PLANT DENSITY EFFECTS ON LINT YIELD AND QUALITY OF THREE STACKED GENE COTTON CULTIVARS

A Thesis

by

SHANE WILLIAM HALFMANN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2005

Major Subject: Agronomy

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Approved as to style and content by:

J. T. Cothren (Chair of Committee)	C. W. Smith (Member)
M. K. Harris (Member)	M. Hussey (Head of Department)

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ABSTRACT

Plant Density Effects on Lint Yield and Quality of Three Stacked Gene Cotton Cultivars. (May 2005)

Shane William Halfmann, B.S., Texas A&M University

Chair of Advisory Committee: Dr. J. Tom Cothren

The increased cost of planting transgenic or stacked gene cotton cultivars has stimulated interest in determining the optimal planting density for commercial production. If seeding rates can be reduced without adversely affecting lint yield and fiber quality, producers could regulate initial inputs by fluctuating seeding rates. However, manipulating plant density per unit area can affect the growth and development of the crop. This altered growth throughout the season could potentially affect fiber quality. Fiber properties, which dictate price discounts, are determined by maturity, diameter and length, as well as by physiological activity at the cellular level. These fiber properties are also affected by genetics and environmental conditions, which ultimately can impact lint production as well as the location of bolls set throughout the plant and the maturation period. The objective of this study was to examine the impact of plant density (including high, ideal and low densities) on growth and development of transgenic cotton cultivars. Field experiments were conducted in 2003 and 2004 at the Texas Agricultural Experiment Station in Burleson County, Texas to assess the effects of plant density on lint yield and fiber quality. Experimental design was a spit-plot design with four replications of three cultivars (SG 215 BG/RR, DP 555 BG/RR, ST 4892 BG/RR) in densities ranging from 74 to 222 thousand plants hectare^{-1}.

Plant density had no significant effect on lint yield in 2003 or 2004. However, low plant density treatments contained significantly more bolls plant^{-1} as a result of the plant's compensatory ability to produce the same number of bolls in a given area. These low density treatments also produced more vegetative biomass plant^{-1}. Due to lower boll numbers and lower ginout percentage, ST 4892 produced the lowest lint yield each year. Lint quality was not significantly affected by density or cultivar treatments either year. However, in 2003 micronaire values were within the discount ranges for ST 4892, and the two lowest density treatments.

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INTRODUCTION

Throughout the past decade biotechnology has continued to increase in importance to crop production worldwide. Producers have come to rely on technologies such as Roundup Ready®, Bollgard® and Yieldgard® crops. Specifically, the use of these tools in cotton (*Gossypium hirsutum*) production has allowed growers to decrease costs and increase lint yield. However, the Final Crop Quality Summary presented by Cotton Incorporated indicated a slight increase in micronaire and a decrease in strength and length from 1995 to 2002. This reduction in quality could be prompted by several different environmental and physiological factors. Late season rains, photoassimilate movement, plant densities, and the use of biotechnology are factors that could potentially contribute to reduced lint quality. The objectives of this research will deal with the latter two of the purported causes.

The Bt protein utilized in certain genetically improved crops, produced by the bacterium *Bacillus thuringiensis,* was discovered in the 1950's. This protein possesses insecticidal properties acting as a stomach toxin to immature lepidopteran larval, yet is safe to humans and animals (Betz et al., 2000). The gene that produces this protein can be incorporated into plant DNA, allowing the toxin to be produced throughout all parts of the plant. The benefit to producers is lepidopteran larvae control throughout the entire growing season, which in turn decreases the amount of insecticides applied to cotton (Betz et al., 2000). Consequently, growers decrease insecticide applications, thus

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reducing total input costs. In 2001, producers in the U.S. planted 500,000 acres (202,500 hectares) of Bollgard® single trait cotton varieties (Anonymous, 2001a). On a global basis, between 1998 and 2001, insecticide applications decreased by at least 50%, resulting in a greater economic benefit to producers and decreased stress on the environment. Specifically, 1.7 billion dollars were saved during these four years due to producers utilizing Bt cotton (James, 2001).

Roundup Ready® technology has also become an important part of U.S. cotton production. This technology provides cotton foliage tolerance to high amounts of glyphosate with no effects on yield. Roundup Ready® crops contain a modified 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) that is not affected by glyphosate herbicide (Anonymous, 2001b). With this technology, growers are able to reduce alternative herbicide applications and tillage frequency, which lowers their overall economic input. According to the National Agricultural Statistics Service (NASS), genetically engineered cotton represented over 88% of cotton planted in 2003. In the same year, US producers grew over 5 million acres (two million hectares) of Roundup Ready® single trait and Roundup Ready/Bollgard® stacked gene varieties (Anonymous, 2001b).

Fewer insecticides, alternative or reduced herbicide applications and less energy inputs through reduced tillage frequency, all produce significant environmental benefits. While these environmental impacts are important, the reality is that adoption of agricultural practices is predominantly driven by economic benefits. The National Center on Food and Agriculture Policy reports that producers saved up to 99 million dollars and eliminated 2.7 million pounds (1.22 million kg) of insecticides since Bt crops have gone into commercial production (Anonymous, 2001a). Furthermore, the Conservation Technology Information Center reports that the use of herbicide resistant crops has increased the practice of conservation tillage. This tillage method has saved producers 2.6 billion dollars to date (Anonymous, 2001a).

Despite savings in operation costs, seed prices have increased exponentially. These increased prices are due to technology fees needed to pay for the development and production of each individual cultivar. Will McCarty, a program leader for cotton at Mississippi State, reports an increase of eight or nine thousand dollars ton^{-1} (907 kg) of cottonseed throughout his 20-year career (Coblentz, 2004). Producers have reacted to increased prices by reducing planting densities, thus reducing overall costs. This reduction in plant densities could have adverse effects on fiber yield and overall quality.

LITERATURE REVIEW

History of Cotton

The Spanish first planted cotton in the United States in 1556. At the turn of the next century, English colonists planted and established cotton as a commercial crop (Smith, 1995). As these colonists moved south, cotton became more important to early American culture, because higher temperatures in this region rendered wearing of wool clothing uncomfortable during the summer months.

Cotton was selected for genetic increases in fiber yield and fiber quality as cotton culture progressed. Also, the North American climate required selection for an annual growth pattern as the early species of cotton grew perennially, and the bolls were not able to mature before frost. The growth of cotton fiber remains unique among plant cells, in that each fiber is an individual cell and is produced at a magnitude of 10,000 to 20,000 single cell units on the surface of each seed coat. Cell elongation occurs in cotton fibers without the complication of cell division or multicellular development. These cells grow at an incredible rate and are the longest single cell in higher plants (Ruan et al., 2001).

Plant Densities

Diverse planting densities affect virtually every aspect of plant growth. Research conducted by Jones and Wells (1998) provides references to numerous studies indicating variations in the rate of node initiation, plant height, high vegetative to reproductive growth ratios, and main stem node number as well as other growth parameters. These parameters can affect yield and are influenced by plant densities.

Physiological cutout, which is determined by evaluating the nodes above the first position white flower (NAWF) (Bourland et al., 1992), can be altered by manipulating plant densities. Fruit set after this important stage of maturity most often does not develop sufficient size and lacks in fiber quality. Bourland et al. (1992) reports physiological cutout to be NAWF=5. This observation of plant maturity can be used in several management decisions. For example, many producers terminate insecticide treatments at 350 heat units after NAWF=5 (Oosterhuis et al., 1999). This eliminates unnecessary insecticide applications as Jenkins et al. (1990) reported that the top five nodes contribute less than 10% of total yield. Thus, the fruit set on nodes lower on the plant is described as the last effective boll population (LEBP). In more specific terms LEBP can be defined as the node where 90-95% of yield is contained on lower nodal positions. Bolls on these positions contribute to economic yield, have a higher rate of retention, are larger in size, and possess better quality than fruit set on the top five nodes. In addition, Oosterhuis et al. (1999) suggest that total lint yield could possibly benefit from insect removal of fruit from the nodes above NAWF=5. This is because carbohydrates produced by the uppermost leaves are partitioned to the older more mature bolls located lower on the plant. However, due to boll weevil eradication programs and continued protection throughout the season by biotechnology, bolls which contribute to yield could be located on nodes previously thought insignificant.

Crop canopy or leaf area index (LAI) is managed by manipulating row spacing, plant density, and plant genotype. LAI is described as the ratio of the crop leaf surface area of the crop to the ground area (Silvertooth, 1999). Producers must recognize that an optimum LAI is necessary for increased light interception and photosynthesis. Photosynthesis, the process that converts carbon dioxide and sunlight into dry matter, occurs primarily in the leaves and is vital to crop production (Silvertooth, 1999). Thus, the assumption can be made that more leaves allow for more photosynthesis. However, Silvertooth (1999) stated that shading of the lower leaves could occur as the LAI increased in high plant density treatments (HPOP). In this particular document, low plant density treatments (LPOP) ranged from 2 to 4 plants meter^{-1} and HPOP ranged from 15 to 17 plants meter^{-1}.

A balance between reproductive and vegetative growth is crucial for improved yields. Obtaining an optimum LAI by selecting accurate plant densities will contribute to an increased harvest index (HI), which is the amount of harvestable bolls hectare^{-1}. Yield hectare^{-1} tends to increase with plant density but eventually levels off and declines (Silvertooth, 1999). Plant densities can increase to the point that yield is adversely affected by intraspecific competition. Silvertooth (1999) also reported that for both conventional and ultra-narrow row systems a plant density of 30,000 to 60,000 seeds acre^{-1} (74-150 K/hectare) proved to be optimal, and densities over 75,000 or fewer than 20,000 (185 and 50 K/hectare) could decrease yields. Thus, optimum planting densities could fluctuate depending on soil type, rainfall and tillage methods.

In some production schemes, planting densities must be increased to compensate for poor germination. Norton et al. (2002) reported that growers in northern Arizona increase seeding rates to ensure sufficient plant germination. However, this strategy can prove detrimental if germination is not hindered. The HPOP can result in an environment where plants become more susceptible to drought injury. Norton et al. (2002) conducted a test with three seeding rates of 10, 20, and 30 lbs. acre^{-1} (11, 22.5 and 33.5 kg/hectare). Deltapine 555 BR, which averages between 4350 and 5550 seeds pound^{-1} (9,582 and 12,225 seeds/kg), was utilized. These rates convert to 50,000, 100,000 and 150,000 seeds acre^{-1} (123,500, 247,000 and 370,500 seeds/hectare) respectively, utilizing an average of 5,000 seeds pound^{-1} (11,013 seeds/kg). Emergence following planting indicated that the higher seeding rates resulted in increased germination rates. Consequently, in this instance, the higher plant densities also created significantly higher yields.

In contrast to previous information, Heitholt (1994), Silvertooth (1999) and Bednarz et al. (2000) provided evidence that increased plant densities can negatively affect crop yield. Heitholt (1994) stated that cotton densities with rapid development of LAI during vegetative growth yield higher than cultivars with slower LAI development. However, late in the season, LAI development was negatively correlated to lint yield. This suggests that lower yielding treatments move photoassimilates to vegetative growth instead of fruit maturation (Wells and Meredith, 1984). Bednarz et al. (2000) conducted a similar study and reported that decreased boll set and weight in HPOP could result from the combined effects of excessive LAI and reduced net assimilation rate. One cause of this relationship could be that HPOP promotes more assimilate partitioning into vegetative rather than reproductive growth.

A photomorphogenic or shade response is common in several crop species when planted at HPOP (Heitholt, 1994). Thus, increasing plant densities can prove to be detrimental by ineffectively utilizing solar radiation throughout the season. Heitholt (1994) also found that the efficiency of light interception per unit leaf area was greater at LPOP. This theory contradicts previously mentioned experiments justifying further investigation of this particular aspect of cotton production.

Lint Quality

Several environmental and cultural conditions can have detrimental effects not only on fiber quality, but also on fiber quantity. Pettigrew (2001) reported that these factors include insufficient photosynthetic assimilates, reduced nighttime temperatures, and moisture stress. All three factors have proven to reduce fiber length and thickness, which reduces overall quality and quantity of fiber produced.

Lint quality is measured by several factors, with one of the most important being micronaire. Micronaire is a measure of maturity and fineness or fiber diameter. The micronaire test is conducted by passing air compressed to a standard volume through a cotton specimen of standard weight and standard volume (Basra, 1999). Micronaire is used to determine the value of a bale of cotton and thus is an important factor in a producer's ability to survive economically. Diameter, a major component of micronaire, increases after initial fiber elongation, and involves secondary cell wall thickening (Jones and Wells, 1998). Because the secondary wall of a cotton fiber is almost pure cellulose (DeLanghe, 1986), an alteration of carbon assimilate could severely affect the quality of fiber produced. A plant density that is too high or too low could have major effects on photoassimilate production and distribution. Pettigrew (1995) conducted a study comparing fiber quality to various environmental factors that often affect assimilate sink/source ratios in developing cotton. Micronaire was altered by various sink/source manipulation treatments. The treatments in this study that represented high source/sink ratios mimicked low plant densities in the field and tested for higher micronaire than the control (Pettigrew, 1995). LPOP treatments showed an increase in micronaire ranging from 3.0 to 35.5% greater than high plant population treatments (HPOP).

Different plant densities can also affect lint quality by altering fruit maturity and boll weights. Jones and Wells (1998) reported that lower densities result in more light penetration and lower plant competition, causing a shift in sink/source ratios. These altered higher ratios in LPOP cause bolls to mature later, thereby increasing boll mass. While higher boll masses may contribute to lint yield, it is proven that micronaire is positively correlated with boll size (Jones and Wells, 1998). In studies by Meredith and Bridge (1973) later maturing bolls possessed decreased values of fiber length and fiber strength after cutout or cessation of nodal extension. The termination of new plant growth may cause physiological changes within the plant that further inhibit assimilate production (Jones and Wells, 1998). Bolls produced during the last two weeks of flowering exhibited inferior boll properties and fiber quality, compared with bolls produced earlier in the season (Jones and Wells, 1998).

The quality of lint produced by transgenic cotton varieties remains under constant speculation. Etheridge and Hequet (2000) conducted a study comparing fiber properties of conventional and transgenic cotton varieties (TCV). Conventional, Roundup Ready® and Bollgard® cultivars were included in the study. These cultivars, grown under identical field conditions and fiber properties, were tested following harvest. Results of these tests showed no differences in fiber properties between any cultivar. Jordon et al. (2003) produced a summary of similar studies dating back to 1998. The studies evaluated in this report produced results similar to those of Ethridge and Hequet (2000) in that TCV did not affect fiber quality. Jordon continued to explain that views regarding TCV and decreased fiber quality are based on anecdotal studies that are opinionated and confusing.

Maturity Requirements

Expected growing season length should be evaluated before selecting a cultivar for a specific location. Short season cultivars are more determinate and can reach cutout up to three weeks before full season cultivars (Silvertooth, 1998). The potential for a beneficial "top crop" decreases with shorter season length. These more determinate cultivars are also more susceptible to stresses, especially water stress, throughout the season. Silvertooth (1998) also reports that a cultivar of any maturity requirments has potential for high yields if planted early or at an optimal date. However, if planting dates are postponed, yield reductions will occur. With this in consideration, full, medium and short season cultivars should be planted before 700 HU, 800 HU, and 1000 HU have been accumulated since January 1, respectively (Silvertooth, 1998).

OBJECTIVES

The objectives of this study were (i) to examine the effects of plant densities, ranging from 30 to 90 thousand plants acre^{-1} (74 to 222 K/hectare), on fiber quality and lint yield, (ii) to evaluate the effects of growing season lengths, by using maturity groups, on last effective boll date, and (iii) assess the impact of density on plant development, yield, and quality of three transgenic cotton cultivars varying in maturity. By including densities both above and below established optimum ranges for the region, we will investigate what adverse affects, if any, occurred from manipulating plant densities.

MATERIALS AND METHODS

Plant Culture and Field Conditions

A experiment was conducted in 2003 and 2004 at the Texas Agricultural Experiment Station located in Burleson County near College Station, TX. The experimental design was a split-plot with four replications. Cultivars were used as whole plots and densities as subplots. Treatments were planted in four-row plots, extending 9.75 m in length. Conventional row spacing of 102 cm was utilized.

Experimental plots were located in the Brazos River Flood Plain on Ships Clay (very fine, mixed, thermic Chromic Hapluderts), a region historically known for cotton, corn and sorghum production. Soil pH within this region fluctuates from 8.0 to 8.5. Prior to planting, soil samples were taken at an average depth of 10- to 20-cm and analyzed for N, P and K levels by the Texas A&M University Soil, Water and Forage Testing Laboratory in College Station TX. Soil test results recommended a supplemental soil applied N at a rate of 54.5 kg ha^{-1}, which was broadcast across the experimental site the last week in February for both years.

Treatments were planted on beds using a four-row cone planter. In 2003 plots were planted on April 30, but due to poor stand counts, replanting took place on May 5. In 2004, treatments were initially planted the first week in April. Again however, poor stand counts warranted replanting on May 27. In both years, replant dates were substantially delayed due to untimely rains. Following emergence, stand counts were established and plots were thinned by hand to insure accurate population densities.

Treatments included plant densities of 74, 111, 148, 185 and 222 thousand plants hectare^{-1} (Table 1). For the remainder of this document these values will be referred to by the numerical values listed above.

In both 2003 and 2004, treatments consisted of three cultivars of differing maturity requirments [DeltaPine 555 BG/RR (full-season), Suregrow 215 BG/RR (early-season) and Stoneville 4892 BG/RR (early- to mid-season)].

A linear irrigation system was used for supplemental irrigation when necessary, and best management practices for the production area for insect pests and weed control were utilized. Daily heat units, monthly rainfall and daily temperatures were recorded by a weather station located nearby.

Biomass

Two biomass measurements were taken during the growing season, an early and late season measurement. Primary readings were taken the week of first bloom, which occurred 55 and 48 days after planting (DAP) in 2003 and 2004, respectively. The second biomass readings were taken before cutout, which was noted 99 and 79 DAP in 2003 and 2004, respectively. These data included dry weights of individual parts of the cotton plant. Specifically, the above ground vegetation of five uniform plants was removed from each plot and dissected. Foliage from each plot was measured separately by a LI-COR 3100 leaf area meter to obtain leaf area plant^{-1}. Subsequently, stems, squares, bolls and leaves were separated and dried at 60°C for approximately 5 days and weighed upon desiccation.

Last Effective Boll Population (LEBP)

To obtain data necessary to estimate LEBP, one-meter of row was marked within each plot; both flower and fruit maturation of selected plants was monitored and recorded. At bloom, each flower petiole was marked with a paper jeweler's tag labeled with the appropriate flowering date that also included the reproductive node and appropriate fruiting position (Figure 1). When the tagged boll matured and opened, the seedcotton was collected and dated to determine the number of days and accumulated heat units from white bloom to full maturity. In addition, the seedcotton from each boll was weighed to determine boll size and potential impact on yield.

Crop Maturity

Nodes above white flower (NAWF), nodes above cracked boll (NACB), and percent open bolls were evaluated to determine maturity levels of each population in the respected cultivars. Each NAWF evaluation consisted of observing ten plants randomly selected from each plot. Main stem nodes above the uppermost first position white flower were averaged for these ten plants for measurements taken at 78 DAP in 2003 and 71 and 76 DAP in 2004. A similar technique was used to determine NACB. However, main stem nodes were counted above the uppermost first position cracked boll, and readings were taken at 105 and 110 DAP in 2003 and 2004, respectively. Percentages of open bolls were calculated on 10 plants $plot^{-1}$ and were recorded at 112 and 118 DAP in 2003 and 2004, respectively. Theses values are used to determine cutout and time harvest aid application.

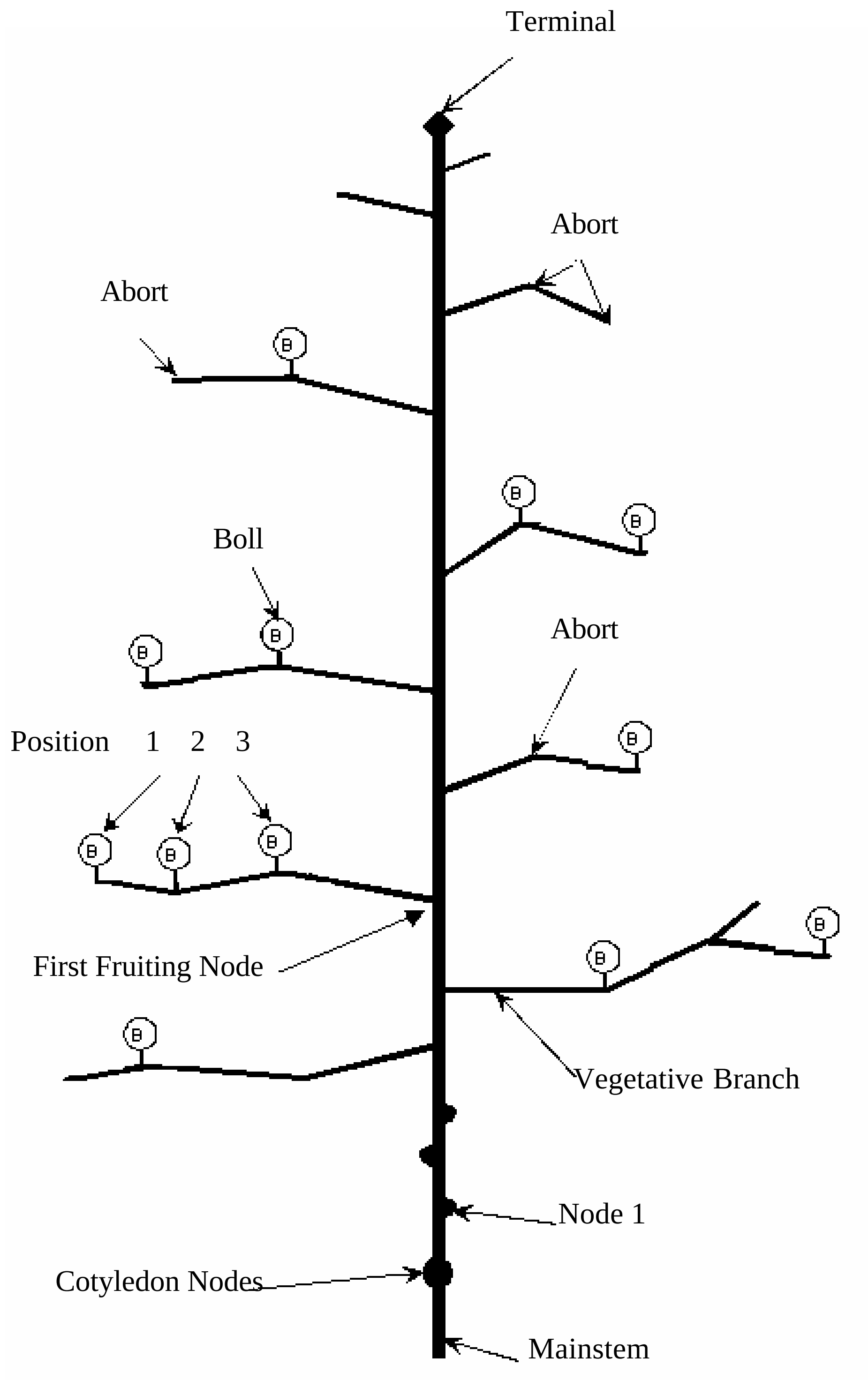

Figure 1. Fruit location on a developing cotton plant.

Lint Yield

Due to the economic implications, lint yield was an important component examined in this study. Application of harvest aids occurred as each plot reached the proper stage of maturity. Dropp®, Def®, and Prep® were applied at an average of 60-70% open bolls. Specific rates of each chemical are displayed in Appendix C.

Because cultivars of differing maturity groups were planted adjacent in the field layout, it was determined prior to plot maturity that potential destruction of adjacent immature plots would preclude the use of a mechanical harvester. Ironically, weather conditions in both years forced all plots to be defoliated on the same date allowing mechanical harvest. Nevertheless, inclement weather still forced hand harvest. By harvesting 13 feet of row, which represents one thousandth of an acre, pounds of seedcotton acre^{-1} can be easily determined. Seedcotton harvested plot^{-1} was weighed and multiplied by 1000 to get lbs acre^{-1}. This amount was then converted to seedcotton/hectare by multiplying by 1.12 (McCarty, 1999).

Lint Quality

A 150 g sample of seedcotton taken from each plot within the study was ginned on a 10-saw research gin and used to determine ginout percentage, which was used to convert kg seedcotton to kg lint ha^{-1} for each plot. In addition, the lint samples were sent to the International Textile Center in Lubbock, TX for HVI analysis. Fiber properties evaluated included micronaire, strength, length, uniformity, elongation, yellowness, and trash content.

Table 1. List of treatments used in 2003 and 2004.

Cultivar†	Maturity§	Population (K/hectare)‡
ST 4892 BG/RR	Early to Mid	74, 111, 148, 185, 222
SG 215 BG/RR	Early to Mid	74, 111, 148, 185, 222
DP 555 BG/RR	Full	74, 111, 148, 185, 222

† Cultivars utilized.
§ Maturity group or expected growing season length.
‡ Plants grown on a per hectare basis for each treatment.

Box Mapping

Box mapping was conducted post defoliation to determine boll distribution on the plant. Six representative plants were removed from each plot before harvest. This form of data collection gives detailed insight on seedcotton distribution throughout the plant. The seedcotton from each reproductive node on the main stem is separated by its position on that respective node (Figure 1). The lint from these fruiting positions is then grouped with nodes from other plants in the plot. These groups of lint are then weighed and compared to determine treatment effect on fruiting distribution location.

Statistical Analysis

Data was analyzed using proc GLM in SAS and means were separated using Fisher's Least Significant Difference (LSD) test at a level of significance of a = 0.05. Data showing a year by treatment interaction will be discussed separately for each year, which is discussed in the following section.

RESULTS AND DISCUSSION

Lint Yield

Compared with surrounding acres under commercial production, all plant density treatments produced competitive yields in 2003 and 2004. Competitive yields were anticipated because treatments contained densities that were considered ideal, as well as above and below plant densities utilized in the local production area. Lint yield was combined for 2003 and 2004, as the interaction between cultivar and year was not significant. In other words, lint **y**ield for both 2003 and 2004 followed similar trends. In both years, ST 4892 produced less lint ha^{-1} when plant density variables were combined for each cultivar. Also, DP 555 and SG 215 were equivalent for lint yield in both 2003 and 2004 (Figure 2).

