PR China	21	68	11	25	5	20	16	32	5.1	66
PI 432874	PR China	20	69	13	26	4	28	16	23	6.0	70
PI 518850	PR China	20	69	12	22	4	23	19	39	6.3	62
PI 357866	Yugoslavia	20	47	13	25	3	14	14	15	6.0	62
PI 400270	Japan	20	62	11	21	3	13	20	35	5.5	67
PI 169387	Turkey	20	63	15	25	4	15	14	28	5.3	61
PI 357851	Yugoslavia	20	58	13	21	4	18	17	30	5.7	64
PI 508457	Korea	20	81	10	26	4	24	24	39	5.7	63
PI 432871	PR China	20	64	13	25	3	20	18	32	4.6	64
PI 390258	Japan	20	50	12	21	3	20	13	14	5.4	69
PI 419041	PR China	20	79	11	29	4	26	18	32	4.1	61
PI 436672	PR China	20	56	12	22	4	18	13	26	5.8	67
PI 432890	PR China	20	54	10	19	3	15	32	45	5.4	66
PI 432888	PR China	20	58	11	30	3	14	16	23	6.3	70
PI 432862	PR China	20	72	12	30	4	23	14	29	6.2	66
PI 436649	PR China	19	55	11	21	4	21	17	23	6.8	66
PI 432853	PR China	19	97	10	31	4	19	23	48	5.5	64
PI 279463	Japan	19	81	9	20	8	48	10	19	5.3	69
PI 182192	Turkey	19	51	11	22	4	23	14	13	6.6	64

Table 5.6. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Quality	Hvst date
PI 432866	PR China	19	91	11	26	4	26	20	48	5.1	67
PI 432861	PR China	19	70	12	27	3	23	15	28	5.4	59
PI 432892	PR China	19	68	10	14	4	23	18	46	5.7	63
PI 508458	Korea	19	77	11	31	4	25	17	27	5.0	62
PI 267742	PR China	19	59	15	25	2	17	11	29	5.1	58
PI 422184	Czech Rep.	19	55	11	17	5	22	16	26	7.7	77
PI 430585	PR China	19	46	11	22	3	11	19	29	5.4	69
PI 390256	Japan	19	68	10	17	3	26	21	36	6.3	61
PI 432860	PR China	19	63	11	28	3	16	16	31	6.4	60
PI 279467	Japan	19	47	11	24	4	11	15	27	5.0	70
PI 432897	PR China	19	71	9	20	5	35	16	23	5.6	68
PI 263084	PR China	19	55	10	20	3	15	18	35	4.9	59
PI 264231	France	19	61	10	24	5	22	14	27	6.1	73
PI 264230	France	19	81	12	40	3	20	14	29	4.5	60
PI 436648	PR China	18	58	11	20	3	21	16	27	6.8	62
PI 390249	Japan	18	74	9	23	5	31	18	32	4.8	64
PI 432880	PR China	18	63	8	7	4	33	21	39	5.7	70
PI 267197	PR China	17	48	11	22	3	14	17	26	4.9	62
PI 357831	Yugoslavia	17	35	11	16	3	10	19	24	5.8	65
PI 169389	Turkey	17	53	11	25	3	13	15	24	5.1	58
PI 487424	PR China	17	52	11	23	2	5	20	41	5.3	67
PI 483339	Korea	17	69	13	24	4	25	7	22	4.9	66
PI 432894	PR China	17	62	8	22	4	22	25	29	5.5	62
PI 255935	Netherlands	17	53	9	19	4	22	14	26	7.6	69
PI 436610	PR China	16	61	10	27	3	22	13	21	6.8	60
PI 483344	Korea	16	84	10	32	3	27	15	30	4.2	64
PI 178887	Turkey	16	42	10	18	3	12	15	29	5.8	62
PI 357841	Yugoslavia	16	38	13	20	2	11	5	19	5.1	64

Table 5.6. continued.

Cultigen	Source	Total wt	Total no.	Early wt	Early no.	Marketable wt	Marketable no.	% Cull wt	% Cull no.	Qua-lity	Hvst date
PI 267741	Japan	16	53	9	15	3	21	19	32	5.0	61
PI 264229	France	16	31	12	11	1	4	16	49	6.8	67
PI 255933	Netherlands	16	57	11	26	3	18	18	24	7.0	64
PI 432895	PR China	15	66	8	16	3	21	23	44	5.5	63
PI 302443	PR China	15	39	9	15	3	15	16	27	5.6	68
PI 227207	Japan	15	53	10	20	2	14	15	34	6.0	64
PI 432882	PR China	15	55	8	17	3	22	20	30	6.7	68
PI 169315	Turkey	15	48	10	20	2	19	18	18	6.0	60
PI 357862	Yugoslavia	15	31	10	14	4	11	12	17	6.4	65
PI 357833	Yugoslavia	15	29	9	14	2	10	14	17	6.4	68
PI 360949	Yugoslavia	14	33	9	17	3	11	13	11	6.8	70
PI 370448	Yugoslavia	14	37	9	15	3	15	13	13	5.3	66
PI 263082	PR China	14	51	8	18	2	15	23	41	5.1	63
PI 267935	Japan	13	50	6	14	3	11	28	44	4.4	68
PI 451973	PR China	13	63	7	17	3	24	15	38	5.9	61
PI 504572	PR China	12	47	6	21	3	13	17	29	4.8	63
PI 105340	PR China	11	54	6	22	4	22	11	20	3.0	73
PI 470254	Indonesia	9	29	7	15	1	9	9	25	3.4	78
PI 357830	Yugoslavia	9	41	3	5	5	32	8	17	7.0	79
PI 167223	Turkey	8	38	4	9	2	16	14	24	6.0	61
PI 368555	Yugoslavia	8	26	5	11	2	12	5	15	5.8	71
PI 368554	Yugoslavia	5	5	4	5	1	0	8	0	5.6	75
Mean		71	23	28	14	22	4	29	17	6.0	64
Range		274	106	118	68	140	32	100	100	7	60
Std Dev		36	13	18	9	19	3	19	10	1	9
CV		50	57	64	65	85	73	64	57	20	15

