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Evaluation of Hybrids, Planting Dates, and Planting Densities on Corn Growth and Yield under Rainfed Systems in Mississippi

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Evaluation of hybrids, planting dates, and planting densities on corn growth and yield under rainfed systems in Mississippi

By

Matthew W. Hock

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Evaluation of hybrids, planting dates, and planting densities on corn growth and yield under rainfed systems in Mississippi

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Improved hybrid genetics and more efficient farming techniques have increased corn (*Zea mays* L.) production and grain yields for Mid-South farmers. Early planting is one technique to mitigate heat and drought stress that negatively influence grain production. The first objective was: a) determine the effect of early planting on grain yield, b) to determine the effects on physiological characteristics and c) determine if some hybrids are better suited for early planting. Data suggest there were yield advantages for early planted treatments. Starkville 2014 yields exhibited the greatest reduction of .80 Mg ha^{-1} for each week that planting was delayed. A second objective was: a) determine optimum plant density when planting early, b) determine population effects on physiological characteristics, and c) determine hybrid responses. Hybrids were evaluated at seeding rates ranging from 49,400 to 98,800 plants ha$_{-1}$. Corn grain yield was maximized at 86, 450 to 98,800 plants ha^{-1}.

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DEDICATION

The driving force behind my decision to pursue a graduate degree was to strengthen my knowledge of crop science and learn the skills necessary to convey that knowledge, in a practical format, to farmers and agriculturists. It is my hope that the contents of this thesis may help at least one farmer or serves as a strong foundation for future investigations. It is for these reasons; I dedicate this work to all farmers.

ACKNOWLEDGEMENTS

First and foremost, thank you to my wife Gaea for your constant support during my graduate degree work. Thank you to my family for supporting my decision to pursue a graduate degree at Mississippi State University. Also, thank you Mississippi farmers, Mississippi Corn Promotion Board, and Mississippi Agricultural and Forestry Experiment Station for funding my research. The project would not have been possible without your support. Thank you to Starkville farm crew, Brooksville farm crew, and the Verona research station members for assistance during experimental site preparation. I appreciate Mississippi State University for providing the facilities to conduct the research. A special thanks to Dr. Brien Henry for providing support and insight during planning and initiation of the experiments. In addition, I am very appreciative to my committee members Drs. Jac Varco, Raja Reddy, and Matt Griffin. Only through their expertise, knowledge and guidance was this research possible. Thanks also to Drs. Rocky Lemus, Brian Baldwin, and Mike Phillips for providing additional advice and support in my research. Undergraduate assistants played an integral role in the day-to-day operations and data collection of my research projects. Special thanks to Tre Smith, Ken Hearn, and Jordan Clark for your assistance, it was a real pleasure to work alongside you. Additionally, I would like to thank my fellow graduate students Patton Slusher, Michael Natress, Johnny Richwine, Jesse Morrison, Judson Lecompte, and Spencer Smith for their support with my project and friendship during my graduate work.

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CHAPTER I

EVALUATION OF HYBRIDS AND PLANTING DATES ON CORN GROWTH AND YIELD UNDER RAINFED SYSTEMS IN MISSISSIPPI

Introduction

Corn yields are heavily influenced by moisture availability throughout the growing season. All cereal crops require water to produce grain, but corn is more sensitive than other crops about the time at which this moisture is received (Nielsen et al., 2010, Nielsen et al., 2009, Ma et al., 2012). These studies outline the critical period for corn production during which moisture must be present to ensure optimum yields. The most critical stage in corn development is a two to three week window around tasseling (Shaw and Newman, 2013).

Unlike producers in the Great Plains (Nielsen et al., 2009), Mid-South corn producers typically begin the year with soil moisture at nearly optimum field capacity. Therefore, assuming adequate fertility and weed control, water availability during the reproductive phase will greatly impact grain yield. Other abiotic stresses such as heat that occur during the critical precipitation window will exacerbate drought stress further depressing grain yield. The greatest yield reduction occurs if moisture stress coincides with the R1 growth phase (silking). Stress during R1-VT interrupts the pollen shed window, decreasing the probability of successful pollen/silk nicking (simultaneous pollen release and silk emergence) (Shaw and Newman, 2013).

Therefore, moisture received during corn's critical precipitation window will largely contribute to explaining yield variability. Consequently, widespread drought adversely influenced corn production throughout the United States in 2012. The challenge then becomes matching plant populations with water availability during corn's reproductive phase in order to optimize grain yields.

The environment greatly influences corn growth and development. However, producers can manipulate several factors affecting corn yield such as hybrid selection, population density, fertility, and weed management. There is less control in alleviating heat and drought stress. This is especially true for producers who rely on rainfall alone to supply needed moisture for crop development. Appropriate management practices allow producers to mitigate potential environmental stressors.

Producers are unable to control weather, but they can shift planting dates forward to help avoid late season heat and drought stress. Shifting planting dates forward increases the likelihood of receiving timely rainfall during corn's critical precipitation window (Wijewardana et al., 2015). Shifting the reproductive phase of corn growth forward into May or early-June will increase the probability of corn tasseling during historically cooler and wetter portions of the growing season.

Lack of moisture during the silking stage causes dehydration of the silks and hastens pollen shed causing plants to miss the pollination window (Darby and Lauer, 2006).Stresses during pollination specifically moisture and heat reduce yield and grain quality. Understanding moisture requirements for specific corn development stages helps producers make better management decisions. Darby and Lauer (2006) documented a 7% yield reduction per day attributed to moisture deficiencies during silking. For that reason, solutions to limit stress, especially during the critical precipitation window are needed to stabilize and increase corn production.

Planting Date

Efforts are constantly being made to increase corn grain yields. Historically, increases in corn grain yield have been accomplished by adopting new genetic varieties and improved crop management practices or a combination of the two (Duvick, 2005). Early planting is one management strategy that many Midwestern producers have used to lengthen their growing season and help reduce the risk of a fall freeze that could potentially harm immature crops (Kucharik, 2008). Extending the growing season has several benefits for producers.

Unlike Mississippi, some regions are limited to a shorter growing season, which limits the relative maturity group of corn hybrids available. In order to plant later maturing, higher yielding, hybrids producers shift planting dates forward to extend the growing season providing these long season hybrids enough time to reach maturity. Shifting planting forward also ensures corn more time to dry down naturally in the field, which reduces elevator drying expenses following harvest. Additionally, planting earlier may also shift the silking and tasseling phase forward allowing pollination to occur under more favorable conditions with better chances of adequate soil moisture and cooler air temperatures (Kucharik, 2008).

Early planting is an inexpensive management practice that can help producers optimize their production operation. Planting earlier reduces the risk of exposure to heat and drought, but increases the risk of wet soils and cold temperatures. However, today’s corn hybrids have greater tolerance to withstand cooler, wetter soil conditions (Kucharik, 2008). Improvements in corn genetics have resulted in hybrids that are more tolerant to environmental stresses such as temperature and moisture extremes. The challenge is to develop region-specific management practices such as planting date, row width, and planting density for the new and improved hybrids to increase grain yields (Duvick and Cassman, 1999).

Climate, season length, and geography are considered to determine optimum planting dates for corn (Bruns, 2003). Corn in the Mississippi Delta and the central region of Mississippi is typically planted between 15 March and 20 April (MSU Cares, 2013). Schneider and Gupta (1985) found that soil temperature plays a major role in corn germination and seedling emergence. Producers use soil temperatures to determine planting initiation. MSU cares (2013) suggests soil temperatures reach 10 to 13°C before planting.

Planting corn too early can result in delayed germination. Shaw (1977) explains that if seeds imbibe water at too low of temperatures and remain in the soil for long periods of time prior to emergence they are more likely to encounter destructive microbes that cause poor seedling development. Consequently, this leads to reduced plant stands, uneven emergence, and slow plant development (Gupta et al., 1988; Ford and Hicks, 1992; Bollero et al., 1996). Because the overall stress tolerance and germination at cool temperatures of newly available commercial corn hybrids has steadily improved over the past 5 to 10 years (Lloyd pers. Comm., 2012), it is likely that reduced seedling vigor, uneven germination and emergence are less of a problem following early planting.

Early season insect control for delayed seed emergence is also now commercially available for producers. Protection is provided in the form of a seed-treatment.

Insecticides applied directly to seeds help control early season soil insects (Andersch and Schwarz, 2003). Clothianidin, applied at a 0.25 mg a.i. seed^{-1} rate, controls early season soil insects, including wireworm (*Melanotus* spp.), black cutworm [*Agrostis ypsilon* (*Agrostis ipsilon*)], seed corn maggot and white grubs [*Lachnosterna implicata* (*Phyllophaga implicata*)]. Clothianidin, applied at a 1.25 mg a.i. seed^{-1} rate, controls the same insect pests in addition to corn rootworm species (*Diabrotica* spp.) (Andersch and Schwarz, 2003). Additionally, Wilde et al. (2004) determined that both rates of clothianidin gave complete control of white grubs, resulting in 30 plants per 9 m of row and 8.1 to 8.5 Mg ha^{-1} grain yield compared to 8 plants per 9 m of row and 1.8 Mg ha^{-1} grain yield in the check treatment. Pons and Albajes, 2002 determined another seed-applied insecticide for corn, imidacloprid [1-(6-chloro-3-pyridin-3-ylmethyl)-N-nitroimidazolidin-2-ylideamine], controlled early season soil insects, including wireworm and cutworm species.

By adopting an early planting strategy for corn, a producer would be trading the certain risk of hot/or probable risk of dry summer months for the risk of cool soils, uneven germination, and late frost. However, with the advent of effective seed-treatments and increased seedling vigor from improved genetics the probability of successful early planting has become more realistic.

The decision to plant early depends upon a producer’s soil type, equipment and especially upon personal risk/reward tolerance. However, research conducted on planting dates showed little or no yield reductions occurred when planting was done before the determined optimum planting date (Bruns and Abbas, 2006). Conversely, planting late can be detrimental to yield and grain quality (NafZiger, 1994; Johnson and Mulvaney, 1980; Lauer et al., 1999; Carter, 1984; Swanson and Wilhelm, 1996). Lauer et al. (1999) determined that planting later than the optimum planting window, decreased grain yield and increased harvest moisture. The first objective of this research was: a) to determine the effect of early planting on grain yield, b) to determine the effects of early planting on physiological characteristics and c) to determine if some hybrids are better suited for early planting.

Planting Density

Corn production in the Mid-South USA has steadily increased over the past 20 years. Total hectares planted in Mississippi alone increased by 380,000 (USDA-NASS, 2013). Mississippi had over 320,000 hectares of corn harvested in 2013 making corn the second largest crop in the state (USDA-NASS, 2013). Mohsen et al. (2011) attributes the increased corn yields to improved hybrid genetics and agronomic management systems adopted by today’s producers. Tollenaar and Lee, (2002) found similar findings in their research, and further accredited yield increases to new hybrids that are better adapted for higher plant populations.

Crop production and yield have greatly improved over time, but managing and varying plant density is not a new concept for producers. However, improvements in corn genetics have changed the way producers select their optimum plant populations. Producers in the 1950’s and 1960’s used density increases as a management strategy, but found the increased populations caused an increase in barren plants, and less grain per plant on those that did produce ears(Bruns and Abbas, 2003). Field research conducted in Illinois attributed barren plant percentages were 1.2, 9.3, 15.7, and 23.6 for populations at 19,760; 29,640; 39,520; and 49,400 plants ha^{-1}. Additionally, an increase in stalk lodging and smaller ear size was observed (Rossman and Cook, 1966; Bunting, 1973).

The negative interaction between increased density and hybrids has since been mitigated with the implementation of new genotypes. Cox and Crasta (1993) found modern hybrid density recommendations have been on an upward trend. Nielson (2013) estimated in 1998 that 46% of Indiana's corn seeding rates were less than 61,750 plants ha^{-1}. However, by 2012 approximately 50% of Indiana's seeding rates were greater than 74,100 plants ha^{-1}. Statewide seeding rates in 2014 averaged approximately 76,199 plants ha^{-1} (USDA-NASS, 2014).

Considering seed germination rates to be 90% to 95% successful, the actual average statewide seeding rate would be between 80,275 and 84,721 plants ha^{-1}. Neilson et al. (2015) attribute the steady increase in plant populations to improved genetics and overall better stress tolerance of current hybrids. Ear size and kernel weight are less affected by increased plant populations and hybrids are less likely to have late-season stalk health problems. Widdicombe and Thelen (2002) determined grain yield was highest at 90,000 plants ha^{-1}.

Improved grain yield is a major focus for producers. As global human population estimates predict an increase from 7.1 billion to 9.3 billion in the year 2050 (U.S. Census Bureau, 2014). Because, humans and animals both consume corn, and corn products it is realistic to anticipate an increase in the demand for corn. As the population increases Roekel (2011) suggest the amount of available farm land will decrease over time. For that reason optimizing the maximum yield in a given area will become even more important to producers. Mohsen et al. (2011) suggests plant density per unit area is one of the significant yield determinates of crops.

All crops species have an optimum plant population, the goal however, is to achieve maximum yield per unit area, and this is determined by cultivar and environment (Bruns and Abbas, 2003). Roth et. al. (1995) describes corn as a high-energy forage crop that requires less labor, machinery, and out-yields other crops per unit area. Monneveux et al. (2005) observed increased efficiency in grain yield following optimal management of planting density. The increase in yield was attributed to hybrid efficiency in capturing more solar radiation within the canopy.

Nafziger, (1994) found that newer hybrids produce greater grain yields at higher plant populations compared to older hybrids. Newer hybrids are more tolerant to abiotic stressors at higher plant densities than older hybrids (Tollenaar, 1991). It is important to note that the optimal plant density is different among hybrids. Hybrids respond differently grown in a denser environment with enhanced competition. In fact, yield increases accomplished by increasing plant density will at some point yield lower incremental per-unit returns. Corn genotypes grown under a particular environmental and management condition will decline when plant density is increased past a certain point (Tollenaar et al., 1992)

Corn planted at lower populations and not limited by fertility or moisture can produce additional tillers that could potentially increase yield for producers. However, these secondary ears are often late silking and suffer from poor pollination contributing minimal yield increases. Corn, unlike other grasses such as wheat or barley has a lower ability to tiller. Therefore, finding the optimal plant density is an important management strategy for producers (Harris et al. 1976).

Yield increases by agronomic management practices such as optimizing planting date and plant populations has been documented in northern corn production areas. Considerations for determining the optimum planting density include seed corn cost as well as market return on the estimated corn harvest (Van Roekel and Coulter 2011). Producers should also take into account the potential reduction in kernel weight and number of kernels associated with increasing population (Hashemi et al., 2005). Ideally, producers will plant corn at high enough populations that the decrease in kernel size and weight caused by the denser stands are offset by the additional plants per unit area, resulting in increased yield.

Corn seeding rates that maximize profitability will vary by hybrid, soil type, row width, and geography. Stranger and Lauer (2006) conducted research to determine the economic optimum plant density for corn production in Wisconsin. Their research suggests the economic optimum density to be approximately 84,000 plants ha^{-1}. However, they did record maximum yields at densities over 100,000 plants ha^{-1}. Porter et al. (1997) found Minnesota's economic optimum plant density to be 86,500 plants ha^{-1}.

Coulter (2009) also conducted research in Minnesota and found the optimum plant densities to be 79,100 to 84,000 plants ha^{-1}. Nafziger (1994) conducted a similar study in Illinois and found their optimum economic plant density to be 74,900 plants ha^{-1}. In New York, Cox (1997) suggests the optimum economic plant density to be 88,900 plants ha^{-1}, and Michigan's is 90,000 plants ha^{-1} (Widdicombe and Thelen 2002). According to MSU Cares (2009) Mississippi's recommended seeding rates are between

59,280 and 69,160 plants ha^{-1} for rain fed corn production and densities up to 88,920 plants ha^{-1} for irrigated producers.

These varying optimum economic planting densities are likely attributed to several factors. Besides geographic location, row spacing, management and environmental variability the use of new stress tolerant hybrids may explain the wide range of optimum economic planting densities. Seed companies routinely release new hybrids for commercial production. Newer generations of maize hybrids are planted at higher populations and evaluated for performance. Nafziger (1994) suggests newer hybrids have greater grain yield at higher plant densities than older hybrids.

Sangoi et al. (2002) describes the changes in hybrids adapted for higher densities as being more compact plants; having more upright leaf architecture, lower ear placement, and having reduced dry matter partitioning to the tassel. Tollenaar and Aguilera (1992) observed that new hybrids have a higher leaf area index at anthesis. Increased leaf area allows plants to capture more of the available photosynthetically active radiation, resulting in increased accumulation of dry matter during vegetative growth stages.

Zinselmeier et al. (1999) determined sun penetrating leaves near the ear of plants increased carbohydrates available for ear development and kernel set. The increase in carbohydrates is provided by the additional photosynthetic radiation entering the canopy from the more erect leaf architecture. Hashemi et al., (2005) observed that increasing plant density affects yield components and growth stages of corn differently. The number of kernel rows, kernel weight, and ears per plant is decreased when densities are increased resulting in less yield per plant. However, Hashemi et al. (2005) also found that current density recommendations for some hybrids are lower than the optimal amount and single ear hybrids should be planted at increased populations.

Increasing plant density decreased plant height, stalk diameter, and leaf area per plant (Boomsma et al., 2009). Hashemi et al. (2005) suggest that stress caused by density related plant competition during early vegetative growth stages has little effect on final grain yield. However, between V5, anthesis, and early grain fill yield is negatively affected by increased populations if moisture is limiting resulting in a yield decrease. Despite the negative effects caused by increasing corn populations it's important to note that the optimum economic plant density has shown to maximize yields. Seed companies have spent decades breeding and selecting traits to improve hybrids. The end result is a modern hybrid that can produce an ear under moisture and density stress better that hybrids used only 30 years ago. Modern hybrids have changed the risk/reward equation giving producers an advantage (Butzen, 2013).

The objective of this research was: a) to determine the optimum plant density to maximize corn grain yield when using an early planting strategy, b) to determine population effects on grain yield and physiological characteristics, and c) to determine whether hybrid influenced these responses.

CHAPTER II

MATERIALS AND METHODS

Planting Date Experiment Materials and Methods

Field experiments were conducted at Starkville, MS at the R.R. Plant Science Foil Research Center (33.472305°-88.784068°) and in Verona, MS at the North Mississippi Research and Extension Center (34.165138° -88.740698°) from 2013 to 2014. The experimental design for each site-year was a split-plot arrangement in a randomized complete block design. Starkville field experiments had four replications and Verona field experiments had three replications.

Planting dates were considered main plots and hybrids were subplots. Planting date and hybrid were randomized within treatment schemes. Hybrids, planting dates, and locations were considered to be fixed effects; years and reps were considered random effects. Field variation from weather caused planting variation between each year and location resulting in different planting dates. Location, planting date, and year interactions were accounted for by analyzing experiments individually by year and location using the GLIMMIX Procedure of SAS [6.1] at $\alpha = 0.05$ to test the main effects and their interactions. Planting dates (Table 2.1) comparison and yield across years and locations. Additional planting dates were added in 2014 to both Starkville and Verona to extend the planting date range for analysis.

Planting dates were determined yearly by field conditions, the earliest point at which soil could maintain the weight of a tractor and planter, planting began and every two weeks thereafter, weather permitting (Table 2.1). Dekalb (DKC Monsanto, St. Louis, MO) ‘6208’, DKC ‘6929’, Pioneer (Pioneer Hi-Bred Int., Johnston, IA) ‘1498’, and Pioneer ‘1319’ hybrids were used for the split plots. Relative maturities for the different hybrids are presented and transgenic resistance characteristics in (Table 2.2). Plots were planted in slight excess of target treatment densities at 61,938 plants ha^{-1}and hand-thinned prior to plants reaching the fifth leaf collar stage (Ritchie et al., 1993) to the desired population of 61,750 plants ha^{-1}. Plots were four 97-cm rows (0.96 m) wide by 9.14 m long.

The 2013 Starkville planting date experiment was planted in Leeper, silty, clay, loam (Fine, smectitic, nonacid, thermic Vertic Epiaquepts) (USDA-NRCS Soil Survey Division, 2014) soil following a previous corn crop. The 2013 Verona experiments were planted in a Marieta loam (Fine-loamy, siliceous, active, Thermic Fluvaquentic) (USDA-NRCS Soil Survey Division, 2014)and 2014 Starkville planting date field experiments were planted in Marieta fine sandy loam (Fine-loamy, siliceous, active, Thermic Fluvaquentic) (USDA-NRCS Soil Survey Division, 2014) soil. The previous crop for the 2014 Starkville field experiments was cotton. Soybean was the previous crop for Verona 2013 field experiments and 2014 followed corn.

Pre-plant soil samples were taken for analysis for both years at all locations. Soil analysis for Starkville indicated no additional plant nutrients were required for either year or location. Verona analysis recommended no additional nutrients for 2013; however, a supplemental application of Zn was applied at a rate of 0.6946 Kg ha^{-1} in 2014. Zinc was applied to the entire study using CITRI-CHE®ZINC 10% Zn solution mixed with water at 140.25 L/ha^{-1} at 144.9 kPa using a hooded sprayer. Nitrogen (N) was applied with a four row liquid fertilizer applicator equipped with coulter-knives approximately 20-cm from the center row in a split application of 224 Kg/ha^{-1} using 32% urea ammonium nitrate (UAN) solution. The first application of N was applied post-emergent to plants at the 3 to 4 leaf stage. The second N application was applied at the 6 to 8 leaf stage.

Weed management for all locations and years was a pre-emergent application of Roundup PowerMax and Halex GT at recommended label rates. Post-emergent weed control was an additional Roudup PowerMax application as needed at labeled recommendations. Field preparation for each location consisted of using a chisel plow to break the soil at a depth of 20 cm in the fall. Fall bed preparation was accomplished by using a packer/roller to flatten the tops of the rows in order to have a wider surface to plant into for spring planting. Corn was planted 6.25 cm deep using a 4-row John Deere 7100 MaxEmerge vacuum planter (Deere and Co., Moline, IL).

Intercepted photosynthetically active radiation and leaf area index (LAI) were measured with an AccuPAR LP-80 (Decagon Devices, Pullman WA) between 10:00 and 3:30 on clear and calm days from all plots at two week intervals throughout the growing season. AccuPar readings were taken using one above-canopy reading, perpendicular to solar orientation, followed by four below-canopy readings averaged. For the below-canopy readings, the probe was positioned before and after the sampled plant(s) at 45-and 315- degree angles, centered on the row without blocking sunlight.

SPAD 502 chlorophyll meter (Konica-Minolta, Japan) was used to measure leaf absorbance in the red and near-infrared electromagnetic regions. The Numerical SPAD value is closely related to plant nutritional condition and provides a surrogate to the amount of chlorophyll present in leaf tissue. SPAD is a nondestructive method to monitor the crop N status. SPAD readings, have been used to predict the N fertilizer demand for top-dressings in rice (*Oryza sativa* L.) (Cabangon et al., 2011), and maize (*Zea mays* L.) (Varinderpal-Singh et al., 2011).