There was, however, a difference in lint production between years. Lint production in 2003 was higher than 2004 for all three cultivars. The difference in lint production between 2003 to 2004 was 178, 80 and 157 kg $hectare^{-1}$ for SG 215, ST 4892 and DP 555, respectively (Figure 3). This could be due to excessive rainfall before planting and throughout the first weeks of the growing season in 2004. Still, there was no density by cultivar interaction either year.

Possible factors affecting lint yield were evaluated throughout the growing season. These included both early and late season vegetative and reproductive measurements. For example, ST 4892 had a higher percentage of square abscission than the other two cultivars at 47 DAP in 2004. These results illustrate a higher retention of squares for SG 215 and a numerical increase for square retention in DP 555 (Figure 4).

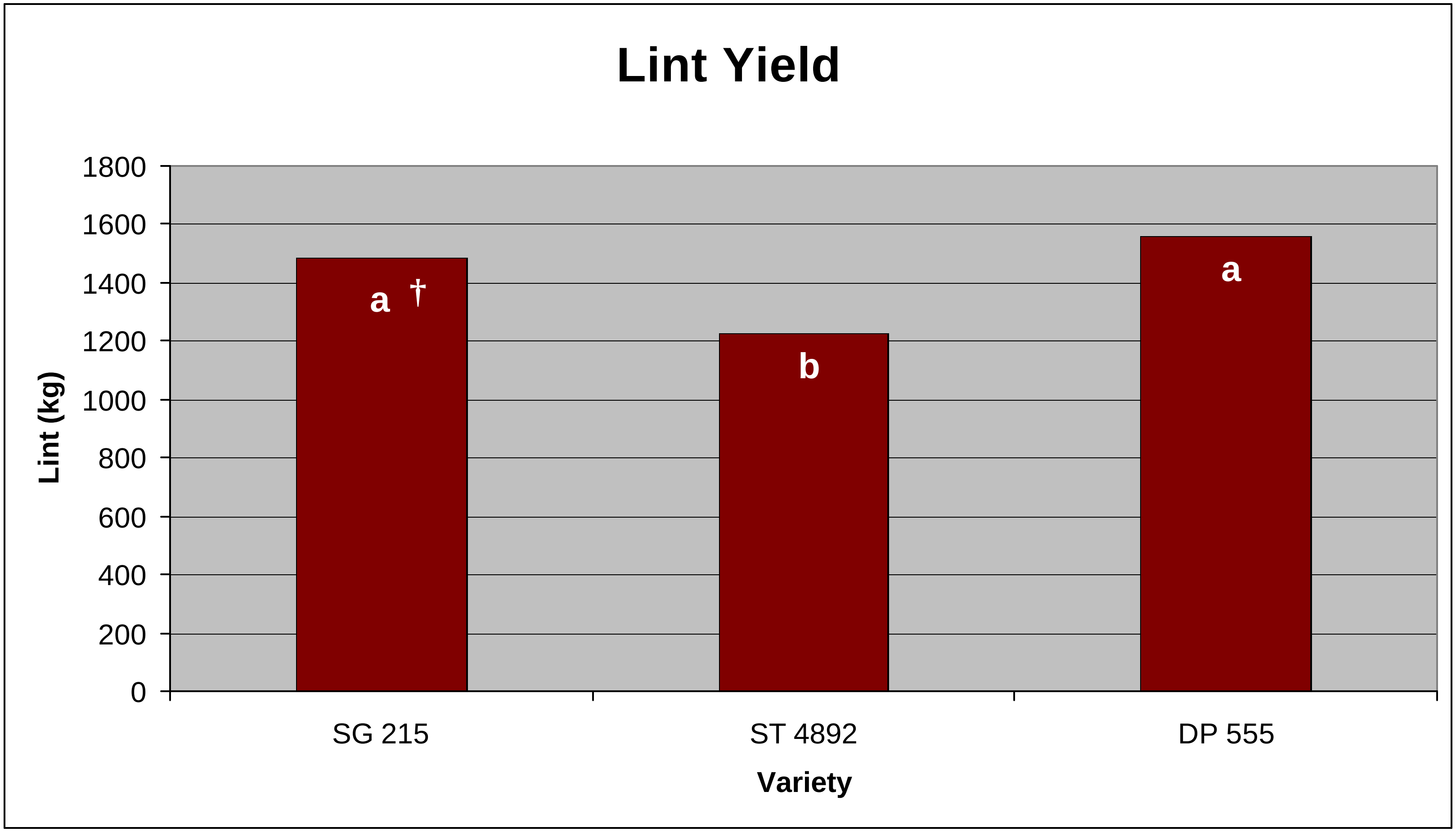

Figure 2. Cultivar effect on lint yield combined over 2003 and 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

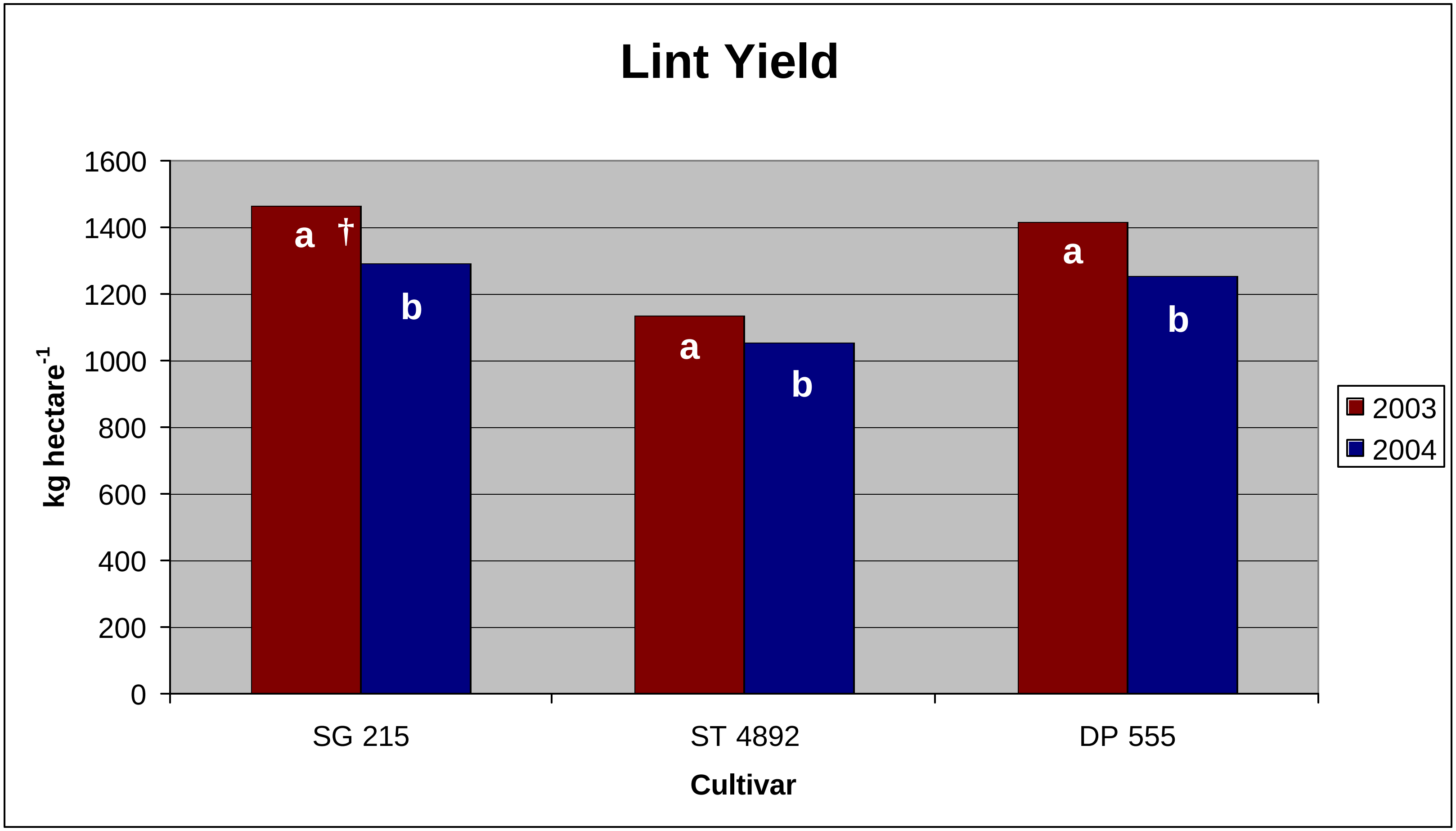

Figure 3. Year effect on lint yield for each individual cultivar.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

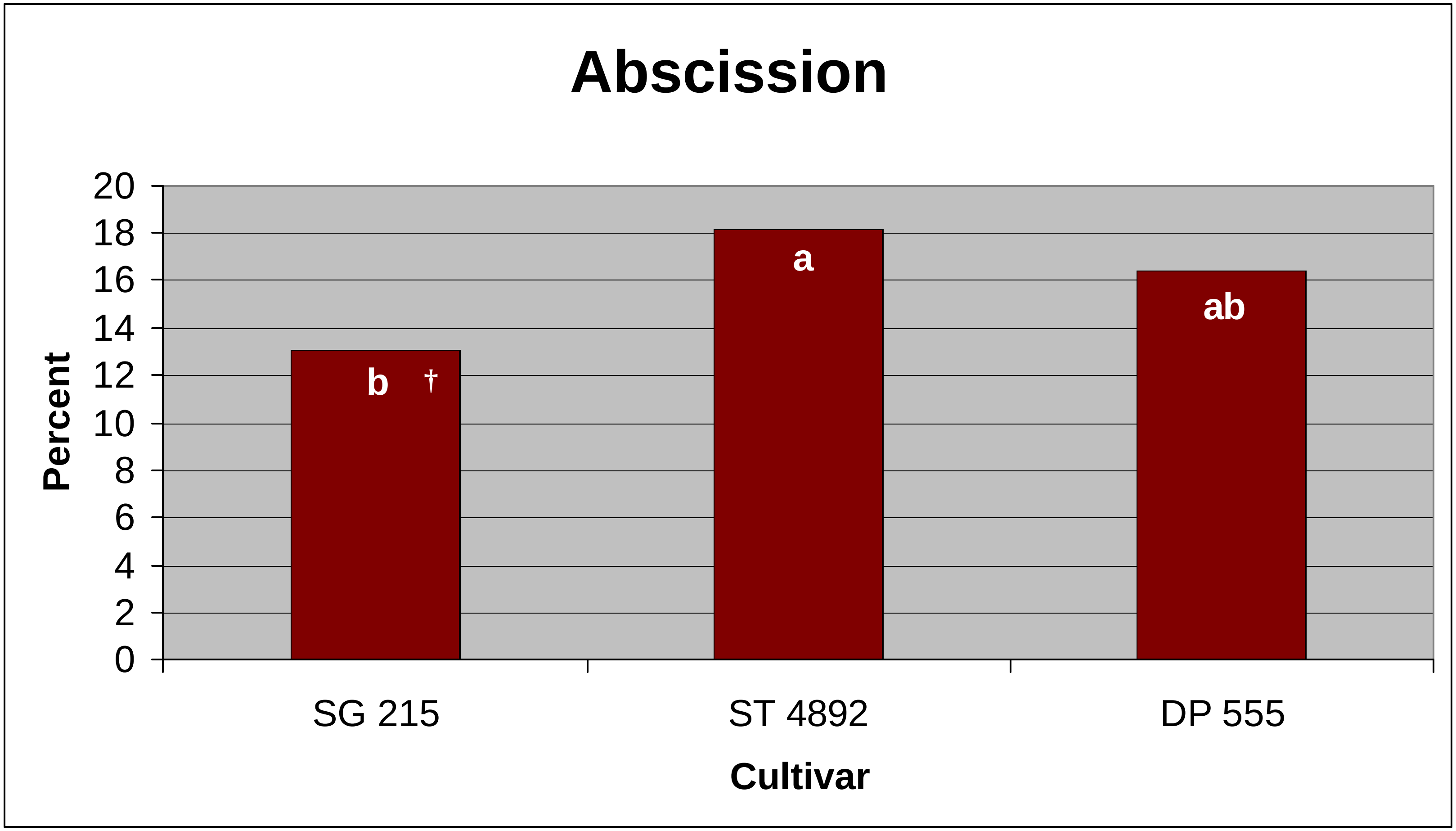

Figure 4. Cultivar effect on percent square abscission, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

Additional early season data included leaf area plant^{-1} (LA), which can affect photoassimilate production and ultimately sink/source ratios. Leaf area at, 47 and 57 DAP, in 2003 and 2004, respectively, proved to be higher for SG 215 than for ST 4892 (Figure 5). The overall lower LA of ST 4892 may have contributed ultimately to its lower lint yield. Silvertooth (1999) explains that an optimum LA is important in realizing the most efficient interception of sunlight and optimum photosynthesis. In addition, Pettigrew (2003) reported that treatments with increased leaf area produced yields 9% higher than the untreated control two out of three years.

The effects of growing season or maturity requirments were also evaluated. Of the three cultivars examined, DP 555 would be expected to yield the least. Under these conciliations the shorter season cultivars would have had a larger planting window than full season cultivars. However, unseasonably warm falls could have allowed DP 555, which matures later than the other two cultivars, the time required to accumulate the HU's needed to compensate for the late planting. Unfortunately, this possibility does not explain the competitive yield produced by the early- to mid-season SG 215.

Harvest Index (HI), the ratio of lint (kg) to total plant biomass (kg) for an individual plant, was higher in 2004 than 2003 as well as different among cultivars (Figure 6). In 2003, SG 215 had a higher HI than ST 4892. Cultivar responses were again present in 2004; however, DP 555 had the highest HI. Measurements for individual boll weight and boll numbers also provided insight on lint yield. In 2003 and 2004, SG 215 produced more seedcotton boll^{-1} than the other two cultivars (Figure 7). This same trend was observed for bolls plant^{-1}; in 2004 SG 215 averaged the most bolls

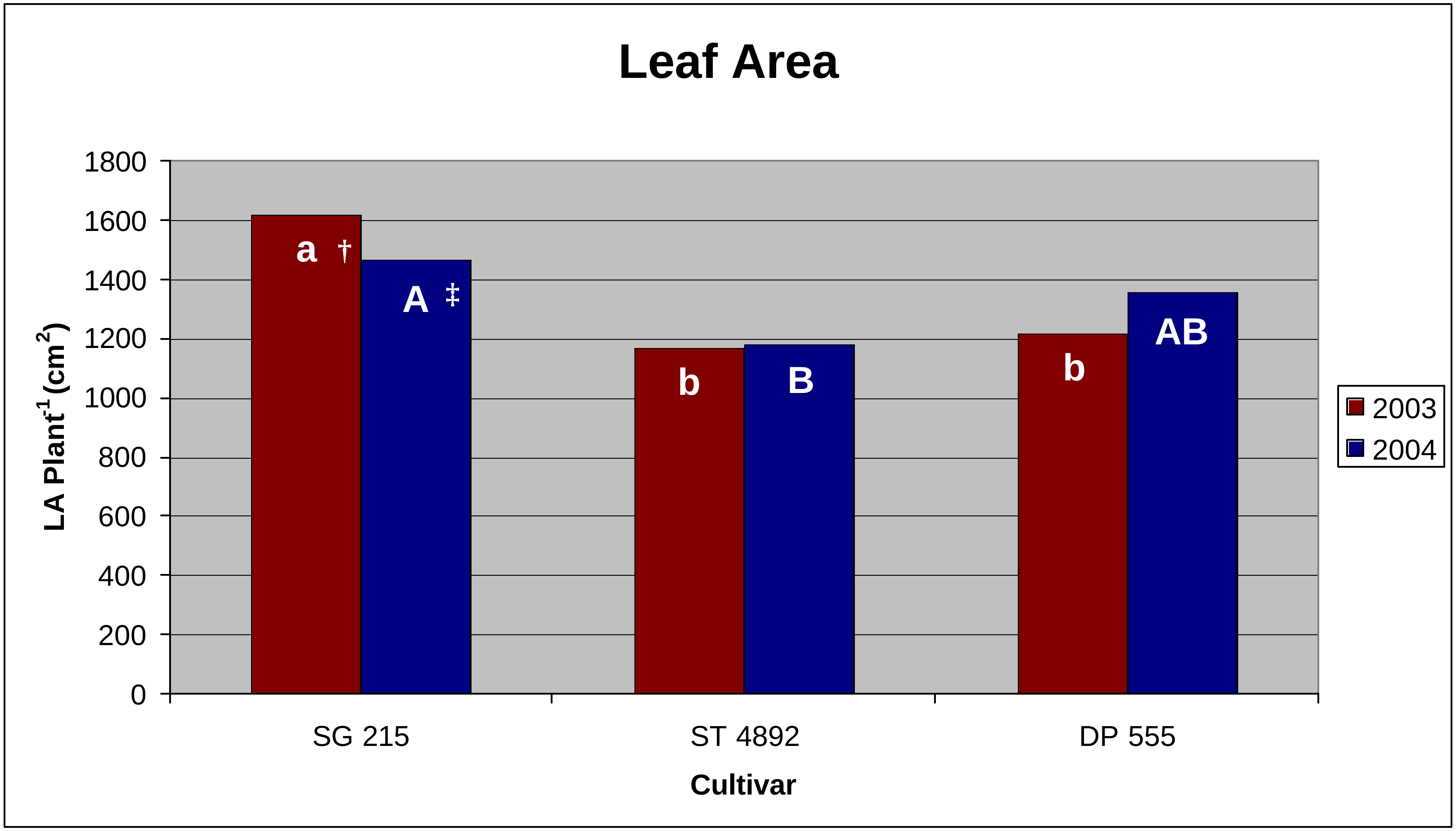

Figure 5. Cultivar effect on LA, 2003 and 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters in higher case represent a separate statistical analysis (2004).

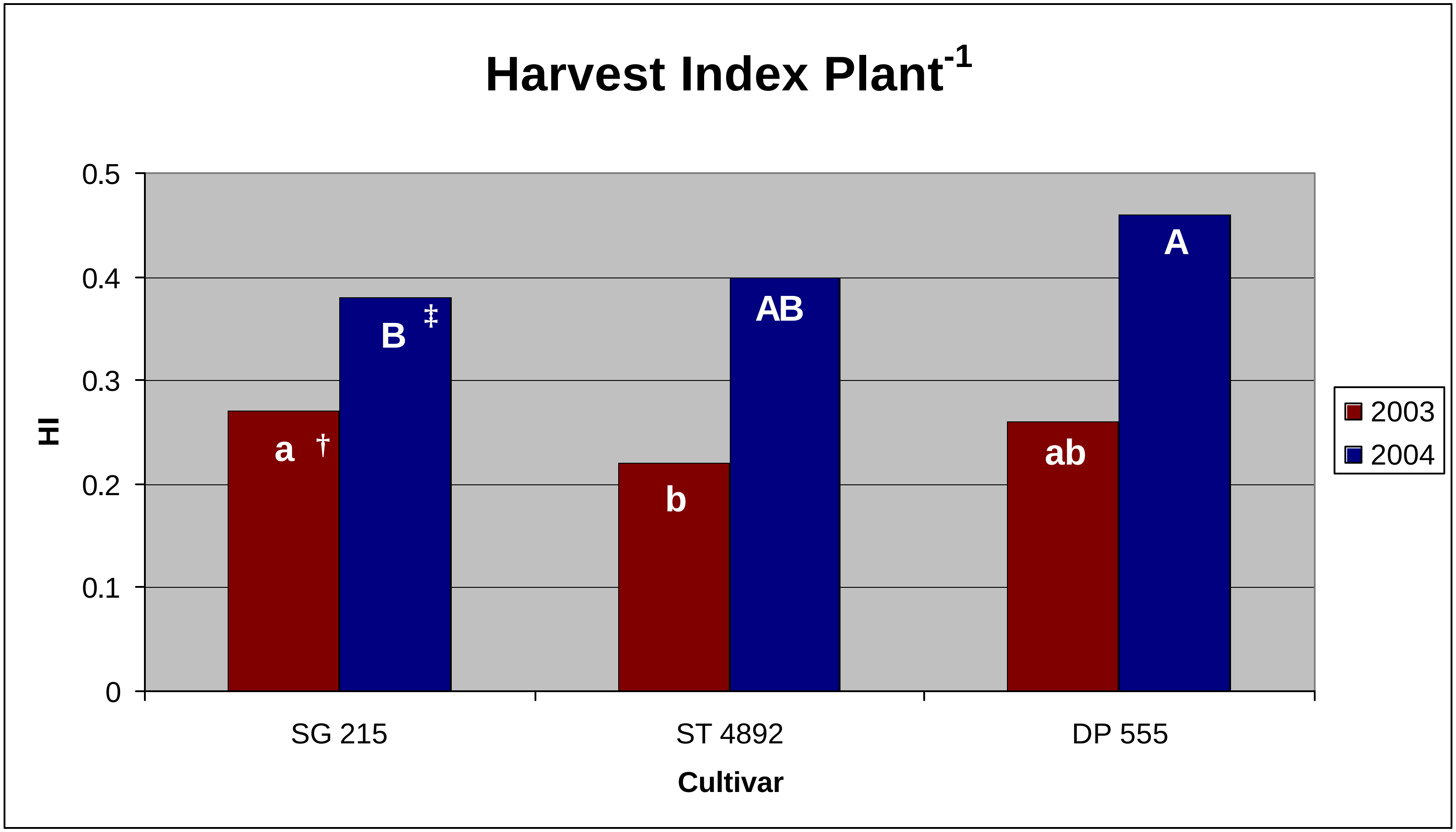

Figure 6. Cultivar effect on HI plant^{-1}, 2003 and 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters in higher case represent a separate statistical analysis (2004).

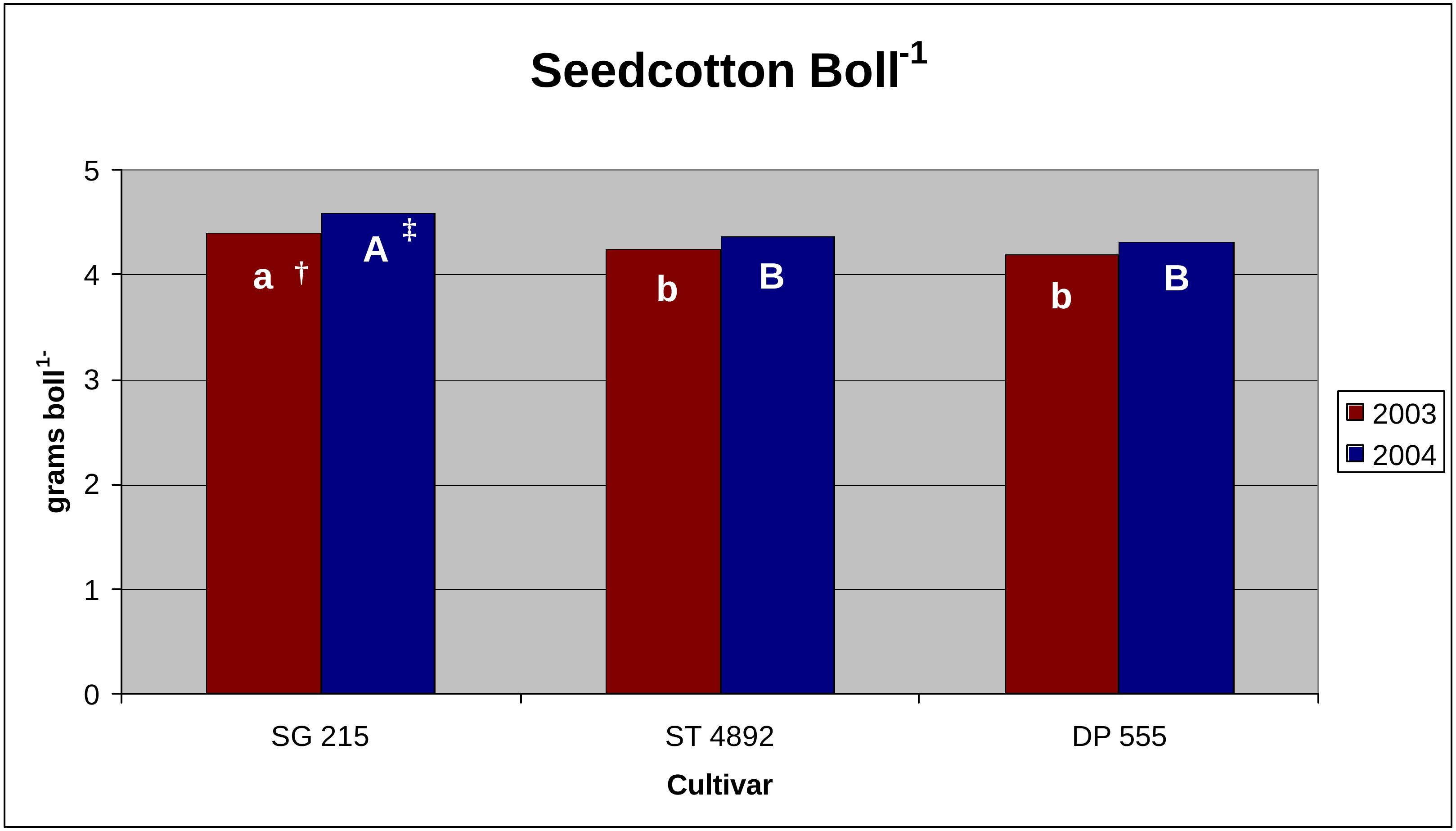

Figure 7. Cultivar effect on seedcotton boll^{-1}, 2003 and 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters in higher case represent a separate statistical analysis (2004).

plant^{-1}and both SG 215 and DP 555 were greater than ST 4892 in 2003 (Figure 8). Because boll number and boll size are important contributors to yield, one would suspect that SG 215 would produce a higher lint yield in 2004. However, the effect of seed size or ginout on overall lint production also impacts final yield and will be discussed for its effect on cultivars later in this document. Lower values were present for ST 4892 in all individual boll parameters measured in 2003 and 2004. These values included seed cotton weight boll^{-1} and the number of individual bolls plant^{-1}, which also translated into lower yields for this cultivar.

The information on yield parameters presented above suggests that SG 215 would produce the highest lint yield in 2003 and 2004. However, the percentage of lint weight to seedcotton weight, or ginout percentage, was higher for DP 555 compared with ST 4892 and SG 215. When the ginout percentage was considered along with the average seedcotton weight, DP 555 produced the most lint boll^{-1}. Therefore, although SG 215 possessed the highest number of bolls plant^{-1} and produced the most seedcotton boll^{-1}, a larger seed or a lower ginout percentage from SG 215 resulted in lint production similar to that of DP 555.

