ABSTRACT

ARTEMAN, LAUREN J'NE. Parthenocarpic Pickling Cucumber Production in North Carolina (Under the direction of Dr. Todd C. Wehner and Dr. Jonathan R. Schultheis).

Parthenocarpic pickling cultivars have the potential to be higher yielding than seeded cultivars for U.S. production. However, information regarding production of parthenocarpic pickling cucumbers for open field conditions is limited. Before growers are likely to purchase seed that is four times more expensive than conventional seed evaluation of production methods is needed.

We conducted two studies in 2014 and 2015 to determine the effect of plant density, season, and cultivar on yield and quality of fruit in a multi-pick (hand harvest) system and a simulated once-over mechanical harvest system. We were interested in seed costs and returns based on current processor prices for parthenocarpic pickles. In a third study, we evaluated the available cultivars suitable for production in the southeast U.S. for yield, greenstock quality, and brinestock quality.

We found that plant density, season, harvest timing, and cultivar affected yield and economic return in both studies. Optimum plant density for hand harvest systems was lower than plant densities currently used for conventional (seeded) cucumbers. We found that a range of plant densities above and below the current recommendation for mechanical harvest systems would be appropriate for these cultivars. Based on results from each of our studies, we confirmed a potential for higher yields with the use of parthenocarpic pickling cucumbers.

Parthenocarpic pickling cucumber production in North Carolina

by
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DEDICATION

For my parents, and my best friend.

BIOGRAPHY

I grew up on our family farm outside of Bellflower, IL with my two brothers. My parents Brian and Angela helped foster my love for landscaping and growing food. I participated in 4-H during my childhood and FFA during high school. These programs helped focus my passion on horticulture and agriculture education. From 2010 to 2014, I pursued a B.S. in Plant and Soil Science at Southern Illinois University, Carbondale. During my time at SIUC, I held varying jobs at the different crop research facilities on campus and my love for horticulture and education grew. It became apparent that I should pursue my M.S. in Horticultural Science. I am currently working in Ag Solutions at BASF. Following the completion of my degree, I wish to prepare plans to start a small fruit and vegetable farm.

ACKNOWLEDGMENTS

I would like to thank my major advisors Dr. Todd Wehner and Dr. Jonathan Schultheis for their guidance during my MS studies. I would also like to thank Gary Bullen for his input throughout the project and Dr. Chris Gunter for joining us so late in the game. I can't forget Brad Thompson for serving as a guide in the field during both summers. Special thanks for fellow students Kyle VandenLangenberg and David Suchoff for their friendship and support. Finally, I would like to thank our lab teams and the crew at the Cunningham Research Station in Kinston, NC for the many hours of hard work on these experiments.

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A Review of Parthenocarpy and Plant Density in Pickling Cucumber (*Cucumis sativus* L.)

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Cucumber

Cucumber (*Cucumis sativus* L.), a member of the Cucurbitaceae family, is the fourth most important vegetable crop grown worldwide, after tomato (*Lycopersicon esculentum* Mill.), cabbage (*Brassica oleracea* var. *capitata* L.), and onion (*Allium cepa* L.) (Tatlioglu, 1993). Cucumbers are a versatile crop. The fruit are eaten freshly sliced in salads, pickled, or used as juice for dressings. The seeds, young leaves, and stems are also eaten in Asia while French cuisine utilizes the oil of cucumber seeds (Robinson and Decker-Walters, 1997). Besides its culinary value, cucumber is also used in lotions, perfumes, and soaps.

Cucumber types include: American slicing, American and European pickling, middle-eastern Beit Alpha, oriental trellis, and European parthenocarpic greenhouse types (Shetty and Wehner, 2002). In 2015, the United States (US) harvested 34,443 ha of pickling cucumbers and 16,212 ha of fresh market cucumbers (USDA NASS, 2016). Pickling cucumbers were valued at $172,715,000 and fresh market cucumbers were value at $176,983,000 in 2015 (USDA NASS, 2016).

Parthenocarpy

Parthenocarpy is the ability of plants to form fruits without pollination or fertilization (Pandolfini et al., 2009). Parthenocarpy occurs in tomato, eggplant, pepper, pear, apple, and cucumber, as well as other species (Gustafson, 1942). Advantages of parthenocarpy in crop plants include seedlessness of fruit, and the ability to set fruit in absence of pollinating insects. Parthenocarpy has been recognized in cucumber since the early 1900s (Gustafson, 1942).

Parthenocarpic cucumbers will be seedless if they are not pollinated. Normally, cucumber cultivars are sold as a blend of gynoecious (88%) and monoecious (12%) types to provide pollen for fruit set (Wehner and Maynard, 2003). For successful parthenocarpic production, cultivars should be highly gynoecious, no pollenizer should be added to the blend that is sold to growers, and growers should not hire beekeepers to provide the usual 2 to 3 hives/ha. Thus, growers save on the cost of bees. The development of fruit prior to anthesis may allow for earlier fruit production and harvest (Pandolfini et al., 2009).

Parthenocarpy in crop plants, and specifically cucumber, can be natural or artificial. Auxin transport-inhibiting chemicals are effective in producing parthenocarpic fruit in cucumbers (Cantliffe, 1972; Beyer and Quebedeaux, 1974). Cantliffe (1972) investigated the ability of nine growth-regulating chemicals to induce parthenocarpy on one cultivar of pickling cucumber in the greenhouse. A significant increase of parthenocarpic fruit set was found with the applications of a morphactin formulation (IT 3456), TIBA, and CCDP. Robinson et al. (1971) investigated morphactin (chlorflurenol) as a chemical means to induce parthenocarpy in cucumbers, both monoecious and gynoecious, which were not genetically parthenocarpic. A combination of ethrel and chlorflurenol sprays resulted in parthenocarpic fruit development. They concluded that foliar chlorflurenol application was an effective way of increasing yield, as well as uniformity and earliness of the cultivars tested (Robinson et al, 1971). In 1976, Cantliffe studied the efficacy of ethephon and chlorflurenol on fruit set of conventional and parthenocarpic cucumbers in both greenhouse and field environments. The ethephon treatment resulted in higher numbers of female flowers on the plants and the combination proved to be effective in enhancing yield of parthenocarpic cultivars (Cantliffe, 1976). Dean and Baker (1983) studied the effects of chlorflurenol as a means to increase yield of four cultivars of gynoecious pickling cucumbers, including two that were parthenocarpic. They determined that the parthenocarpic cultivars tested were higher yielding, regardless of treatment with chlorflurenol, but that the treatment did enhance the performance of the parthenocarpic cultivars. The non-parthenocarpic cultivars were less responsive to the chlorflurenol application.

Although parthenocarpy can be induced with plant growth regulators, genetic parthenocarpy is more economical for commercial production. Parthenocarpic slicing cucumbers became important in glasshouse production in Europe in the 1950s (Ponti, 1976). Advantages included seedless fruit for the consumer, and no need for pollinating insects for the grower. Beginning in the 1960s, genetically parthenocarpic pickling cucumbers were developed for production in Europe, especially in areas that were less conducive to bee activity due to rainfall and cool temperatures at flowering time (Baker et al., 1973; Pike and Peterson, 1969). Early studies of parthenocarpic pickling cucumbers showed an advantage in higher yields compared with non-parthenocarpic types, but disadvantages in fruit quality (softness and bloating) in fermentation and processing factories (Dean and Baker, 1983; Denna, 1973; Ponti, 1976; Zwinkels, 1988). However, parthenocarpic pickling cucumber cultivars remained desirable because fruit set was not affected in environments where pollination conditions were unfavorable. First-fruit inhibition was also reduced in parthenocarpic cucumbers (Denna, 1973), resulting in more fruit per plant.

Recently, the improvement of fruit firmness and bloater resistance has made parthenocarpic pickling cucumbers attractive to producers in the U.S. However, information regarding the production of parthenocarpic pickling cucumber in open field conditions is needed.

Plant density

Plant growth is affected by population density (Cantliffe and Phatak, 1975; Tan et. al., 1983; Neinhuis et. al., 1984; Widders and Price, 1989). Light, water, and nutrient availability all become limited at high planting density (O'Sullivan, 1980; Ortega and Kretchman, 1982; Tan et al, 1983). For multiple harvest systems, cucumbers are often grown at 62,000 plants/ha. For once-over systems using machines for harvest, the optimum density is 2 to 3 times higher. Numerous studies have demonstrated that pickling cucumber yield is affected by plant density (Cantliffe and Phatak, 1975; Chambliss and Turner, 1972; Morrison and Ries, 1967; Schultheis et al., 1998; Wann, 1993). Determining this effect can be difficult since plant genotype and growing environment also affect plant growth (Neinhuis et al., 1984).

In pickling cucumber production, both crown fruit dominance and the reduction of yield in once-over mechanical harvest (compared to multiple-harvest systems) have led to studies of high population density (Cantliffe and Phatak, 1975; Chambliss and Turner, 1972; Downes et al., 1972; Morrison and Ries, 1967; O'Sullivan, 1980). Morrison and Ries (1967) studied different cultural practices for machine harvest of cucumbers for pickling and reported that the highest plant density tested (31.5 thp/ha) gave the greatest return in dollars/ha. Widders and Price (1969) investigated the effects of plant density, specifically between-row and within-row spacing, on the growth and biomass partitioning of two cultivars of pickling cucumber. They determined that a reduction of between-row spacing to increase the plant density was less than that of the reduction of within-row spacing on shoot growth and leaf area index (Widders and Price, 1969). Highest fruit yields in once-over systems were achieved with lower plant densities (Widders and Price, 1969). In contrast, Cantliffe and Phatak (1975) showed that a plant density of 500,000 plants/ha gave significantly higher yield over densities of 50,000 to 250,000 plants/ha. O'Sullivan (1980) also showed significant yield increases when increasing plant densities from 190,000 to 740,000 plants/ha, but expressed the need for supplemental irrigation when using high plant densities. Wann (1993) evaluated eight cultivars at several plant densities and spatial arrangements to determine their effect on yield. This research showed no interaction between cultivar and plant density and suggested that a plant density between 160,000 plants/ha and 215,000 plants/ha would be acceptable at locations with similar environmental conditions. Schultheis et al. (1998) studied the effect of plant density and harvest stage on three pickling cucumber cultivars including a little leaf line (H-19) and two normal-leaf cultivars. Little leaf plants are parthenocarpic and have small leaves and multibranched vines (Goode et al., 1980). Its concentrated fruit set, high fruit to vine ratio, and improved growth in adverse conditions (dry and windy) made it advantageous over normal-leaf cultivars (Wehner et. al, 1987). H-19 was higher yielding than the other cultivars and reached the highest dollar value at a plant density of 330,000 plants/ha, while densities of 200,000 and 240,000 plants/ha were ideal for cultivars Sumter and Regal, respectively (Schultheis et al. 1998). Thus, optimum plant density for yield or economic return was cultivar-specific.

Justification

Parthenocarpic pickling cucumbers have potential for commercial field production in the United States. Seed companies including Rijk Zwaan, Nunhems, and Seminis Vegetable Seeds have cultivars suitable for production in the southeast U.S. Before growers are likely to purchase seed that is four times more expensive than conventional ($12 for seedless vs. $3 for seeded) (Chris Dyk, personal communications; Bayer Crop Science), evaluation of production methods is needed. Optimum plant density for high yield and quality of seedless pickling cucumbers in once-over and multiple-harvest systems will be the first step in optimizing production practices. Seed costs and returns based on current prices will be important considerations in the determination of optimum density.

References

Baker, L.R., Scott, J.W., Wilson, J.E. 1973. Seedless pickles, a new concept (Research Report No. 227). Michigan State University.

Beyer, E.M., Quebedeaux, B. 1974. Parthenocarpy in cucumber: mechanism of action of auxin transport inhibitors. J. Am. Soc. Hortic. Sci. 99:385–390.

Cantliffe, D.J. 1972. Parthenocarpy in the cucumber induced by some plant growth-regulating chemicals. J. Plant Sci. 52:781-785.

Cantliffe, D.J. 1974. Alteration of growth and flowering habit in cucumber by chlorflurenol. Can. J. Plant Sci. 54:771-776.

Cantliffe, D.J., Phatak, S.C. 1975. Plant population studies with pickling cucumbers grown for once-over harvest. J. Am. Soc. Hortic. Sci. 100:464–466.

Cantliffe, D.J. 1976. Improved fruit set on cucumbers by plant growth regulator sprays. Proc. Fla. State Hort. Soc. 89:94-96.

Chambliss, O. L., Turner, J. L. 1972. High density plantings give higher production of cucumbers, southern peas. Highlights Agric. Res. - Ala. Agric. Exp. Stn. 19:10–10.

Dean, B.B., Baker L.R. 1983. Parthenocarpy in gynoecious cucumber as affected by chlorflurenol, genetical parthenocarpy, and night temperatures. HortScience 18(3):349-351.

Denna, D.W. 1973. Effects of genetic parthenocarpy and gynoecious flowering habit on fruit production and growth of cucumber (*Cucumis sativus* L.). J. Am. Soc. Hortic. Sci. 98: 602–604.

Downes, J.D., Carpenter, T.G., Reed, R.R. 1972. Plant Populations and Harvest Scheduling of Pickling Cucumbers for Once-Over Machine Harvesting. HortScience 7(3):337 (Abstr.).

Goode, M. J., Bowers, J.L. and Bassi, A. Jr. 1980. Little-leaf, a new kind of pickling cucumber plant. Arkansas Farm Res 29(3):4.

Gustafson, F.G. 1942. Parthenocarpy: Natural and Artificial. Bot. Rev. 8:599–654.

Morrison, F.D., Ries, S.K. 1967. Cultural requirements for once-over mechanical harvest of cucumbers for pickling. J. Am. Soc. Hortic. Sci. 91:339-346.

Neinhuis, J., Lower, R.L., Miller, C.H. 1984. Effects of genotype on the stability of sex expression in cucumber. HortScience 19:273-274.

Ortega, D.G., Kretchman, D.W. 1982. Water stress effects on pickling cucumber. J.Amer. Soc. Hort. Sci. 107(3):409-412.

O'Sullivan, J. 1980. Irrigation, spacing and nitrogen effects on yield and quality of pickling cucumbers grown for mechanical harvesting. Can. J. Plant Sci. 60:923–928.

Pandolfini, T., Molesini, B., Spena, A. 2009. Parthenocarpy in Crop Plants, in: Østergaard, L. (Ed.), Annual Plant Reviews Volume 38: Fruit Development and Seed Dispersal. Wiley-Blackwell, 326–345.

Pike, L.M., Peterson, C.E. 1969. Inheritance of parthenocarpy in the cucumber (*Cucumis sativus* L.). Euphytica 18:101–105.

Ponti, O.M.B. de.1976. Breeding parthenocarpic pickling cucumbers (*Cucumis sativus* L.): Necessity, genetical possibilities, environmental influences and selection criteria. Euphytica 25:29–40.

Robinson, R.W., Decker-Walters, D.S. 1997. Cucurbits. CAB International, Wallingfod, Oxon; New York, N.Y.

Robinson, R.E., Cantliffe, D.J., Shannon, S. 1971. Morphactin-induced parthenocarpy in the Cucumber. Science. 171:1251-1252.

Schultheis, J.R., Wehner, T.C., Walters, S.A. 1998. Optimum planting density and harvest stage for little-leaf and normal-leaf cucumbers for once-over harvest. Can. J. Plant Sci. 78:333–340.

Shetty, N.V., Wehner, T.C. 2002. Screening the cucumber germplasm collection for fruit yield and quality. Crop Sci. 42:2174–2183.

Tan, C.S., Nuttall, V.W., Fulton, J.M. 1983. The influence of soil moisture stress and plant populations on the yield of pickling cucumbers. Sci. Hortic. 21: 217–224.

Tatlioglu, T. 1993. Cucumbers. In: Kalloo, G. and B.O. Bergh. eds. Genetic improvement of vegetable crops. Pergamon Press, New South Wales, Australia.

United States Department of Agriculture, National Agricultural Statistics Service. 2016. Cucumbers: National Statistics. 2016. <http://www.nass.usda.gov/>

Wann, E.V. 1993. Cucumber Yield Response to Plant Density and Spatial Arrangement. J. Prod. Agric. 6.

Wehner, T.C., Staub, J. E. and Peterson, C. E. 1987. Inheritance of litteleaf and multi-branched plant type in cucumber. Cucurbit Genetics Cooperative Report 10: 33-34.

Wehner, T.C., Maynard, D.N. 2003. Cucumbers, Melons, and Other Cucurbits. In: Encyclopedia of Food and Culture. 474-479.

Widders, I.E., Price, H.C. 1989. Effects of plant density on growth and biomass partitioning in pickling cucumbers. J. Am. Soc. Hortic. Sci. 114:751–755.

Zwinkels, L. A. M. 1988. The present situation and future development in breeding of parthenocarpic pickling cucumber. Acta Hortic. 129–133.

Chapter Two

Plant Density, Harvest Stage, Cultivar, and Season Affect Economic Profitability of Parthenocarpic Cucumber in a Once-over Mechanical Harvest System

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Plant Density, Harvest Stage, Cultivar, and Season Affect Economic Profitability of Parthenocarpic Cucumber in a Once-over Mechanical Harvest System

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Abstract

Parthenocarpic pickling cucumbers are potentially higher yielding than seeded types. Information regarding production of parthenocarpic pickling cucumbers for mechanical harvest is limited. We evaluated the effect of plant density and harvesting time on yield, profitability, and fruit quality for two commercially available cultivars in two years. The experiment was a randomized complete block with 2 years (2014, 2015), 2 seasons (spring, summer), 2 cultivars (‘Merengue’, ‘Puccini’), 3 harvest stages (early, mid, late), 5 densities (8 in 2015), and 3 replications. Yield data along with data including the number of fruit per plant were collected upon harvest. At the plant density of 198 thousand plants per hectare, around 30% of the plants did not produce any fruit. Based on current seed costs, densities as low as 100 thousand plants per hectare may be sufficient for a good economic return. The late harvest resulted in highest economic return, but also in the largest percentage of oversize fruit.

Introduction

Cucumber (*Cucumis sativus* L.) is a member of the Cucurbitaceae family and the fourth most widely cultivated vegetable in the world (Pitrat et al, 1999). In 2015, there were 15,400 hectares of fresh market cucumbers harvested and 34,500 hectares of pickling cucumbers in the United States (USDA NASS, 2017). Michigan, Florida, and Georgia ranked top three in cucumber producers with North Carolina following at number 5 in the United States in 2015 (USDA NASS, 2017).

Pickling cucumbers accounted for $162 million of agricultural industry in the United States in 2015 (USDA NASS, 2017). Pickling cucumbers are harvested by hand, usually in six or more harvests, and by machine, usually a single destructive harvest. While the predominant form of harvest for pickling cucumbers in North Carolina is by hand, once-over mechanically harvested systems are used more widely in other pickling cucumber producing states, such as Michigan and Wisconsin.

Parthenocarpic pickling cucumbers are seedless and do not require pollinating insects for fruit development. Open field production of parthenocarpic pickling cucumbers has recently become popular with growers in the U.S. due to the potential for high yield. Recent improvements in fruit firmness and bloater resistance have made cultivars commercially viable. However, more information is needed to optimize production practices for parthenocarpic cultivars.

Plant density affects growth and yield in non parthenocarpic pickling cucumber (Cantliffe and Phatak, 1975; Tan et al., 1983; Wann, 1993; Widders and Price, 1989). At high plant density, light, water, and nutrient availability all become limited. The effect of plant density on yield and quality of pickling cucumber has been studied extensively, especially in once-over systems using machines for harvest (Morrison and Ries, 1967; O'Sullivan, 1980; Schultheis et al., 1998; Wann, 1993). However, no reports have been published for parthenocarpic cultivars. Current plant densities of about 72,000 plants per hectare are being used for seedless pickling cucumber production for machine harvest in Michigan to account for the increased seed cost (Phillips, 2016). Timing of harvest in once-over systems has significant effects on yield (Miller and Hughes, 1969; Morrison and Ries, 1967; Schultheis et al., 1998). Miller and Hughes (1969) suggested that maximum returns could be obtained by harvesting when 14 to 31% of total weight was in oversized fruit. Schultheis et al. (1998) reported that a harvest stage of 10% oversize fruit was optimum for fruit quality and dollar value in a study evaluating different types, including littleleaf and determinate cultivars.

The objective of this study was to evaluate the effect of plant density and harvest time on the yield and quality of two parthenocarpic pickling cucumber cultivars, and to provide recommendations to growers for open field production in once-over mechanically harvested systems.

Materials and Methods

The study was conducted at the Cunningham Research Station in Kinston, NC to isolate these trials from non-parthenocarpic cucumbers. Cultivars 'Puccini' (Rijk Zwaan; Salinas, CA) and 'Merengue' (Seminis Vegetable Seeds, Inc.; St. Louis, MO) were seeded at 5 plant densities in 2014 and 8 plant densities in 2015. Harvests of each plot were made over a 5 to 9-day period to target developmental stages that averaged 10%, 25%, and 50% oversize fruit. The experiment was a randomized complete block with 2 years, 2 seasons, 2 cultivars, 5 (8 in 2015) densities, 3 harvest stages, and 3 replications. The years were 2014 and 2015, the seasons were spring and summer, and the harvest stages were early, mid (approximately half week later), and late (about a full week later).

2014. Five plant densities (25, 49, 99, 198, and 395 thousand plants per hectare) were evaluated. The spring season study was planted 6 May. Harvest occurred 50 DAP (24 June), 53 DAP (27 June), and 56 DAP (30 June). The summer season study was planted on 17 June. Harvest occurred 41 DAP (28 July), 44 DAP (31 July) and 50 DAP (6 August).

2015. Three additional plant densities (148, 247, and 297 thousand plants per hectare) along with the original five (25, 49, 99, 198, and 395 thousand plants per hectare) were evaluated. The spring season study was planted on 21 May. Harvest occurred 46 DAP (6 July), 50 DAP (10 July), and 54 DAP (14 July). The summer season study was planted on 15 June. Harvest occurred 39 DAP (24 July), 42 DAP (27 July), and 44 DAP (29 July).

Cultural practices. Plots were 4 rows, each 3 m long, spaced on 76 cm centers planted in a Norfolk loamy sand (Typic Kandiudults) (NRCS, 2017). To avoid pollination of fruits, plots were spatially isolated from honeybees and other cucumbers. Plots were over-seeded by 15% of the desired density at a depth of 25 mm and covered by hand. These plots were thinned to the proper treatment density 15 days after planting (DAP). Standard production practices were followed (Schultheis et al, 2000). At each harvest date, the center 2 rows of the 4 row plots were hand pulled to simulate a destructive mechanical harvest and fruit were removed for data collection.

Data collection. Vines having 0, 1, or 2 (or more) fruit were counted in each plot at harvest. Fruit were collected and separated into grades 1 (0 to 27 mm), 2 (28 to 38 mm), 3 (39 to 51mm), 4 (greater than 51mm in diameter; oversize), and misshapen culls (nubbins, crookeds) (Wehner, 1986). Weights were summed by grade for each plot. In 2015, the number of fruit per grade was also counted. Five grade 2 fruit were measured to determine average length : diameter ratio for each plot. Fruit firmness was measured on three grade 3 fruit using a Magness-Taylor tester with an 8 mm (5/16") tip.

Data analysis. Data were subjected to PROC GLIMMIX (ANOVA), PROC REG (regression), and *post-hoc* Tukey-Kramer procedure within PROC GLIMMIX using SAS v 9.4 (SAS Institute, Cary, NC). Years were analyzed separately. Dollars per hectare and return per hectare were calculated based on the weights of the marketable fruit (grade 1, 2, and 3, excluding misshapen and oversize culls). Dollar value of marketable grades was determined using industry values (P. Denlinger, 2016, Mt. Olive Pickle Co., Mt. Olive, NC, personal communication, 2016). The values used for grades 1, 2 and 3 were $13.50/bu, $8.50/bu, and $6.00/bu, respectively. Economic return was determined using the dollar value of marketable yields, less the expense of seeds (at varying prices) to establish the desired plant density. The varying prices included $3, $6, $12, and $24/thousand seeds to represent potential changes in seed cost for parthenocarpic cultivars.

Results and Discussion

Heavy rain within three days of planting in the summer season of 2014 led to the loss of some plots. In both years, targeted harvest stages of 10%, 25%, and 50% oversize fruit (based on weight) were not met and are thus referred to as early, mid, and late harvest stages. However, delaying harvest resulted in an increased percentage of oversize (grade 4) fruit.

Fruit yield

2014 ANOVA. Marketable yield (Mg/ha) was significantly affected by three different interactions: plant density and harvest stage, plant density and cultivar, and cultivar and season. Two interactions, plant density and cultivar, and plant density and season, had significant effects on total yield (Mg/ha). The main effect of harvest stage also had a significant effect on total yield. The percentage of culls was significantly affected by the interaction of density, harvest stage, and season. The interaction between harvest stage and cultivar also had a significant effect on the percentage of culls. The percentage of oversize fruit was significantly affected by two interactions: plant density and cultivar, and cultivar and season. The main effect of harvest stage also had a significant effect on the percentage of oversize fruit (Table A2.1).

2015 ANOVA. Marketable yield was significantly affected by the interaction of all the main effects: plant density, harvest stage, cultivar, and season. The interactions of plant density and cultivar, harvest stage and season, and cultivar and season all had a significant effect on total yield. The percentage of culls was significantly affected by two interactions: plant density, harvest stage, and season, and density and cultivar. The interactions of harvest stage, cultivar, and season, plant density and cultivar, and plant density and season had significant effects on the percentage of oversize fruit (Table A2.2).

2014 Tables and Figures. Marketable yield responded quadratically as density increased for each of the three harvest stages (Figure 2.1). R-squared values ranged from 0.25 to 0.55 for the three regressions. While variability exists around these predicted regressions, yields decreased above a plant density of 198 thousand plants per hectare. According to the regression lines, greatest marketable yields could be obtained at approximately 225, 250, and 270 thousand plants per hectare at the early, mid, and late harvest stages, respectively. There was a quadratic response for marketable yield with both cultivars as plant density increased (Figure 2.2). R-squared values were 0.56 for ‘Merengue’ and 0.25 for ‘Puccini’. Predicted marketable yields were greatest for ‘Merengue’ at 270 thousand plants per hectare and at 225 thousand plants per hectare for ‘Puccini’. Again, yields were after the measured plant density of 198 thousand plants per hectare. Marketable yield was not significantly different between the spring and the summer for ‘Merengue’ while ‘Puccini’ had a significantly higher marketable yield in the spring than in the summer (Table 2.1). Our results were similar to those of Schultheis et al (1997). Optimum plant density varied based on harvest stage and cultivar, but these optimums existed in a smaller range (225 to 270 thousand plants per hectare vs. 200 to 330 thousand plants per hectare).

There was a quadratic response for total yield with respect to plant density for both cultivars (Figure 2.3). R-squared values were relatively low at 0.24 and 0.14 for ‘Merengue’ and ‘Puccini’, respectively, indicating some variability around the predicted regression equations. The highest predicted total yields were at the plant density of 245 thousand plants per hectare for ‘Merengue’ and 200 thousand plants per hectare for ‘Puccini’. The increase in yield was relatively flat between the measured plant densities of 99 and 198 thousand plants per hectare. Total yield responded quadratically as plant density increased in both the spring and the summer (Figure 2.4). R-squared values for the predicted regression equations were around 0.25 for both seasons. While the optimum plant density was around 200 thousand plants per hectare in the spring and 300 in the summer based on the regression, the relationship of plant density to total yield was rather flat after about 99 thousand plants per hectare. Yields were generally lower in the summer than in the spring. The late harvest stage produced a significantly higher total yield than the early and mid harvest stages (Table 2.2). Total yield includes marketable, culls, and oversize fruits. Delayed harvest led to an increase of oversize fruit.

The percentage of culls was not different among plant densities and harvest stage combinations in the spring (Table 2.3). This percentage was higher for the highest density at the early harvest stage in the summer, with a similar trend for the spring and the summer regardless of harvest stage. This trend could be due to water limitations caused by the increased competition at the higher plant densities. O’Sullivan (1980) found that ‘off-shape’ or cull fruit were decreased with irrigation and increased with higher plant densities. Schultheis et al. (1998) reported a linear increase of cull fruits with the increase of plant density. They also recognized differences in the percentages of cull fruit between cultivars. The percentage of culls was significantly higher for ‘Merengue’ in the spring than the summer and ‘Puccini’ in the spring and the summer (Table 2.4). This could be due to a genotype-environment interaction.

The percentage of oversize fruit was the lowest at the two highest plant densities for ‘Merengue’ while the percentage was similarly low for the three highest densities of ‘Puccini’ (Table 2.5). Increased competition between plants could have contributed to the reduction of the percentage of oversize fruit. Morrison and Ries (1967) suggested that fruit development slowed at higher plant densities. ‘Merengue’ in the spring had a higher percentage of oversize fruit compared to the summer and ‘Puccini’ in both the spring and the summer (Table 2.6). Again, a genotype-environment interaction is probably responsible. The percentage of oversize fruit corresponded with the separate harvest stages (Table 2.7). The late harvest stage had a higher percentage of oversize fruit than the mid harvest stage which had a higher percentage than the early harvest stage. We targeted 10, 25, and 50% oversize fruit, but actually had 13, 20, and 31%.

2015 Tables and Figures. The response of marketable yield to plant density was quadratic for each combination of season and harvest stage for ‘Merengue’ (Figure 2.5). R-squared values ranged from 0.19 to 0.84 depending on season and harvest stage. The predicted regressions peaked at much higher plant densities in the summer than the spring for this cultivar. The measured plant density of 148 thousand plants per hectare seemed to be the optimum with no increase for the early and mid harvest stages in both seasons. The measured plant density of 198 thousand plants per hectare was optimal for both seasons at the late harvest stage. Marketable yield responded quadratically with plant density for ‘Puccini’ for all season and harvest stage combinations (Figure 2.6). R-squared values ranged from 0.14 to 0.58. For this cultivar, the predicted optimum plant density ranged from 180 to 290 thousand plants per hectare, depending on season and harvest stage. In the spring, the measured plant density of 247 thousand plants per hectare offered the highest marketable yield for the early and later harvest stages, while the increase of yield was relatively flat as density increased after 147 thousand plants per hectare in the mid harvest stage. In the summer, marketable yield did not increase as density increased after 198 thousand plants per hectare at any harvest stage.