Three SPAD readings were taken from two plants within the middle two rows. The values were then averaged. SPAD measurements were taken from the middle portion of the leaf parallel to the mid-vein of the most matured leaf at time of collection. SPAD was taken throughout the growing season on two week intervals to capture differences among hybrids N status and planting dates. Because N is the primary mineral nutrient needed for chlorophyll production it plays a key role in a plants life cycle (Muñoz-Huerta et al., 2013). By capturing a plants N status across the season we would have information to potentially explain yield differences among hybrids and planting dates.

Plant height was taken by measuring from the ground to the point of the highest collared leaf. The number of collared leaves was also recorded along with the total number of leaves at time of collection. Growth characteristics were taken throughout the growing season on two week intervals until plants reached tasseling (VT). Measurements were taken from three random plants within the two inner rows and at least 1-m from the edge of the front of the plot.

One meter of biomass was collected for each plot on one of the two outside rows for all experiments for both years. Biomass was calculated by taking a single plant from each plot and drying in a forced air oven at 75°C until it reached a constant weight. Using one plant as an average representative within one meter, the dry plant sample weight was multiplied by the number of plants within a meter in a given plot to give a total weight for one meter of above ground biomass g kg $^{-1}$. The same process was used for evaluating a meter worth of corn ear biomass.

Ear samples were collected from five consecutive plants in the center portion of the outer two rows of each plot prior to harvest. The number of kernel rows (around) and number of kernels per row (long) were counted and averaged for comparison. Yield and test weight was determined with a small plot combine. The middle two rows of each plot were harvested. Yield calculations from the plots were adjusted to 155 g kg^{-1} moisture.

A sub-sample of grain was taken from each plot after yield was calculated to collect 100 kernel weights. Test weight and moisture content of the sample was measured with a Dickey-John GAC 2100 grain moisture tester (Dickey-John Corporation, Auburn, Illinois). Kernel weight was then determined by weighing 100 kernels and adjusting moisture content to 155 g kg^{-1}.

Planting Density Experiment Materials and Methods

The 2013 field experiments were conducted at Starkville, MS at the R.R. Plant Science Foil Research Center (33.472305°-88.784068°), Verona, MS at the North Mississippi Research and Extension Center (34.165138° -88.740698°) and Brooksville, MS at the Black Belt Experiment Station (33.263536° -88.540222°). Field experiments were replicated at the Starkville and Verona location, but not Brooksville for the 2014 growing season. The experimental design for each site-year was a split-split plot arrangement in a randomized complete block design. Starkville and Brooksville field experiments had four replications. Verona field experiments had three replications. Main plots consisted of three corn hybrids and five plant densities. Split plots were two planting dates (early and late) embedded within each experiment.

Planting dates were determined yearly by field conditions, the earliest point at which soil could maintain the weight of a tractor and planter, planting began (Table 2.6). The second planting date differed for locations. Starkville experiments were between 33 and 38 days after the initial planting. Verona experiments were planted 13 to 21 days after initial planting. The difference in planting dates between Starkville and Verona reflects the variance in geographic location, weather, and planting feasibility in regards to time and weather conditions. Dekalb (DKC Monsanto, St. Louis, MO) '6757', Pioneer (DuPont Pioneer Hi-Bred Int., Johnston, IA) '1498', and Agrisure (Syngenta Crop Protection, Greensboro, NC) 'N68B-3111' hybrids were used for the main plots. Relative maturities for the different hybrids are presented in (Table 2.7) as well as transgenic resistance characteristics. Plots were planted in slight excess of the target treatment densities and hand-thinned to the exact desired population of plants ha^{-1} prior to plants reaching the fifth leaf collar stage. Final plant densities were 49,400 plants ha^{-1}, 61,750 plants ha^{-1}, 74,100 plants ha^{-1}, 86,450 plants ha^{-1}, and 98,800 plants ha^{-1}. Plots were four 97-cm rows (.96 m) wide by 9.14 m long. Standard rainfed corn populations for this region are 69,160 plants ha^{-1}.

The 2013 Starkville planting density experiment was planted in Leeper, silty, clay, loam (Fine, smectitic, nonacid, thermic Vertic Epiaquepts) soil following a previous corn crop. The 2013 Brooksville planting density study was planted in Brooksville, silty, clay, (Fine, smectitic, thermic, Aquic, Hapluderts) also following corn. The 2013 Verona and 2014 Starkville planting density field experiments were planted in Marietta loam

(Fine loamy, siliceous, active, thermic Fluvaquentic) soil (USDA-NRCS Soil Survey Division, 2014). The previous crop for the 2014 Starkville field experiment was cotton. Soybean was the previous crop for 2013 and corn for 2014 at Verona.

Pre-plant soil samples were taken for analysis for both years at all locations. Soil analysis for Starkville and Brooksville indicated that no additional plant nutrients were required for either year or location. Verona analysis recommended no additional nutrients for 2013; however, a supplemental application of Zn was applied at a rate of 0.6946 Kg ha^{-1} in 2014. Zinc was applied to the entire study using a CITRI-CHE® ZINC 10% Zn solution mixed with water at 140.25 L/ha^{-1} at 144.9 kPa using a hooded sprayer. Nitrogen (N) was applied with a four row liquid fertilizer applicator equipped with coulter-knives approximately 20-cm from the center row in a split application of 224 Kg/ha^{-1} using a 32% urea ammonium nitrate (UAN) solution. The first application of N was applied post-emergent to plants at the 3 to 4 leaf stage. The second N application was applied at the 6 to 8 leaf stage.

Weed management for all locations and years was a pre-emergent application of Glyphosate (Roundup PowerMax) and Halex GT at recommended labeled rates. Post-emergent weed control was an additional Roudup PowerMax application as needed at labeled recommendations. Field preparation for each location consisted of using a chisel plow to break the soil at a depth of 20-cm in the fall. Fall bed preparation was accomplished by using a packer/roller to flatten the tops of the rows to have a wider surface to plant into in the spring. Corn was planted 6.25-cm deep using a 4-row John Deere 7100 MaxEmerge vacuum planter (Deere and Co., Moline, IL).

Intercepted photosynthetically active radiation and leaf area index (LAI) were measured with an AccuPAR LP-80 (Decagon Devices, Pullman WA) between 10:00 and 3:30 on clear and calm days from all plots at two week intervals throughout the growing season. AccuPar readings were taken using one above-canopy reading, perpendicular to solar orientation, followed by four below-canopy readings averaged. For the below-canopy readings, the probe was positioned before and after the sampled plant(s) at 45-and 315- degree angles, centered on the row without blocking sunlight.

A SPAD 502 chlorophyll meter (Konica-Minolta, Japan) was used to measure leaf absorbance in the red and near-infrared electromagnetic regions. The Numerical SPAD value is closely related to plant nutritional condition and provides a surrogate to the amount of chlorophyll present in leaf tissue. SPAD is a nondestructive method to monitor the crop N status. SPAD readings have been used to predict the N fertilizer demand for top-dressings in rice (*Oryza sativa* L.) (Cabangon et al., 2011), and maize (*Zea mays* L.) (Varinderpal-Singh et al., 2011).

Three SPAD readings were taken from two plants within the middle two rows of each plot. The values were then averaged. SPAD measurements were taken from the middle portion of the leaf parallel to the mid-vein of the most matured leaf at time of collection. SPAD was taken throughout the growing season at two week intervals to capture treatment differences among hybrids, N status, and planting dates. Because N is the primary mineral nutrient needed for chlorophyll production it plays a key role in a plants life cycle (Muñoz-Huerta et al., 2013). By capturing a plants N status across the season we would have information to potentially explain yield differences among hybrids and planting dates.

Plant height was taken by measuring from the ground to the point of the highest collared leaf. The number of collared leaves was also recorded along with the total number of leaves at time of collection. Growth characteristics were taken throughout the growing season on two week intervals until plants reached tasseling (VT). Measurements were taken from three random plants within the two inner rows and at least 1-m from the edge of the front of the plot.

One meter of biomass was collected for each plot on one of the two outside rows for all experiments for both years. Biomass was calculated by taking a single plant from each plot and drying in a forced air oven at 75°C until it reached a constant weight. Using one plant as an average representative within one meter, the dry plant sample weight was multiplied by the number of plants within a meter in a given plot to give a total weight for one meter of above ground biomass g kg $^{-1}$. The same process was used for evaluating a meter worth of corn ear biomass.

Ear samples were collected from five consecutive plants in the center portion of the outer two rows of each plot prior to harvest. The number of kernel rows (around) and number of kernels per row (long) were counted and averaged for comparison. Yield and test weight were collected using a Kincaid 8-XP small plot combine (Kincaid Equipment Manufacturing, Haven, KS). The middle two rows of each plot were harvested. Yield calculations from the plots were adjusted to 155 g kg^{-1} moisture.

A sub-sample of grain was taken from each plot after yield was calculated to collect 100 kernel weights. Test weight and moisture content of the sample was measured with a Dickey-John GAC 2100 grain moisture tester (Dickey-John Corporation, Auburn, Illinois). Kernel weight was then determined by weighing 100 kernels and adjusting moisture content to 155 g kg^{-1}.

CHAPTER III

RESULTS AND DISCUSSION

Planting Date Results and Discussion

Starkville 2013

Starkville 2013 grain yield was affected by planting date and hybrid but not by the interaction between planting date and hybrid (Table 2.4). When hybrids were averaged across the four planting dates grain yield was not significantly different for the first three planting dates. However, grain yield for the earliest planting was 7% greater than the latest planting date (Table 2.1). Hybrid DKC 62-08 averaged 13.2 Mg ha^{-1} and was significantly greater than DKC 69-29, P-1498, and P-1319. Hybrid P-1319 was significantly better than DKC 69-29 but no different than P-1498 (Figure 3.2).

When analyzed across all hybrids, there was a linear exponential response of corn grain yield to planting date (Figure 3.1). An estimated maximum corn grain yield of 12.77 Mg ha^{-1} occurred at the earliest planting date and yields declined for each additional planting date thereafter. Lauer et al. (1999) found similar results of declining yield as planting occurred later than the optimum planting window. These results indicate that the penalty associated with delayed planting was more harmful to yield than early planting for Starkville 2013 and support similar findings by Kucharik (2008) suggesting that today’s corn hybrids have greater tolerance to withstand cooler, wetter soil conditions.

The 100 kernel weight was affected by hybrid but not planting date or the interaction of planting date and hybrid (Table 2.4). Analysis of hybrids showed there was no difference in kernel weight between DKC 62-08 and DKC 69-29 (Figure 2.4). Additionally, DKC 69-29 and P-1319 were also not significantly different from one another. However, hybrid DKC 62-08 kernel weight was 12% greater, than P- 1319. Pioneer-1498 kernel weight was significantly lower than DKC 62-08, DKC 69-29, and P-1319 (Figure 3.3).The insignificant difference in kernel weight between hybrids and lack of planting date effect support Neilson et al. (2015) findings suggesting that kernel weights have become more consistent because today's hybrids are more stress tolerant.

The number of kernel rows was affected by hybrid, but not planting date or the interaction between planting date and hybrid (Table 2.4). Hybrid DKC 62-08 and DKC 69-29 were not significantly different from one another, but were significantly greater than P-1498 and P-1319. Hybrids P-1498 and P-1319 were not significantly different in number kernel rows; however when averaged they were 10% less than DKC 62-08 and DKC 69-29 (Figure 3.4).

The number of kernels per row was affected by hybrid and planting date but not the interaction between hybrid and planting date (Table 2.4). The earliest planting date, Julian day 80, resulted in significantly higher number of kernels per row than Julian days 113 and 129. There was no difference between Julian days 80 and 99, but numerically 80 did have more kernels per row (Figure 3.5). Hybrid P-1319 had significantly more kernels per row than DKC 62-08, DKC 69-29, and P-1498. Hybrids DKC 69-29 and P-1498 were not significantly different from one another, but were significantly greater than DKC 62-08 in number of kernels per row (Figure 3.6).

Verona 2013

Grain yield for Verona 2013 was affected by planting date, but not hybrid or the interaction between planting date and hybrid (Table 2.4). Grain yield across hybrids was significantly greater for the two earliest planting dates. Julian days 108 and 120 yielded greater than Julian days 135 and 148. The yield trend for all planting dates decreased as planting was delayed. The earliest planting date yielded 20% more grain than the latest planting date (Figure 3.7).

Analyzed across all hybrids, there was a linear response of corn grain yield to planting date (Figure 3.7). An estimated maximum corn grain yield of 13.55 Mg ha^{-1} occurred at the earliest planting date and yields declined for each additional planting date thereafter. Similar results of declining yield were seen at the Starkville location 2013. These results indicate that for Verona 2013 there was a yield advantage associated with early planting.

The 100 kernel weight was affected by hybrid and planting date, but not by the interaction between planting date and hybrid (Table 2.4). Kernel weights for Julian day 108 were significantly greater than all other planting dates (Figure 3.8). Analysis of hybrids showed no difference in kernel weight between DKC 62-08 and DKC 69-29, but these two hybrids were significantly greater than hybrids P-1319 and P-1498 (Figure 3.9).

The number of kernel rows was affected by hybrid and planting date, but not by the interaction between planting date and hybrid (Table 2.4). The earliest Julian day 108 had the greatest number of kernel rows and was significantly greater than all other planning dates (Figure 3.10). Hybrids DKC 62-08 and P-1498 were not significantly different from one another, but were significantly greater than P-1319 and DKC 69-29.

Hybrids 62-08 and P-1498 average number of kernel rows was 7.5% greater than hybrids P-1319 and DKC 69-29 (Figure 3.11).

The number of kernels per row was affected by hybrid and planting date but not by the interaction between hybrid and planting date (Table 2.4). The earliest planting date or Julian day 108 was not significantly different than Julian day 120, but they were both significantly better the last two planting dates 135 and 148 (Figure 3.12). Hybrid P-1319 had significantly more kernels per row than DKC 62-08 and DKC 69-29. Hybrids DKC 69-29 and P-1498 were not significantly different from one another, but P-1498 was significantly greater than DKC 62-08 (Figure 3.13).

Starkville 2014

Grain yield for Starkville 2014 was affected by planting date, but not hybrid or the interaction between planting date and hybrid (Table 2.4). When hybrids were averaged across the five planting dates grain yield was significantly greatest for the second planting date 111. Julian days 86 and 126 yielded greater than Julian days 139 and 144 (Figure 3.1). The yield trend for all planting dates other than the second planting decreased as planting was delayed. The increased yield in the second planting 111 compared to the 86 and 126 planting; is likely due the above average rainfall and lower temperatures we received later in the growing season, specifically during June and July (Table 2.3).

When analyzed across all hybrids, there was a quadratic response in corn grain yield to planting date (Figure 3.1). An estimated maximum corn grain yield of 15.33 Mg ha^{-1} occurred at the second planting date and yields declined for each additional planting date thereafter. Similar trends of declining yield were observed at both Starkville and Verona locations in 2013. With the exception of the earliest planting date, these results follow the same trend as the 2013 experiments. There are yield advantages to early planting compared to later planting. However if conditions are optimal during late season, as they were for a portion of the 2014 growing season, corn growth, development, and yield can remain elevated for later planting so long as moisture is not limiting.

The 100 Kernel weight was affected by the interaction between planting date and hybrid (Table 2.4). Because of this the interaction, interpretation of the statistical analysis is less concise. Summarizing the differences in kernel weight for hybrid by planting date does reveal a trend. Much like the previously discussed link between yield and planting date, for the majority of hybrid by planting date trends, there is a decline in kernel weight as planting is delayed. In all hybrids numerically kernel weight was lowest for the last planting date Julian day 144 (figure 3.14).

The number of kernel rows was affected by hybrid, but not planting date or the interaction between planting date and hybrid (Table 2.4). Hybrids 62-08 and P-1498 were significantly greater than DKC 69-29 and P-1319. Hybrid DKC 69-29 was significantly greater than P1319. The average number of kernel rows for hybrids 62-08 and P-1498 was 13.2% greater than hybrids DKC 69-29 and P-1319 (Figure 3.15).

The number of kernels per row was affected by hybrid and planting date, but not by the interaction between hybrid and planting date (Table 2.4). The earliest planting date or Julian day 86 was not significantly different than Julian day 111 or 126, but they were significantly better than the last two planting dates 139 and 144 (Figure 3.16). Hybrid P-1319 had significantly more kernels per row than DKC 62-08, DKC 69-29, and

P-1498. Hybrid P-1498 was not significantly different than DKC 62-08, but was significantly greater than DKC 69-29 (Figure 3.17).

Verona 2014

The overall grain yield for all planting dates at Verona 2014 was very good. In fact, yields were historically high for this location. Early and late plantings produced high yields; likely because of the above average rainfall that was received throughout the growing season and especially during June and July. The combination of cooler temperatures and non-limiting moisture produced ideal conditions for growing corn, likely diminishing any penalty for delayed planting (Table 2.3).

Grain yield for Verona 2014 was affected by an interaction between planting date and hybrid (Table 2.4). Because of the interaction, the statistical analysis interpretation is less concise (Figure 3.18). However, if we evaluate by individual planting dates, we notice differences among hybrids. For the earliest planting date, Julian day 72 hybrids DKC 69-29 and P-1319 grain yields were significantly greater than P-1498 (Figure 3.19).

The second planting date, Julian day 86, resulted in no statistically significant difference among hybrids, but DKC 69-29 did have the highest numerical grain yield of 14.31 Mg ha^{-1} (Figure 3.20). The third planting date Julian day 111 hybrids DKC 62-08 and P-1913 were significantly greater than hybrid DKC 69-29. There was no significant difference between hybrids DKC 69-29 and P-1498 (Figure 3.21). Grain yield ranged from 13.21 Mg ha^{-1} for DKC 69-29 to 14.08 Mg ha^{-1} for P-1319.

The fourth planting, Julian day 125, yields varied slightly for each hybrid. The highest yielding hybrid was DKC 62-08 at 14.61 Mg ha^{-1} and was significantly greater than hybrid P-1319 at 13.18 Mg ha^{-1} (Figure 3.22). The fifth planting date, Julian day 132 did have yield differences among hybrids, but there was no significant difference between them. The highest yield of 13.80 Mg ha^{-1} came from DKC 69-29 and the lowest yielding hybrid was P-1319 at 12.16 Mg ha^{-1} (Figure 3.23).

The last planting, Julian day 147 revealed that hybrid DKC-62-08 was significantly greater than all other hybrids for this planting date. Additionally, hybrid P-1319 was significantly greater than hybrids DKC 69-29 and P-1498. There was no significant difference between hybrids DKC 69-29 and P-1498. The highest yield of 13.95 Mg ha^{-1} was produced by DKC 62-08 and the lowest was 11.69 Mg ha^{-1} produced by P-1498 (Figure 3.24).

The 100 kernel weight was affected by hybrid and planting date, but not by the interaction between planting date and hybrid (Table 2.4). Kernel weights for Julian days 86 and 111 were not significantly different from one another, but Julian day 111 was significantly greater than the other planting dates (Figure 3.25). The last planting date, Julian day 147 had the lowest kernel weight and was significantly the lowest among treatments. Analysis of hybrids showed DKC 62-08 to be significantly greater than all other hybrids. Second in kernel weight was DKC 69-29 and it too was significantly greater than both pioneer varieties. Hybrid P-1319 was significantly greater than P-1498 in kernel weight (Figure 3.26).

The number of kernel rows was affected by the interaction between planting date and hybrid (Table 2.4). Due to the interaction, the statistical analysis interpretation is less concise (Figure 3.27). Nevertheless, the trend was hybrids DKC 62-08 and P-1498 had more kernel rows than the two other hybrids in all planting dates. Additionally, hybrid P-1319 had the lowest number of kernel rows for all planting dates except Julian day 125.

The number of kernels per row was affected by hybrid, but not planting date or the interaction between hybrid and planting date (Table 2.4). Hybrid P-1319 was significantly greater than all other hybrids in number of kernels per row. The hybrid with the second most kernels per row was P-1498 and it was also significantly greater than both DKC 62-08 and DKC 69-29 which were not significantly different from each other. The Pioneer hybrids averaged 11% more kernels per row than the Dekalb varieties. There was a 16% increase in number of kernels per row for P-1319 as compared to the hybrid DKC 69-29 which had the fewest number of kernels per row (Figure 3.28).

Plant Growth and Development for Planting Date Experiment

SPAD measurements were collected for the planting date experiments to capture potential yield loss from fertility deficiencies. SPAD 502 Plus meter was used to measure chlorophyll content or "greenness" of plants. Thus, confirming quantifiable changes or trends in plant health without running traditional destructive fertility analysis. SPAD measurements were taken at tasseling to observe plant health differences among hybrids and planting dates.

Leaf SPAD readings for Starkville 2013 were affected by planting date and hybrid, but not by the interaction between planting date and hybrid (Table 2.4). Hybrids P-1319 and DKC 69-29 were not significantly different from each other, but had significantly greater SPAD values than P-1498 and DKC 62-08. Although, the SPAD values were significantly different they were within 4% of each other. In fact all hybrids were 56 or greater in value which indicated that all hybrids were adequately fertilized based on the chlorophyll levels from SPAD values. SPAD values averaged across hybrids showed no difference for Julian days 80, 99 or 113 at Starkville 2013, but the last planting date, Julian day 129 did have a significantly lower SPAD value compared to the earlier planting dates.

Verona 2013, Verona 2014, and Starkville 2014 were affected by only a planting date effect (Table 2.4). Planting date experiments revealed a trend with earlier planting dates having higher SPAD values. The lower value was likely caused by late season leaf diseases like rust, rather than low fertility. It is plausible that later planted treatments were more susceptible to leaf diseases during the reproductive phase causing lower SPAD values.

Additional advantages attributed to earlier planting include avoiding common leaf diseases such as rust that occur later in the growing season. Although, all treatments were exposed to the same leaf diseases, the earlier planted treatments appeared to escape penalty because kernel set and yield had already been determined. Unlike later planted treatments the impact of leaf disease caused a decrease in photosynthesis and the plants ability to convert light energy into chemical energy as sufficiently, consequently affecting yield.

AccuPar LP-80 measurements were taken at tasseling to quantify the amount of light transmitted through the plant canopy giving us the leaf area index (LAI) for hybrids and planting date treatments. The numerical value for LAI helps predict photosynthetic evapotranspiration and is used as reference tool to observe crop growth and development. After statistical analysis the following LAI differences in canopy coverage were observed for hybrids and planting dates. Additional advantages to canopy coverage include shading out competing plants for plant resources.

Starkville 2013 LAI was affected by planting date, but not by hybrid or the interaction between planting date and hybrid (Table 2.4). The latest planting date Julian day 129 had an LAI value of 3.0 and was significantly lower in LAI compared to the three earlier planting dates. Starkville 2014 LAI was affected by planting date and hybrid, but not by the interaction between planting date and hybrid. Results for planting date effects were similar to Starkville 2013. The last planting date had an LAI value of 3.66 and was significantly lower in LAI than all other planting dates.

Hybrid P-1319 had the highest numerical LAI value of 4.50 followed by P-1498 with 4.48. Dekalb 62-08 was third in LAI with 4.37 and DKC 69-29 had the lowest LAI of 3.97. Differences among hybrids LAI values compared to visual inspection in the field do correlate. Plant height differences among hybrids were documented at multiple times throughout the growing season. Pioneer hybrids averaged 14% taller than Dekalb hybrids at Verona 2014. After further evaluation it is likely that height differences between hybrids is a combination of environmental factors and plant genetics. Pioneer hybrids appear to be taller than the Dekalb hybrids even under optimal conditions.