Evaluation of plant densities indicated that yield was not affected by plant densities that were higher, lower and equivalent to those used in commercial agriculture throughout the growing region in either year of the study (Figure 9). The hypothetical explanations for this lack of response phenomenon are discussed below.

Although growth parameters showed trends earlier in the season that were expected to impact lint yield, each plant density compensated for yield prior to cutout.

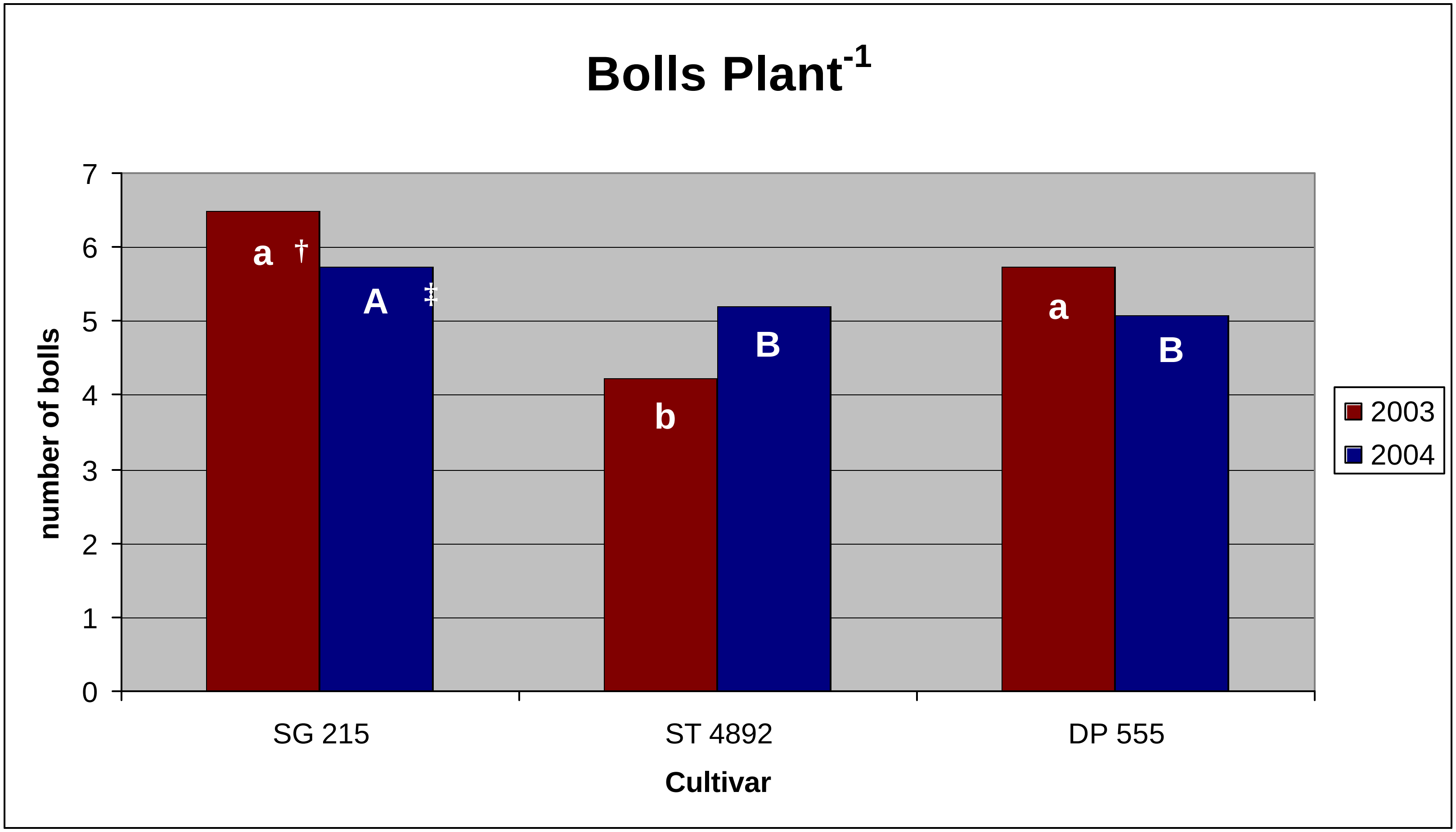

Figure 8. Cultivar effect on bolls plant^{-1}, 2003 and 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters in higher case represent a separate statistical analysis (2004).

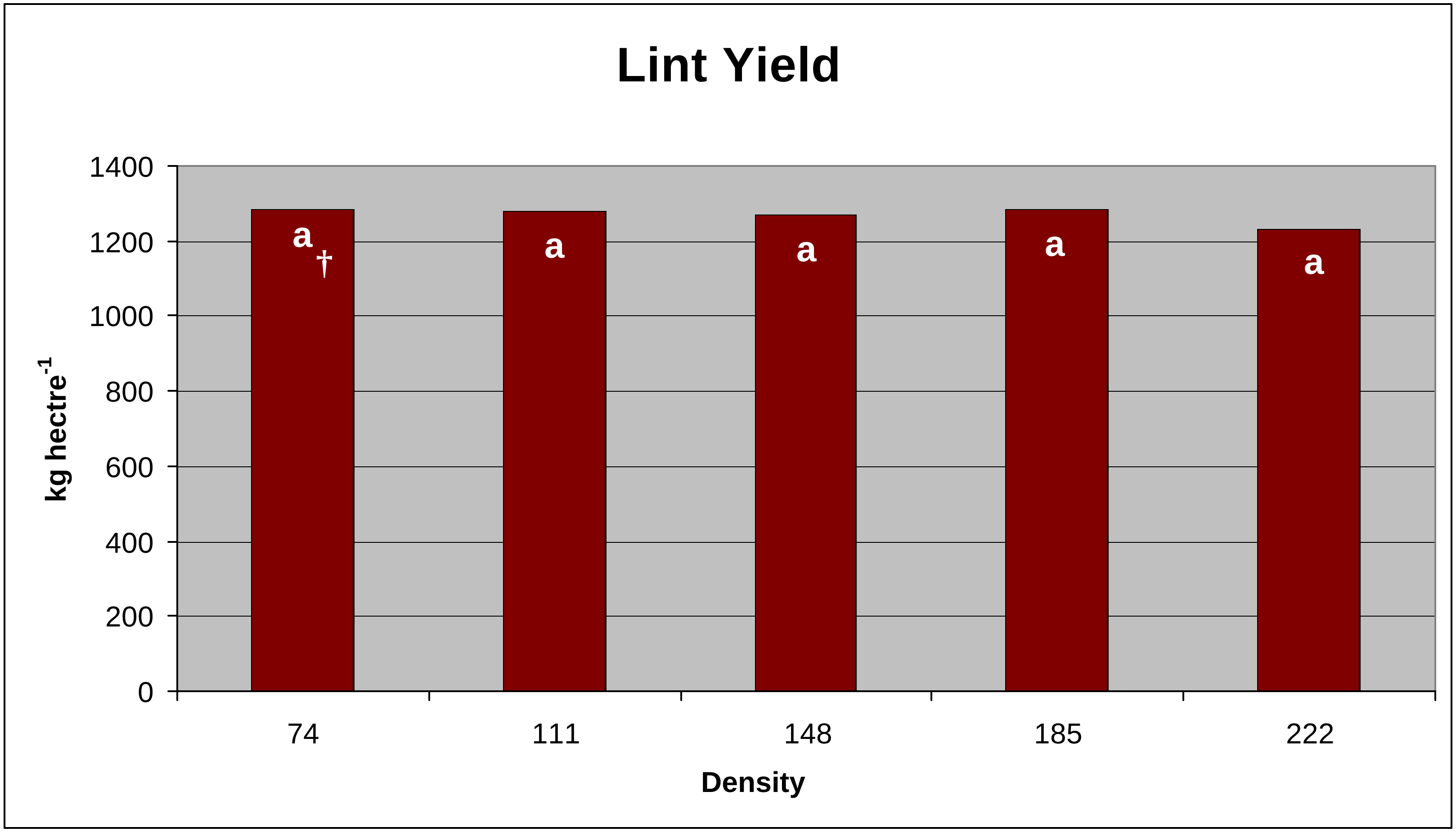

Figure 9. Density effect on lint yield hectare^{-1}, 2003 and 2004.

Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

For example, the 74 treatments produced more LA per plant (47 DAP in 2003 and 57 DAP in 2004) than the 111 treatments. This trend continued for the highest treatment of 222, which exhibited the lowest LA of any density (Figure 10). Square abscission data for 2004 indicated that abscission decreased as plant density increased, which suggested that LA and abscission were inversely related (Figure 11). However, the differences that were observed in growth earlier in the season did not impact lint production as all density treatments yielded the same (Figure 9).

Harvest index (HI) compared among plant densities illustrated similar trends in both 2003 and 2004 (Figure 12). In both years, a larger HI was observed for the 74 treatments than for the than 148, 185 and 222 treatments. A slight decrease in HI was apparent for each incremental increase in density, with 222 possessing the lowest HI of the densities examined. Because the HI revealed that more biomass was partitioned to reproduction at the lower density, it would appear that lower plant densities would be more advantageous. However, treatments with higher densities compensated for a lower HI with additional plants unit^{-1} area.

Lint Quality

Fiber analysis presented no statistical differences for any properties tested in 2003 or 2004. In addition, all fiber characteristics were within acceptable marketing ranges, and would not have received discounts except for micronaire in 2003. Micronaire was higher in 2003 than 2004, and in some treatments it was high enough to warrant a discount. Cultivar ST 4892 had a micronaire value of 5.1, which exceeded the acceptable range of 3.5 to 4.9. The 74 and 111 treatments also tested above the

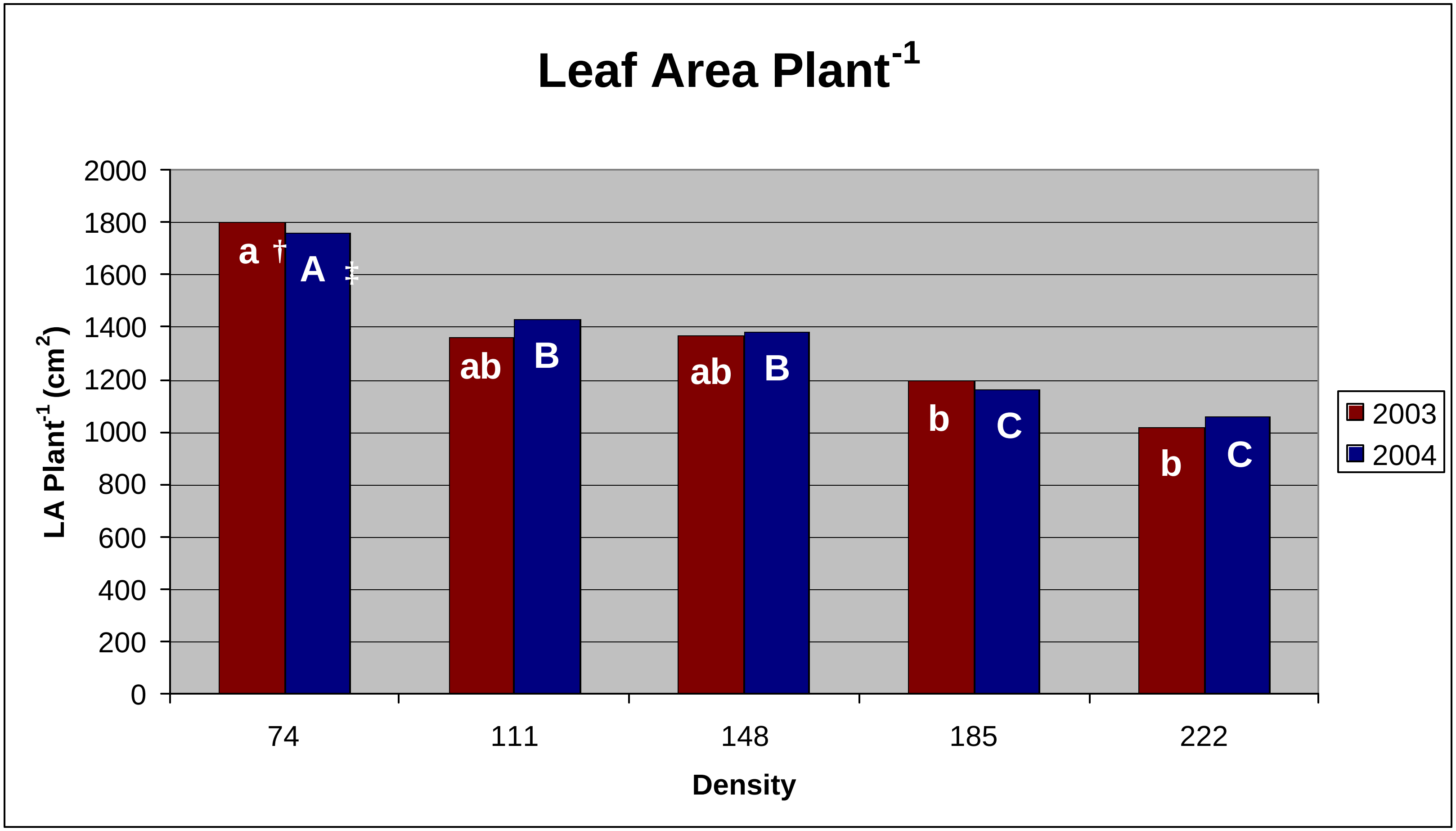

Figure 10. Density effect on leaf area plant^{-1}, 2003 and 2004.

†Representing individual years with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters in upper case represent a separate statistical analysis (2004).

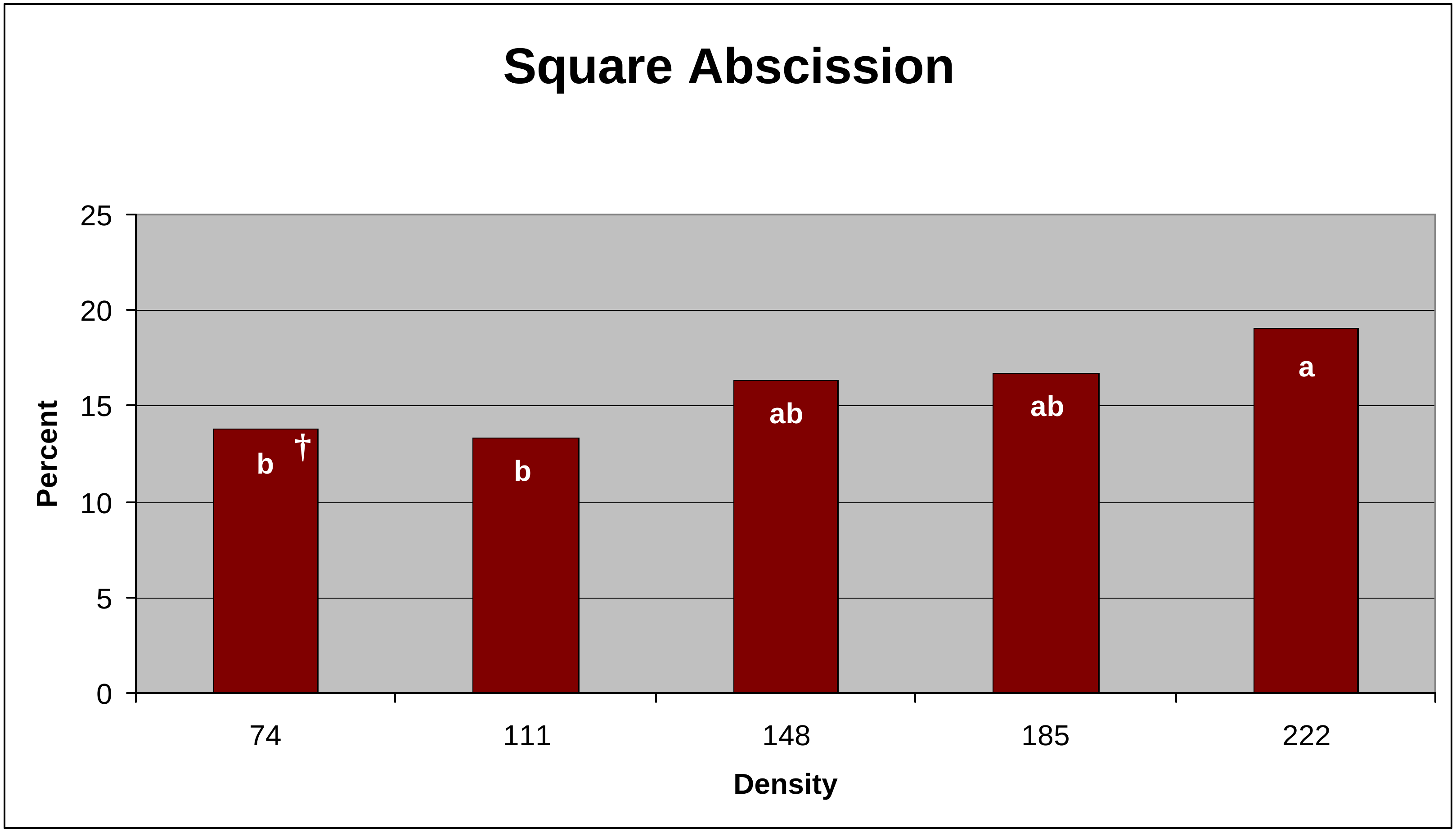

Figure 11. Density effect on percent square abscission, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

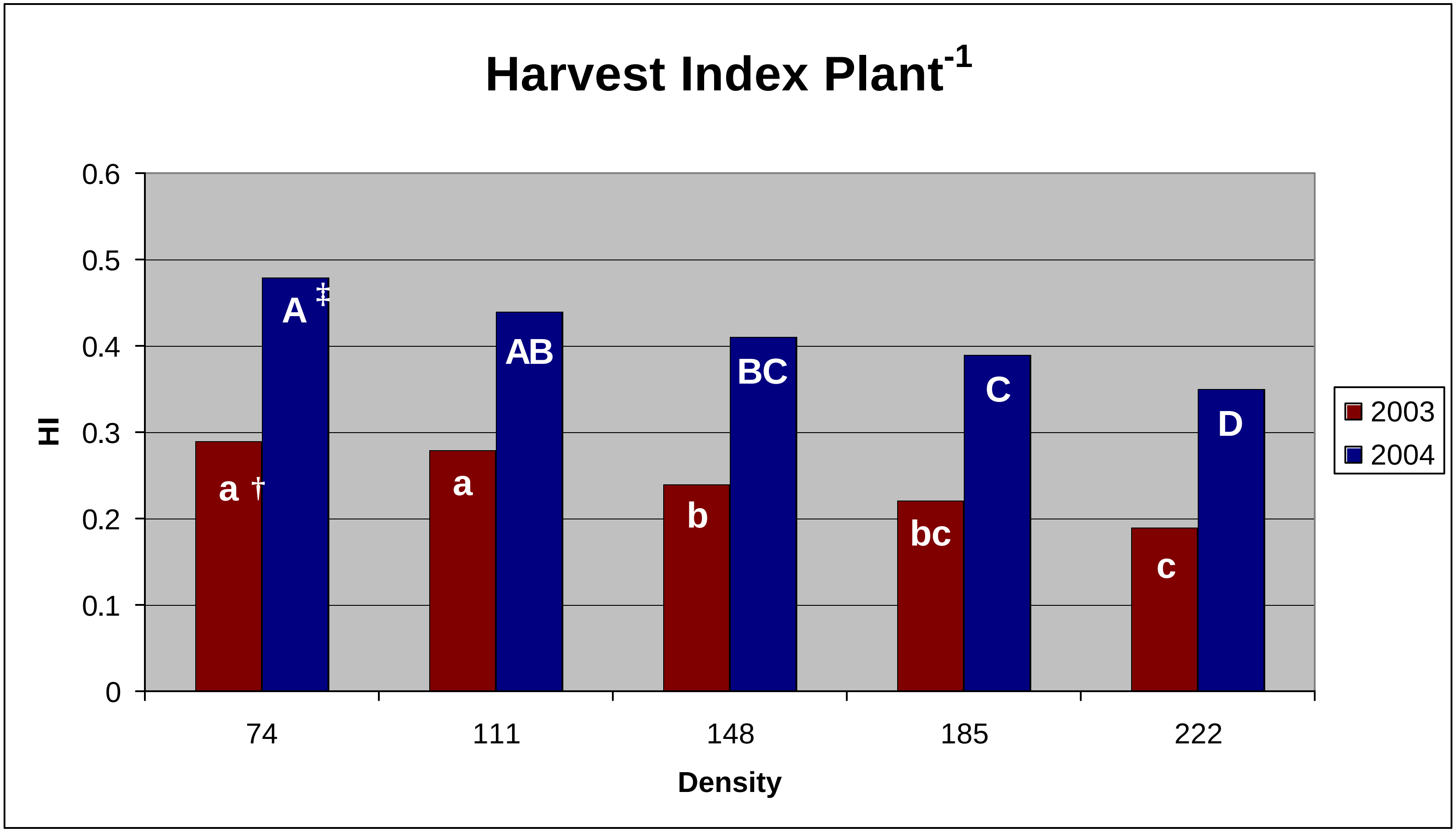

Figure 12. Density effect on HI plant^{-1}, 2003 and 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters in higher case represent a separate statistical analysis (2004).

range for micronaire with both giving values of 5.02 (Data not shown).

Biomass

Biomass partitioning was analyzed for all treatments at 57 and 104 DAP in 2003 and at 47 and 71 DAP in 2004. Reproductive and vegetative components of the plant were evaluated to examine the impact of individual density treatments on distribution of photoassimilates.

The LA, at 57 DAP (primary) in 2003, produced opposite trends than similarly data taken 104 DAP (secondary) (Figure 13). Differences in biomass partitioning between dates were anticipated, as DP 555 is a full season cultivar and produces less biomass at the beginning of the season than the other two cultivars. Comparisons of LA and leaf weight by densities, however, followed similar trends throughout the season. For example, 74 produced more LA and leaf weight than higher density treatments (Data not shown). Square weights also were examined in the primary biomass. Square weights followed a similar trend to leaf area in that SG 215 produced the most grams plant^{-1} of reproductive biomass. Changes observed among cultivars between primary and secondary biomass included an increase in reproductive growth by DP 555 later in the season. Open and reproductive boll weights were not different among cultivars, but the LPOP treatments consistently produced more fruit plant^{-1}. A similar trend was evident for vegetative bolls, which were produced at a higher rate for 74 compared to any other treatment (Figure 14). In 2004, biomass was assessed for LA and leaf weight at 47 and 71 DAP. Trends for LA plant^{-1} were consistent for both years; 74 treatments produced more LA than 148, 185 and 222 in both primary and secondary measurements

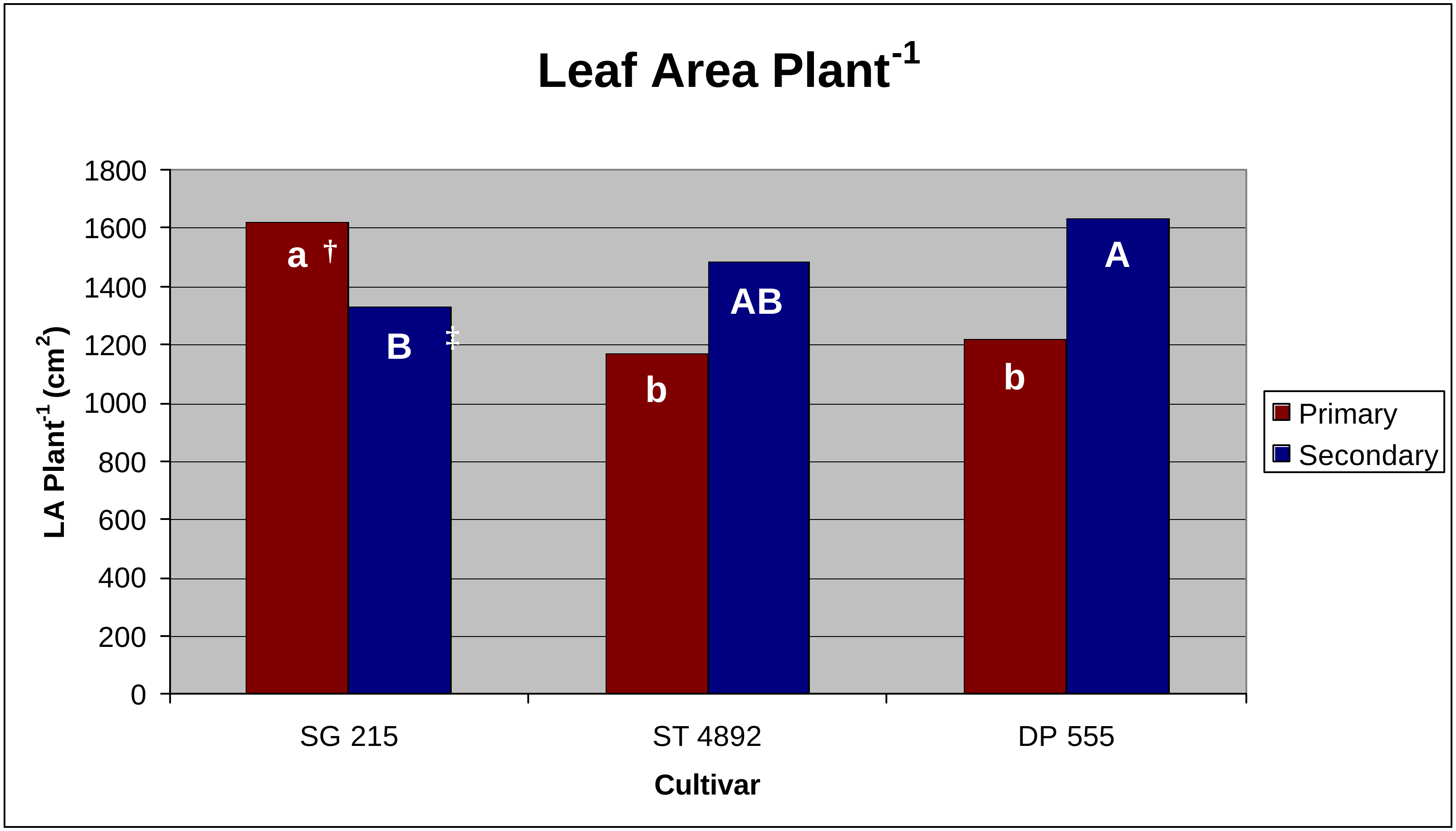

Figure 13. Cultivar effect on leaf area plant^{-1}, 2003.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters in higher case represent a separate statistical analysis.