Total yield responded quadratically to plant density for both cultivars (Table 2.8). ‘Merengue’ produced less than ‘Puccini at most plant densities. Total yield was significantly higher at the late harvest stage in the spring than in the summer (Table 2.9). Total yield increased as harvests were delayed. There were no differences for the early and mid harvest stages by season. The total yield was significantly higher for ‘Puccini’ in the spring than in the summer and ‘Merengue’ in either season (Table 2.10).

The percentage of culls was high for the two highest densities at the early harvest stage in the summer, while all other treatment combinations were statistically similar (Table 2.11). There were differences among the percentage of culls for each density and cultivar (Table 2.12). ‘Puccini’ had a higher percentage of culls at the plant densities of 25, 198, 247, 297, and 395 thousand plants per hectare than ‘Merengue’ at the lower plant densities. Increased irrigation in 2015 could account for the difference in response of the percentage of culls to the treatments between years. Tan et al. (1983) reported that plant density had little effect on marketable yield when the plants had supplemental irrigation.

The percentage of oversize fruit generally decreased as the plant density increased for both cultivars (Table 2.13). The trend was similar for season, as plant density increased, the percentage of oversize fruit decreased (Table 2.14). This finding is consistent with our 2014 results.

Economic profitability

2014 ANOVA. Dollar value per hectare was significantly affected by three interactions: plant density and harvest stage, plant density and cultivar, and cultivar and season. Economic return was significantly affected by those same interactions (Table A2.3).

2015 ANOVA. The interaction of density, harvest stage, cultivar, and season had a significant effect on dollar value per hectare. Economic return was also significantly affected by the interaction of density, harvest stage, cultivar, and season (Table A2.4).

2014 Tables and Figures. There was a quadratic response for dollar value per hectare for each harvest stage as plant density increased (Figure 2.7). R-squared values were 0.27, 0.32, and 0.59 for regressions corresponding with the early, mid, and late harvest stages. Predicted dollar value was highest (~$6,000 per hectare) at the late harvest stage when plant densities were 280 thousand plants per hectare. Predicted dollar value was nearly the same for the early and late harvest stages at 240 and 260 thousand plants per hectare, respectively. Both cultivars had a quadratic relationship with plant density for dollar value per hectare (Figure 2.8). The R-squared value for the predicted regression for ‘Merengue’ was 0.59 and was 0.27 for ‘Puccini’. ‘Merengue’ had potentially more than $600 per hectare than ‘Puccini’ at each cultivar’s respective optimum plant density. While ‘Merengue’ yielded similarly in both spring and summer, ‘Puccini’ had a significantly higher dollar value per hectare in the spring versus the summer considered over all plant densities (Table 2.15).

The relationship between each harvest stage and the increase of plant density for return per hectare was quadratic, with greater returns when harvested late (Figure 2.9). R-squared values were between 0.37 and 0.45. Predicted return per hectare was highest at the plant density of around 190 thousand plants per hectare at the early harvest stage, 200 thousand plants per hectare for the mid harvest stage, and 240 thousand plants per hectare for the late harvest stage. The predicted optimum densities are 40 to 60 thousand plants per hectare less than those for the predicted regressions for dollar value. Ngouajiou et al. (2006) recommended including seed cost in economic analysis in studies evaluating optimum plant densities when seed prices were less than $2.00 per thousand seeds. With seed that costs $12 per thousand, considering seed cost in the economic analysis is imperative. The relationship between both cultivars and the increase in plant density was also quadratic for economic return (Figure 2.10). The R-squared values were 0.43 and 0.41 for ‘Merengue’ and ‘Puccini’, respectively. Highest predicted economic returns per hectare for ‘Puccini’ could be obtained at 180 thousand plants per hectare compared to 235 thousand plants per hectare for ‘Merengue’. Again, when seed cost is considered, the optimum plant density is lower. While economic return for ‘Merengue’ was similar in both the spring and the summer, ‘Puccini’ had a significantly higher return per hectare in the spring than the summer (Table 2.16).

2015 Tables and Figures. There was a quadratic response for ‘Merengue’ at each harvest stage as plant density increased for dollar value per hectare (Figure 2.11). R-squared values ranged from 0.23 to 0.85. Some predicted regressions were more tightly fit to the data than others. In general, the optimum plant density was lower in the spring than in the summer. The regression equations for all harvest stages in the summer for ‘Merengue’ predicted optimum plant densities above 400 thousand plants per hectare. Based on the measured plant densities, 198 thousand plants per hectare for the early and late harvest stages, and 247 thousand plants per hectare for the mid harvest stage would be optimum with regards to dollar value. 'Puccini' also had a quadratic response at all harvest stages for the relationship of plant density and dollar value per hectare. While the predicted optimum was lower for the early harvest stage in spring (~195 thousand plants per hectare with a return of $6,600/ha), the other combinations had similar predicted optimums (~240 to 300 thousand plants per ha) (Figure 2.12). R-squared values ranged from 0.23 to 0.65. Based on measured plant densities, there was not much improvement after 198 thousand plants per hectare for the late harvest stage in spring and the early and mid harvest stage in summer.

For economic return, there was a loosely fit quadratic response for 'Merengue' at the mid harvest stage in the summer as plant density increased (Figure 2.13). R-squared values ranged from 0.03 to 0.25 for the other predicted regressions for season and harvest stage combinations. The relationship between plant density and these factors was rather flat. There was no benefit to increasing plant density above 198 thousand plants per hectare, except perhaps for the mid harvest stage in the spring. In the spring, the optimum plant density was lower than in the summer for each harvest stage. 'Puccini' also had a quadratic response at all harvest stages with respect to economic return (Figure 2.14). R-squared values ranged from 0.15 to 0.49. Again, the predicted optimum plant density was lower at the early harvest stage in spring (148 thousand plants per hectare) than all other season and harvest stage combinations (ranging from 170 to 260 thousand plants per hectare).

Fruit quality measurements and fruit set

2014 ANOVA. The interaction of harvest stage and cultivar had a significant effect on length : diameter ratio. Fruit firmness was significantly affected by the interaction of harvest stage and season along with the main effect of cultivar. Four interactions: plant density and harvest stage, plant density and cultivar, plant density and season, and cultivar and season had significant effects of the percentage of vines without fruit (Table A2.5).

2015 ANOVA. The interaction of density, harvest stage, cultivar, and season significantly affected the length : diameter ratio of fruit. Fruit firmness was significantly affected by two interactions: density, cultivar, and season and harvest stage, cultivar, and season. The percentage of vines without fruit was significantly affected by the interaction of harvest stage, cultivar, and season, as well as the main effect of plant density (Table A2.6).

2014 Tables and Figures. The length : diameter ratio was significantly higher at the late harvest stage for 'Merengue' than at the early and mid harvest stages (Table 2.17). The ratio was higher for 'Puccini' at the late harvest stage than the mid, but not the early harvest stage. Tolla (1985) suggested that as the season progressed, length : diameter ratios increased within specific fruit grades. That observation did depend on environment and cultivar. The late harvest stage resulted in significantly softer fruit in the spring than the other harvest stages (Table 2.18). There was no difference in fruit firmness for the summer with regards to harvest stage. 'Merengue' had significantly softer fruit than 'Puccini' (Table 2.19).

While there were statistical differences between the harvest stage and plant density combinations for the percentage of vines without fruit, the general trend was an increase of vines without fruit as the density increased (Figure 2.15). Both 'Merengue' and 'Puccini' followed the same trend; as plant density increased, so did the percentage of vines without fruit (Figure 2.16).

Only at the highest plant density was there a greater percentage of 'Puccini' vines without fruit (65%) compared with 'Merengue' (52%). The percentage of vines without fruit was similar (~15%) for the lowest three plant densities in the spring and the summer (Figure 2.17). The plant density of 198 thousand plants per hectare resulted in statistically lower fruitless vines than the highest plant density of 395 thousand plants per hectare. The general trend of an increase of vines without fruit at increased plant densities is consistent with the findings of Morrison and Ries in 1967. Although, they were investigating plant arrangement, as well.*

2015 Tables and Figures. Differences due to treatment in length : diameter ratio were minimal (Table 2.20). A few specific two-way comparisons (i.e. 'Merengue', early harvest stage in the spring at 297 thousand plants per hectare with a 2.7 length : diameter ratio versus 'Merengue', mid harvest stage in the spring at 25 or 49 thousand plants per hectare) were significant. Fruit firmness was consistently higher for 'Puccini' in the spring at all plant densities than 'Merengue' in both the spring and the summer (Table 2.21). Firmness for 'Puccini' in the summer tended to be slightly higher than that of 'Merengue' in both the spring and the summer. 'Puccini' and 'Merengue' tended to have slightly softer fruit in the summer than in the spring. Fruit firmness was highest for 'Merengue' at the early harvest stage in the spring (Table 2.22). In general, 'Puccini' had firmer fruit than 'Merengue'.

The percentage of vines without fruit was significantly higher at the early harvest stage in the spring for 'Merengue' than the rest of the harvest stage and season combinations for that cultivar (Table 2.23). The percentages of plants without fruits for 'Puccini' range between 19 to 30% and were generally slightly higher than 'Merengue'. The percentage of vines without fruit increased gradually as plant density increased (Figure 2.18). The percentage of plants without fruits at 25, 49, and 99 thousand plants per hectare was 11 to 14%; 148, 198, and 247 thousand plants per hectare was 23 and 34%; and 297 or 395 thousand plants per hectare was 45 to 49%. These results confirm the trend from 2014. At plant densities over 99 thousand plants per hectare, plants without fruit increase to about a third of the plants in the field.

Conclusions

Plant density, harvest stage, season, cultivar, and combinations of those factors had significant effects on various response variables surrounding yield and fruit quality. While quadratic relationships between the main effects and yield or economic response variables fit the data, the general relationship of plant density and yield was relatively flat after the plant density of 198 thousand plants per hectare in most cases. The percentage of plants without fruit at the plant density of 198 thousand plants per hectare was around 30% and was significantly lower at the plant density of 99 thousand plants per hectare. It might be advisable to reduce the plant density to around 100 thousand plants per hectare to avoid the cost of seeds that result in plants with no fruit. Potential economic return was higher at the late harvest stage than the mid and early for both cultivars in both seasons, but fruit length : diameter ratio and the number of oversize fruit was increased. Harvesting when fewer than 15% of the fruit are oversize would result lower marketable yields, but fewer unmarketable oversize fruit.

References

Cantliffe, D.J., Phatak, S.C. 1975. Plant population studies with pickling cucumbers grown for once-over harvest. J. Am. Soc. Hort. Sci. 100:464-466.

Downes, J.D., Carpenter, T.G., Reed, R.R. 1972. Plant populations and harvest scheduling of pickling cucumbers for once-over machine harvesting. HortScience 7(3):337 (Abstr.).

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

Morrison, F.D., Ries, S.K. 1967. Cultural requirements for once-over mechanical harvest of cucumbers for pickling. J. Am. Soc. Hort. Sci. 91:339-346.

Ngouajio, M., Wang, G., Hausebeck, M.K. 2006. Changes in pickling cucumber yield and economic value in response to planting density. Crop Science. 46: 1570-1575.

O'Sullivan, J. 1980. Irrigation, spacing and nitrogen effects on yield and quality of pickling cucumbers grown for mechanical harvesting. Can. J. Plant Sci. 60:923-928.

Phillips, Ben. 2016. Seedless cucumbers are a different pickle. Michigan State University Extension. http://msue.anr.msu.edu/news/seedless_cucumbers_are_a_different_pickle

Pitrat, M., Chauvet, M., Foury, C. 1999. Diversity, history and production of cultivated cucurbits. Acta horticulturae 492-21.

Schultheis, J.R., Averre, C., Boyette, M., Estes, E., Holmes, G., Monks, D., Sorenson K. 2000. Commercial production of pickling and slicing cucumbers in North Carolina. N.C. State Ag. Extension. https://content.ces.ncsu.edu/commercial-production-of-pickling-and-slicing-cucumbers-in-north-carolina

Schultheis, J.R., Wehner, T.C., Walters, S.A. 1998. Optimum planting density and harvest stage for little-leaf and normal-leaf cucumbers for once-over harvest. Can. J. Plant Sci. 78:333-340.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. 2017. https://websoilsurvey.sc.egov.usda.gov/.

Tan, C.S., Nuttall, V.W., Fulton, J.M. 1983. The influence of soil moisture stress and plant populations on the yield of pickling cucumbers. Sci. Hort. 21:217-224.

United States Department of Agriculture, National Agricultural Statistics Service. 2017. Cucumbers: National Statistics. 2017. <http://www.nass.usda.gov/>

Wann, E.V. 1993. Cucumber yield response to plant density and spatial arrangement. J. Prod. Agric. 6:253-255.

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

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

Tables

Table 2.1. Interaction of cultivar and season on marketable yield (Mg/ha)[z] for parthenocarpic pickling cucumbers, 2014.[y]

	Season	
Cultivar	Spring	Summer
Merengue	11.16 abx	10.56 ab
Puccini	12.33 a	9.45 b

[z] Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.
[y] Data are means of 3 replications for plots harvested every half week.
[x] Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.2. Main effect of harvest stage on total yield (Mg/ha)[z] for parthenocarpic pickling cucumbers, 2014.[y]

Harvest Stage	Total yield (Mg/ha)
Early	13.48 b[x]
Mid	15.06 b
Late	19.56 a

[z]Total yield (Mg/ha) includes grades 1, 2, 3, 4 (oversize), and misshapen cull cucumbers.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by harvest stage combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.2. Interaction of plant density, harvest stage, and season on percentage of culls for parthenocarpic pickling cucumbers, 2014.[y]

		Season	
Harvest Stage	Density	Spring	Summer
Early	25,000	4.53 ef[x]	8.16 cdef
	49,000	3.96 ef	18.17 ab
	99,000	5.02 def	13.25 bcde
	148,000	3.04 ef	13.09 bcde
	395,000	9.00 bcdef	24.63 a
Mid	25,000	2.99 f	10.05 bcdef
	49,000	3.59 ef	2.88 f
	99,000	2.79 f	7.14 cdef
	148,000	3.62 ef	9.20 bcdef
	395,000	7.08 cdef	14.86 bcd
Late	25,000	2.99 f	5.23 def
	49,000	2.19 f	7.46 cdef
	99,000	3.23 ef	5.76 def
	148,000	3.18 ef	9.08 bcdef
	395,000	6.71 def	15.77 abc

[z]Percentage culls are the percentage of misshapen cull fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density, harvest stage, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.4. Interaction of harvest stage and cultivar on percentage of culls[z] for parthenocarpic pickling cucumbers, 2014.[y]

	Season	
Cultivar	Spring	Summer
Merengue	37.54 a[x]	15.20 b
Puccini	19.36 b	12.89 b

[z]Percentage culls are the percentage of misshapen cull fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by harvest stage and cultivar combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.5. Interaction of plant density and cultivar on percentage of oversize fruit[z] parthenocarpic pickling cucumbers, 2014.[y]

	Cultivar	
Density (plants/ha)	Merengue	Puccini
25,000	36.16 a[x]	29.38 ab
49,000	36.19 a	19.36 bc
99,000	32.31 ab	12.77 c
148,000	18.56 bc	13.14 c
395,000	8.63 c	5.98 c

[z]Percentage oversize are the percentage of oversize fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density and cultivar combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.6. Interaction of cultivar and season on percentage of oversize fruit[z] for parthenocarpic pickling cucumbers, 2014.[y]

	Season	
Cultivar	Spring	Summer
Merengue	37.54 a[x]	15.20 b
Puccini	19.36 b	12.89 b

[z]Percentage oversize are the percentage of oversize fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

Table 2.7. Main effect of harvest stage on percentage of oversize fruit[z] for parthenocarpic pickling cucumbers, 2014.[y]

Harvest Stage	Percentage oversize fruit
Early	12.82 c[x]
Mid	19.96 b
Late	30.96 a

[z]Percentage oversize are the percentage of oversize fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by harvest stage by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.8. Interaction of plant density and cultivar on total yield (Mg/ha)[z] for parthenocarpic pickling cucumbers, 2015.[y]

	Cultivar	
Density (plants/ha)	Merengue	Puccini
25,000	14.25 f[x]	23.88 cde
49,000	17.68 ef	29.71 abcd
99,000	27.24 abcd	34.10 ab
148,000	29.96 abcd	31.11 abc
198,000	26.70 abcde	35.37 a
247,000	24.28 bcde	31.65 abc
297,000	21.11 def	28.50 abcd
395,000	25.31 bcde	24.05 cde

[z]Total yield (Mg/ha) includes grades 1, 2, 3, 4 (oversize), and misshapen cull cucumbers.

[y] Data are means of 3 replications for plots harvested every half week.

[x] Means separated by harvest stage and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.9. Interaction of harvest stage and season on total yield (Mg/ha)[z] for parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Harvest Stage	Spring	Summer
Early	17.92 d[x]	16.64 d
Mid	27.11 c	24.67 c
Late	40.17 a	32.86 b

[z]Total yield (Mg/ha) includes grades 1, 2, 3, 4 (oversize), and misshapen cull cucumbers.
[y] Data are means of 3 replications for plots harvested every half week.
[x] Means separated by harvest stage and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.10. Interaction of cultivar and season on total yield (Mg/ha)[z] for parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	23.25 b[x]	23.41 b
Puccini	33.56 a	26.04 b

[z]Total yield (Mg/ha) includes grades 1, 2, 3, 4 (oversize), and misshapen cull cucumbers.
[y] Data are means of 3 replications for plots harvested every half week.
[x] Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.11. Interaction of plant density, harvest stage, and season on percentage of culls[z] for parthenocarpic pickling cucumbers, 2015.[y]

		Season	
Harvest Stage	Density (plants/ha)	Spring	Summer
Early	25,000	3.07 cd[x]	3.91 cd
	49,000	3.57 cd	2.57 cd
	99,000	1.62 d	3.82 cd
	148,000	3.52 cd	4.94 bcd
	198,000	5.35 bcd	5.65 bcd
	247,000	3.12 cd	8.90 abc
	297,000	4.03 cd	15.58 a
	395,000	2.93 cd	10.55 ab
Mid	25,000	3.01 cd	3.45 cd
	49,000	2.00 cd	1.92 cd
	99,000	2.56 cd	2.51 cd
	148,000	2.53 cd	4.15 cd
	198,000	2.95 cd	4.64 cd
	247,000	3.65 cd	4.23 cd
	297,000	4.34 cd	5.93 bcd
	395,000	5.60 bcd	4.94 bcd
Late	25,000	3.45 cd	2.49 cd
	49,000	1.92 cd	1.55 d
	99,000	2.51 cd	3.92 cd
	148,000	4.15 cd	2.18 cd
	198,000	4.64 cd	4.16 cd
	247,000	4.23 cd	4.51 cd
	297,000	5.93 bcd	4.31 cd
	395,000	4.94 bcd	3.27 cd

[z]Percentage culls are the percentage of misshapen cull fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density, harvest stage, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.12. Interaction of plant density and cultivar on percentage of culls[z] for parthenocarpic pickling cucumbers, 2015.[y]

	Cultivar	
Density (plants/ha)	Merengue	Puccini
25,000	1.53 fg[x]	5.03 abcd
49,000	1.35 g	3.41 cdefg
99,000	2.30 defg	3.32 cdefg
148,000	1.95 efg	4.52 abcdef
198,000	3.64 bcdefg	5.12 abcd
247,000	4.60 abcdef	4.80 abcde
297,000	6.69 ab	6.11 abc
395,000	4.44 abcdefg	6.78 a

[z]Percentage culls are the percentage of misshapen cull fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density and cultivar combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.13. Interaction of plant density and cultivar on percentage of oversize fruit[z] for parthenocarpic pickling cucumbers, 2015.[y]

	Cultivar	
Density (plants/ha)	Merengue	Puccini
25,000	37.80 abc[x]	40.83 a
49,000	39.18 ab	30.71 abcd
99,000	37.78 abc	26.66 bcde
148,000	37.50 abc	23.81 def
198,000	26.17 cde	23.52 def
247,000	21.02 def	17.26 ef
297,000	19.07 def	15.03 ef
395,000	16.66 ef	12.44 f

[z]Percentage oversize are the percentage of oversize fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density and cultivar combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.14. Interaction of plant density and season on percentage of oversize fruit[z] for parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Density (plants/ha)	Spring	Summer
25,000	36.80 ab[x]	41.82 a
49,000	35.57 ab	34.31 ab
99,000	37.10 ab	27.35 bcde
148,000	36.38 ab	24.94 bcdef
198,000	28.71 abcd	20.98 defg
247,000	28.14 bcde	10.14 fg
297,000	21.91 cdefg	12.19 fg
395,000	16.38 efg	12.72 g

[z]Percentage oversize are the percentage of oversize fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.15. Interaction of cultivar and season on dollar value per hectare[z] for parthenocarpic pickling cucumbers, 2014.[y]

Cultivar	Season	
	Spring	Summer
Merengue	3623 ab[x]	3499 ab
Puccini	4229 a	3012 b

[z]Dollar value per hectare determined using industry values of marketable fruit.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

Table 2.16. Interaction of cultivar and season on economic return[z] for parthenocarpic pickling cucumbers, 2014.[y]

Cultivar	Season	
	Spring	Summer
Merengue	2672 ab[x]	2555 ab
Puccini	3270 a	2073 b

[z]Economic return determined using industry values of marketable fruit and seed costs based on seeding density.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

Table 2.17. Interaction of harvest stage and cultivar on length : diameter ratio[z] of parthenocarpic pickling cucumbers, 2014.[y]

	Cultivar	
Harvest Stage	Merengue	Puccini
Early	3.03 c[x]	3.22 bc
Mid	3.05 c	3.13 c
Late	3.46 a	3.36 ab

[z]Length : diameter ratio determined by averaging the ratio of five grade 2 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by harvest stage combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.18. Interaction of harvest stage and season on fruit firmness (N)[z] of parthenocarpic pickling cucumbers, 2014.[y]

	Season	
Harvest Stage	Spring	Summer
Early	69.25 a[x]	59.16 bc
Mid	63.61 ab	63.83 ab
Late	53.45 c	59.76 b

[z]Fruit firmness (N) determined by averaging the firmness measurement using a Magness-Taylor tester with an 8mm tip of three grade 3 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by harvest stage and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.19. Main effect of cultivar on fruit firmness (N) [z] of parthenocarpic pickling cucumbers, 2014.[y]

Cultivar	Fruit Firmness (N)
Merengue	55.23 b[x]
Puccini	67.79 a

[z]Fruit firmness (N) determined by averaging the firmness measurement using a Magness-Taylor tester with an 8mm tip of three grade 3 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by harvest stage and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.20. Interaction of plant density, harvest stage, cultivar, and season on length : diameter[z] ratio of parthenocarpic pickling cucumbers, 2015.[y]

		Season			
		Spring		Summer	
Harvest Stage	Density (plants/ha)	Merengue	Puccini	Meregnue	Puccini
Early	25,000	3.18 abcdef[x]	2.90 abcdef	3.04 abcdef	3.02 abcdef
	49,000	3.07 abcdef	3.01 abcdef	3.04 abcdef	2.89 abcdef
	99,000	3.02 abcdef	3.00 abcdef	2.90 abcdef	2.97 abcdef
	148,000	2.86 cdef	2.80 def	2.83 def	2.93 abcdef
	198,000	2.78 def	3.05 abcdef	2.88 abcdef	3.02 abcdef
	247,000	2.92 abcdef	2.92 abcdef	3.11 abcdef	2.84 def
	297,000	2.74 ef	2.97 abcdef	2.90 abcdef	3.00 abcdef
	395,000	3.04 abcdef	2.98 abcdef	3.41 abc	3.03 abcdef
Mid	25,000	3.42 ab	3.12 abcdef	3.24 abcde	2.87 bcdef
	49,000	3.51 a	3.01 abcdef	3.11 abcdef	2.97 abcdef
	99,000	3.30 abcd	3.10 abcdef	2.84 def	3.04 abcdef
	148,000	3.26 abcde	3.19 abcdef	3.07 abcdef	2.95 abcdef
	198,000	3.23 abcde	3.17 abcdef	2.78 def	3.08 abcdef
	247,000	3.17 abcdef	3.16 abcdef	2.94 abcdef	3.13 abcdef
	297,000	3.26 abcde	2.97 abcdef	2.95 abcdef	3.04 abcdef
	395,000	2.90 abcdef	2.94 abcdef	3.31 abcd	3.06 abcdef
Late	25,000	3.47 a	3.28 abcde	3.50 a	3.43 ab
	49,000	3.16 abcdef	3.26 abcde	3.14 abcdef	3.00 abcdef
	99,000	3.20 abcde	3.28 abcde	3.21 abcde	3.08 abcdef
	148,000	3.08 abcdef	3.12 abcdef	2.98 abcdef	2.95 abcdef
	198,000	3.09 abcdef	3.18 abcdef	2.86 cdef	3.00 abcdef
	247,000	2.98 abcdef	3.26 abcde	3.19 abcdef	2.93 abcdef
	297,000	3.04 abcdef	3.24 abcde	2.91 abcdef	2.96 abcdef
	395,000	3.25 abcde	3.01 abcdef	2.65 f	2.99 abcdef

[z]Length : diameter ratio determined by averaging the ratio of five grade 2 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density, harvest stage, cultivar, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.21. Interaction of plant density, cultivar, and season on fruit firmness (N) [z] of parthenocarpic pickling cucumbers, 2015.[y]

Cultivar	Density (plants/ha)	Season	
		Spring	Summer
Merengue	25,000	71.67 efghij[x]	65.24 fghij
	49,000	67.71 efghij	63.43 ghij
	99,000	69.20 efghij	60.79 ij
	148,000	72.16 efghij	61.29 hij
	198,000	70.18 efghij	58.32 j
	247,000	68.21 efghij	76.21 bcdefghi
	297,000	67.22 fghij	72.75 defghij
	395,000	70.18 efghij	53.47 j
Puccini	25,000	91.44 abc	79.08 bcdefg
	49,000	94.40 ab	83.53 abcde
	99,000	97.37 a	76.61 bcdefgh
	148,000	88.47 abcd	77.60 bcdefg
	198,000	89.95 abcd	80.56 bcdef
	247,000	88..97 abcd	77.60 bcdefg
	297,000	98.36 a	77.10 bcdefg
	395,000	93.41 ab	76.12 cdefghi

[z]Fruit firmness (N) determined by averaging the firmness measurement using a Magness-Taylor tester with an 8mm tip of three grade 3 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density, cultivar, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.22. Interaction of harvest stage, cultivar, and season on fruit firmness (N) [z] of parthenocarpic pickling cucumbers, 2015.[y]

		Cultivar	
Season	Stage	Merengue	Puccini
Spring	Early	69.32 de[x]	85.07 b
	Mid	71.17 cd	87.48 b
	Late	68.21 de	105.83 a
Summer	Early	73.68 cd	86.93 b
	Mid	57.34 f	68.95 de
	Late	60.79 ef	79.70 bc

[z]Fruit firmness (N) determined by averaging the firmness measurement using a Magness-Taylor tester with an 8mm tip of three grade 3 fruit for each plot.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by plant density, cultivar, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 2.23. Interaction of harvest stage, cultivar, and season on the percentage of vines with zero fruit[z] of parthenocarpic pickling cucumbers, 2015.[y]

		Cultivar	
Season	Stage	Merengue	Puccini
Spring	Early	47.16 a[x]	29.72 bc
	Mid	19.87 c	35.12 ab
	Late	17.93 c	18.87 c
Summer	Early	25.08 bc	28.71 ab
	Mid	22.20 bc	29.66 bc
	Late	17.10 c	21.15 c

[z]The percentage of vines with zero fruit was a measurement made upon destructive harvest.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by harvest stage, cultivar, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Figures

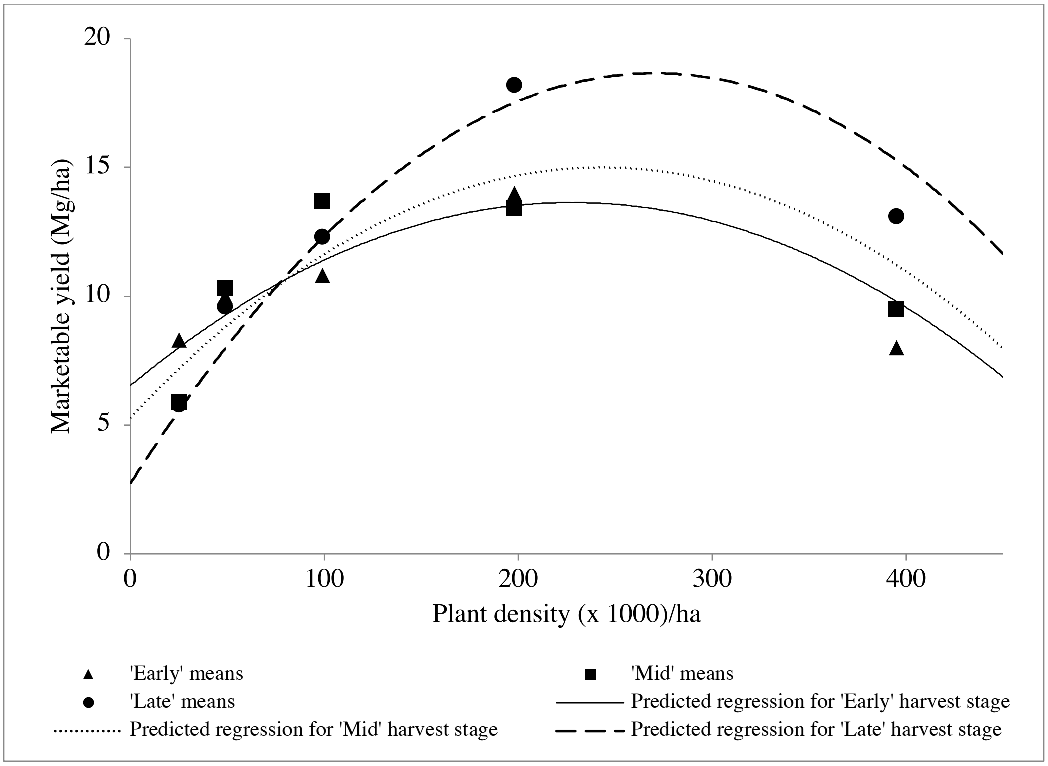

Figure 2.1. Relationship of marketable yield (Mg/ha) and plant density in 2014 for harvest stage: Early [$y=6.5319 + 0.0624x - 0.0001x^2$, $R^2 = 0.2569$]; Mid [$y = 5.2841 + 0.0170x – 0.0001x^2$, $R^2 = 0.2906$]; Late [$y = 2.7393 + 0.1177x - 0.0002x^2$, $R^2 = 0.5583$].

