THE RELATIONSHIP BETWEEN GRAIN YIELD AND WAXY ENDOSPERM IN *SORGHUM BICOLOR* (LINN.) MOENCH

A Dissertation

by

SELAHATTIN AYDIN

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

DOCTOR OF PHILOSOPHY

May 2004

Major Subject: Plant Breeding

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ABSTRACT

The Relationship between Grain Yield and Waxy Endosperm

in *Sorghum bicolor* (Linn.) Moench.

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In sorghum, a single recessive gene *Wx* conditions waxy endosperm type. While parental inbred lines and hybrids with waxy endosperm have been developed, there has been little to no adoption of these hybrids by producers, primarily because waxy hybrids consistently yield 5-10% less than non-waxy hybrids and end-use buyers will not pay for the utilization benefits. While current waxy germplasm does not yield competitively at this time, there is a question as to whether the yield reduction is due to a negative relationship between waxy per se or due to the lack of effort to develop high yielding waxy germplasm. The purpose of this study is to determine the relationship between the waxy endosperm phenotype and grain yield in sorghum. From each of two F_2 breeding populations segregating for waxy endosperm, 50 inbred lines were derived, selected only for homozygosity of endosperm type. No selection for yield was practiced during the development of these lines. Approximately 25 waxy and 25 non-waxy lines were selected for further evaluation from each population. These lines and a set of testcross hybrids were evaluated in four environments. When combined across environments and populations, waxy inbred lines and hybrids yielded 17% less than non-waxy inbred lines and hybrids. However, analysis of the individual inbred lines and hybrids indicated that several waxy inbred lines were competitive in yield with the best non-waxy genotypes. The results indicate that it should be possible to develop waxy hybrids that are competitive in yield, but that this will require additional breeding efforts to identify the correct inbred lines and hybrids.

DEDICATION

I dedicate this dissertation to my family and friends for their unconditional love, permanent support and full understanding. They inspire me to work hard and encourage me when difficult times were depressing and sorrowful.

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The author is thankful to Dr. William L. Rooney for his guidance during the course of this study. Working with him is a privilege that I enjoyed. Also thanks all the committee members for their help and suggestions during various phases of this study.

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CHAPTER I

INTRODUCTION

In terms of production, grain sorghum (*Sorghum bicolor* [Linn.] Moench) is the third most important cereal crop grown in the United States and the fifth most important cereal crop grown in the world after wheat, rice, maize and barley (FAO, 2001). It is primarily grown in tropical and subtropical regions of the world with minimal rainfall. It is particularly important in hot and dry tropical regions where corn and wheat and other crops are not adapted, and productive. In addition to the tropics, sorghum is also grown in drier temperate regions of the world.

Historians believe that sorghum originated in northeast Africa where a large amount of variability in wild and cultivated species is still found today. It was probably domesticated in Ethiopia between 5000 and 7000 years ago (http://www.icrisat.org/text/coolstuff/crops/gcrops2.html). From there, it was distributed along trade and shipping routes around the African continent, and through the Middle East to India about 3000 years ago. It then journeyed along the Silk Route into China. Grain sorghum was first introduced to the U.S. in the 18th century via the slave trade from West Africa. It was reintroduced in the late 19th century for commercial cultivation and subsequently spread to South America and Australia.

The genus *Sorghum* is a member of the Poaceae family, which are cane-like grasses ranging in height from 0.5 to 6-m tall. Sorghum is primarily a self-pollinating species but it does readily cross-pollinate when the opportunity arises. Sorghum plants

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This dissertation follows the style and format of Crop Science.

have a fibrous root system that can penetrate up to 5 to 8 ft into the soil. The sorghum leaves are very much like those of corn with 14 to 18 alternate side-growing leaves on the stem. Because of its origins near the equator most sorghums are photoperiod sensitive, requiring longer night lengths to initiate reproductive growth. However, photoperiod insensitive sorghums have been identified and these types are predominantly grown in temperate regions of the world.

Harlan and his colleagues (1976) identified four wild species and five cultivated races for cereal sorghums. The four wild races of *Sorghum bicolor* are arundinaceum, virgatum, aethiopicum, and verticilliflorum. These species generally create fertile progeny when hybridized with cultivated sorghums. Generally, the wild races of *S. bicolor* are largely adapted in wet and humid parts of forested central and West Africa. *Sorghum bicolor* ssp. *bicolor* is divided into five races; bicolor, guinea, kafir, caudatum, and durra. These races provide the basis for modern sorghum cultivars and hybrids and they also valuable as sources of new characteristics, ranging from disease resistance to grain quality.

Sorghum bicolor is a diploid species (2n=2x=20) with a haploid chromosome number of ten. Like *S. bicolor*, most of the members of *Sorghum* genus are diploid 2n=2x=20. However, there are several tetraploid species within the genus such as *S. halepense* (2n=4x=40). In addition, there are several species in Sorghum that are diploid with a base chromosome number of five (2n=2x=10). While there is molecular cytogenetic data to support the tetraploid origins of *S. bicolor* (Gomez et al., 1997), the lack of consistent synteny of linkage groups indicates that *S. bicolor* is an ancient tetraploid (and now highly diploidized (Yu et al., 1991).

Over 200 genes controlling simply inherited traits have been described in sorghum germplasm (Rooney, 2000). For example, four major genes (Dw_1, Dw_2, Dw_3, and Dw_4) have been described that control major changes in plant height (Quinby and Martin, 1954). Additional and undescribed genes modify the effect of these loci to provide continual variation in height in a breeding program. Six major genetic loci (Ma_1 – Ma_6) have been described that influence days to anthesis (Quinby, 1974; Rooney and Aydin, 1999). Genes controlling both cytoplasmic and genetic male sterility have been described (Ayyangar and Ponniaya, 1937; Stephens and Holland, 1954). The sorghum hybrid seed industry is based on the cytoplasmic male sterility system. Finally, genes controlling phenotypic and stress response traits are well documented for many traits (Rooney, 2000).

In 1996, the global area harvested to sorghum was about 47 million hectares with the largest production areas in Africa and India. The highest average yields occur in North America. Average yields in sorghum are low relative to other major cereal grains because sorghum is often grown in stressful environments. However, sorghum has high yield potential with the highest recorded yield for the crop is 20.1 tons per hectare.

In the U.S., grain sorghum was grown on 3.1 million ha with a production of 13.2 million metric tones (518.7 million bushels) in 1998 (Smith, 2000). The first significant grain sorghum production in the U.S. was in California in the 1870s (Smith, 2000), and production gradually increased to 1.6 million ha in U.S. by 1920. Sorghum production peaked again to 5-6 million ha in the 1980's. U.S. sorghum production is concentrated in the central and southern plains with five states Kansas, Texas, Nebraska, Oklahoma, and

Missouri (listed in ranking order) representing approximately 85 percent of total production.

Like the other crops, sorghum has had distinctive stages in the genetic improvement of the crop. Initially introduced as a forage crop, genotypes were selected for various purposes ranging from forage to syrups and grain. Until the mid 1950's, sorghum production relied on cultivars, but as hybrids became available they were rapidly adopted. Current grain and forage production in the U.S. and other industrialized countries relies exclusively on hybrids.

Utilization of the Grain

Form and function can be found with all portions of the crop. The grain is used as both a human food and animal feed. As a food grain, sorghum is used in products like porridge, unleavened bread, cookies, cakes, couscous, and malted beverages. Primary use of sorghum as a food grain occurs throughout Africa and in India. In the Americas and Australia, almost all sorghum production is used to feed livestock and poultry. The feed value of grain sorghum is considered to be 96-98% that of corn (Riley, 1985; Hancock, 2000). In addition to food and feed uses, industrial uses for the crop have been developed. These include ethanol production and starch extraction.

Because the feed and food value of sorghums is slightly less than that of other cereal grains, researchers have studied to determine why the nutritional value and is less and then to identify methods to improved the digestibility of the grain. While the reasons for the reduced digestibility are complex, the packing of starch and protein in the endosperm appears to be a primary factor in reducing digestibility (Rooney and Pflugfelder, 1986).

To improve the digestibility, several potential methods are available. These include processing and genetics. It has long been known that processing methods affect the digestibility of sorghums (Dreher et al., 1983; Rooney and Pflugfelder, 1986). However, these approaches typically require additional expense and management for which processors are not willing to pay. A second alternative is to alter the grain through plant breeding and genetics. One such alteration is waxy endosperm sorghums. Waxy sorghums were identified and characterized many years ago (Meyer, 1886; Kempton, 1921; Karper, 1933)) and they have been maintained in modern breeding programs. In addition, waxy endosperm sorghum has been documented to improve digestibility resulting in better-feed values (Hibberd et al., 1978; Hancock, 2000).

To meet this perceived need, sorghum improvement programs developed waxy and hetero-waxy hybrids (Hancock, 2000). However, these hybrids have had limited acceptance because the yields of these waxy hybrids have been consistently lower than non-waxy hybrids (Hancock, 2000). The specific cause of the yield reduction is unknown but may be due to (1) undesirable genetic linkages between the waxy genetic locus and yield, (2) the pleiotrophic effect of the waxy phenotype *per* se or (3) a general lag in breeding efforts in waxy endosperm sorghum that could be overcome with additional breeding efforts. If the yield reduction is caused by pleiotrophy, then it will be impossible to overcome the inherent yield reduction associated with waxy endosperm in sorghum. However, if the yield reduction is due to undesirable linkages or ineffective breeding, then it should be possible to develop high-yielding waxy endosperm sorghum.

The objective of this study is to determine whether or not the yield reduction associated with the waxy endosperm trait in sorghum is due to a pleiotrophy or undesirable genetic associations with the waxy locus.

CHAPTER II

REVIEW OF LITERATURE

Sorghum Caryopsis Structure

Pericarp and Testa

The sorghum caryopsis is composed of several different components. The outer layer of the kernel is the pericarp and it accounts for approximately eight percent of the total weight of the kernel (Hubbard et al., 1950). The pericarp originates from the ovary wall (Saunders, 1955; Glennie et al., 1984), and is composed of several different layers including the epicarp, mesocarp, and endocarp (Earp and Rooney, 1982). The epicarp, the outermost layer of the pericarp, is usually covered by a thin layer of the wax. This layer is generally two-three cells thick and containing pigments, resulting in the epicarp color (Waniska and Rooney, 2000). Although the most cereal grains do not contain starch in the mesocarp, sorghum genotypes carrying a homozygous recessive (*zz*) genes at the *Z* locus contain small starch granules in its mesocarp (Earp and Rooney, 1982; Rooney and Miller, 1982). The innermost pericarp tissue is the endocarp and it consists of cross and tube cells. Pericarp thickness ranges from 8 to 160 µm (Blakely et al., 1979; Earp and Rooney, 1982). The thickness of the pericarp even varies within the individual kernel. The thickest areas are located at the poles of the kernel, and the thinnest areas are located at the side of the kernel. The black layer or hilum is located at the tip of the germ, and develops at the physiological maturity. The stylar area is located on the opposite side of the hilum.

Variation in the pericarp color of sorghum is controlled by simply inherited genetic loci. Pericarp color is controlled by two genes, designated as *R* and *Y*. The epistatic interaction of alleles at these two loci result in red (*R_Y_*), yellow (*rrY_*) or white (*R_yy* or *rryy*) pericarp sorghums (Graham, 1916; Vinall and Cron, 1921). When present in the dominant form, an intensifier gene (designated *I*) increases the brightness of the pericarp color (Ayyangar et al., 1933). Mesocarp thickness is controlled by alleles at the *Z* locus with the dominant allele resulting in a thin pericarp (Ayyangar et al., 1934).

Below the pericarp may be a testa or seed coat layer. The presence of this layer is contingent on the epistatic interaction of two complementary dominant loci designated B1 and B2 (Laubscher, 1945; Stephens, 1946). When present, the testa or seed coat layer develops from the ovule integument beneath the pericarp layer. As in the pericarp, the thickness of the testa is also variable within the kernel, and ranging from 8 to 40 µm (Blakely et al., 1979; Earp and Rooney, 1982). The thickest area of the seed coat is around the style with thickness decreasing through the sides of the kernel. The testa layer contains tannins if the caryopsis have a pigmented testa (*B1_B2_*) and dominant (*S_*) or recessive (*ss*) spreader gene in the genome (Hahn and Rooney, 1986). Condensed tannins are phenolic compounds, which impart a bitter taste to the grain unless removed and effectively bind protein, making it indigestible to non-ruminant animals. Consequently food and feed values of sorghums with tannins are significantly reduced as compared to sorghum without a pigmented testa layer. For these reasons, the presence of a pigmented testa is an undesirable trait in most regions of the world.

Embryo

The sorghum embryo composes approximately ten percent of the total weight of the kernel (Hubbard et al., 1950). The embryonic axis is divided into a radicle and plumule. At the time of germination, the radicle (or primary root) emerges first followed by hypocotyls (which protecting the first true leaf or plumule. The scutellum stores primary nutrients (high in oil, protein, enzymes, and minerals) needed at germination. Also it provides the connection between embryo and endosperm. In cereal crops, the scutellum contains a single cotyledon. The amount of protein, fat, and ash is highest in the germ or embryo. Because of the relatively small proportion of the embryo to total seed size, it has a small effect on grain composition.