Verona 2013 and 2014 planting date experiments had a planting date by hybrid interaction for LAI. In both years LAI values for mid-to-late May planting dates had the lowest LAI values. The decrease in LAI was mostly likely attributable to the combination of hot and dry growing conditions and late season diseases that reduced plant growth. Verona 2013 LAI values dropped from 3.20 for the earliest planting date to 2.52 for the latest planting date.

Verona 2014 LAI values ranged from 5.39 for the earliest planting to 4.99 for the latest planting date. The highest LAI values for Verona 2014 took place on the third planting date, Julian day 111 with a value of 5.94. All hybrids at this planting date showed no significant difference from one another, most likely because of the optimal growing conditions. LAI values for the Julian day 111 were higher than earlier planting dates. However, yield penalty associated with early planting appears to be less severe than the yield decrease for treatments planted 21 days later.

Table 3.1 Planting dates (Julian day) at Starkville and Verona, MS for the planting date experiment.

Location	Year	Planting Date Experiment					
		(Julian Day)					
Starkville	2013	21-March(80)	9-April(99)	23-April(113)	9-May(129)		
	2014	27-March(86)	21-April(111)	6-May(126)	19-May(139)	24-May(144)	
Verona	2013	18-April(108)	30-April(120)	15-May(135)	28-May(148)		
	2014	13-March(72)	27-March(86)	21April(111)	5-May(125)	12-May(132)	27-May(147)

Table 3.2 Description of hybrids used in the planting date experiment evaluated at Starkville and Verona, MS in 2013 and 2014.

Planting Date Experiment					
Brand	Hybrid	Technology Trait(s)*	Maturity Days (RM)	(GDU) Mid Silk	(GDU) Black Layer
DEKALB	DKC 62-08	GENSSRIB	112	1365	2800
DEKALB	DKC 69-29	GENVT3P	119	1359	2975
Pioneer	P-1498	HX1/LL/RR2	114	1370	2700
Pioneer	P-1319	HX1/LL/RR2	113	1400	2730

*Technology Traits
*GENSSRIB: Genuity® SmartStax®RIB Complete®
*GENVT3P: Genuity® VT Triple PRO®
*HX1: Herculex®
*LL: Liberty Link®
*RR2: Roundup Ready® Corn 2
†Relative maturity (RM)
§Growing degree units (GDU)

Table 3.3 Observed and long-term mean rainfall and temperature for the planting date study.

Location	Year	March	April	May	June	July	August
Monthly rainfall, mm (30 year Mean)							
Starkville	2013	144 (-2)	183 (45)	184 (60)	70 (-35)	102 (-10)	58 (-41)
	2014	116 (-29)	253 (115)	86 (-38)	207 (102)	56 (-55)	74 (-25)
Verona	2013	110 (-29)	125 (5)	165 (23)	52 (-67)	75 (-32)	98 (0)
	2014	86 (-53)	182 (62)	106 (-36)	260 (141)	145 (39)	41 (-57)
Monthly mean air temperature, °C (30 year Mean)							
Starkville	2013	7.7 (-4.7)	15.3 (-1.5)	19.6 (-1.8)	25.3 (-0.2)	5 (-2.3)	5.6 (-1.4)
	2014	10.3 (-2.1)	16.4 (-0.4)	21.6 (0.2)	26 (0.6)	5.7 (-1.6)	7 (0.2)
Verona	2013	9.0 (-3.0)	16.2 (-0.4)	20.5 (-1.1)	25.9 (0.4)	6.4 (-0.8)	6.6 (-0.5)
	2014	8.7 (-3.2)	15.7 (-0.8)	20.7 (-0.8)	25.3 (-0.2)	4.5 (-2.8)	6.1 (-1.0)

Observed and long-term mean rainfall and temperature during March through August at Starkville and Verona, MS in 2013 and 2014. Difference in observed and long-term (30 yr) normal was obtained by subtracting total precipitation and mean temperature from their respective long-term values.

Table 3.4 Significance of *F*-Values for fixed sources of variation from statistical analysis of the 2-yr planting date study.

			Fixed source of variation		
Location	Year	Dependent variable	Planting date (PD)	Hybrid (H)	PD x H
Starkville	2013	Grain yield	.006	<.0001	.2664
		100 Kernel weight†	.7129	.0002	.9436
		kernel rows‡	.6823	<.0001	.0849
		Kernels per row§	.0117	<.0001	.3072
		LAI††	<.0001	.9311	.4410
		SPAD‡‡	<.0001	.0006	.0846
		Plant height	.	.	.
Starkville	2014	Grain yield	<.0001	.7914	.9813
		100 Kernel weight†	<.0001	.0002	.0242
		kernel rows‡	.5369	<.0001	.3003
		Kernels per row§	.0011	<.0001	.1752
		LAI††	<.0001	.0452	.7919
		SPAD‡‡	<.0001	.5754	.7072
		Plant height	.	.	.
Verona	2013	Grain yield	<.0001	.2626	.5542
		100 Kernel weight†	.0064	.0002	.6379
		kernel rows‡	.0002	<.0001	.3511
		Kernels per row§	<.0001	.0259	.1267
		LAI††	.0002	.1444	<.0001
		SPAD‡‡	.0030	.7413	.9790
		Plant height	.1941	.1720	.0173
Verona	2014	Grain yield	.0013	.0011	.0082
		100 Kernel weight†	<.0001	<.0001	.1645
		kernel rows‡	.0009	<.0001	.0178
		Kernels per row§	.1682	<.0001	.0707
		LAI††	<.0001	.3703	.0071
		SPAD‡‡	<.0001	.3138	.6809
		Plant height	.0572	<.0001	.0708

† Weight of 100 kernels adjusted to 155 g kg^{-1} moisture.

‡ Number of kernels around an ear of corn.

§ Number of kernels long from tip to end.

†† Leaf area index (LAI) measurements taken when hybrids reached the silking stage.

‡‡ Numerical SPAD value used to measure leaf absorbance in the red and near-infrared electromagnetic regions.

Table 3.5 Observed precipitation seven days before planting (7DBP), seven days after planting (7DAP), and monthly totals at Starkville and Verona, MS in 2013 and 2014

Planting date precipitation totals mm						
Location	Year	Date	Julian Day	(7DBP)	(7DAP)	Monthly Total
Starkville	2013	21-Mar	80	12.95	42.67	143.76
		9-Apr	99	15.75	98.04	182.63
		23-Apr	113	37.85	28.70	182.63
		9-May	129	52.83	13.72	184.40
	2014	27-Mar	86	18.80	38.86	116.33
		21-Apr	111	81.28	27.43	252.98
		6-May	126	35.81	13.72	86.11
		19-May	139	31.75	0.00	86.11
		24-May	144	0.76	44.96	86.11
Verona	2013	18-Apr	108	69.09	13.97	124.97
		30-Apr	120	17.53	46.74	124.97
		15-May	135	17.27	80.01	164.85
		28-May	148	42.67	19.30	164.85
	2014	13-Mar	72	2.54	16.26	85.85
		27-Mar	86	5.08	39.88	85.85
		21-Apr	111	33.27	22.10	182.12
		5-May	125	60.45	1.78	106.43
		12-May	132	1.78	67.31	106.43
		27-May	147	0.00	57.66	106.43

Table 3.6 Planting dates at Starkville, Verona, and Brooksville, MS for the planting density experiment.

		Planting Density Experiment	
Location	Year	(Julian Day)	
Starkville	2013	21-March (80)	23-April (113)
	2014	14-March (73)	21-April (111)
Verona	2013	18-April (108)	1-May (121)
	2014	21-April (111)	12-May (132)
Brooksville	2013	18-April (108)	

Table 3.7 Description of hybrids used in the planting density experiment evaluated at Starkville, Brooksville, and Verona, MS in 2013 and 2014.

Planting Density Experiment					
Brand	Hybrid	Technology Trait(s)*	Maturity Days (RM)	(GDU) Mid Silk	(GDU) Black Layer
DEKALB	DKC 67-57	GENVT3P	117	1350	2925
Pioneer	P-1498	HX1/LL/RR2	114	1370	2700
Syngenta	AGR-N68B-311	311	111	1405	2580

*Technology Traits
*GENVT3P: Genuity® VT Triple PRO®
*HX1: Herculex®
*LL: Liberty Link®
*RR2: Roundup Ready® Corn 2
*311: Agrisure® Viptera® 311
†Relative maturity (RM)
§Growing degree units (GDU)

Table 3.8 Observed and long-term mean rainfall and temperature for the planting density study.

Monthly rainfall, mm
(30 year Mean)

Location	Year	March	April	May	June	July	August
Brooksville	2013	131 (-19)	196 (60)	78 (-27)	117 (7)	90 (-30)	166 (71)
Starkville	2013	144 (-2)	183 (45)	184 (60)	70 (-35)	102 (-10)	58 (-41)
	2014	116 (-30)	253 (115)	86 (-38)	207 (102)	56 (-56)	74 (-25)
Verona	2013	110 (-29)	125 (5)	165 (23)	52 (-67)	75 (-32)	98 (0)
	2014	86 (-53)	182 (62)	106 (-36)	260 (141)	145 (40)	41 (-57)

Monthly mean air temperature, °C
(30 year Mean)

Location	Year	March	April	May	June	July	August
Brooksville	2013	9.9 (-3.3)	14.6 (-3.0)	20.5 (-1.1)	25.3 (0.1)	28.3 (1.2)	28.1 (1.5)
Starkville	2013	7.7 (-4.7)	15.3 (-1.5)	19.6 (-1.8)	25.3 (-0.2)	25 (-2.3)	25.6 (-1.4)
	2014	10.3 (-2.1)	16.4 (-0.4)	21.6 (0.2)	26 (0.6)	25.7 (-1.6)	27 (0.0)
Verona	2013	9.0 (-3.0)	16.2 (-0.4)	20.5 (-1.1)	25.9 (0.4)	26.4 (-0.9)	26.6 (-0.5)
	2014	8.7 (-3.2)	15.7 (-0.9)	20.7 (-0.9)	25.3 (-0.2)	24.5 (-2.8)	26.1 (-1.0)

Observed and long-term mean rainfall and temperature during March through August at Brooksville, Starkville, and Verona, MS in 2013 and 2014. Difference in observed and long-term (30 yr) normal was obtained by subtracting total precipitation and mean temperature from their respective long-term values.

Table 3.9 Significance of *F*-Values for fixed sources of variation from statistical analysis of the 2-yr planting density study.

			Fixed source of variation						
Location	Year	Dependent variable	Population (POP)	Planting date (PD)	Hybrid (H)	POP x PD	POP x H	PD x H	POP x PD x H
Starkville	2013	Grain yield	.3343	<.0001	.3379	.9046	.9216	.0218	.7092
		100 Kernel weight†	.0100	.1370	.0002	.1237	.0403	.4603	.6663
		kernel rows‡	.0003	.2794	<.0001	.5018	.3701	.7087	.7552
		Kernels per row§	.0003	<.0001	.0120	.5225	.4313	.9386	.8294
		SPAD‡‡	<.0001	<.0001	<.0001	.1049	.4484	.4036	.5040
		LAI††	.0370	.0087	.0080	.9104	.8486	.3881	.9543
		Plant height	.0439	<.0001	<.0001	.2179	.9121	.9578	.5681
Starkville	2014	Grain yield	<.0001	<.0001	.0016	.8112	.0680	.3774	.7375
		100 Kernel weight†	.6162	.3517	<.0001	.1671	.1996	.6627	.0953
		kernel rows‡	.0913	.3706	<.0001	.9100	.0333	.1000	.2320
		Kernels per row	.0182	.6779	.0015	.5055	.4886	.4898	.3688
		SPAD‡‡	.0008	<.0001	<.0001	.0697	.5297	.0073	.1506
		LAI††	<.0001	<.0001	.3618	.0175	.5542	.0735	.6523
		Plant height	.2892	<.0001	<.0001	.9129	.8145	.4927	.1008
Verona	2013	Grain yield	.0001	.0163	.0576	.5287	.6035	.9030	.7147
		100 Kernel weight†	.1587	.9017	.0012	.6660	.9650	.2085	.9043
		kernel rows‡	.0401	.5154	.0032	.3134	.3343	.2065	.3245
		Kernels per row§	<.0001	.4711	.0050	.1950	.6860	.8189	.7770
		SPAD‡‡	.0552	.0011	.0004	.9409	.4146	.7311	.9852
		LAI††	.0008	.0532	.0006	.4963	.4284	.1286	.7596
		Plant height	.0060	.0005	<.0001	.7769	.9925	.2674	.9091
Verona	2014	Grain yield	<.0001	.9934	<.0001	.3072	.7623	.0372	.9010
		100 Kernel weight†	<.0001	<.0001	<.0001	.4926	.4643	.0088	.6952
		kernel rows‡	.0537	.9348	<.0001	.0323	.0440	.4960	.1918
		Kernels per row§	<.0001	.0002	<.0001	.8059	.0183	.0110	.0729
		SPAD‡‡	.0013	<.0001	.0035	.9803	.3651	.0004	.9973
		LAI††	<.0001	.6670	.0005	.6326	.2841	.8182	.8949
		Plant height	.0015	<.0001	<.0001	.0338	.7929	<.0001	.7494
Brooksville	2013	Grain yield	.0005	.	.0331	.	.0259	.	.
		100 Kernel weight†	.0005	.	<.0001	.	.8759	.	.
		kernel rows‡	.0014	.	<.0001	.	.1155	.	.
		Kernels per row§	<.0001	.	<.0001	.	.1660	.	.
		SPAD‡‡	<.0001	.	.5392	.	.7658		.
		LAI††	<.0001	.	.1006	.	.8356		.
		Plant height	.0002	.	<.0001	.	.7327		.

† Weight of 100 kernels adjusted to 155 g kg-1 moisture.
‡ Number of kernels around an ear of corn.
§ Number of kernels long from tip to end.
‡‡ Numerical SPAD value used to measure leaf absorbance in the red and near-infrared electromagnetic regions.
†† Leaf area index (LAI) measurements taken when hybrids reached the silking stage.

Table 3.10 Observed precipitation seven days before planting (7DBP), seven days after planting (7DAP), and monthly totals at Brooksville, Starkville, and Verona, MS in 2013 and 2014

Planting date precipitation totals mm						
Location	Year	Date	Julian Day	(7DBP)	(7DAP)	Monthly Total
Starkville	2013	21-Mar	80	12.95	42.67	143.76
		9-Apr	99	15.75	98.04	182.63
		23-Apr	113	37.85	28.70	182.63
		9-May	129	52.83	13.72	184.40
	2014	27-Mar	86	18.80	38.86	116.33
		21-Apr	111	81.28	27.43	252.98
		6-May	126	35.81	13.72	86.11
		19-May	139	31.75	0.00	86.11
		24-May	144	0.76	44.96	86.11
Verona	2013	18-Apr	108	69.09	13.97	124.97
		30-Apr	120	17.53	46.74	124.97
		15-May	135	17.27	80.01	164.85
		28-May	148	42.67	19.30	164.85
	2014	13-Mar	72	2.54	16.26	85.85
		27-Mar	86	5.08	39.88	85.85
		21-Apr	111	33.27	22.10	182.12
		5-May	125	60.45	1.78	106.43
		12-May	132	1.78	67.31	106.43
		27-May	147	0.00	57.66	106.43
Brooksville	2013	18-Apr	108	68.07	43.18	196.09

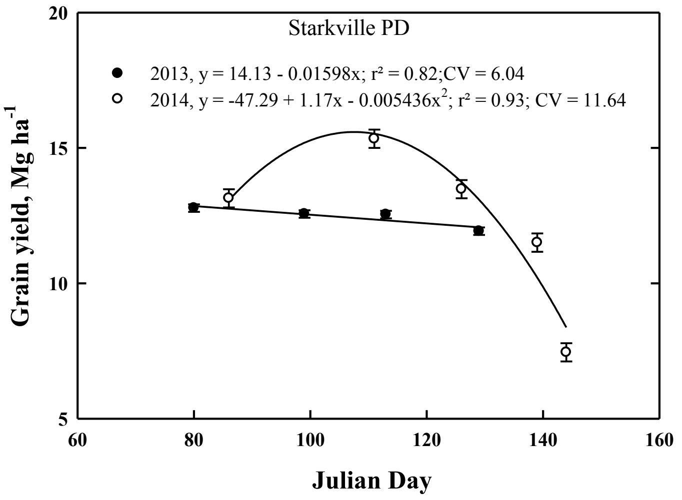

Figure 3.1 Regression analysis of corn grain yield for Starkville 2013 and 2014.

Relationship between grain yield and Julian day at Starkville 2013-2014. Grain yield averaged across hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, for each Julian day.

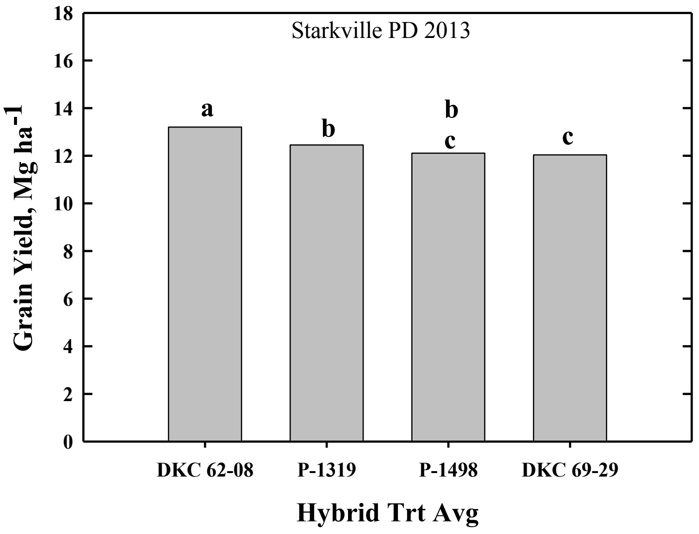

Figure 3.2 Corn grain yield as affected by hybrid, across Julian days at Starkville 2013.

Grain yield for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, across Julian days (80, 99, 113, 129) at Starkville 2013. Hybrids with the same letter are not significantly different (α =0.05).

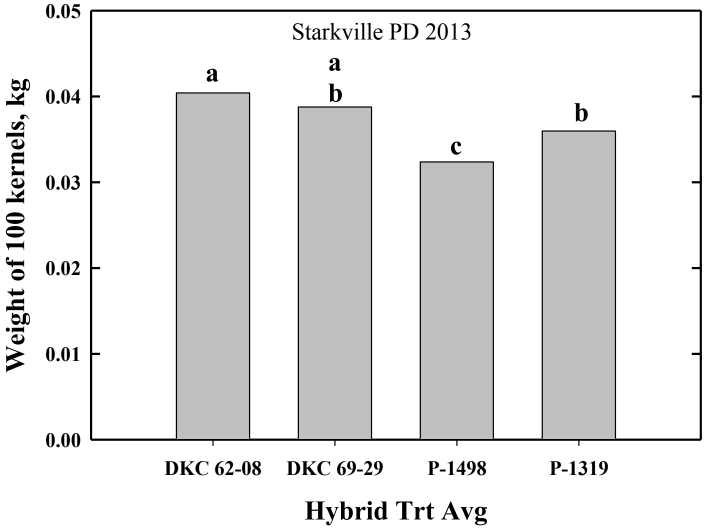

Figure 3.3 Weight of 100 corn kernels as affected by hybrid, across Julian days at Starkville 2013.

Weight of 100 kernels for hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 averaged across Julian days (80, 99, 113, 129) at Starkville 2013. Hybrids with the same letter are not significantly different (α =0.05).

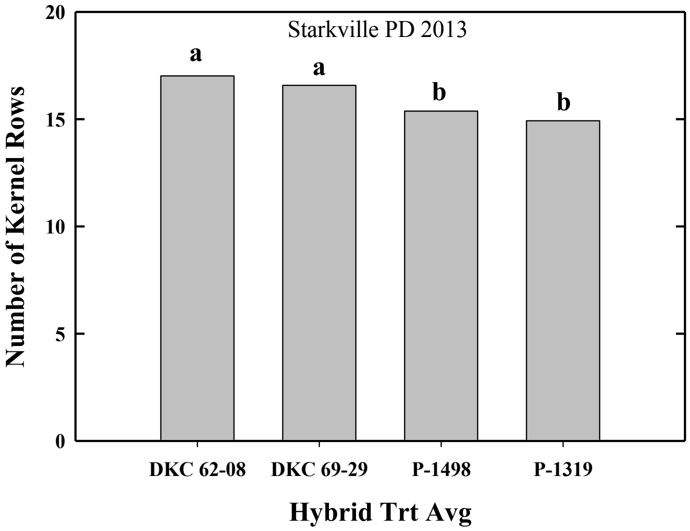

Figure 3.4 Number of corn kernel rows as affected by hybrid, across Julian days at Starkville 2013.

Number of kernel rows for hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 averaged across Julian days (80, 99, 113, 129) at Starkville 2013. Hybrids with the same letter are not significantly different (α =0.05).

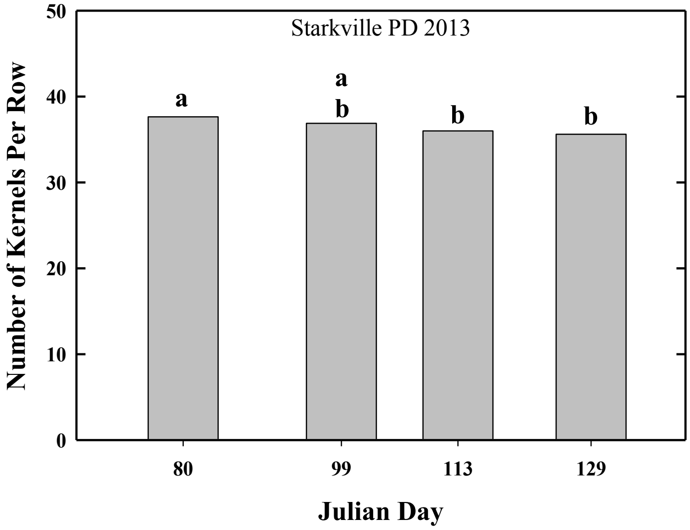

Figure 3.5 Number of corn kernels per row as affected by Julian day, across hybrids at Starkville 2013.

Number of kernels per row averaged across hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Julian days (80, 99, 113, 129) at Starkville 2013. Julian days with the same letter are not significantly different (α =0.05).

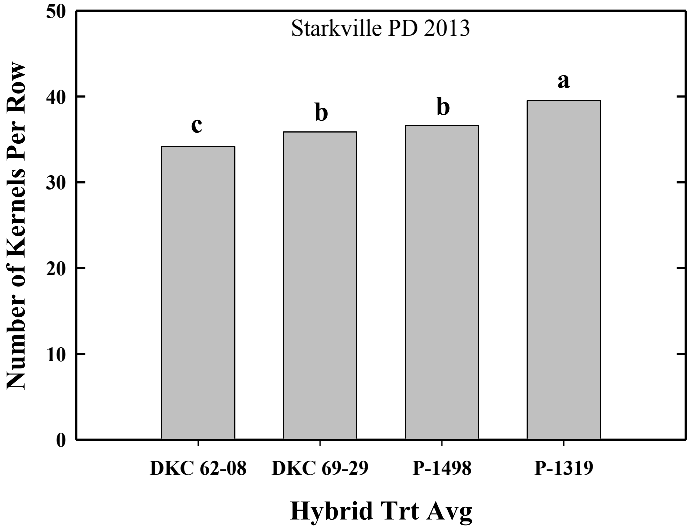

Figure 3.6 Number of corn kernels per row as affected by hybrid, across Julian days at Starkville 2013.