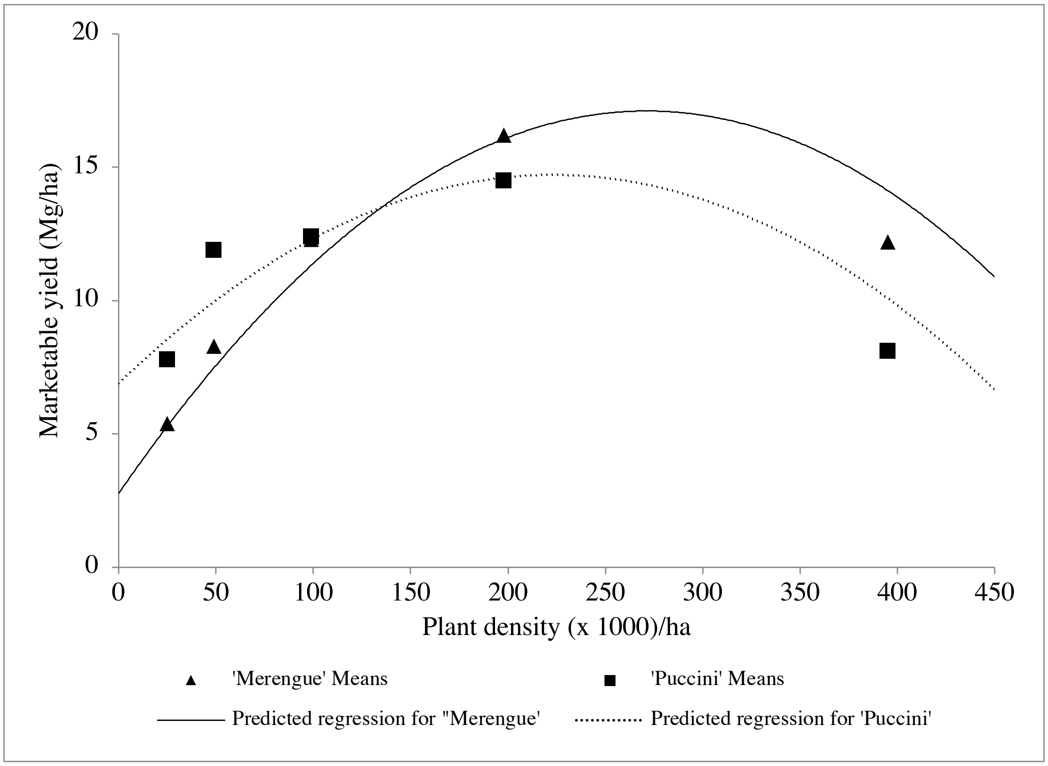

Figure 2.2. Relationship of marketable yield (Mg/ha) and plant density in 2014 for cultivars: Merengue [$y = 2.7758 + 0.1057x – 0.0002x^2$, $R^2 = 0.5609$]; Puccini [$y = 6.9061 + 0.0700x – 0.0002x^2$, $R^2 = 0.2531$].

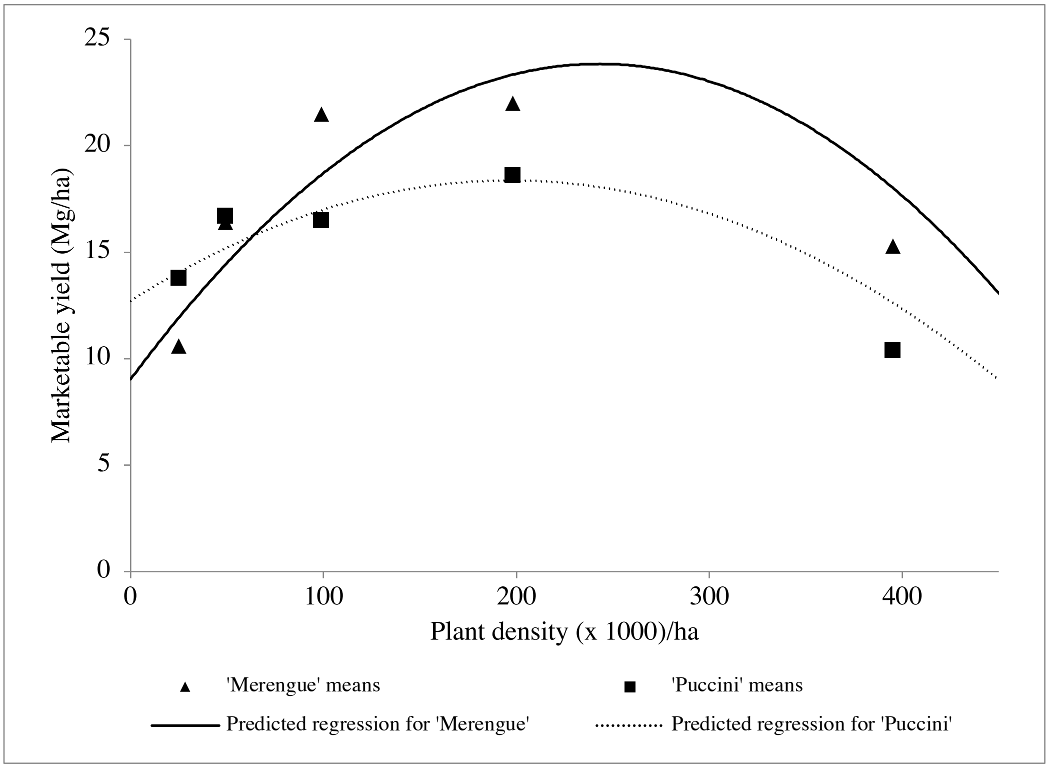

Figure 2.3. Relationship of total yield (Mg/ha) and plant density in 2014 for cultivars: Merengue [$y = 9.0358 + 0.1220x - 0.0003x^2$, $R^2 = 0.2422$]; Puccini [$y = 12.7129 + 0.0575x - 0.0001x^2$, $R^2 = 0.1438$].

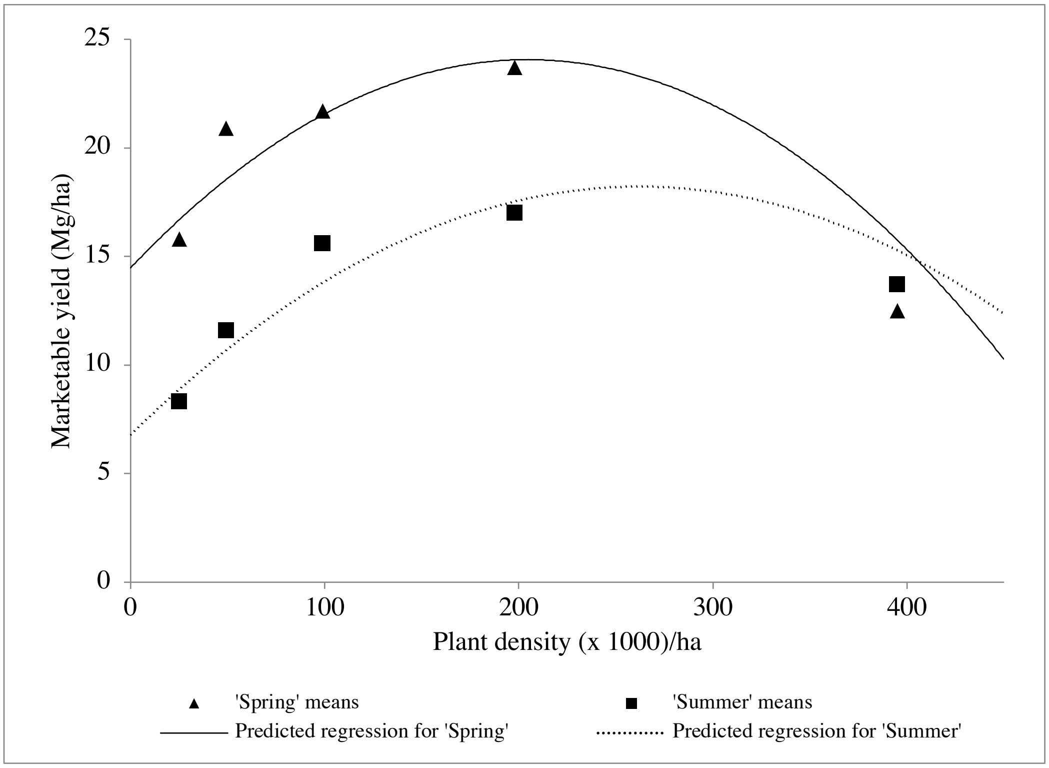

Figure 2.4. Relationship of total yield (Mg/ha) and plant density in 2014 for seasons: Spring [$y = 14.4844 + 0.0937x - 0.0002x^2$, $R^2 = 0.2512$]; Summer [$y = 6.7941 + 0.0872x - 0.0002x^2$, $R^2 = 0.2477$].

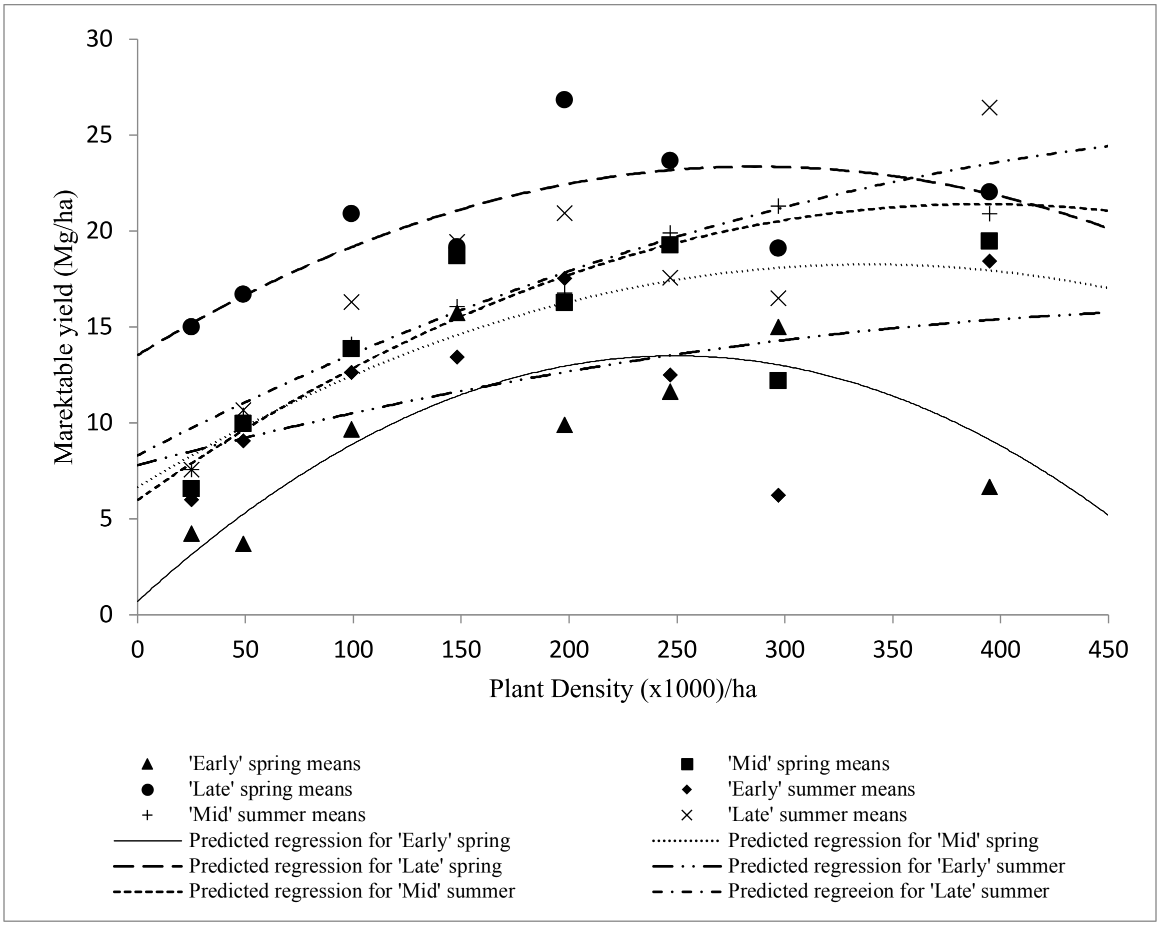

Figure 2.5. Relationship of marketable yield (Mg/ha) and plant density in 2015 for cultivar 'Merengue' for harvest stage and season: Spring Early [$y= 0.7091+0.1027\ x - 0.0002x^2$, $R^2 =0.2385$]; Spring Mid [$y = 6.6574+ 0.0685x - 0.0001x^2$, $R^2 = 0.3937$]; Spring Late [$y = 13.5413+ 0.0686x - 0.0001x^2$, $R^2 = 0.2741$]; Summer Early [$y= 7.8013+ 0.0300x - 0.00003x^2$, $R^2 = 0.188$]; Summer Mid [$y= 5.9868+ 0.0789x - 0.0001x^2$, $R^2 = 0.8454$]; Summer Late [$y= 8.3149+ 0.0578x - 0.00005x^2$, $R^2 = 0.5926$].

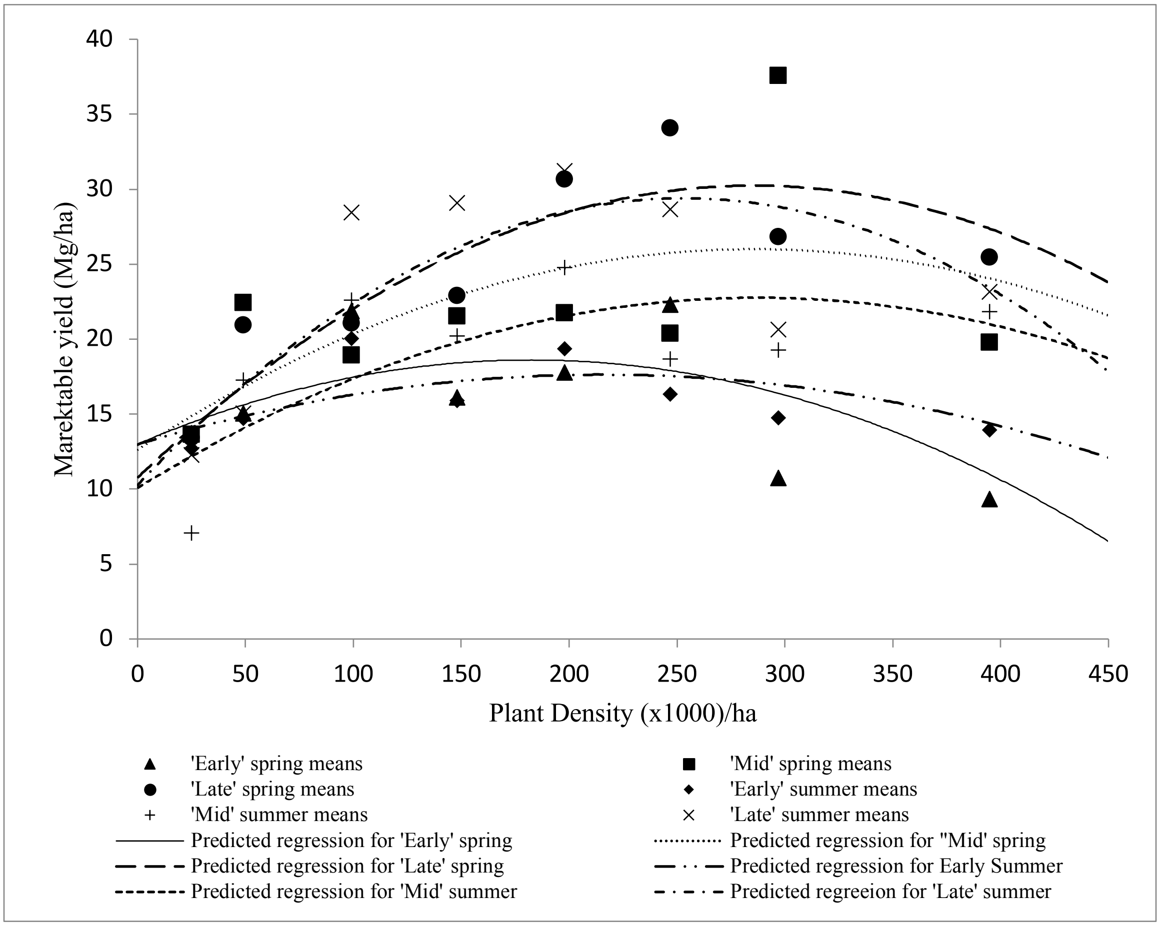

Figure 2.6. Relationship of marketable yield (Mg/ha) and plant density in 2015 for cultivar 'Puccini' for harvest stage and season: Spring Early [$y= 13.0011+ 0.0615x – 0.0002x^2$, $R^2 = 0.2779$]; Spring Mid [$y = 12.6218+ 0.0937x –0.0002x^2$, $R^2 =0.2265$]; Spring Late [$y = 10.7676+ 0.1365x – 0.0002x^2$, $R^2 = 0.5847$]; Summer Early [$y = 12.9763 + 0.0433x – 0.0001x^2$, $R^2 = 0.1438$]; Summer Mid [$y= 10.0160 + 0.0882x – 0.0002x^2$, $R^2 = 0.3595$]; Summer Late [$y = 10.2855+ 0.1509x – 0.0003x^2$, $R^2 = 0.3748$].

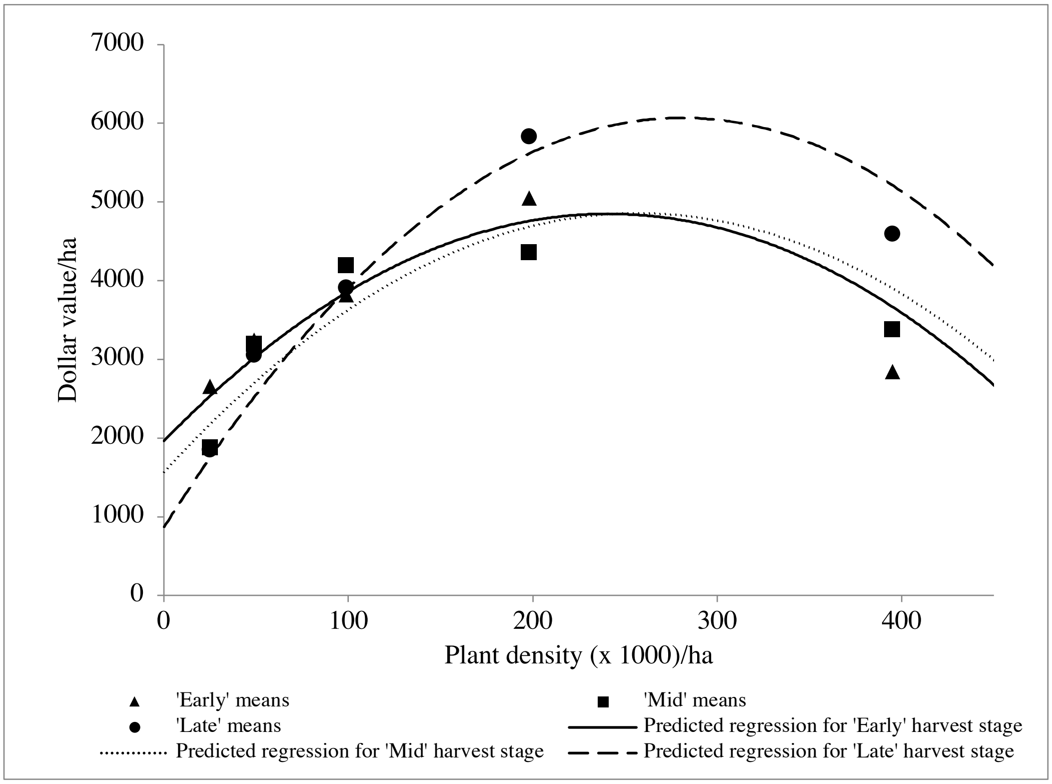

Figure 2.7. Relationship of dollar value per hectare and plant density in 2014 for harvest stage: Early [$y= 1963.5354 + 23.9605x – 0.0497x^2$, $R^2 = 0.2746$]; Mid [$y = 1564.7685 + 25.6493x – 0.0659x^2$, $R^2 = 0.3212$]; Late [$y = 864.9070 + 37.0446x – 0.0659x^2$, $R^2 = 0.5946$].

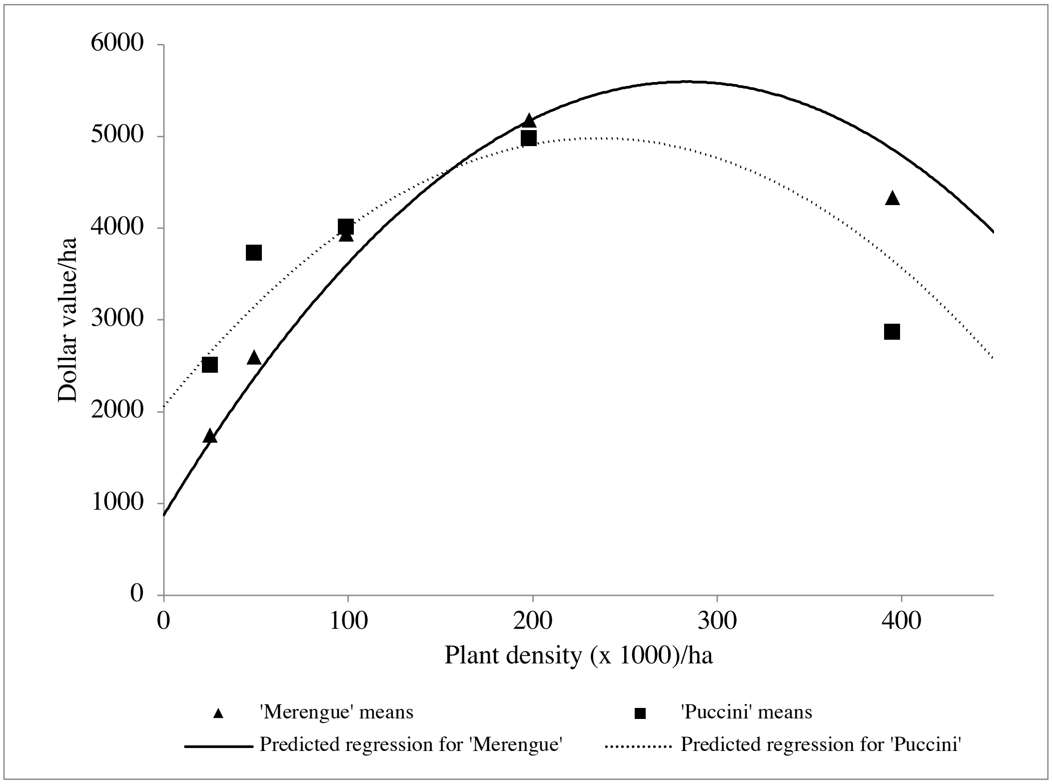

Figure 2.8. Relationship of dollar value per hectare and plant density in 2014 for cultivars: Merengue [$y = 876.1031 + 33.3345x - 0.0589x^2$, $R^2 = 0.5949$]; Puccini [$y = 2060.0106 + 24.7690x - 0.0525x^2$, $R^2 = 0.2683$].

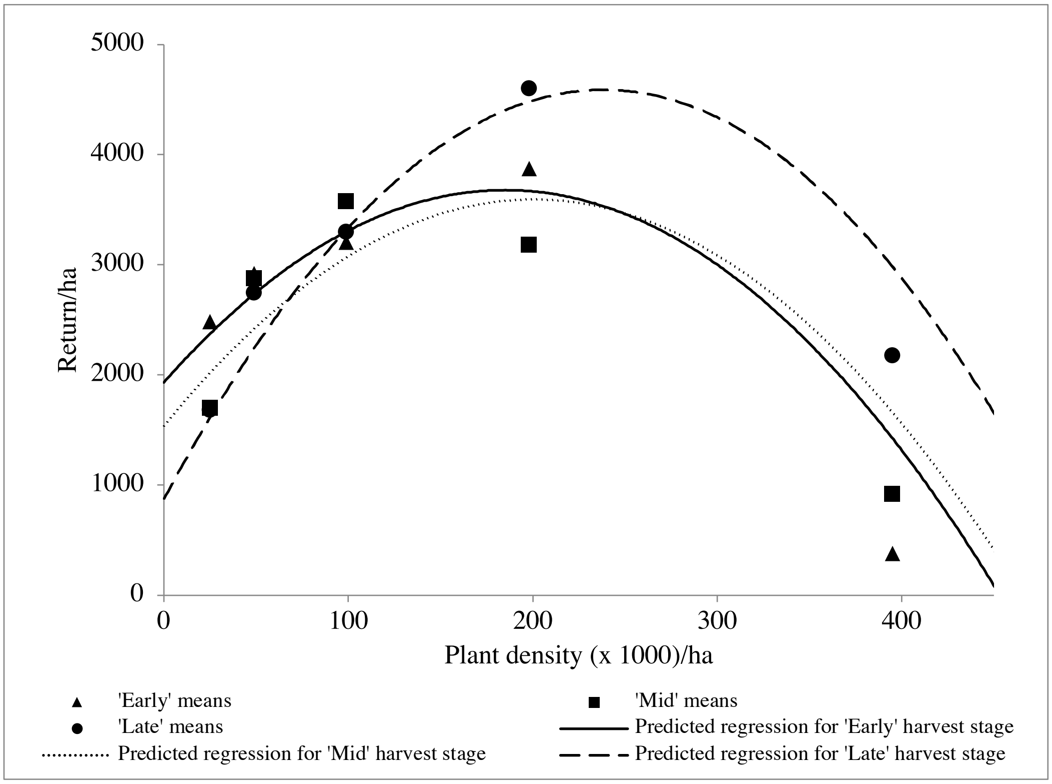

Figure 2.9. Relationship of dollar return per hectare and plant density in 2014 for harvest stage: Early [$y = 1934.2334 + 18.8796x - 0.0511x^2$, $R^2 = 0.4061$]; Mid [$y = 1537.8403 + 20.5106x - 0.0511x^2$, $R^2 = 0.3709$]; Late [$y = 874.2573 + 31.1826x - 0.0654x^2$, $R^2 = 0.4489$].

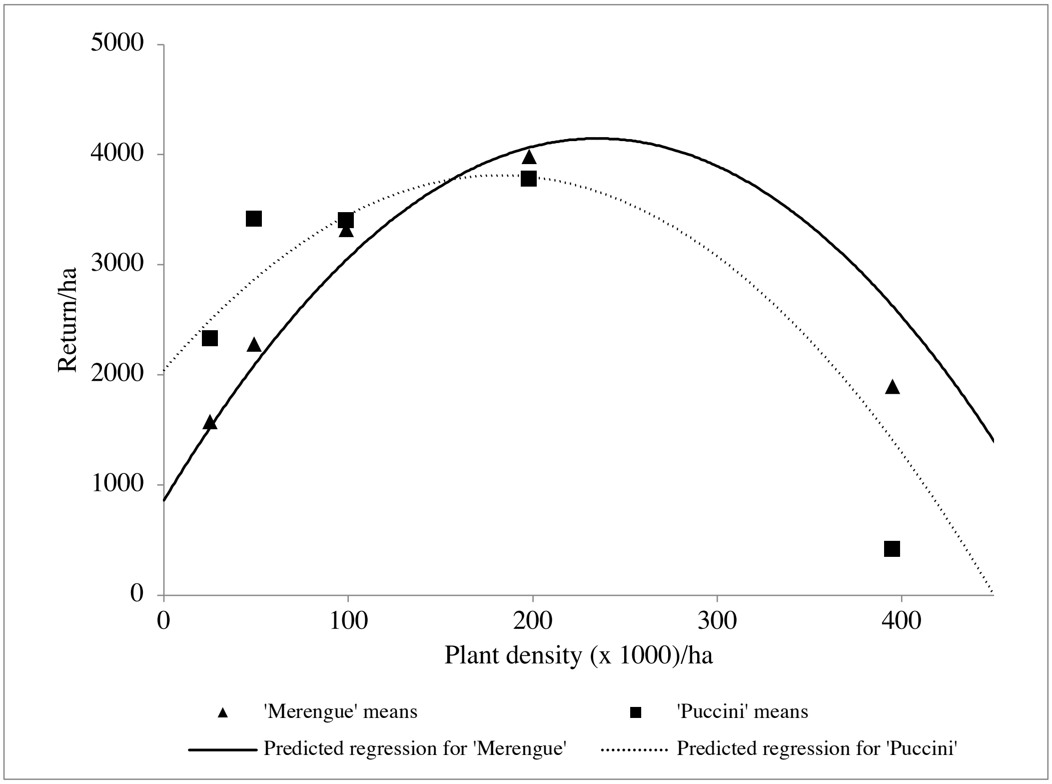

Figure 2.10. Relationship of dollar return per hectare and plant density in 2014 for cultivars: Merengue [$y = 861.4824 + 27.9553x - 0.0595x^2$, $R^2 = 0.4312$]; Puccini [$y = 2045.0084 + 19.3939x - 0.0532x^2$, $R^2 = 0.4099$].