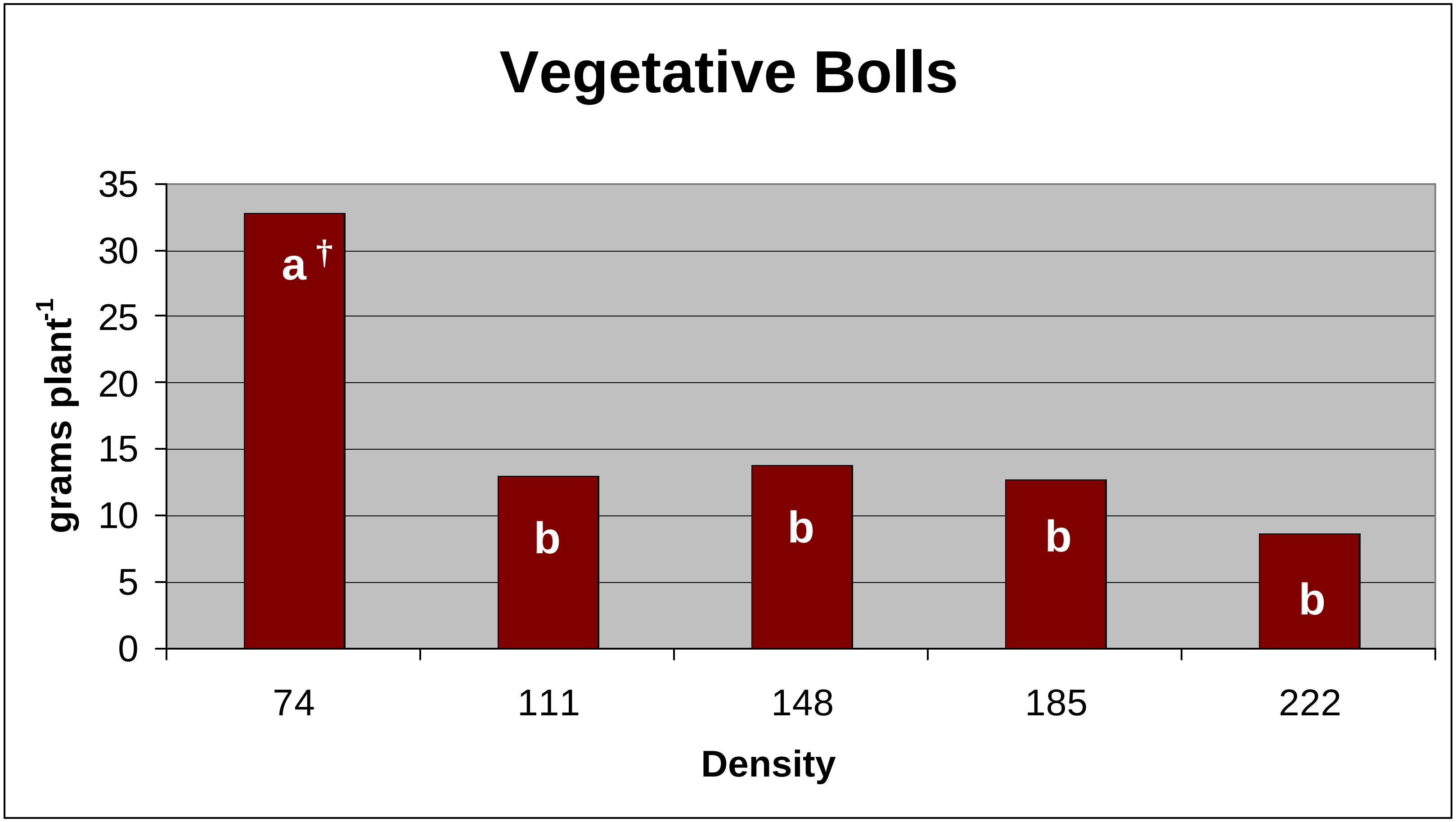

Figure 14. Density effect on vegetative boll weight, 2003.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

(Figure 15). Similar results were observed in stem and leaf weights. 74 and 111 treatments allowed for the most carbon assimilation and biomass production (Figure 16). However, these differences among densities were not apparent for lint production at harvest. In addition, dry weight of the reproductive components revealed that DP 555 produced the fewest grams of immature bolls for the cultivars examined 71 DAP (Figure 17). Still, in the 55 days remaining to harvest, this full season cultivar produced adequate lint to be competitive with the other two cultivars.

Box Mapping

Box mapping is a technique utilized to determine location and boll distribution throughout the plant canopy. From box mapping data, one gains an accurate assessment of where the majority of lint was produced and retained, as well as the mean weight of bolls. Due to a year by treatment interaction, box mapping data is presented separately for 2003 and 2004.

2003

Mean Boll Weight

In 2003 there was no mean separation between total boll weight plant^{-1} when averaged either by node or fruiting position on individual nodes between cultivars. DP 555 produced higher total boll and total reproductive boll weights than the other two cultivars (Figure 18). In addition, DP 555 had higher overall number of bolls plant^{-1} with 9 and 15 more bolls plant^{-1} than SG 215 and ST 4892, respectively. Total seed cotton weight plant^{-1} Varied among the plant densities tested the 74 treatments producing the highest mean seedcotton weight plant^{-1} (Figure 19).

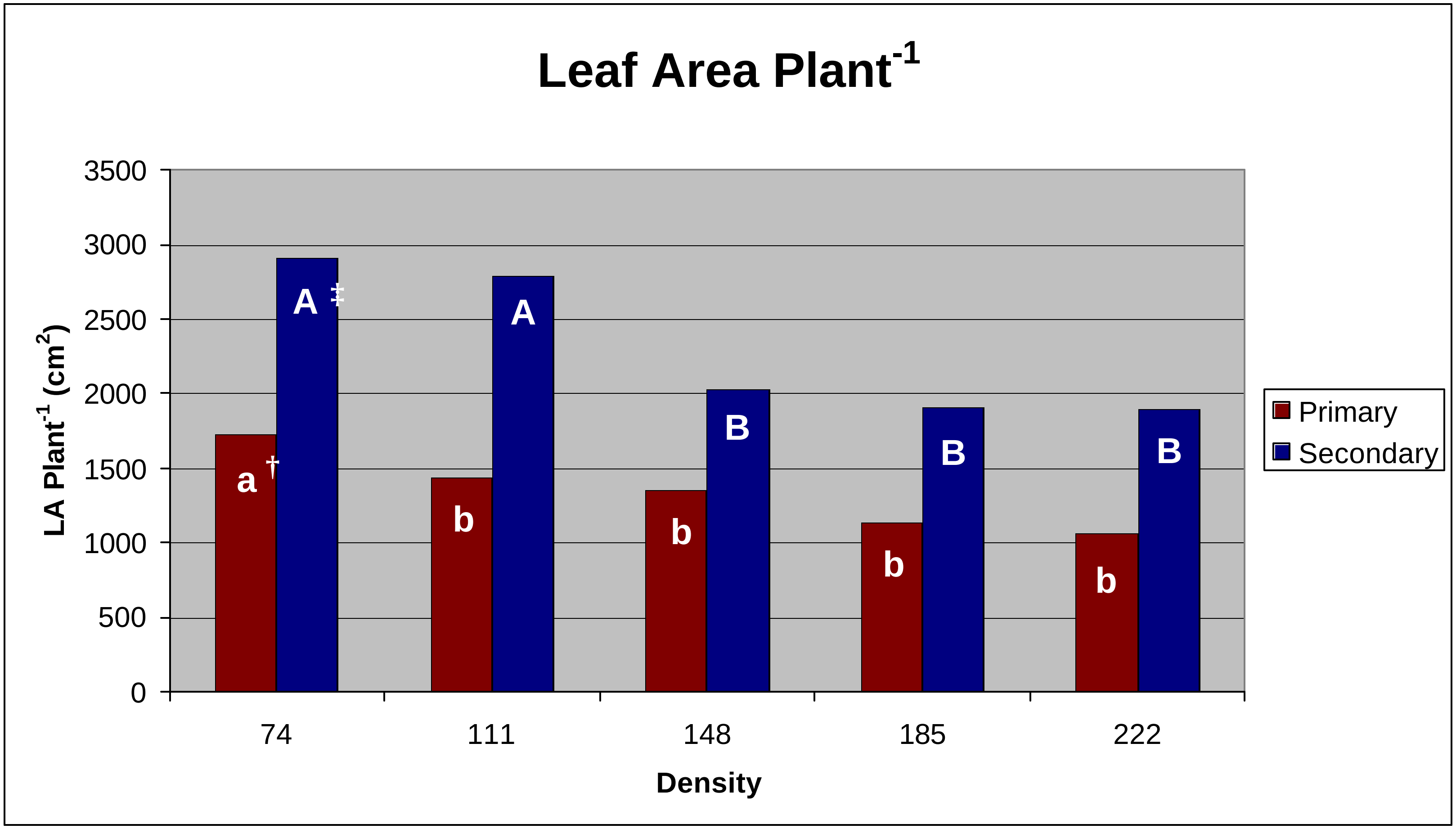

Figure 15. Density effect on LA, 2004.

†Means between columns with different letters are significantly different at $P<0.05$ according to Fisher's protected LSD.
‡Letters in higher case represent a separate statistical analysis. (Primary – early season; Secondary – Late season)

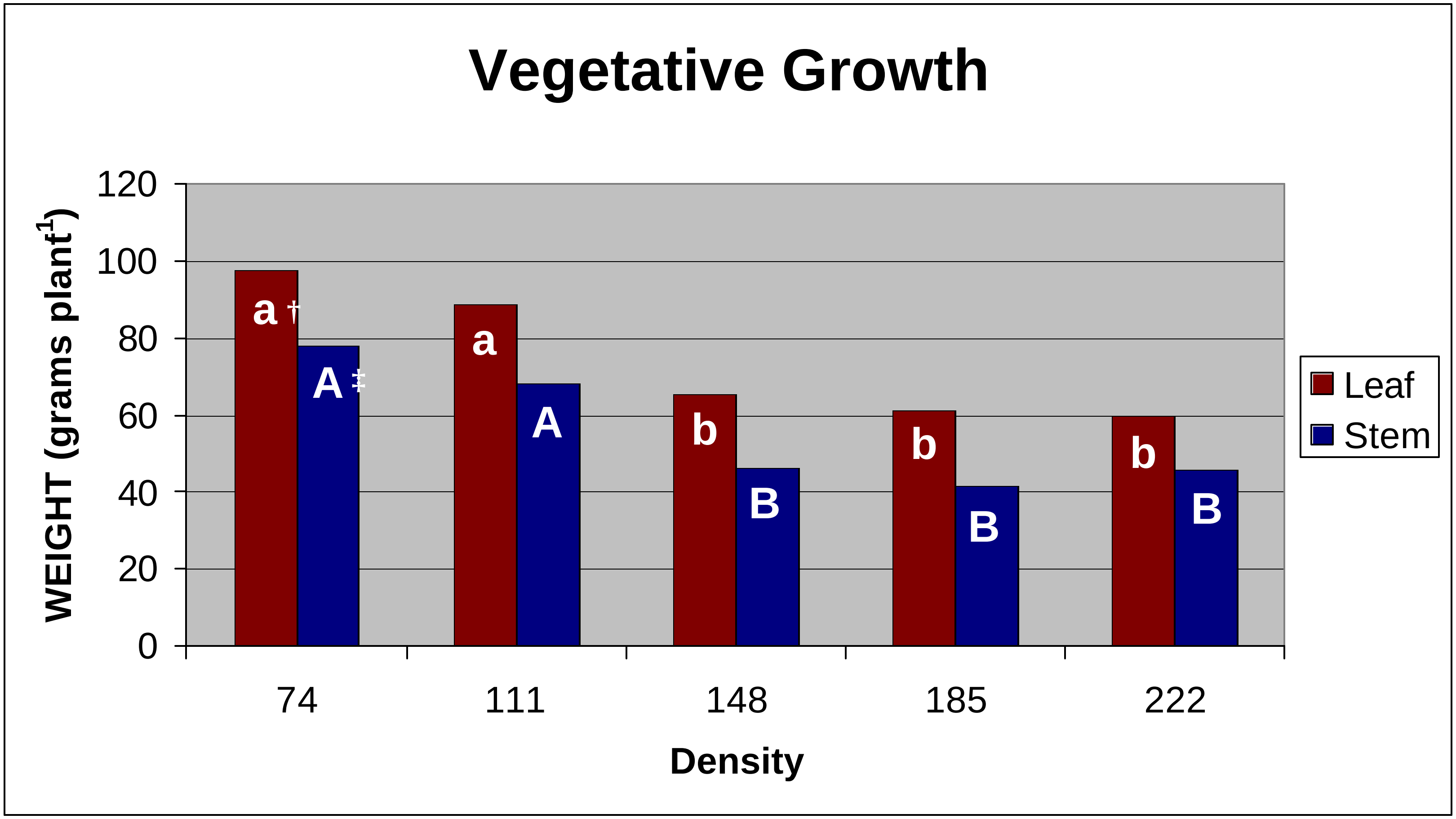

Figure 16. Density effect on vegetative growth parameters combined over 2003 and 2004.

†Means between columns with different letters are significantly different at $P<0.05$ according to Fisher's protected LSD.
‡Letters in higher case represent a separate statistical analysis.

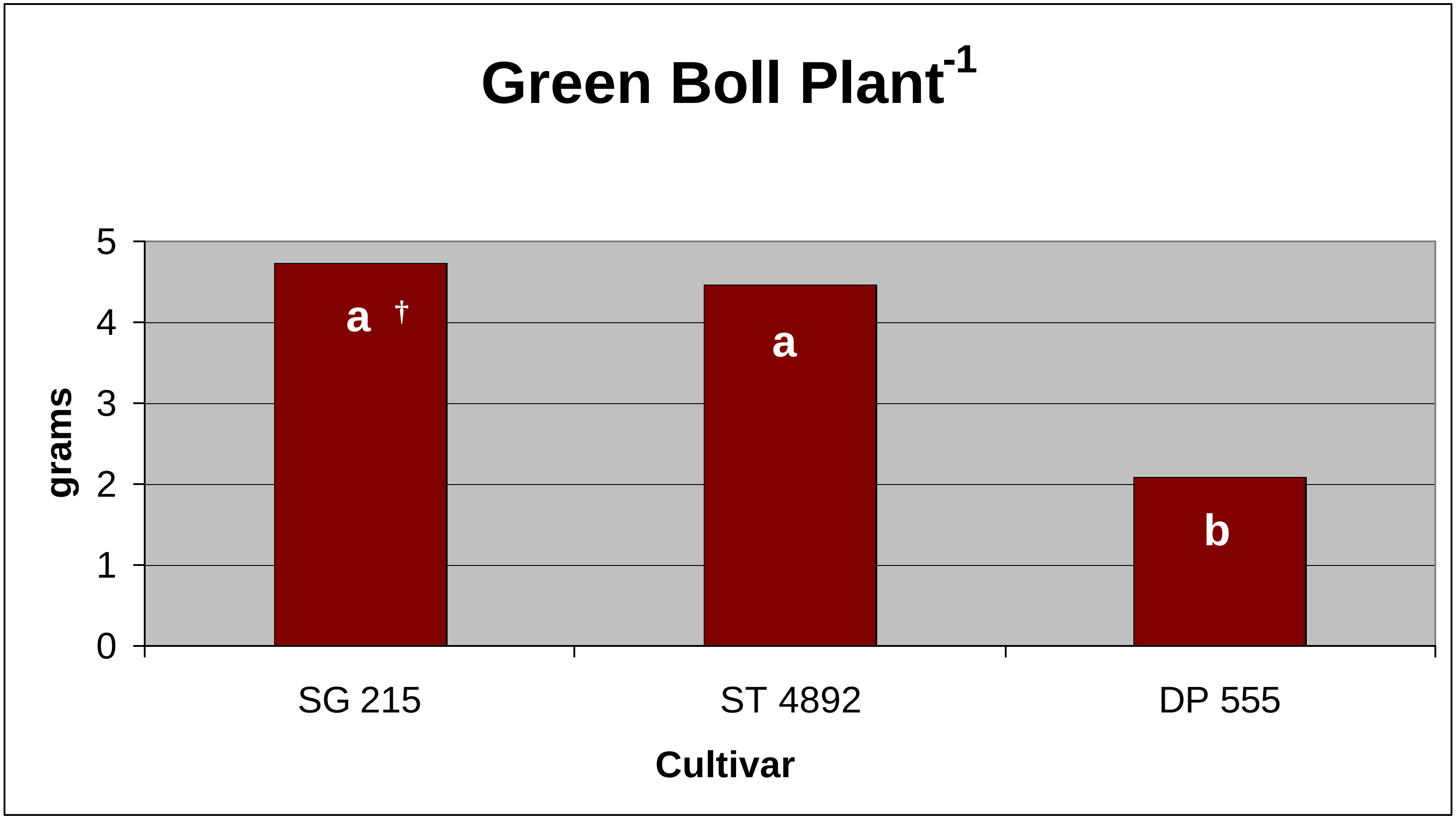

Figure 17. Cultivar effect on green bolls plant^{-1}, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

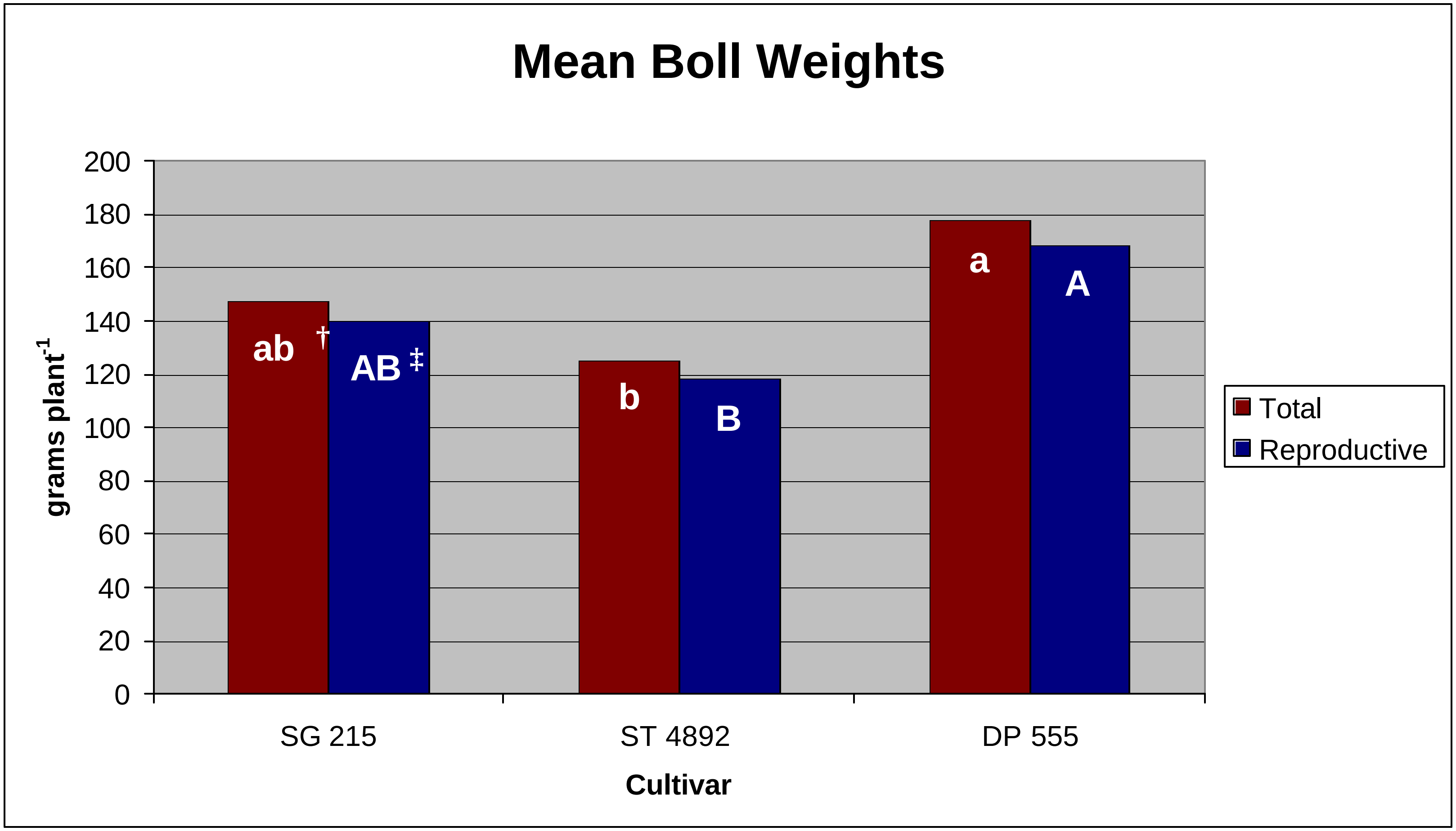

Figure 18. Cultivar effect on mean weight of total and reproductive bolls, 2003.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters of higher case represent a separate statistical analysis.

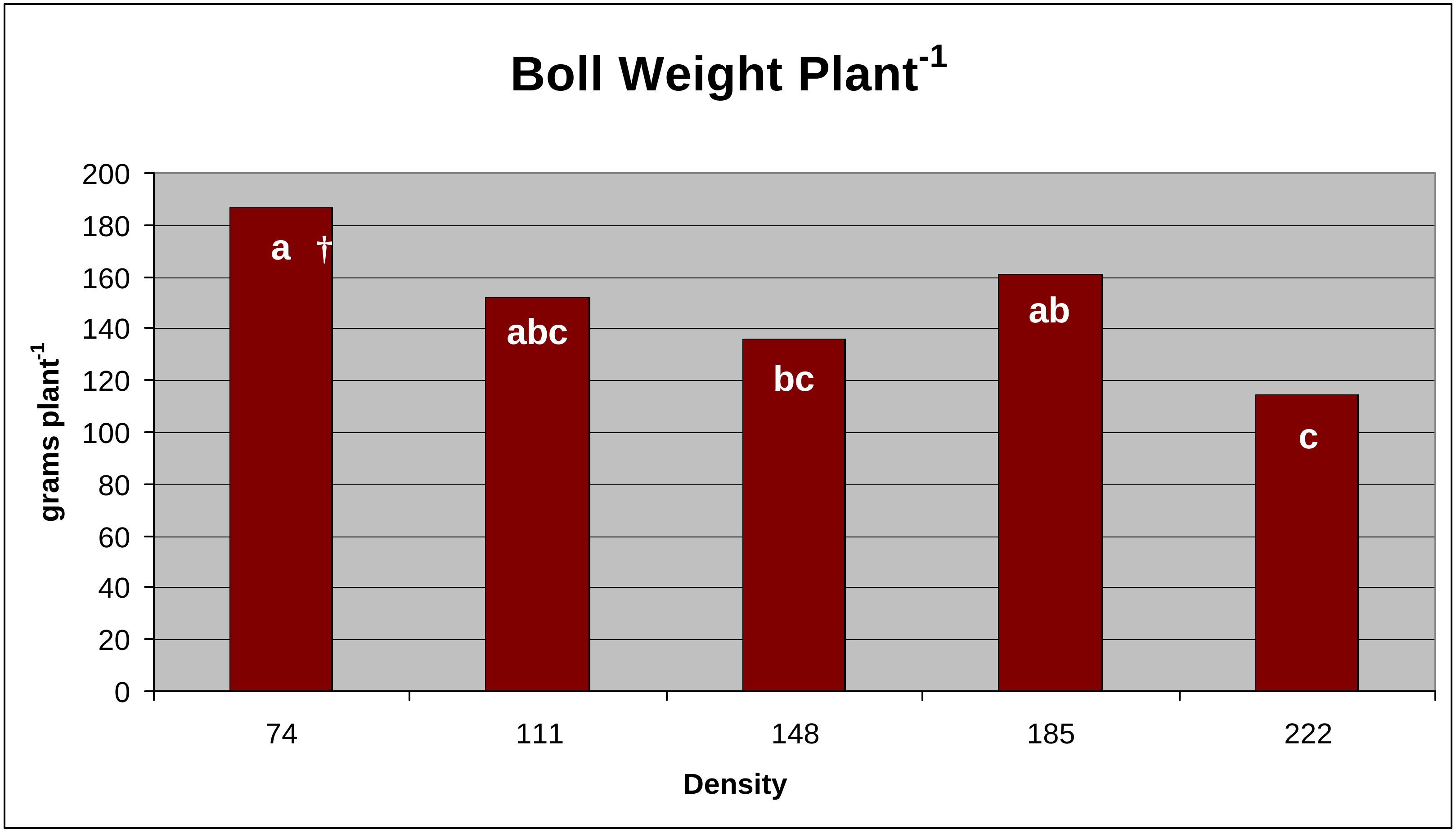

Figure 19. Density effect on boll weight plant^{-1}, 2003.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

Boll Number Plant^{-1}

In general, the LPOP treatments produced the most bolls plant^{-1} (Figure 20). The 74 treatments had more bolls than 222 at positions 1 and 2. This density treatment also produced more bolls at position 3 than 111, 148, 185 and 222. The increased boll number plant^{-1} allowed the LPOP treatment to compensate for having fewer plants hectare^{-1}; higher density treatments, on the other hand, produced fewer bolls plant^{-1} but had an increased number of plants per unit area.

2004

Mean Boll Weight

Boll weight is affected by boll distribution within the canopy and can have a major effect on lint yield (Parkin and Atkins, 1997). Historically bolls located on the first position nearest the main stem contribute more to overall yield. First position bolls contribute from 66 to 75 percent of the total yield produced by the plant (Mauney and Stewart, 1986; Jenkins et al., 1990; Ritchie et al., 2004). This principle was illustrated by the distribution of boll weights at first, second and third position bolls in 2004 (Figure 21). Position one boll weights were lower for ST 4892 and DP 555 than for SG 215. These data show a distinct decrease in grams of seedcotton boll^{-1} between fruiting positions. Position one produced more seedcotton boll^{-1} than positions two or three. Mean seedcotton boll^{-1}weights were combined according to the reproductive node at which they were retained. Seedcotton boll^{-1} weight was determined for nodes three to five, six to ten, eleven to fifteen and sixteen to twenty. Of these, only nodes sixteen to twenty showed significant results.