Number of kernels per row, across Julian days (80, 99, 113, 129) for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Starkville 2013. Hybrids with the same letter are not significantly different (α =0.05).

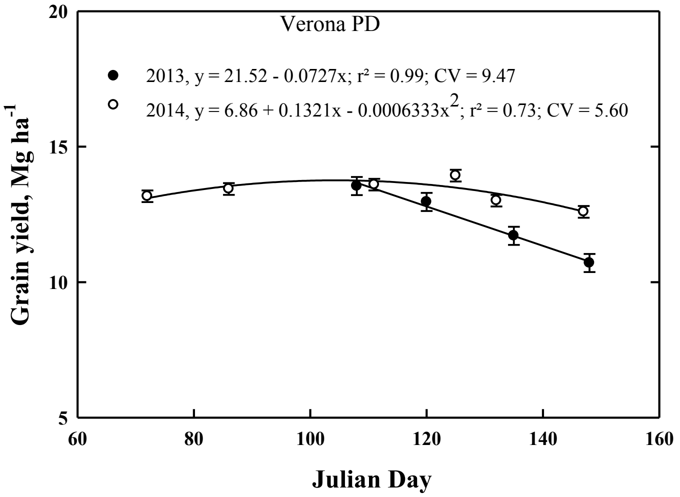

Figure 3.7 Regression analysis of corn grain yield for Verona 2013.

Relationship between grain yield and Julian day at Verona 2013. Grain yield averaged across hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, for each Julian day.

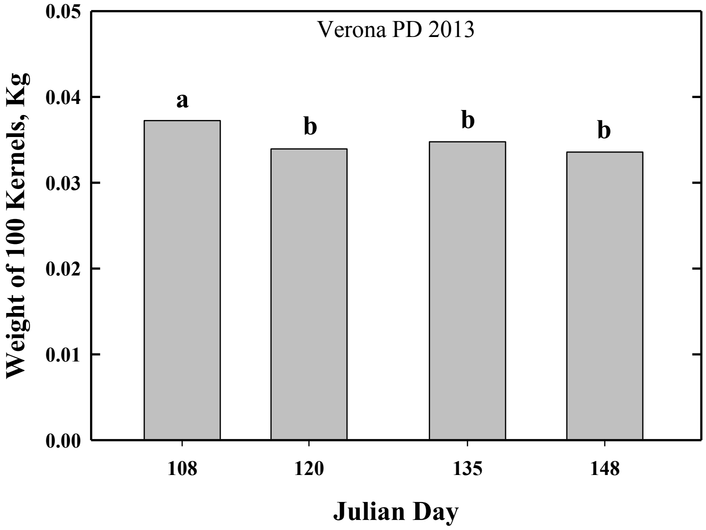

Figure 3.8 Weight of 100 corn kernels as affected by Julian day, across hybrids at Verona 2013.

Weight of 100 kernels for Julian days (108, 120, 135, 148) across hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Verona 2013. Julian days with the same letter are not significantly different (α =0.05).

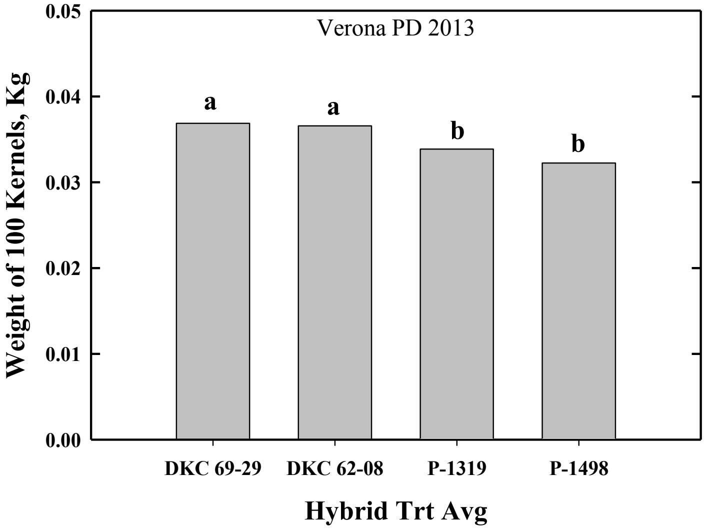

Figure 3.9 Weight of 100 corn kernels as affected by hybrids, across Julian days at Verona 2013.

Weight of 100 kernels averaged across Julian days (108, 120, 135, 148) for hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Verona 2013.. Hybrids with the same letter are not significantly different (α =0.05).

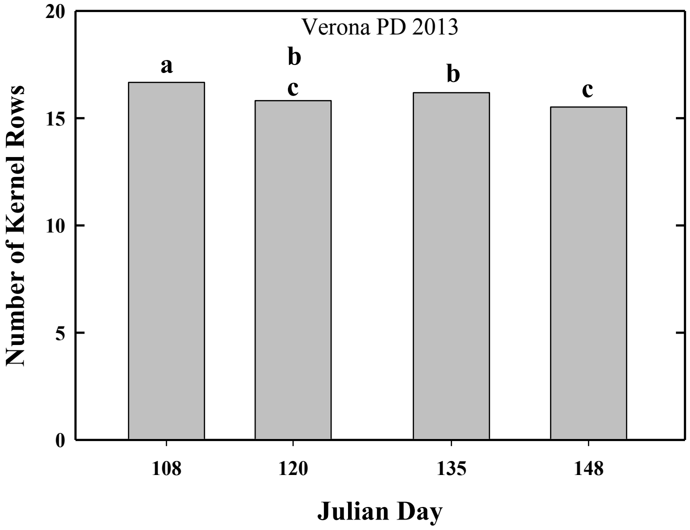

Figure 3.10 Number of corn kernel rows as affected by Julian day, across hybrids at Verona 2013.

Number of kernel rows across hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 averaged for Julian days (108,120,135,148) at Verona 2013. Julian days with the same letter are not significantly different (α =0.05).

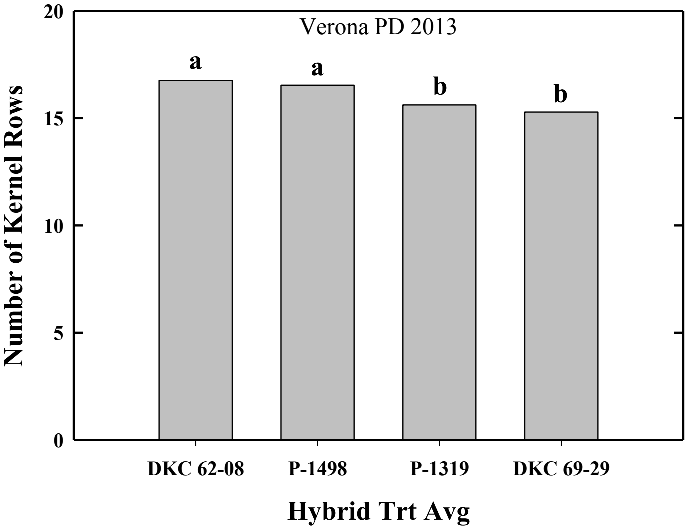

Figure 3.11 Number of corn kernel rows as affected by hybrid, across Julian days at Verona 2013.

Number of kernel rows, across Julian days (108,120,135,148) for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Verona 2013. Hybrids with the same letter are not significantly different (α =0.05).

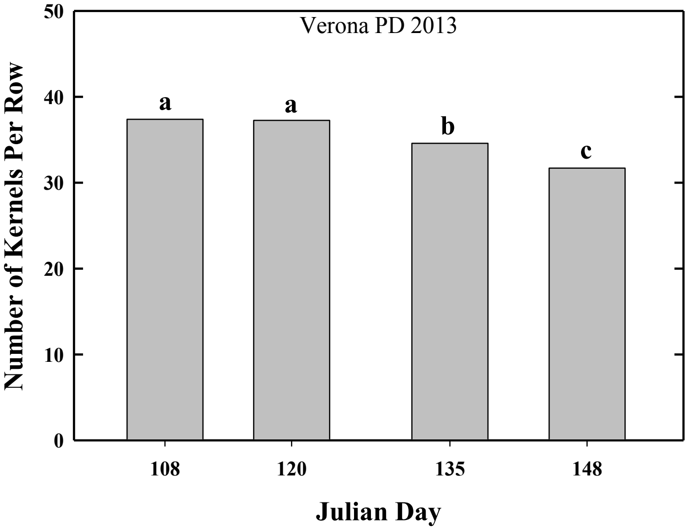

Figure 3.12 Number of corn kernels per row as affected by Julian day, across hybrids at Verona 2013.

Number of kernels per row, across hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Julian days (108, 120,135,148) at Verona 2013. Julian days with the same letter are not significantly different (α =0.05).

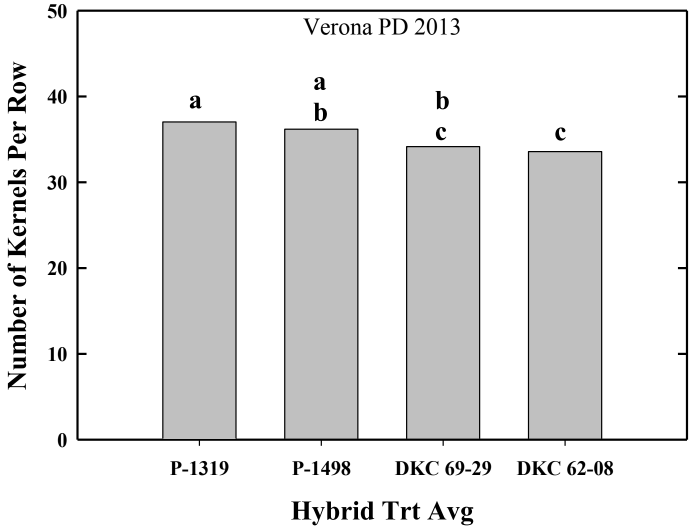

Figure 3.13 Number of corn kernels per row as affected by hybrid, across Julian days at Verona 2013.

Number of kernels per row, across Julian days (108, 120, 135, 148) for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Verona 2013. Hybrids with the same letter are not significantly different (α =0.05).

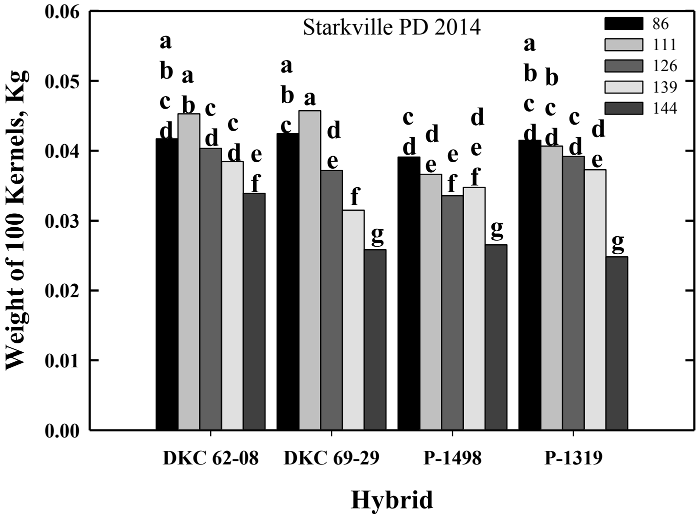

Figure 3.14 Weight of 100 corn kernels as affected by the interaction between hybrid and Julian day at Starkville 2014.

Weight of 100 kernels for the interaction between Julian days (86, 111, 126, 139, 144) and hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Starkville 2014. Treatments with the same letter are not significantly different (α =0.05).

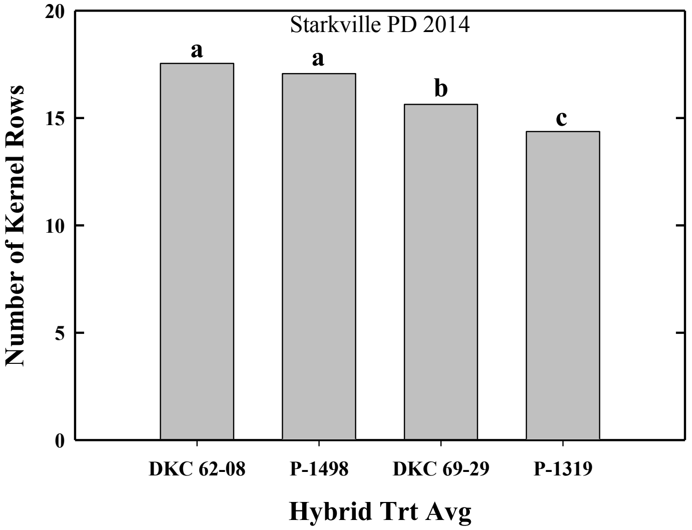

Figure 3.15 Number of corn kernel rows as affected by hybrid, across Julian days at Starkville 2014.

Number of kernel rows, across Julian days (86, 111, 126, 139, 144) for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Starkville 2014. Hybrids with the same letter are not significantly different (α =0.05).

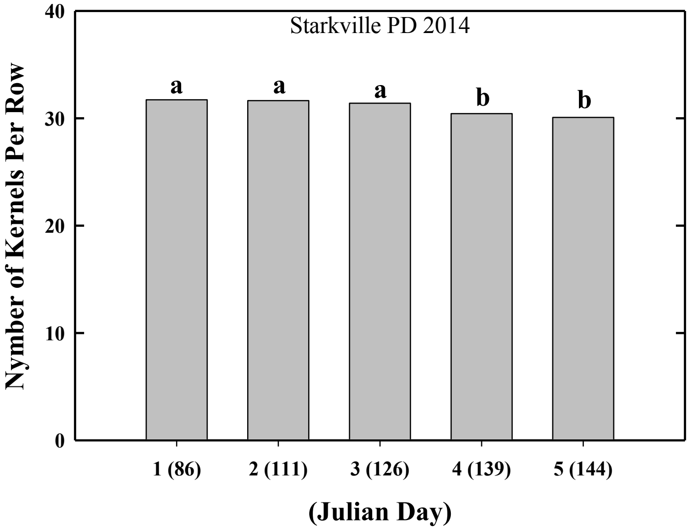

Figure 3.16 Number of corn kernels per row as affected by Julian day, across hybrids at Starkville 2014.

Number of kernels per row, across hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Julian days (86, 111, 126, 139, 144) at Starkville 2014. Julian days with the same letter are not significantly different (α =0.05).

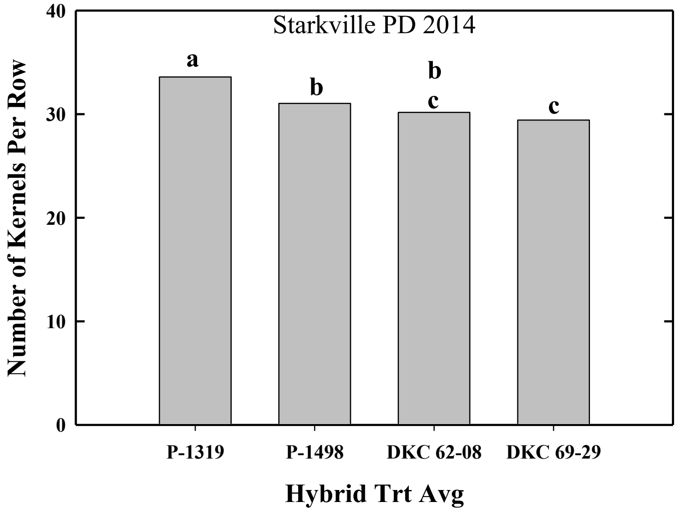

Figure 3.17 Number of corn kernels per row as affected by hybrid, across Julian days at Starkville 2014.

Number of kernels per row, across Julian days (86, 111, 126, 139, 144) for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Starkville 2014. Hybrids with the same letter are not significantly different (α =0.05).

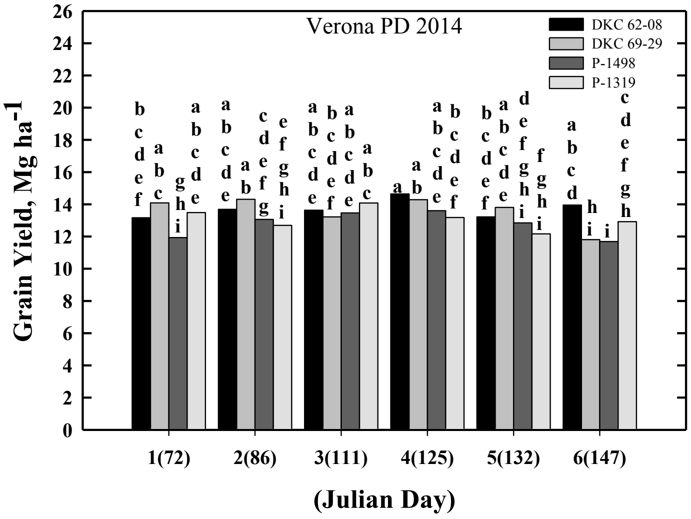

Figure 3.18 Corn grain yield as affected by the interaction between hybrid and Julian day at Verona 2014.

Grain yield for the interaction between Julian days (72, 86, 111, 125, 132, 147) and hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Verona 2014. Treatments with the same letter are not significantly different (α =0.05).

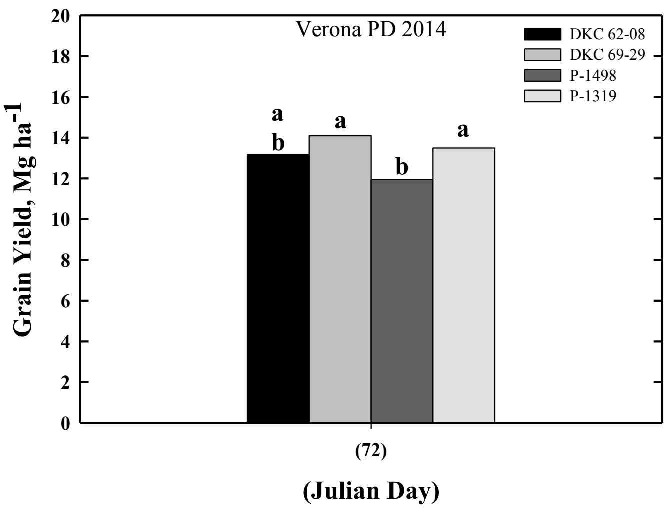

Figure 3.19 Corn grain yield as affected by Julian day 72 for all hybrids at Verona 2014.

Grain yield for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Julian day (72) at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

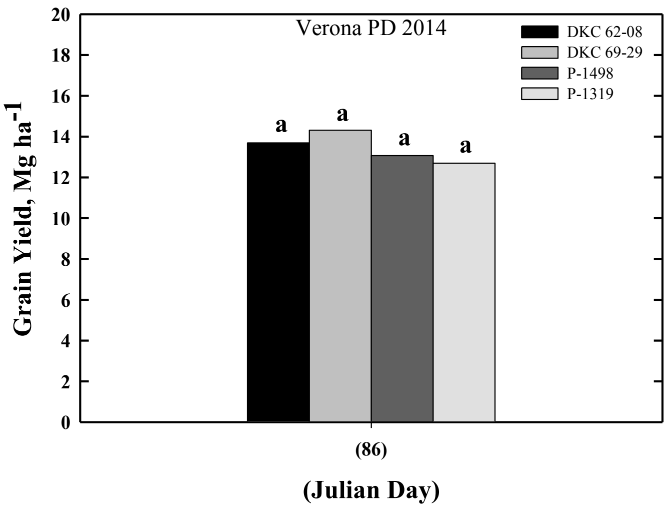

Figure 3.20 Corn grain yield as affected by Julian day 86 for all hybrids at Verona 2014.

Grain yield for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Julian day (86) at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05)

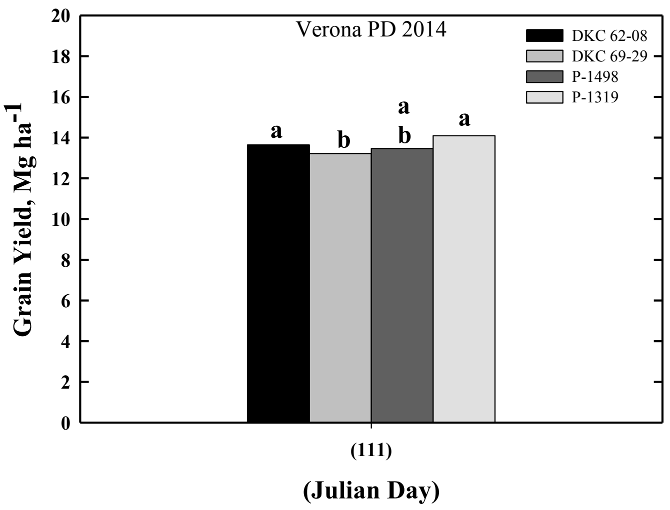

Figure 3.21 Corn grain yield as affected by Julian day 111 for all hybrids at Verona 2014.

Grain yield for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Julian day (111) at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

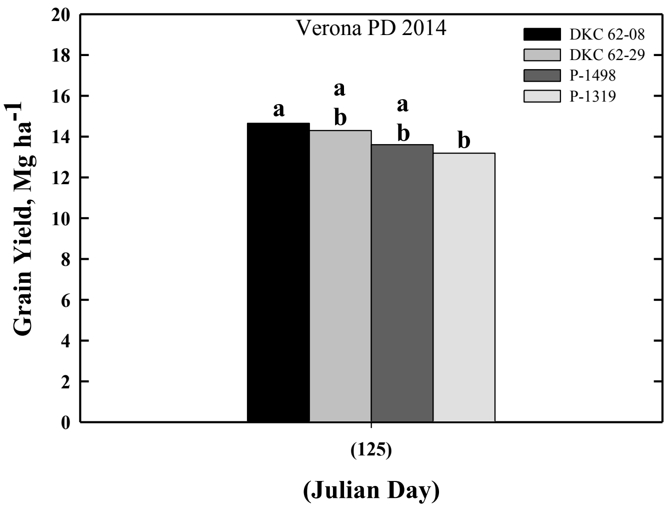

Figure 3.22 Corn grain yield as affected by Julian day 125 for all hybrids at Verona 2014.

Grain yield for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Julian day (125) at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

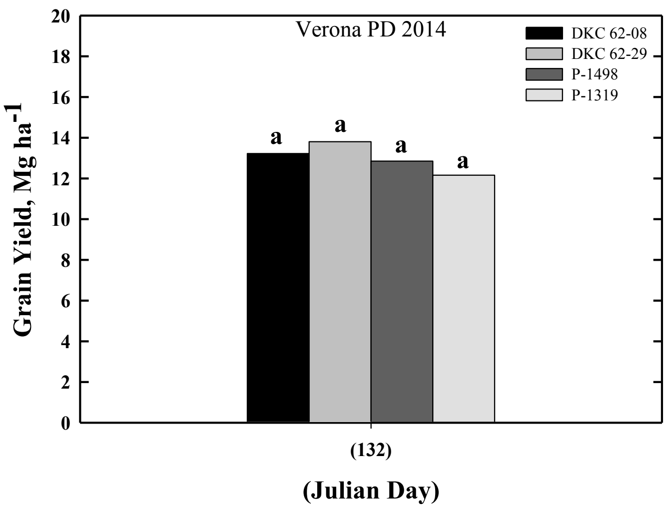

Figure 3.23 Corn grain yield as affected by Julian day 132 for all hybrids at Verona 2014.