Endosperm

Unlike the embryo, the endosperm is triploid with the male parent providing one genome, and two polar nuclei from the megagametophyte providing the remaining two haploid genomes. Proportionally, the sorghum endosperm composes approximately 82% of total kernel weight (Hubbard et al., 1950). The endosperm of the sorghum kernel consists of the aleurone layer, peripheral, corneous, and floury endosperm (Earp and Rooney, 1982). The outer layer of the endosperm is the aleurone layer, and consists of a single layer of rectangular cells just beneath the testa or tube cells. The cells in the aleurone layer have a thick cell wall, high amount of protein, ash, and oil. Beneath the aleurone layer, there are several dense cell layers designated the peripheral area. This area contains more protein and small starch granules than corneous area. It should be mentioned that the peripheral area and the corneous endosperm are translucent in appearance, and they do effect the kernel processing and nutrient digestibility.

The endosperm is predominantly starch with some protein, and small amounts of fat and fiber. The sorghum endosperm contains both corneous and floury types in each grain. In most sorghums, the floury endosperm is located in the middle of the endosperm and is surrounded by corneous endosperm. Major components of the corneous and floury endosperm are starch granules, protein matrix, protein bodies, and cell walls mainly containing cellulose, β-glucans, and hemicellulose. The protein matrix generates a continuous protein network in the corneous and peripheral areas, and the starch granules and protein bodies are embedded within this protein network (Seckinger and Wolf, 1973; Hoseney et al., 1974). In the corneous endosperm, the starch granules are smaller, angular, and compressed by the protein bodies. In the floury endosperm, starch molecules are larger, spherical, and free from dents. The protein bodies are varying from 0.4 to 2.0 μm in size, and typically circular in shape (Taylor et al., 1984). While protein networks are present in the peripheral and corneous endosperm, the floury endosperm does not generate the continuous protein network. In fact, the floury endosperm may contain air voids between starch granules, and loosely packed round starch granules in its structure (Hoseney et al., 1974). The light diffracting ability of air voids gives the floury endosperm its opaque appearance.

Sorghum Caryopsis Chemical Composition

Chemically the sorghum kernel is composed primarily of carbohydrates, protein, and oil, with trace amounts of ash and minerals (Hubbard et al., 1950). Three distinctive carbohydrate classes are found with starch being the most abundant class, followed by soluble sugars, and fiber composed of cellulose, hemicellulose, and pentosans. The sorghum pericarp is rich in fiber and contains some starch granules ranging in size from 1 to 4 µm in the mesocarp layer. Carbohydrate concentrations in sorghum are similar to those of corn, while protein content of sorghum is slightly higher and fat content is slightly lower than that found in corn (Waniska and Rooney, 2000). Protein in sorghum is deficient in the amino acid lysine. While genetic variation for lysine content is present in sorghum, it is associated with poor grain quality traits (Mohan and Axtell, 1975).

Carbohydrates

Sorghum grain contains three carbohydrates classes; starch, soluble sugar, and fiber composed of pentosans, cellulose, and hemicellulose. Starch is the main carbohydrate class in cereal grains varying from 1/2 to 3/4 of the total grain weights (Hubbard et al., 1950). Amylose and amylopectin molecules are packed in a highly organized manner in starch granules, and held together by hydrogen bonds (Rooney and Pflugfelder, 1986). Amylose molecules are linear chains of about 1500 glucose units, and amylopectin molecules are branched chains of glucose units which are approximately 3000 chains averaging 15 to 20 glucose units. The properties, milling, and uses of sorghum starch are similar to those of corn starches (Watson, 1984; Rooney and Serna-Saldivar, 1999). In normal sorghum endosperm, the ratio of amylopectin and amylose is 75% and 25%, respectively. Waxy endosperm sorghums (also known in corn, rice, barley and wheat) contain 96-100% amylopectin. Mutants with lower amylopectin content are known in corn, barley, and rice. These types contain 25-65% amylopectin starch (Reddy and Seib, 2000). High amylose corns, with 90% amylose have been developed and grown for commercial applications (Shi et al., 1998).

Waxy endosperm sorghums have a phenotypically distinct grain. They can be detected in the field simply cutting the kernel and evaluating the endosperm which looks much like candle wax when shaved with a knife. In addition, starch produced from waxy sorghum endosperm has notable characteristic in terms of resistance to gel formation and retrogradation, high peak viscosity, paste clarity, rapid cooking, high water binding capacity, poor stability during cooking, and higher starch digestibility when compared with starch from normal endosperm type of sorghum (Watson, 1984; Akingbala and Rooney, 1987; Subramanian et al., 1994; Perez et al., 1997; Hibberd et al 1982a; Rooney and Pflugfelder, 1986; Kotarski et al., 1992).

Usually the native waxy starches are not used directly in food industry but the processed waxy starches are used as thickeners in salad dressing, sauces, gravies, pie filling, and some other areas (Reddy and Seib, 2000). For example, the quality of Japanese noodles can be improved using waxy wheat because it shows a negative relation with amylose content of the flour (Oda et al., 1980). Waxy corn, corn, tapioca, potato, and wheat starches are commercially modified to meet the requirements of the food processing industries (Reddy and Seib, 2000).

The soluble sugar content of sorghum caryopsis is varies during maturity. At physiological maturity, the soluble sugar content of the mature caryopsis ranges from 2.2 to 3.8%. The water-insoluble and water-soluble dietary fiber portions of sorghum plant are 6.5% to 7.9% and 1.1% to 1.23% respectively. The water-soluble dietary fiber is β-glucans comprising most of the soluble fiber in sorghum (Bach-Knudsen and Munck, 1985). The fiber amount present in sorghum caryopsis is in the insoluble form which comprises about 86% of total fiber, and is located in the pericarp (Waniska and Rooney, 2000). The products made from sorghum contain variable amount of fiber depending upon the extent of the decortication.

Protein

The sorghum endosperm, germ, and pericarp contain 80%, 16%, and 3% protein respectively (Taylor and Schussler, 1986). The protein fractions of sorghum caryopsis are mostly kafirins, and glutelins primarily located in the protein bodies and protein matrix of the sorghum endosperm, whereas the germ is rich in albumins and globulins. The kafirin protein fraction has limited amounts of lysine, threonine, and tryptophan, resulting in deficiencies if sorghum is the sole grain in a diet to monogastric animals. While the albumin, globulin, and glutelin protein fractions contain high amounts of lysine and other essential amino acids, they compose a very small percentage of total protein.

Fat and Lipids, Vitamins and Ash

Lipid content in sorghum caryopsis ranges from 2.1% to about 5.0%, and the classification of the lipids is 90% non-polar lipids, 6% glycolipids, and 4% phospholipids. In sorghum caryopsis, lipids are minor constituents. Approximately 75% of the lipids are located in the scutellum area of the germ while the remainder is evenly distributed throughout the pericarp and endosperm. The fatty acid composition of sorghum is similar to that found in corn and pearl millet (Hoseney, 1998).

The vitamins are mostly located in the aleurone layer and in the germ. The sorghum grain is rich in vitamins B, but not a good source for B_{12}, and vitamins C, also a good source for vitamins E, some cultivars with yellow endosperm contain some vitamin A. In terms of minerals, the sorghum caryopsis has a good amount of potassium, and a moderate amount of, iron, zinc magnesium, and copper, and a poor amount of sodium and calcium. Minerals are localized in the germ, aleurone layer, and pericarp layer (Hubbard et al., 1950).

Starch – Chemistry and Biochemistry

Starch is the most important carbohydrate consumed on a worldwide basis because of its abundance and low cost (Dreher et al., 1983). Cereal grain and tuber crops are composed predominantly of starch and protein, and starch is the primary energy storage component for the seed. In starch granules, two types of polymers are chemically distinguishable: amylose and amylopectin. Amylose is essentially linear polymers of the α-D-glucose molecules containing several hundreds or thousands of glucose units linked by 1,4-alpha-glucopyranosidic bonds. Unlike amylose, amylopectin is highly branched polymers of α-D-glucose molecules which have a large number of chains containing 16-28 glucose units linked by 1,4-alpha-glucopyranosidic bonds, with a small percentage of interconnecting 1,6-alpha-glucopyranosidic branching units (Dreher et al., 1983). The starch granules from different sources are widely varied in shape, in size, in strength of intermolecular bonding, and amount of amylose and amylopectin. Waxy endosperm sorghum contains nearly 100% amylopectin and the endosperm looks like candle wax (Rooney and Miller, 1982). Non-waxy sorghum endosperm contains 23-30% amylose in the endosperm (Horan and Heider, 1946; Ring et al., 1982). This characteristic generates great variability in food and feed processing industries.

Tover et al. (1977) and Lichtenwalner et al. (1978) reported that the hydrolysis of the starch granules might be affected by the dosage of the waxy gene in the endosperm because the endosperm is triploid and the female parent contributes two gametes while the male contributes only one. The incremental increase of the waxy gene does affect the structure of the kernel. When the dosage of waxy gene increases in the endosperm tissue, the percentage of amylose is reduced. In order to get significant reduction of amylose percentage, two doses of the waxy gene are required (Lichtenwalner et al., 1978). Also the incremental dosage of waxy gene does affect the starch digestibility and protein solubility in a positive manner.

Generally it is easier to process waxy endosperm sorghums than it is to process non-waxy endosperm sorghum. In addition, waxy endosperm sorghums have higher digestibility than non-waxy endosperm sorghums (Hinder and Eng, 1970; McCollough, 1973; Davis and Harbers, 1974). These positive advantages of the waxy endosperm generate interest in the utilization of waxy endosperm sorghum in food and feed processing industries.

The digestibility of the starch granules varies widely, both in vitro and in vivo, depending on starch source, food processing, and storage condition. Digestibility of the starch can be improved by processing such as cooking, steam flaking, and heat treatment, possibly due to the changes in starch granule gelatinization, crystalinity, or the inactivation of enzyme inhibitors (Dreher et al., 1983). The degree of starch digestibility may be influenced by dietary fiber components such as cellulose, hemicellulose and lignin, and the utilization of plant nutrients such as protein, fat, vitamins, and minerals may be affected by starch digestion (Snow and O'Dea, 1981).

Sorghum is considered to have the lowest starch (Rooney and Pflugfelder, 1986) and protein (Walker and Lichtenwalner, 1977) digestibility among the cereals. In addition, sorghum has variable grain quality (Miller et al., 1962), resulting in inconsistent cattle growth rates and efficiency (McCollough et al., 1972, Hibberd et al., 1982a,b), and lower feeding value than that of corn (National Research Council, 1984). The studies from feeding and digestion trials have clearly shown that the waxy endosperm feeds consistently improve the performance of the animals. Nishimuta et al (1969) found that rations made with waxy sorghum grain rations were higher in digestibility than non-waxy sorghum rations fed to sheep. Sherrod et al. (1969), Brethour and Duitsman (1965), McCullough et al. (1972) reported that waxy sorghum grain improved feed utilization efficiency between 8 to 20% when compared to normal grain sorghum.

Those statements were supported by the results from Sullins and Rooney (1975) who found that the waxy sorghum endosperm has increased starch susceptibility to enzyme degradation. In addition, less dense peripheral endosperm area just beneath the aleurone layer with larger starch granules embedded into considerably less protein matrix increased the utilization of the waxy sorghum endosperm. The results from Sullins and Rooney (1975) study are responsible for increased feedlot utilization and more available energy source of waxy sorghum over the non-waxy sorghum grain. Results from Walker and Lichtenwalner (1977) supported the same hypothesis. Starch digestibility of waxy sorghum grain can be improved further using the different processing methods, such as steam flaking, grinding, to the value of the corn (McDonough et al. 1998). In addition, Walker and Lichtenwalner (1977) found that protein in waxy sorghum varieties is more soluble and more digestible than the protein in non-waxy sorghum varieties.

While most studies indicate that waxy sorghums are higher in digestibility, the exact reason for this increase in digestibility is not known. Due to the increased frequency of branching in amylopectin, it is hypothesized that waxy starch is easier to hydrolyze in digestive fluids. Tover et al. (1977) confirmed that waxy starch was easier to digest than non-waxy starch in the presence of porcine α-amylase or rumen fluids.

Experiments done in corn support the findings reported here in sorghum. Sandstedt et al. (1962) found that high-amylose corn starch was highly resistant to enzymatic digestion, whereas it was reported that the waxy corn starch is highly susceptible to enzymatic hydrolysis (Sandstedt et al. 1968). In non-waxy sorghums, the peripheral endosperm area contains small starch granules embedded in a dense protein matrix, whereas waxy sorghum has less dense peripheral endosperm area with larger starch granules and more evenly distributed protein matrix (Sullins and Rooney, 1974).

Recently, research conducted at the University of Kentucky has shown that the traditional yellow dent corn hybrids can be effectively replaced with the Nutri-Dense and waxy corn hybrids in lactating dairy cow rations (Akay and Jackson, 2001). Dado (1999) stated that the improved agronomic performance, better digestibility, and rich nutrient content of waxy corn hybrids, Nutri-Dense hybrids, and high oil corn hybrids are considered as an effective reason to substitute the conventional yellow dent corn in animal feeding. Lactating dairy cows fed waxy corn grain or silage produced more milk compared with the conventional corn silage or grain (Schroeder et al., 1996; Moreira et al., 2000). Increased microbial protein synthesis was achieved by using waxy corn diets

(Sniffen and Robinson, 1987; Akay and Jackson, 2001). Also, higher protein, fat, and milk yields were accomplished in lactating dairy cows by using steam flaking corn or sorghum that increasing the ruminally available starch (Chen et al., 1994; Akay and Jackson, 2001). Akay et al. (1999) stated that higher digestibility and rates have been observed with fiber material of waxy corn silage compared with conventional yellow dent corn and Nutri-Dense corn silage fiber. There is an 8% digestibility difference for cows fed with waxy corn diet and Nutri-Dense corn diet (Akay and Jackson, 2001).