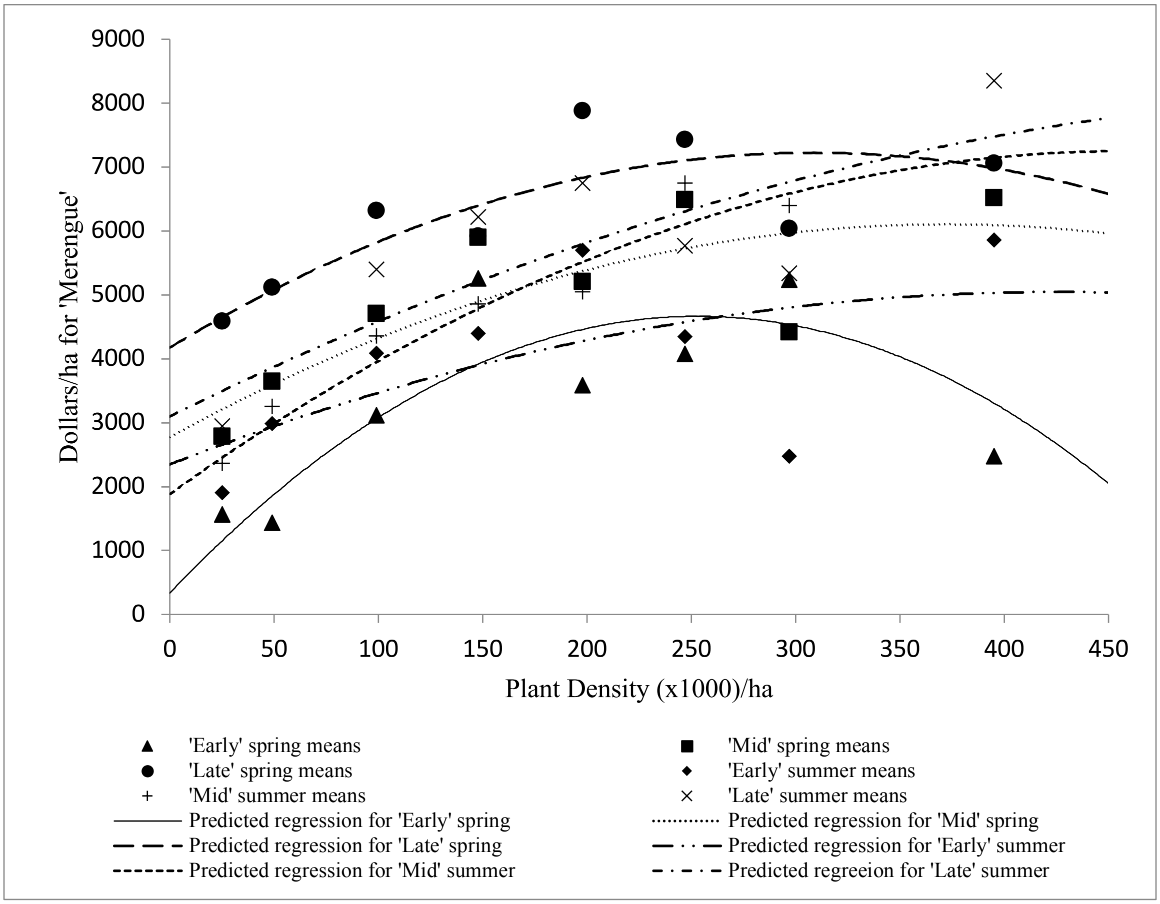

Figure 2.11. Relationship of dollar value per hectare and plant density for cultivar 'Merengue' in 2015 for harvest stage and season: Spring Early [$y = 336.7929 + 34.1992x – 0.0675x^2$, $R^2 = 0.2268$]; Spring Mid [$y = 2774.6432 + 17.8792x – 0.024x^2$, $R^2 = 0.4283$]; Spring Late [$y = 4174.9082 + 19.7723x –0.0321x^2$, $R^2 = 0.3229$]; Summer Early [$y = 2347.4509 + 12.7044x – 0.0150x^2$, $R^2 = 0.2463$]; Summer Mid [$y = 1880.9081+ 23.4214x – 0.0255x^2$, $R^2 = 0.8496$]; Summer Late [$y = 3098.4947 + 16.181x – 0.0129x^2$, $R^2 = 0.5748$].

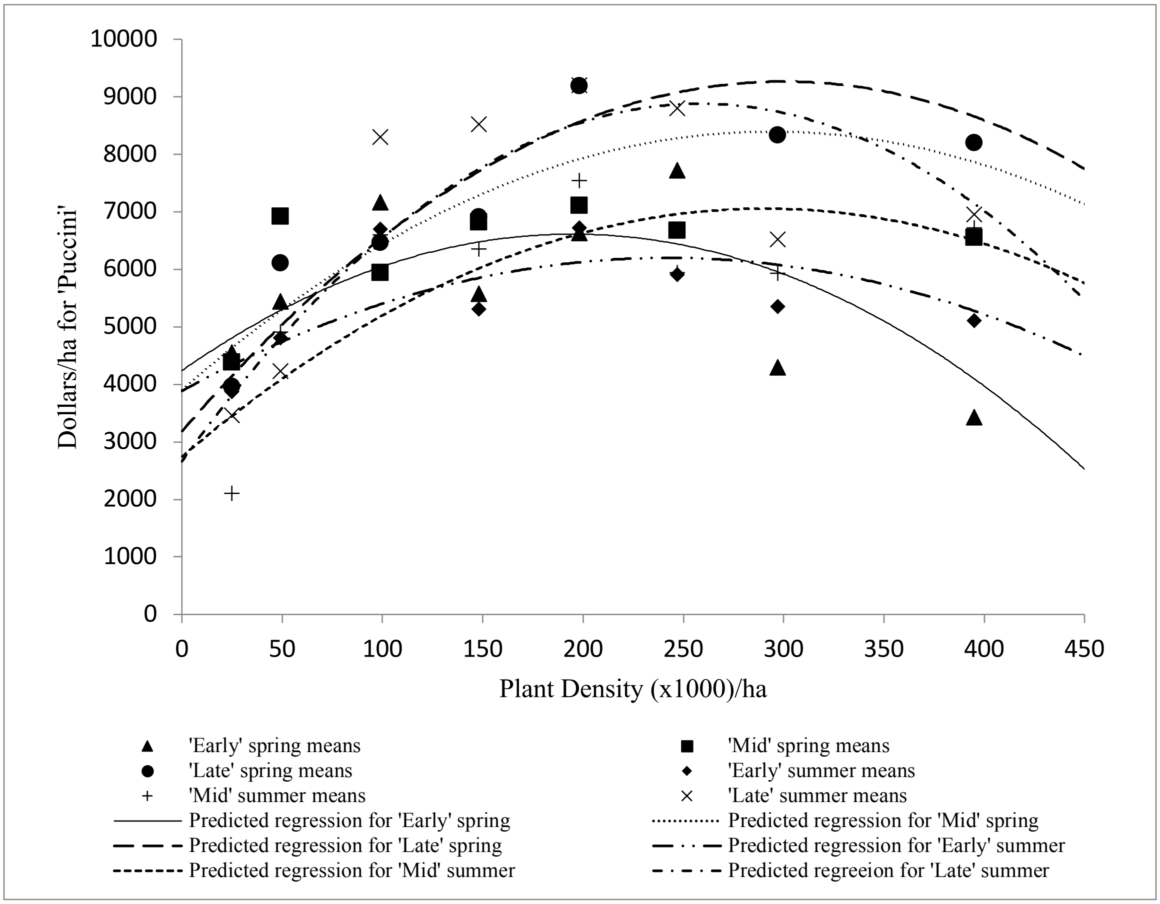

Figure 2.12. Relationship of dollar value per hectare and plant density for cultivar 'Puccini' in 2015 for harvest stage and season: Spring Early [$y = 4238.3665 + 24.3906x - 0.0627x^2$, $R^2 = 0.3303$]; Spring Mid [$y = 3903.2762 + 30.5430x - 0.0519x^2$, $R^2 = 0.2786$]; Spring Late [$y = 3180.9265 + 40.5469x - 0.0676x^2$, $R^2 = 0.6478$]; Summer Early [$y = 3885.3182 + 19.1155x - 0.0395x^2$, $R^2 = 0.2289$]; Summer Mid [$y = 2741.72 + 29.6731x - 0.0510x^2$, $R^2 = 0.4832$]; Summer Late [$y = 2665.4029 + 48.0896x - 0.0931x^2$, $R^2 = 0.4506$].

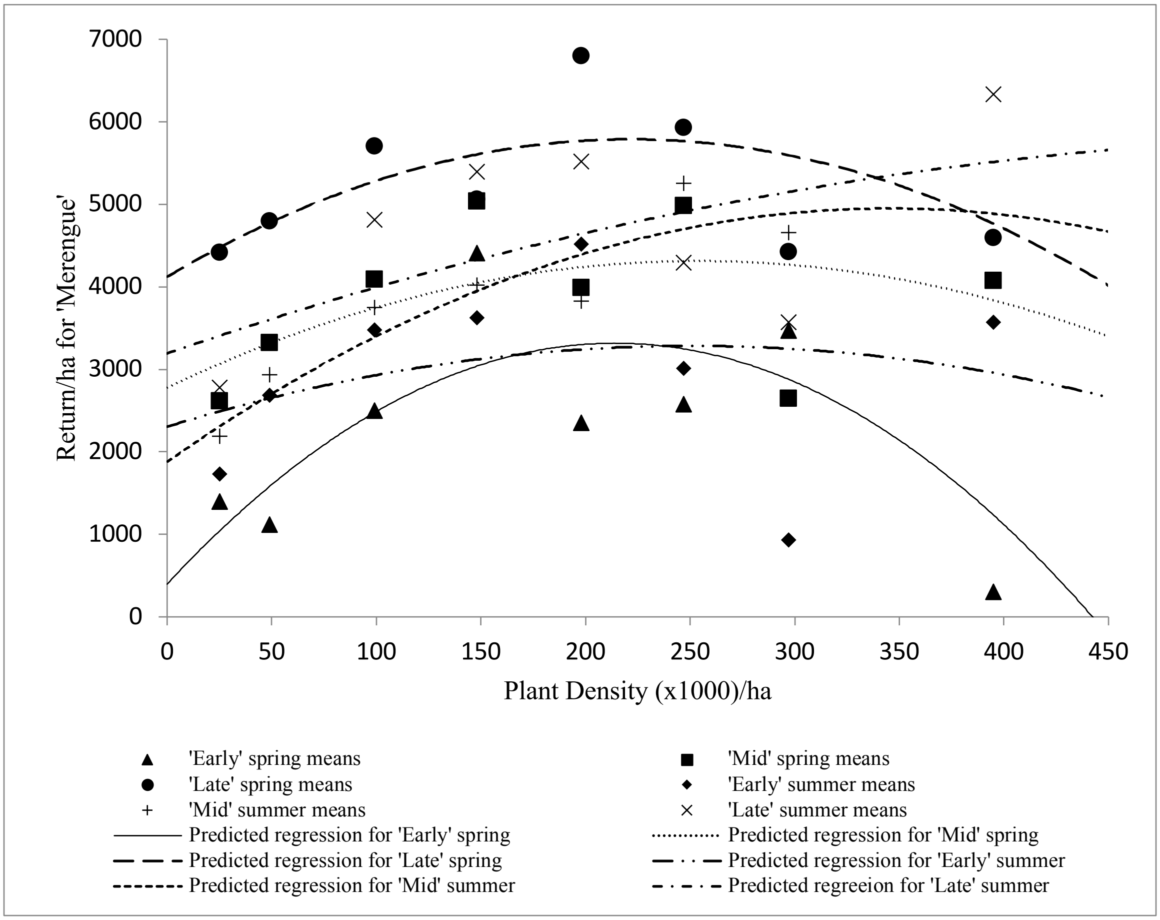

Figure 2.13. Relationship of dollar return per hectare and plant density for cultivar 'Merengue' in 2015 for harvest stage and season: Spring Early [$y = 397.7966 + 27.2655x – 0.0637x^2$, $R^2 = 0.1769$]; Spring Mid [$y = 2778.1794 + 12.0929x – 0.0238x^2$, $R^2 = 0.1185$]; Spring Late [$y = 4119.6064 + 15.0652x – 0.034x^2$, $R^2 = 0.1607$]; Summer Early [$y = 2304.2227 + 7.8250x – 0.0156x^2$, $R^2 = 0.0362$]; Summer Mid [$y = 1878.8139 + 17.7866x – 0.0258x^2$, $R^2 = 0.6744$]; Summer Late [$y = 3192.6157 + 8.7453x – 0.0073x^2$, $R^2 = 0.259$].

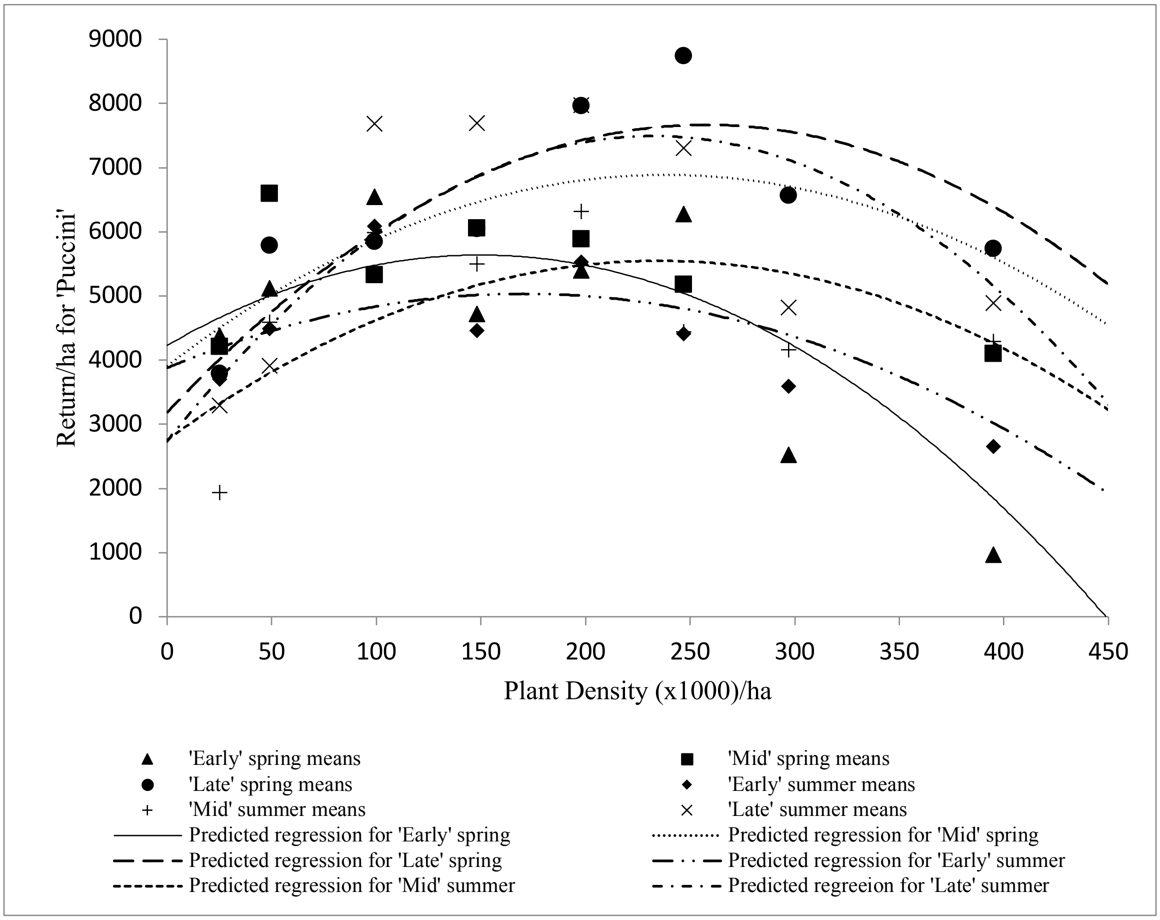

Figure 2.14. Relationship of dollar return per hectare and plant density for cultivar ‘Puccini’ in 2015 for harvest stage and season: Spring Early [$y = 4227.9124 + 18.8492x – 0.063x^2$, R^2 = 0.4895]; Spring Mid [$y = 3908.0984 + 24.9908x – 0.0524x^2$, R^2 = 0.1525]; Spring Late [$y = 3184.2642 + 34.7719x – 0.0674x^2$, R^2 = 0.4836]; Summer Early [$y = 3877.1641 + 13.5871x – 0.0399x^2$, R^2 = 0.3161]; Summer Mid [$y = 2755.9754 + 13.5871x – 0.0399x^2$, R^2 = 0.2956]; Summer Late [$y = 27736.2540+ 40.9500x – 0.0882x^2$, R^2 = 0.3552].

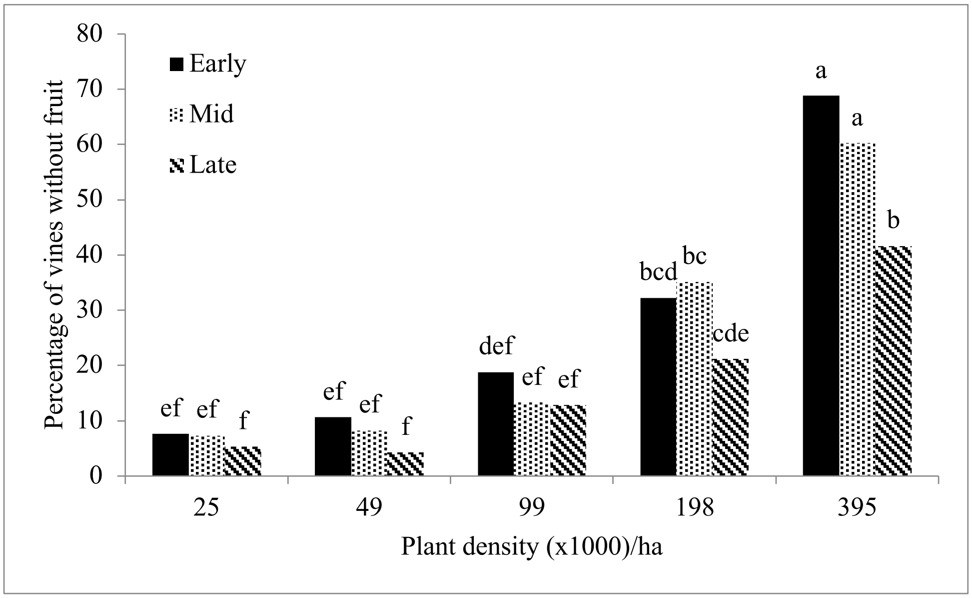

Figure 2.15. Interaction of plant density and harvest stage on the percentage of vines with zero fruit[z] of parthenocarpic pickling cucumbers, 2014.[yx]

[z]The percentage of vines with zero fruit was a measurement made upon destructive harvest.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by harvest stage, cultivar, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

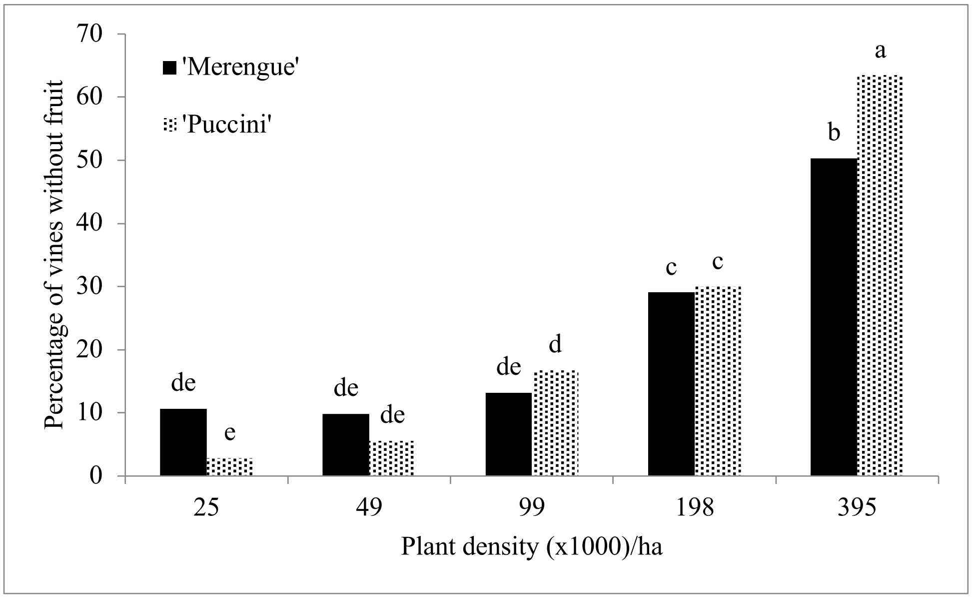

Figure 2.16. Interaction of density and cultivar on the percentage of vines with zero fruit [z] of parthenocarpic pickling cucumbers, 2014.[yx]

[z]The percentage of vines with zero fruit was a measurement made upon destructive harvest.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by harvest stage, cultivar, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

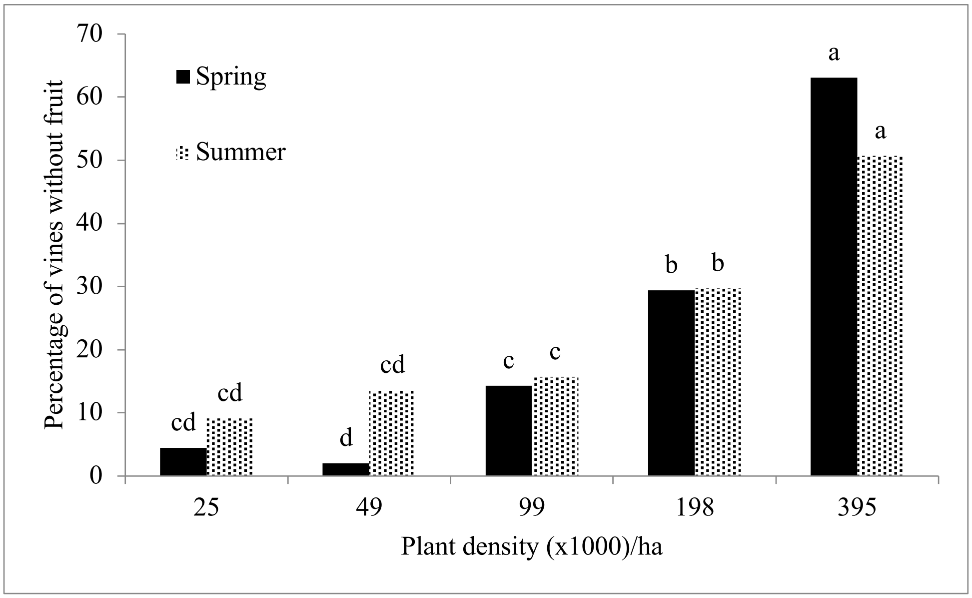

Figure 2.17. Interaction of density and season on the percentage of vines with zero fruit[z] of parthenocarpic pickling cucumbers, 2014.[yx]
[z]The percentage of vines with zero fruit was a measurement made upon destructive harvest.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by harvest stage, cultivar, and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

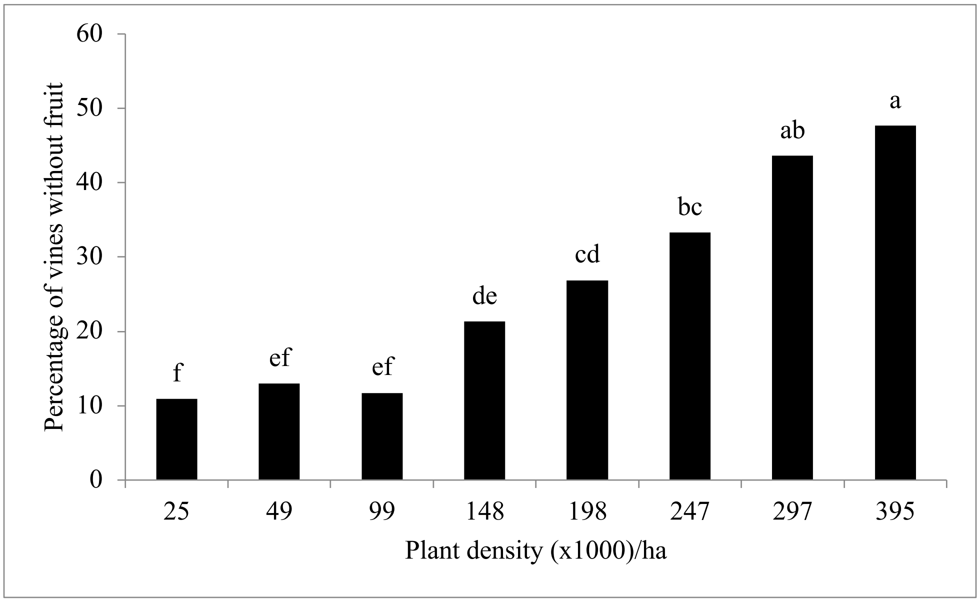

Figure 2.18. Main effect of plant density on the percentage of vines with zero fruit [z] of parthenocarpic pickling cucumbers grown, 2015.[yx]

[z]The percentage of vines with zero fruit was a measurement made upon destructive harvest.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by harvest stage, cultivar, and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Chapter Three

Yield of Parthenocarpic Pickling Cucumber in a Multiple-Harvest System is Affected by Planting Density and Cultivar

Lauren J. Arteman, Todd C. Wehner, S. Gary Bullen, and Jonathan R. Schultheis

Yield of Parthenocarpic Pickling Cucumber in a Multiple-Harvest System is Affected by Planting Density and Cultivar

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Abstract

Cultivars of parthenocarpic pickling cucumber that are adapted to production in open field conditions are newly available and offer advantages compared to seeded types. A major advantage of parthenocarpy is higher yield, but at a higher cost of seeds. We evaluated the effect of plant density and growing season on the yield, profitability, and fruit quality of cultivars ‘Merengue’ and ‘Puccini’ in two years. The experiment was a randomized complete block with 2 years (2014, 2015), 2 seasons (spring, summer), 2 cultivars ('Merengue', 'Puccini'), 5 densities (8 in 2015), and 3 replications. In 2014, 5 plant densities were evaluated on bare ground. In 2015, 8 plant densities were evaluated on black plastic mulch. Six to 8 harvests were made, and the fruit were graded by diameter after removal of culls (crooked and nubbin fruit). Considering yield and seed cost, economic return was highest at a plant density of 49 to 74 thousand plants per hectare over years, seasons, and cultivars. There was variation between cultivar with regard to yield and fruit quality response to plant density and season. Yield differences between years were significant probably due to the addition of plastic mulch and drip irrigation.

Introduction

Cucumber (*Cucumis sativus*, L.) is the fourth most widely cultivated vegetable in the world and a member of the Cucurbitaceae family (Pitrat et al, 1999). Approximately 50,000 hectares of cucumber (fresh: 15,400 ha, pickling: 34,5000 ha) were harvested in the United

States in 2015 (USDA, 2017). North Carolina is among the top five cucumber producing states in the US. Also, in the US, the pickling cucumber industry was worth $162 million in 2016.

The predominant method of harvest of pickling cucumbers in North Carolina is by hand. Multiple-pick harvest is labor intensive but results in higher yield of more marketable sizes than once-over harvest by machine. Productive fields are preferred by labor crews, since their payment is often a share of gross sales (Schultheis et al., 2000). Increasing yield of plants and also return on seed costs, while reducing other production costs would be ideal for growers.

Parthenocarpic pickling cucumber cultivars are now available for the southeast U.S. They are suitable for open field production and have been improved for fruit firmness and bloater resistance in brine tanks. These cultivars have the potential to achieve a higher yield than seeded cultivars, and there is no need to provide each field with honey bees for pollination, or 12% monoecious pollenizer in the field planting. The seed cost for parthenocarpic cultivars is currently four times that of seeded cultivars. Optimization of production practices is needed for those interested in using these new parthenocarpic cultivars.

Plant density has been shown to affect yield of pickling cucumber (Cantliffe and Phatak, 1975; Tan et al., 1983; Wann, 1993; Widders and Price, 1989). Light, water, and nutrient availability may become limiting at higher plant densities. Currently, plant densities around 62 thousand plants per hectare (thp/ha) are being used in multiple-harvest systems for pickling cucumbers. No optimum plant density has been established for parthenocarpic cultivars.

The objective of this study was to evaluate the effect of plant density on yield, economic profitability, and fruit quality for two parthenocarpic cultivars, and to provide recommendations for growers using multiple-harvest (hand-picked) systems.

Materials and Methods

The study was conducted to determine the effect of planting density, season, and cultivar on the yield, economic return, and quality of parthenocarpic pickling cucumbers in a hand pick, multiple harvest system. The experiments were run at the Cunningham Research Station in Kinston, NC where they could be isolated from non-parthenocarpic cucumbers. Cultivars 'Puccini' (Rijk Zwaan; Salinas, CA) and 'Merengue' (Seminis Vegetable Seeds; St. Louis, MO) were planted at 5 densities in 2014 (8 in 2015). These plots were harvested 6 times (7 or 8 in the spring season). The experiment was a randomized complete block with 2 years (2014, 2015), 2 seasons (spring, summer), 2 cultivars, 5 (8 in 2015) densities, and 3 replications. Densities are listed below for each year.

2014. Five plant densities were evaluated: 12, 25, 49, 99, and 198 thousand plants per hectare. The spring season study was planted on 6 May. Harvests occurred 20 (45 DAP), 24, 27, 30 June, 3, 8, 11, and 15 July. The summer season study was planted on 19 June. Harvests occurred 25 (36 DAP), 28, 31 July, and 4, 11, 15 August.