Grain yield for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Julian day (132) at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

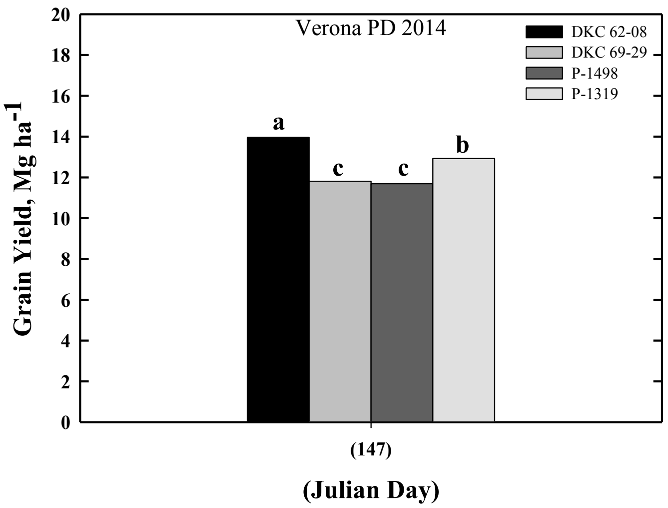

Figure 3.24 Corn grain yield as affected by Julian day 147 for all hybrids at Verona 2014.

Grain yield for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Julian day (147) at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

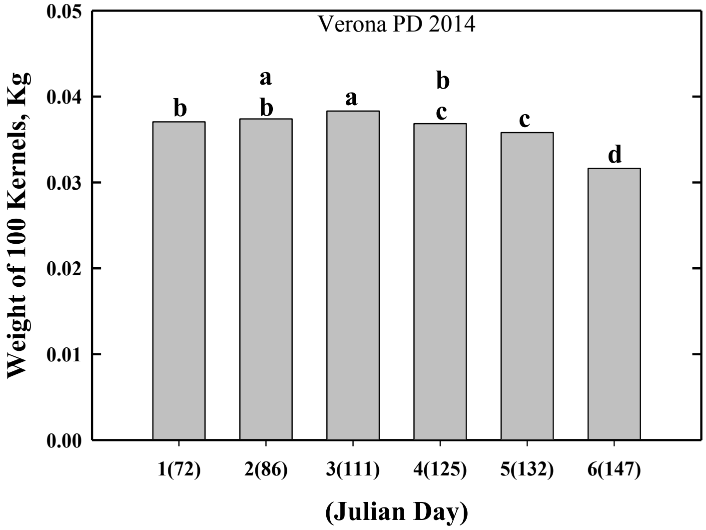

Figure 3.25 Weight of 100 corn kernels as affected by Julian day, across hybrids at Verona 2014.

Weight of 100 kernels across hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Julian days (72, 86, 111, 125, 132, 147) at Verona 2014. Julian days with the same letter are not significantly different (α =0.05).

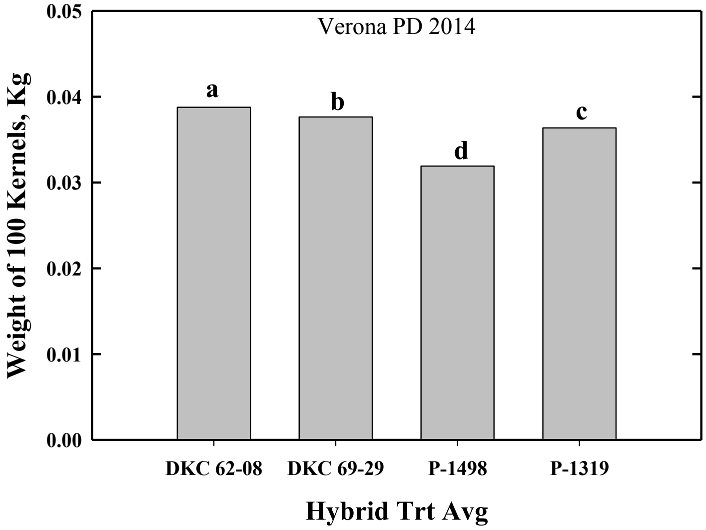

Figure 3.26 Weight of 100 corn kernels as affected by hybrid, across Julian days at Verona 2014.

Weight of 100 kernels across Julian days (72, 86, 111, 125, 132, 147) for hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

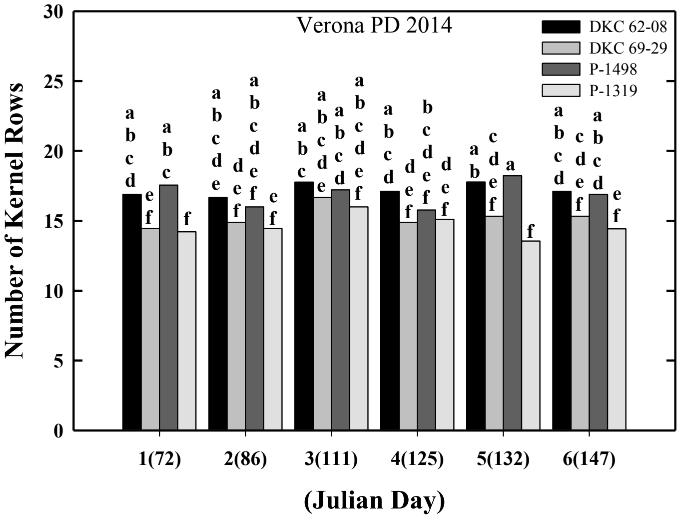

Figure 3.27 Number of corn kernel rows as affected by the interaction between Julian day and hybrid at Verona 2014.

Number kernel rows for the interaction between Julian days (72, 86, 111, 125, 132, 147) and hybrids DKC 62-08, DKC 69-29, P-1498, and P-1319 at Verona 2014. Treatments with the same letter are not significantly different (α =0.05)

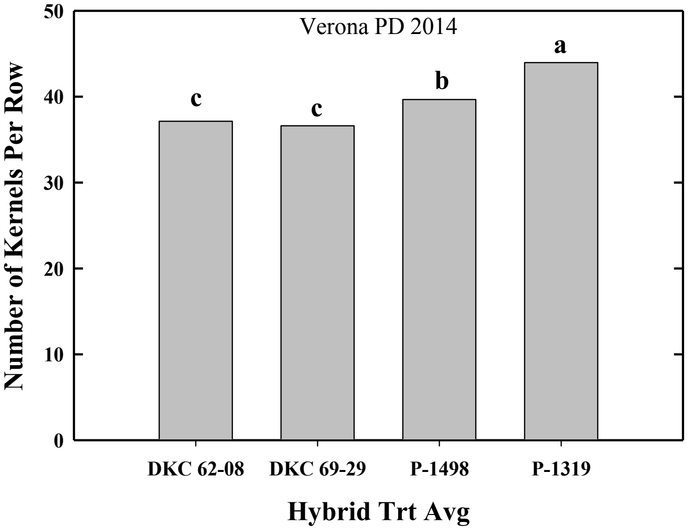

Figure 3.28 Number of corn kernels per row as affected by hybrid, across Julian days at Verona 2014.

Number of kernels per row, across Julian days (72, 86, 111, 125, 132, 147) for hybrids DKC 62-08, DKC 69-29, P-1498, P-1319, at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

Planting Density Results and Discussion

Starkville 2013

Grain yield for Starkville 2013 was affected by planting date and the interaction between planting date and hybrid (Table 2.9). Yield was not affected by population for Starkville 2013. However, it is important to note, as we examined the treatments throughout the growing season we noticed drainage problems in the lower half of the planted area. As the growing season continued visual and documented confirmation of drainage issues and field variability for this particular test site likely decreased overall yield on half of the planted treatments. Consequently, skewing data and eliminating yield differences that would have otherwise been observed by increasing populations.

Nevertheless, early planted treatments were significantly better than later planted treatments. In fact, averaged across hybrids there was an 18% grain yield advantage for early planting. Hybrid AGR-N68 had the highest grain yield of 7.89 Mg ha^{-1} at Julian day 80 and the lowest grain yield of 5.49 Mg ha^{-1} at Julian day 113. Hybrids AGR-N68 and DKC-67-57 at Julian day 80 were not significantly different from one another, but were significantly greater than P-1498 at Julian day 80 and 113 (Figure3.29).

The 100 kernel weight was affected by the interaction between population and hybrid (Table 2.9). In an effort to explain the population by hybrid interaction, hybrids were compared at each plant population individually (Figure 3.30). No statistical difference was observed between hybrids at populations of 49,400 and 61,750 plants ha^{-1}. However, hybrids DKC 67-57 and AGR-N68 were significantly greater than P-1498 at 74, 100 plants ha^{-1}. Hybrid DKC 67-57 kernel weight was 9.6% greater than P-1498 and

17.5 % greater than AGR-N68 at 86,450 plants ha^{-1}. At the highest population of 98, 800 plants ha^{-1} hybrid AGR-N68 had the lowest kernel weight of .026 Kg per 100 kernels.

Number of kernel rows was affected by both population and hybrid (Table 2.9). Averaged across hybrids the lowest plant population 49,400 plants ha^{-1} had the greatest number of kernel rows and was significantly greater than all other plant densities (Figure 3.31). Regardless of the hybrid, the number of kernel rows decreased as plant populations increased. However, hybrid P-1498 had significantly more kernel rows than DKC 67-57 and AGR-N68 (Figure 3.32).

The number of kernels per row was affected by population, planting date and hybrid (Table 2.9). Julian day 80 had significantly more kernels per row than Julian day 113. Early planted treatments had a 21% advantage in kernels per row compared to later planted treatments (Figure 3.35). Much like the number of kernel rows previously mentioned, kernels per row decreased as populations increased. The lowest population 49, 400 plants ha^{-1} averaged 33 kernels per row per ear and was significantly greater than all other plant populations (Figure 3.33). Hybrid AGR-N68 averaged 31 kernels per row per ear across populations and was significantly greater than DKC 67-57 and P-1498 (Figure 3.34).

Verona 2013

Grain yield for Verona 2013 was affected by population, hybrid, and planting date (Table 2.9). Grain yield averaged across hybrids was highest at 86,450 plants ha^{-1} and produced 12.6 Mg ha^{-1}. There was no statistical difference between 74,100 and 86,450 plants ha^{-1}; however, both produced significantly more grain yield than 49,400 plants ha^{-1} (Figure 3.38). Hybrid DKC 67-57 had the highest grain yield of 12.04 Mg ha^{-1} followed by AGR-N68 with 11.39 Mg ha^{-1} and P-1498 with 11.30 Mg ha^{-1}. Hybrid DKC 67-57 was significantly greater than P-1498 (Figure 3.36) and early planted treatments once again significantly out yielded the later planted treatments by .67 Mg ha^{-1} ($P< 0.05$). Yields averaged across hybrids and populations ranged from 11.91 for Julian day 80 to 11.24 Mg ha^{-1} for Julian day 113 (Figure 3.37). Regression analysis of grain yield for Verona 2013 indicated that yields rose with increasing plant populations up until the point of 86,450 plants ha^{-1}, and then began to decrease as population increased (Figure 3.38).

The 100 kernel weight for Verona 2013 was affected by hybrid, but not population or planting date. Hybrid DKC 67-57 had significantly higher kernel weights as compared to P-1498 and AGR-N68. In fact DKC 67-57 had a 5 % or greater kernel weight advantage over AGR-N68 and P-1498(Figure 3.39).

Number of kernel rows was affected by both population and hybrid (Table 2.9). Averaged across hybrids the plant population of 61,750 plants ha^{-1} had the greatest number of kernel rows. Although there was no significant difference between 49,400 and 61, 750 plants ha^{-1} with respect to kernel rows, they produced significantly more kernels than all other treatment populations (Figure 3.40). Hybrid P-1498 averaged 16.70 kernel rows and was significantly greater than DKC 67-57 averaging 14.87 kernel rows (Figure 3.41).

Number of kernels per row was affected by population and hybrid (Table 2.9). There was a decrease in number of kernels per row as populations increased. The lowest population of 49,400 plants ha^{-1} was significantly greater and produced 17% more kernels per row than the highest population of 98,800 plants ha^{-1} (Figure 3.42). Hybrid

P-1498 averaged 35.75 kernels per row per ear and was slightly lower than hybrid AGR-N68 averaging 37.02. Both hybrids were significantly greater than DKC-67-57 averaging 33.84 kernels per row per ear.

Brooksville 2013

Grain yield for Brooksville 2013 was affected by the interaction between population and hybrid (Table2.9). Because of the interaction grain yield is presented by hybrid for each population individually (Figure 3.44). Overall trends for grain yield regardless of hybrid showed a yield increase with increasing populations up to 86,450 plants ha^{-1}. Although hybrids did respond and yield differently to plant populations there was no statistical difference between hybrids at 49,400; 61,750; or 74,100 plants ha^{-1}. However, DKC 67-57 was significantly greater than AGR-N68 at 86,450 and 98,800 plants ha^{-1}.

The 100 kernel weight was affected by population and hybrid (Table 2.9). Kernel weights at 49,400 plant ha^{-1} averaged 15% higher than plants at 98,800 plants ha^{-1}. Regardless of hybrid, kernel weights decreased as population increased (Figure 3.45). Hybrid DKC 67-57 averaged 0.0348 Kg per 100 kernels and was significantly greater than P-1498 and AGR-N68. Hybrid P-1498 was also significantly greater than AGR-N68averaging 0.0282 Kg per 100 kernels (Figure 3.46).

Kernel rows were affected by population and hybrid (Table 2.9). Averaged across hybrids the lowest plant population 49,400 plants ha^{-1} produced the greatest number of kernel rows. Population averages ranged from 16.08 kernel rows to 14.65 kernel rows at 98,800 plants ha^{-1} (Figure 3.47). Hybrid P-1498 averaged 16.58 kernel rows across all populations and was significantly greater than DKC 67-57 and AGR-N68. There was no significant difference between DKC 67-57 and AGR-N68 (Figure 3.48).

Number of kernels per row was affected by population and hybrid (Table 2.9). Trends for number of kernels per row mimics what has been seen at previous locations with a decrease in kernels per row as populations increased. Across hybrids, the lowest population averaged 40.57 kernels per row and was significantly greater than all other treatments. A close second was 61,750 plants ha^{-1} averaging 37.53 kernels per row. There was no statistical difference between populations 74,100; 86,450; and 98,800 although they were all significantly lower than treatments at 61, 750 plants ha^{-1} (Figure 3.49). Hybrid AGR-N68 averaged 37.7 kernels per row across all populations and was significantly greater than DKC 67-57 and P-1498 (Figure 3.50)

Starkville 2014

Grain yield for Starkville 2014 was affected by population, hybrid, and planting date (Table 2.9). Grain yield averaged across hybrids was highest at 98,800 plants ha^{-1} and produced 15.5 Mg ha^{-1}. There was no statistical difference between treatments at 98,800 and 86,450 plants ha^{-1}; however, both produced significantly more grain yield than all other treatment populations. Grain yield trended up with each incremental rise in plant population (Figure 3.53).

Hybrid AGR-N68 had the highest grain yield of 14.51 Mg ha^{-1} followed by P-1498 with 14.10 Mg ha^{-1} and DKC 67-57 with 13.85 Mg ha^{-1}. Hybrid AGR-N68 was significantly greater than P-1498 and DKC 67-57(Figure 3.51). Contrary to previous planting date trends, later planted Julian day 111, produced significantly higher grain yields than Julian day 73(Figure 3.52). However, this advantage was only 4% and likely resulted from the uncharacteristically cool and wet growing conditions later in the season (Table 2.8). Regression analysis of grain yield for Starkville 2014 indicated that yields rose steadily with increasing plant populations to the highest population of 98,800 plants ha^{-1}(Figure 3.53). These results again suggest that late season moisture and reduced temperatures positively impacted grain yield and plant development. Regardless of population, plants were not limited by moisture.

The 100 kernel weight for Starkville 2014 was affected by hybrid, but not population or planting date. Like Verona 2013, DKC 67-57 had significantly higher kernel weights compared to P-1498 and AGR-N68. In fact, DKC 67-57 had a 14% or greater kernel weight advantage over AGR-N68 and P-1498 (Figure 3.54).

Number of kernel rows was affected by the interaction between population and hybrid (Table 2.9). Therefore, hybrids were compared at each individual population. Hybrid P-1498 averaged more kernel rows across all plant populations. Hybrids DKC 67-57 and P-1498 had less variation with respect to number of kernel rows (Figure 3.55).

Number of kernels per row was affected by population and hybrid (Table 2.9). Overall there was a decreasing trend in number of kernels per row as populations increased. Across hybrids the greatest number of kernels per row occurred at 61,750 plants ha^{-1}. However, there was no significant difference between 49,400 and 61,750 plants ha^{-1} (Figure 3.56). Hybrid AGR-N68 averaged 44.02 kernels per row per ear and was slightly higher than hybrid P-1498 averaging 40.75. Both hybrids were significantly greater than DKC-67-57 averaging 35.48 kernels per row per ear (Figure 3.57).

Verona 2014

Grain yield for Verona 2014 was affected by the interaction between Julian day and hybrid (Table2.9). Grain yield across hybrids for each Julian day resulted in 13.3 Mg ha^{-1} average (Figure 3.58). Hybrid DKC 67-57 averaged the highest grain yield at both Julian days 111 and 132. Hybrid AGR-N68 averaged slightly less than DKC 67-57 at both Julian days, but was not significantly less at Julian day 111. The lowest yielding hybrid for both Julian days was P-1498 at 12.43 Mg ha^{-1} planted early and 12.76 Mg ha^{-1} planted late.

The 100 kernel weight was affected by the interaction between Julian day and hybrid (Table 2.9). Kernel weights for DKC 67-57 were significantly higher than all other hybrids regardless of Julian day. Hybrids P-1498 and AGR-N68 achieved significantly higher kernel weights at Julian day 111 compared to 132. Averaged across hybrids, Julian day 111 had a 7% kernel weight advantage over Julian day 132 (Figure 3.59).

Number of kernel rows was affected by two separate interactions, a population by hybrid and population by Julian day (Table 2.9). Therefore, hybrids and Julian days were compared at each individual population. Hybrid P-1498 for a second time averaged significantly more kernel rows across populations. Hybrid DKC 67-57 and AGR-N68 showed no significant difference in number of kernel rows with the exception of 98,800 plants ha^{-1}, at which AGR-N68 had an 11% advantage over DKC67-57(Figure 3.60). Averaged across hybrid and population there was a slight advantage in number of kernel rows for Julian day 111 over 132. Additionally, Julian day 111 averaged more kernel rows at 49,400; 61,750; and 86,450 plants ha^{-1}compared to the same hybrids planted on Julian day 132 (Figure 3.61).

Number of kernels per row was affected by the interaction between population by hybrid and population by Julian day (Table 2.9). For that reason, hybrids and Julian days were compared at each individual population. Hybrid DKC 67-57 had significantly fewer kernels per row than P-1498 and AGR-N68at 49,400; 74,100; and 86,450 plants ha^{-1}. However, at 61,750 and 98,800 there was no significant difference among hybrid response to population. Hybrid AGR-N68 had a 7% advantage over P-1498 at 86,450 plants ha^{-1}, but neither hybrid was significantly different from one another at any other population (Figure 3.62). Hybrids planted at Julian day 111 averaged 5% more kernels per row than those planted on Julian day 132. Contrary to DKC 67-57 having fewest number of kernels per row at Julian day 132, AGR-N68 had significantly more kernels per row than any other hybrid at Julian day 111 (Figure 3.63).

Plant Growth and Development for Planting Density Experiments

Leaf SPAD measurements were collected for the population density experiments to act as a surrogate for N-status throughout the season. SPAD 502 Plus meter was used to measure chlorophyll content or “greenness” of plants. Thus, confirming quantifiable changes or trends in plant health without running traditional, destructive fertility analysis. SPAD measurements were taken at tasseling to observe plant health differences among populations, hybrids and planting dates.

Leaf SPAD readings for Starkville 2013 were affected by population, planting date, and hybrid (Table 2.9). SPAD values ranged from 40.63 at 49,400 plants ha^{-1} to 32.44 at 61,750 plants ha^{-1}. SPAD values for all populations varied by 20% or less. Early planted treatments had 28% higher SPAD values and were significantly greater than later planted treatments. Hybrid AGR-N68 was significantly greater than DKC 67-57 and P-1498. Although, SPAD values were significantly different across treatments, they were within 17% of each other. In fact, all hybrids were 32 or greater in value and differences were more likely caused by field variability rather than fertility.

Verona 2013 SPAD values were affected by planting date and hybrid (Table2.9). Early planting once again resulted in higher SPAD values and AGR-N68 was significantly greater than DKC 67-57 and P-1498. Brooksville 2013 did not have a planting date component so planting date was not a factor. Populations however revealed higher SPAD values for lower populations. There was a decrease in value for each increase in population. SPAD values ranged from 57.55 at 49,400 plants ha ha^{-1} to 51.08 at 98,800 plants ha^{-1}.

Starkville and Verona 2014 SPAD values were affected by a planting date hybrid interaction (Table 2.9). Once again early planted treatments exhibited higher SPAD values and AGR-N68 lead other hybrids. Starkville SPAD values ranged from 55.93 for AGR-N68 at Julian day 73 to 39.13 for P-1498 at Julian day 111. Verona SPAD values ranged from 49.43 at Julian day 111 to 36.07 at Julian day 132 for AGR-N68.

AccuPar LP-80 measurements were taken at tasseling (VT) to quantify the amount of light transmitted through the plant canopy giving us the leaf area index (LAI) for populations, hybrids and planting date treatments. The LAI numerical value helps predict photosynthetic evapotranspiration and was used as reference tool to observe crop growth and development. After statistical analysis the following LAI differences in canopy coverage were observed for populations, hybrids and planting dates.

Starkville 2013 LAI was affected by population, planting date and hybrid (Table 2.9). LAI values increased as population increased. Values ranged from 3.85 at 98,800 plants ha^{-1} to 3.05 at 49,400 plants ha^{-1}. Earlier planted treatments also had higher values ranging from 3.67 to 3.24. Hybrid AGR-N68 had the highest LAI of 3.76 and was significantly higher than P-1498 at 3.14.

Verona 2013 exhibited similar LAI data. Population LAI values ranged from 5.05 at 98,800 plants ha^{-1} to 3.91 at 49,400 plants ha^{-1}. LAI values for Julian day 108were 4.74 and 4.38 for Julian day 121. Hybrid AGR-N68 once again had the highest LAI of 5.04 and was significantly higher than P-1498 and DKC 67-57.