Starch Synthesis - Genetics

Variation in starch composition in the endosperm is under genetic control. Karper (1933) was the first to report that the waxy phenotype in sorghum is inherited as a simple Mendelian recessive. Melvin and Sieglinger (1952) also reported that a single recessive mutant gene conditions waxy endosperm type in sorghum grain. They designated this locus as *Wx*. Non-waxy endosperm type shows incomplete dominance to the waxy endosperm type and the trait is expressed solely in the endosperm. Genes controlling endosperm traits are expressed in the developing seed as opposed to plant-based traits expressed when the seed is germinated. Because of this, the expression of waxy endosperm occurs during grain development on the maternal parent. Therefore, grain produced from the cross of a waxy female pollinated by a non-waxy male would be non-waxy. If producers grew those seeds as a hybrid line, the grain would segregate for the expression of waxy endosperm. In that production, approximately 25% of the grain would have waxy endosperm. These types of hybrids are referred to as "hetero-waxy" because of the segregation for the trait.

In addition to sorghum, waxy endosperm has been found in corn, *Zea mays* L. (Collins, 1909); rice, *Oryza sativa* L. (Parnell, 1921); barley, *Hordeum vulgare* L.; proso millet, *Panicum miliaceum* L. (Cushing, 1943), wheat, *Triticum spp*. (Yamamori et al., 1994). In almost all species, a single mutant gene (*wx*) controls the change from normal endosperm to waxy endosperm. A maize selection made in China in the early 1900s had been described as possessing an endosperm with waxy-like appearance (Collins, 1909). In corn, Kramer et al. (1958) described the waxy mutant gene in corn, designated as wx, and its mode of expression and inheritance were identical to the waxy mutant described in sorghum. Some other mutant alleles at the *Wx* locus have been reported having similar starch properties as in the *wx* alleles (Bear, 1944; Nelson, 1968). In addition, various researchers have shown that the wx mutant gene has epistatic interaction with all known endosperm mutants in corn (Creech, 1968; Boyer et al., 1976). The wheats with waxy endosperm were first developed in Japan in 1994 using traditional breeding methods (Reddy and Seib, 2000). In addition, waxy cDNA sequence of hexaploid wheat is also documented (Clark et al., 1991; Ainsworth et al., 1993), and the complete genomic structure of three waxy genes in hexaploid wheat has been reported (Murai et al., 1999).

In rice, the *Waxy* (*Wx*) locus conditioning the endosperm type has been well characterized using the traditional genetic methods (Nagao and Takahashi, 1963; Iwata and Omura, 1971a; IRRI, 1976; and Li et al., 1965, 1968). Iwato and Omura (1971) localized the *waxy* locus in rice to chromosome 6. Sano (1984) reported that in addition to the *wx* mutant alleles, there are at least two different Wx alleles (Wx^a and Wx^b) which regulate the quantitative level of the major gene product as well as the amount of amylose in the triploid endosperm of rice.

The rice endosperm normally contains approximately 15 to 30% amylose and 70 to 85% amylopectin while homozygous waxy mutant endosperm types contain only amylopectin (Iwata and Omura, 1971b; IRRI, 1974). In sorghum endosperm, three different genotypic combinations are possible: homozygous non-waxy (*WxWxWx*), intermediate waxy (*WxWxwx* or *Wxwxwx*), and homozygous waxy mutant genotypes (*wxwxwx*). The incremental increase of waxy mutant gene (wx) in the genotype of endosperm results in decreasing amounts of amylose, but two doses of waxy mutant gene (wx) in the genotype of endosperm ere required to get significant reduction in the amount of amylose content (Lichtenwalner et al., 1978). The dosage effect in rice similar to that described in sorghum (Sano, 1984). Sano (1984) also reported that amylase content was dosage dependent with amylose content increasing in the presence of each additional *Wx* allele. The Wx gene expression is inactivated or the product of the *Wx* gene is profoundly reduced when the genotype in the endosperm is in the homozygous waxy mutant condition (*wxwxwx*) in rice. Also the incremental increases of the wx mutant gene in endosperm decreases the amount of the amylose content (Echt and Schwartz, 1981).

The gene responsible for the production of waxy endosperm has been isolated in several different species. Nelson and Rines (1962) reported that the *Waxy* locus in maize encoded the granule-bound starch synthase. Shure et al. (1983) cloned the *Wx* gene in maize. Later, the *Wx* gene in rice was cloned using the maize *Wx* gene as a probe (Okagaki and Wesler, 1988; Wang et al., 1990; Hirano and Sano, 1991; Umeda et al., 1991). Also Echt and Schwartz (1981) reported that the starch granule bound protein associated with the *Wx* gene of rice is very similar to *Wx* protein in maize.

The wheat plant has two genomes in tetraploid (macaroni) wheat AABB, and three genomes in hexaploid (bread) wheat AABBDD. Each genome of hexaploid wheat has one waxy locus encoding the waxy protein, also called granule-bound starch synthase (Echt and Schwartz, 1981), is a nuclear-encoded enzyme that synthesis the amylose molecules (Vos-Scheperkeuter et al., 1989). The granule-bound starch synthase encoding the waxy protein showed more than 85% similarity in cereal crops (Murai et al., 1999). The cDNA and genomic DNA sequences encoding the granule-bound starch synthase (Waxy protein) of sorghum (Hsieh et al., 1996), rice (Wang et al., 1990), barley (Rohde et al., 1988), maize (Klosgen et al., 1986), potato (Van der Leij et al., 1991), pea (Dry et al., 1992), and cassava (Salehuzzaman et al., 1993) have been documented. The process of amylose synthesis is catalyzed by the granule-bound starch synthase adding one glucose unit at a time to α-1,4-glucosyl chain, while the process of amylopectin synthesis is catalyzed by the starch branching enzyme and possibly the soluble starch synthase (Preiss, 1991). Smith et al. (1997) reported that the rate of amylose synthesis and the amount of amylose in endosperm are mainly determined by the amount of waxy protein.

Agronomic Productivity of Waxy Endosperm Cultivars and Hybrids

Cultivars having waxy endosperm tend to be lower yielding than those having non-waxy endosperm (Tover et al., 1977). Boyer et al. (1976) reported in maize that the waxy gene has no negative effect on kernel dry weight or endosperm starch up to 36 days after the pollination; however, another recessive gene allele, named *ae* (amylose-extender), showed a dosage effect in decreasing kernel weight and endosperm starch.

In maize there has been a significant effort to improve waxy corns, with most of the waxy maize breeding being done by plant breeders in private sector. Presently in the market, there are about six private seed companies working on the improvement of waxy maize hybrids. Unlike the complexities in developing high amylose maize, waxy maize and other waxy cereals breeding programs are generally more traditional and less laborious because of the unique expressions of waxy mutant gene, which is easy to screen and easier to transfer between populations. The trait can even be screened in the pollen by staining with potassium iodide solution (Brink and MacGillivray, 1924). In practice, waxy hybrids are created by converting the elite non-waxy dent maize lines to waxy types and then creating a hybrid. Therefore, waxy hybrids can be developed that are essentially isogenic to a non-waxy version. In theory, the waxy hybrids should be equal in yield to their normal dent counterparts.

Research on the effect of waxy endosperm on grain yield indicate that the cereals with waxy endosperm shows some degree (about 5 to 10%) of yield drag when they compared with the normal counterparts. The yield comparison among Custom Farm Seed waxy hybrids and their normal dent hybrid counterparts showed that the yield performance of the waxy hybrids is 95% or more of the standard dent maize counterparts (http://web.aces.uiuc.edu/value/factsheets/corn/fact-waxy-corn.htm). In addition, the waxy hybrids produce grain with a higher test weight than normal dent maize. Graybosch (1998) reported that the grain yield of the highest yielding spring waxy wheats was not significantly different from that of normal spring wheat cultivars. It was concluded that waxy wheat cultivars could be developed that will not carry a penalty in grain yield (Graybosch, 1998). It was reported that waxy hull-less barley varieties show poor yield performance about 20% compared with the normal varieties (http://info.ag.uidaho.edu/resources/PDFs/CIS1050.pdf). One of the major reason for yield drag might be that the waxy endosperm lines are generally converted from the current elite lines using backcross breeding method, and secondly the extensive breeding schemes are not used to develop new waxy hybrid lines. Thirdly, the waxy endosperm materials do not have the base population with broad range variability from which to select.

The current situation in waxy maize is applicable to all cereal crops with waxy mutant gene in their genome. It should be emphasized that the breeding program applied to normal dent corn or any other cereal crops are applicable with minor changes to plants with waxy endosperm. The major problem is that the base breeding population with enough genetic diversity to provide proper selection for waxy trait is not available. Waxy maize is considered as specialty type, and does not have a market potential like normal corn, therefore few private seed companies are involved in marketing and developing the waxy hybrids in their breeding program.

The information from the experiments about the performance of the waxy sorghum shows that the waxy sorghum hybrids and the inbred lines perform consistently less than the non-waxy sorghum inbred lines around 5-10% (Rooney, 2000), but the difference between waxy and non-waxy sorghum grain yield is not clear yet, whether the reduction is due to the endosperm type or the negative gene interaction. The gene, expresses the waxy condition, itself may have a negative effect on the yield performance of the waxy sorghum inbred lines, also its interactions with the other genes might be responsible for the yield reduction in waxy sorghum inbred lines. However, in grain sorghum production, most producers use the sorghum hybrids with non-waxy endosperm since the waxy sorghum hybrids do not yield competitively with the non-waxy sorghum hybrids.

CHAPTER III

MATERIALS AND METHODS

Population Development

Two populations segregating for waxy endosperm were selected to develop lines to test the relationship between waxy endosperm and yield. The first population, designated the B-Line population, was created from the cross of BTxARG-1 x BTx623. The second population, designated the R-Line population, was created from the cross of RTx2907 x RTx430.

BTxARG-1 was developed and released in 1991 by TAES as a parental line (Miller et al., 1992a). BTxArg-1 is a waxy endosperm line with the pedigree of (MR807*BTx624). A/BTxARG-1 is genetically 3-dwarf, and has good exertion, translucent white seed color, and no pigmentation in the testa. The line has good resistance to Fusarium head blight (caused by *Fusarium* spp) and has tan necrotic plant color. The line has wide adaptation, and good general combining ability in hybrid combination for yield, drought resistance, and general disease resistance. The parental line BTx623 was developed by the Texas Agricultural Experiment Station, and released in 1977. A/BTx623 was selected from the cross of (BTx3197*SC170-6-4-4). SC170-6 is a partially converted line from PI from Ethiopia. BTx623 has a non-waxy endosperm, it is 3-dwarf in height, and white seeded, and has purple plant color. BTx623 is resistant to downy mildew (caused by *Peronosclerospora sorghi*), zonate leaf spot (caused by *Gloeocercospora sorghi*), and insecticidal leaf burn. The line is used as a female in hybrid grain production, and has adaptation to tropical areas.

Tx2907 germplasm was released in 1994 by TAES (Miller et al., 1996). Tx2907 is an R-line with waxy endosperm with a white translucent pericarp and tan plant color. It is genetically a three-dwarf in height. Tx2907 is resistant to anthracnose caused by *Colletotrichum graminicola,* head blight caused by (*Fusarium* spp.), rust (caused by *Puccinia purpurea*), and leaf blight (*Exserohilum turcicum*). Because of its desirable food processing qualities, Tx2907 can be used for the production of waxy endosperm food quality hybrids. RTx430 was developed and released by the Texas Agricultural Experiment Station in 1976 (Miller, 1984). RTx430 has resistance to head smut caused by *Sphacelotheca reiliana*, downy mildew pathotype 1 caused by *Peronosclerospora sorghi*. RTx430 has a white pericarp, thin mesocarp and yellow endosperm. Tx430 does not have a pigmented testa, and the plant is genetically a three-dwarf in height with purple plant color. The line is widely adapted throughout the U.S. sorghum belt and in the tropics where photoperiod insensitive hybrids are useful. RTx430 has non-waxy endosperm (*WxWx*).

For each population, F_1 hybrids were made in the summer of 1995. For the B-line population, the cross of BTxARG-1 was used as the female parent and BTx623 was the pollinator. For the R-line population, Tx2907 was used as the female parent and RTx430 was the pollinator. F_1 progeny were grown and self-pollinated to create F2 seed in an off-season nursery in Puerto Rico in the winter of 1995-96. F_2 progeny were grown in College Station, and 120 individual F_2 plants in each population were self-pollinated and advanced as $F_{2:3}$ lines. From this material, in each population, a single panicle in each $F_{2:3}$ line was selfed and advanced. Seed from the $F_{3:4}$ generation were screened to identify inbred lines which are homozygous for waxy and non-waxy endosperm.

This screening was conducted using the potassium iodide test. From each line, 100 sorghum grains were randomly selected and cut in half. Each grain was examined visually for waxy or non-waxy endosperm and uniform samples were confirmed using the potassium iodide test. When stained with an aqueous solution of potassium iodide and iodine, waxy endosperm sorghum stains reddish-brown while non-waxy endosperm stains a deep blue color (Karper, 1933). The differentiation between waxy and non-waxy can be determined by examining the pollen grains with a potassium iodide solution. The waxy pollen of rice, corn, sorghum (Brink, 1925), and wheat (Kiribuchi-Otobe et al., 1997) likewise stain a reddish-brown color and the non-waxy pollen stains blue when treated with a potassium iodide solution. The F_4 lines in this study were classified into three groups; waxy, non-waxy and segregating, and lines uniform for endosperm class were advanced. Inbred lines with 100% waxy endosperm were designated as waxy while inbred lines with 100% non-waxy endosperm were designated as non-waxy. Inbred lines segregating for waxy endosperm were discarded. For consistency in agronomic evaluation, any lines that were significantly later or earlier or taller or shorter were also eliminated. No other selection was practiced throughout the development of these populations. In the B-line population, 25 waxy and 25 non- waxy endosperm inbred lines were selected for further study. From the R-line population, 20 waxy and 20 non-waxy endosperm inbred lines were identified for replicated testing.