Chapter Six

Efficient Estimation of Fruit Grade Weights Based on Fruit Number and Total Fruit Weight in Cucumber

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Breeding and germplasm resources

Efficient Estimation of Fruit Grade Weights Based on Fruit Number and Total Fruit Weight in Cucumber

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Abstract

Measurement of cucumber fruit weight in small research plots involves more labor and resources than just counting the number of fruit per plot. Therefore, plant breeders are interested in an efficient method for estimating fruit weight per grade (early, marketable, and cull) based on fruit number and total fruit weight. We evaluated the cucumber germplasm collection of 810 plant introduction accessions (supplied by the U.S.D.A. Regional Plant Introduction Station at Ames, Iowa) along with 7 check cultivars for yield. Correlations were calculated for all pairs of fruit number and fruit weight combinations for each grade. In general, the lowest correlations were observed between the fruit weight of each grade (early, marketable, and cull) and total fruit weight or number per plot. High correlations were observed for fruit weight and fruit number within each grade (early, marketable, and cull). An efficient method for estimating fruit weight/ha of early, marketable, and cull grades is to count total, early, and cull fruit, then measure total fruit weight. Our results showed that the fruit weight of each grade (early, marketable, and cull) was best estimated using the fruit number of that grade (early, marketable, and cull) along with the total fruit weight and total fruit number.

Breeding for yield in cucumber (*Cucumis sativus* L.) has been a major objective of many cucumber breeding programs over the last few decades (Wehner, 1989). Measurement of yield in a diverse array of cucumber cultivars, breeding lines, and plant introduction accessions (hereafter collectively referred to as cultigens) is expensive. Cucumber breeders are interested in more efficient methods for yield measurement in test plots. Common methods used to assess yield in cucumber include measuring the number of fruit and fruit weight for each grade. Fruit number was found to be more stable than fruit weight or fruit value for yield measurement in a once-over harvest of cucumber (Ells and McSay, 1981). Fruit number was also found to have a higher heritability (0.17) than fruit weight (0.02) (Smith and Lower, 1978). However, fruit weight is the trait of greatest interest for breeders since that is the basis on which growers are paid. Based on our experience with yield trials in cucumber, measurement of fruit weight of cucumber in small plots unfortunately involves more labor and resources than counting the number of fruit. Measuring fruit weight can also be time consuming if the weight of different grades (early, marketable, and cull) is needed. Therefore, we wanted to develop an efficient method for estimating fruit weight by grade (early, marketable, and cull) based on the number of each fruit grade along with total fruit weight.

Wehner and Miller (1984) and Wehner (1986) recommended the use of once-over harvest trials having three replications for maximum efficiency to determine which cucumber lines should be tested further in multiple-harvest trials. Swallow and Wehner (1986) found that a plot size of 1.2 m x 1.5 m was optimum for yield evaluation for once-over harvest of pickling cucumber harvested using paraquat. Wehner and Miller (1987) recommended the use of small, single-row plots without end borders rather than large, multiple-row, bordered plots. In cucumber, small-plot, single-harvest trials were found to be more efficient than large-plot, multiple-harvest trials (Wehner, 1986; Wehner, 1989; Wehner and Miller, 1984).

Swallow and Wehner (1989) reported that maximum information (1/variance) was obtained by allocating test plots of cucumber cultigens to different seasons and years rather than different locations and replications. That was the case even though locations and replications were easier and less expensive to use than seasons and years. Finally, field evaluation at the Clinton location provided more information for a given cost than three other locations tested in North Carolina (Wehner, 1987).

Robinson et al. (1968) reported that the plant growth regulator ethephon (2-chloroethanephosphonic acid) greatly increased the number of female flowers in the monoecious cucumber inbred 'Wisconsin SMR 18' when applied at the first and third leaf stage. McMurray and Miller (1969) reported that the most effective concentration of ethephon to convert SC 23, a monoecious cucumber inbred, to a gynoecious one with continuous pistillate nodes was four applications at 120 ppm, or two applications at 240 ppm. The authors also reported an increase in yield and earliness due to the chemical treatment (McMurray and Miller, 1969).

Miller and Hughes (1969) recommended harvesting at the 14 to 31% oversized fruit stage (>51 mm diameter) to achieve maximum value in once-over harvest for 'Piccadilly' and 'Southern Cross' gynoecious pickling type hybrids in North Carolina. Oversize for slicing (fresh-market) cucumber would be fruit >60 mm diameter. Chen et al. (1975), using a computer simulation model, reported that plots harvested at 10% oversized fruit stage gave an optimum yield for 'Piccadilly' pickling hybrid under North Carolina conditions. Colwell and O'Sullivan (1981) reported that the optimum harvest stage to maximize yield for 'Femcap' and 'Greenstar' gynoecious pickling hybrids occurred when 5 to 15% of the plot contained oversized fruit.

The objective of this experiment was therefore to develop a set of regression equations that could best predict the cucumber fruit weights by grade (early, marketable, and cull) based on individual fruit grade numbers and/or total fruit weight in a plot.