2015. Three extra planting densities (74, 123, and 148 thousand plants per hectare) along with the original five (12, 25, 49, 99, and 198 thousand plants per hectare) were evaluated in 2015. The spring season study was planted on 21 May. Harvests occurred 26 (36 DAP), 29 June, 2, 6, 9, 14, 17, and 21 July. The summer season study was planted on 15 June. Harvests occurred 4 (46 DAP), 7, 14, 18, 21, 25, and 28 August.

Cultural practices. Plots consisted of 3 rows on raised beds, each plot 6 m long, spaced on 1.5 m centers on bare ground in 2014. Irrigation was provided by overhead sprinkler. The center row was harvested, leaving the 2 side rows for competition at each treatment density. In 2015, we used black plastic mulch in spring and white plastic mulch in summer with drip tape placed underneath for irrigation. The soil type for both years was a Norfolk loamy sand (Typic Kandiudults) (NRCS, 2017). Plots were over-seeded by 15% of the desired density at a depth of 25 mm and covered by hand. These plots were thinned to proper treatment density 15 days after planting (DAP). Standard production practices were followed (Schultheis et al, 2000). Plots were harvested 6 times (7 or 8 in the spring season).

Data collection. At each harvest, fruit were collected and separated into grades 1 (0 to 27 mm), 2 (28 to 38 mm), 3 (39 to 51mm), 4 (greater than 51mm in diameter; oversize), and misshapen culls (nubbins, crookeds) (Wehner, 1986). Weights were summed by grade for each plot. Five grade 2 fruit from each plot were measured to determine length : diameter ratio. Fruit firmness was measured on three grade 3 fruit using a Magness-Taylor tester with a tip diameter of 8 mm (5/16").

Data analysis. Data were subjected to PROC GLIMMIX (ANOVA) and *post-hoc* Tukey-Kramer procedure within PROC GLIMMIX using SAS v 9.4 (SAS Institute, Cary, NC). Years were analyzed separately. Dollars per hectare and return per hectare were calculated based on marketable fruit weight (grade 1, 2, and 3, excluding cull and oversize). Dollar value of marketable grades was determined using industry values (P. Denlinger, 2016, Mt. Olive Pickle Co., NC, personal communication, 2016). The values used for grades 1, 2, and 3 were $13.50, $8.50, and $6.00/bushel, respectively. Values were converted from bushel to Mg basis. Economic return was determined using the dollar value of marketable yields, less the expense of seeds (at varying prices) to determine the optimum plant density. The varying prices included $3, $6, $12, and $24/thousand seeds to represent potential changes in seed cost for parthenocarpic cultivars. We reported economic return based on the seed cost of $12/thousand seeds.

Results and Discussion

Fruit yield

2014 ANOVA. Early marketable yield (Mg/ha for harvests 1 and 2) was significantly affected by plant density. Total marketable yield (Mg/ha summed over harvests) was significantly affected by plant density, cultivar, and season. Early total yield (Mg/ha including misshapen and oversize fruit for harvests 1 and 2) was significantly affected by the interaction of plant density and season. Plant density, cultivar, and season separately had significant effects on the total yield (Mg/ha including misshapen and oversize fruit summed over harvests). The percentage of culls was significantly affected by plant density and cultivar. Plant density had a significant effect of the percentage of oversize fruit (Table A3.1).

2015 ANOVA. Early marketable yield was significantly affected by the interactions of plant density and cultivar, plant density and season, and cultivar and season. Total marketable yield was significantly affected by those same interactions; plant density and cultivar, plant density and season, and cultivar and season. Early total yield was significantly affected by the interactions of plant density and cultivar, plant density and season, and cultivar and season. Total yield was significantly affected by the interaction of plant density, cultivar, and season. The same interaction of plant density, cultivar, and season had a significant effect on the percentage of culls. The percentage of oversize fruit was significantly affected by plant density and the interaction of cultivar and season. (Table A3.2)

2014 Tables and Figures. Early marketable yield was significantly higher at the densities of 49 and 99 thousand plants per hectare than the highest and lowest plant densities and similar to that at 25 thousand plants per hectare (Figure 3.1). Suggested plant densities for hand-harvested pickling cucumbers in North Carolina is around 75,000 plants per hectare (Schultheis et al, 2000). Our results suggest planting 25 to 99 thousand plants per hectare would provide around 4 or 5 Mg/ha from the first two harvests in either season on bare ground.

Total marketable yield was statistically similar across all densities with the exception of the two-way comparison between 49 and 198 thousand plants per hectare (Figure 3.2). The relationship between total marketable yield and density was relatively flat. There is was no benefit to increasing plant density from 99 to 198 thousand plants per hectare. 'Merengue' garnered a significantly higher marketable yield over eight harvests than 'Puccini' (Table 3.1). 'Merengue' had fewer misshapen cull fruit than 'Puccini'. A genotype - environment interaction might explain this result. Total marketable yield was higher in the spring than the summer (Table 3.2). A number of factors could have affected this. Variation in irrigation and/or disease incidence could have influenced this relationship.

The percentage of culls was significantly higher (~10% higher) at the densities of 99 and 198 thousand plants per hectare than 12, 25, and 49 thousand plants per hectare (Figure 3.3). These results are consistent with other plant density studies in pickling cucumber. O'Sullivan (1980) found that culls or 'off-shape' fruit were decreased with irrigation and increased with higher plant densities. Schultheis et al. (1998) reported a linear increase of cull fruit with an increase in plant density. 'Merengue' had a lower percentage of culls (~10% lower) than 'Puccini' (Table 3.3). Schultheis et al. (1998) also reported differences in the percentages of cull fruit due to cultivar.

The lowest plant densities (12 and 25 thousand plants per hectare) had significantly higher percentages of oversize fruit than the highest plant densities (99 and 198 thousand plants per hectare) (Figure 3.4). The increase of competition for resources at higher plant densities could have contributed to the reduction of oversize fruit. In a study regarding cultural practices for mechanically harvested pickling cucumbers, Morrison and Ries (1967) suggested that fruit development slowed at higher plant densities."

2015 Tables and Figures. Early marketable yield was generally higher for 'Puccini' than 'Merengue' at all plant densities (Figure 3.5). While the early marketable yield was not statistically different across plant densities for 'Puccini', the plant density of 12 thousand plants per hectare yielded significantly lower than the densities of 74, 99, 123, 148, and 198 thousand plants per hectare for 'Merengue'. Early marketable yield was statistically similar (between 5 and 7 Mg/ha) for all plant densities in spring (Table 3.4). The early marketable was higher in summer by 12 to 25 Mg/ha than spring. The lowest plant density, 12 thousand plants per hectare, was significantly lower than the highest 6 plant densities with regard to total marketable yield in summer. Early marketable yield was higher for 'Puccini' in both spring and summer than for 'Merengue' (Table 3.5).

Total marketable yield was statistically similar across most two-way comparisons of plant density and cultivar combinations with the exception of the lowest plant density (12 thousand plants per hectare) of 'Merengue' and the plant densities of 74 and 99 thousand plants per hectare for 'Merengue' and 49, 74, 99, and 123 thousand plants per hectare for 'Puccini' (Figure 3.6). Total marketable yield was significantly lower at 12 thousand plants per hectare than 74 and 99 thousand plants per hectare in the spring and 74 thousand plants per hectare in the summer (Figure 3.7). This data (Fig 3.6 and 3.7) suggests there is little benefit with regard to total marketable yield in increasing plant density above 25 thousand plants per hectare. There were no statistical differences between plant densities in summer with regard to total marketable yield. Total marketable yield was higher in spring than in summer for 'Merengue' while the opposite was true for ‘Puccini’ (Table 3.6). ‘Merengue’ had a higher total marketable yield than ‘Puccini’ in the spring with the opposite being true in summer.

The percentage of culls for ‘Merengue’ was lower in both the spring and summer than for ‘Puccini’ at all plant densities (Figure 3.8). There were no statistical differences between plant densities for ‘Merengue’ in either season. The same is true for ‘Puccini’ with the exception of two two-way comparisons in the spring. The difference in cull percentages between cultivars is consistent with our 2014 results and the results of other studies. However, the increase of culls at higher plant densities is not apparent. Plastic mulch and drip irrigation could have mitigated issues with water stress from less consistent irrigation or competition that were seen in 2014.

The percentage of oversize fruit was higher for ‘Merengue’ in the summer than in the spring, as well as ‘Puccini’ in the spring and the summer (Table 3.7). The percentage of oversize fruit was significantly higher (~16%) for the plant density of 12 thousand plants per hectare than the plant densities of 148 and 198 thousand plants per hectare (~7 and 9% respectively) (Figure 3.9). The percentage of oversize fruit for the middle plant densities ranged from ~10.7 to 13.2%. This is consistent with our 2014 results.

Economic profitability

2014 ANOVA. Early dollar value (dollar value from harvests 1 and 2) was significantly affected by the interaction of density and season. Total dollar value (dollar value from eight harvests) was significantly affected by the main effects: plant density, cultivar, and season. The interactions of plant density x cultivar and plant density x season had a significant effect on early economic return (dollar return from harvests 1 and 2). Total economic return (dollar return from eight harvests) was significantly affected by the main effects of plant density, cultivar, and season (Table A3.3).

2015 ANOVA. The interactions of plant density x cultivar, plant density x season, and cultivar x season all had a significant effect on early dollar value, total dollar value, early economic return, and total economic return (Table A3.4).

2014 Tables and Figures. Early dollar value was higher ($1720 to $1800/ha) at the plant densities of 25, 49, and 99 thousand plants per hectare than at the plant density of 198 thousand plants per hectare (~$700/ha) in the spring (Figure 3.10). Early dollar value ranged from $1000 to $1700 per hectare in the summer season. Total dollar value was nearly $900 per hectare higher for 'Merengue' than 'Puccini' (Table 3.8). Total dollar value was nearly $2000 per hectare higher in the spring than summer (Table 3.9).

Early economic return was lowest at the plant density of 198 thousand plants per hectare for 'Merengue' and negative for 'Puccini' (Figure 3.12). This value ranged from $890 to $1540 per hectare for all other plant density and cultivar combinations. This result confirms that higher plant densities can be cost prohibitive and even unprofitable for growers especially if they rely on early yield. In the spring, early economic return was lowest (-$450/ha) at the plant density of 198 thousand plants per hectare (Figure 3.13). Similarly, the plant density of 198 thousand plants per hectare yielded the lowest value ($285/ha) in the summer season but was only statistically lower than that value ($1491/ha) at the plant density of 49 thousand plants per hectare. Total economic return was lowest at the plant density of 198 thousand plants per hectare at $1687 per hectare, while the other plant densities garnered statistically similar values of ~$3000 to $3500 per hectare (Table 3.10). 'Merengue' had a higher total economic return than 'Puccini' by nearly

$1000 per hectare (Table 3.11). Total economic return was higher in spring than summer by nearly $2000 per hectare (Table 3.12).

2015 Tables and Figures. Early dollar value was lower in general for 'Merengue' than 'Puccini' (Figure 3.14). Plant density had little effect on early dollar value for 'Puccini', this value ranged from ~$6000 to $7700 per hectare. The plant density of 12 thousand plants per hectare garnered the lowest early dollar value ($1874/ha) for 'Merengue'. In general, the plant densities of 74 to 198 yielded higher early dollar values (~$4400 to $4900/ha) for 'Merengue'. These results contradict the results of 2014 where 'Merengue' outperformed 'Puccini' and the plant density of 198 thousand plants per hectare resulted in the lowest yield. Differences in environment between the years were stark. The difference in cultivar performance between 2014 and 2015 could be a result of genotype-environment interaction since plants were grown on plastic mulch with drip irrigation in 2015. The addition of plastic mulch and drip irrigation would have a large impact on water availability.

Yields were higher in 2015 than in 2014. In the spring, early dollar value was statistically similar at each plant density and ranged from $1984 to $2635 per hectare (Figure 3.15). Early dollar value was higher in summer than in spring across all plant densities. The plant densities of 12 and 25 thousand plants per hectare yielded the lowest early dollar values for 'Puccini' ($5392 and 6931/ha, respectively). The plant densities of 74, 99, 123, 148, and 198 thousand plants per hectare had $7900 to 9500 per hectare in the summer. 'Puccini' outperformed 'Merengue' with regard to early dollar value in both seasons (Table 3.13). Both cultivars had much higher early dollar values in the summer than spring. These results were different from those in 2014. The addition of plastic mulch and drip irrigation could have provided a more optimal environment in the summer season than the bare ground and overhead irrigation in the summer of 2014.

Few relevant statistical differences present themselves in the interaction between plant density and cultivar for total dollar value (Figure 3.16). For 'Merengue', the plant densities of 74 and 99 thousand plants per hectare were higher yielding with regard to total dollar value ($17053 and 15791/ha, respectively) than the plant density of 12 thousand plants per hectare ($11821/ha). The relationship between total dollar value and plant density remains relatively flat as more densities are reviewed. In 2015, the clear drop in marketable yield/total dollar value is not apparent at the highest plant densities. The addition of drip irrigation and plastic mulch for moisture retention could account for this difference. Again, few statistical differences existed for the interaction of plant density and season with regard to total dollar value (Figure 3.17). Total dollar value was lowest ($12186 and 11740/ha) at the plant densities of 12 and 25 thousand plants per hectare in the summer, while it was similar (~$14300 to 17200/ha) for all other plant density and season combinations. These results show that the current suggested plant density of ~75 thousand plants per hectare is reasonable and that using a plant density around 49 thousand plants per hectare to reduce input cost could be beneficial for growers. 'Merengue' yielded lower total dollar values by nearly $2500 per hectare in the summer than in the spring; 'Merengue' was lower than 'Puccini' in both seasons (Table 3.14).

Early economic return was lower for 'Merengue' than 'Puccini' (Figure 3.18). The plant density of 12 thousand plants per hectare had a lower early economic return ($1764/ha) than those of 74, 99, 123, and 148 thousand plants per hectare ($3990 to 4330/ha) for 'Merengue'. There was little difference among plant densities for 'Puccini' with regard to early economic return. The effect of plant density on economic return was different for the two cultivars. This result is consistent with numerous studies that confirmed the difficulty of determining the relationship between plant density and yield. This value was lower by at least $3000 per hectare across all plant densities in the spring than the summer (Figure 3.19). In summer, the plant density of 12 thousand plants per hectare yielded lower by $2300 to 3300 per hectare than the highest six plant densities. Early economic return was higher in the summer than the spring for both cultivars (Table 3.15). Cooler temperatures in early spring versus warmer temperatures in early summer could be responsible for this stark difference. 'Puccini' garnered higher early economic return than 'Merengue' in both seasons.

Total economic return was statistically similar for nearly every combination of plant density and cultivar (Figure 3.20). The plant density of 74 thousand plants per hectare yielded higher than that of 12 thousand plants per hectare with regard to total economic return. Similarly, few relevant statistical differences existed between the plant density and season combinations (Figure 3.21). Total economic return was lowest for 'Merengue' in the summer ($12681/ha) and ranged from ~$15000 to $15300 per hectare for 'Merengue' in the spring and 'Puccini' in both seasons (Table 3.16).

Fruit quality measurements

2014 ANOVA. The length : diameter ratio was significantly affected by the interaction of plant density and cultivar. The interaction of plant density and season and main effect cultivar had a significant effect on fruit firmness (N) (Table A3.5).

2015 ANOVA. The length : diameter ratio was significantly affected by the interaction of cultivar and season, and by the main effect plant density. Fruit firmness (N) was significantly affected by the interactions of plant density and season, and cultivar and season (Table A3.6).

2014 Tables and Figures. There were few statistical differences between the plant density and cultivar combinations for the length : diameter ratio (Table 3.17). Fruit were shorter at the plant densities of 99 and 198 thousand plants per hectare than that of 25 thousand plants per hectare for ‘Merengue’. Most combinations resulted in fruit that would be considered “medium-long” to “long” for pickling purposes (L : D of 3.0 to 3.5), while one resulted in “short” fruit (Schultheis et al., 2000).

Fruit firmness was similar, ranging from ~57 to 63 N, across all plant density and season combinations with the exception of the plant densities of 25 and 99 thousand plants per hectare in the spring (Table 3.18). ‘Merengue’ had fruit that were less firm than those of ‘Puccini’ (Table 3.19). Most pickling cultivars are slightly more firm ~67 to 89 N.

2015 Tables and Figures. The length : diameter ratio was similar for both cultivars in the spring, while ‘Merengue’ had slightly longer fruit than ‘Puccini’ in the summer (Table 3.20). There was a significant difference in the length : diameter ratio of the fruit at plant densities of 12 and 49 thousand plants per hectare (3.45) and those from plant densities 74 and 148 thousand plants per hectare (3.31) (Table 3.21). This difference is not significant for the purposes of pickle growers or processors.

Fruit firmness was similar for all plant densities in both seasons with the exception of the plant density of 123 thousand plants per hectare, which resulted in firmer fruit in the spring than the summer (Table 3.22). In general, fruit were more firm in 2015 than 2014. Fruit firmness ranged from 69.2 to 78.6 in 2015. ‘Puccini’ had a higher fruit firmness than ‘Merengue’ in both seasons (Table 3.23). While there was no difference in fruit firmness between seasons for ‘Merengue’, ‘Puccini’ had firmer fruit in the spring than the summer. These results are consistent with 2014.

Conclusions

We set out to find the effect of plant density and season on the yield and quality of two parthenocarpic cultivars in order to suggest optimum plant density. Based on an economic analysis considering the cost of seeds, a plant density of 49 thousand plants per hectare would be ideal for a multiple harvest system. In the case that seed cost decreases, there is a potential for higher profit at the increased plant density of 74 to 99 thousand plants per hectare. Results differed between the cultivars in nearly every parameter which could be expected based on previous research. The difference in yield between years suggests that the use of plastic mulch and drip irrigation in the production of parthenocarpic pickling cucumber for multiple harvest is imperative. We did not include economic analysis with these expenses in mind. The cultivars tested had generally softer fruit than non-parthenocarpic cultivars. The difference of early economic return between seasons suggests growers should not expect to rely on early season yields in the spring for most of the harvest.

References

Cantliffe, D.J. and S. C. Phatak. 1975. Plant population studies with pickling cucumbers grown for once-over harvest. J. Am. Soc. Hort. Sci. 100: 464–466.

Nienhuis, J., R. L. Lower and C. H. Miller. 1984. Effects of genotype and within-row spacing on the stability of sex expression in cucumber. HortScience 19: 273-274.

Pitrat, M., Chauvet, M., Foury, C. 1999. Diversity, history and production of cultivated cucurbits. Acta Horticulturae 492-21.

Schultheis, J.R., C. Averre, M. Boyette, E. Estes, G. Holmes, D. Monks and K. Sorenson. 2000. Commercial Production of Pickling and Slicing Cucumbers in North Carolina. N.C. State Ag. Extension. https://content.ces.ncsu.edu/commercial-production-of-pickling-and-slicing-cucumbers-in-north-carolina.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. 2017. https://websoilsurvey.sc.egov.usda.gov/.

Tan, C. S., V. W. Nuttall and J. M. Fulton. 1983. The influence of soil moisture stress and plant populations on the yield of pickling cucumbers. Sci. Hort. 21, 217–224.

United States Department of Agriculture, National Agricultural Statistics Service. 2017. Cucumbers: National Statistics. 2017. <http://www.nass.usda.gov/>

Wann, E.V. 1993. Cucumber Yield Response to Plant Density and Spatial Arrangement. J. Prod. Agric. 6.

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

Widders, I.E. and H. C. Price. 1989. Effects of plant density on growth and biomass partitioning in pickling cucumbers. J. Am. Soc. Hortic. Sci. 114: 751–755.

Tables

Table 3.1. Main effect of cultivar on marketable yield (Mg/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2014.[y]

Cultivar	Mg/ha
Merengue	10.0 a[x]
Puccini	7.7 b

[z]Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means are separated by cultivar by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.2. Main effect of season on marketable yield (Mg/ha) [z] for eight harvests of parthenocarpic pickling cucumbers, 2014.[y]

Season	Mg/ha
Spring	11.3 a[x]
Summer	6.4 b

[z]Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means are separated by season by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.3. Main effect of cultivar on percentage of culls [z] for parthenocarpic pickling cucumbers, 2014.[y]

Cultivar	Percentage of culls
Merengue	15.2 b[x]
Puccini	24.7 a

[z]Percentage culls are the percentage of misshapen cull fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.4. Interaction of plant density and season on marketable yield (Mg/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Density (plants/ha)	Spring	Summer
12,000	6.4 c[x]	18.1 b
25,000	6.3 c	23.6 ab
49,000	6.3 c	25.4 a
74,000	7.1 c	29.6 a
99,000	6.1 c	28.4 a
123,000	5.7 c	30.3 a
148,000	5.0 c	28.1 a
198,000	5.1 c	28.3 a

[z] Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.
[y] Data are means of 3 replications for plots harvested every half week.
[x] Means separated by plant density and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.5. Interaction of cultivar and season on marketable yield (Mg/ha) for harvests one and two of parthenocarpic pickling cucumbers, 2015.

	Season	
Cultivar	Spring	Summer
Merengue	3.9 d[x]	20.5 b
Puccini	8.1 c	32.4 a

[z] Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.

[y] Data are means of 3 replications for plots harvested every half week.

[x] Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.6. Interaction of cultivar and season on marketable yield (Mg/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	42.9 b[x]	39.3 d
Puccini	40.9 c	47.2 a

[z] Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.

[y] Data are means of 3 replications for plots harvested every half week.

[x] Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.7. Interaction of cultivar and season on percentage of oversize fruit[z] for parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	9.2 b[x]	17.3 a
Puccini	8.5 b	10.6 b

[z]Percentage oversize are the percentage of oversize fruit of the total yield.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

Table 3.8. Main effect of cultivar on dollar value ($/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2014.[y]

Cultivar	Dollars/ha
Merengue	3963 a[x]
Puccini	3081 b

[z]Dollar value per hectare determined using industry values of marketable fruit.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

Table 3.9. Main effect of season on dollar value ($/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2014.[y]

Season	Dollars/ha
Spring	4452 a[x]
Summer	2593 b

[z]Dollar value per hectare determined using industry values of marketable fruit.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.10. Main effect of plant density on economic return ($/ha)^{z} for eight harvests of parthenocarpic pickling cucumbers, 2014.^{y}

Density (plants/ha)	Dollar return/ha
12,000	3063 a^{x}
25,000	3516 a
49,000	3733 a
99,000	3473 a
198,000	1687 b

^{z}Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.
^{y}Data are means of 3 replications for plots harvested every half week.
^{x}Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.11. Main effect of cultivar on economic return ($/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2014.[y]

Cultivar	Dollar return/ha
Merengue	3550 a[x]
Puccini	2639 b

[z]Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.12. Main effect of season on economic return ($/ha)^{z} for eight harvests of parthenocarpic pickling cucumbers, 2014.^{y}

Season	Dollar return/ha
Spring	4007 a^{x}
Summer	2182 b

^{z}Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.
^{y}Data are means of 3 replications for plots harvested every half week.
^{x}Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.13. Interaction of cultivar and season on dollar value ($/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	1476 d[x]	6246 b
Puccini	3279 c	10159 a

[z]Dollar value per hectare determined using industry values of marketable fruit.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

Table 3.14. Interaction of cultivar and season on dollar value ($/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	15647 a[x]	13216 b
Puccini	15470 a	15757 a

[z]Dollar value per hectare determined using industry values of marketable fruit.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.15. Interaction of cultivar and season on economic return ($/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	1137 d[x]	5710 b
Puccini	2850 c	9624 a

[z]Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

Table 3.16. Interaction of cultivar and season on economic return ($/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	15308 a[x]	12681 b
Puccini	15041 a	15222 a

[z]Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.17. Interaction of plant density and cultivar on length : diameter ratio[z] from three harvests of parthenocarpic pickling cucumbers, 2014.[y]

	Cultivar	
Density (plants/ha)	Merengue	Puccini
12,000	3.45 ab[x]	3.56 a
25,000	3.63 a	3.37 ab
49,000	3.36 ab	3.59 a
99,000	3.20 b	3.45 ab
198,000	2.16 b	3.38 ab

[z]Length : diameter ratio determined by averaging the ratio of five grade 2 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated plant density and cultivar combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.18. Interaction of plant density and season on fruit firmness (N)[z] from three harvests of parthenocarpic pickling cucumbers, 2014.[y]

	Season	
Density (plants/ha)	Spring	Summer
12,000	60.1 ab[x]	60.4 ab
25,000	63.8 a	63.4 a
49,000	57.1 ab	59.3 ab
99,000	53.4 b	63.0 ab
198,000	59.3 ab	57.8 ab

[z]Fruit firmness (N) determined by averaging the firmness measurement using a Magness-Taylor tester with an 8mm tip of three grade 3 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.19. Main effect of cultivar on fruit firmness (N)[z] from three harvests of parthenocarpic pickling cucumbers, 2014.[y]

Cultivar	Firmness (N)
Merengue	55.2 b[x]
Puccini	64.3 a

[z]Fruit firmness (N) determined by averaging the firmness measurement using a Magness-Taylor tester with an 8mm tip of three grade 3 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.20. Interaction of cultivar and season on length : diameter ratio[z] of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	3.29 c[x]	3.50 a
Puccini	3.32 c	3.40 b

[z]Length : diameter ratio determined by averaging the ratio of five grade 2 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.21. Main effect of plant density on length : diameter ratio[z] of parthenocarpic pickling cucumbers, 2015.[y]

Density (plants/ha)	L:D
12,000	3.45 a[x]
25,000	3.41 ab
49,000	3.45 a
74,000	3.31 b
99,000	3.34 ab
123,000	3.37 ab
148,000	3.31 b
198,000	3.37 ab

[z]Length : diameter ratio determined by averaging the ratio of five grade 2 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.22. Interaction of plant density and season on fruit firmness (N)[z] of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Density (plants/ha)	Spring	Summer
12,000	73.4 ab[x]	77.1 ab
25,000	74.1 ab	74.6 ab
49,000	74.9 ab	72.9 ab
74,000	75.9 ab	70.4 ab
99,000	75.9 ab	70.7 ab
123,000	78.6 a	69.2 b
148,000	75.1 ab	73.4 ab
198,000	74.1 ab	70.7 ab

[z]Fruit firmness (N) determined by averaging the firmness measurement using a Magness-Taylor tester with an 8mm tip of three grade 3 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by plant density and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Table 3.23. Interaction of cultivar and season on fruit firmness (N)[z] of parthenocarpic pickling cucumbers, 2015.[y]

	Season	
Cultivar	Spring	Summer
Merengue	64.0 c[x]	65.3 c
Puccini	86.5 a	79.5 b

[z]Fruit firmness (N) determined by averaging the firmness measurement using a Magness-Taylor tester with an 8mm tip of three grade 3 fruit for each plot.
[y]Data are means of 3 replications for plots harvested every half week.
[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

Figures

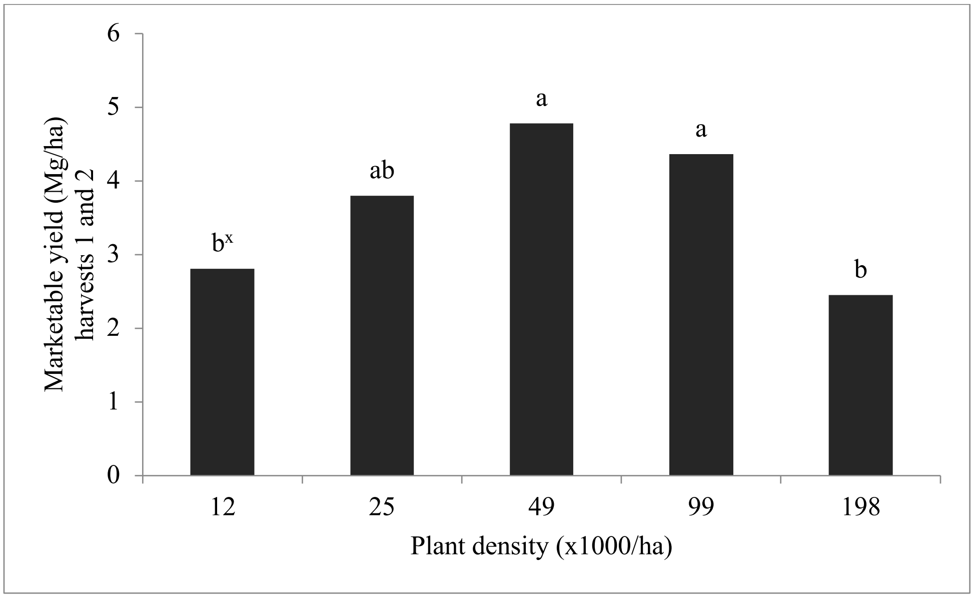

Figure 3.1. Main effect of plant density on marketable yield (Mg/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2014.[y]

[z]Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means are separated by plant density by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

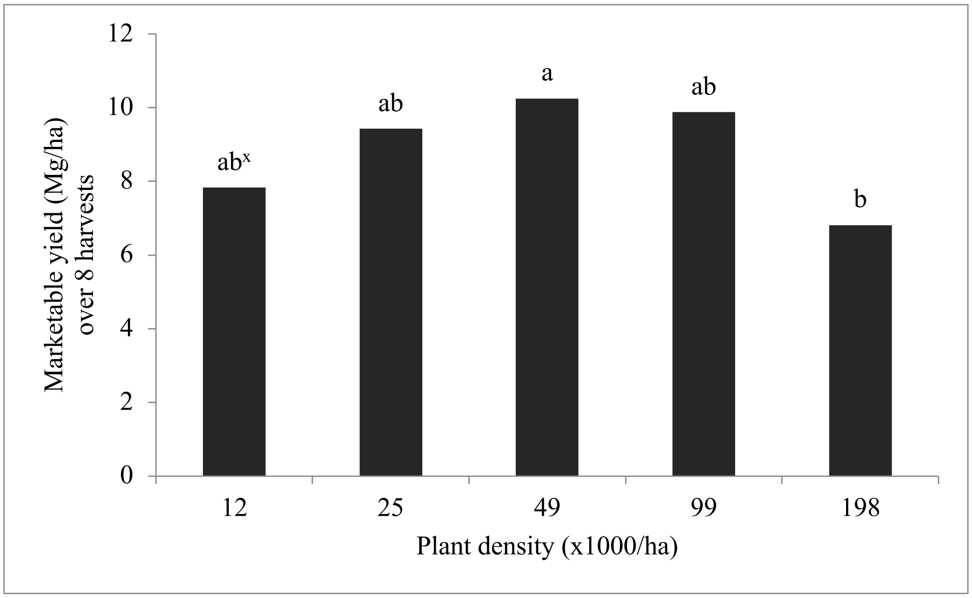

Figure 3.2. Main effect of plant density on marketable yield (Mg/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2014.[y]

[z]Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means are separated by plant density by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

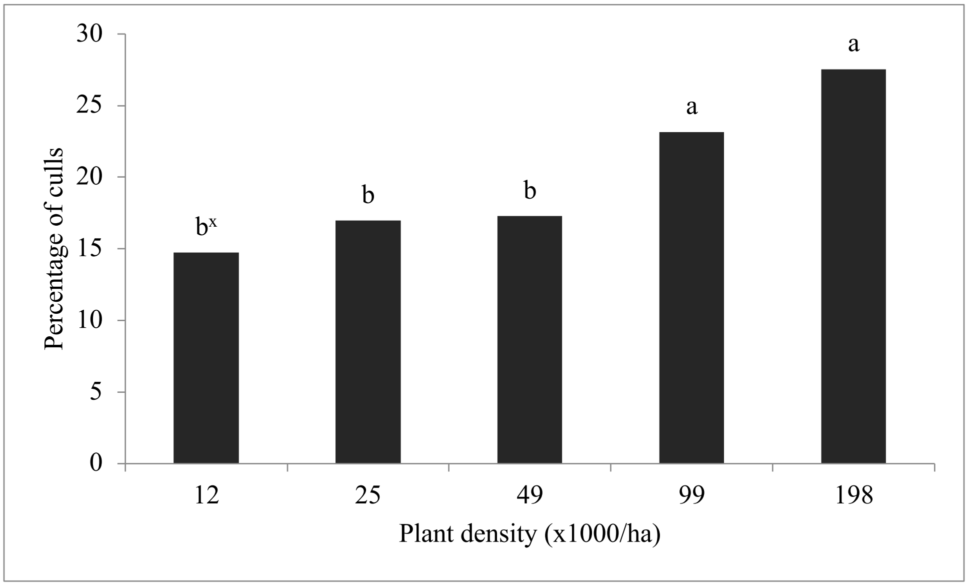

Figure 3.3. Main effect of plant density on percentage of culls^{z} for parthenocarpic pickling cucumbers, 2014.^{y}

^{z}Percentage culls are the percentage of misshapen cull fruit of the total yield.