To test the effect of these inbred lines in hybrid combination, testcross hybrids were developed from each individual inbred line. Lines derived from the B- line population were hybridized as a pollinator onto A3Tx436, and lines derived from the R-line population were hybridized to ATx631 (Miller, 1986). A3Tx436 is a female sterile version of RTx436 (Miller, 1992b) in A3 cytoplasm. It was developed to use for testing hybrid vigor of new B-inbred lines prior to sterilization (Lee et al., 1992). Since A3 testcross hybrids will be male-sterile, pollinator rows will be included to provide pollination. Since both testers are non-waxy, all waxy inbred lines will produce hetero-waxy hybrids while non-waxy inbred lines will produce non-waxy hybrids. Seed of these hybrids was produced in a crossing block in College Station, Texas in 1998.

Agronomic Evaluation

Line Evaluation: The B-line and R-line tests were evaluated using a randomized complete block design with two replications. These tests were conducted as separate experiments on TAES research farms near College Station in 1998, 1999, and 2000 and on the TAES research farm near Halfway, Texas in 1998 and 1999 for a total of five environments. The soil type at the College Station location was *Ships clay loam* and the soil type at Halfway was *Pullman clay loam*. In each test, the respective parents and four hybrids (ATxARG-1*RTx2907, ATxARG-1*RTx430, ATx631*RTx2907, andATx623*RTx430) were included with the experimental lines.

The trials were planted following production practices normal for sorghum in each region. Specific planting dates are provided in Table 1. Both locations in each year were irrigated as needed to insure consistent growth and development. Fertility and insecticides were utilized to maximize and protect production capacity (Table 1). Plot size in College Station in 1998 was one row 5.2 m in length with 76-cm row spacing. In College Station in 1999 and 2000, the plot size was two rows 5.2 m and 5.5 m in length respectively and spaced 76-cm apart. In Lubbock, the plots were one row in 1998 and two-row in 1999. Plot length was 5.2 m length with a row spacing of 102 cm. The Lubbock trials were hand harvested, and threshed with an Almaco plot thresher. The College Station trials were harvested by hand in 1998, but in 1999 and 2000 the College Station trials were harvested using a MF8 plot combine with weigh buckets to measure yield, test weight and grain moisture.

In both tests and in each environment, the following traits were measured:

1. Plant height (cm) was collected by randomly selecting three plants in a plot, and the height of the selected three plants was measured in centimeters with a height stick.
2. Days to mid-anthesis were recorded as the number of days from planting to the date when 50% of the plot was at mid-anthesis.
3. Grain yield was measured by pound for each plot in College Station and Lubbock, then the collected data converted to the metric system. Grain yields were adjusted to 13% moisture for consistency in comparison. Yields are expressed in this study as kg/ha^{-1}.

Hybrid Testcross Evaluation: The testcross hybrids from the B-line population and from the R-line population were grown as separate trials with checks in three locations (Weslaco, Corpus Christi, College Station, and Halfway, Texas) in 2000. The soil type in the College Station was *Ships clay loam*, in Halfway the soil type was *Pullman clay loam*, in Corpus Christi the soil type was *Victoria clay* and in Weslaco the soil type was *Raymondville clay loam*. In addition to the experimental testcross hybrids in each test, ten check hybrids were included in the B-line hybrid tests and nine check hybrids were included in the R-line hybrid test (Table 1).

Table 1. The control checks used in the hybrid B and R-line populations.

Checks	
Hybrid B-line	Hybrid R-line
BTXARG-1	TX2907
BTX623	RTX430
RTX436	BTX631
ATX631*RTX436	ATXARG-1*RTX436
ATX623*TX2907	ATXARG-1*TX2907
ATX623*RTX436	ATXARG-1*RTX430
ATXARG-1*TX2907	ATX631*RTX436
ATXARG-1*RTX436	ATX631*TX2907
A3TX436*BTXARG-1	ATX631*RTX430
A3TX436*BTX623	

In each environment, the experimental design was a randomized complete block with two replications. Because the B-line hybrids were male sterile, pollinator rows were systematically placed in a four row (experimental hybrid) to two rows (pollinator row) ratio throughout the length of the trial. The pollinator row was a blend of six hybrids varying in maturity to ensure that adequate pollen was available for pollination during anthesis. All hybrids in the pollinator blend were non-waxy endosperm.

The trials were planted following production practices normal for sorghum in each region. Specific planting dates are provided in Table 1. The trials at Weslaco, College Station and Halfway were irrigated as needed to insure consistent growth and development. The Corpus Christi environment was rain fed. Fertilization and insecticides were utilized to maximize and protect production capacity (Table 2). The hybrid trials in College Station and Weslaco were planted in two-row plot 5.5 m and 5.1816 m in length and spaced 76 cm and 102 cm inches apart respectively. In Corpus Christi and Lubbock, plots were one row, 5.2 m in length and spaced 97 and 102 cm apart respectively. The Weslaco and College Station trials were harvested by combine harvesting, and Lubbock trials were harvested by hand. Due to drought conditions, the trials in Corpus Christi were abandoned and data from that location is not included in this study.

1. Plant height (cm) was collected by randomly selecting three plants in a plot, and the height of the selected three plants was measured in centimeters with a height stick.
2. Days to mid-anthesis were recorded as the number of days from planting to the date when 50% of the plot was at mid-anthesis.
3. Grain yield was measured by pound for each plot in College Station and Lubbock, then the collected data converted to the metric system. Grain yields were adjusted to 13% moisture for consistency in comparison. Yields are expressed in this study as kg/ha^{-1}.

Table 2. Cultural practices of the experiments.

Locations	Plant date	Irrigation	Fertilization	Harvest date
1998 College Station-Inbred	Mar/30	Apr/10, May/25, Jun/15	Jan 12-12-6 667lb/ac, May/7 32-0-0 156 lb/ac	Jul/24
1998 Lubbock-Inbred	Jun/15	None		Oct/19-23
1999 College Station-Inbred	Mar/24	None	Jan/8 32-0-0 225 lb/ac Apr/30 32-0-0 300 lb/ac	Jul/21
1999 Lubbock-Inbred	Jun/17	None		Oct/25
2000 College Station-Inbred	May/12	Jul/15 Jul/24	Jan/19 N 100 lb/ac Jun/2 32-0-0 235 lb/ac	Aug/14-18
2000 College Station-Hybrid	May/12	Jul/15 Jul/24	Jan/19 N 100 lb/ac Jun/2 32-0-0 235 lb/ac	Aug/14-18
2000 Corpus Christy-Hybrid	Mar/8	None	N 100 lb/ac P 14 lb/ac Z 0.4 lb/ac	Jul/12
2000 Lubbock-Hybrid	May/23			Oct/2
2000 Weslaco-Hybrid	Feb/15	Feb/18 Apr/19	Preplant 4-10-10 50 gal/ac Mar/23 N 100 lb/ac	

Statistical Analysis and Comparison

Line Evaluation

In this study, the data were subjected to statistical analysis using two different models(Tables 3 and 4), depending on the particular source of variation tested. Model I addresses the effect of endosperm and entry (endosperm) for significance while Model II tests for differences among genotypes (or entries). The first model will be used for testing the specific effects of endosperm on agronomic traits while in the second model the goal is to determine if differences among genotypes exist regardless of the endosperm type present. The second model will thus identify the best performing genotypes, independent of endosperm type.

For both models, data collected from the line *per se* trials was analyzed statistically using the analysis of variance procedure in SPSS statistical analysis program (SPSS, 1998). Data from each environment was analyzed separately using both models. Differences among means within an environment were identified using a Fisher's Protected LSD test at the $P < 0.05$ (Steel and Torrie, 1980).

Prior to combining data across environments, the homogeneity of variance was tested using the Levene test (Levene, 1960) of the homogeneity of variance in SPSS program. The data transformation was used if it was necessary to meet the assumption of a normal distribution for the analysis of variance. As mentioned for the individual environments two different models were used to address the effect of endosperm (Model I) (Table 3) and entry (Model II) (Table 4). In the combined models, a mixed model was used where environment, replication, and genotypes were random effects and endosperm type was a fixed effect. Appropriate tests of significance were based on expected mean squares (Tables 5,6).

Table 3. The statistical model with endosperm.

Source of variation	df	Expected Mean Square
Replication	r-1	$\sigma_e^2 + yn\sigma_R^2$
Endosperm	n-1	$\sigma_e^2 + r\sigma_{Y(N)}^2 + ry\sigma_N^2$
Entry(Endosperm)	y-1	$\sigma_e^2 + r\sigma_{Y(N)}^2$
Error	(y-1)(n-1)(r-1)	σ_e^2

Table 4. The statistical model without endosperm.

Source of variation	df	Expected Mean Square
Replication	r-1	$\sigma_e^2 + y\sigma_R^2$
Entry(Endosperm)	y-1	$\sigma_e^2 + r\sigma_Y^2$
Error	(y-1)(r-1)	σ_e^2

Table 5. The combined environments statistical model with endosperm.

Source of variation	df	Expected Mean Square
Environment	e-1	$\sigma_e^2 + r\sigma_{Y(N)E}^2 + ny\sigma_{R(E)}^2 + ryn\sigma_E^2$
Replication(Environment)	e(r-1)	$\sigma_e^2 + ny\sigma_{R(E)}^2$
Endosperm	n-1	$\sigma_e^2 + r\sigma_{Y(N)E}^2 + re\sigma_{Y(N)}^2 + ry\sigma_{NE}^2 + rey\sigma_N^2$
Endosperm*Environment	(n-1)(e-1)	$\sigma_e^2 + r\sigma_{Y(N)E}^2 + ry\sigma_{NE}^2$
Entry(Endosperm)	y-1	$\sigma_e^2 + r\sigma_{Y(N)E}^2 + re\sigma_{Y(N)}^2$
Entry(Endosperm)*Environment	(y-1)(e-1)	$\sigma_e^2 + r\sigma_{Y(N)E}^2$
Error		σ_e^2

Table 6. The combined environments statistical model without endosperm.

Source of variation	df	Expected Mean Square
Environment	e-1	$\sigma_e^2 + r\sigma_{YE}^2 + y\sigma_{R(E)}^2 + ry\sigma_E^2$
Replication(Environment)	e(r-1)	$\sigma_e^2 + y\sigma_{R(E)}^2$
Entry	y-1	$\sigma_e^2 + r\sigma_{YE}^2 + re\sigma_Y^2$
Entry*Environment	(y-1)(e-1)	$\sigma_e^2 + r\sigma_{YE}^2$
Error		σ_e^2

Data from each location was first checked for the appropriateness in terms of the assumptions in the ANOVA model using the SPSS statistical package (SPSS, 1998). The normality and homogeneity of variance test were performed for each statistical analysis using Kolmogorov-Smirnov and Levene test respectively. After the preliminary analysis of the data, the mixed ANOVA model was performed to determine the significance of the main effect of the endosperm type on the sorghum grain yield. In model II, endosperm was removed from the statistical model, and the remaining terms were run again to look for the main effect of entries that the differences among entries were statistically significant or not.

CHAPTER IV

INBRED LINE RESULTS

B-line Population – Inbred Line Performance

Analysis by Environments in B-line Population

Model I: Analysis by environments detected significant differences in yield due to endosperm type in the 1999 and 2000 College Station environments. In all five environments, significant variation was detected among genotypes within an endosperm (Table 7). In each case where significant differences among endosperm were detected, the non-waxy endosperm types were significantly greater in yield than waxy endosperm lines (Table 8). For plant height, significant variation due to endosperm and entry (endosperm) was detected in all five environments (Table 9). In each environment, the non-waxy endosperm lines were taller than waxy endosperm lines (Table10). For days to anthesis, no significant variation was detected due to endosperm type, but variation for entry (endosperm) was significant in all environments (Table 11). Also the means of the endosperm types for days to anthesis are very similar in all environments (Table 12).

Table 7. Mean squares of grain yield from the analysis of variance of 50 $F_{2:4}$ B-lines from the cross of (BTxArg-1*BTx623) grown in five environments in Texas.

	College Station			Lubbock	
Source	1998	1999	2000	1998	1999
Replication	6,952,160**	439	1,211,637	3,850,232**	613,007
Endosperm	7,612,605	15,437,308**	7,056,089**	192,421	24,590
Entry(Endosperm)	2,833,394**	1,099,324**	1,375,958**	1,456,593**	665,084**
Error	588,946	581,421	663,196	572,194	382,501

** Significance at P < .05

Table 8. Grain yield (kg/ha^{-1}) means for waxy and non-waxy B-lines from the cross of (BTxArg-1*BTx623) grown in five environments in Texas.

	College Station			Lubbock	
Endosperm Type	1998	1999	2000	1998	1999
Waxy	2,899	3,569	3,718	2,680	2,111
Non-Waxy	3,451	4,354	4,250	2,768	2,143
L.S.D.	617	613	655	ns	ns

Table 9. Mean squares for plant height from the analysis of variance of 50 $F_{2:4}$ B-lines from the cross of (BTxArg-1*BTx623) grown in five environments in Texas.