Verona 2014 had the highest overall LAI values compared to previous years and locations. This was likely a result of the exceptional season long growing conditions. LAI values ranged from 6.39 at 98,800 plants ha^{-1} to 4.14 at 49,400 plants ha^{-1}. Furthermore, hybrid P-1498 treatments grew taller than DKC-67-57 and AGR-N68. Julian day 73 at 98,800 plants ha^{-1} averaged 50% higher LAI values than treatments at 49,400 plants ha^{-1} planted on Julian day 111. Hybrid AGR-N68 at 98,800 plants ha^{-1} again had the highest LAI of 4.88.

Plant heights for Starkville 2013 were affected by population, planting date, and hybrid (Table 2.9). Heights ranged from 212.54 cm at 49,400 plants ha^{-1} to 199.54 cm at 86,450 plants ha^{-1}. Julian day 80 plant heights averaged 8% taller and were significantly greater than Julian day 113. Hybrid P-1498 was significantly taller than DKC 67-57 and AGR-N68.

Plant heights for Verona 2013 were also affected by population, planting date, and hybrid (Table 2.9). Heights ranged from 252.95 cm at 49,400 plants ha^{-1} to 232.81 cm at

98,800 plants ha^{-1}. Julian day 108 plant heights averaged 5% taller and were significantly greater than Julian day 121. Hybrid P-1498 averaged 13% taller and was significantly greater than DKC 67-57 and AGR-N68.

Brooksville 2013 plant heights were affected by population and hybrid (Table 2.9). Heights ranged from 274.67 cm at 49,400 plants ha^{-1} to 257.96 cm at 98,800 plants ha^{-1}. Hybrid P-1498 was 10–13 percent taller and significantly greater than DKC 67-57 and Syn-31.

Verona 2014 results were similar to 2013. Plant heights were affected by population, planting date, and hybrid (Table 2.9). Heights ranged from 250.95 cm tall at 49,400 plants ha^{-1} to 239.01 cm at 98,800 plants ha^{-1}. Julian day 111 plant heights averaged 7% taller and were significantly greater than treatments at Julian day 132. Hybrid P-1498 was significantly taller than DKC 67-57 and AGR-N68. Both hybrids were 11% shorter than P-1498.

Starkville 2014 plant heights were affected by planting date and hybrid, but not population (Table 2.9). Unlike previous results Julian day 111 plant heights averaged 6% taller and were significantly greater than Julian day 73. However, DKC 67-57 and AGR-N68 were again significantly shorter than P-1498.

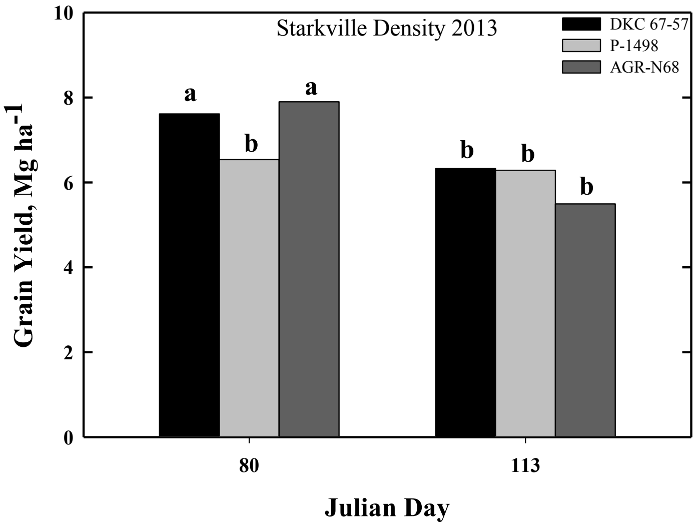

Figure 3.29 Corn grain yield as affected by the interaction between Julian day and hybrid at Starkville 2013.

Grain yield interaction between hybrids DKC 67-57, P-1498, AGR-N68and Julian days, across populations at Starkville 2013. Hybrids with the same letter are not significantly different (α =0.05).

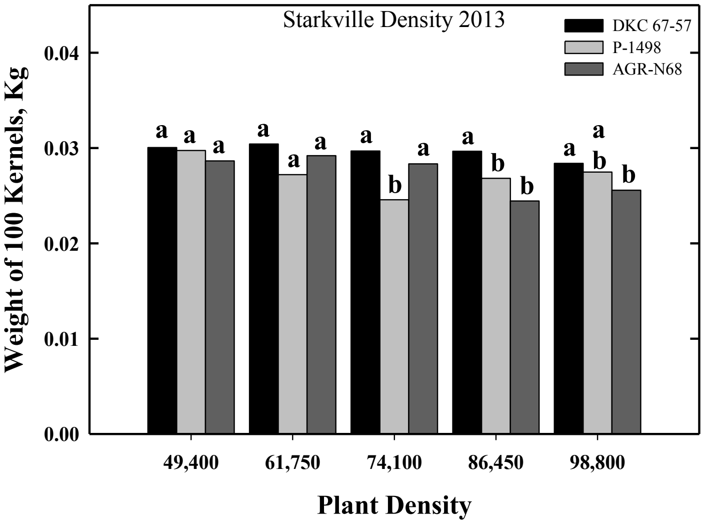

Figure 3.30 Weight of 100 corn kernels as affected by the interaction between hybrid and population across Julian days at Starkville 2013.

Weight of 100 kernels interaction between populations and hybrids DKC 67-57, P-1498, and AGR-N68 across Julian days (80, 113) at Starkville 2013. Hybrids within each population with the same letter are not significantly different (α =0.05).

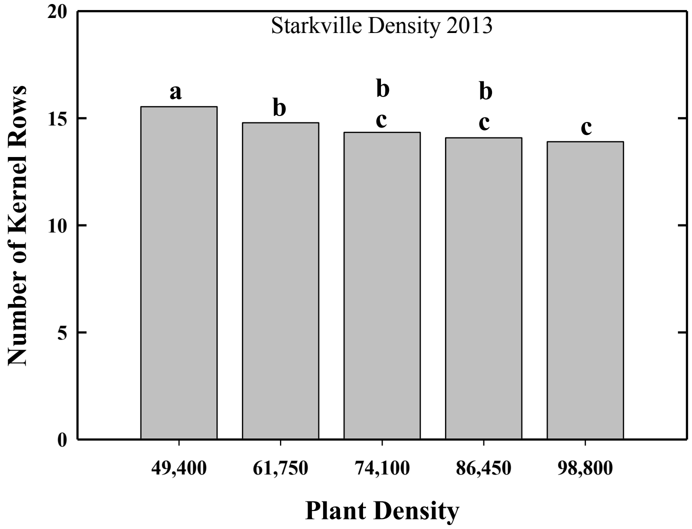

Figure 3.31 Number of corn kernel rows as affected by population, across hybrids at Starkville 2013.

Number of kernel rows affected by population, across hybrids DKC 67-57, P-1498, AGR-N68, and Julian days (80, 113) at Starkville 2013. Populations with the same letter are not significantly different (α =0.05).

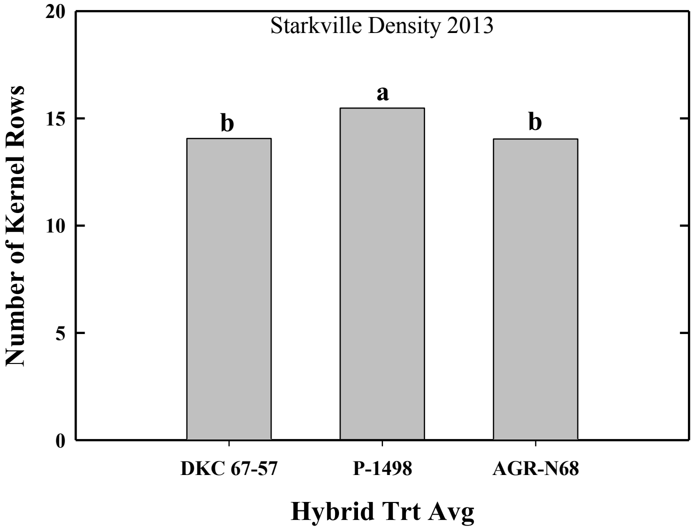

Figure 3.32 Number of corn kernel rows as affected by hybrid, across populations and Julian days at Starkville 2013.

Number of kernel rows affected by hybrids DKC 67-57, P-1498, AGR-N68, across populations and Julian days (80, 113) at Starkville 2013. Hybrids with the same letter are not significantly different (α =0.05).

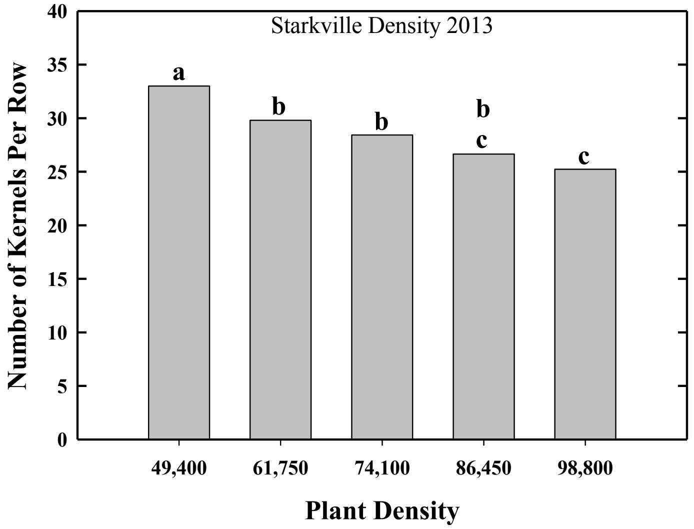

Figure 3.33 Number of corn kernels per row as affected by population, across hybrids and Julian days at Starkville 2013.

Number of kernels per row affected by population, across hybrids DKC 67-57, P-1498, AGR-N68, and Julian days (80, 113) at Starkville 2013. Populations with the same letter are not significantly different (α =0.05).

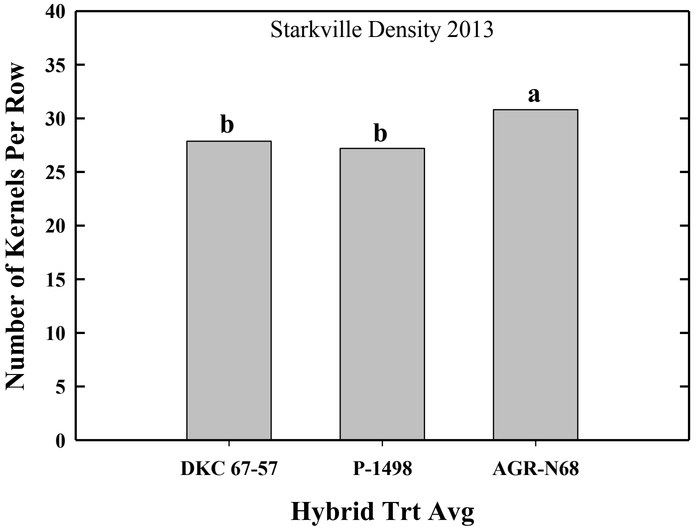

Figure 3.34 Number of corn kernels per row as affected by hybrid, across populations and Julian days at Starkville 2013.

Number of kernels per row affected by hybrids DKC 67-57, P-1498, AGR-N68, across populations and Julian days (80, 113) at Starkville 2013. Hybrids with the same letter are not significantly different (α =0.05).

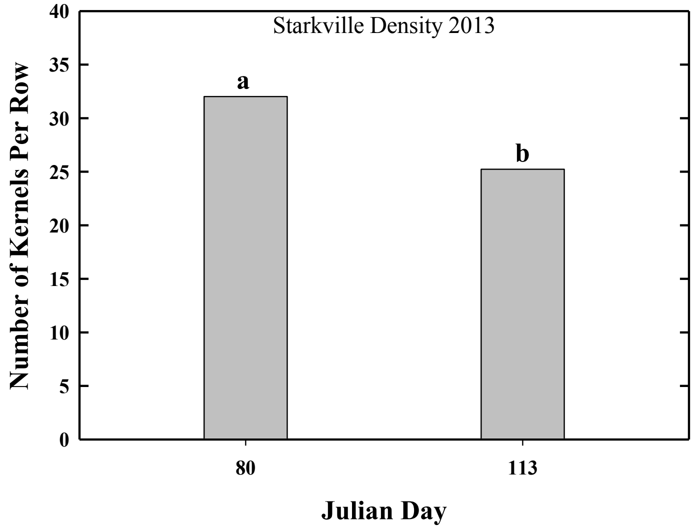

Figure 3.35 Number of corn kernels per row as affected by Julian day across hybrids and populations at Starkville 2013.

Number of kernels per row affected by Julian day, across hybrids DKC 67-57, P-1498, AGR-N68 and populations at Starkville 2013. Julian days with the same letter are not significantly different (α =0.05).

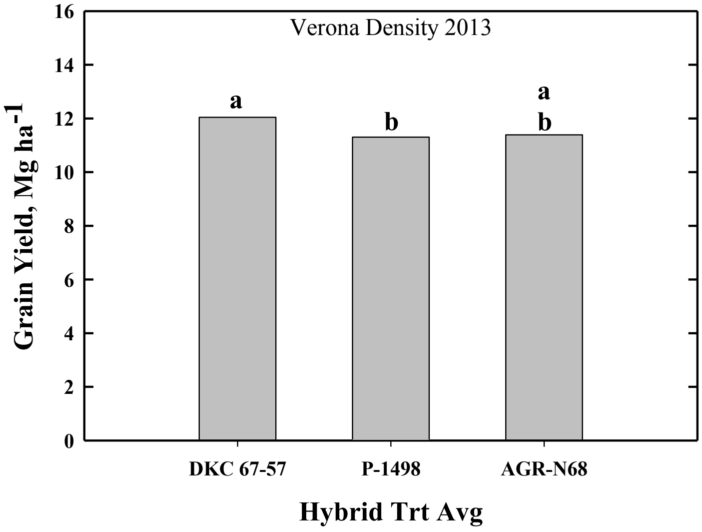

Figure 3.36 Corn grain yield as affected by hybrid across populations and Julian days at Verona 2013.

Grain yield affected by hybrids DKC 67-57, P-1498, AGR-N68, across populations and Julian days at Verona 2013. Hybrids with the same letter are not significantly different (α =0.05).

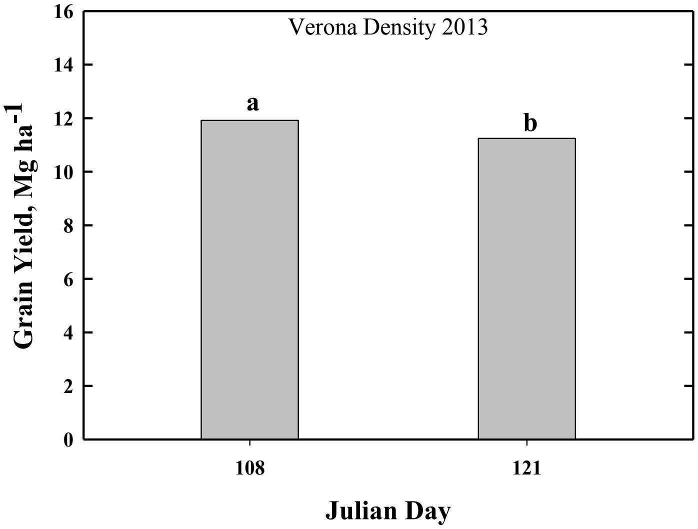

Figure 3.37 Corn grain yield as affected by Julian day across populations and hybrids at Verona 2013.

Grain yield affected by Julian day, across populations and hybrids DKC 67-57, P-1498, AGR-N68 at Verona 2013. Julian days with the same letter are not significantly different (α =0.05).

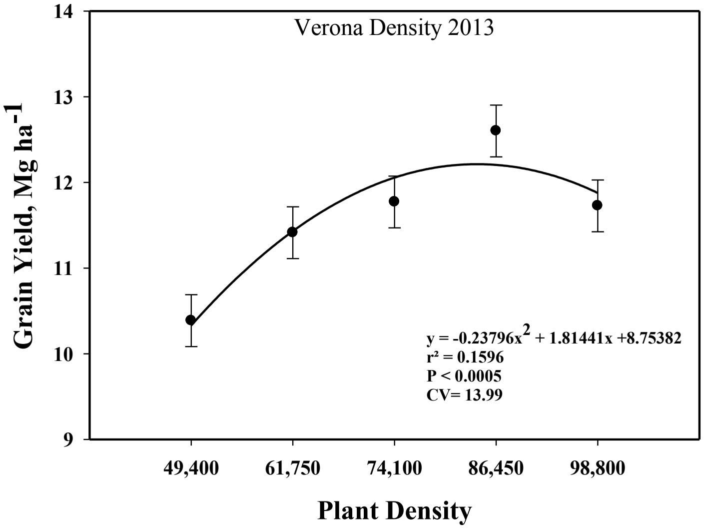

Figure 3.38 Regression analysis of corn grain yield for Verona 2013.

Relationship between grain yield and population at Verona 2013. Grain yield averaged across hybrids DKC 67-57, P-1498, AGR-N68, and Julian days.

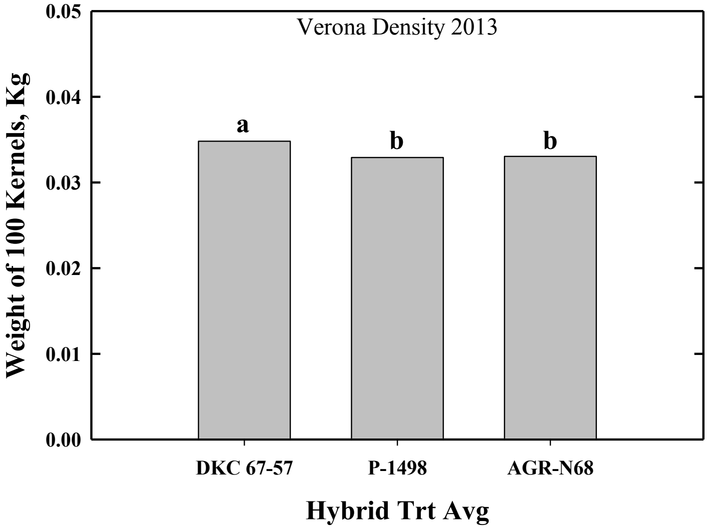

Figure 3.39 Weight of 100 corn kernels as affected by hybrid, across populations and Julian days at Verona 2013.

Weight of 100 kernels affected by hybrids DKC 67-57, P-1498, AGR-N68, across populations and Julian days at Verona 2013. Hybrids with the same letter are not significantly different (α =0.05).

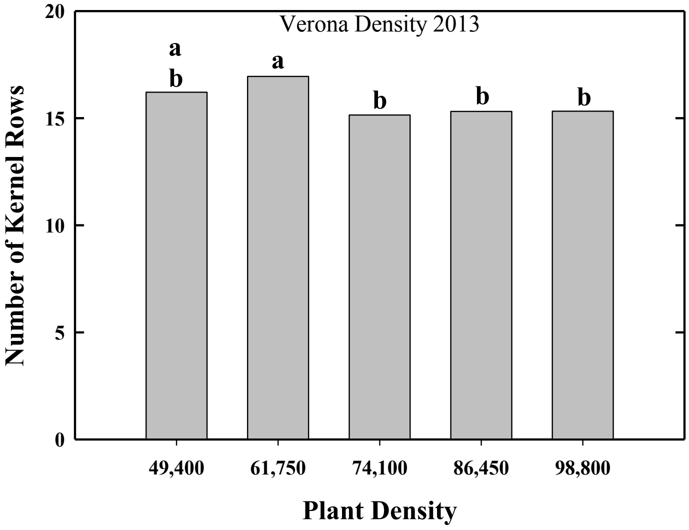

Figure 3.40 Number of corn kernel rows as affected by population, across hybrids and Julian days at Verona 2013.

Number of kernel rows affected by population, across hybrids DKC 67-57, P-1498, AGR-N68, and Julian days at Verona 2013. Populations with the same letter are not significantly different (α =0.05).

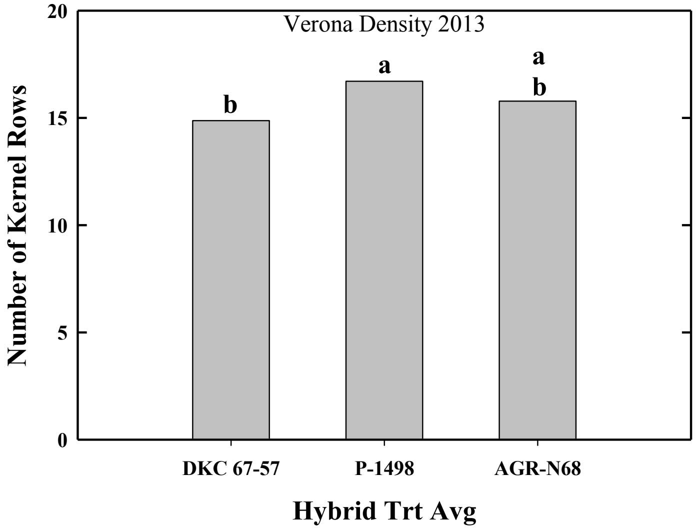

Figure 3.41 Number of corn kernel rows as affected by hybrid, across populations and Julian days at Verona 2013.

Number of kernel rows affected by hybrids DKC 67-57, P-1498, AGR-N68, across populations and Julian days at Verona 2013. Hybrids with the same letter are not significantly different (α =0.05).

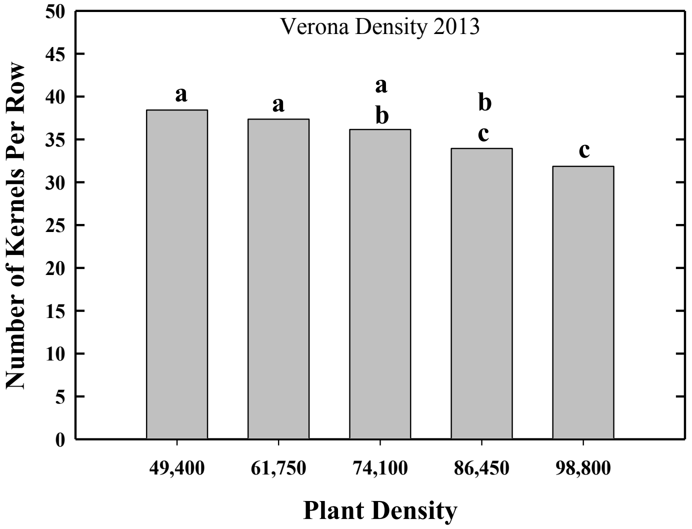

Figure 3.42 Number of corn kernels per row as affected by population, across hybrids and Julian days at Starkville 2013.

Number of kernels per row affected by population, across hybrids DKC 67-57, P-1498, AGR-N68, and Julian days at Verona 2013. Populations with the same letter are not significantly different (α =0.05).