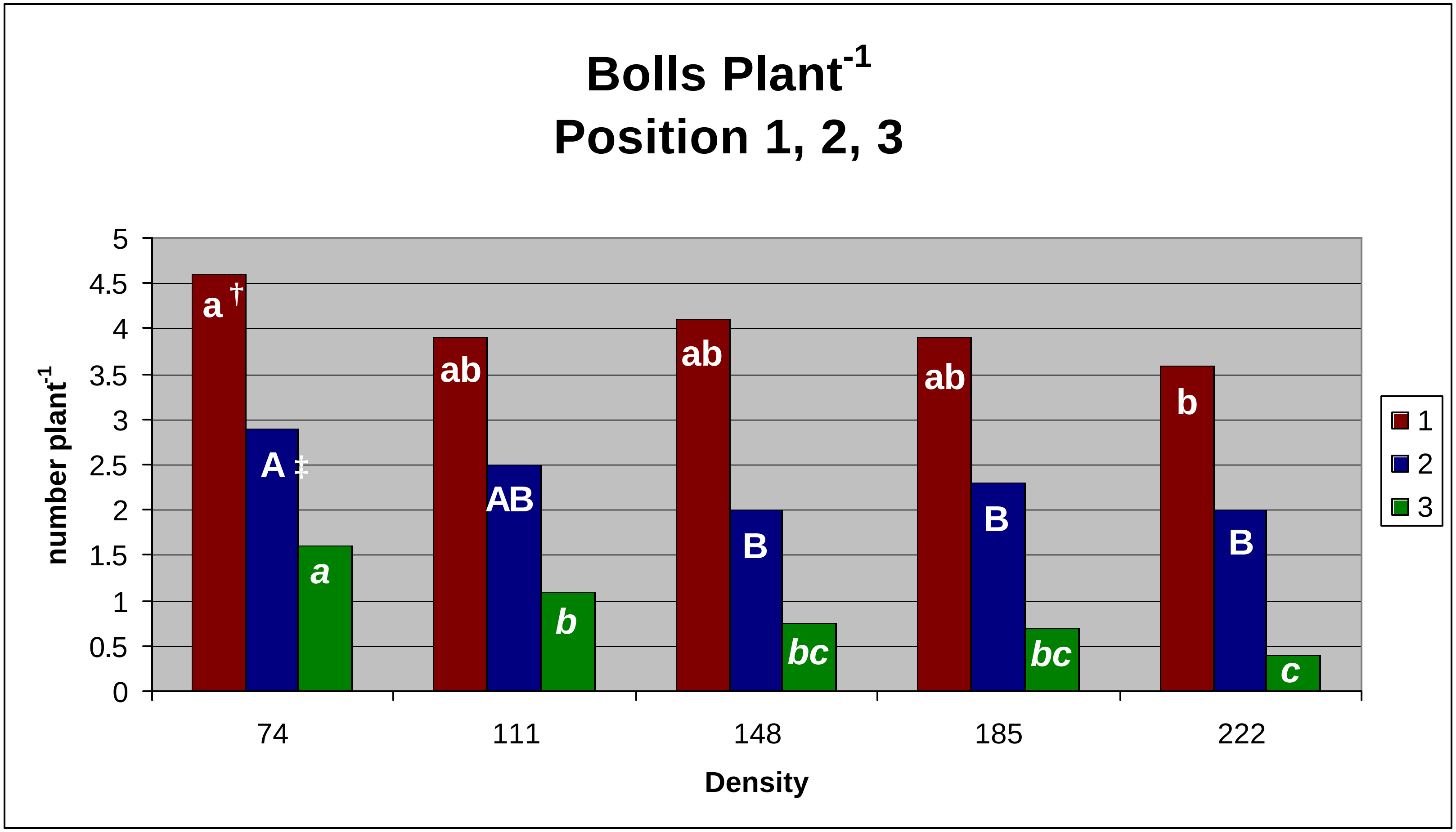

Figure 20. Density effect on bolls plant^{-1} by position, 2003.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters of different styles represent a separate statistical analysis.

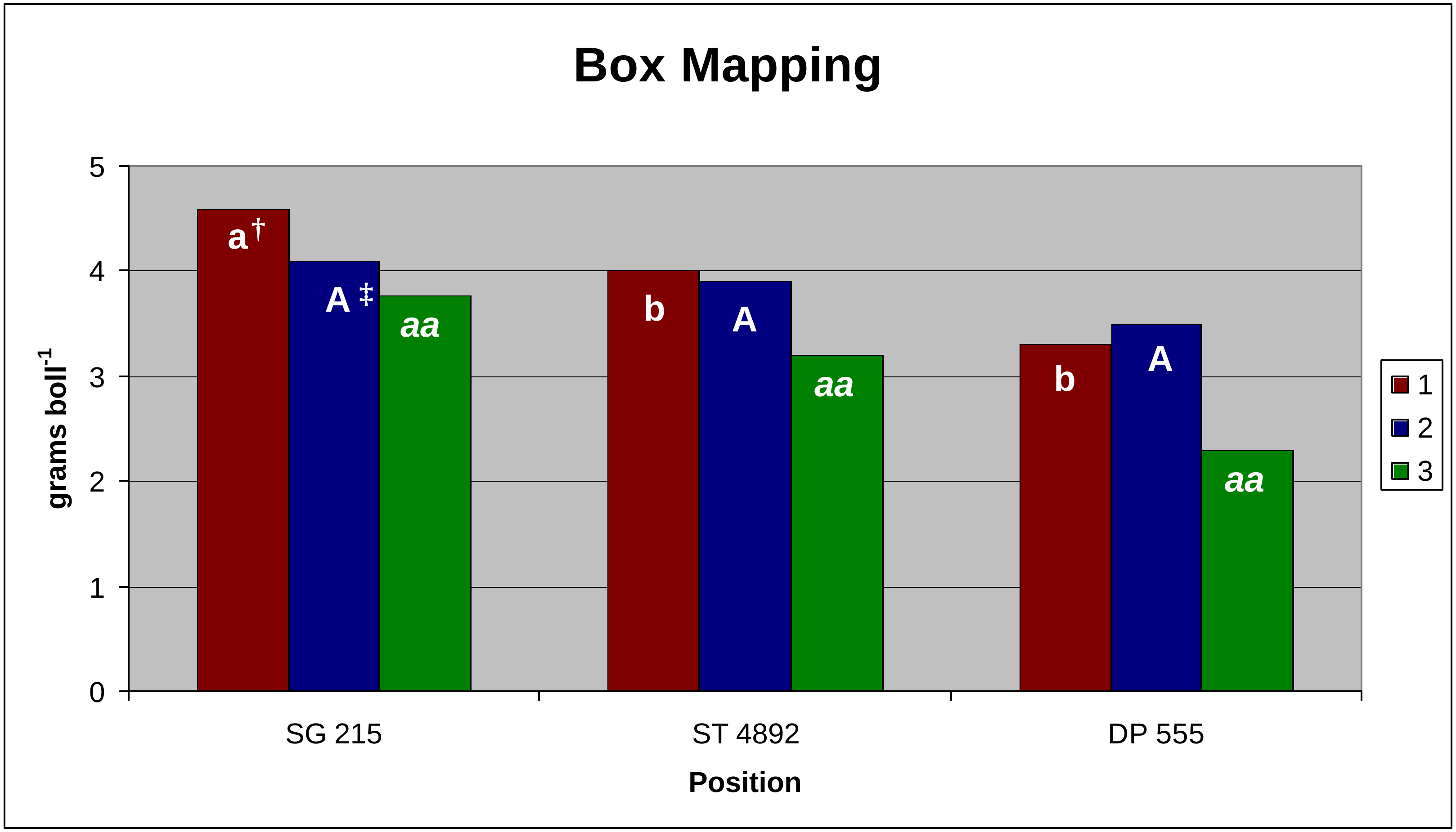

Figure 21. Cultivar effect on seedcotton boll^{-1} weight for first, second and third position, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters of different styles represent a separate statistical analysis.

Cultivar DP 555 produced more seedcotton at nodes in the top of the canopy, which corresponds to the ability of the full-season cultivar to set and mature fruit later in the season (Figure 22).

Boll Number Plant^{-1}

Differences for boll number plant^{-1} were present for fruiting position one in both cultivar and density variables and on position two and three in density treatments (Figure 23 and 24). By increasing the number of bolls produced at distal fruiting positions, the lower density treatment yielded competitively with treatments at higher plant densities. Total boll number plant^{-1} was higher for the 74 and 111 treatments than for higher density treatments (Figure 25).

Boll number plant^{-1} was examined by combining the lint weights produced from several main stem nodal positions to compare the partitioning effects for each density and cultivar treatment evaluated. Fruit production and retention at fruiting nodes 3 to 5 was significantly important in SG 215 as this cultivar produced a greater percentage of its yield early in the season. At higher nodal positions, DP 555 became more competitive and produced more bolls on nodes 11-15 and 16-20 than the other two cultivars. However, because total bolls plant^{-1} was not different, the location of boll set in the canopy had no effect on total boll production. Total and reproductive node data provided by box mapping revealed that DP 555 had a greater amount of reproductive nodes than ST 4892 and SG 215 (Figure 26). The presence of a greater number of nodes in DP 555 increased fruiting sites plant^{-1} giving this cultivar the potential to produce bolls.

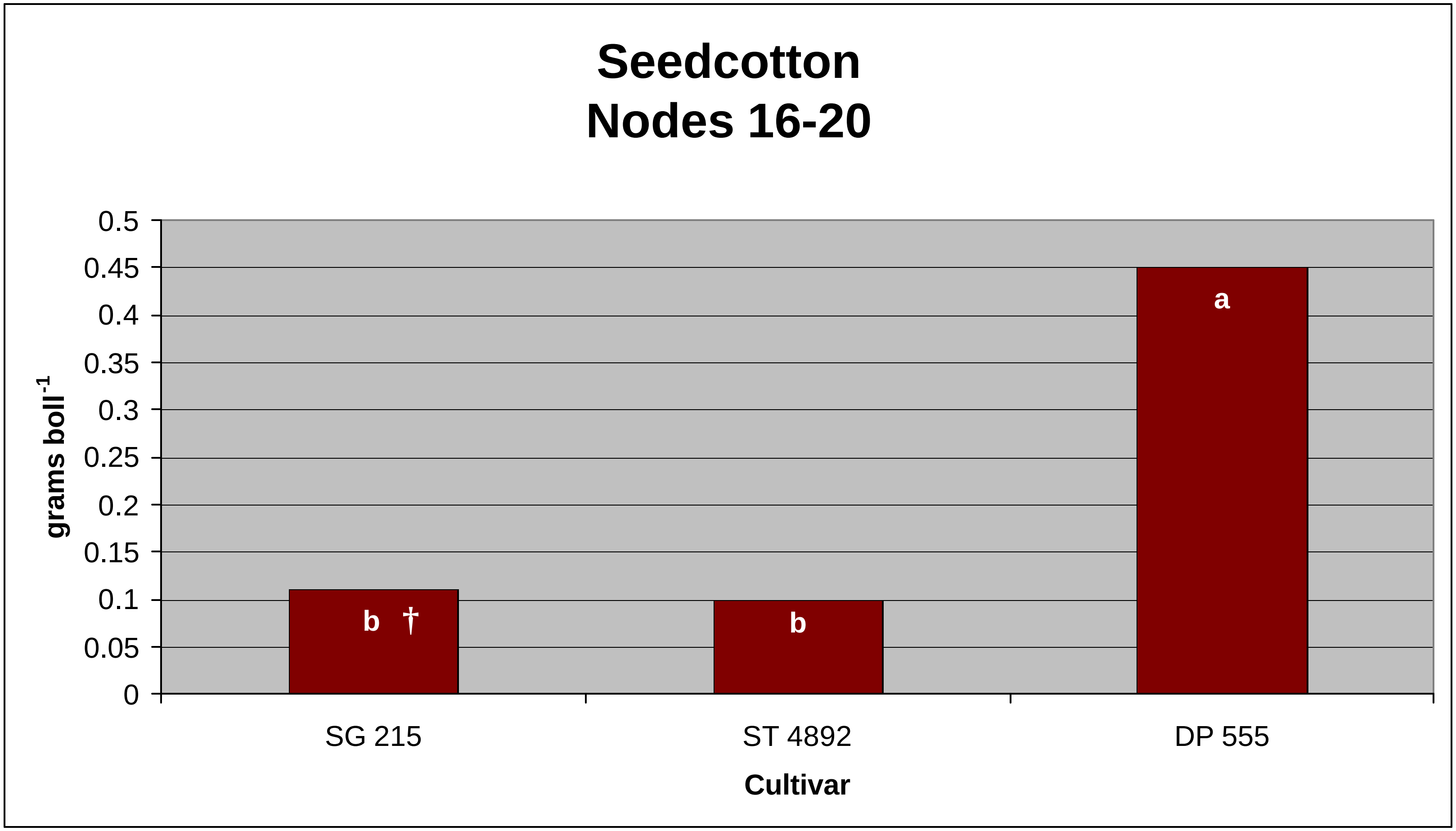

Figure 22. Cultivar effect on seedcotton weight for nodes 16-20, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

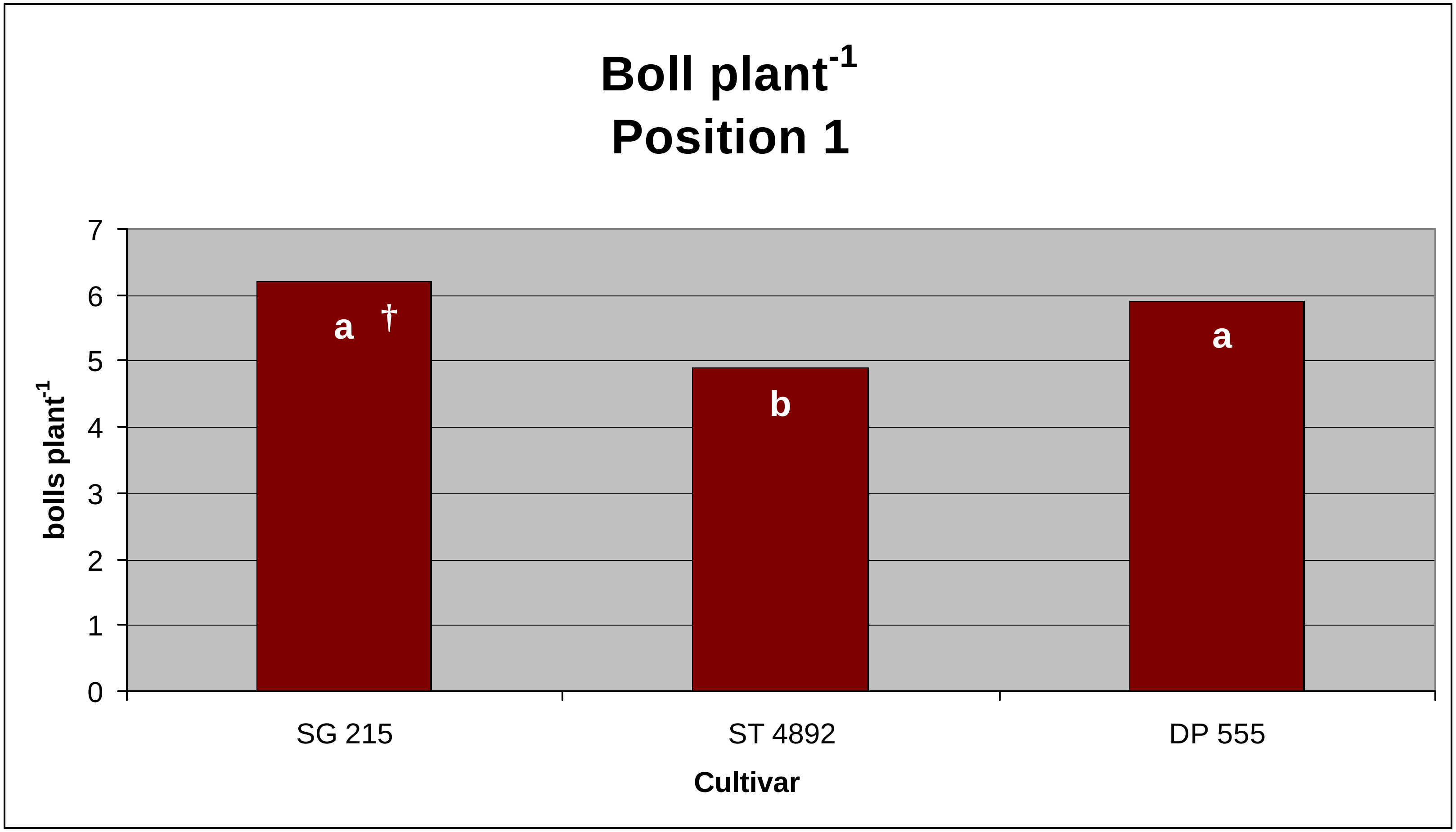

Figure 23. Cultivar effect on boll number plant^{-1}, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

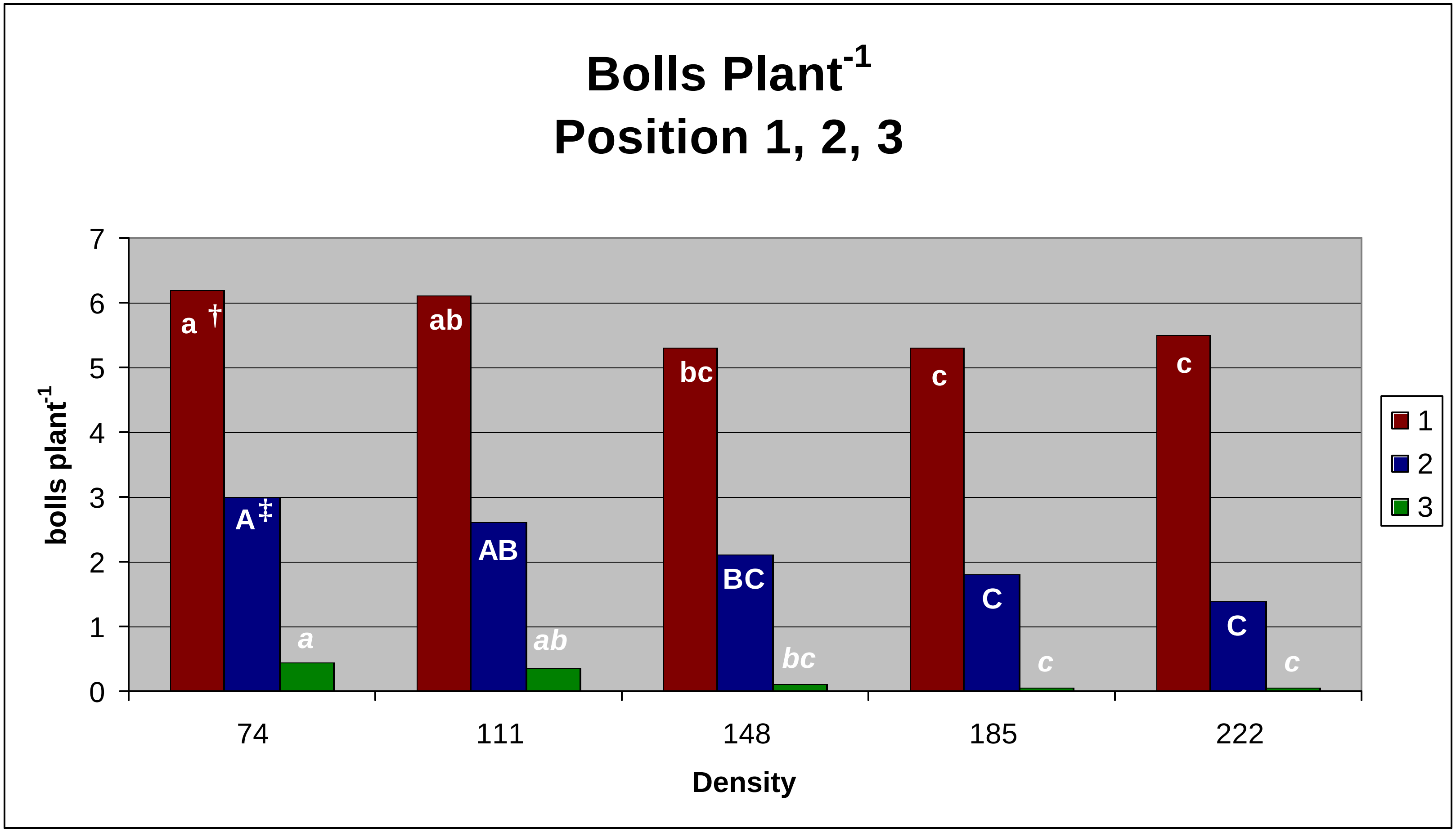

Figure 24. Density effect on bolls per plant by position, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters of different styles represent a separate statistical analysis.

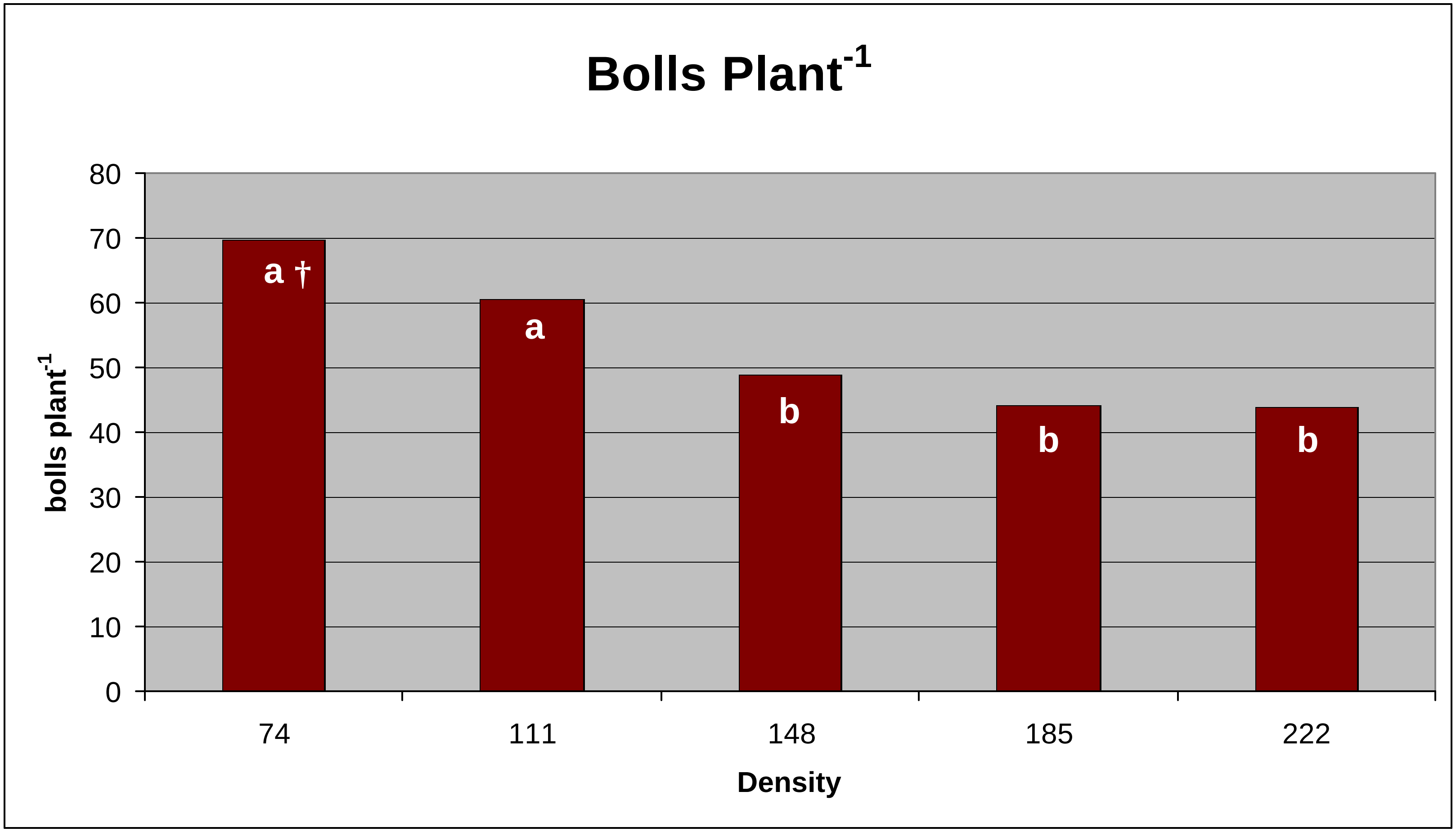

Figure 25. Density effect on bolls plant^{-1}, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

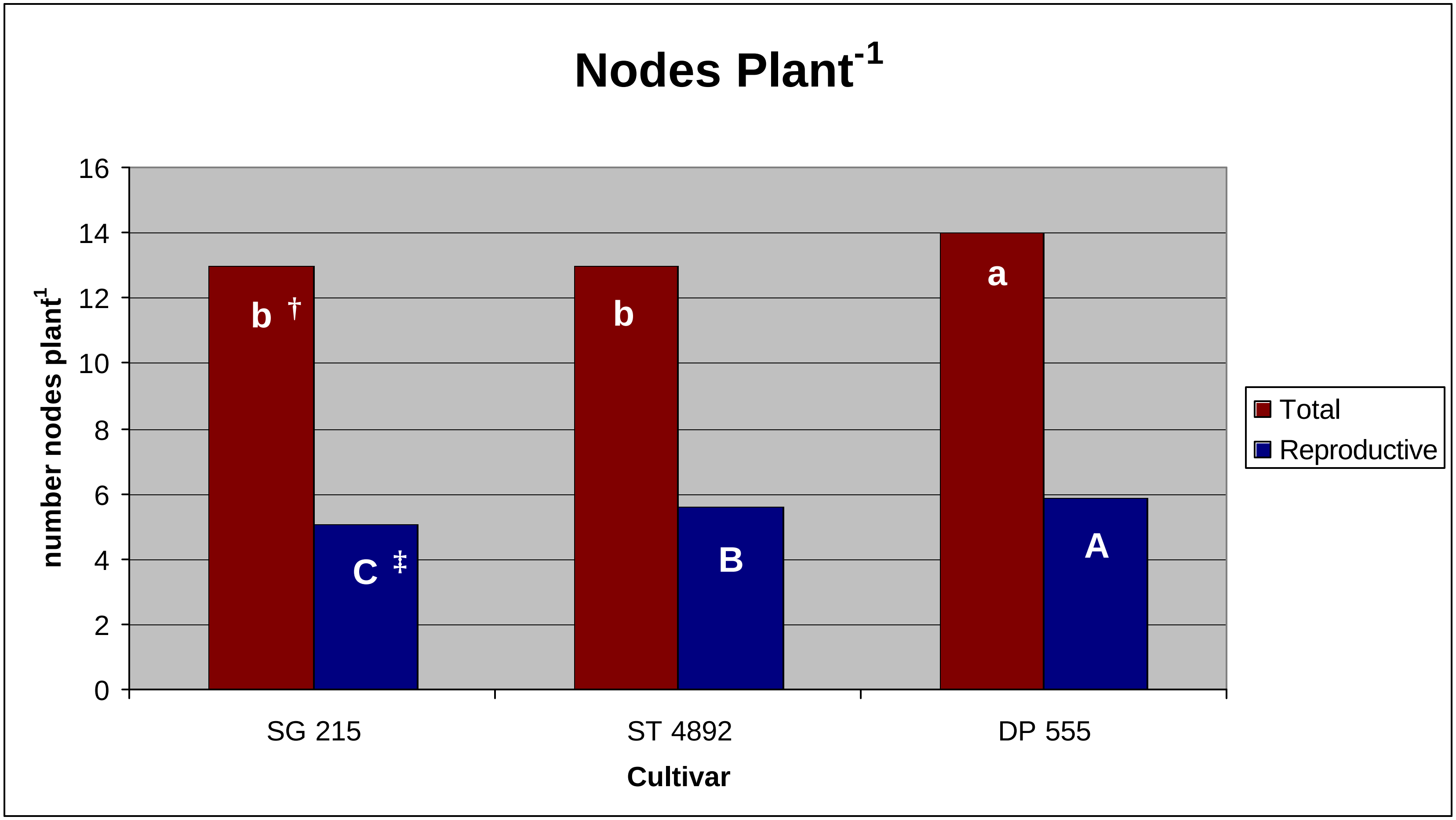

Figure 26. Cultivar effect on total and reproductive nodes plant^{-1}, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters of different styles represent a separate statistical analysis.