	College Station			Lubbock	
Source	1998	1999	2000	1998	1999
Replication	181.2**	0.3	12.6	20.9	12.6
Endosperm	382.5**	868.1**	1530.1**	392.5**	372.6**
Entry(Endosperm)	79.0**	94.5**	129.2**	43.5**	64.6**
Error	28.6	14.6	27.1	11.4	15.6

** Significance at P < .05

Table 10. Plant height (cm) means for waxy and non-waxy B-lines from the cross of (BTxArg-1*BTx623) grown in five environments in Texas.

	College Station			Lubbock	
Endosperm Type	1998	1999	2000	1998	1999
Waxy	127.6	125.2	129.9	111.2	113.9
Non-Waxy	131.6	131.1	137.8	115.2	117.8
L.S.D.	4.3	3.1	4.2	2.7	3.2

Table 11. Mean squares for days to anthesis from the analysis of variance of 50 $F_{2:4}$ B-lines from the cross of (BTxArg-1*BTx623) grown in three environments in Texas.

	College Station		
Source	1998	1999	2000
Replication	21.2	21.2**	5.7**
Endosperm	.6	1.0	4.8
Entry(Endosperm)	17.7**	10.9**	4.5**
Error	6.9	4.4	1.2

** Significance at P < .05

Table 12. Mean days to anthesis for waxy and non-waxy B-lines from the cross of (BTxArg-1*BTx623) grown in three environments in Texas.

	College Station		
Endosperm Type	1998	1999	2000
Waxy	75.9	73.4	59.5
Non-Waxy	75.8	73.2	59.1
L.S.D.	ns	ns	ns

Model II: Model II was designed to compare means among all genotypes independent of endosperm type. When endosperm type is removed from the model, significant variation among genotypes was detected for yield in all five environments (Table 13). When genotype yields are graphed and each genotype is classified by endosperm type, the distribution of waxy endosperm lines was skewed to lower yields (Figure 1). In addition, in every environment, non-waxy endosperm genotypes dominated the top yielding lines (Tables 14 and 15).

For plant height, significant variation was detected among genotypes in all five environments (Table 16). When the plant height of the genotypes is graphed and each entry is delineated by endosperm type, the waxy endosperm genotypes trended to the shorter classes (Figure 2). In all five locations, the non-waxy endosperm genotypes predominated the ten tallest lines (Tables 17 and 18).

For days to anthesis, significant variation was observed in all three environments for genotypes (Table 19). When the data was graphed and delineated by endosperm type the frequency distribution of endosperm types showed no difference (Figure 3). In all three locations, most of the latest lines were waxy endosperm genotypes (Table 20). In the earliest genotypes, there was no specific pattern to show any significance between endosperm types (Table 21).

Table 13. Mean squares of plant yield from the analysis of variance of 50 $F_{2:4}$ B-lines from the cross of (BTxArg-1*BTx623) grown in five environments in Texas.

	College Station			Lubbock	
Source	1998	1999	2000	1998	1999
Replication	6,952,160**	439	1,211,637	3,850,232**	613,007
Entry	2,930,928**	1,391,936**	1,491,879**	1,430,794**	652,013**
Error	588,946	581,421	663,196	572,194	382,501

** Significance at P < .05

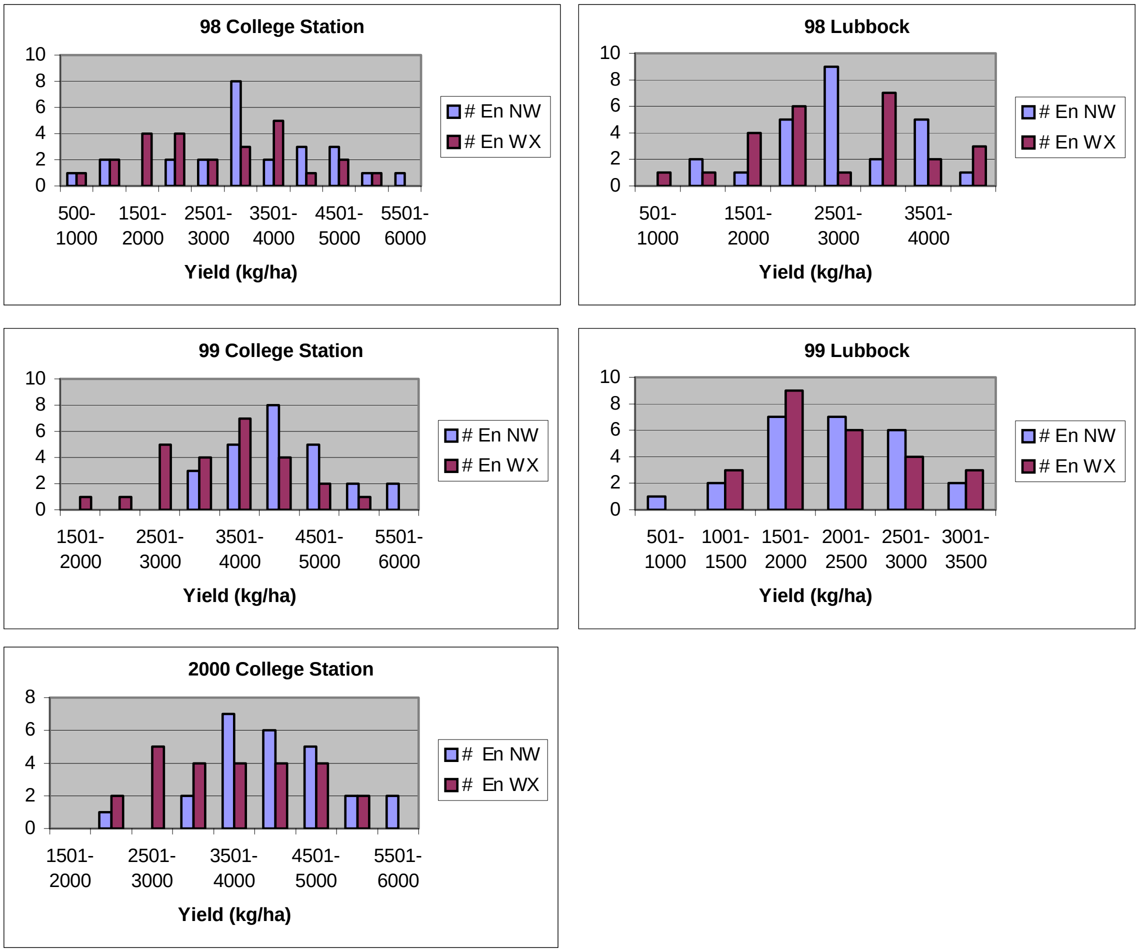

Figure 1. Histogram of B-line genotypes classed by mean grain yield (kg/ha^{-1}). Entries are color-coded based on endosperm type. A. College Station 1998. B. College Station, 1999. C. College Station, 2000. D. Lubbock, 1998. E. Lubbock, 1999.

Table 14. Mean grain yield (kg/ha^{-1}) of ten highest yielding $F_{3:5}$ B-lines in each College Station environment. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	1998		1999		2000	
Rank	Entry	Yield	Entry	Yield	Entry	Yield
1	13	5,655	19	5,967	17	5,583
2	43	5,201	22	5,610	24	5,582
3	24	5,090	6	5,316	45	5,293
4	17	4,990	43	5,157	6	5,156
5	25	4,836	18	5,107	28	5,066
6	42	4,816	23	4,924	25	5,042
7	41	4,579	29	4,900	5	4,910
8	10	4,509	12	4,897	32	4,892
9	5	4,442	8	4,897	14	4,886
10	15	4,441	17	4,803	16	4,765
L.S.D.		3,084		3,063		3,272

Table 15. Mean grain yield (kg/ha^{-1}) of ten highest yielding $F_{3:5}$ B-lines in each Lubbock environment. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	1998		1999	
Rank	Entry	Yield	Entry	Yield
1	43	4,230	13	3,129
2	41	4,217	43	3,110
3	30	4,194	38	3,055
4	21	4,145	26	3,031
5	24	3,831	10	3,017
6	32	3,744	23	2,777
7	25	3,701	21	2,723
8	6	3,682	30	2,696
9	8	3,621	8	2,655
10	34	3,607	14	2,616
L.S.D.		3,040		2,485

Table 16. Mean squares of plant height from the analysis of variance of 50 $F_{2:4}$ B-lines from the cross of (BTxArg-1*BTx623) grown in five environments in Texas.

	College Station			Lubbock	
Source	1998	1999	2000	1998	1999
Replication	181.2**	.3	12.6	20.9	12.6
Entry	85.2**	110.3**	157.7**	50.6**	70.9**
Error	28.6	14.6	27.1	11.4	15.6

** Significance at P < .05

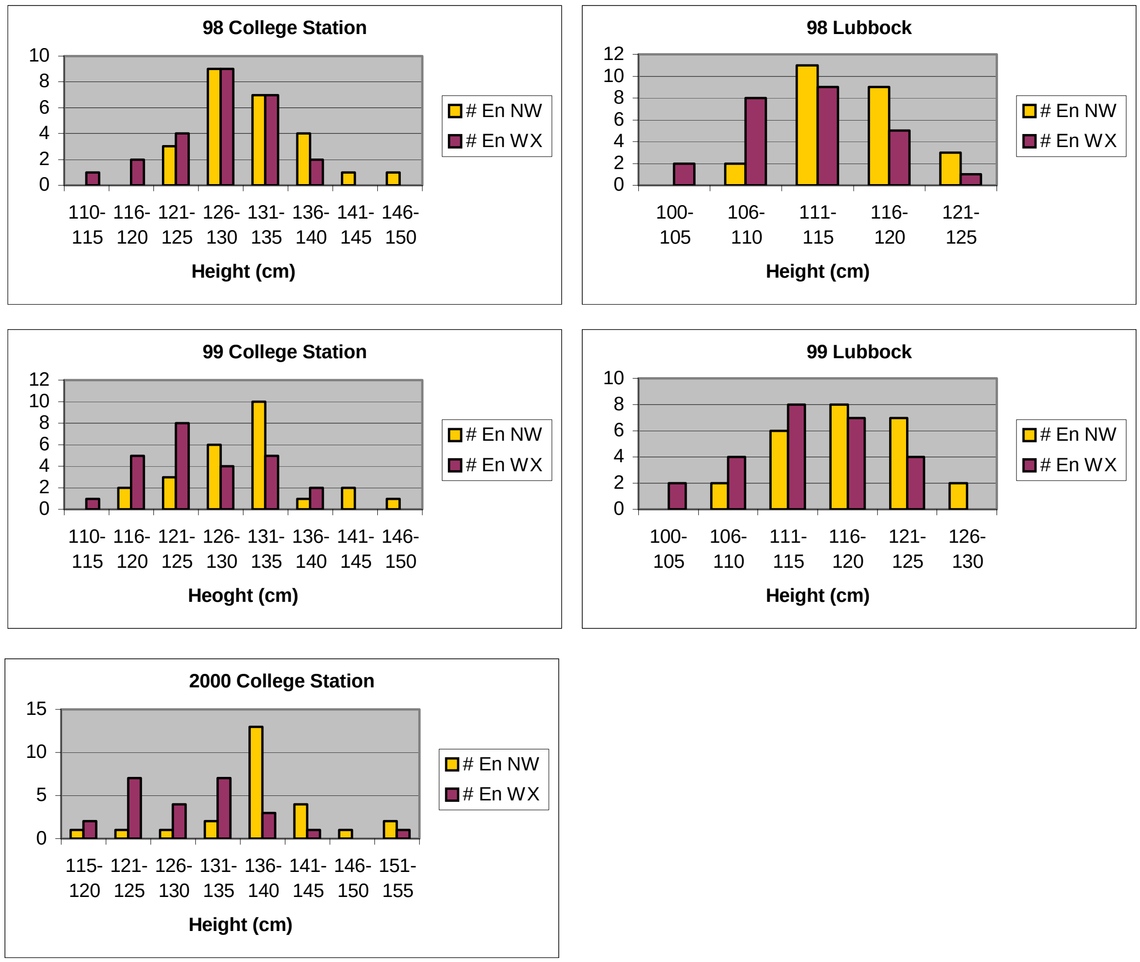

Figure 2. Histogram of B-line genotypes classed by genotype mean plant height (cm). Entries are color-coded based on endosperm type. A. College Station, 1998. B. College Station, 1999. C. College Station, 2000. D. Lubbock, 1998. E. Lubbock, 1999.

Table 17. Mean plant height (cm) of the ten tallest $F_{3:5}$ B-lines in each College Station environment. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	1998		1999		2000	
Rank	Entry	Plant Height	Entry	Plant Height	Entry	Plant Height
1	19	146.1	4	146.1	1	154.9
2	8	144.8	1	144.8	19	153.7
3	41	139.7	19	142.2	45	152.4
4	25	138.4	8	139.7	10	147.3
5	37	138.4	27	135.9	22	143.5
6	15	137.2	29	135.9	8	142.2
7	11	135.9	3	134.6	37	142.2
8	17	135.9	14	134.6	4	140.9
9	1	134.6	25	134.6	7	140.9
10	5	134.6	5	133.3	3	139.7
L.S.D.		21.5		15.4		20.9

Table 18. Mean plant height (cm) of the ten tallest $F_{3:5}$ B-lines in each Lubbock environment. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	1998		1999	
Rank	Entry	Plant Height	Entry	Plant Height
1	11	124.4	4	128.3
2	10	123.2	8	125.7
3	37	121.9	1	124.4
4	15	120.6	39	124.4
5	13	119.4	41	124.4
6	39	119.4	2	123.2
7	16	118.1	5	123.2
8	23	118.1	19	123.2
9	42	118.1	13	121.9
10	50	118.1	27	121.9
L.S.D.		13.6		15.9

Table 19. Mean squares of plant maturity from the analysis of variance of 50 $F_{2:4}$ B-lines from the cross of (BTxArg-1*BTx623) grown in three environments in Texas.