Materials and Methods

The experiment was conducted at the Horticultural Crops Research Station, Clinton, NC using recommended horticultural practices (Schultheis, 1990).

Cultural Practices

Fertilizer was incorporated before planting at a rate of 90-39-74 kg/ha (N-P-K), with an additional 34 kg N/ha applied at the vine tip-over stage. Curbit (ethalfluralin N-ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluromethyl)benzenamine) was applied for weed control. Irrigation was applied when needed for a total (irrigation plus rainfall) of 25 to 40 mm per week. Seeds were planted on raised, shaped beds 1.5 m apart on 17 April 1997. Plots were 1.2 m long and 1.5 m wide with 1.2 m alleys at each end. Guard rows were planted on the outside of the field, and at the end of each row. 'Sumter' pollenizer was planted on each side of the experiment as well as every 11th row, to provide pollen. Plots were planted with 16 seeds and thinned to a uniform stand of 12 plants per plot approximately one month after planting. No disease problems were observed. Plots with a stand count (plant number) of less than 50% were eliminated from the statistical analysis and plots with stand count ranging from 50 to 80% were corrected using the formula: corrected yield = (total yield/ stand) x 10 according to the method of Cramer and Wehner (1998).

Ethephon application

Ethephon (2-chloroethyl phosphonic acid) was sprayed on seedlings at the first to second true leaf stage approximately five weeks after planting. Ethephon was prepared using Florel [3.9% ethephon (2-chloroethyl phosphonic acid)] (Southern Agricultural

Insecticides, Inc. Palmetto, FL 34220) at the rate of 2.5 ml/l for a concentration of 21%. A Solo back-pack sprayer at 100 to 140 kPa (15 to 20 psi) was used to spray the ethephon on the leaves and stems till run-off.

Plots were harvested once, beginning approximately two months after planting for a period of four weeks. Plots were harvested when 10% of the fruit in a plot were oversized (>51 mm diameter for pickling cucumber and >60 mm diameter for fresh market cucumber).

Cultivars evaluated

Prediction equations were developed for the cucumber germplasm collection from NC State University and the USDA germplasm collection in Ames, Iowa. The collection consisted of 810 plant introduction accessions originating from 50 countries along with 7 check cultivars. Countries with the most accessions were Turkey, P.R. China, former Yugoslavia, Iran, former USSR, Japan, and India. The seven checks used in the experiment were 'Calypso', 'Sumter', 'Dasher II', 'Poinsett 76', 'Wis. 2757', 'Sprint 440', and 'Marketmore 76'.

Traits measured

Data collected were number and weight of total, early, and cull fruit per plot. Early fruit were the ones that were oversized fruit at the time of once-over harvest. Total fruit weight was the sum of early, marketable, and cull fruit per plot. The number and weight of marketable fruit was calculated as total minus cull fruit. Fruit numbers were converted to thousands of fruit per hectare, and fruit weight was converted to Mg/ha. Cultigens were classified (based on their fruit type) as pickling, slicing, middle-eastern (Beit Alpha), and oriental trellis.

Data analysis

The experiment was a randomized complete block design with 817 cultigens and 3 replications. Data were analyzed using GLM and REG procedures of SAS (SAS Institute, Inc., Cary, NC). Regression was used to predict early fruit weight from: early number; total number; total weight; early number plus total number; early number plus total weight; total number plus total weight; and early number, total number, and total weight. Regression analyses were also used in the same way to predict marketable fruit weight and cull fruit weight.

Results and Discussion

Cultigens evaluated in the study differed significantly in yield as measured by early, marketable, cull, and total fruit number and weight (data not presented). Based on regression analysis between the individual fruit weight grades (early, marketable, and cull), the respective fruit numbers (early, marketable, and cull), and total fruit weight, several equations were obtained that provided good estimates of weight of each grade (Tables 6.1, 6.2, and 6.3). The prediction equations were developed based on data that was collected on total fruit weight (Mg/ha), total fruit number per plot, fruit number and fruit weights for the different fruit grade types (early, marketable, and cull). The plots were classified into four distinct cucumber fruit types (pickling, slicing, Beit Alpha and trellis). Since the data represents the entire cucumber germplasm collection, the prediction equations we have proposed are the most conservative for their respective classes. However, the prediction equations may change for different cultigens and environments.

The prediction equations in the tables apply to each of the cucumber types (pickling, slicing, Beit Alpha, and trellis). If data is collected on total fruit number and/or fruit number of each grade (early, marketable, and cull) and/or total fruit weight per plot, then one could estimate the early, marketable, and cull fruit weight based on the equations in Tables 6.1, 6.2, and 6.3. For example, if one is working with slicing cucumber and has data for early fruit number (number/ha), total fruit number (no./ha), and total fruit weight (Mg/ha), then early fruit weight (Mg/ha) could be estimated using the formula: early fruit weight = -0.28 - 0.13 (total fruit number) + 0.20 (early fruit number) + 0.82 (total weight). The prediction equation had an R^2 of 0.96 and a CV of 17.53 for the early fruit weight that was actually measured (Table 6.1).

Correlations between early, marketable, or cull fruit weight and the other traits (total, early, marketable, or cull number, or total fruit weight) ranged from a minimum of 0.03 (correlation between cull fruit weight and total fruit weight for the Beit Alpha type, Table 6.3) to a maximum of 0.96 (correlation between early fruit weight and early fruit number, total fruit number, and total fruit weight for slicers, Table 6.1).