Individual Boll Data

Individual boll data reflects the box mapping data discussed earlier but is more accurate and provides additional information on fruit retention and production. Additional measurements obtained for this data included flowering dates, heat unit (HU) accumulation and days from bloom to harvest.

2003

In 2003, all flowers within one randomly selected meter of row in each plot were tagged and dated. Following harvest of individually tagged bolls, days from anthesis to harvest (DPA), average flower date (AFD), heat unit accumulation between flower and harvest (HU), total seedcotton weight (TWT), mean seedcotton weight (WT), and number of bolls meter^{-1} of row (NUM) were determined. No significant differences were present for any of these factors when analyzed by density. The density response for NUM indicated in boxmapping was not detected when bolls were evaluated on an individual basis. Differences were apparent however, when the properties above were compared by cultivar. Higher values for both WT and NUM of the bolls were noted for SG 215 compared with ST 4892 and DP 555 (Figure 27 and 28).

Due to differences in the ratio of lint produced per unit seedcotton (ginout), DP 555 yielded the most lint boll^{-1} (Figure 27). Although, SG 215 had the lowest ginout, it produced a sufficient number of bolls to produce a lint yield greater than ST 4892 (Figure 2).

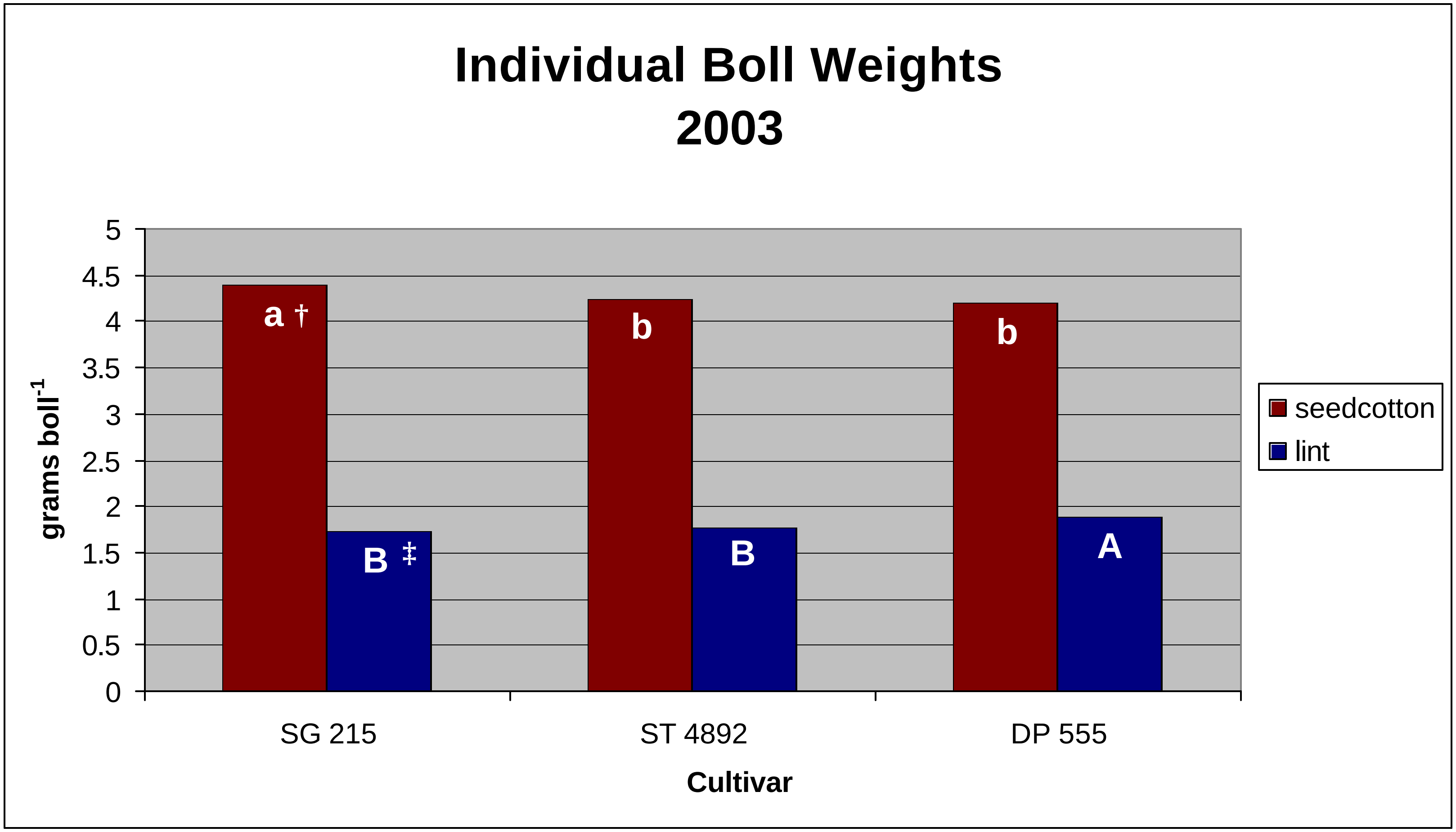

Figure 27. Cultivar effect on seedcotton and lint boll^{-1}, 2003.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters of different styles represent a separate statistical analysis.

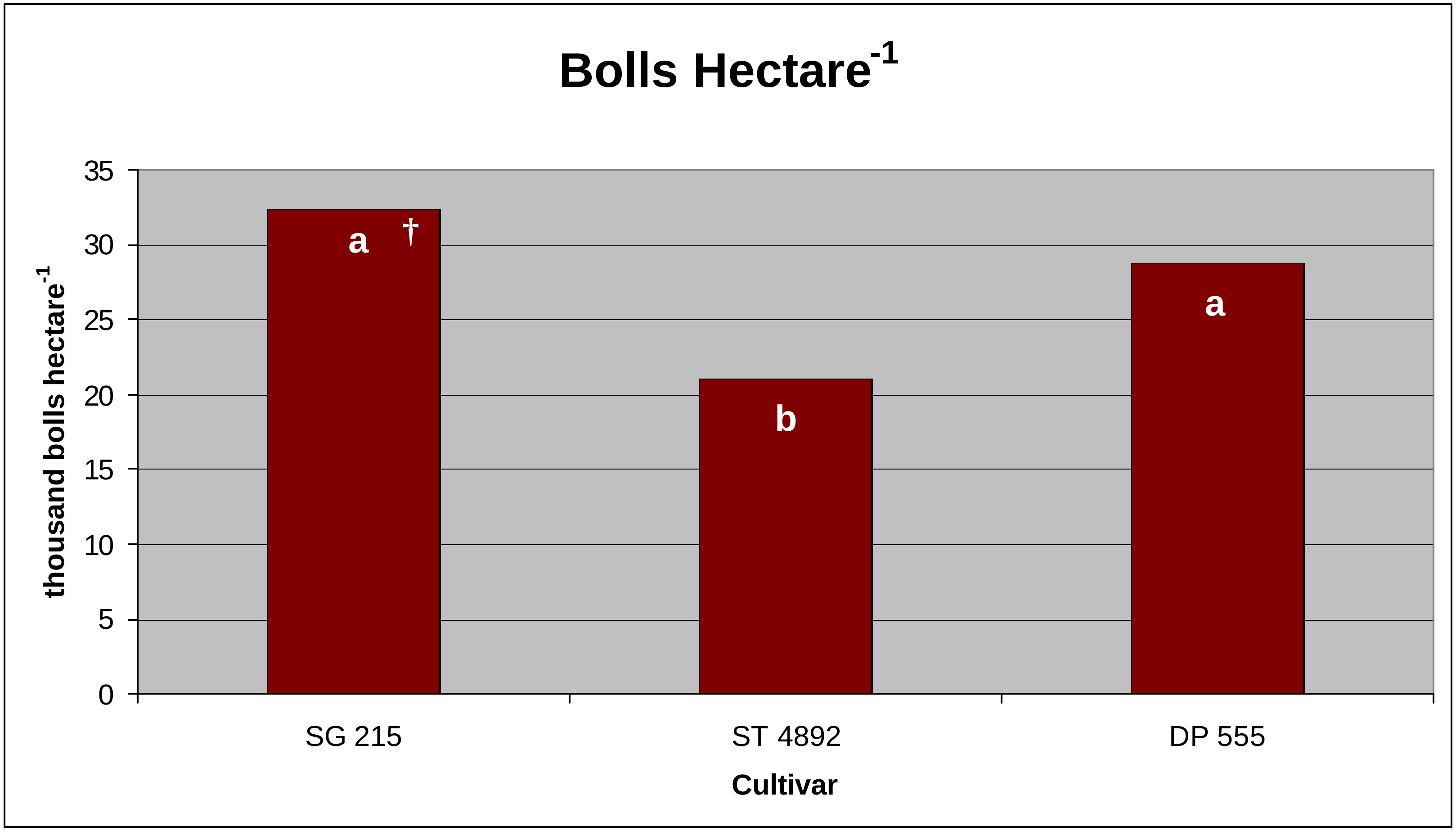

Figure 28. Cultivar effect on number of bolls hectare^{-1}, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

2004

All factors for individual boll data evaluated in 2004 were identical to 2003 with two additional measurements. In 2004, node and fruiting position were recorded for each individual boll to provide a more accurate assessment of location of seedcotton production throughout the plant.

As in 2003, SG 215 again produced bolls with greater seedcotton weight than the other two cultivars in 2004. Also, ginout percentages were similar to the previous year; thus, DP 555 yielded more grams of lint boll^{-1} (Figure 29). If this figure is compared to figure 2 grams of lint boll^{-1} corresponds with kg lint hectare^{-1}.

As indicated from boxmapping, the LPOP treatments contained higher numbers of bolls at more distal fruiting positions from the main stem. For example, 74, 111 and 148 treatments contained around six or seven thousand bolls hectare^{-1} on the second or third position for each plot. The higher density treatments 185 and 222 contained only around three thousand bolls hectare^{-1} on distal positions (Figure 30). This increase of distal boll set allows lower density treatments to compete in overall lint yield.

Boll Data by Node

Individual boll data was also analyzed by fruiting node. A significant interaction between cultivar and fruiting node was present for DPA, AFD, HU and TWT but not WT. Significant differences for WT were noted for seedcotton boll^{-1} between nodal positions (Figure 31). Nodes that were centrally located (nodes 10-12) had a higher mean WT than nodes at the top (node 14) or base (node 6-8) of the plant. All other

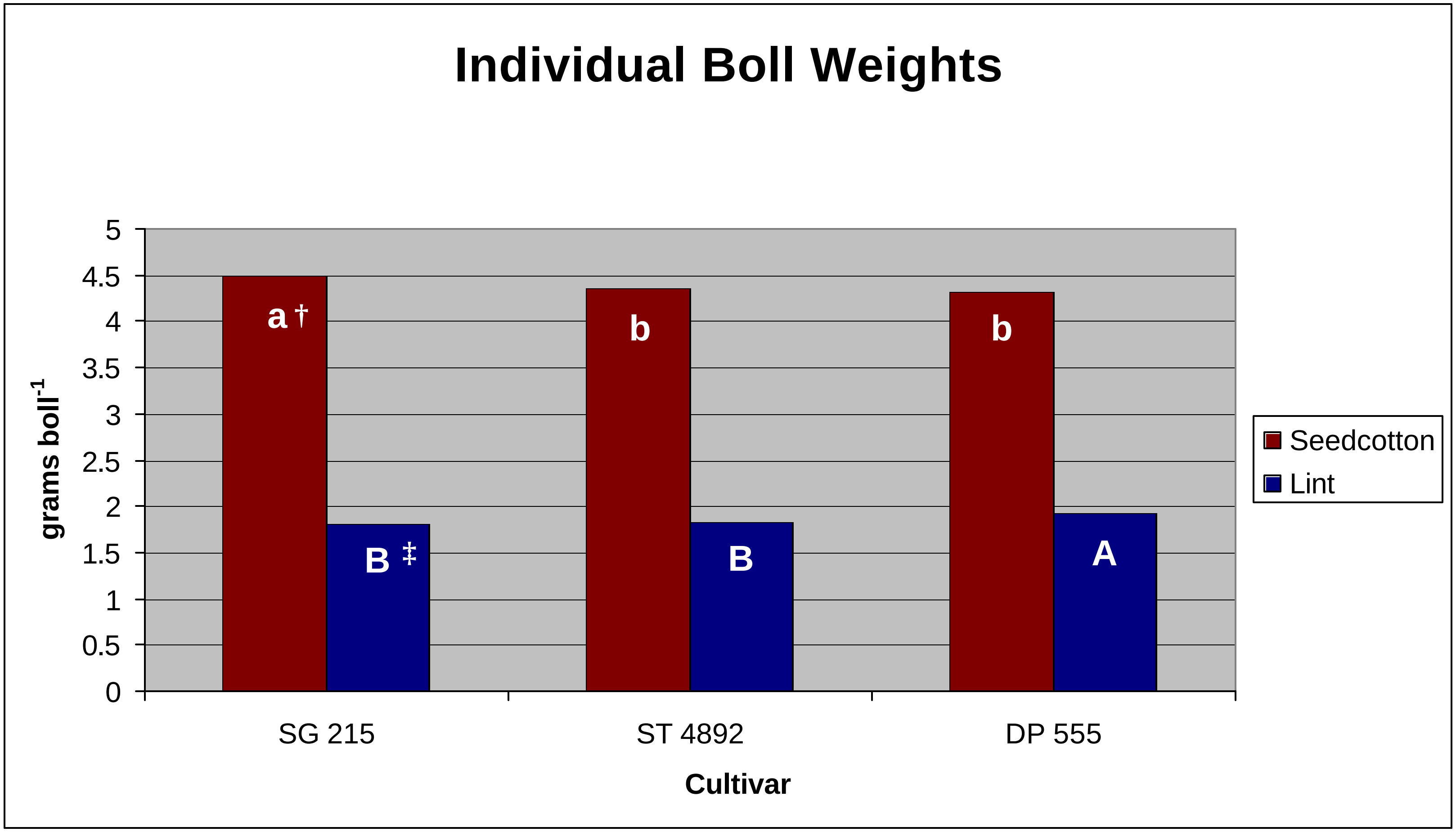

Figure 29. Cultivar effect on seedcotton and lint boll^{-1}, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.
‡Letters of different styles represent a separate statistical analysis.

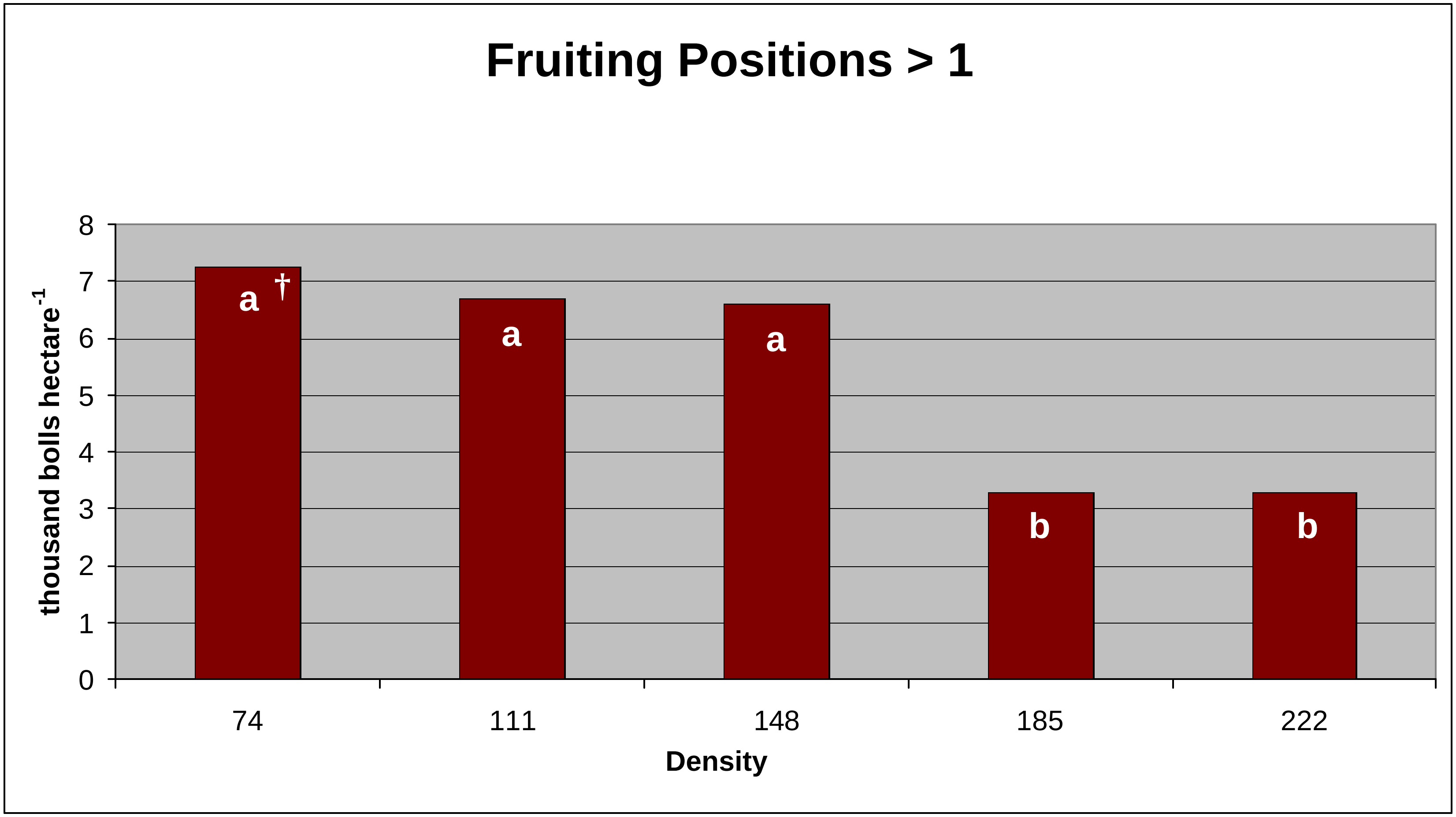

Figure 30. Density effect on number of fruiting positions greater than one, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

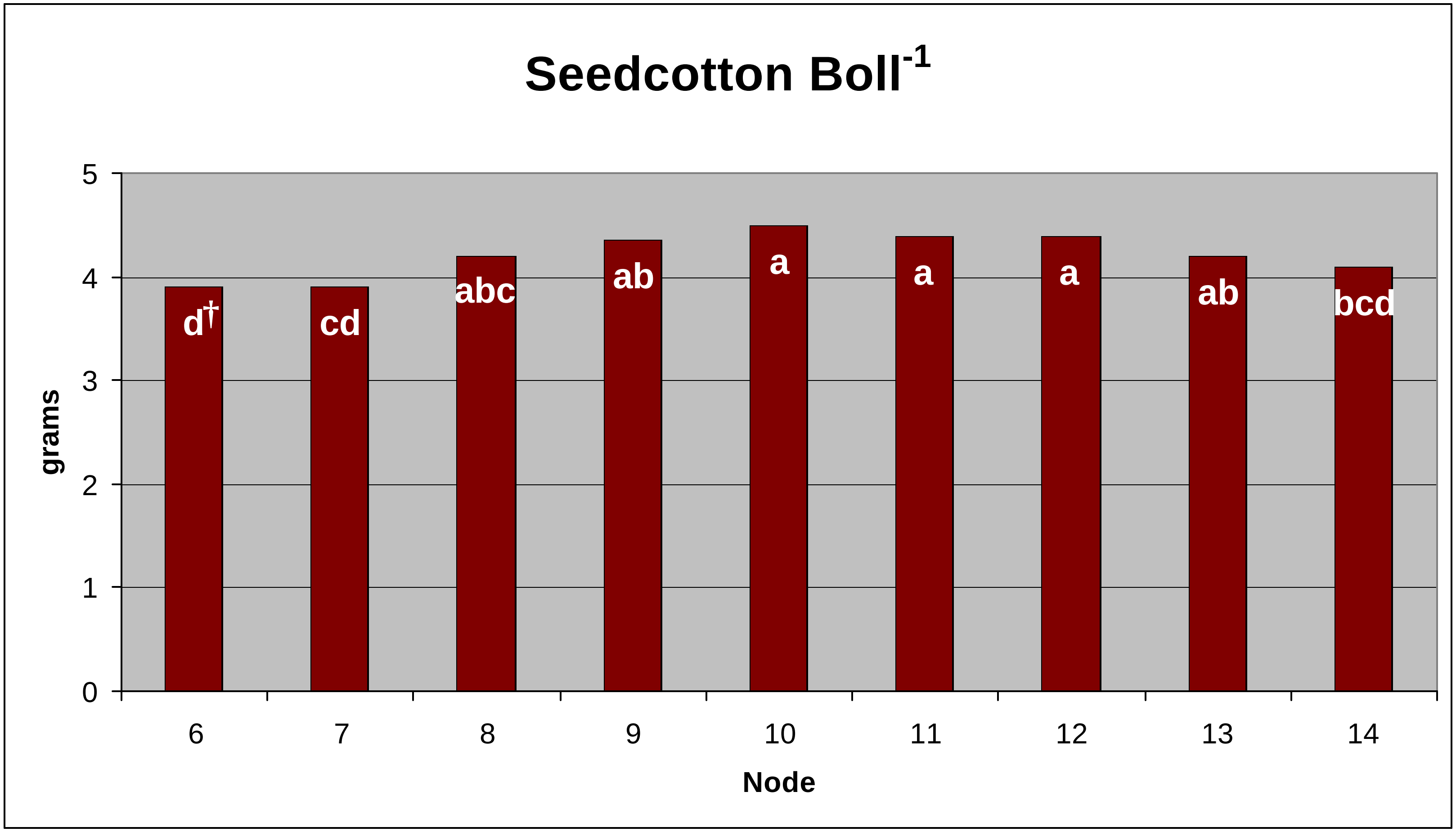

Figure 31. Nodal effect on seedcotton boll^{-1}, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

measurements, including TWT, DPA, HU and AFD possessed interaction between nodal positions and thus were analyzed by individual node. Due to the different cultivar and density responses evaluated, these values were analyzed and discussed for each individual node. These values are listed in table 2 or 3 for density or cultivar treatments, respectively. Within these tables, means can be compared within a specific row, which are labeled by the appropriate nodal position, but not between columns. In addition, cultivar treatments and density treatments were analyzed separately. Because of the importance of HU and TWT to commercial production and the objectives of this study, both of these parameters will be discussed. Node five failed to produce enough bolls to complete a F-test. However, the means are listed to show this node's slight contribution to total yield. Average seedcotton production was statistically identical for all treatments on node six. HU requirement on node six were not different between density treatments. In spite of this, DP 555 (the longer season cultivar) required more heat units, than ST 4892, to produce a harvestable boll. At node seven, 222 produced more seedcotton than 74, 111 or 185. In addition, SG 215 had more seedcotton on node seven than ST 4892, reflecting that it is a faster fruiting cultivar. No differences were noted between HU for any treatment on node seven. At node eight, the 222 treatments produced more seedcotton than the 74 treatments, the two extremes of the density treatments. Nodes eight, nine and ten exhibited no difference between any treatments for HU accumulation. Furthermore, seedcotton production on nodes nine and ten were not affected by either density or cultivar. At node eleven, both HU accumulation and seedcotton production were affected by density and cultivar treatments. First, 222 produced less seedcotton on

Table 2. Density effect on HU and WT for nodal position, 2004.

Node	HU	WT	HU	WT	HU	WT	HU	WT	HU	WT
14	818a§	6A‡	901a	7A	909a	10A	865a	7A	943a	3A
13	909a	13A	904a	6B	926a	10AB	859a	5B	743a	7B
12	928a	14A	944a	17A	921a	12AB	917a	12AB	893a	9B
11	954ab	17AB	952ab	21A	953a	19AB	960a	17AB	927b	11B
10	978a	17A	963a	18A	963a	21A	949a	21AB	952a	20A
9	972a	18A	1005a	18A	996a	24A	993a	20A	994a	21A
8	996a	17B	998a	21AB	959a	20AB	975a	21AB	1007a	28A
7	1004a	9B	1002a	14B	1020a	18AB	999a	13B	1010a	24A
6	993a	8A	1040a	12A	1011a	8A	1016a	8A	989a	13A
5	1088?	6	1025	5	1042	4	724	8	989	3
	74†		111		148		185		222	

† Density treatments.

§ Lowercase letters indicate means analyzed for HU on indicated node (p<0.05).

‡ Capital letters indicate means analyzed for WT on indicated node (p<0.05).

? Insufficient data points for statistical analysis.

Table 3. Cultivar effect on HU and WT for nodal position, 2004.