	College Station		
Source	1998	1999	2000
Replication	21.2	21.2**	5.7**
Entry	17.4**	10.7**	4.5**
Error	6.9	4.4	1.2

** Significance at P < .05

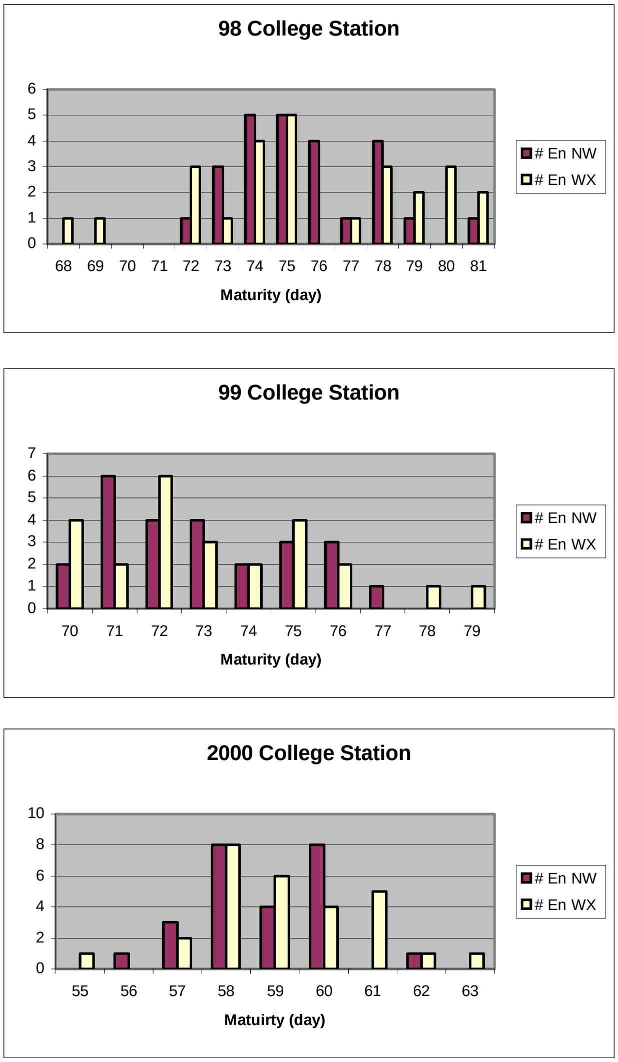

Figure 3. Histogram of B-line genotypes classed by genotype mean for the number of days to anthesis. Entries are color-coded based on endosperm type. A. College Station, 1998. B. College Station, 1999. C. College Station 2000.

Table 20. Genotype and days to anthesis of the ten latest $F_{3:5}$ B-lines in College Station over three years. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	1998		1999		2000	
Rank	Entry	Days to Flower	Entry	Days to Flower	Entry	Days to Flower
1	20	81.5	44	79.5	31	63.0
2	29	81.0	38	78.0	20	62.5
3	31	81.0	7	77.5	27	62.0
4	37	80.5	10	76.5	50	61.0
5	50	80.5	11	76.5	29	61.0
6	27	80.0	20	76.5	38	61.0
7	2	79.5	35	76.5	44	61.0
8	44	79.0	41	76.5	46	61.0
9	48	79.0	40	75.5	7	60.5
10	12	78.5	45	75.5	15	60.5
L.S.D.		10.5		8.5		4.4

Table 21. Genotype and days to anthesis of the ten earliest $F_{3:5}$ B-lines in College Station over three years. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	1998		1999		2000	
Rank	Entry	Days to Flower	Entry	Days to Flower	Entry	Days to Flower
1	45	68.5	17	70.0	36	55.5
2	36	69.5	21	70.0	5	56.0
3	24	72.0	32	70.0	4	57.0
4	28	72.0	36	70.0	1	57.5
5	43	72.0	29	70.5	6	57.5
6	34	72.5	33	70.5	28	57.5
7	25	73.0	8	71.0	47	57.5
8	6	73.5	24	71.0	32	58.0
9	14	73.5	26	71.0	35	58.0
10	30	73.5	28	71.0	2	58.5
L.S.D.		10.5		8.5		4.4

Combined Analysis in B-line Population

Model I: Tests of homogeneity of variance were conducted and the result from the statistical analysis indicated that the variances were not heterogeneous. Thus, it is acceptable to combine the data from all environments.

In the combined analysis of model I, significant variation in the model was detected for grain yield and plant height but not for days to anthesis (Table 22). Of most importance in the current study, the effect of endosperm was significant and non-waxy endosperm lines yielded significantly more than waxy endosperm sorghums (Table 23). In addition, plant height was reduced in the waxy endosperm group when compared to the non -waxy group (Table 23). In addition, the data indicated that the plant maturity was not effected by the endosperm type in B-line population (Table 13).

Table 22. Combined analysis of the 50 $F_{3:5}$ B-lines from the cross of (BTxArg-1* BTx623). Data from five environments were combined in this analysis for model I.

Source	Yield	Maturity	Plant Height
Environment	64,324,856**	8,062.2**	8,212.8**
Replication (Environment)	2,525,495**	11.6**	45.5**
Endosperm	19,760,449**	11.2	3,238.7**
Endosperm*Environment	2,640,641	0.7	76.8
Entry(Endosperm)	2,343,297**	18.3**	216.2**
Entry(Endosperm)*Environment	1,271,764**	6.3**	48.6**
Error	557,652	2.8	19.5
C.V.	39.5%	11.1%	8.9%

** Significance at P < .05

Table 23. Means for waxy and non-waxy endosperm classes of sorghum from a set of 50 $F_{3:5}$ B-lines evaluated in five environments.

Class	Grain Yield kg/ha^{-1}	Maturity day	Plant Height cm
Waxy	2,995	69.7	121.6
Non-Waxy	3,393	69.4	126.7
L.S.D.	263	ns	1.5

In the combined analysis of model II, significant variation was detected for plant height, grain yield and days to anthesis (Table 24). The reduction in yield in the waxy endosperm class in model I infers that waxy may actually reduce yield. However, if individual lines with waxy endosperm can be identified that are higher in yield, this would imply that the negative association of yield with waxy is due to other factors and not the waxy trait per se. In the combined analysis, the yield distribution of genotypes was normal, but when they are distributed based on endosperm types, the waxy endosperm types are skewed toward lower yield (Figure 4). Like in the grain yield, the distribution of plant heights based on endosperm types is skewed toward shorter plant height in waxy endosperm (Figure 5). However, the distribution of days to anthesis based on endosperm types shows similar pattern (Figure 6). In detailed analysis of average yields in the combined analysis, seven of the top ten yielding lines are non-waxy. However, a waxy line (entry 43) was second in the test and not significantly different from the highest yielding line in the test (Table 25). This result seems to indicate that some waxy lines can yield with the best non-waxy types.

Table 24. Combined analysis of the 50 $F_{3:5}$ B-lines from the cross of (BTxArg-1* BTx623). Data from five environments were combined in this analysis for model II.

Source	Yield	Maturity	Plant Height
Environment	64,324,856**	8,062.2**	8,212.8**
Replication (Environment)	2,525,495**	11.6**	45.5**
Entry	2,698,749**	18.1**	277.9**
Entry*Environment	1,299,700**	6.1**	49.2**
Error	557,652	2.8	19.5
C.V.	39.5%	11.2%	8.9%

** Significance at P < .05

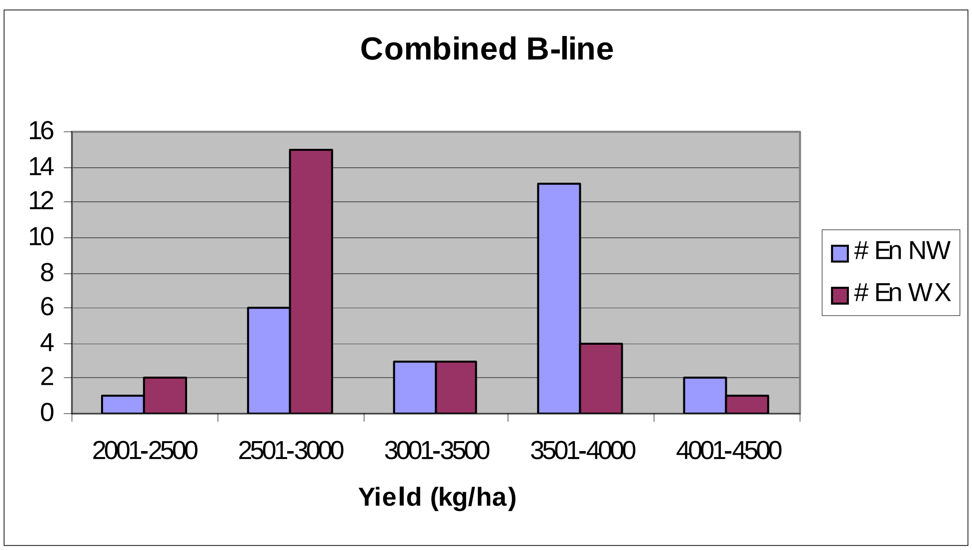

Figure 4. Entry means for grain yield (kg/ha^{-1}) of genotypes from the combined B-line analysis of five environments. Genotypes are delineated by endosperm type.

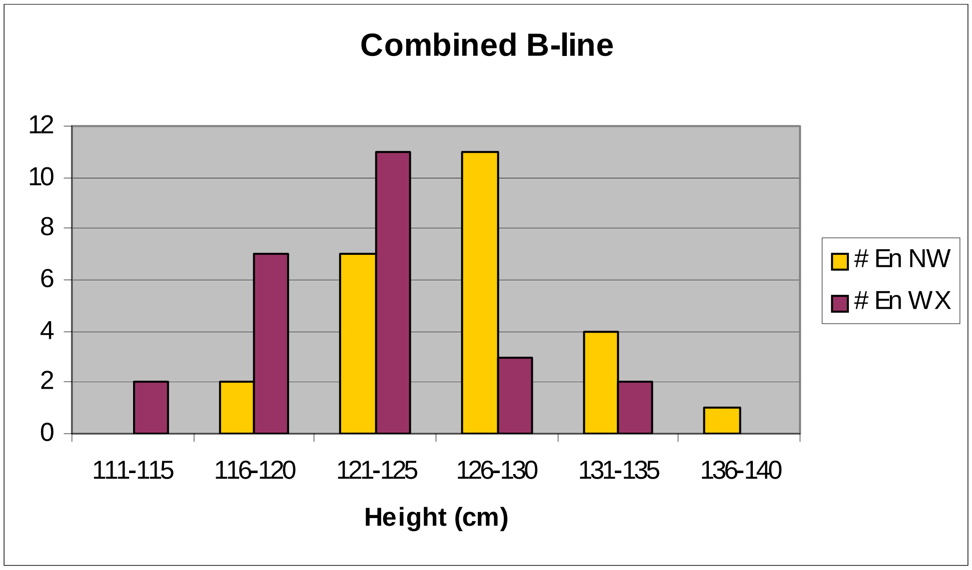

Figure 5. Entry means for plant height (cm) of genotypes from the combined B-line analysis of five environments. Genotypes are delineated by endosperm type.

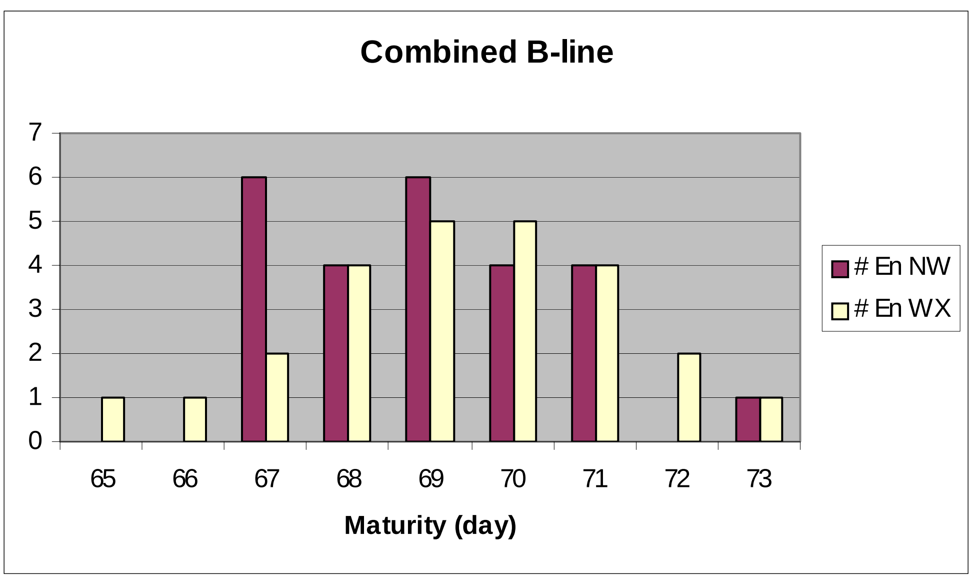

Figure 6. Entry means for days to anthesis of genotypes from the combined B-line analysis of three environments. Genotypes are delineated by endosperm type.