Prediction of early fruit weight

There was a wide range in correlation between early fruit weight and the fruit number of the different cucumber fruit grades. The lowest R^2 value measured was 0.09 for early fruit weight estimated from total fruit number (pickling type); the highest R^2 was 0.96 for early fruit weight estimated from early fruit number, total fruit number, and total fruit weight (slicing type). In general, the lowest correlations were between total fruit number and early fruit weight. The other grades measured were intermediate to high in their R^2 values. The trait combination that provided the best correlation with early marketable weight were early fruit number, total fruit number, and total fruit weight (R^2 range 0.93 to 0.96, Table 6.1).

Prediction of marketable fruit weight

There were differences in the correlation values (R^2) between marketable fruit weight and the weights of the other grades measured. The range in R^2 varied from 0.14 to 0.77

(Table 6.2). The highest correlation values were observed when marketable fruit weight was regressed on marketable fruit number, total fruit number, and total fruit weight for all the fruit types (Table 6.2).

In general, the highest correlations for marketable fruit weight across all cucumber types were obtained when marketable fruit weight was regressed on either marketable fruit number and total fruit weight, or on marketable fruit number, total fruit number, and total fruit weight. The R^2 values were found to be intermediate when regression was computed to total fruit number and total fruit weight, marketable fruit number, and total fruit number and marketable fruit number. R^2 values were smallest when regression was based only on total fruit number or total fruit weight (Table 6.2).

Prediction of cull fruit weight

Large differences in correlation were observed when cull fruit weight was regressed on fruit weight or number of the different grades. The highest correlations (R^2 values) across all cucumber types was observed when cull fruit weight was regressed on cull fruit number and total fruit weight, or on cull fruit number, total fruit number, and total fruit weight. Correlations were low when cull fruit weight per plot was regressed on total fruit weight, on total fruit number, or on total fruit weight and number (Table 6.3).

In general, the lowest correlations across all fruit types were observed between fruit grade weights (early, marketable, and cull) and total fruit weight or total fruit number. The highest correlations across all cucumber fruit types were observed between fruit grade weights (early, marketable, and cull) and fruit number for each grade (total and early, marketable, or cull) along with total fruit weight. Estimation of early fruit weight from early fruit number, total fruit number, and total fruit weight had the highest predictive value (R^2 range 0.93 to 0.96, Table 6.1). Next highest predictive value was for estimation of marketable fruit weight from marketable fruit number, total fruit number, and total fruit weight (R^2 range 0.66 to 0.77, Table 6.2). The lowest predictive value was for estimation of cull fruit weight from cull fruit number, total fruit number, and total fruit weight (R^2 range 0.60 to 0.70, Table 6.3).

In summary, the fruit weight of each grade (early, marketable, and cull) is best estimated using the fruit number of that grade, along with the total fruit weight and total fruit number. The next best alternatives would be to use fruit number of a particular grade along with total weight (for estimating marketable and culled fruit weights) or using total fruit number and total fruit weight (for predicting early fruit weight). However, if one had to choose just one trait for predicting fruit grade weights due to lack of resources, we recommend the use of total fruit weight in a plot for predicting early fruit number (R^2 range 0.54 to 0.74, Table 6.1), marketable fruit number (R^2 range 0.50 to 0.72, Table 6.2), and cull fruit number (R^2 range 0.55 to 0.63) (Table 6.3) for estimating the weights of early, marketable, and cull fruit.

Literature Cited

Chen, L. H., C. H. Miller, and R. S. Sowell. 1975. Simulation models for harvesting of pickling cucumbers. J. Amer. Soc. Hort. Sci. 100: 176-179.

Colwell, H. T. M. and J. O'Sullivan. 1981. Economics of harvest timing for once over harvesting of cucumbers. J. Amer. Soc. Hort. Sci. 106: 163-167.

Cramer, C. S. and T. C. Wehner. 1998. Stand correction methods for cucumber fruit yield. Cucurbit Genet. Coop. Rpt. 21: 18-20.

Ells, J. E. and A. E. McSay. 1981. Yield comparisons of pickling cucumber cultivar trials for once-over harvesting. HortScience 16: 187-189.

McMurray, A. L. and C. H. Miller. 1968. Cucumber sex expression modified by 2 -chloroethanephosphonic acid. Science 162: 1396-397.

Miller, C. H. and G. R. Hughes. 1969. Harvest indices for pickling cucumbers in once-over harvest systems. J. Amer. Soc. Hort. Sci. 94: 485-487.

Robinson, R. W., S. Shannon, and M. D. de la Guardia. 1968. Regulation of sex expression in the cucumber. BioScience 19: 141-142.

Schultheis, J. R. 1990. Pickling cucumbers. N.C. State Ag. Extension. Horticulture Information Leaflet No. 14-A.

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: 92-94.

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size for measurement of yield in multiple and once over harvest trials of pickling and fresh market cucumbers. Euphytica 35: 493-501.

Swallow, W. H. and T. C. Wehner. 1989. Optimum allocation of plots to years, seasons, locations, and replications, and its applications to once-over harvest cucumber trials. Euphytica 43: 59-68.

Wehner, T. C. 1986. Efficiency of 3 single-harvest tests for evaluation of yield in pickling cucumber. Euphytica 35: 493-501.

Wehner, T. C. 1987. Value of 12 season-location combinations for cucumber yield trials in North Carolina. Cucurbit Genet. Coop. Rpt. 6: 38-39.

Wehner, T. C. 1989. Breeding for improved yield in cucumber. Plant Breed. Rev. (Ed.) J. Janick. Vol. 6: 323-359.

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: 659-664.

Wehner, T. C. and C. H. Miller. 1987. Optimum plant density for multiple-harvest yield of determinate cucumbers. Cucurbit Genet. Coop. Rpt. 10: 29-30.