^{y}Data are means of 3 replications for plots harvested every half week.

^{x}Means separated by plant density by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

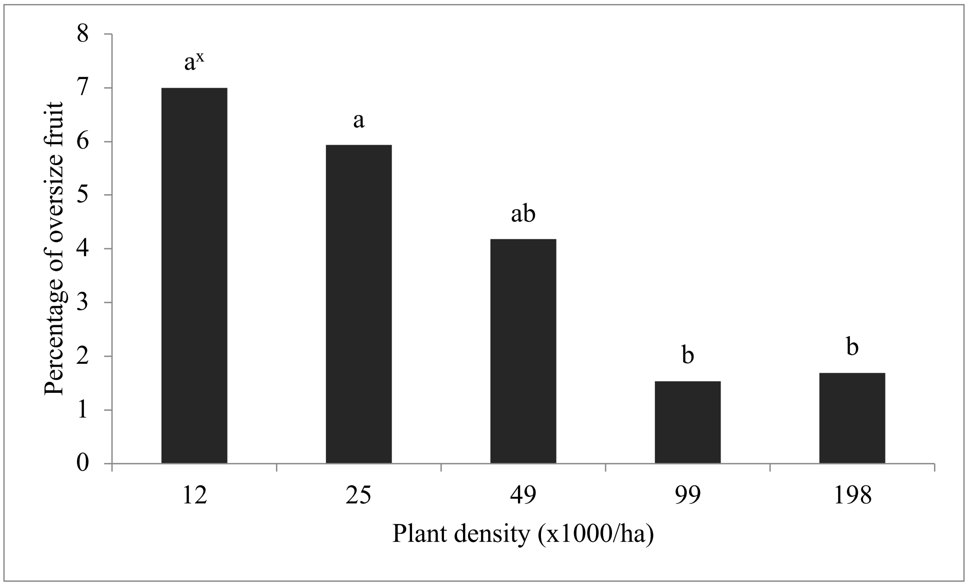

Figure 3.4. Main effect of plant density on percentage of oversize fruit[z] for parthenocarpic pickling cucumbers, 2014.[y]

[z]Percentage oversize are the percentage of oversize fruit of the total yield

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by plant density by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

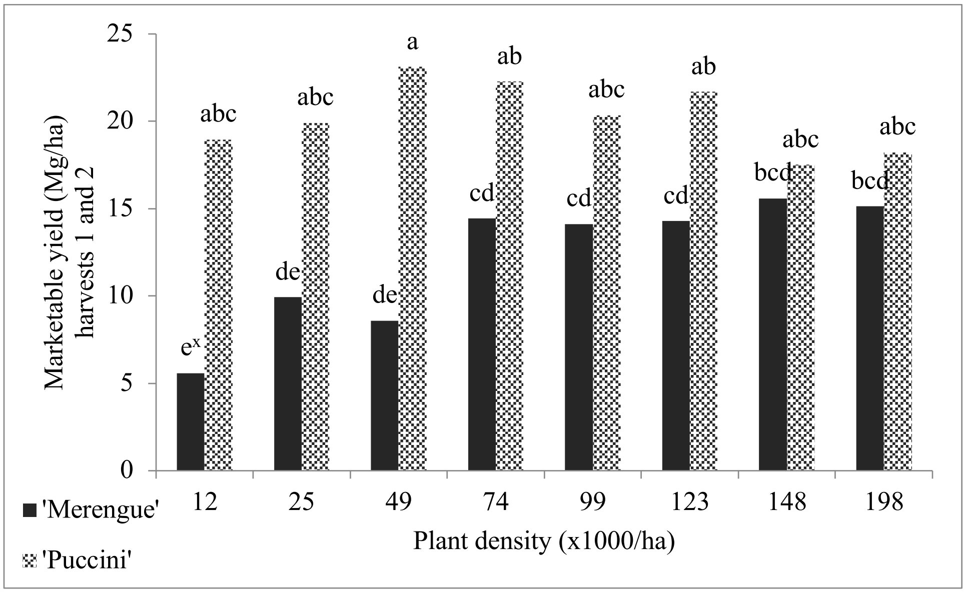

Figure 3.5. Interaction of plant density and cultivar on marketable yield (Mg/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2015.[y]

[z] Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.

[y] Data are means of 3 replications for plots harvested every half week.

[x] Means separated by plant density and cultivar combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

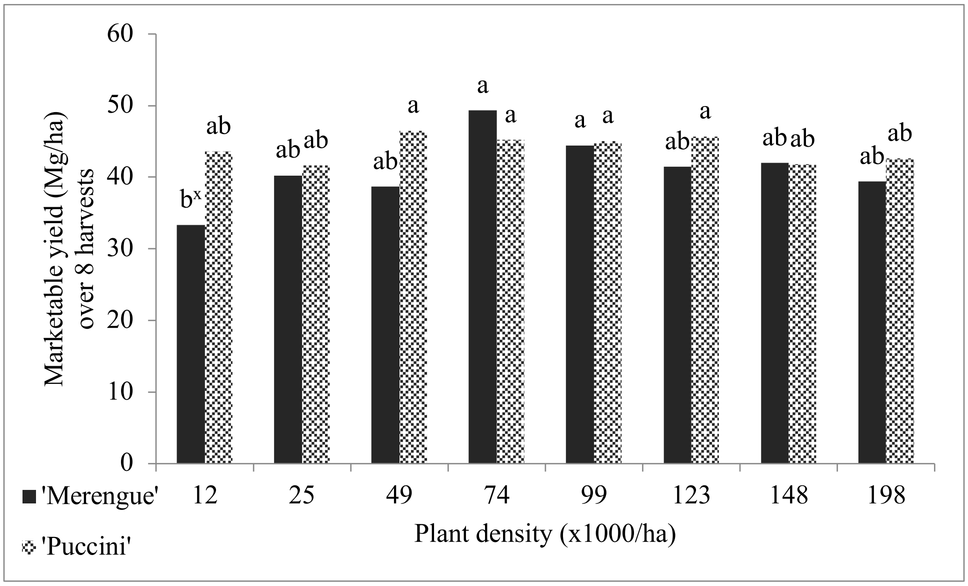

Figure 3.6. Interaction of plant density and cultivar on marketable yield (Mg/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2015.[y]

[z] Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.

[y] Data are means of 3 replications for plots harvested every half week.

[x] Means separated by plant density and cultivar combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

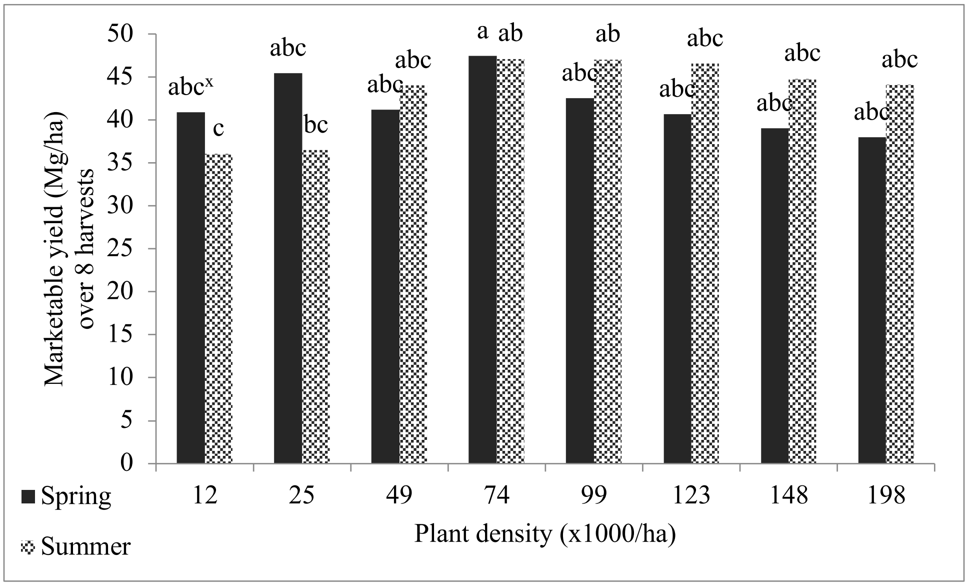

Figure 3.7. Interaction of plant density and season on marketable yield (Mg/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2015.[y]

[z] Marketable yield (Mg/ha) includes grades 1, 2, and 3 of cucumbers.

[y] Data are means of 3 replications for plots harvested every half week.

[x] Means separated by plant density and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

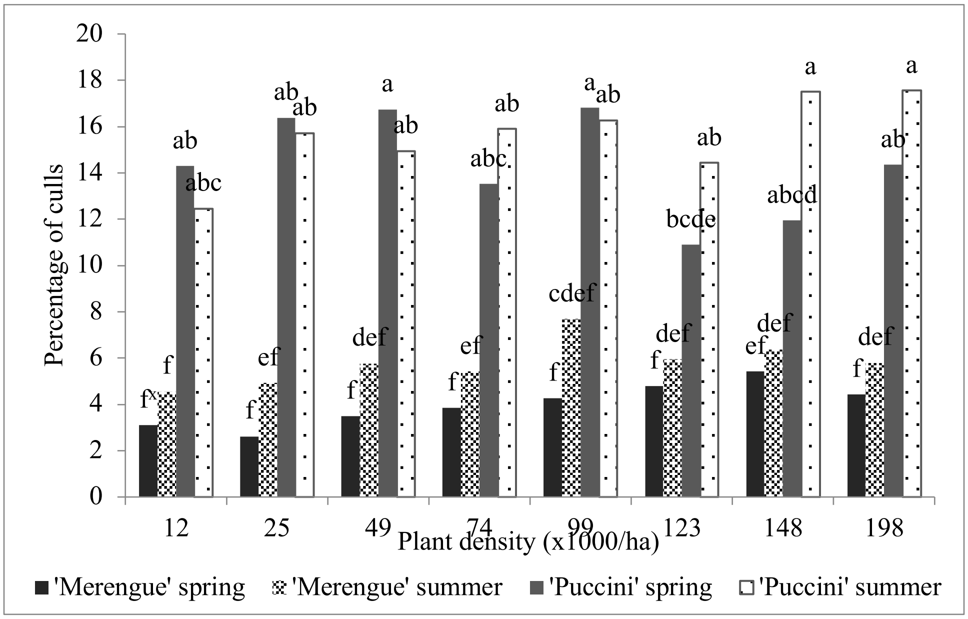

Figure 3.8. Interaction of plant density, cultivar, and season on percentage of culls[z] for parthenocarpic pickling cucumbers, 2015.[y]

[z]Percentage culls are the percentage of misshapen cull fruit of the total yield.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by plant density, cultivar, and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

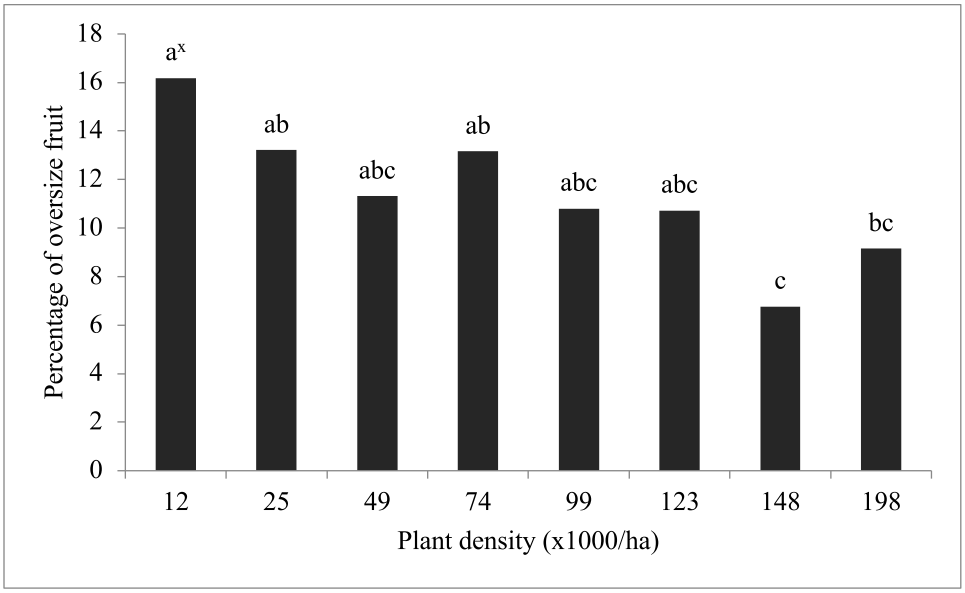

Figure 3.9. Main effect of plant density on the percentage of oversize fruit^z for parthenocarpic pickling cucumbers, 2015.^{y}

^{z}Percentage oversize are the percentage of oversize fruit of the total yield.

^{y}Data are means of 3 replications for plots harvested every half week.

^{x}Means separated by plant density and cultivar combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

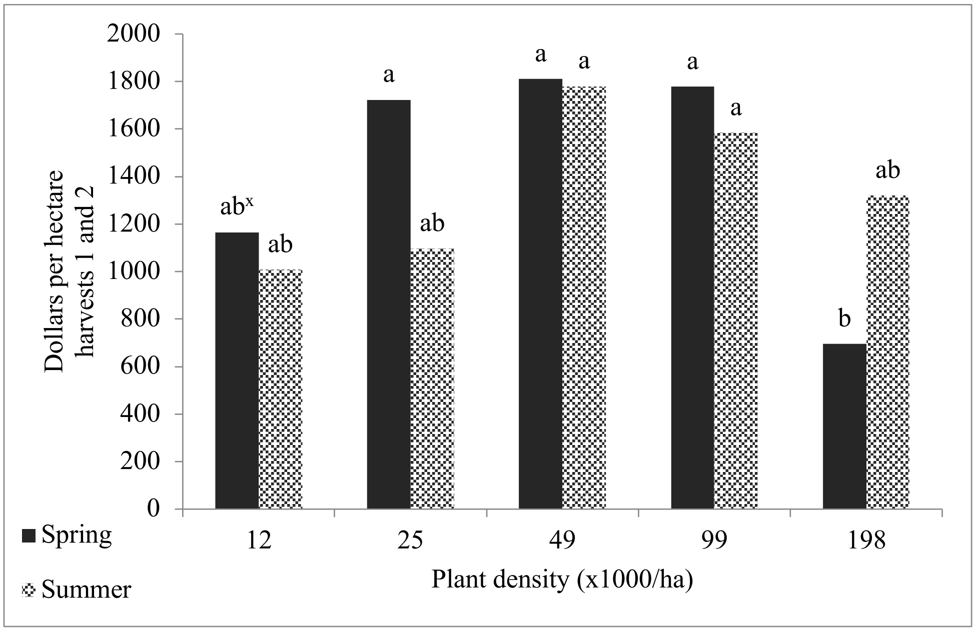

Figure 3.10. Interaction of plant density and season on dollar value ($/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2014.[y]

[z]Dollar value per hectare determined using industry values of marketable fruit.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

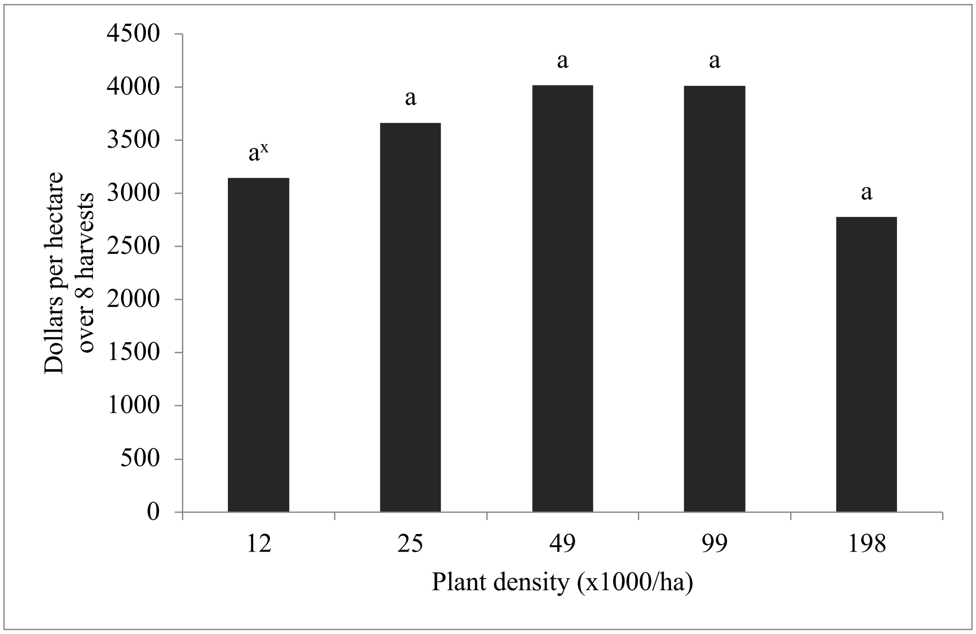

Figure 3.11. Main effect of plant density on dollar value ($/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2014.[y]

[z]Dollar value per hectare determined using industry values of marketable fruit.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

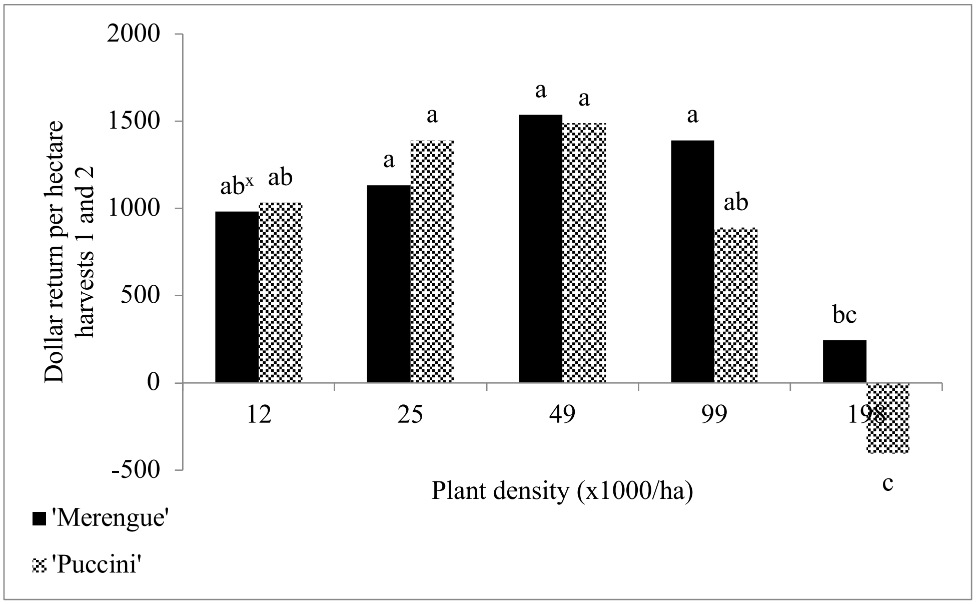

Figure 3.12. Interaction of plant density and cultivar on economic return ($/ha)^{z} for harvests one and two of parthenocarpic pickling cucumbers, 2014.^{y}

^{z}Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.

^{y}Data are means of 3 replications for plots harvested every half week.

^{x}Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

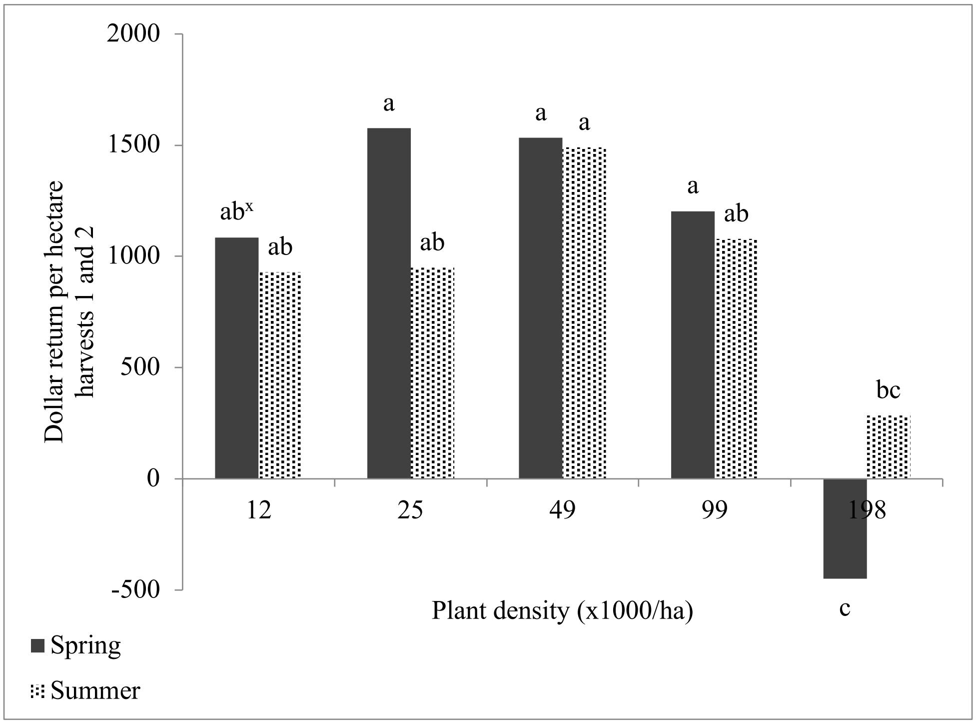

Figure 3.13. Interaction of plant density and season on economic return (\$/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2014.[y]

[z]Economic return determined using industry values of marketable fruit and seed costs (\$12/thousand seeds) based on seeding density.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, $P \leq 0.05$. Means followed by the same letter within table are not significantly different.

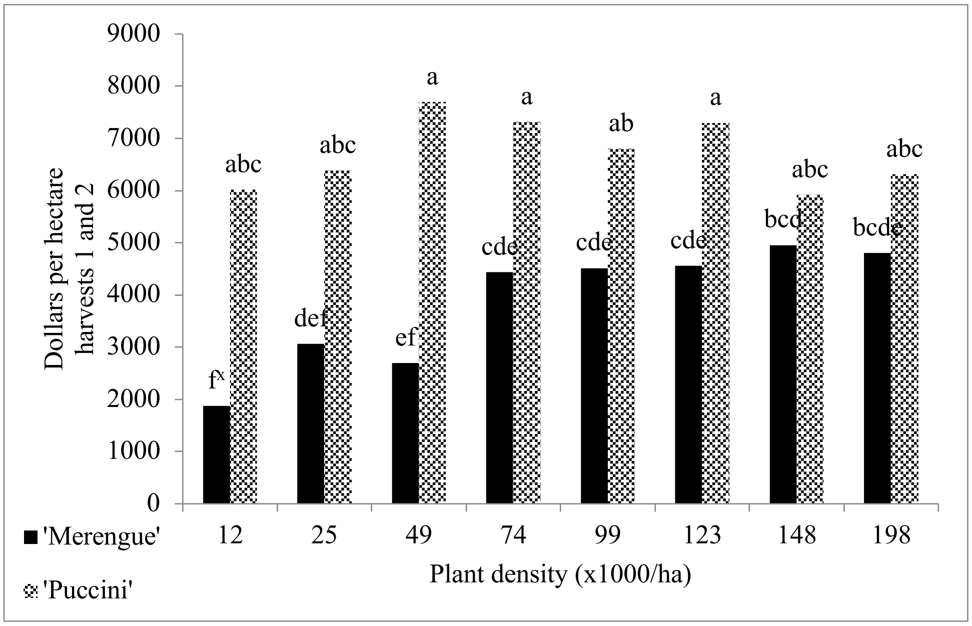

Figure 3.14. Interaction of plant density and cultivar on dollar value ($/ha)^{z} for harvests one and two of parthenocarpic pickling cucumbers, 2015.^{y}

^{z}Dollar value per hectare determined using industry values of marketable fruit.

^{y}Data are means of 3 replications for plots harvested every half week.

^{x}Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

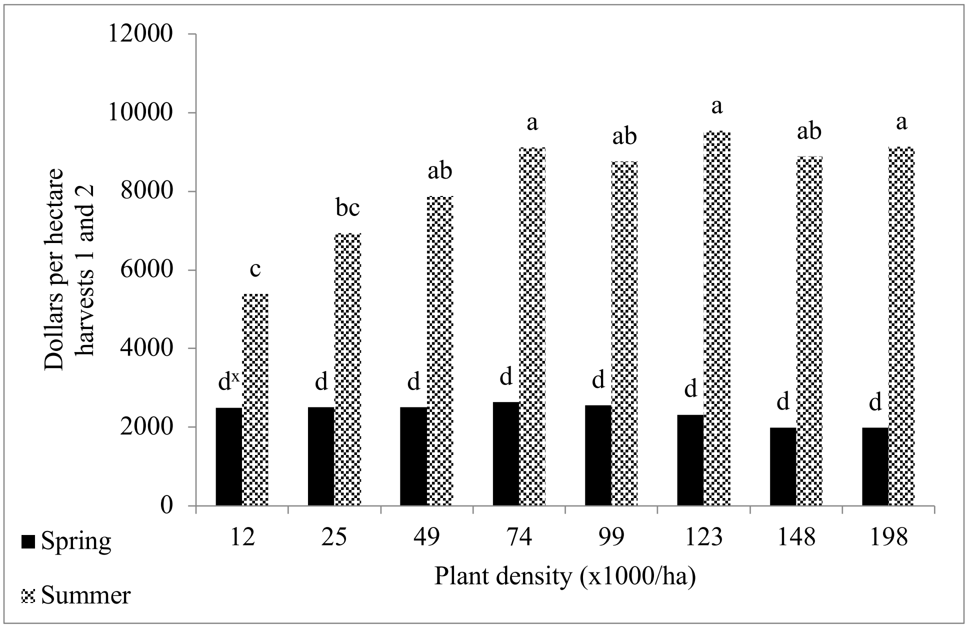

Figure 3.15. Interaction of plant density and season on dollar value ($/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2015.[y]

[z]Dollar value per hectare determined using industry values of marketable fruit.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

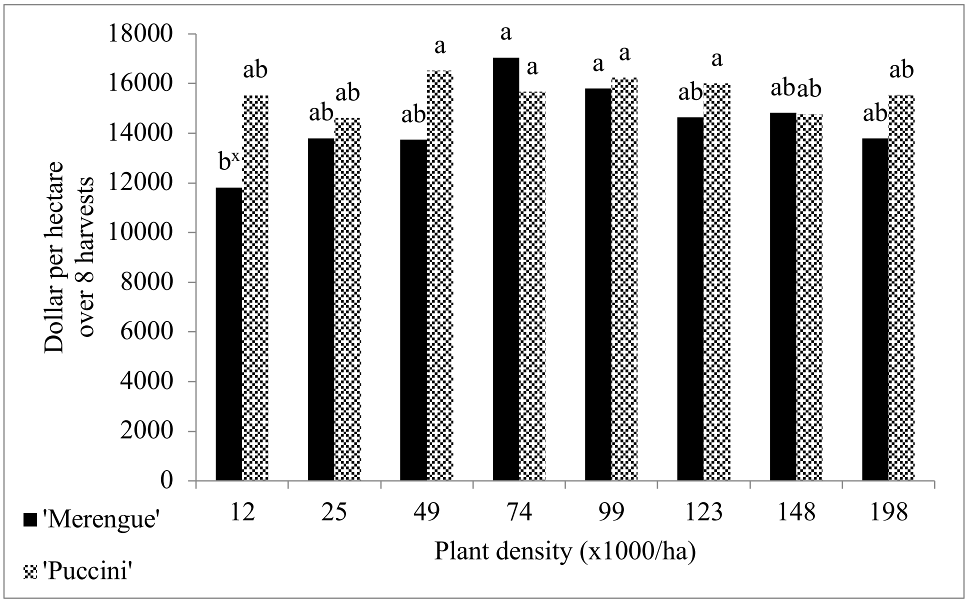

Figure 3.16. Interaction of plant density and cultivar on dollar value ($/ha)^z for eight harvests of parthenocarpic pickling cucumbers, 2015.^{y}

^{z}Dollar value per hectare determined using industry values of marketable fruit.