Node	HU	WT	HU	WT	HU	WT
14	.	.	880a	5a	915a	10a
13	870a§	5a‡	897a	8a	838a	10ab
12	891a	11a	920a	14a	947a	12ab
11	943a	15b	943a	15b	961a	20a
10	946a	19a	964a	15a	974a	21a
9	1006a	25a	968a	17a	1001a	24a
8	997a	27a	979a	23ab	986a	20ab
7	1030a	24a	967a	13b	1023a	18ab
6	1012ab	13a	971a	8a	1064a	8a
5	1004?	5	1006	4	986	4
	SG 215†		ST 4892		DP 555	

† Cultivar treatments.
§ Letters indicate means analyzed for HU on indicated node (p<0.05).
‡ Letters indicate means analyzed for WT on indicated node (p<0.05).
? Insufficient data points for statistical analysis.

.

this node than 111. Plant competition at the higher density tends to lower position of bolls that contribute to yield. However, the 222 required less HU than 185 to produce a harvestable boll. DP 555 produced more seedcotton than ST 4892 and SG 215 on node eleven. This delayed production was expected as DP 555 is a full-season variety and matures later in the season. Neither density nor cultivar responses were expressed for HU accumulation on nodes 12-14. However, on node 12, 111 produced more seedcotton than 222. 74 produced more seedcotton than 222, 185, and 111 on node 13. Neither cultivar nor density treatments were evaluated on node 14.

In conclusion, at the higher nodal positions (12-14) the lower density plants tended to yield more seedcotton than the higher densities. SG 215 produced more seedcotton lower on the plant than DP 555 and ST 4892 (node 7). DP 555 produced more seedcotton higher in the canopy than SG 215 or ST 4892 (node 11)

Last Effective Boll Population (LEBP)

Last effective boll population is defined as the bolls that contribute to yield. These bolls should possess several characteristics including a) a high rate of retention, b) the probability of developing to an adequate size and c) possessing acceptable lint quality. This population is determined by setting an arbitrary value to which additional gain in yield is insignificant. For this study, all nodes that contributed to yield, up to 95% of the total, were considered significant. Nodes contributing significant percentages of seedcotton were similar for each treatment (both density and cultivare) (Figure 32). However, these values indicated significant contributions to seedcotton yield within the top five nodes of the plant. These data contradict previously accepted LEBP values

(NAWF = 5) (Bourland et al., 1992; Oosterhuis et al., 1999). The percentages of seedcotton set up to this traditional cutout period equaled around 60% of the total seedcotton production. Data from the present study indicated that two nodes above white flower would more accurately reflect cutout as approximately 30% of the total seedcotton yield was produced after the designation of cutout at NAWF=5. The percentages for lint yield produced on each individual node for each cultivar show that the full-season cultivar DP 555 produced a higher percentage of its lint at higher nodes in the canopy than did SG 215 or ST 4892 (Figure 33). Conversely, SG 215 produced superior seedcotton yields at lower nodal positions on the plant than did the other two cultivars. Distribution of seedcotton yield for each node showed similar results when evaluated by density treatments (Figure 34). A higher percentage of seedcotton was produced on the middle nodes of the plant compared to the extremities. At LPOP a higher percent of seedcotton yield was found on nodes higher in the plant whereas HPOP produced more seedcotton on lower positions (Table 4). The average for percent seedcotton by node of all treatments for 2004 contradicts that previously accepted for the LEBP which indicates NAWF = 5 as physiological maturity or when the bolls that are present represent 95% of the yield (Bourland et al., 1992; Oosterhuis et al., 1999). Furthermore, results indicated higher percentages of seedcotton within the top three nodes of the plant in our study. For example, in 2004 as much as 35% of seedcotton production was located on the nodes that were 2 and 5 nodes below the terminal (Figure 32). This difference in effective lint production could be due to several factors, including end of season weather, geographical location, and bollweevil eradication.

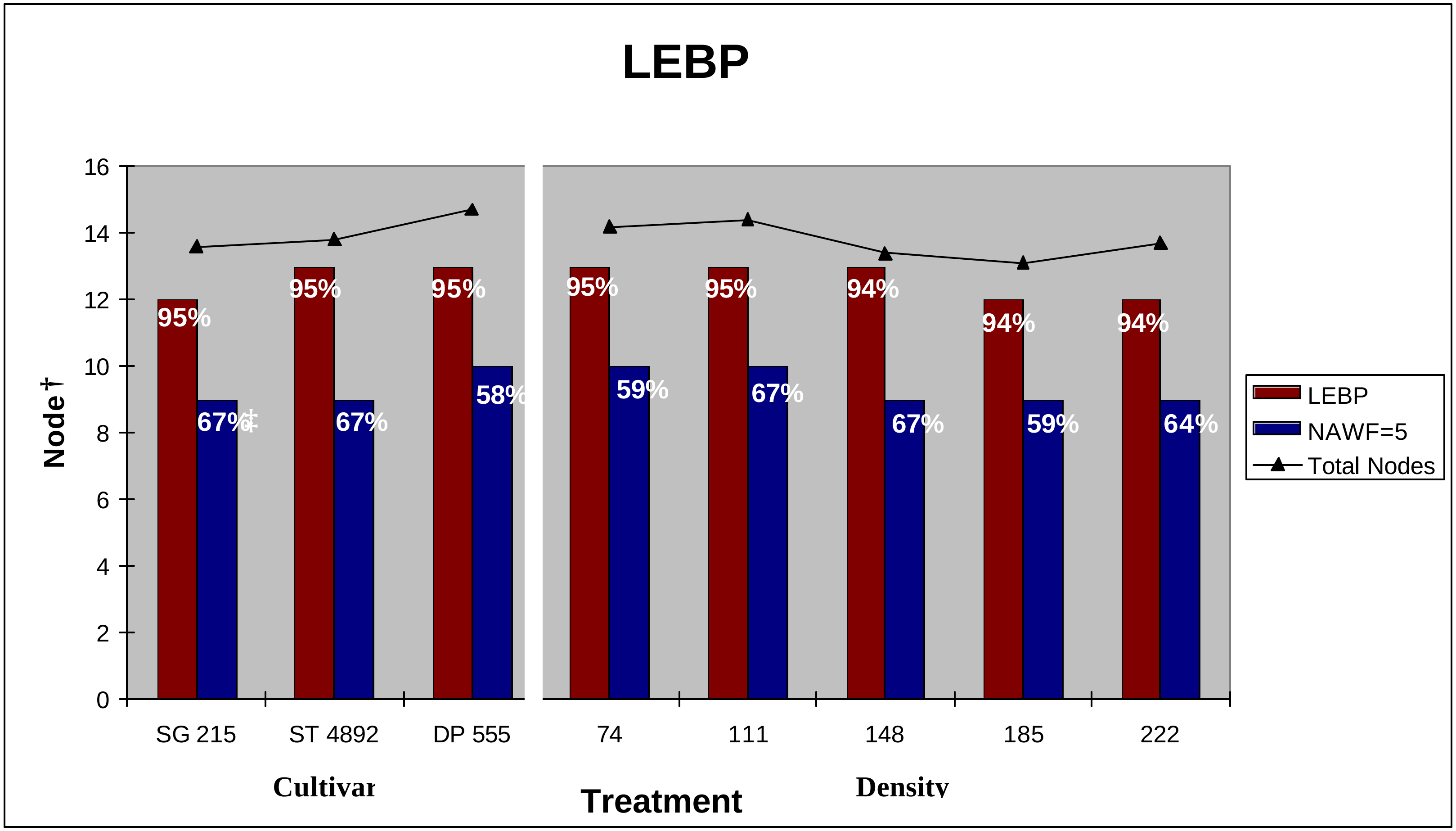

Figure 32. Cultivar and density effect on LEBP, 2004.

† Nodal position for LEBP at 95% of yield.
‡ Percent of total lint production present at physiological cutout (NAWF=5); ? Mean total nodes for each treatment.

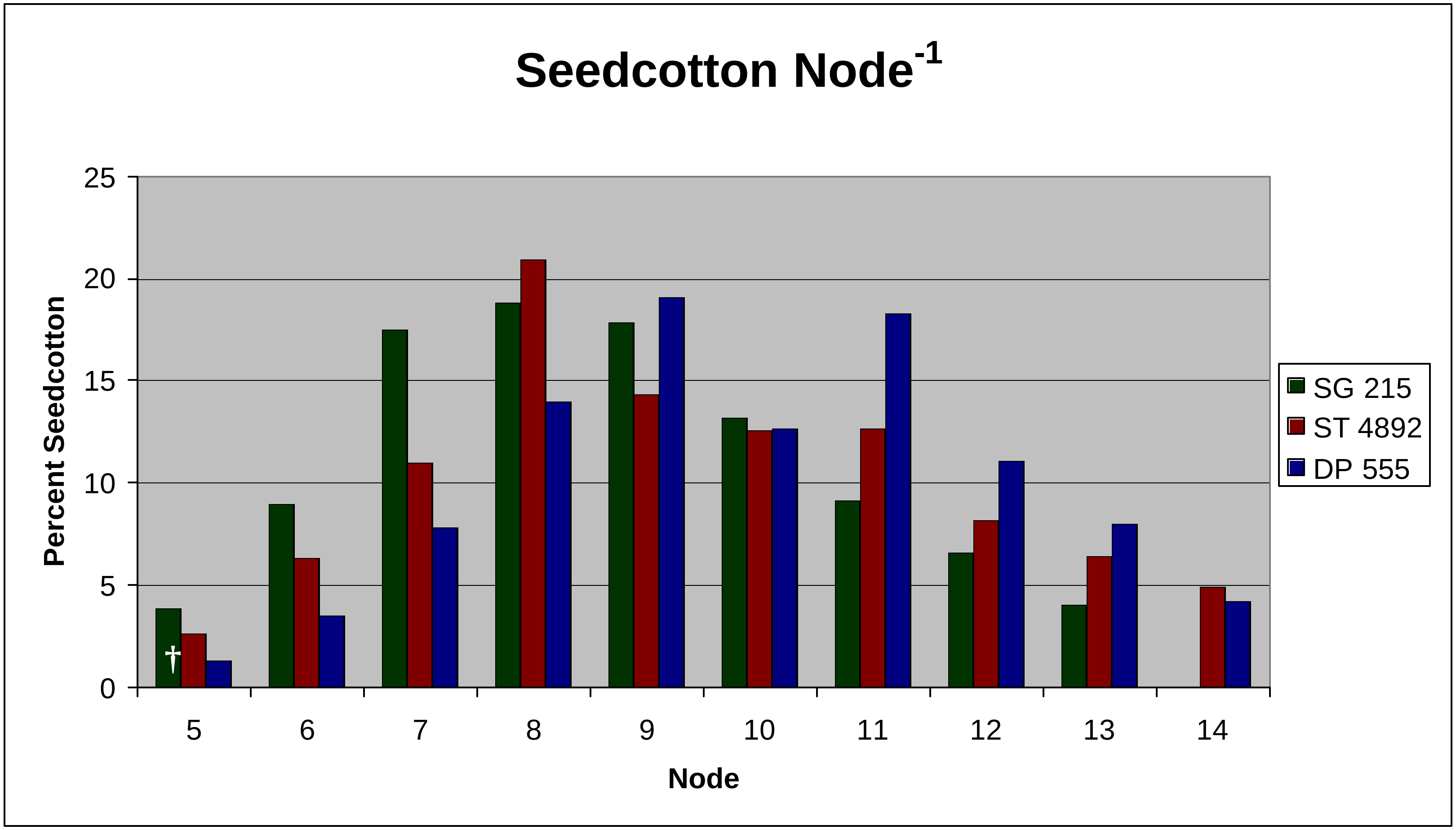

Figure 33. Cultivar effect on the percent of seedcotton node^{-1}, 2004.

†Means between columns indicate different cultivars.

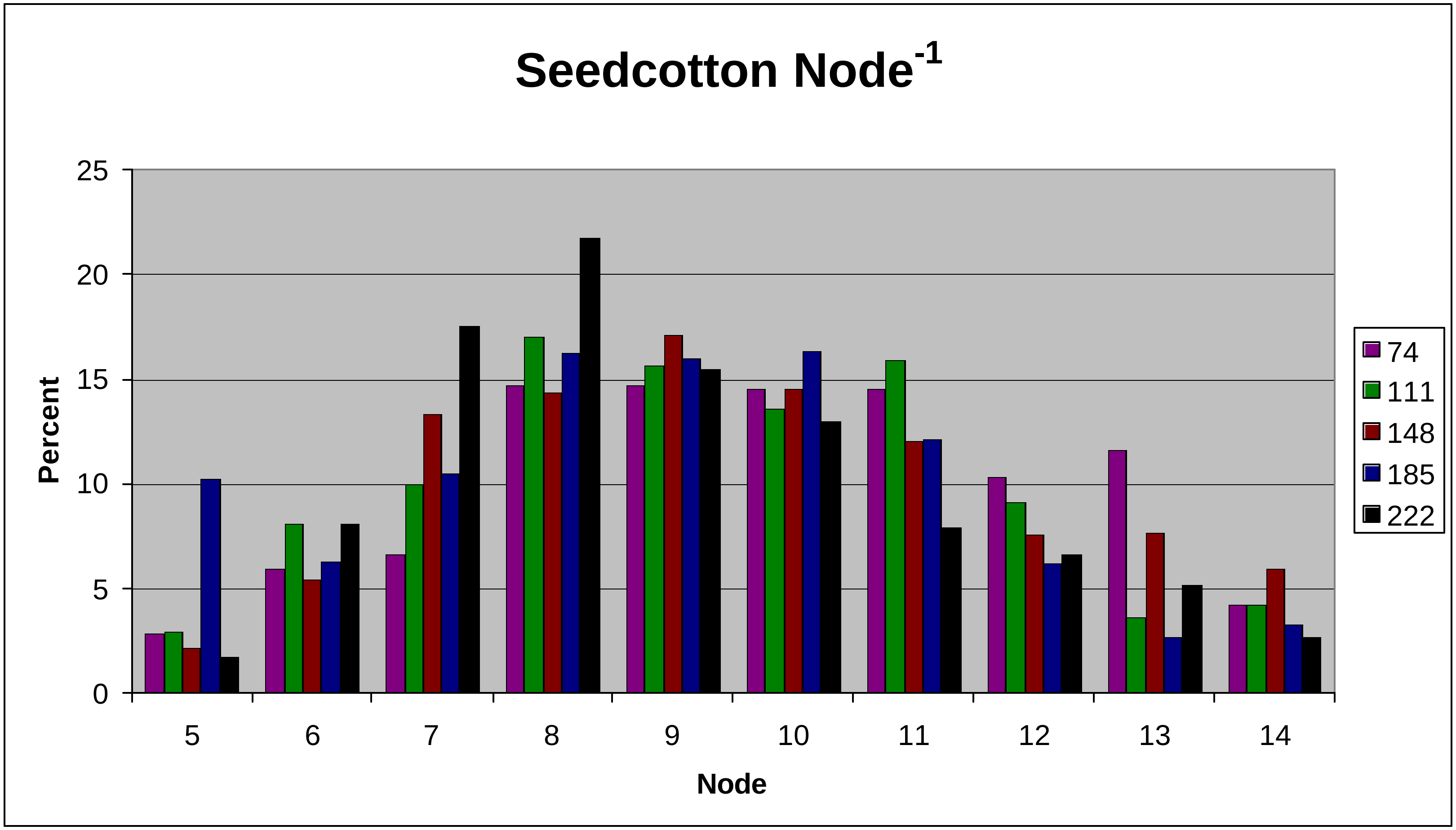

Figure 34. Density effect on seedcotton node^{-1}, 2004.

†Means between columns with different letters are significantly different at P<0.05 according to Fisher's protected LSD.

Table 4. Treatment effect on percent of total seedcotton weight for nodal position, 2004.

Node	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	**Percent**
14	.	4.9	4.2	4.1	4.2	5.9	3.2	2.6	**3.9**
13	4	6.4	7.9	11.6	3.5	7.6	2.9	5.1	**6.7**§
12	6.6	8.1	11	10.3	9	7.5	6.2	6.6	**7.65**§
11	9.1	12.6	18.3	14.5	15.9	12	12.1	7.9	**11.6**
10	13.1	12.5	12.6	14.5	13.5	14.5	16.3	13	**14.5**
9	18.8	14.3	19	14.6	15.6	17	16	15.4	**15.7**
8	18.8	20.9	13.9	14.6	16.9	14.3	16.2	21.7	**16.7**
7	17.5	11	7.8	6.6	9.9	13.3	10.5	17	**11.8**
6	8.9	6.3	3.5	5.9	8	5.4	6.3	8	**6.4**
5	3.8	2.3	1.3	2.8	3	2.1	10.3	1.7	**4.2**
	SG 215‡	ST 4892	DP 555	74†	111	148	185	222	**Average**

‡ Cultivar treatments.
† Density treatments.
§ Average nodal position for LEBP.

Also, insect control other than bollweevil or the use of biotechnology could potentially change the cotton plant's ability to produce lint in the upper portion of the plant.

Economic Significance

The 2004 Commodity Credit Corporation (CCC) Loan Schedule was used to make an economic comparison of the yield obtained from the different treatments for 2003 and 2004. These values are discussed separately by year due to year by treatment interaction. In 2003, although lint quality at different densities exhibited no statistical differences, the discounts received from high micronaire values negated any savings from reduced seed cost. The net return hectare^{-1}, which took into consideration the seed and technology cost for each density, was similar for all densities in 2003 (Figure 35). In 2004, the 74 treatments returned the most dollars hectare^{-1}. The remaining density treatments revealed small differences in economic yield despite drastically different seed prices (Figure 36). These values suggest that producers may benefit from reduced planting rates. Cultivar utilized also affected monetary return (Figure 37 and 38). With a greater return for DP 555 in both 2003 and 2004 despite a higher seed and technology cost than the other two cultivars.

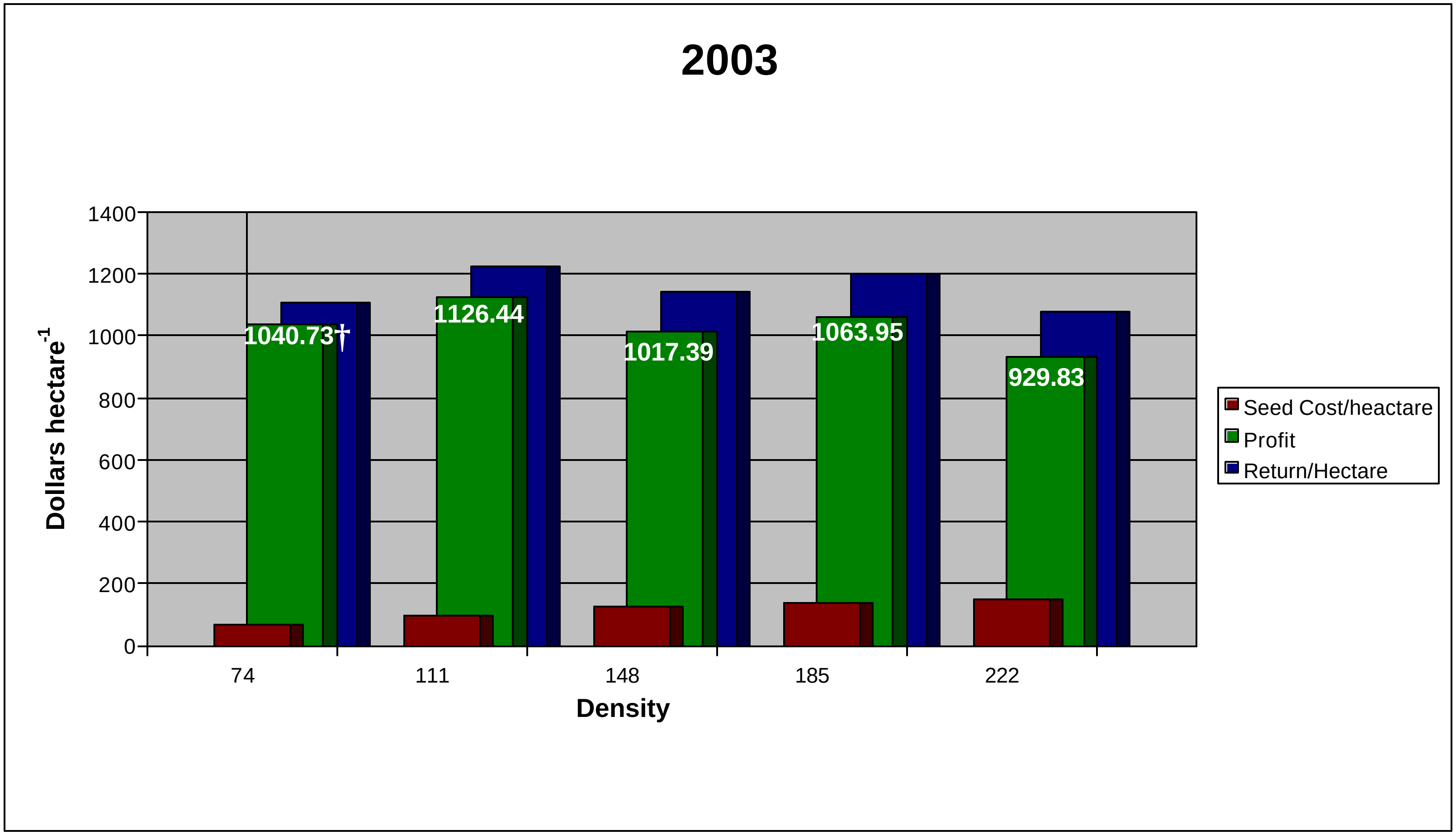

Figure 35. Density effect on financial return hectare^{-1}, 2003.

†Financial return hectare^{-1} (2004 Commodity Credit Corporation (CCC) Loan Schedule for Upland and Extra-Long Staple (ELS) Cotton)

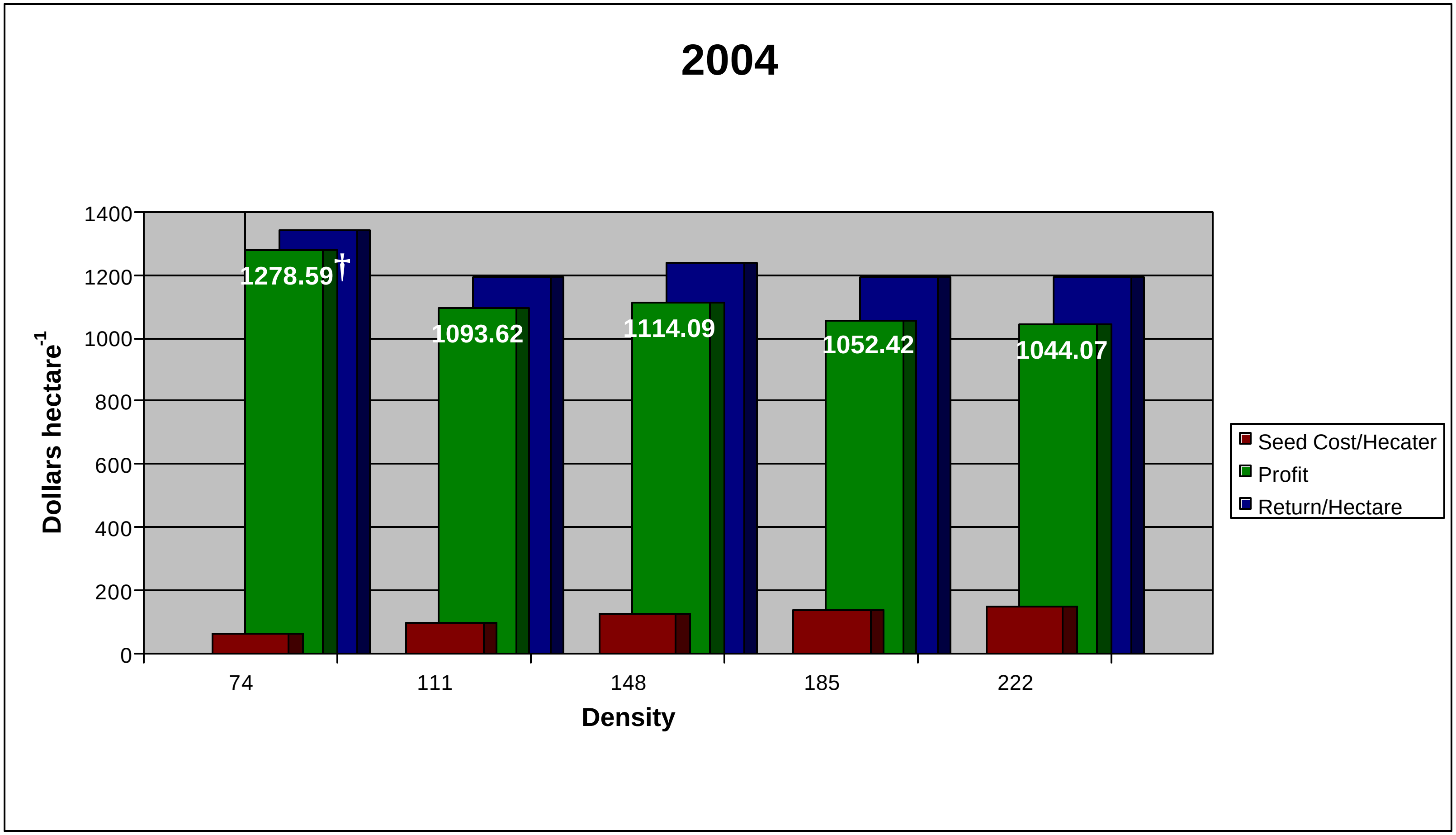

Figure 36. Density effect on financial return hectare^{-1}, 2004.