Table 6.1. Predicted regression equations for early fruit weight (EW) based on total fruit number (TN), early fruit number (EN), and total fruit weight (TW).[z]

Equation	CV	R^2	Inter-cept	Total number	Early number	Total weight
Pickling						
EW=5.30 + 0.01(TN)	71.52	0.09	5.30	0.01	-	-
EW=2.88-0.04(TN)+0.31(EN)	49.14	0.57	2.88	-0.04	0.31	-
EW=1.30+0.27(EN)	50.53	0.54	1.30	-	0.27	-
EW=-1.71+0.80(TW)	31.89	0.82	-1.71	-	-	0.80
EW=-2.46+0.09(EN)+0.65(TW)	28.67	0.85	-2.46	-	0.09	0.65
EW=0.18-0.05(TN)+0.90(TW)	28.16	0.86	0.18	-0.05	-	0.90
EW=0.03-0.08(TN)+0.14(EN)+0.73(TW)	18.77	0.94	0.03	--0.08	0.14	0.73
Slicing						
EW=3.27+0.16(TN)	79.52	0.23	3.27	0.16	-	-
EW=0.75+0.46(EN)	53.74	0.65	0.75	-	0.46	-
EW=2.25-0.06(TN)+0.53(EN)	52.71	0.66	2.25	-0.06	0.53	-
EW=-2.79+0.84(TW)	31.23	0.88	-2.79	-	-	0.84
EW=-3.11+0.10(EN)+0.71(TW)	29.58	0.89	-3.11	-	0.10	0.71
EW=-0.58-0.09(TN)+1.00(TW)	25.48	0.92	-0.58	-0.09	-	1.00
EW=-0.28-0.13(TN)+0.20(EN)+0.82(TW)	17.53	0.96	-0.28	-0.13	0.20	0.82

Table 6.1. continued.

Equation	CV	R^2	Inter-cept	Total number	Early number	Total weight
Beit Alpha						
EW=5.64+0.10(TN)	64.25	0.12	5.64	0.10	-	-
EN=1.88+0.35(EN)	43.88	0.59	1.88	-	0.35	-
EW=3.68-0.05(TN)+0.41(EN)	42.34	0.62	3.68	-0.05	0.41	-
EW=-1.67+0.80(TW)	27.85	0.83	-1.67	-	-	0.80
EW=-2.28+0.12(EN)+0.64(TW)	24.80	0.87	-2.28	-	0.12	0.64
EW=0.10-0.06(TN)+0.90(TW)	24.86	0.87	0.10	-0.06	-	0.90
EW=0.33-0.10(TN)+0.20(EN)+0.71(TW)	15.30	0.95	0.33	-0.10	0.20	0.71
Trellis						
EW=1.95+0.17(TN)	67.98	0.29	1.95	0.17	-	-
EW=-0.18+0.56(EN)	40.87	0.74	-0.18	-	0.56	-
EW=0.94-0.04(TN)+0.62(EN)	40.26	0.75	0.94	-0.04	0.62	-
EW=-1.90+0.70(TW)	32.94	0.83	-1.90	-	-	0.70
EW=-0.24-0.06(TN)+0.81(TW)	30.83	0.85	-0.24	-0.06	-	0.81
EW=-2.80+0.25(CN)+0.47(TW)	26.61	0.89	-2.80	-	0.25	0.47
EW=-0.17-0.11(TN)+0.34(EN)+0.58(TW)	18.14	0.95	-0.17	-0.11	0.34	0.58

[z] Regression calculations made with plot weights in Mg/ha and fruit numbers in thousands/ha.

Table 6.2. Predicted regression equations for marketable fruit weight (MW) based on total fruit number (TN), marketable fruit number (MN), and total fruit weight (TW).[z]

Equation	CV	R^2	Inter-cept	Total number	Market number	Total weight
Pickling						
MW=0.78+0.16(TW)	85.49	0.20	0.78	-	-	0.16
MW=0.09+0.04(TN)	82.79	0.25	0.09	0.04	-	-
MW=-0.44+0.03(TN)+0.09(TW)	80.07	0.30	-0.44	0.03	-	0.09
MW=0.68+0.00(TN)+0.09(MN)	67.78	0.50	0.68	0.00	0.09	-
MW=0.79+0.10(MN)	67.76	0.50	0.79	-	0.10	-
MW=-0.79+0.09(MN)+0.12(TW)	59.56	0.61	-0.79	-	0.09	0.12
MW=-0.16-0.03(TN)+0.12(MN)+0.17(TW)	56.27	0.66	-0.16	-0.03	0.12	0.17
Slicing						
MW=1.95+0.11(TW)	84.23	0.14	1.95	-	-	0.11
MW= 0.57+0.06(TN)	76.21	0.30	0.57	0.06	-	-
MW=0.54+0.06(TN)+0.01(TW)	76.30	0.30	0.54	0.06	-	0.01
MW=0.44+0.00(TN)+0.18(MN)	48.19	0.72	0.44	0.00	0.18	-
MW=0.51+0.18(MN)	48.13	0.72	0.51	-	0.18	-
MW=-0.21+0.17(MN)+0.05(TW)	45.74	0.75	-0.21	-	0.17	0.05
MW=0.09-0.02(TN)+0.20(MN)+0.08(TW)	44.23	0.77	0.09	-0.02	0.20	0.08

Table 6.2. continued.