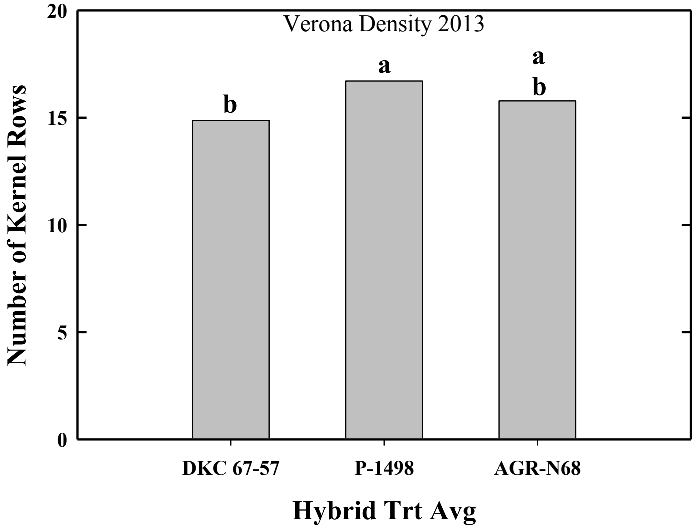

Figure 3.43 Number of corn kernel rows as affected by hybrid, across populations and Julian days at Verona 2013.

Number of kernels per row affected by hybrids DKC 67-57, P-1498, and AGR-N68across populations and Julian days at Verona 2013. Hybrids with the same letter are not significantly different (α =0.05).

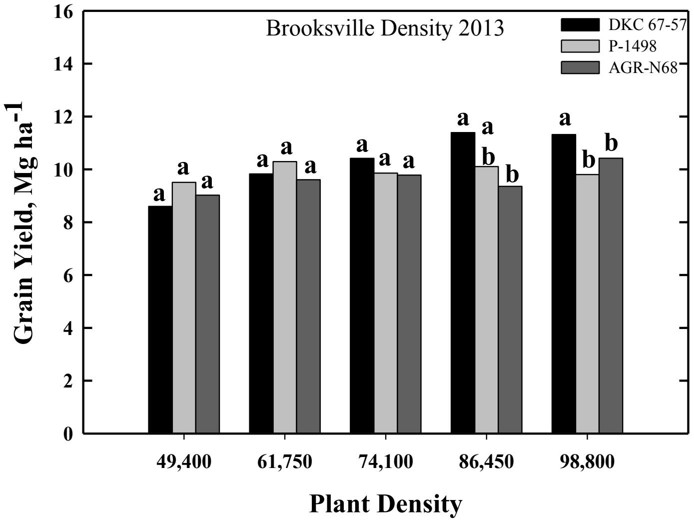

Figure 3.44 Corn grain yield as affected by the interaction between population and hybrid at Brooksville 2013.

Grain yield affected by hybrids DKC 67-57, P-1498, and AGR-N68 and populations at Brooksville 2013. Hybrids within each population that have the same letter are not significantly different (α =0.05).

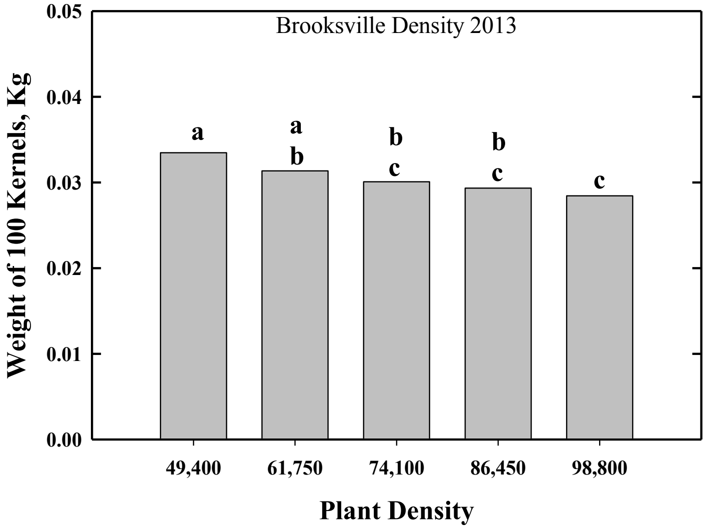

Figure 3.45 Weight of 100 corn kernels as affected by population, across hybrids at Brooksville 2013.

Weight of 100 kernels affected by population across hybrids DKC 67-57, P-1498, and AGR-N68 at Brooksville 2013. Populations with the same letter are not significantly different (α =0.05).

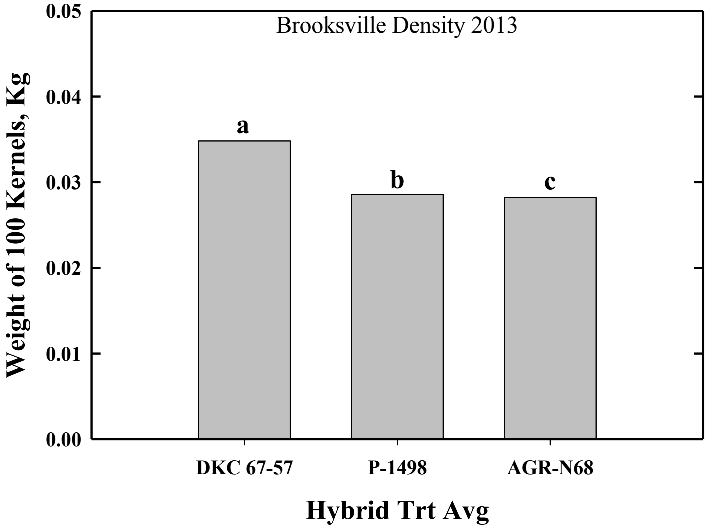

Figure 3.46 Weight of 100 corn kernels as affected by hybrid, across populations at Brooksville 2013.

Weight of 100 kernels affected by hybrids DKC 67-57, P-1498, and AGR-N68, across populations at Brooksville 2013. Hybrids with the same letter are not significantly different (α =0.05).

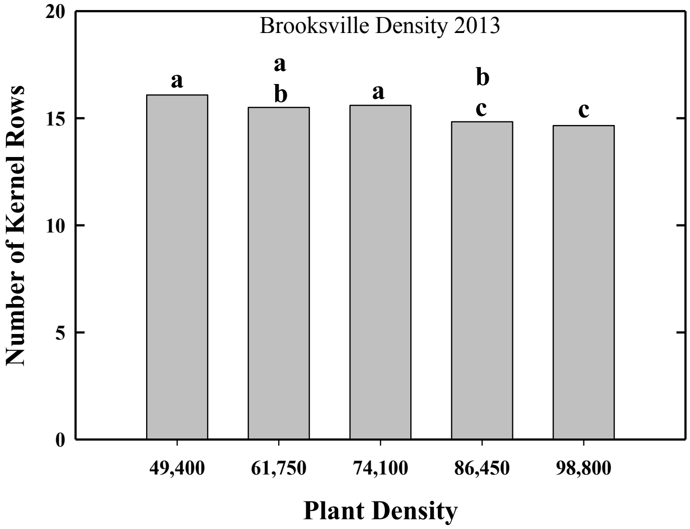

Figure 3.47 Number of corn kernel rows as affected by population, across hybrids at Brooksville 2013.

Number of kernel rows affected by population, across hybrids DKC 67-57, P-1498, AGR-N68, at Brooksville 2013. Populations with the same letter are not significantly different (α =0.05).

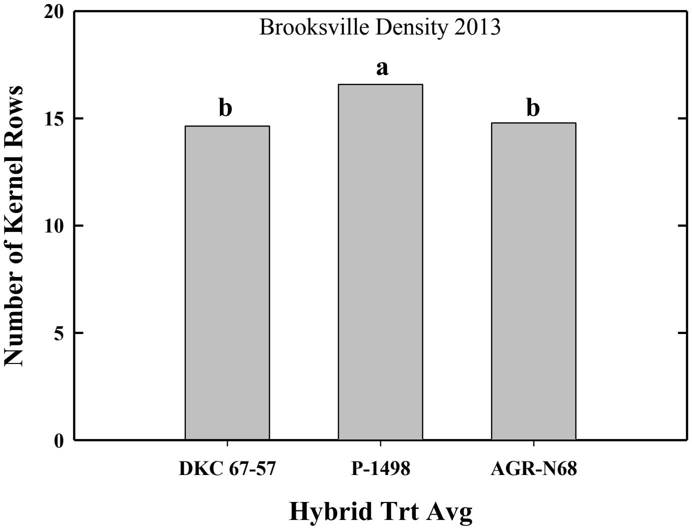

Figure 3.48 Number of corn kernel rows as affected by hybrid, across populations at Brooksville 2013.

Number of kernel rows affected by hybrids DKC 67-57, P-1498, and AGR-N68, across populations at Brooksville 2013. Hybrids with the same letter are not significantly different (α =0.05).

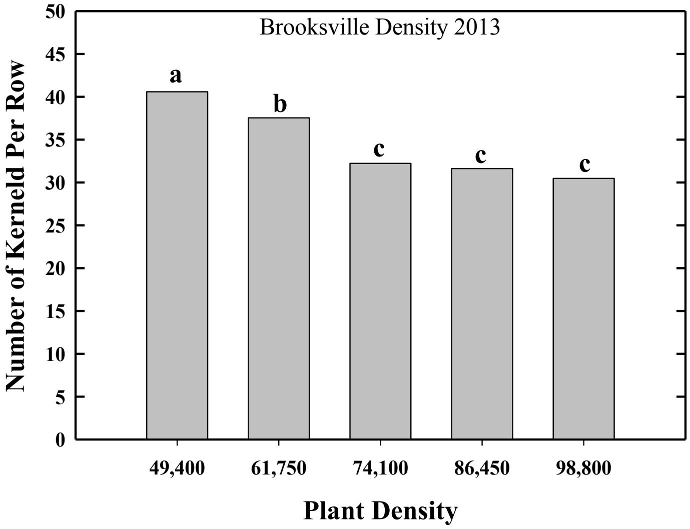

Figure 3.49 Number of corn kernels per row as affected by population, across hybrids at Brooksville 2013.

Number of kernels per row affected by population, across hybrids DKC 67-57, P-1498, AGR-N68,at Brooksville 2013. Populations with the same letter are not significantly different (α =0.05).

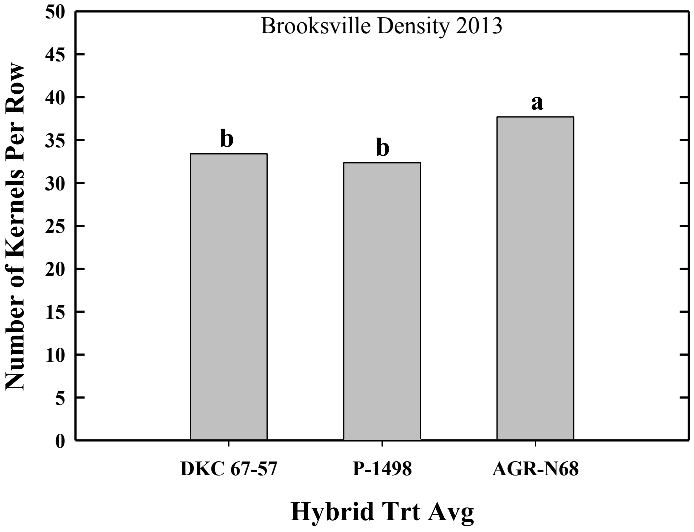

Figure 3.50 Number of corn kernels per row as affected by hybrid, across populations at Brooksville 2013.

Number of kernels per row affected by hybrids DKC 67-57, P-1498, and AGR-N68, across populations at Brooksville 2013. Hybrids with the same letter are not significantly different (α =0.05).

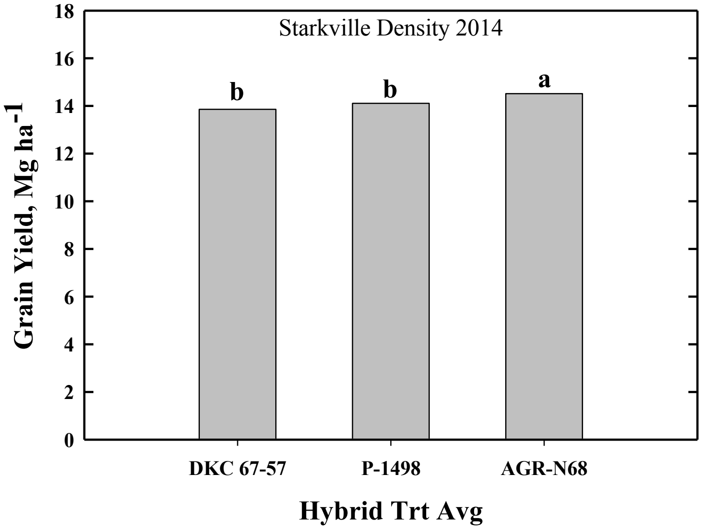

Figure 3.51 Corn grain yield as affected by hybrid, across populations and Julian days at Starkville 2014.

Grain yield affected by hybrids DKC 67-57, P-1498, AGR-N68, across populations and Julian days at Starkville 2014. Hybrids with the same letter are not significantly different (α =0.05).

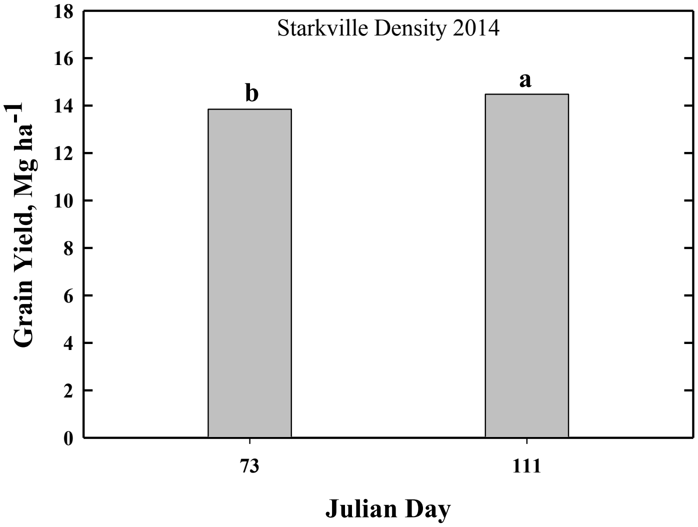

Figure 3.52 Corn grain yield as affected by Julian day, across populations and hybrids at Starkville 2014.

Grain yield affected by Julian Day across, populations and hybrids DKC 67-57, P-1498, AGR-N68at Starkville 2014. Julian days with the same letter are not significantly different (α =0.05).

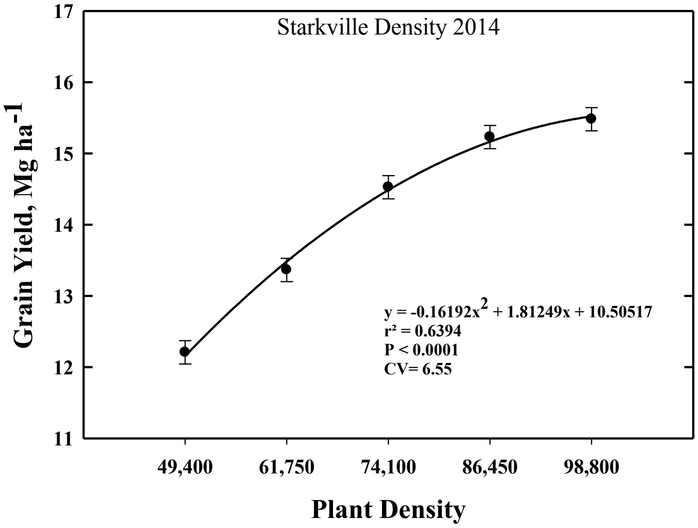

Figure 3.53 Regression analysis of corn grain yield for Starkville 2014.

Relationship between grain yield and population at Starkville 2014. Grain yield averaged across hybrids DKC 67-57, P-1498, AGR-N68, and Julian days.

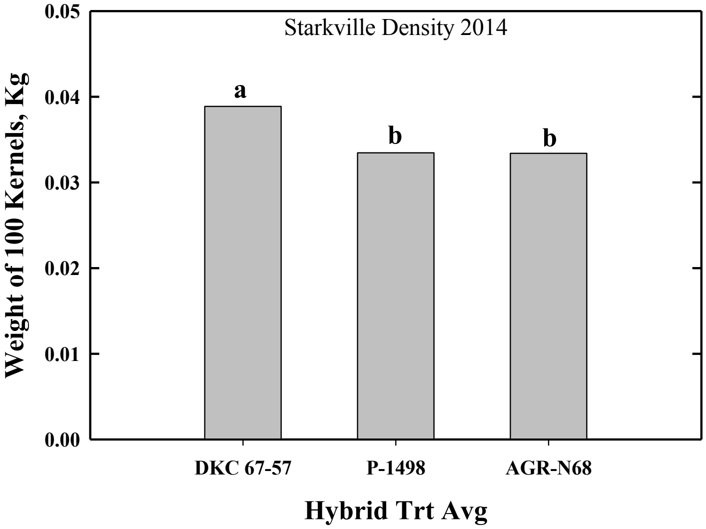

Figure 3.54 Weight of 100 corn kernels as affected by hybrid, across populations and Julian days at Starkville 2014.

Weight of 100 kernels affected by hybrids DKC 67-57, P-1498, and AGR-N68, across populations and Julian days at Starkville 2014. Hybrids with the same letter are not significantly different (α =0.05).

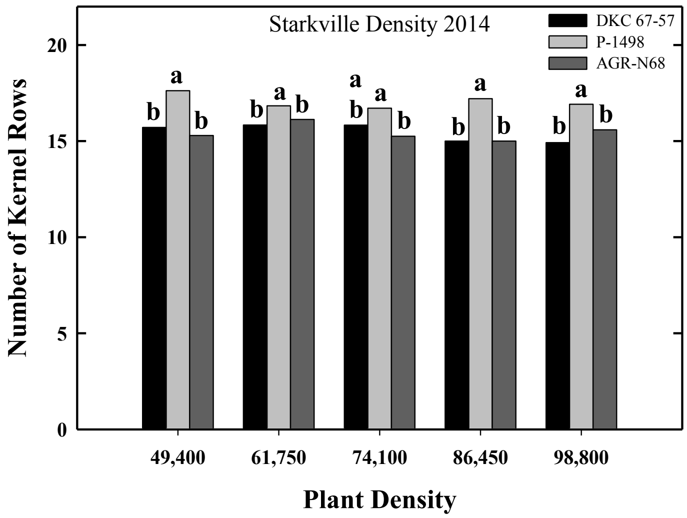

Figure 3.55 Number of corn kernel rows as affected by the interaction between population and hybrid at Starkville 2014.

Number of kernel rows, affected by hybrids DKC 67-57, P-1498, and AGR-N68 and population at Starkville 2014. Hybrids within each population that have the same letter are not significantly different (α =0.05).

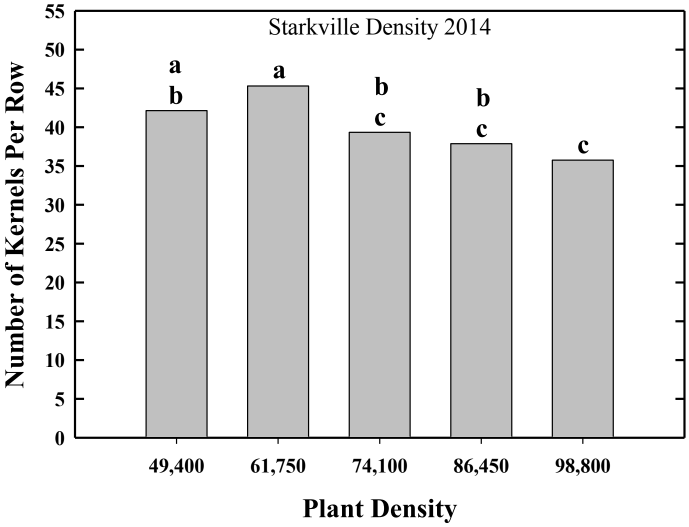

Figure 3.56 Number of corn kernels per row as affected by population, across hybrids and Julian days at Starkville 2014.

Number of kernels per row affected by population, across hybrids DKC 67-57, P-1498, AGR-N68 and Julian days at Starkville 2014. Populations with the same letter are not significantly different (α =0.05).

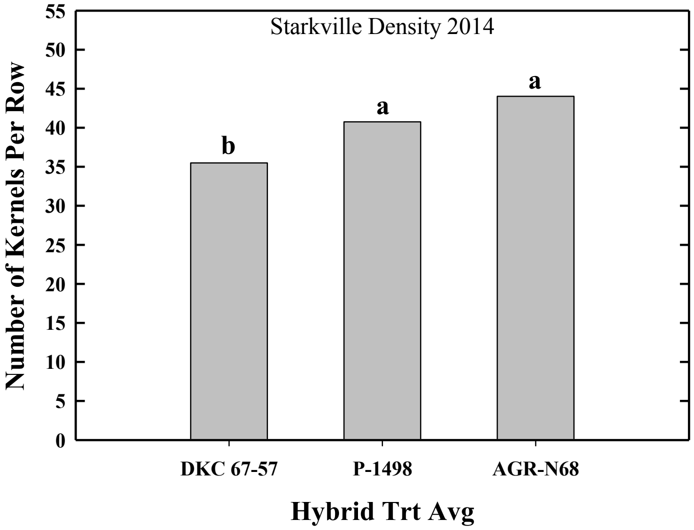

Figure 3.57 Number of corn kernels per row as affected by hybrid, across populations and Julian days at Starkville 2014.

Number of kernels per row affected by hybrids DKC 67-57, P-1498, and AGR-N68, across populations and Julian days at Starkville 2014. Hybrids with the same letter are not significantly different (α =0.05).

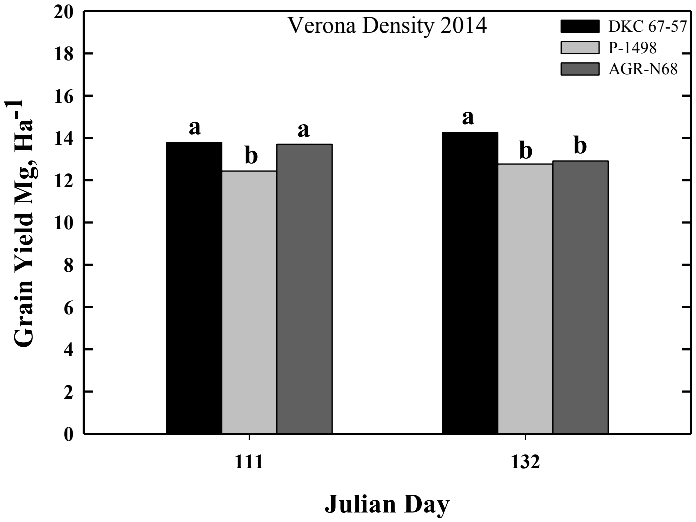

Figure 3.58 Corn grain yield as affected by the interaction between Julian day and hybrid at Verona 2014.

Grain yield interaction between hybrids DKC 67-57, P-1498, AGR-N68and Julian days, across populations at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

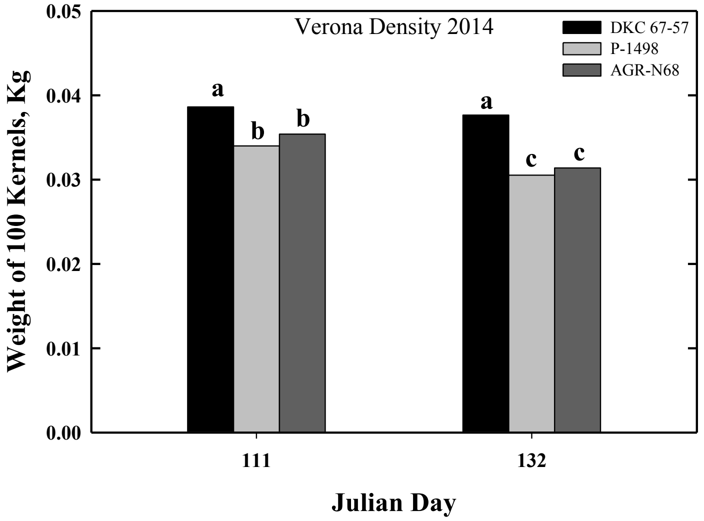

Figure 3.59 Weight of 100 corn kernels as affected by the interaction between hybrid and Julian day, across population at Verona 2014.