†Financial return hectare^{-1} (2004 CCC Loan Schedule for Upland and ELS Cotton)

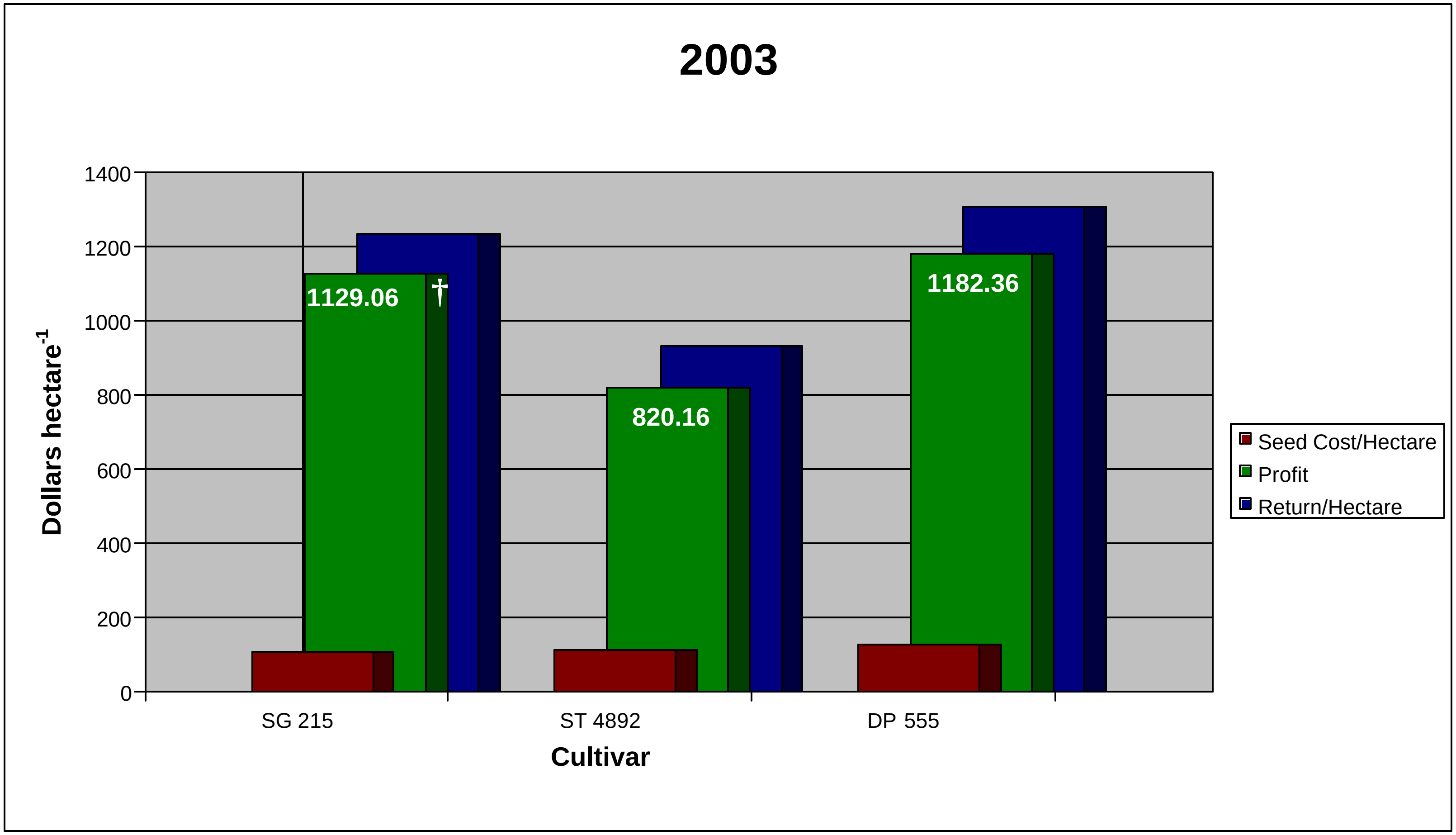

Figure 37. Cultivar effect on financial return hectare^{-1}, 2003.

†Financial return hectare^{-1} (2004 CCC Loan Schedule for Upland and ELS Cotton)

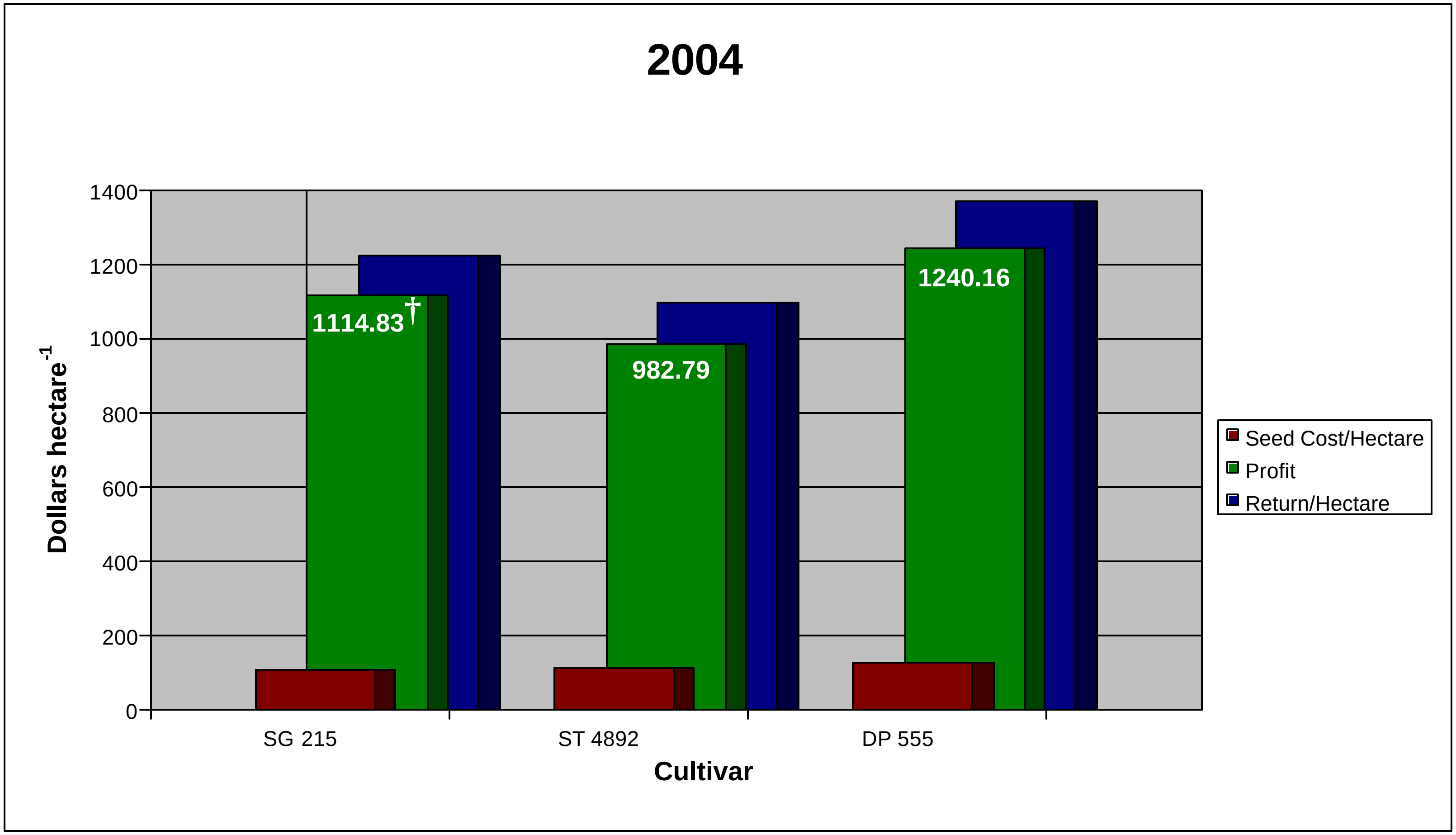

Figure 38. Cultivar effect on financial return hectare^{-1}.

†Financial return hectare^{-1} (2004 CCC Loan Schedule for Upland and ELS Cotton)

CONCLUSIONS

Due to the high costs associated with technology fees and transgenic cultivars, management decisions pertaining to seeding densities will continue to be important to cotton producers. Data from this study, indicated that altering plant densities, from 74 to 222 thousand plants hectare^{-1}, did not affect lint yield. Observations in this evaluation included biomass evaluations, box mapping and yield data pertaining to individual nodes. The LPOP treatments produced increased values for LA and leaf weight, as well as increased fruit set, throughout the growing season. In addition, box mapping data revealed that the LPOP treatments produced more seedcotton plant^{-1}. Box mapping indicated that HPOP detrimentally affect seedcotton production at distal fruiting positions. Individual boll data reinforced these findings. Higher boll retention was present at fruiting positions greater than one for LPOP treatments. However, these data also revealed that even though the LPOP maintained higher numbers of bolls plant^{-1}, HPOP compensated for fewer bolls plant^{-1} through the increased number of plants for a given area.

Fiber quality was not significantly affected by plant density. However, micronaire values in 2003 were higher than 2004. The increase in micronaire was great enough that 74 and 111 treatments received a monetary discount.

The LEBP was affected by plant density, but the results were varied and no definitive conclusions could be drawn between densities. However, these results suggest that the previously designated arbitrary value of NAWF=5 for physiological cutout may be inappropriate for some production schemes. Significant lint yield was located at nodes above this value across all density and cultivar treatments. This data indicated that cutout could be skewed, to higher nodal positions, across locations and cultivars, or different for an early maturing cultivars.

Cultivar responses evaluated at the beginning of the season affected lint yield at harvest differently than the above results. For example, ST 4892 possessed a significantly lower square retention and LA than the other two cultivars during early season biomass readings. As a result, this cultivar produced the least amount of lint for 2003 and 2004. Similar to density treatments, each cultivar produced comparable LEBP results. For SG 215, 95 percent of the total seedcotton produced was obtained by node 11 whereas ST 4892 and DP 555 both reached this stage at node 12. With SG 215 producing only 13 nodes and ST 4892 and DP 555 producing only 14 nodes a significant amount of yield was produced two or three nodes from the terminal. This indicates that further consideration should be given to upper nodal positions and their effect on total lint yield.

A brief economic analysis was conducted to determine the effect of seed cost and technology fees on monetary return to the producer. Density effects were different for each year of the study with 111 possessing the highest economic return in 2003 and 74 in 2004. However when comparing cultivar treatments, DP 555 returned more to the producer in both 2003 and 2004 than ST 4892 and SG 215.

In conclusion, plant density did not significantly affect lint yield in either year of this 2-year study as a similar number of bolls was produced per unit area due to the compensatory nature of cotton. Producers may consider reducing seeding rates to save input costs, but the risks of early season injury and poor germination must also be considered before making this decision. Additional studies over location and cultivars are needed to substantiate these results.

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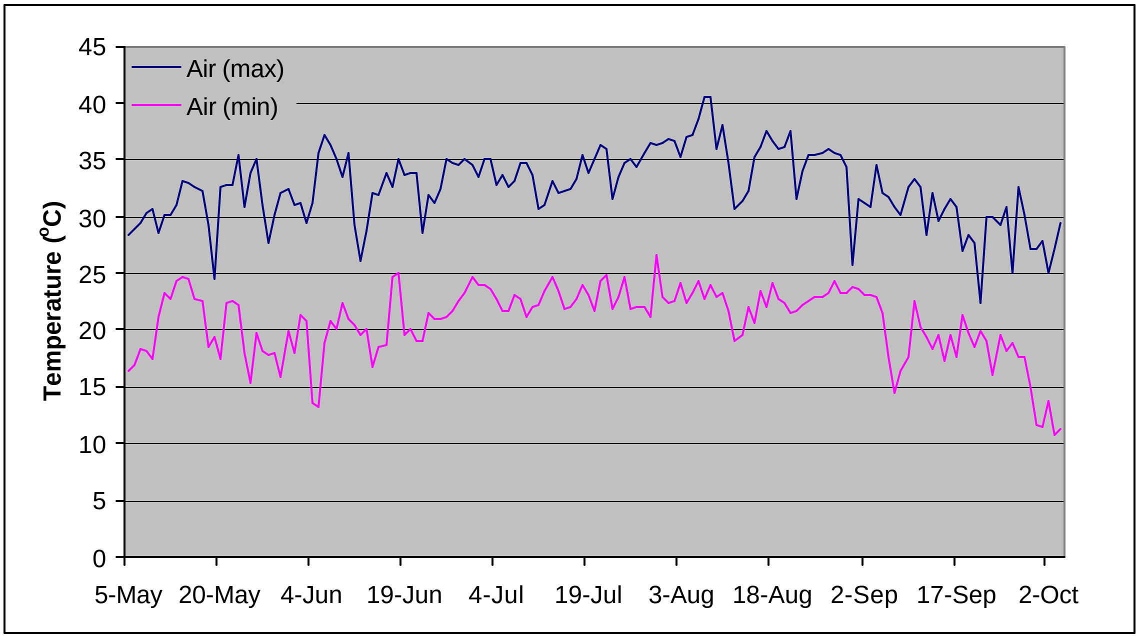
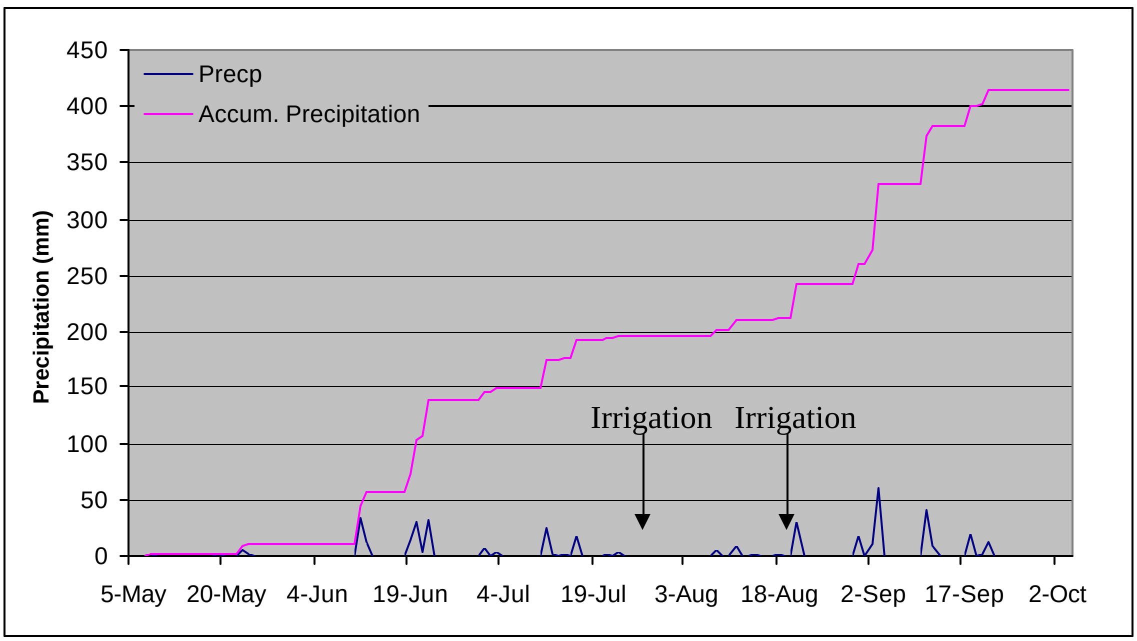
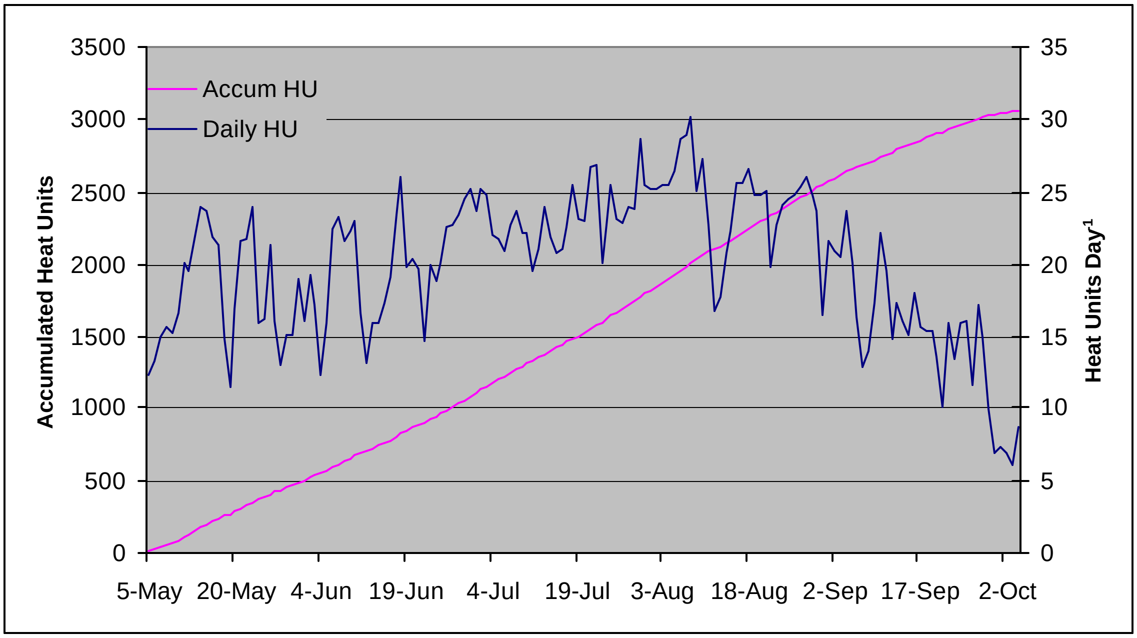
APPENDIX A

2003 Weather Data – Burleson County, TX







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Daily HU
Accumulated Heat Units
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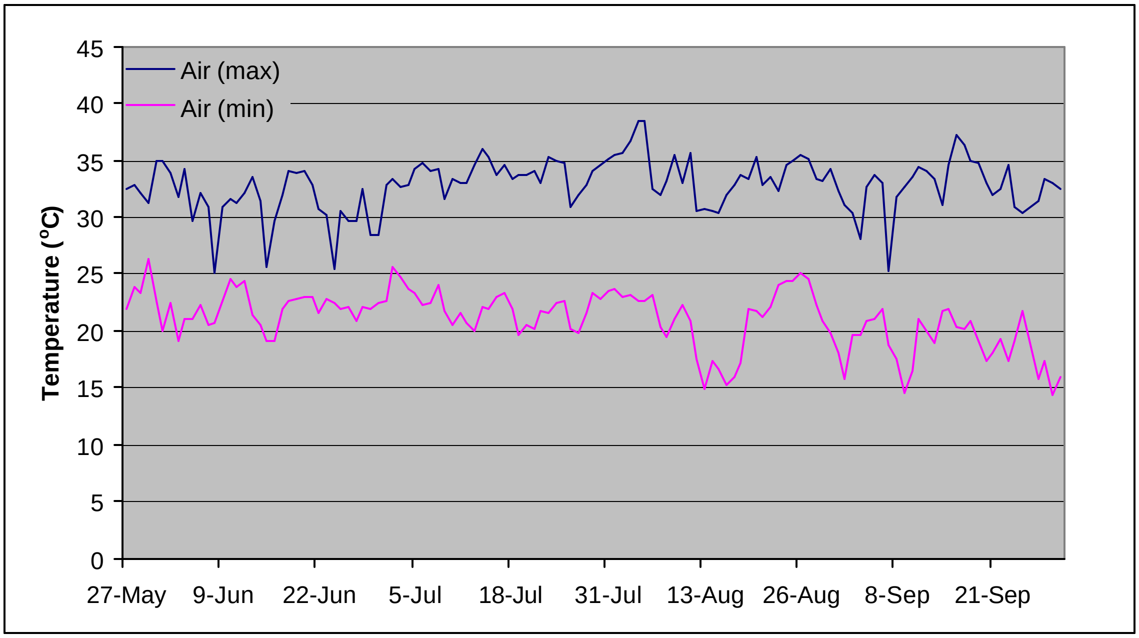
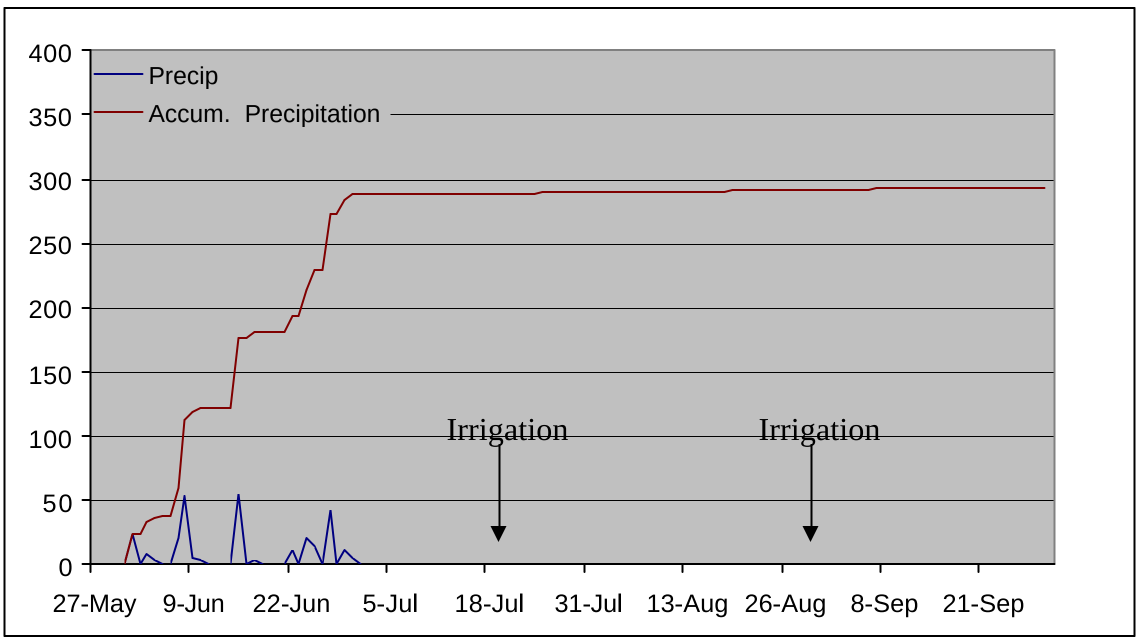
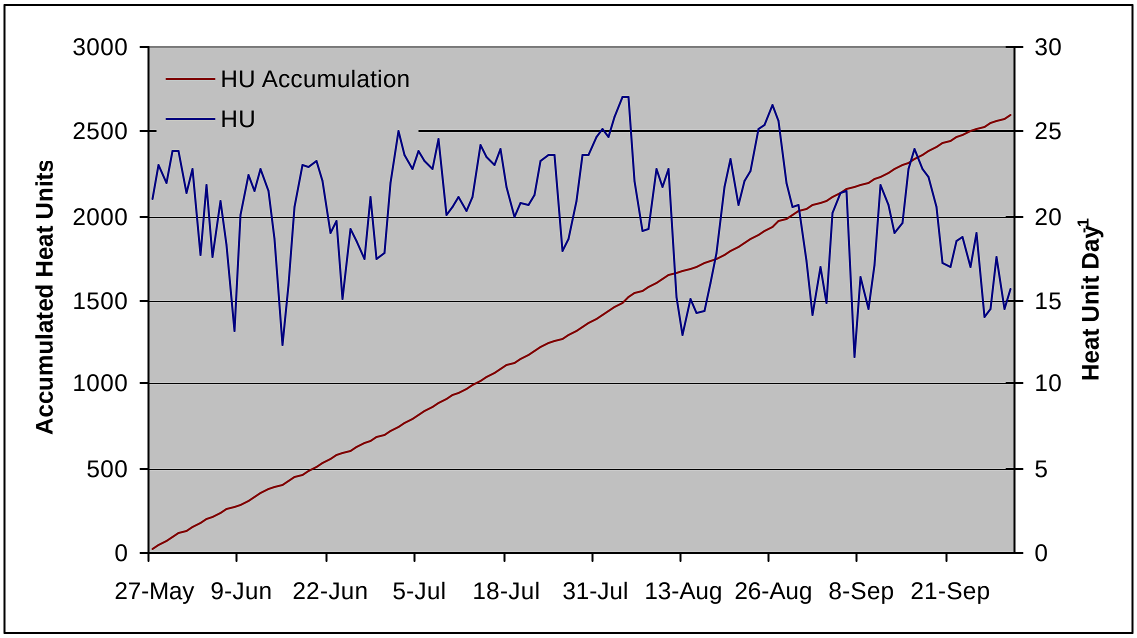
5-May
20-May
4-Jun
19-Jun
4-Jul
19-Jul
3-Aug
18-Aug
2-Sep
17-Sep
2-Oct

APPENDIX B

2004 Weather Data – Burleson County, TX







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Accumulated Heat Units
Heat Unit Day-1
27-May
9-Jun
22-Jun
5-Jul
18-Jul
31-Jul
13-Aug
26-Aug
8-Sep
21-Sep

APPENDIX C

CROP PRODUCTION PRODUCTS USED IN

THE BRAZOS BOTTOMS 2003-2004

The following products were used at the rates indicated for weeds and pests indicated.

Preplant

Broadleaf weeds (primarily *Amaranthus sp.*) and annual grasses	Treflan® 4EC - trifluralin: 1.86 L ha^{-1} a,a,a-trifluoro-2,6-dinitro-*N*,*N*-diprophyl-*p*-tolidine

Early Season

Thrips (*Thrips tabaci*)	Temik® 15G – aldicarb: 5.61 kg ha^{-1} [2-methyl-2-(methylthio)propionaldehyde0-(methylcarbamoyl)]
	Bidrin® 8 – dicrotoghos: 0.29 L ha^{-1} Dimethyl phosphate of 3-hydroxy-*N*,*N*-dimethyl-*cis*-crotonamide
Broadleaf weeds (*Ipomea sp.*)	Roundup Weathermax® - glyphosate: 1.61 L ha^{-1} N(phosphonomethyl)glycine, potassium salt form

Mid- to Late Season

Cotton Bollworm (*Heliothis zea*)	Capture® 2EC - bifenthrin: 0.30 L ha^{-1} (2 methyl[1,1'-biphenyl]-3-yl)methyl 3-(2-chloro-3,3,3-trigluoro-1-propenyl-2,2-dimethylcyclopropanecarboxylate
Boll Weevil	Fyfanon® - malathion: 0.87 ha^{-1} O,O-dimethyl phosphorodithioate of diethyl mercaptosuccinate

Plant Growth Regulator	Pix® - mepiquat chloride: 0.58 L ha^{-1} N,N-dimethylpiperidinium chloride
Harvest Aids	Dropp® 50WP – thiadiazuron: 0.11 kg ha^{-1} N-phenyl-N'-1,2,3-thiadiazol-5-ylurea Def® 6 - tribulos: 0.58 L ha^{-1} and 0.94 L ha^{-1} *S,S,S*-tributyl phosphorotrithioate Prep® - ethephon: 0.58 L ha^{-1} (2-choloroethyl) phosphonic acid

VITA

Shane William Halfmann, son of William and Nancy Halfmann, was born on June 4, 1980 in San Angelo, Texas. Shane grew up on the family farm and ranch in Runnels and Concho Counties. He graduated from Ballinger High School in 1998 and enrolled at Angelo State University in San Angelo, Texas, planning to obtain a degree while continuing to assist with the family business. A year later he transferred to Texas A&M University in College Station, Texas, where he received a B.S. degree in Agronomy in December of 2002. He began work on his master's degree in cotton physiology the following semester and completed his requirements for graduation in May of 2005. His permanent address is 2618 Fm 383, Norton, TX, 76865.