^{y}Data are means of 3 replications for plots harvested every half week.

^{x}Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

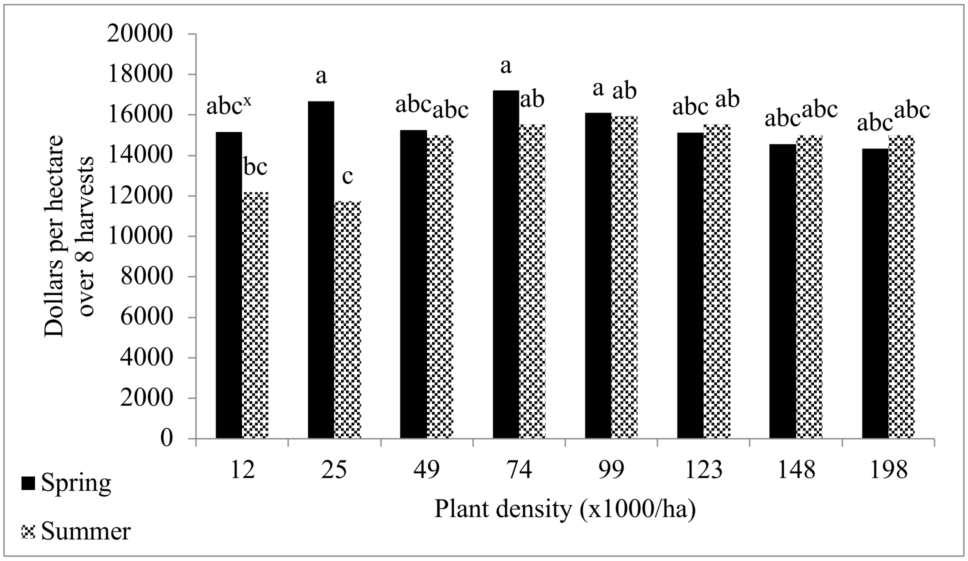

Figure 3.17. Interaction of plant density and season on dollar value ($/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2015.[y]

[z]Dollar value per hectare determined using industry values of marketable fruit.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

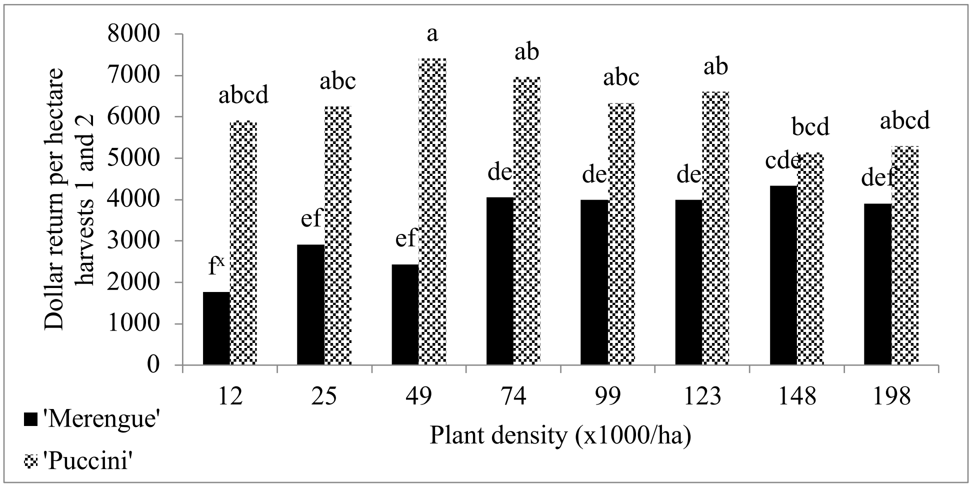

Figure 3.18. Interaction of plant density and cultivar on economic return ($/ha)^z for harvests one and two of parthenocarpic pickling cucumbers, 2015.^{y}

^{z}Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.

^{y}Data are means of 3 replications for plots harvested every half week.

^{x}Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

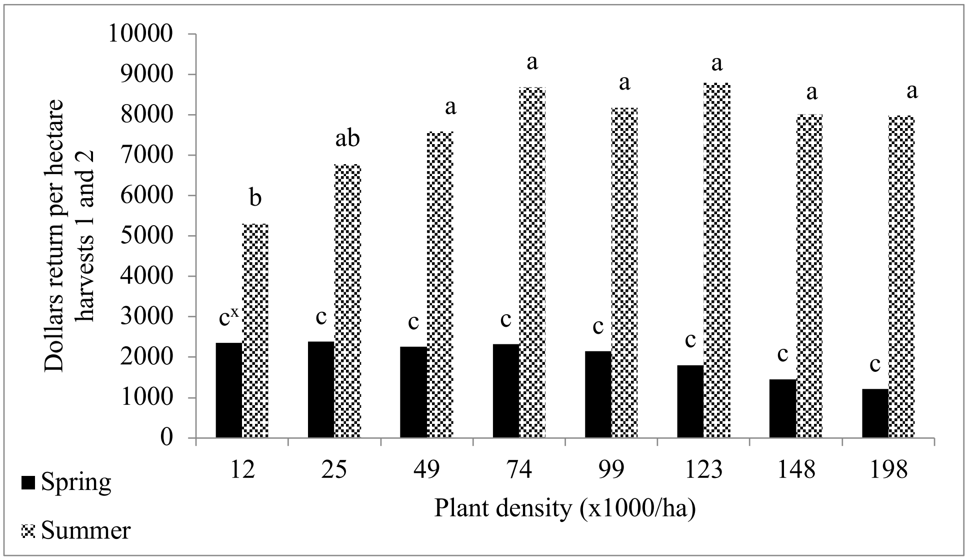

Figure 3.19. Interaction of plant density and season on economic return (\$/ha)[z] for harvests one and two of parthenocarpic pickling cucumbers, 2015.[y]

[z]Economic return determined using industry values of marketable fruit and seed costs (\$12/thousand seeds) based on seeding density.

[y]Data are means of 3 replications for plots harvested every half week.

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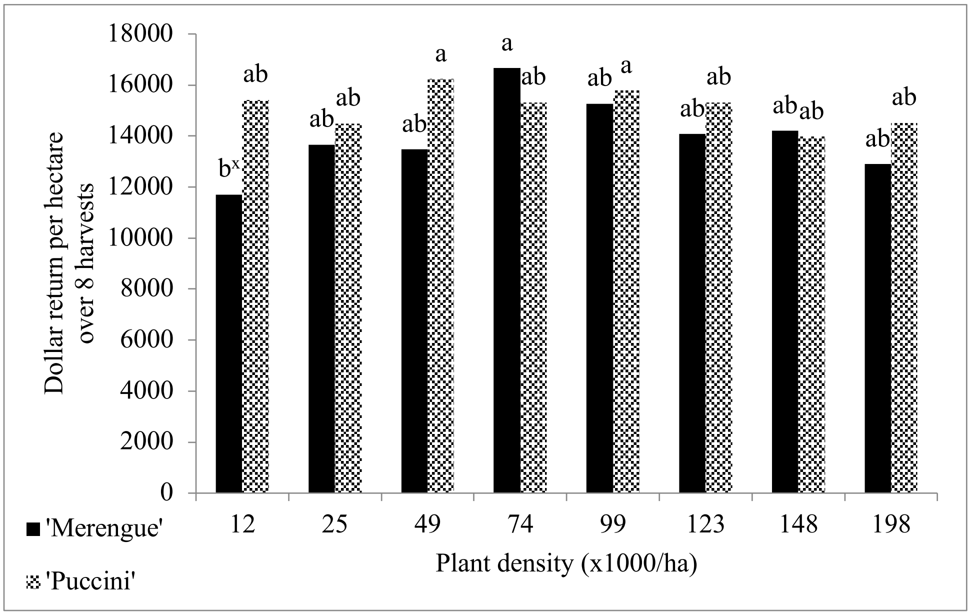

Figure 3.20. Interaction of plant density and cultivar on economic return ($/ha)^{z} for eight harvests of parthenocarpic pickling cucumbers, 2015.^{y}

^{z}Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.

^{y}Data are means of 3 replications for plots harvested every half week.

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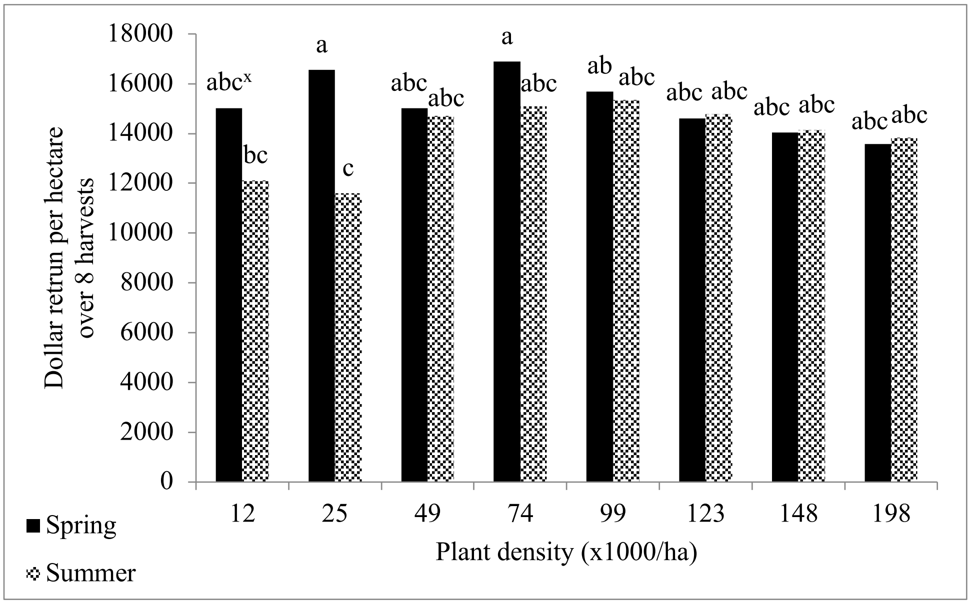

Figure 3.21. Interaction of plant density and season on economic return ($/ha)[z] for eight harvests of parthenocarpic pickling cucumbers, 2015.[y]

[z]Economic return determined using industry values of marketable fruit and seed costs ($12/thousand seeds) based on seeding density.

[y]Data are means of 3 replications for plots harvested every half week.

[x]Means separated by cultivar and season combination by Tukey-Kramer significant difference, P ≤ 0.05. Means followed by the same letter within table are not significantly different.

Chapter Four

North Carolina Performance Trials for Cultivars of Parthenocarpic Pickling Cucumber

Lauren J. Arteman, Todd C. Wehner, and Jonathan R. Schultheis

North Carolina Performance Trials for Cultivars of Parthenocarpic Pickling Cucumber

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Abstract

Parthenocarpic pickling cucumber cultivars were evaluated in trials for yield, fruit quality and brinestock quality in 2014 (17 cultivars) and 2015 (23 cultivars). Replicated field plots were harvested 8 times (6 in summer of 2014). Fruit quality data included length-diameter ratio and fruit firmness taken from 3 harvests. Fruit from those harvests were brined at Mt. Olive Pickle Co. for evaluation of brine quality. In 2015, some disease ratings and assessment of spininess were added to the data collection.

Earliness was affected by season and cultivar in both years. Among the top performers in both years were Puccini, and 12-109 from Rijk Zwaan. Cultivar and judge affected the average fruit rating. Cultivars with high average brinestock ratings in both years included; Gershwin, Stravinsky, 12-109. In 2015, cultivars NUN2001, and 10-170 were also rated among the highest for brinestock quality. Yields were much higher in 2015 than in 2014. Inconsistency of performance between years is a problem facing growers in the southeast. Fruit texture upon brine is of concern to industry members as well. While challenges exist, the potential for a larger profit margin with parthenocarpic cultivars is clear.

Introduction

Parthenocarpic pickling cucumbers set fruit without pollination and are potentially higher yielding than conventional seed types (Pandolfini et al., 2009). There is no need for growers to provide hives of honeybees to pollinate the crop in each field. Higher yields along with higher fruit quality make parthenocarpic cultivars an attractive alternative for pickling cucumber growers.

Cultivars are available from seed companies including: Bejo Seeds, Nunhems, Rijk Zwaan, Seminis, HortAg, and US Agriseeds. Seeds of parthenocarpic pickling cultivars from these companies were obtained to evaluate performance in two years and two seasons in North Carolina.

Materials and Methods

The study was conducted at the Cunningham Research Station in Kinston, NC to evaluate yield and quality of parthenocarpic pickling cucumber cultivars for production in North Carolina. Soils were a Norfolk loamy sand (Typic Kandiudults) (NRCS, 2017).

2014. Spring plots were sown on 6 May. Harvests were made on 20, 24, 27, 30 June and 3, 8, 11, 15 July. Summer plots were sown on 17 June. Harvests were made on 25, 28, 31 July, and 4, 11, 15 August.

2015. Spring plots were planted 19 May. Harvests were made on 23, 26, 29 June, 3, 7, 10, 14, and 20. Summer plots were planted 25 June. Harvests were made on 31 July, 4, 7, 11, 14, 18, 21, and 25 August.

Cultural Practices. Plots were planted on raised beds covered in black plastic mulch in 2014. In 2015, spring plots were planted on black plastic mulch and summer plots were on white plastic mulch. Plots were 6 m long and on 1.5 m centers. We over-seeded plots by 15% of the desired planting density (49,000 plants/ha) at a depth of 10-15 mm and covered by hand. At 15 days after planting (DAP), plots were thinned to 49,000 plants/ha. Standard production practices were followed (Schultheis et al., 2000). Plots were harvested 8 times (6 in the summer season of 2014).

Fruit yield and fresh fruit quality. At each harvest, fruit were collected and separated into grades 1 (0 to 27 mm), 2 (28 to 38 mm), 3 (39 to 51mm), 4 (greater than 51mm in diameter; oversize), and misshapen culls (nubbins, crookeds) (Wehner, 1986). Weights were summed by grade for each plot. Five grade 2 fruit were measured to determine average length : diameter ratio of each plot. Fruit firmness was measured on three grade 3 fruit using a Magness-Taylor tester with an 8 mm (5/16") tip.

Brined fruit quality, bloater, and defect evaluation. After data collection at the second, fourth, and sixth harvest, fruit of each cultivar were combined over replication in a burlap sack and transported to Mt. Olive Pickle Company in Mt. Olive, NC to be brined for later evaluation of fruit quality.

In November of both years, cucumber industry personnel were invited to Mt. Olive Pickle Company to judge the brined fruit quality of the cultivars. There were 9 judges in 2014 and 11 judges in 2015. Fruit quality was rated 1-9 (1 = poor, 5 = average, 9 = excellent) for categories including fruit shape, exterior color, seed cell size, fruit uniformity, and fruit texture. Those ratings were averaged for an average quality rating. Fruit firmness was measured on ten grade 3 fruit using a Magness-Taylor tester with an 8 mm (5/16") tip.

Longitudinal cross sections of ten to twenty grade 3 fruit were evaluated for bloaters (balloon, lens, honeycomb) and defects (blossom-end, placental hollows, soft centers). Estimates of total volume as a percentage of each fruit that was damaged was recorded.

Disease ratings. In 2015, disease ratings were taken twice for symptoms of Downey mildew and once for symptoms of anthracnose. Disease ratings were from 0 to 9, with 0 meaning no disease, 1-2 meaning trace, 3-4 slight, 5-6 moderate, 7-8 severe, and 9 dead.

Spininess. The level of spininess or amount of spines on the fruit surface was rated by two individuals in the field on a 0 to 9 scale (0 = no spines, 3 = few spines, 5 = moderate spines, 7 = numerous spines).

Data analysis. Data were subjected to PROC MEANS and GLM (ANOVA) using SAS v 9.4 (SAS Institute, Cary, NC). Years were analyzed separately. Fruit value ($/ha) was calculated based on the weight of the marketable fruit (grades 1, 2, and 3, excluding cull and oversize). Early yield percentage, total yield, total marketable yield, and corresponding dollar values were calculated based on the first two harvests and all harvests, respectively. Fruit value of each grade was determined using industry values (P. Denlinger, 2016, Mt. Olive Pickle Co., NC, personal communication, 2016), and that was used to calculated total and early fruit value. The values used for grades 1, 2 and 3 were $13.50/bu, $8.50/bu, and $6.00/bu, respectively.

Results

2014 trials

ANOVA. Early dollar value (dollars per hectare from harvests one and two) was affected by season, replication, and cultivar (Table A4.1). Early yield percentage (percentage of total tonnage from harvests one and two) was affected by season and cultivar. Season, replication, and cultivar had a significant effect on total dollar value (dollars per hectare from harvests one through eight), total tonnage (Mg/ha), and marketable tonnage. The percentage of culls and percentage of oversize fruit were affected by cultivar.

The length : diameter ratio and firmness of fresh fruit were affected by replication and cultivar (Table A4.2). Brined fruit firmness was affected by cultivar.

Average quality ratings of brined fruit were affected by cultivar and judge (Table A4.3). Brined fruit shape, exterior, texture, and uniformity ratings were affected by harvest, cultivar, and judge. Seed cell ratings of brined fruit were affected by cultivar and judge. Cultivar had no effect on bloaters or defects (Table A4.4).

Yield measurements. Early dollar value ranged from $316 to $2177 per hectare (Table 4.1). Cultivars that performed well for earliness achieving 40 percent or more of the total tonnage in the first two harvests included: 2943, Ansor F1, and Artist F1 (Bejo Seeds), NUN-55007 (Nunhems), 12-109, 12-110, Gershwin, Puccini, Stravinsky, and Surya (Rijk Zwaan), and Merengue (Seminis). Total dollar value for all cultivars ranged from $1989 to $4423 per hectare. Desired planting density was not achieved for 8 of the 17 cultivars tested in 2014. Total dollar value was statistically similar for each of the cultivars that were tested at the planting density of 41 to 50 thousand plants per hectare. While the planting density was less (34-39) for cultivars:

2943, Artist F1, and Karaoke (Rijk Zwaan), the total dollar value was similar to that of the cultivars planted at the higher plant densities.

The percentage of culls was lowest (9 – 13%) for cultivars: 2943, Aviator F1 (Bejo Seeds), HSX-4415-1 (HortAg), NCSU-01 (NC State), NUN-55007 (Nunhems), Karaoke, Wagner (Rijk Zwaan), and Merengue (Seminis) (Table 4.1). The percentage of oversize fruit was high for two cultivars: USACR10540 (US Agriseeds) and HSX-4415-2.

Fruit quality. Cultivars with long fruit (L:D ratios of 3.8 to 4.0) included: 12-110, 12-109, and Gershwin (Rijk Zwaan) and NUN-55007 (Nunhems) (Table 4.2). Cultivars with L:D ratios of 3.2 to 3.5 included: Merengue, Puccini, Surya, Wagner, Stravinsky, Artist F1, Ansor F1, and USACR10540. Shorter cultivars (L:D ratios of 2.9 to 3.1) were 2943, Karaoke, NCSU-01, HSX-4415-2, and Aviator F1.

Cultivars 12-109, Surya, Gershwin, NCSU-01, and Wagner were among the firmest fresh fruit with firmness 80 to 92 N. Brined fruit firmness was highest (90 to 102 N) for cultivars 12-110, 12-109, Puccini, Surya, Gershwin, Karaoke, Wagner, and Stravinsky.

Judges were in agreement between high and low quality brined fruit of the cultivars evaluated for shape, exterior, texture, seed cell, and uniformity. Average quality ratings for brined fruit were highest (6.3 to 6.6) for cultivars: 12-109, 12-110, Gershwin, Stravinsky, Surya, and Wagner (Table 4.2). Brined fruit texture ratings were highest for cultivars 12-109, 12-110, Stravinsky, and Surya. Cultivars that were rated highly for uniformity were 2943, Aviator F1, NCSU-01, 12-110, Gershwin, Surya, and Wagner.

2015 trials

ANOVA. Early dollar value and early yield percentage were affected by the interaction of cultivar and season (Table A4.4). Total dollar value and marketable tonnage were affected by replication and cultivar. Total tonnage was affected by season, replication, and cultivar. The percentage of culls was affected by the interaction of season and cultivar. The percentage of oversize fruit was affected by the main effects: season and cultivar.

The length : diameter ratio was affected by replication and cultivar (Table A4.5). Fresh and brined fruit firmness was affected by cultivar.

Average quality ratings of brined fruit along with exterior, texture, seed cell, and uniformity ratings were affected by harvest, cultivar, and judge (Table A4.6). Ratings of brined fruit shape were affected by cultivar and judge. Cultivar did not affect bloater ratings, but had an effect on total defects (Table A4.8).

Yield measurements. Early dollar value ranged from $816 to $7280 per hectare (Table 4.3). Cultivars that performed well for earliness, achieving more than 30 percent of their total tonnage in the first two harvests, were NUN0001 (Nunhems), 20002, 12-109, Bowie, Gershwin, Puccini, RZ-12, RZ-13, and Wagner (Rijk Zwaan). Total dollar value was highest ($16,008 to $19,903 per hectare) for cultivars: 10-170 (Bejo Seeds), NUN0001, 12-109, Bowie, Gershwin, Karaoke, Liszt, RZ-17, Stravinsky, Surya, and Wagner. The percentage of culls was high (15-20%) for cultivars: 20002, 12-109, Gershwin, Puccini, RZ-15, and Stravinsky. The percentage of oversize fruit was high for two cultivars: NQ5007 and NUN2001 (14 and 21%, respectively).

Fruit quality. Cultivars with long fruit (L:D ratios of 3.7 to 4.0) included: NQ5007, NUN0001, NUN2002, Bowie, Gershwin, Liszt, Rubinstein, RZ-12, and Wagner (Table 4.4).Cultivars with L:D ratios ranging between 3.2 to 3.6 included: 10-170, 21-340, Atik, NUN2001, 20002, 12-109, Karaoke, Puccini, RZ-13, RZ-15, RZ-17, Stravinsky, and Merengue. Fresh fruit firmness was highest (87 – 94 N) for cultivars RZ-13, Stravinsky, Surya, and Wagner.

Brined fruit firmness was highest (98 to 112 N) for cultivars: 20002, 12-109, Gershwin, Karaoke, Puccini, RZ-13, and Wagner.

Average quality ratings were highest in (5.6 to 6.0) for cultivars: 10-170, NUN2001, 12-109, Bowie, Gershwin, Karaoke, Liszt, Puccini, RZ-15, and Stravinsky. Ratings for brined fruit texture were highest for the cultivars: 10-170, NUN2002, 20002, 12-109, Gershwin, Karaoke, Liszt, Puccini, RZ-15, and Stravinsky. Uniformity ratings were highest (5.8 to 6.2) for cultivars: 10-170, Atik, NUN2001, NUN2002, Bowie, Gershwin, Karaoke, Liszt, RZ-16, and RZ-17. Total defects were highest (2.3-4.3) for cultivars: Atik, 12-109, Stravinsky, and Wagner (Table 4.6).

Disease ratings. For all cultivars, downy mildew ratings were between 4 and 6 (Table 4.5). Cultivars with low (3) one-time ratings for anthracnose symptoms included: 10-170, 20002, Surya, and Wagner.

Spininess ratings. Cultivars with numerous spines (7 to 9) included: 10-170, Atik, Karaoke, NUN0001, NUN2001, NUN2002, Liszt, Rubinstein, and RZ-17 (Table 4.5). Cultivars with moderately spiny (4 to 6) included: NQ5007, RZ-12, RZ-15, and Merengue. Cultivars with few spines included: 21-340, 20002, 12-109, Bowie, Gershwin, Puccini, RZ-13, Stravinsky, Surya, and Wagner.

References

Pandolfini, T., Molesini, B., Spena, A. 2009. Parthenocarpy in Crop Plants, in: Østergaard, L. (Ed.), Annual Plant Reviews Volume 38: Fruit Development and Seed Dispersal. Wiley-Blackwell, 326–345.

Schultheis, J.R., Averre, C., Boyette, M., Estes, E., Holmes, G., Monks, D., Sorenson, K. Commercial Production of Pickling and Slicing Cucumbers in North Carolina. N.C. State Ag. Extension. https://content.ces.ncsu.edu/commercial-production-of-pickling-and-slicing-cucumbers-in-north-carolina

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. 2017. https://websoilsurvey.sc.egov.usda.gov/

United States Department of Agriculture, National Agricultural Statistics Service. 2009. Cucumbers: National Statistics. 2016. https://www.nass.usda.gov

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

Tables

Table 4.1. Fruit yield of parthenocarpic pickling cucumbers tested in Kinston, NC for spring and summer seasons of 2014 (cultivars are ranked by dollar value summed over 8 harvests).

		Yield Summary					Fruit grade distribution (percentage by weight)						
		Harvests 1 & 2		Harvests 1-8			Harvests 1-8						
Cultivar	Seed Source	% of Mg/ha total	$/ha	$/ha	Mg/ha Total	Mg/ha Marketable	culls	no. 1	no. 2	no. 3	no. 4	market able	thp /ha
12-110	Rijk Zwaan	52[z]	1973	4423	13	11	17	17	44	20	2	81	50
12-109	Rijk Zwaan	54	1923	3999	11	9	16	21	45	17	1	82	42
Merengue	Seminis	46	1465	3979	12	11	13	10	43	31	2	85	44
Puccini	Rijk Zwaan	60	2177	3937	13	10	21	12	38	26	2	76	48
Surya	Rijk Zwaan	45	1439	3777	12	9	19	15	43	20	4	78	49
Gershwin	Rijk Zwaan	53	1444	3615	11	9	21	14	47	18	0	79	44
NUN-55007	Nunhems	49	1493	3597	13	10	13	10	35	38	5	82	42
USACR10540	US Agriseeds	34	1102	3519	13	10	16	8	34	30	12	72	41
2943	Bejo Seeds	44	1105	3404	11	9	12	10	48	25	4	84	39
Karaoke	Rijk Zwaan	27	740	3389	11	9	13	14	42	25	6	80	35
Artist F1	Bejo Seeds	41	984	3301	11	9	18	18	43	19	2	80	34
NCSU-01	NC State	24	738	3280	11	9	9	8	30	28	9	79	28
Wagner	Rijk Zwaan	27	922	3114	9	8	11	17	37	17	1	85	42
Stravinsky	Rijk Zwaan	50	1095	2642	8	6	24	15	40	20	1	75	36
HSX-4415-2	Hort Ag	16	316	2124	7	5	9	14	31	19	10	77	24
Ansor F1	Bejo Seeds	40	572	2031	7	5	17	17	48	16	2	81	30
Aviator F1	Bejo Seeds	31	416	1989	6	5	11	15	56	17	1	89	27
Mean		40	1171	3301	11	9	16	14	41	23	4	80	39
LSD (5%)		16	598	1360	4	4	7	8	11	11	6		10

[z]Data are means of three replications from either harvests one and two or harvests one through eight.

Table 4.2. Fruit quality data collected on fresh and brined parthenocarpic pickling cucumber cultivars, 2014.

Cultivar	Seed source	Length:diameter	Fresh firmness (N)	Brined firmness (N)	Judged brinestock quality					
					Average	Shape	Exterior	Texture	Seedcell	Uniformity
2943	Bejo Seeds	3.0[z]	65	66	5.7	5.2	6.1	5.4	5.4	6.5
Ansor F1	Bejo Seeds	3.3	61	65	5.5	4.6	5.6	5.6	6.1	5.6
Artist F1	Bejo Seeds	3.3	59	61	5.5	4.9	5.4	5.4	6.3	5.4
Aviator F1	Bejo Seeds	2.9	53	60	5.7	4.5	5.7	6.0	6.2	6.1
HSX-4415-2	Hort Ag	2.9	67	80	5.0	4.1	4.2	5.7	5.7	5.4
NCSU-01	NC State	3.2	80	91	5.6	5.8	5.5	5.2	5.3	6.2
NUN-55007	Nunhems	3.8	71	83	5.6	5.4	6.2	5.2	5.7	5.7
12-109	Rijk Zwaan	3.8	92	99	6.3	5.2	6.5	6.9	7.0	5.9
12-110	Rijk Zwaan	4.0	77	99	6.3	5.6	6.2	6.8	7.0	6.1
Gershwin	Rijk Zwaan	3.8	86	98	6.3	5.5	6.3	6.7	6.8	6.1
Karaoke	Rijk Zwaan	3.1	73	90	5.5	4.9	5.1	5.8	5.7	5.8
Puccini	Rijk Zwaan	3.5	71	96	5.9	5.3	6.1	6.4	6.3	5.6
Stravinsky	Rijk Zwaan	3.4	73	94	6.5	5.6	6.5	7.3	7.3	6.0
Surya	Rijk Zwaan	3.3	83	102	6.6	6.1	6.5	7.1	7.1	6.2
Wagner	Rijk Zwaan	3.5	85	97	6.4	6.3	6.4	6.4	6.6	6.3
Merengue	Seminis	3.5	64	64	5.6	5.6	5.9	5.1	5.6	5.8
USACR10540	US Agriseeds	3.3	70	87	5.7	5.6	5.7	5.6	5.4	6.0
Mean		3.4	51	84	5.9	5.3	5.9	6.0	6.2	5.9
LSD (5%)		0.3	13	12	0.3	0.6	0.4	0.5	0.5	0.4

[z]Data are means of three replications (taken from harvests 2, 4 and 6).