Weight of 100 kernels interaction between Julian day and hybrids DKC 67-57, P-1498, and AGR-N68 across populations at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

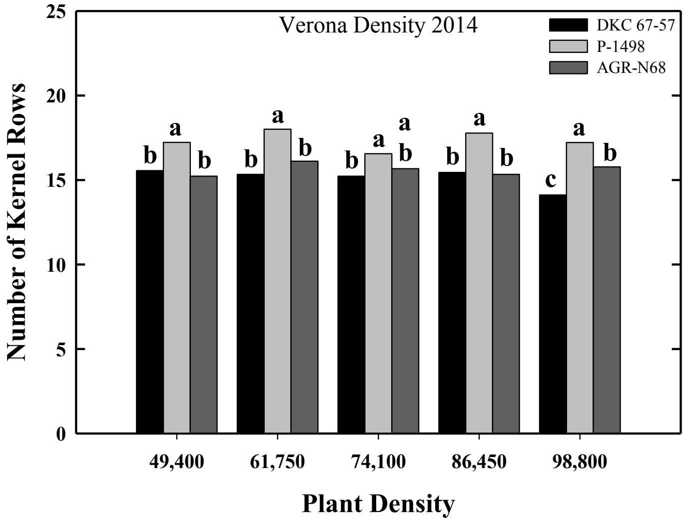

Figure 3.60 Number of corn kernel rows as affected by the interaction between population and hybrid at Verona 2014.

Number of kernel rows interaction between population and hybrids DKC 67-57, P-1498, AGR-N68, across Julian days (111, 132) at Verona 2014. Hybrids within each population that have the same letter are not significantly different (α =0.05).

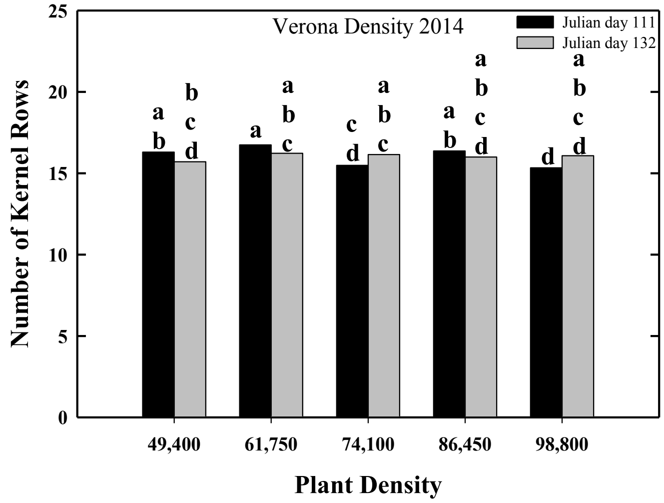

Figure 3.61 Number of corn kernel rows as affected by the interaction between population and Julian day at Verona 2014.

Number of kernel rows interaction between population and Julian day, across hybrids DKC 67-57, P-1498, AGR-N68 at Verona 2014. Julian days with the same letter are not significantly different (α =0.05).

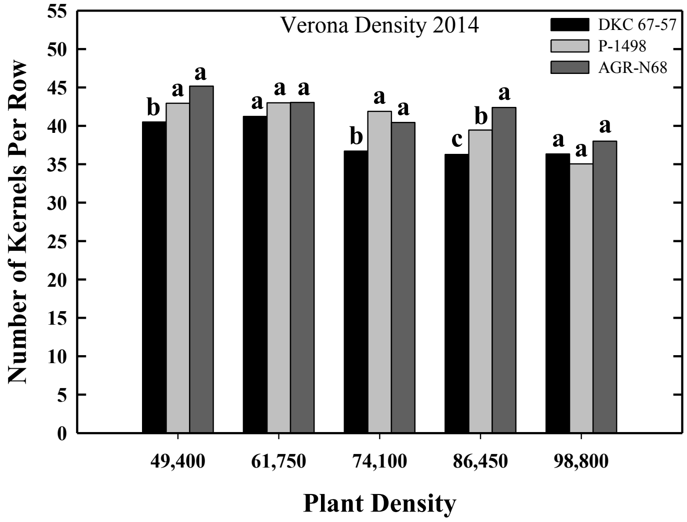

Figure 3.62 Number of corn kernels per row as affected by the interaction between population and hybrid, across Julian days at Verona 2014.

Number of kernels per row interaction between population and hybrids DKC 67-57, P-1498, AGR-N68, across Julian days (111, 132) at Verona 2014. Hybrids within each population that have the same letter are not significantly different (α =0.05).

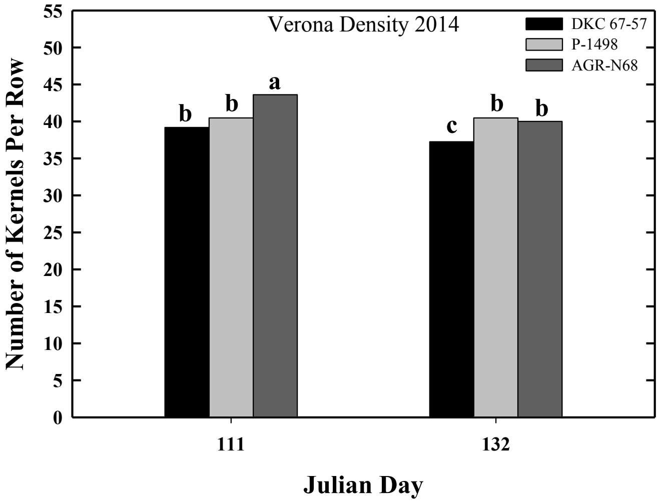

Figure 3.63 Number of corn kernels per row as affected by the interaction between hybrid and Julian day, across populations at Verona 2014.

Number of kernel rows interaction between Julian day and hybrids DKC 67-57, P-1498, AGR-N68, across populations at Verona 2014. Hybrids with the same letter are not significantly different (α =0.05).

Weather

Rainfall and temperature varied at Starkville and Verona, MS during 2013 and 2014 experiments (Table 2.3). Because growth and development of the corn experiments took place between March and August air temperature and rainfall was evaluated at that time period. Spring conditions for the most part were considered normal. Early planting conditions were wet and cold however, late season conditions were less representative of what has been seen in recent years. Rainfall was more frequent the latter part of the growing season, especially June. The overall temperatures of both growing seasons were lower, but night time temperatures especially appeared lower than what is considered normal.

Starkville 2013

Starkville 2013 rainfall was slightly below the 30-year average during March. Rainfall during April however was 25% above the 30-year average. May was also higher receiving 33% more rainfall than the 30-year average. June, July, and August all received less rainfall than the 30-year average. Temperatures for Starkville 2013 were below the 30-year average for March through August. The most noticeable difference in 30-year mean temperature was a 38% decrease for March.

Verona 2013

Verona 2013 was 21% below the 30-year average for rainfall during March, but 4% greater during April. May precipitation was 14% above the 30-year average. June received 56% less rainfall than the 30-year average and July was 30% below normal.

August rainfall accumulation was average. Temperatures for the Verona 2013 growing season were all below the 30-year average excluding a 2% temperature increase for June.

Brooksville 2013

Long term weather data specifically for Brooksville was not available so the 2013 weather data was compared to Starkville's 30-year average for comparison. Brooksville 2013 March precipitation was 10% and May was 37% below the 30-year average. April however was 30% above the 30-year average. June received 20% and August 40% more precipitation than the 30-year average. July received 20% less rainfall than the 30-year mean. Brooksville average monthly temperatures were below the 30-year average during March, April, May and June. Although, July and August both averaged greater than 3% higher temperatures compared to the 30-year average.

Starkville 2014

Starkville 2014 rainfall was below the 30-year average for March, May, July, and August by. However, April was 45% and June was 49% above the 30-year average. Monthly temperatures for Starkville 2014 averaged below the 30-year average during March, April, and July. Temperatures during May and June were slightly higher averaging between .2°C and .5°C above the 30-year average. August mean temperatures were normal.

Verona 2014

Verona 2014 precipitation was below the 30-year average for March, May, and August. Rainfall received during April was 34% above the 30-year average. June and July received 54% and 26% above the 30-year average rainfall. Temperatures for Verona

2014 were below the 30-year average for March through August. The most noticeable temperature decrease was in July with temperatures 10% cooler than the 30-year average.

CHAPTER IV

CONCLUSIONS

Planting Date Conclusion

During the two years and two locations in central Mississippi, corn response to planting date and hybrid varied by year and location. Both years and locations experienced, for the most part, normal early season wet and cool growing conditions. Like most years, early planted experiments started with adequate soil moisture near field capacity and were exposed to poor growing conditions. Additional stress was put on the early planting experiments with less than optimal soil temperature ranging from 8.8°C to 10°C. Although, conditions were not conducive for seeds to emerge as quickly as some of the later planted treatments there was no observed stand or germination penalties associated with early planting.

Some treatments took 18 to 21 days to emerge because of cool temperatures and early planting, but the delayed emergence did not appear to harm plants or negatively affect yield. Yield penalties for early planting were less significant than the yield loss associated with delayed planting. Starkville 2013 suffered a grain yield loss of .12 Mg ha^{-1} for each week that planting was delayed after the initial planting date. Hybrid DKC 62-08 was the highest yielding at 13.20 Mg ha^{-1} and Dekalb hybrids had higher 100 kernel weights than Pioneer hybrids. DKC 62-08 and P-1498 had the highest kernel rows and earlier planting appeared to increase the number of kernels per row and LAI values.

Verona 2013 yields ranged from 13.54 Mg ha^{-1} for the earliest planting date to 10.70 Mg ha^{-1} for the latest planting date. May planting resulted in decreased number of kernel rows and yield losses of .49 Mg ha^{-1} per week for planting after Julian day 108. Hybrids DKC 62-08 and P-1498 again had the most kernel rows, and the two Dekalb hybrids had greater kernel weights than the Pioneer hybrids. SPAD values at or above 55 indicated that fertility was not limiting, but planting date did affect LAI and plant height negatively as plating dates extended into May.

Starkville 2014, yields ranged from 14.08 Mg ha^{-1} for the earliest planting date to 7.45 Mg ha^{-1} for the latest planting date. The 58 day planting delay resulted in a 6.63 Mg ha^{-1} yield loss or approximately 0.80 Mg ha^{-1} loss per week. The second planting date Julian day 111 had an 8% higher grain yield than the earliest planting date Julian day 86, but this was most likely caused by receiving atypical late season rainfall.

Growing conditions for 2014 were very favorable for corn production. Timely rains came throughout the season, likely affecting 100 kernel weights and the measurable hybrid genetic differences. However, the trend remained with hybrids DKC 62-08 and P-1498 having the greatest number of kernel rows and Pioneer hybrids having more kernels per row than Dekalb hybrids. SPAD values indicated that plant nutrients were not limiting for treatments, but earlier plantings did have higher SPAD values than later planted treatments.

Verona 2014 yield trends remained similar to previous years and locations with the latest planting date producing the lowest grain yield. Yields ranged from 13.43 Mg ha^{-1} for the earliest planting date to 12.59 Mg ha^{-1} for the latest planting date. Dekalb hybrids once again had higher 100 kernel weights compared to the two Pioneer hybrids.

Furthermore, SPAD values for early planting were greater than later planting and hybrids DKC 62-08 and P-1498 had the greatest number of kernel rows, but Pioneer hybrids had more kernels per row than Dekalb hybrids. Hybrids LAI values in response to planting dates varied, but overall they followed the trend of earlier being better.

Whether planting early or late, fluctuating planting dates will affect corn growth and development. The optimal planting window for corn varies slightly from year to year. Although, we have recommended planting dates to plant corn, recent advancements in hybrid genetics with improved stress tolerance allow producers to plant earlier. Of course weather and especially water availability play a major role in the development of the plant and ultimately determine the final grain yield.

Data suggest that there are benefits to early corn planting in Mississippi and that hybrid selection affects yield. The ultimate decision to plant early depends upon a producer's soil type, equipment and especially upon personal risk/reward tolerance. However, in selecting a planting date, there appears to be far greater yield penalties associated with late planting as compared to early planting.

Yield overall in the 2 years of this trial were very good due to decreased temperatures and abundant rainfall during critical growth stages for (even the later planting dates). I believe benefits associated with early corn planting were not fully capitalized on during these two years of field experiments. We did encounter some late season heat and drought stress, but it was minimal compared the last 10 growing seasons. Evaluation of a greater number of hybrids with a broader range of relative maturities planted at the end February and first of March would be useful to further classify planting date effects in a rainfed Mid-South production system

Planting Density Conclusion

During the two years and three locations in central Mississippi, corn response to population, planting date, and hybrid varied by year and location. Both years and locations experienced, for the most part, normal early season wet and cold growing conditions. Early planted treatments were exposed to suboptimal growing environments. Although, there were no stand or germination issues as a result of early planting.

Starkville 2013 field experiments had considerably lower grain yields than other locations and years. This was most likely caused by field variability and poor drainage. The end result of these circumstances eliminated possible statistical significance of population effects in regards to grain yield. Early planting, however resulted in an 18% yield advantage across hybrids. Hybrid AGR-N68 planted early yielded 3% higher than DKC 67-57 planted at the same time. Both hybrids were higher yielding than early planted P-1498 and all later planted treatments. The greatest reduction in yield from hybrids planted early compared to late was AGR-N68. Grain yield was reduced by 30% as a result of the 33 day planting delay. DKC 67-57 had a 17% reduction in grain yield for the same planting delay. Hybrid P-1498was the lowest yielding hybrid planted early and subsequently had the least yield penalty for delayed planting.

Hybrid kernel weight response to population revealed no significant difference among hybrids at or below populations of 61,750 plants ha^{-1}. Across hybrids there was a 5% reduction in kernel weight as populations increased from 61,750 to 74,100 plants ha^{-1}. There was also a small increase in kernel weight as plant populations increased from 74,100 to 86,450 plants ha^{-1}.

Number of kernel rows was highest at 49,400 plants ha^{-1} and declined with increasing populations. There was a 5% reduction in kernel rows that occurred when populations increased from 49,400 to 61,750 plants ha^{-1}. Across hybrids there was only a .7% reduction when populations increased from 86,450 to 98,800 plants ha^{-1}. Regardless of population P-1498 had the most kernel rows.

Population similarly affected the number of kernels per row. Hybrids at 49,400 plants ha^{-1} had the highest number of kernels per row and the greatest reduction occurred as population increased to 61,750 plants ha^{-1}. Hybrid AGR-N68 averaged 12% more kernels per row than P-1498 and 10% more than DKC 67-57. Planting date response to number of kernels per row revealed a 21% advantage for early planted treatments.

Verona 2013 grain yield ranged from 10.38 Mg ha^{-1} at 49,400 plants ha^{-1} to 12.60 Mg ha^{-1} at 86,450 plants ha^{-1}. Increasing seeding rates from 49,400 to 61,750 plants ha^{-1} resulted in a 10% yield increase. A 3% yield increase was observed when seeding rates increased to 74, 100 plants ha^{-1} and 7% at 86,450 plants ha^{-1}. Yield was reduced by 7% as seeding rates exceeded 86,450 plants ha^{-1}. Regardless of population, hybrid DKC 67-57 out yielded P-1498 and AGR-N68. There was also a 6% yield advantage for planting on Julian day 108 compared to 121.

Hybrid DKC 67-57 kernel weights averaged 5% heavier than P-1498 and AGR-N68. The number of kernel rows improved by 4.5% as seeding rates increased from 49,400 to 61,750 plants ha^{-1}, but also declined 10% when increased to 74,100 plants ha^{-1}. There was little difference and no penalty in kernel rows for additional population increases. Regardless of population P-1498 outperformed DKC 67-57 by 11% and AGR-N68 by 6% in number of kernel rows. Trends for number of kernels per row declined as populations increased. The smallest reduction occurred when seeding rates went from 49,400 to 61,750 plants ha^{-1}. Hybrid AGR-N68 averaged 4% more kernels per row than P-1498 and 9% more than DKC 67-57.

Yield components such as kernel weight, kernel rows and kernels per row multiplied by the number of ears per ha^{-1} are used to equate the final grain yield. Verona 2013, data suggest that kernel weight was the most important factor contributing to yield variability among hybrids. The intrinsic kernel weight advantage for hybrid DKC 67-57 in this given growing season influenced grain yield the most. This data supports similar conclusions affirming that some hybrids kernel size and weight contribute to grain yield variations. (Gustavo et al., 2006; Echarte et al., 2000; Otegui, 1995)

Brooksville 2013 grain yield response to hybrid and population indicated no hybrid difference for seeding rates below 86,450 plants ha^{-1}. Despite hybrid, the largest increase in yield with respect to population occurred when seeding rates increased from 49,400 to 61,750 plants ha^{-1} in which yields increased by 9%. There was a 3% yield increase for raising plant populations to 86,450 and 98,800 plants ha^{-1}. Hybrid DKC 67-57 yields were maximized at seeding rates above 61, 750 plants ha^{-1}, whereas at lower populations P-1498 yielded the highest. DKC 67-57 grain yield was approximately 11.3 Mg ha^{-1} at both 86,450 and 98,800 plants ha^{-1}. Hybrid P-1498 grain yield was 4% higher than DKC 67-57 at 61,750 plants ha^{-1} and 10% greater at 49,400 plants ha^{-1}.

Kernel weights declined marginally as seeding rates increased. The largest decline in kernel weight occurred when populations increased from 49,400 to 61,750 plants ha^{-1}. A 3% decline in kernel weight occurred at each population increase above 61,750 plants ha^{-1}. Hybrid DKC 67-57 kernel weights exceeded P-1498 by 17% and AGR-N68 by

19%. There was also a reduction in number of kernel rows as seeding rates increased. Hybrid P-1498 again had the greatest number of kernel rows regardless of population.

Number of kernels per row response to population revealed minor reductions for population increases once seeding rates reached 74,100 plants ha^{-1}. However, increasing seeding rates from 61,750 to 74,100 plants ha^{-1} resulted in a 14% reduction in number of kernels per row. Hybrid AGR-N68 averaged 14% more kernels per row than P-1498 and 11% more than DKC 67-57.

Starkville 2014 grain yields ranged from 15.48 Mg ha^{-1} at the highest population to 12.20 Mg ha^{-1} at the lowest seeding rate. There was linear increase in grain yield with increasing populations. Thou little gain from increasing plant population past 86,450 plants ha^{-1}. Yield improved by 9% by raising seeding rates from 49,400 to 61,750 and also 61,750 to 74,100 plants ha^{-1}. The highest yielding hybrid was AGR-N68 followed by P-1498 and finally DKC 67-57. Unlike previous findings, grain yield was 4% higher for treatments planted at Julian day 111 compared to 73.

Kernel weights for DKC 67-57 were 14% to 15% greater than P-1498 and AGR-N68. Regardless of population P-1498 had the greatest number of kernel rows. Plant populations at 61,750 plants ha^{-1} produced the highest number of kernels per row. Consequently, hybrids planted at 98,800 plants ha^{-1} had 21% fewer kernels per row resulting in shorter ears across all hybrid treatments. Similar to previous results hybrid AGR-N68 averaged 7% more kernels per row than P-1498 and 20% more than DKC 67-57.

Verona 2014 grain yields planted at either Julian day averaged 13.3 Mg ha^{-1}. Hybrid DKC 67-57 yielded highest at both Julian days 111 and 132. Additionally, hybrid

P-1498 yielded lowest at both planting dates. There was an 8% kernel weight advantage to hybrids planted at Julian day 111 compared to 132. Hybrids planted at 61, 750 plants ha^{-1} had the highest average number of kernel rows regardless of planting date. Compared to other hybrids P-1498 had more kernel rows at all seeding rates.

Hybrids planted at 49,400 plants ha^{-1} averaged 15% more kernels per row than hybrids planted at 98,800 plants ha^{-1}. Seeding rates excluding at 74,100 plants ha^{-1} hybrid AGR-N68 had more kernels per row than DKC 67-57 and P-1498. Hybrids planted at Julian day 111 averaged 5% more kernels per row than hybrids at Julian day 132. There was an 8% reduction in kernels per row for AGR-N68 when planting was delayed 21 days. Hybrid DKC 67-57 suffered a 5% loss in kernels per row for delayed planting and P-1498 remained the same despite planting date.

The physiological response to planting date, plant population, and hybrid were greatly influenced by weather for each year and location. Plant height, kernel weight, kernel rows, and kernels per row responded differently, but trends did emerge. Environment and especially genetics seem to affect these characteristic. Hybrids AGR-N68 and P-1498 were overall taller plants than DKC 67-57 even in optimal growing conditions. Kernel weights were higher for DKC 67-57 and P-1498 had the most kernel rows among hybrids. Hybrid AGR-N68 consistently had the most kernels per row regardless of population.

LAI values paralleled seeding rates and trended up with each population increase. SPAD values varied more between hybrids and planting dates than population. However, all treatment values suggested that fertility was not a limiting factor. Increasing seeding rates resulted in a yield increase, but the rate of increase differed between populations.

Grain yields improved linearly as seeding rates increased up to 86,450 and levelled out at 98,800 plants ha^{-1}. The most significant increase occurred when populations increased from 49,400 to 61,750 or 61,750 to 74,100 plants ha^{-1}. Genetic traits embedded within each hybrid revealed a competition factor that appeared more clearly at these certain plant densities. Seeding rates that maximized yield in this study were 86, 450 to 98,800 plants ha^{-1}. However, as population increased the yield benefit associated with the increased seeding rate diminished.

Overall, early planting appeared to be advantageous with the exception of Starkville 2014. It is however important to note that field experiments planted on Julian day 73 were among the earliest planted treatments in both the planting date and density experiments. These same treatments also suffered a light frost when plants were at V2 growth stage. The reduction in yield suggests that the penalty for early planting was minimal even with suboptimal early season growing conditions. It is also worth noting that late season rainfall was well above average and day and nighttime temperatures were much lower than what is considered normal. The combination of these factors likely favored later planted treatments in this given growing season.

Ultimately the advancements in hybrid genetics have improved the stress tolerance allowing producers to push the limits of early planting, population density, and have mitigated the negative effects of late season stress. Of course weather and especially water availability play a major role in the development of the plant and ultimately determine the final grain yield.

Evaluation of a greater number of hybrids with a broader range of relative maturity would be useful to further classify population effects in a rainfed Mid-South production system. Additionally, a cost analysis of seed to grain income should be investigated to determine the optimum economic population for corn producers. Lastly seeding rates should be further evaluated at populations above 86,450 plants ha^{-1} using smaller increments of increasing populations allowing researchers to better estimate the optimal seeding rate.

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