Table 25. Means of the ten highest entries for grain yield (kg/ha^{-1}), the ten tallest entries for plant height (cm), and the ten latest and ten earliest entries for days to anthesis in the combined B-line analysis from up to five environments. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

Rank	Entry	Yield	Entry	Plant Height	Latest Entry	Days to Flower	Earliest Entry	Days to Flower
1	17	4,225	19	135.9	20	73.5	36	65.0
2	43	4,103	8	133.8	44	73.2	28	66.8
3	24	4,050	1	133.8	31	72.5	24	67.2
4	5	3,963	37	131.1	50	72.2	5	67.3
5	6	3,898	4	131.1	27	71.8	6	67.5
6	25	3,868	10	130.6	38	71.3	32	67.5
7	41	3,803	41	130.1	7	71.3	43	67.5
8	21	3,731	25	129.3	48	71.2	17	67.7
9	8	3,703	15	129.1	45	71.2	21	67.8
10	30	3,694	11	128.5	2	71.0	8	67.8
L.S.D		1,316		7.8		3.8		3.8

R-line Population – Inbred Line Performance

Analysis by Environments in R-line Population

Model I: Analysis by environments detected significant variation for grain yield in three of five environments for endosperm type and in all five environments for among entry (endosperm) (Table 26). In each case where significant differences among endosperm were detected, the non-waxy endosperm types were greater in yield than waxy endosperm lines (Table 27). In the remaining environments, the non-waxy endosperm was numerically higher in yield (Table 27).

For plant height, significant variation due to endosperm was detected in only one of five environments while significant variation due to entry (endosperm) was detected in all five environments (Table 28). In 1998 College Station, the waxy group had higher plant height than non-waxy group, but in the other four environments there was no difference in height (Table 29).

For days to anthesis, significant variation due to endosperm was detected in only one of three environments (Table 30). In the one environment where significant difference between endosperm types was detected, the waxy endosperm types were later than non-waxy endosperm lines (Table 31). In all three environments, significant variation was detected among genotypes within an endosperm for plant maturity (Table 30).

Table 26. Mean squares for grain yield from the analysis of variance of 40 $F_{2:4}$ R-lines from the cross of (Tx2907*RTx430) grown in five environments in Texas.

	College Station			Lubbock	
Source	1998	1999	2000	1998	1999
Replication	279,805	270,676	3,012,168**	88	426,242
Endosperm	4,628,845	36,922,889**	5,709,529**	5,185,280	9,165,178**
Entry(Endosperm)	2,738,903**	1,656,407**	1,621,372**	2,347,495**	832,301**
Error	480,857	500,869	607,122	412,727	145,355

** Significance at P < .05

Table 27. Grain yield (kg/ha^{-1}) means for waxy and non-waxy R-lines from the cross of (Tx2907*RTx430) grown in five environments across Texas.

	College Station			Lubbock	
Endosperm Type	1998	1999	2000	1998	1999
Waxy	2,584	2,461	2,805	2,665	1,432
Non-Waxy	3,065	3,820	3,339	3,174	2,109
L.S.D.	ns	640	705	ns	345

Table 28. Mean squares of plant height from the analysis of variance of 40 $F_{2:4}$ R-lines from the cross of (Tx2907*RTx430) grown in five environments in Texas.

	College Station			Lubbock	
Source	1998	1999	2000	1998	1999
Replication	18.1	2.9	13.6	82.6**	13.6
Endosperm	35.5	774.5**	0.7	142.2	280.7
Entry(Endosperm)	294.1**	154.8**	189.5**	109.7**	103.7**
Error	74.9	37.6	36.3	21.8	40.6

** Significance at P < .05

Table 29. Plant height (cm) means for waxy and non-waxy R-lines from the cross of (Tx2907*RTx430) grown in five environments in Texas.

	College Station			Lubbock	
Endosperm Type	1998	1999	2000	1998	1999
Waxy	114.9	109.9	115.5	102.9	112.9
Non-Waxy	113.6	116.2	115.7	105.6	116.6
L.S.D.	ns	5.5	ns	ns	ns

Table 30. Mean squares days to anthesis from the analysis of variance of 40 $F_{2:4}$ R-lines from the cross of (Tx2907*RTx430) grown in five environments in Texas. Data was not collected for days to anthesis in Lubbock in either year.

	College Station		
Source	1998	1999	2000
Replication	0.2	105.8**	13.6**
Endosperm	64.8	80**	0.6
Entry(Endosperm)	18.2**	9.1**	2.9**
Error	3.8	4.1	1.3

** Significance at P < .05

Table 31. Days to anthesis means for waxy and non-waxy R-lines from the cross of (Tx2907*RTx430) grown in three environments in Texas.

	College Station		
Endosperm Type	1998	1999	2000
Waxy	79.1	74.5	59.4
Non-Waxy	77.2	72.5	59.5
L.S.D.	ns	1.8	ns

Model II: With endosperm type removed from the model, significant variation due to entry (or genotype) was detected for grain yield in all five environments (Table 32). When entries are graphed and individual entries a delineated by endosperm, the distribution of waxy endosperm lines was skewed to lower yields (Figure 7). In addition, in every environment, the non-waxy endosperm genotypes were predominating in the top yielding lines (Tables 33 and 34).

For plant height, analysis using model II detected significant variation due to entries in all five environments (Table 35). There was no specific pattern in the distribution of the with regard to height; both non-waxy and waxy lines were equally distributed in the ten shortest and tallest groups (Tables 36 and 37). When entries are graphed and individual entries a delineated by endosperm, the distribution of waxy and non-waxy endosperm lines were not showed any specific pattern for plant height (Figure 8).

For days to anthesis, significant variation due to entries was detected in all three environments (Table 38). Histogram of entry means for days to anthesis revealed variable responses by environments. This resulted in the lack of significant effect due to endosperm (Figure 9). In addition, endosperm classification had no effect on the latest and earliest lines (Tables 39 and 40).

Table 32. Mean squares of plant yield from the analysis of variance of 40 $F_{2:4}$ R-lines from the cross of (Tx2907*RTx430) grown in five environments in Texas.

	College Station			Lubbock	
Source	1998	1999	2000	1998	1999
Replication	279,805	270,676	3,012,168**	88	426,242
Entry	2,787,363**	2,560,675**	1,726,196**	2,420,259**	1,045,964**
Error	480,857	500,869	607,122	412,727	145,355

** Significance at P < .05

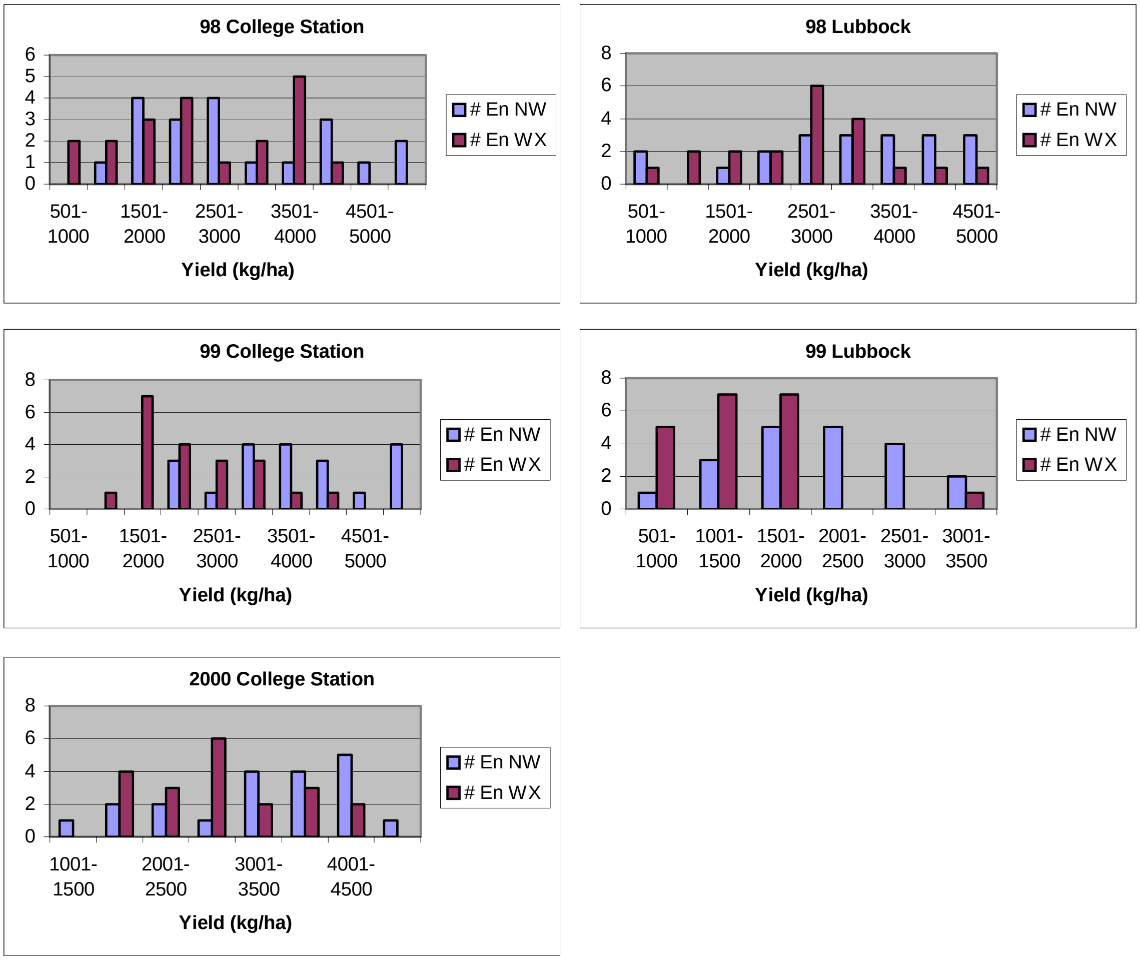

Figure 7. Histogram of R-line entry means by grain yield (kg/ha^{-1}) and delineated by endosperm class for five environments. A. College Station, 1998. B. College Station, 1999. C. College Station, 2000. D. Lubbock, 1998. E. Lubbock, 1999.

Table 33. Entry means for grain yield (kg/ha^{-1}) of ten highest yielding $F_{3:5}$ R-lines from the cross of (Tx2907 x RTx430) for each College Station environment. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	1998		1999		2000	
Rank	Entry	Yield	Entry	Yield	Entry	Yield
1	9	5,328	8	5,270	15	4,949
2	4	5,273	17	5,241	17	4,349
3	19	4,668	6	5,191	35	4,214
4	17	4,446	10	5,061	16	4,207
5	15	4,359	1	4,818	14	4,174
6	35	4,114	16	4,481	9	4,113
7	10	4,037	40	4,464	28	4,054
8	28	3,962	5	4,150	6	4,027
9	14	3,950	4	4,114	19	3,987
10	34	3,768	14	3,859	13	3,790
L.S.D.		2,805		2,863		3,152

Table 34. Entry means for grain yield (kg/ha^{-1}) of ten highest yielding $F_{3:5}$ R-lines from the cross of (Tx2907 x RTx430) for each Lubbock environment. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	1998		1999	
Rank	Entry	Yield	Entry	Yield
1	9	4,674	14	3,496
2	1	4,579	32	3,267
3	16	4,578	8	3,233
4	35	4,574	6	2,853
5	10	4,430	15	2,741
6	19	4,277	5	2,686
7	27	4,164	4	2,686
8	15	4,149	9	2,494
9	6	3,808	18	2,127
10	17	3,745	20	2,104
L.S.D.		2,598		1,541

Table 35. Mean squares of plant height from the analysis of variance of 40 $F_{2:4}$ R-lines from the cross of (Tx2907*RTx430) grown in five environments in Texas.

	College Station			Lubbock	
Source	1998	1999	2000	1998	1999
Replication	18.1	2.9	13.6	82.6**	13.6
Entry	287.4**	170.7**	184.6**	110.6**	108.3**
Error	74.9	37.6	36.3	21.8	40.6

** Significance at P < .05

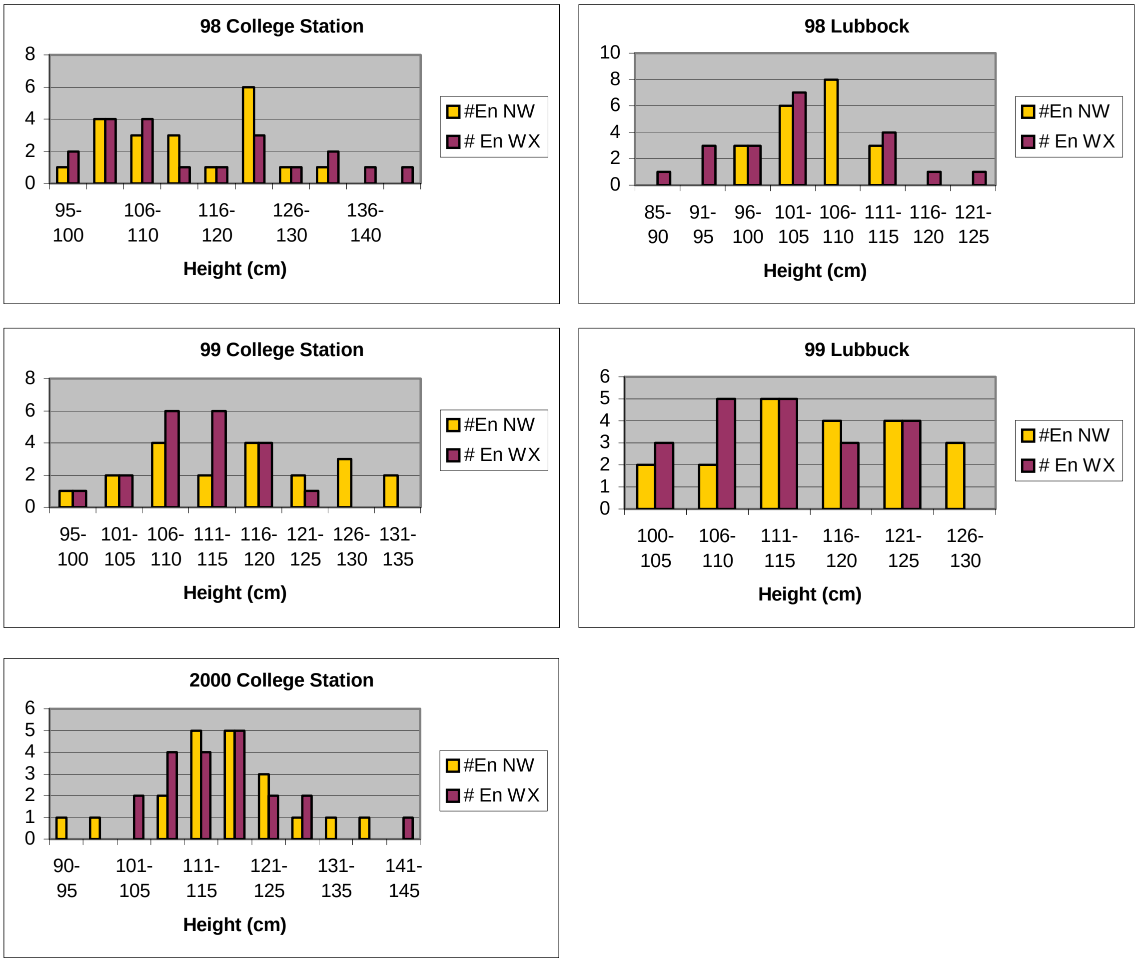

Figure 8. Histogram of R-line entry means by plant height (cm) and delineated by endosperm class for five environments. A. College Station, 1998. B. College Station, 1999. C. College Station, 2000. D. Lubbock, 1998. E. Lubbock, 1999.