Equation	CV	R^2	Inter-cept	Total number	Market number	Total weight
Beit Alpha						
MW=0.28+0.05(TN)	80.56	0.23	0.28	0.05	-	-
MW=0.63+0.17(TW)	80.61	0.23	0.63	-	-	0.17
MW=-0.38+0.03(TN)0.11(TW)	77.04	0.30	-0.38	0.03	-	0.11
MW=0.63+0.00(TN)+0.16(MN)	56.84	0.62	0.63	0.00	0.16	-
MW=0.51+0.15(MN)	56.83	0.62	0.51	-	0.15	-
MW=-1.00+0.13(MN)+0.11(TW)	49.43	0.71	-1.00	-	0.13	0.11
MW=-0.32-0.04(TN)+0.17(MN)+0.16(TW)	45.03	0.76	-0.32	-0.04	0.17	0.16
Trellis						
MW=0.95+0.06(TN)	74.33	0.23	0.95	0.06	-	-
MW=1.38+0.15(TW)	72.46	0.27	1.38	-	-	0.15
MW=0.66+0.03(TN)+0.10(TW)	71.21	0.30	0.66	0.03	-	0.10
MW=0.73+0.00(TN)+0.18(MN)	57.41	0.54	0.73	0.00	0.18	-
MW=0.97+0.18(MN)	57.47	0.54	0.97	-	0.18	-
MW=-0.46+0.16(MN)+0.09(TW)	51.27	0.64	-0.46	-	0.16	0.09
MW=0.27-0.04(TN)+0.20(MN)+0.16(TW)	47.55	0.69	0.27	-0.04	0.20	0.16

[z] Regression calculations made with plot weights in Mg/ha and fruit numbers in thousands/ha.

Table 6.3. Predicted regression equations for cull fruit weight (CW) based on total fruit number (TN), cull fruit number (CN), and total fruit weight (TW).[z]

Equation	CV	R^2	Inter-cept	Total number	Cull number	Total weight
Pickling						
CW=0.93+0.04(TW)	94.35	0.05	0.93	-	-	0.04
CW=0.28+0.02(TN)	88.11	0.17	0.28	0.02	-	-
CW=0.26+0.02(TN)+0.00(TW)	88.16	0.17	0.26	0.02	-	0.00
CW=0.42+0.0(TN)+0.08(CN)	58.74	0.63	0.42	0.00	0.08	-
CW=0.34+0.08(CN)	58.78	0.63	0.34	-	0.08	-
CW=-0.07+0.08(CN)+0.03(TW)	56.57	0.66	-0.07	-	0.08	0.03
CW=0.15-0.01(TN)+0.09(CN)+0.05(TW)	54.63	0.68	0.15	-0.01	0.09	0.05
Slicing						
CW=0.83+0.05(TW)	110.07	0.10	0.83	-	-	0.05
CW=0.01+0.03(TN)	100.14	0.25	0.01	0.03	-	-
CW=0.04+0.03(TN)-0.01(TW)	100.24	0.25	0.04	0.03	-	-0.01
CW=0.27+0.00(TN)+0.10(CN)	77.49	0.55	0.27	0.00	0.10	-
CW=0.48+0.10(CN)	77.76	0.55	0.48	-	0.10	-
CW=-0.04+0.10(CN)+0.03(TW)	74.61	0.59	-0.04	-	0.10	0.03
CW=0.12-0.01(TN)+0.11(CN)+0.05(TW)	73.76	0.60	0.12	-0.01	0.11	0.05

Table 6.3. continued.

Equation	CV	R^2	Inter-cept	Total number	Cull number	Total weight
Beit Alpha						
CW=1.04+0.04(TW)	101.28	0.03	1.04	-	-	0.04
CW=0.20+0.02(TN)	93.98	0.17	0.20	0.02	-	-
CW=0.27+0.03(TN)-0.01(TW)	93.92	0.17	0.27	0.03	-	-
	0.01					
CW=0.45+0.00(TN)+0.09(CN)	68.91	0.55	0.45	0.00	0.09	-
CW=0.40+0.09(CN)	68.88	0.55	0.40	-	0.09	-
CW=-0.15+0.09(CN)+0.03(TW)	66.40	0.59	-0.15	-	0.09	0.03
CW=0.10-0.02(TN)+0.11(CN)+0.06(TW)	63.70	0.62	0.10	-0.02	0.11	0.06
Trellis						
CW=-0.19+0.06(TN)	82.99	0.30	-0.19	0.06	-	-
CW=0.52+0.15(TW)	83.14	0.30	0.52	-	-	0.15
CW=-0.43+0.04(TN)+0.09(TW)	79.97	0.35	-0.43	0.04	-	0.09
CW=0.59+0.16(CN)	67.06	0.54	0.59	-	0.16	-
CW=0.22+0.01(TN)+0.14(CN)	66.80	0.55	0.22	0.01	0.14	-
CW=-0.88+0.13(CN)+0.09(TW)	58.65	0.65	-0.88	-	0.13	0.09
CW=-0.11-0.05(TN)+0.18(CN)+0.16(TW)	54.18	0.70	-0.11	-0.05	0.18	0.16

[z] Regression calculations made with plot weights in Mg/ha and fruit numbers in thousands/ha.

General References

Arora, S. K., M. L. Pandita, P. S. Partap and A. S. Sidhu. 1985. Effect of ethephon, gibberellic acid, and maleic hydrazide on vegetative growth, flowering, and fruiting of cucurbitaceous crops. J. Amer. Soc. Hort. Sci. 110: 442-445.

Atsmon, D. and E. Galun. 1962. Physiology of sex in *Cucumis sativus* (L.) leaf age patterns and sexual differentiation of floral buds. Ann. Bot 26: 137-146.