Table 4.3. Quality evaluation for brined parthenocarpic pickling cucumber cultivars, 2014.[z]

Cultivar	Seed Source	Total	Total bloaters	% Balloon	Total defects	% Placental Hollows	% Blossom end defects	% Soft centers
2943	Bejo Seeds	7.3	2.7	2.7	4.7	0.0	0.0	4.7
Ansor F1	Bejo Seeds	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Artist F1	Bejo Seeds	1.0	1.0	1.0	0.0	0.0	0.0	0.0
Aviator F1	Bejo Seeds	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HSX-4415-2	Hort Ag	3.3	0.0	0.0	3.3	0.7	0.0	2.7
NCSU-01	NC State	2.0	0.0	0.0	2.0	1.3	0.0	0.7
NUN-55007	Nunhems	1.3	0.7	1.0	0.7	0.0	0.0	0.7
12-109	Rijk Zwaan	6.7	0.0	0.0	6.7	6.7	0.0	0.0
12-110	Rijk Zwaan	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gershwin	Rijk Zwaan	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Karaoke	Rijk Zwaan	1.7	0.0	0.0	1.7	0.3	0.0	1.3
Puccini	Rijk Zwaan	0.7	0.0	0.0	0.7	0.7	0.0	0.0
Stravinsky	Rijk Zwaan	2.3	1.0	1.0	1.3	1.3	0.0	0.0
Surya	Rijk Zwaan	2.7	1.3	1.3	1.3	0.7	0.7	0.0
Wagner	Rijk Zwaan	2.0	0.0		2.0	1.7	0.0	0.3
Merengue	Seminis	4.3	3.7	3.7	0.7	0.7	0.0	0.0
USACR10540	US Agriseeds	4.0	1.3	1.3	2.7	0.7	0.7	1.3
Mean		2.3	0.7	0.7	1.6	0.9	0.1	0.7
LSD (5%)		6.2	2.7	2.7	5.6	4.8	0.6	2.7

[z]Data are means of three replications (taken from harvests 2, 4 and 6).

Table 4.4. Fruit yield of parthenocarpic pickling cucumbers tested in Kinston, NC for spring and summer seasons of 2015 (cultivars are ranked by fruit value).

		Yield Summary					Fruit grade distribution (percentage by weight)					
		Harvests 1 & 2		Harvests 1-8			Harvests 1-8					
Cultivar	Seed Source	$/ha	% of total	$/ha	Mg/ha Total	Mg/ha Marketable	culls	no. 1	no. 2	no. 3	no. 4	market able
Wagner	Rijk Zwaan	6532[z]	31	19903	59	51	11	13	49	25	3	86
Surya	Rijk Zwaan	4888	25	19786	56	49	9	15	51	21	4	87
Gershwin	Rijk Zwaan	6084	32	19746	63	51	16	11	47	22	4	80
Bowie	Rijk Zwaan	6662	34	19267	56	49	10	13	51	24	2	88
10-170	Bejo Seeds	5021	29	18862	54	49	4	12	54	25	6	90
RZ-17	Rijk Zwaan	4835	26	18221	50	46	7	15	53	23	3	91
Liszt	Rijk Zwaan	4105	20	18075	54	48	5	11	45	31	8	87
Stravinsky	Rijk Zwaan	7280	40	17049	57	46	16	10	37	31	6	79
12-109	Rijk Zwaan	6239	36	16321	51	42	15	13	45	24	3	82
Karaoke	Rijk Zwaan	3436	21	16009	53	44	7	8	41	34	10	83
NUN0001	Nunhems	5693	37	16008	49	43	7	10	45	32	6	87
RZ-15	Rijk Zwaan	6374	41	15614	51	41	15	11	42	28	5	80
Rubinstein	Rijk Zwaan	3104	20	15288	46	40	6	12	48	27	7	87
Puccini	Rijk Zwaan	4889	33	15034	52	40	17	11	41	25	7	77
RZ-12	Rijk Zwaan	4557	33	14682	50	40	9	9	37	35	10	81
RZ-13	Rijk Zwaan	5238	40	13282	41	35	12	11	44	29	4	84
Merengue	Seminis	2523	20	13090	41	35	6	11	42	33	9	86
NQ5007	Nunhems	3416	26	13080	46	36	7	7	37	35	14	79
Atik	Bejo Seeds	1396	12	12605	41	35	5	8	42	34	10	84
21-340	Bejo Seeds	3067	23	12396	43	34	9	8	38	32	12	79
20002	Rijk Zwaan	4333	34	11650	39	29	20	12	41	22	5	75
NUN2001	Nunhems	1631	15	11395	48	33	9	4	27	39	21	69
NUN2002	Nunhems	816	8	10746	35	29	7	9	41	33	10	83
Mean		4440	28	15570	49	41	10	11	43	29	7	83
LSD (5%)		1946	9	4084	13	11	3	3	5	6	4	4

[z]Data are means of three replications.

Table 4.5. Fruit quality data collected on fresh and brined parthenocarpic pickling cucumber cultivars, 2015.[z]

					Judged Brined Quality					
Cultivar	Seed Source	Length:diameter	Fresh Firmness (N)	Brined Firmness (N)	Average	Shape	Exterior	Texture	Seed Cell	Uniformity
10-170	Bejo Seeds	3.3	78	91	6.0	5.7	5.6	6.2	6.3	6.1
21-340	Bejo Seeds	3.4	82	94	4.7	4.3	4.1	5.1	5.2	4.6
Atik	Bejo Seeds	3.3	71	81	5.4	5.3	5.3	5.4	5.3	5.9
NQ5007	Nunhems	4.0	71	91	5.1	5.1	4.7	5.2	5.5	5.2
NUN0001	Nunhems	3.7	80	96	5.3	5.4	5.8	4.8	5.3	5.5
NUN2001	Nunhems	3.6	77	88	5.6	5.6	5.3	5.5	5.7	5.9
NUN2002	Nunhems	3.7	75	85	5.5	5.1	4.6	5.9	5.9	5.8
20002	Rijk Zwaan	3.5	83	98	5.4	4.9	5.0	5.8	6.0	5.1
12-109	Rijk Zwaan	3.5	92	104	5.6	5.3	5.4	6.2	5.7	5.5
Bowie	Rijk Zwaan	3.8	82	90	5.7	5.3	6.0	5.7	5.8	5.8
Gershwin	Rijk Zwaan	3.7	82	104	6.0	5.6	6.0	6.1	6.3	5.8
Karaoke	Rijk Zwaan	3.3	83	102	5.6	5.7	4.3	5.8	6.0	5.9
Liszt	Rijk Zwaan	3.7	66	74	5.9	6.3	5.1	5.9	6.2	6.2
Puccini	Rijk Zwaan	3.4	81	100	5.8	5.5	5.7	6.1	6.2	5.6
Rubinstein	Rijk Zwaan	3.7	77	80	5.4	5.4	5.3	5.3	5.3	5.6
RZ-12	Rijk Zwaan	3.7	77	88	5.0	4.9	4.6	5.5	5.2	5.1
RZ-13	Rijk Zwaan	3.5	94	99	5.4	5.2	5.9	5.3	5.1	5.6
RZ-15	Rijk Zwaan	3.6	79	88	5.8	5.9	5.7	5.8	6.0	5.8
RZ-17	Rijk Zwaan	3.2	66	70	5.3	5.0	4.8	5.1	5.5	5.9
Stravinsky	Rijk Zwaan	3.6	84	88	5.6	5.0	5.9	6.1	5.7	5.3
Surya	Rijk Zwaan	3.6	91	95	5.4	5.1	5.3	5.7	5.8	5.1
Wagner	Rijk Zwaan	3.8	87	112	5.5	5.5	5.7	5.4	5.5	5.5
Merengue	Seminis	3.5	63	77	5.5	5.7	4.7	5.7	5.9	5.6
Means		3.6	79	91	5.5	5.3	5.3	5.6	5.7	5.6
LSD (5%)		0.1	9	15	0.4	0.7	0.5	0.6	0.6	0.6

LSD = least significant difference

[z]Data are means of three replications (taken from harvests 2, 4 and 6).

Table 4.6. Quality evaluation for brined parthenocarpic pickling cucumber cultivars, 2015.[z]

Cultivar	Seed Source	Total	Total bloaters	% Balloon	% Lens	% Honeycomb	Total defects	% Placental Hollows	% Blossom end defects	% Soft centers
10-170	Bejo Seeds	1.3	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0
21-340	Bejo Seeds	4.3	2.7	2.0	0.7	0.0	1.7	1.0	0.0	0.7
Atik	Bejo Seeds	2.3	0.0	0.0	0.0	0.0	2.3	1.0	0.7	0.7
NQ5007	Nunhems	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NUN0001	Nunhems	1.3	0.0	0.0	0.0	0.0	1.3	0.0	0.0	1.3
NUN2001	Nunhems	2.0	0.7	0.3	0.0	0.3	1.3	0.3	0.0	1.0
NUN2002	Nunhems	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20002	Rijk Zwaan	1.3	0.7	0.7	0.0	0.0	0.7	0.0	0.0	0.7
12-109	Rijk Zwaan	2.3	0.0	0.0	0.0	0.0	2.3	0.7	0.0	1.7
Bowie	Rijk Zwaan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gershwin	Rijk Zwaan	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Karaoke	Rijk Zwaan	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3
Liszt	Rijk Zwaan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Puccini	Rijk Zwaan	0.7	0.0	0.0	0.0	0.0	0.7	0.7	0.0	0.0
Rubinstein	Rijk Zwaan	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0
RZ-12	Rijk Zwaan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RZ-13	Rijk Zwaan	4.7	3.7	3.7	0.0	0.0	1.0	0.0	0.0	1.0
RZ-15	Rijk Zwaan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RZ-17	Rijk Zwaan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stravinsky	Rijk Zwaan	4.3	0.0	0.0	0.0	0.0	4.3	2.0	0.0	2.3
Surya	Rijk Zwaan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wagner	Rijk Zwaan	3.7	0.7	0.7	0.0	0.0	3.0	1.3	0.0	1.7
Merengue	Seminis	3.3	2.3	2.3	0.0	0.0	1.0	1.0	0.0	0.0
Mean		1.4	0.6	0.5	0.0	0.0	0.9	0.3	0.0	0.5
LSD (5%)		3.8	2.7	2.7	0.4	0.2	2.3	1.8	0.4	1.6

[z]Data are means of three replications (taken from harvests 2, 4 and 6).

Table 4.7. Disease and spininess ratings for parthenocarpic pickling cucumber cultivars, 2015.

		Disease Rating		
Cultivar	Seed Source	Downy Mildew	Anthracnose	Spininess
10-170	Bejo Seeds	6[z]	3[y]	7
21-340	Bejo Seeds	6	7	3
Atik	Bejo Seeds	5	7	7
NQ5007	Nunhems	6	7	6
NUN0001	Nunhems	5	7	7
NUN2001	Nunhems	5	6	7
NUN2002	Nunhems	4	5	7
20002	Rijk Zwaan	5	3	3
12-109	Rijk Zwaan	5	7	3
Bowie	Rijk Zwaan	6	7	3
Gershwin	Rijk Zwaan	5	7	3
Karaoke	Rijk Zwaan	5	6	7
Liszt	Rijk Zwaan	4	6	8
Puccini	Rijk Zwaan	4	7	3
Rubinstein	Rijk Zwaan	6	7	7
RZ-12	Rijk Zwaan	6	7	5
RZ-13	Rijk Zwaan	6	7	3
RZ-15	Rijk Zwaan	5	5	4
RZ-17	Rijk Zwaan	6	5	8
Stravinsky	Rijk Zwaan	6	8	3
Surya	Rijk Zwaan	5	3	3
Wagner	Rijk Zwaan	4	3	3
Merengue	Seminis	6	7	6
Mean		5	6	5

[z]Data are means of two ratings of three replications.

[y]Data are means of one rating of three replications.

APPENDICES

Appendix A

Table A2.1. Probability > F for yield component means for parthenocarpic pickling cucumbers at Kinston, NC in 2014.

	Marketable yield	Total yield	Percentage of total yield					
	Mg/ha	Mg/ha	Culls	no. 1	no. 2	no. 3	no. 4	marketable
Variable								
Density (D)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Harvest Stage (H)	0.0431	<.0001	<.0001	0.1711	<.0001	0.0001	<.0001	<.0001
Cultivar (C)	0.9534	0.0324	<.0001	0.199	0.0007	0.6494	<.0001	0.0032
Season (S)	0.1008	0.0135	0.0031	<.0001	0.2807	<.0001	0.0036	0.0002
D x H	0.001	0.1573	0.0474	0.0411	0.8508	0.0003	0.2472	0.2742
D x C	<.0001	0.0044	0.1033	0.0253	0.1831	0.0017	0.0287	0.0126
H x C	0.1421	0.8716	0.001	0.0178	0.0008	<.0001	0.0777	0.007
D x S	0.1272	0.004	0.0079	0.0044	0.6688	0.082	0.2001	0.0294
H x S	0.4945	0.1316	0.0003	0.0007	0.6978	0.1351	0.1116	0.0036
C x S	0.0384	0.2449	0.3414	0.0158	<.0001	0.7762	0.0001	<.0001
D x H x C	0.7843	0.3487	0.0665	0.8692	0.207	0.2092	0.0987	0.2508
D x H x S	0.7154	0.8928	0.0326	0.224	0.3968	0.3638	0.3687	0.7836
D x C x S	0.9596	0.7496	0.531	0.6053	0.6367	0.4131	0.9171	0.9775
H x C x S	0.9987	0.4766	0.0801	0.0307	0.6068	0.0779	0.0926	0.2988
D x H x C x S	0.5762	0.0918	0.1539	0.2293	0.9839	0.6759	0.4743	0.5617

Table A2.2. Probability > F for yield component means for parthenocarpic pickling cucumbers, 2015.

	Marketable yield	Total yield	Percentage of total yield					
	Mg/ha	Mg/ha	Culls	no. 1	no. 2	no. 3	no. 4	marketable
Variable								
Density (D)	<.0001	<.0001	<.0001	0.0005	<.0001	0.0008	<.0001	<.0001
Harvest Stage (H)	<.0001	<.0001	<.0001	<.0001	<.0001	0.0031	<.0001	<.0001
Cultivar (C)	<.0001	<.0001	<.0001	0.0055	0.9652	<.0001	<.0001	0.0021
Season (S)	0.55	0.0364	0.0415	0.0738	0.6774	<.0001	0.0218	0.0232
D x H	0.0014	0.0853	0.0453	0.0125	0.3786	<.0001	0.176	0.0285
D x C	0.0264	0.0136	0.0242	0.0145	0.2732	0.1211	0.0352	0.0195
H x C	0.9912	0.6076	0.7276	0.0035	0.0145	0.0353	0.3732	0.4114
D x S	0.0243	0.06	0.0032	0.4494	0.0022	0.7544	0.0009	0.0071
H x S	0.0469	0.0227	<.0001	<.0001	<.0001	0.0461	<.0001	0.0017
C x S	0.2425	<.0001	0.2747	0.2897	0.0155	0.1505	0.0012	0.0027
D x H x C	0.0955	0.665	0.2866	0.7772	0.7192	0.4315	0.2277	0.1478
D x H x S	0.6083	0.5617	<.0001	0.1401	0.1539	0.0034	0.1813	0.0123
D x C x S	0.2966	0.6777	0.5949	0.629	0.9836	0.6964	0.609	0.6608
H x C x S	0.0363	0.0787	0.0863	0.0053	0.4426	<.0001	<.0001	<.0001
D x H x C x S	0.013	0.0668	0.4793	0.0049	0.013	0.0004	0.1355	0.0606

Table A2.3. Probability > F for economic means for parthenocarpic pickling cucumbers, 2014.

	Density	Return/ha				
	thp/ha	$/ha	$12 seeds	$3 seeds	$6 seeds	$24 seeds
Variable						
Density (D)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Harvest Stage (H)	0.9909	0.0865	0.0871	0.0865	0.0865	0.0898
Cultivar (C)	0.7212	0.7306	0.7386	0.7325	0.7345	0.7478
Season (S)	0.2152	0.0628	0.0678	0.064	0.0652	0.0735
D x H	0.5501	0.004	0.0039	0.0039	0.0039	0.0041
D x C	0.9957	<.0001	<.0001	<.0001	<.0001	<.0001
H x C	0.3174	0.4723	0.4196	0.4586	0.4453	0.3729
D x S	0.1227	0.0795	0.1068	0.0855	0.0921	0.1438
H x S	0.5421	0.3919	0.4278	0.4004	0.4093	0.4679
C x S	0.6847	0.0021	0.0023	0.0021	0.0022	0.0027
D x H x C	0.3665	0.8992	0.918	0.9043	0.9092	0.9321
D x H x S	0.8453	0.8954	0.8698	0.8892	0.8828	0.8431
D x C x S	0.8549	0.9178	0.9155	0.9172	0.9167	0.913
H x C x S	0.2871	0.8441	0.7905	0.8312	0.8179	0.7335
D x H x C x S	0.268	0.5715	0.5829	0.5745	0.5774	0.5922

Table A2.4. Probability > F for economic means for parthenocarpic pickling cucumbers, 2015.

	Density	Return/ha				
	thp/ha	$/ha	$12 seeds	$3 seeds	$6 seeds	$24 seeds
Variable						
Density (D)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Harvest Stage (H)	0.0097	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivar (C)	0.016	<.0001	<.0001	<.0001	<.0001	<.0001
Season (S)	0.0999	0.3457	0.3672	0.3509	0.3561	0.3915
D x H	0.0167	0.0054	0.0049	0.0053	0.0051	0.0044
D x C	0.378	0.0195	0.0146	0.0181	0.0168	0.011
H x C	0.0467	0.3341	0.3842	0.3462	0.3586	0.4372
D x S	0.0355	0.0183	0.0121	0.0165	0.0149	0.008
H x S	0.152	0.0705	0.0647	0.069	0.0675	0.0596
C x S	0.5974	0.0875	0.0796	0.0854	0.0833	0.073
D x H x C	0.438	0.0603	0.0483	0.057	0.0539	0.039
D x H x S	<.0001	0.6349	0.6835	0.6497	0.6627	0.7039
D x C x S	0.7347	0.3672	0.3702	0.3678	0.3684	0.3752
H x C x S	0.2165	0.1361	0.1149	0.1305	0.1251	0.0971
D x H x C x S	0.4	0.0239	0.0252	0.0242	0.0245	0.0271

Table A2.5. Probability > F for quality and vine count means for parthenocarpic pickling cucumbers, 2014.

	Fruit quality		Fruit set
	Length:diameter	Fruit firmness (N)	% of vines without fruit
Variable			
Density (D)	0.2371	0.4889	<.0001
Harvest Stage (H)	<.0001	<.0001	<.0001
Cultivar (C)	0.1831	<.0001	0.4912
Season (S)	0.1066	0.3149	0.6763
D x H	0.338	0.1717	0.0037
D x C	0.1189	0.3843	0.0011
H x C	0.0175	0.4103	0.8069
D x S	0.7624	0.4201	0.0004
H x S	0.5844	<.0001	0.3897
C x S	0.243	0.769	0.0086
D x H x C	0.4492	0.6254	0.701
D x H x S	0.3117	0.5339	0.1879
D x C x S	0.9647	0.3844	0.2382
H x C x S	0.3271	0.1863	0.0967
D x H x C x S	0.7144	0.7777	0.1529

Table A2.6. Probability > F for quality and vine count means for parthenocarpic pickling cucumbers, 2015.

	Fruit quality		Fruit set
	Length:diameter	Fruit firmness (N)	% of vines without fruit
Variable			
Density (D)	<.0001	0.1805	<.0001
Harvest Stage (H)	<.0001	<.0001	<.0001
Cultivar (C)	0.0798	<.0001	0.1641
Season (S)	<.0001	0.0023	0.0136
D x H	0.0911	0.0552	0.9716
D x C	<.0001	0.0591	0.7452
H x C	0.0389	<.0001	<.0001
D x S	0.4807	0.0245	0.3397
H x S	0.0252	<.0001	0.0063
C x S	0.6583	<.0001	0.1015
D x H x C	0.0847	0.4477	0.1206
D x H x S	0.2435	0.3382	0.6943
D x C x S	0.3591	0.0065	0.7197
H x C x S	0.0072	0.0025	0.0023
D x H x C x S	0.019	0.3725	0.0857

Appendix B

Table A3.1. Probability > F for yield component means for parthenocarpic pickling cucumbers, 2014.

		Harvests 1 & 2		Harvests 1 - 8		Percentage of total yield					
		Market able yield	Total yield	Marketable yield	Total yield	Culls	no. 1	no. 2	no. 3	no. 4	market able
Variable	df	Mg/ha	Mg/ha	Mg/ha	Mg/ha						
Density (D)	4	0.0002	0.0007	0.0224	0.0455	<.0001	0.6174	0.1291	0.0249	0.0009	0.0039
Cultivar(C)	1	0.059	0.1773	0.0029	0.0423	<.0001	0.1663	0.1227	0.0582	0.1671	<.0001
Season (S)	1	0.509	0.7149	0.0039	0.0021	0.2801	0.1014	0.0274	0.4037	0.2678	0.4585
D*C	4	0.2385	0.5821	0.8797	0.8277	0.1613	0.8109	0.0007	0.1367	0.0766	0.3751
D*S	4	0.0583	0.0316	0.2491	0.3479	0.4194	0.0514	0.2646	0.5022	0.3381	0.6897
C*S	1	0.5863	0.306	0.103	0.0835	0.1632	0.0677	0.8715	0.5533	0.4202	0.1013
D*C*S	4	0.226	0.2769	0.3848	0.5396	0.5324	0.9336	0.6095	0.4353	0.899	0.5593

Table A3.2. Probability > F for yield component means for parthenocarpic pickling cucumbers at Kinston, NC in 2015.

		Harvests 1 & 2		Harvests 1 - 8		Percentage of total yield					
		Marketable yield	Total yield	Marketable yield	Total yield	Culls	no. 1	no. 2	no. 3	no. 4	marketable
Variable	df	Mg/ha	Mg/ha	Mg/ha	Mg/ha						
Density (D)	7	0.0023	0.0216	0.007	0.0002	0.013	0.0002	0.05	0.1118	0.0005	0.007
Cultivar(C)	1	<.0001	<.0001	0.0085	<.0001	<.0001	0.4233	0.1577	<.0001	0.0003	<.0001
Season (S)	1	<.0001	<.0001	0.2038	<.0001	0.1065	0.0003	0.0001	0.0005	0.0067	<.0001
D*C	7	0.0002	0.0001	0.0408	0.0781	0.0369	0.0046	0.1207	0.0399	0.2682	0.3516
D*S	7	0.0005	0.0239	0.0036	0.0128	0.2464	0.0976	0.4301	0.3631	0.1127	0.4927
C*S	1	<.0001	<.0001	<.0001	0.0002	0.4114	<.0001	0.0127	0.0205	0.0027	0.0012
D*C*S	7	0.751	0.3583	0.2814	0.0127	0.0134	0.0224	0.027	0.0002	0.2761	0.1128

Table A3.3. Probability > F for economic means for parthenocarpic pickling cucumbers, 2014.

		Economic components			
Variable	df	$/ha (harvests 1 and 2)	$/ha (total harvest)	return/ha (harvests 1 & 2)	return/ha (total harvest)
Density (D)	4	<.0001	0.0338	<.0001	<.0001
Cultivar(C)	1	0.1797	0.0039	0.0506	0.002
Season (S)	1	0.5619	0.003	0.9758	0.0049
D*C	4	0.1196	0.965	0.0184	0.9901
D*S	4	0.0165	0.2291	0.0017	0.1556
C*S	1	0.811	0.2267	0.5936	0.3567
D*C*S	4	0.2085	0.4202	0.1148	0.4188

Table A3.4. Probability > F for economic means for parthenocarpic pickling cucumbers at Kinston, NC in 2015.

		Economic components			
Variable	df	\$/ha (harvests 1 and 2)	\$/ha (total harvest)	return/ha (harvests 1 & 2)	return/ha (total harvest)
Density (D)	7	0.0002	0.0125	0.0091	0.0168
Cultivar(C)	1	<.0001	0.0024	<.0001	0.0034
Season (S)	1	<.0001	0.0057	<.0001	0.0017
D*C	7	0.0002	0.0371	0.0001	0.0375
D*S	7	<.0001	0.0028	<.0001	0.0063
C*S	1	<.0001	0.0006	<.0001	0.0004
D*C*S	7	0.9104	0.4248	0.909	0.4793

Table A3.5. Probability > F for quality and vine count means for parthenocarpic pickling cucumbers, 2014

Variable	df	Length:diameter	Fruit firmness (N)
Density (D)	4	0.0048	0.0144
Cultivar(C)	1	0.0254	<.0001
Season (S)	1	0.4718	0.3465
D*C	4	0.0078	0.0856
D*S	4	0.6552	0.0198
C*S	1	0.685	0.8948
D*C*S	4	0.68	0.4893

Table A3.6. Probability > F for quality and vine count means for parthenocarpic pickling cucumbers at Kinston, NC in 2015.

Variable	df	Length:diameter	Fruit firmness (N)
Density (D)	7	0.0038	0.8734
Cultivar(C)	1	0.1172	<.0001
Season (S)	1	<.0001	0.0029
D*C	7	0.2547	0.6665
D*S	7	0.1119	0.0366
C*S	1	0.0039	<.0001
D*C*S	7	0.1475	0.6353

Appendix C

Table A4.1. Probability > F for dollar value and yield component means for 8 harvests of parthenocarpic pickling cucumber cultivars, 2014.

		Yield Summary					Fruit grade distribution (percentage by weight)						
		Harvests 1 & 2		Harvests 1 - 8			Harvests 1 - 8						
Source	df	$/ha	% of total	$/ha	Mg/ha Total	Mg/ha Market able	cull	no. 1	no. 2	no. 3	no. 4	market able	thp/ha
Season	1	0.0013	<.0001	<.0001	<.0001	<.0001	0.17	0.2441	0.0002	0.3386	0.6922	0.0052	<.0001
Replication (Season)	4	<.0001	0.1179	<.0001	<.0001	0.0001	0.862	0.7927	0.4898	0.0601	0.066	0.9088	<.0001
Cultivar	16	<.0001	<.0001	0.0123	0.005	0.0212	0.0003	0.0593	0.0018	0.0031	0.0022	0.0016	<.0001
Cultivar*Season	16	0.7167	0.2916	0.9475	0.8289	0.8561	0.3993	0.7633	0.0285	0.1618	0.3245	0.019	0.0049

Table A4.2. Probability > F for fresh fruit quality means of parthenocarpic pickling cucumber cultivars, 2014.

Source	df	L:D	Fresh Firmness (N)	Brined Firmness (N)
Replication (Season)	2	<.0001	0.0048	0.0544
Cultivar	16	<.0001	<.0001	<.0001

Table A4.3. Probability > F for brined fruit quality means of parthenocarpic pickling cucumber cultivars, 2014.

Source	df	Average quality	Shape	Exterior	Texture	Seed Cell	Uniformity
Harvest	2	0.4164	0.0076	0.0072	0.0024	0.3284	<.0001
Cultivar	16	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Judge	9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivar*Judge	144	0.5052	0.8333	0.3057	0.9559	0.3004	0.442

Table A4.4. Probability > F for brined fruit evaluation means of parthenocarpic pickling cucumber cultivars, 2014.

Source	df	Total	Total bloaters	% Balloon	Total defects	% Placental Hollows	% Blossom end defects	% Soft centers
Harvest	2	0.0395	0.0129	0.0129	0.2905	0.2897	0.135	0.0365
Cultivar	16	0.4117	0.2491	0.2491	0.5528	0.5794	0.4807	0.0781

Table A4.5. Probability > F for dollar value and yield component means for 8 harvests of parthenocarpic pickling cucumber cultivars, 2015.

		Yield Summary					Fruit grade distribution (percentage by weight)					
		Harvests 1 & 2		Harvests 1-8			Harvests 1-8					
Source	df	$/ha	% of total	$/ha	Mg/ha Total	Mg/ha Marketable	culls	no. 1	no. 2	no. 3	no. 4	marketable
Season	1	<.0001	<.0001	0.074	0.1051	0.015	<.0001	<.0001	0.4953	<.0001	<.0001	0.0005
Replication (Season)	4	0.0457	0.5779	<.0001	<.0001	<.0001	0.17	0.2892	0.2458	0.6645	0.4015	0.1009
Cultivar	22	<.0001	<.0001	<.0001	0.0022	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivar*Season	22	0.0271	0.0013	0.3823	0.4649	0.3858	0.0167	0.0239	0.0095	0.0475	0.0844	0.0163

Table A4.6. Probability > F for fruit quality means of parthenocarpic pickling cucumber cultivars, 2015.

Source	df	L:D	Fresh Firmness (N)	Brined Firmness (N)
Replication (Season)	2	<.0001	0.2324	0.0782
Cultivar	23	<.0001	<.0001	<.0001

Table A4.7. Probability > F for brinestock quality means of parthenocarpic pickling cucumber cultivars, 2015.

Source	df	Average quality	Shape	Exterior	Texture	Seed Cell	Uniformity
Harvest	2	<.0001	0.0921	<.0001	<.0001	<.0001	<.0001
Cultivar	22	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Judge	9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivar*Judge	198	0.9852	0.7202	0.0786	0.8853	0.9874	0.7711

Table A4.8. Probability > F for brined fruit evaluation means of parthenocarpic pickling cucumber cultivars, 2015.

Source	df	Total	Total bloaters	% Balloon	% Lens	% Honeycomb	Total defects	% Placental Hollows	% Blossom end defects	% Soft centers
Harvest	2	0.1307	0.1758	0.142	0.3761	0.3761	0.4296	0.7665	0.3761	0.1701
Cultivar	22	0.1296	0.3236	0.4552	0.4836	0.4836	0.0168	0.6654	0.4836	0.1151

Table A4.9. Probability > F for disease and spininess rating means of parthenocarpic pickling cucumber cultivars, 2015.

Source	df	Downy Mildew	Anthracnose	Spininess
Cultivar	1	0.2111	0.1069	0.2135
Replication (Season)	4	0.2169	<.0001	<.0001