Burg, S. P. and E. A. Burg. 1966. The interaction between auxin and ethylene and its role in plant growth. Proc. Nat. Acad. Sci. U.S.A. 55: 262-269.

Cantliffe, D. J. 1981. Alteration of sex expression in cucumber due to changes in temperature, light intensity and photoperiod. J. Amer. Soc. Hort. Sci. 106: 133-136.

Cantliffe, D. J. and S. C. Phatak. 1975. Use of ethephon and chlorflurenol in a once-over pickling cucumber production system. J. Amer. Soc. Hort. Sci. 100: 264-267.

Cargill, B. F., D. E. Marshall and J. H. Levin. 1975. Harvesting cucumbers mechanically. Mich. State Univ. Ext. Bull. 859.

Chen, L. H., C. H. Miller and R. S. Sowell. 1975. Simulation models for harvesting of pickling cucumbers. J. Amer. Soc. Hort. Sci. 100: 176-179.

Colwell, H. T. M. and J. O'Sullivan. 1981. Economics of harvest timing for once over harvesting of cucumbers. J. Amer. Soc. Hort. Sci. 106: 163-167.

Cramer, C. S. and T. C. Wehner. 1998. Stand correction methods for cucumber fruit yield. Cucurbit Genet. Coop. Rpt. 21: 18-20.

Cramer, C. S. and T. C. Wehner. 1998. Stand correction methods for cucumber fruit yield. Cucurbit Genet. Coop. Rpt. 21: 18-20.

Dhillon, H. S. 1966. Sex expression and sex determination in Cucurbitaceae. Indian J. Agr. Sci. 53: 437-441.

Edmond, J. B. 1931. Seasonal variation of sex expression of certain cucumber varieties. Proc. Amer. Soc. Hort. Sci. 27: 329-332.

El-Bakry, A. M., H. M. Goma, A. F. Omran and E. T. El-kholy. 1978. Effects of yield and fruit quality of cucumber. Annals of Agric. Sc. Moshtohor 10: 127-132.

Ells, J. E. and A. E. McSay. 1981. Yield comparisons of pickling cucumber cultivar trials for once-over harvesting. HortScience 16: 187-189.

Galun, E. 1959. The role of auxin in the sex expression of the cucumber. Physiol. Plant 12: 48-61.

Galun, E. 1961. Study of the inheritance of sex expression. The inheritance of major genes with modifying genetic and non-genetic factors. Genetica 32: 134.

George, W. L. Jr. 1971. Influence of genetic background on sex conversion by 2-chloroethanephosphonic acid in monoecious cucumbers. J. Amer. Soc. Hort. Sci. 96: 152-154.

Harlan, J. R. 1975. Crops and man. Am. Soc. Agron., Crop Sci. Soc. Am., Madison, WI.

Heslop-Harrison, J. 1957. The experimental modification of sex expression in flowering plants. Biol. Rev. 32: 38-90.

Hogue, E. J. and H. B. Heeney. 1974. Ethephon and high density plantings increase yield of pickling cucumbers. HortScience 9: 72-74.

Iwahori, S., J. N. Lyons and O.E. Smith. 1970. Sex expression in cucumber as affected by 2-chloroethanephosphonic acid, ethylene and growth regulators. Plant Physiol. 46: 412-415.

Karchi, Z. 1970. Effects of 2-chloroethanephosphonic acid on flower types and flowering sequences in muskmelon. J. Amer. Soc. Hort. Sci. 95: 515-518.

Lower, R. L., C. H. Miller, F. H. Baker, and C. L. Combs. Effects of 2-chloroethylphosphonic acid treatment at various stages of cucumber development. HortScience 5: 433-434.

Malepszy, S. and K. Niemirowicz-Szczytt. 1991. Sex determination in cucumber (*Cucumis sativus*) as a model system for molecular biology. Plant Science 39-47.

McMurray, A. L. and C. H. Miller. 1968. Cucumber sex expression modified by 2-chloroethanephosphonic acid. Science 162: 1396-1397.

McMurray, A. L. and C. H. Miller. 1969. The effect of 2-chloroethanephosphonic acid (ethrel) on the sex expression and yields of *Cucumis sativus*. J. Amer. Soc. Hort. Sci. 94: 400-402.

Miller, C. H. and G. R. Hughes. 1969. Harvest indices for pickling cucumbers in once-over harvest systems. J. Amer. Soc. Hort. Sci. 94: 485-487.

Miller, C. H., and R. L. Lower. 1972. Effect of ethephon on fresh-pack and brined cucumbers. HortScience 7: 418-420.

Miller, C. H., R. L. Lower and A. L. McMurray. 1969. Some effects of ethrel (2-chloroethanephosphonic acid) on vegetable crops. HortScience 4: 248-249.

Miller, C. H., R. L. Lower and H. P. Fleming. 1970. Evaluation of pickles from cucumber plants treated with 2-chloroethylphosphonic acid. HortScience 5: 434-435.

Mitchell, W. D. and S. H. Wittwer. 1962. Chemical regulation of flower sex expression and vegetative growth in *Cucumis sativus* L. Science 136: 880-881.

Nerson, H., H. S. Paris, Z. Karchi, A. Govers, M. Edelstein and Y. Burger. 1987. Comparison of fruit-set concentration of pickling cucumbers under greenhouse and field conditions. Cucurbit Genet. Coop. Rpt. 10: 2-3.

Nitsch, J. P., E. B. Kurz, Jr., J. L. Liverman, and F. W. Went. 1952. The development if sex expression in cucurbit flowers. American J. Bot. 39: 32-43.

Peterson, C. E. 1975. Plant introductions in the improvement of vegetable cultivars. HortScience 10: 575-579.

Peterson, C. E. and L. D. Anhder. 1960. Induction of staminate flowers in gynoecious cucumber with GA_3. Science 131: 1673-1674.

Pratt, H. K. and J. D. Goeschl. 1969. Physiological roles of ethylene in plants. Annual Review of Plant Physiology 20: 541-584.

Robinson, R. W., H. M. Munger, T. W. Whitaker and G. W. Bohn. 1976. Genes of Cucurbitaceae. HortScience 11: 554-568.

Robinson, R. W., S. Shannon, and M. D. de la Guardia. 1968. Regulation of sex expression in the cucumber. BioScience 19: 141-142.

Rudich, J., A. H. Halevy, and N. Kedar. 1969. Increase in femaleness of three cucurbits by treatment with Ethrel, an ethylene releasing compound. Planta 86: 69-76.

Rudich, J., A. H. Halevy, and N. Kedar. 1972. The levels of phytohormones in monoecious and gynoecious cucumbers as affected by photoperiod and ethephon. Plant Physiol. 50: 585-590.

Sadhu, M. K. and P. C. Das. 1978. Effect of ethrel (ethephon) on the growth, flowering and fruiting of three cucurbits. J. Hort Science 53: 1-4.

SAS Institute. 1989. SAS/STAT User's guide, Release 6.12 edition. SAS Institute Inc., Cary, NC.

Schultheis, J. R. 1990. Pickling cucumbers. N.C. State Ag. Extension. Horticulture Information Leaflet No. 14-A.

Shannon, S. and M. D. De La Guardia. 1969. Sex expression and the production of ethylene induced by auxin in the cucumber (*Cucumis sativus* L.). Nature 223: 186.

Shannon, S. and R. W. Robinson. 1978. Genetic differences in sex-expression and responses to ethephon in summer squash (*Cucurbita pepo* L.). Cucurbits Genetic Coop. 1: 33.

Shetty, N. V. and T. C. Wehner. 2000a. Effect of Ethrel and Harvest on Pickling Cucumber Yield and Quality. Crop Science (in review)

Shetty, N. V. and T. C. Wehner. 2000b. Effect of Ethrel and Harvest on Slicing Cucumber Yield and Quality. HortScience (in review)

Shetty, N. V. and T. C. Wehner. 2000c. Effects of ethrel on vegetative and floral traits in cucumbers. Euphytica (in review)

Shetty, N. V. and T. C. Wehner. 2000d. Effect of Ethrel on Isogenic lines of Cucumber for Gynoecious Sex Expression. Scientia Horticulturae (in review)

Shetty, N. V. and T. C. Wehner. 2000e. Efficient Estimation of Fruit Grade Weights Based on Fruit Number and Total Fruit Weight in Cucumber. HortScience (in review).

Shifriss, O. 1961. Sex control in cucumbers. J. Hered. 52: 5.

Sitterly, W. R. 1972. Breeding for disease resistance in cucurbits. Ann. Rev. Phytopathology 10: 471.

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

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size for measurement of yield in multiple and once over harvest trials of pickling and fresh market cucumbers. Euphytica 35: 493-501.

Swallow, W. H. and T. C. Wehner. 1986. Optimum plot size for measurement of yield in multiple and once over harvest trials of pickling and fresh market cucumbers. Euphytica 35: 493-501.

Swallow, W. H. and T. C. Wehner. 1989. Optimum allocation of plots to years, seasons, locations, and replications, and its applications to once-over harvest cucumber trials. Euphytica 43: 59-68.

Tatlioglu, T. 1993. Cucumbers. In: Genetic Improvement of vegetable crops. (Ed.) G. Kalloo and B.O. Bergh. Pergamon Press.

Tiedjens, V. A. 1928. Sex-ratios in cucumber flowers affected by different conditions of soil and light. J. Agr. Res. 36;721-746.

U. S. Department of Agriculture. 1959-98. Agricultural statistics. U. S. Government Printing Office, Washington D. C.

Warner, H. L. and A. C. Leopold. 1969. Ethylene evolution from 2-chloroethylphosphonic acid. Plant Physiology 44: 156-158.

Wehner, T. C. 1986. Efficiency of 3 single-harvest tests for evaluation of yield in pickling cucumber. Euphytica 35: 493-501.

Wehner, T. C. 1987. Value of 12 season-location combinations for cucumber yield trials in North Carolina. Cucurbit Genet. Coop. Rpt. 6: 38-39.

Wehner, T. C. 1987b. Genotype-environment interaction for cucumber yield in 23 North Carolina environments. Cucurbit Genet. Coop. Rpt. 10: 25-26.

Wehner, T. C. 1989. Breeding for improved yield in cucumber. Plant Breed. Rev. (Ed.) J. Janick. Vol. 6: 323-359.

Wehner, T. C. 1989. Breeding for improved yield in cucumber. Plant Breed. Rev. (Ed.) J. Janick. Vol. 6: 323-359.

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: 659-664.

Wehner, T. C. and C. H. Miller. 1987. Optimum plant density for multiple-harvest yield of determinate cucumbers. Cucurbit Genet. Coop. Rpt. 10: 29-30.

Wehner, T. C., T. J. Monaco and A. R. Bonanno. 1984. Chemical defoliation of cucumber vines for simulation of once-over harvest in small-plot yield trials. HortScience 19: 671-673.

Yang, S. F. 1969. Ethylene evolution from 2-chloroethylnephosphonic acid. Plant Physiology 44: 1203-1204.