Table 36. Entry means for plant height (cm) of ten highest yielding $F_{3:5}$ R-lines from the cross of (Tx2907 x RTx430) for each College Station environment. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	1998		1999		2000	
Rank	Entry	Plant Height	Entry	Plant Height	Entry	Plant Height
1	30	140.9	8	133.3	28	142.2
2	28	137.7	6	130.8	1	137.2
3	34	134.6	1	129.5	8	130.8
4	1	132.1	9	129.5	30	127.1
5	35	130.8	4	127.1	6	125.7
6	36	127.1	28	123.2	34	125.7
7	8	125.7	10	120.6	36	124.4
8	22	124.4	12	120.6	7	121.9
9	3	123.2	2	119.4	9	120.6
10	7	123.2	7	119.4	10	120.6
L.S.D.		35.1		24.8		24.4

Table 37. Entry means for plant height (cm) of ten highest yielding $F_{3:5}$ R-lines from the cross of (Tx2907 x RTx430) for each Lubbock environment. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	1998		1999	
Rank	Entry	Plant Height	Entry	Plant Height
1	28	120.6	9	129.5
2	30	118.1	4	128.3
3	1	114.3	1	127.1
4	36	114.3	8	124.4
5	7	113.1	30	124.4
6	9	113.1	6	123.2
7	27	110.5	19	123.2
8	29	110.5	33	121.9
9	34	110.5	34	121.9
10	3	109.2	12	120.6
L.S.D.		18.9		25.7

Table 38. Mean squares of plant maturity from the analysis of variance of 40 $F_{2:4}$ R-lines from the cross of (Tx2907*RTx430) grown in three environments in Texas.

	College Station		
Source	1998	1999	2000
Replication	0.2	105.8**	13.6**
Entry	19.4**	10.8**	2.8**
Error	3.8	4.1	1.3

** Significance at P < .05

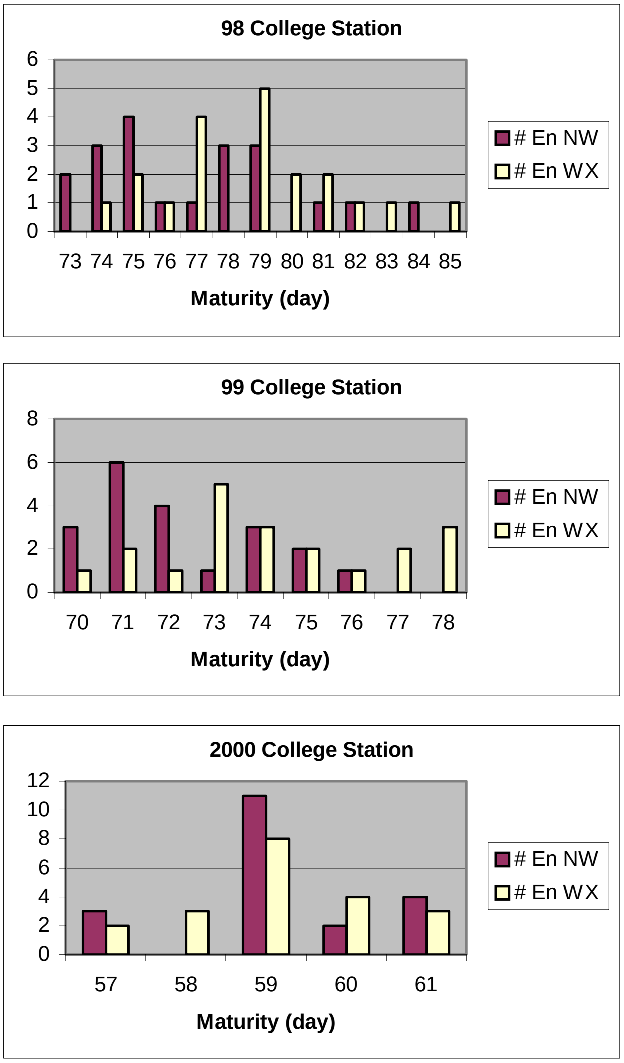

Figure 9. Distribution of plant maturity for R-line genotypes classed as waxy and non-waxy in three different environments. A. College Station, 1998. B. College Station, 1999. C. College Station, 2000.

Table 39. Mean days to anthesis the ten latest $F_{3:5}$ R-lines from the cross of (Tx2907* RTx430) in College Station over three years. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	1998		1999		2000	
Rank	Entry	Days to Flower	Entry	Days to Flower	Entry	Days to Flower
1	23	85.5	37	78.5	2	61.5
2	7	84.0	31	78.0	3	61.5
3	33	83.0	36	78.0	36	61.5
4	11	82.5	39	77.5	11	61.0
5	36	82.5	30	77.0	19	61.0
6	2	81.5	19	76.0	23	61.0
7	34	81.5	23	76.0	31	61.0
8	39	81.0	7	75.5	1	60.5
9	31	80.5	34	75.5	7	60.5
10	32	80.5	3	75.0	25	60.5
L.S.D.		7.9		8.1		4.6

Table 40. Mean days to anthesis the ten earliest $F_{3:5}$ R-lines from the cross of (Tx2907* RTx430) in College Station over three years. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	1998		1999		2000	
Rank	Entry	Days to Flower	Entry	Days to Flower	Entry	Days to Flower
1	9	73.5	8	70.5	24	57.0
2	16	73.5	10	70.5	14	57.5
3	10	74.0	16	70.5	16	57.5
4	14	74.0	32	70.5	17	57.5
5	35	74.0	1	71.0	30	57.5
6	19	74.5	5	71.0	28	58.0
7	15	75.0	13	71.0	32	58.0
8	17	75.0	14	71.0	29	58.5
9	18	75.0	17	71.0	6	59.0
10	28	75.0	27	71.0	9	59.0
L.S.D.		7.9		8.1		4.6

Combined Analysis in R-line Population

Tests of homogeneity of variance were conducted and the results indicated that the variances were not equal cross the environments. The data transformation was attempted but it did not the homogeneity of data. Therefore, the untransformed data was used for statistical analysis.

Model I: In the combined analysis of model I, significant variation due to endosperm was detected for grain yield but not for plant height or days to anthesis (Table 41). Non waxy endosperm lines yielded significantly more than waxy endosperm lines in this population (Table 42). Significant interaction terms were detected for all traits and all interactions (Table 41). The importance of these interactions is unknown, but they indicate that response between environments is occurring. Additional research would be needed to delineate the significance of these effects in the current model. However, the significance of the main effect even with the presence of the interaction indicates that the main effect is of significant importance.

Table 41. Combined analysis of the 40 $F_{3:5}$ R-lines from the cross of (Tx2907*RTx430). Data from five environments were combined in this analysis for model I.

Source	Yield	Maturity	Plant Height
Environment	25,010,703**	7,553.5**	1,712.6**
Replication (Environment)	797,796	39.8**	26.2
Endosperm	50,701,278**	87.6	528.4
Endosperm*Environment	2,727,611**	28.9**	176.3**
Entry(Endosperm)	4,536,190**	18.3**	572.3**
Entry(Endosperm)*Environment	1,165,072**	5.9**	69.9**
Error	429,386	3.1	42.2
C.V.	44.6%	11.9%	9.8%

** Significance at P < .05

Table 42. Means for waxy and non-waxy endosperm classes of sorghum from a set of 40 $F_{3:4}$ R-lines evaluated in five environments.

Class	Grain Yield kg/ha^{-1}	Maturity day	Plant Height cm
Waxy	2,389	70.9	111.3
Non-Waxy	3,101	69.7	113.6
L.S.D.	259	ns	ns

In the combined analysis of using model II, significant variation due to genotype was detected for plant yield in the combined analysis. Several other sources of variation were significant as well (Table 43). In model I, the reduction in yield infers that waxy may actually reduce yield. However, if individual lines with waxy endosperm can be identified that are higher in yield, this would imply that the negative association of yield with waxy is due to other factors and not the waxy trait per se. In the combined analysis, the yield distribution of genotypes was normal, but when they are distributed based on endosperm types, the waxy endosperm types are skewed toward lower yield (Figure 10). In detailed analysis of average yields in the combined analysis, nine of the top ten yielding lines are non-waxy, and one of them is waxy line from the highest yielding line in the test (Table 44). This result seems to indicate that there are no waxy lines that can yield with the best non-waxy types in R-line population. However, the difference between the best non-waxy line (line 15) and waxy line (line 35) was not statistically significant.

For plant height, significant variation due to genotype was detected for plant height in the combined analysis (Table 43). Other sources of variation were statistically significant for plant height (Table 43). In the combined analysis, the yield distribution of genotypes was normal, and when they are distributed based on endosperm types, there was no indication for any skewness for any endosperm types (Figure 11). In detailed analysis of average plant height in the combined analysis, six of the top ten highest lines are non-waxy, and four of them is waxy line from the highest lines in the test (Table 44).

For plant days to anthesis, significant variation due to genotype was detected for days to anthesis in the combined analysis (Table 43). Other sources of variation were statistically significant for days to anthesis as well (Table 43). In the combined analysis, the days to anthesis distribution of genotypes was normal, but when they are distributed based on endosperm types, the waxy endosperm types are skewed toward later days to anthesis (Figure 12). In detailed analysis of average days to anthesis in the combined analysis, seven of the top ten latest lines are waxy, and three of them are non-waxy lines from the latest days to anthesis lines in the test (Table 44). However, in average days to anthesis in the combined analysis, seven of the top ten latest lines are non-waxy, and three of them are waxy lines from the earliest days to anthesis lines in the test (Table 44).

Table 43. Combined analysis of the 40 $F_{3:5}$ R-lines from the cross of (Tx2907*RTx430). Data from five environments were combined in this analysis for model II.

Source	Yield	Maturity	Plant Height
Environment	25,010,703**	7,553.5**	1,712.6**
Replication (Environment)	797,796	39.8**	26.2
Entry	5,719,910**	20.1**	571.2**
Entry*Environment	1,205,137**	6.5**	72.6**
Error	429,386	3.1	42.3
C.V.	44.6%	11.9%	9.8%

** Significance at P < .05

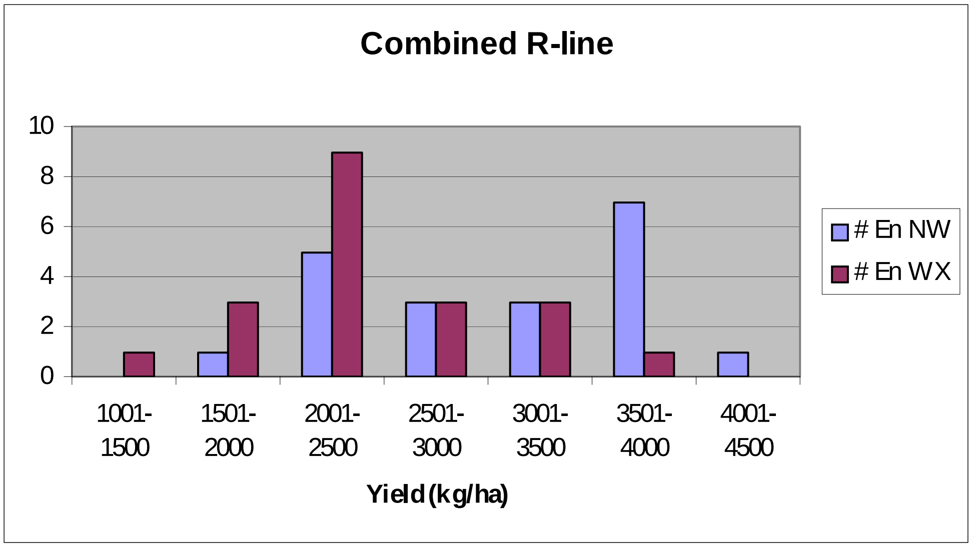

Figure 10. Distribution of combined grain yield (kg/ha^{-1}) for R-line genotypes classed as waxy and non-waxy in five different environments.

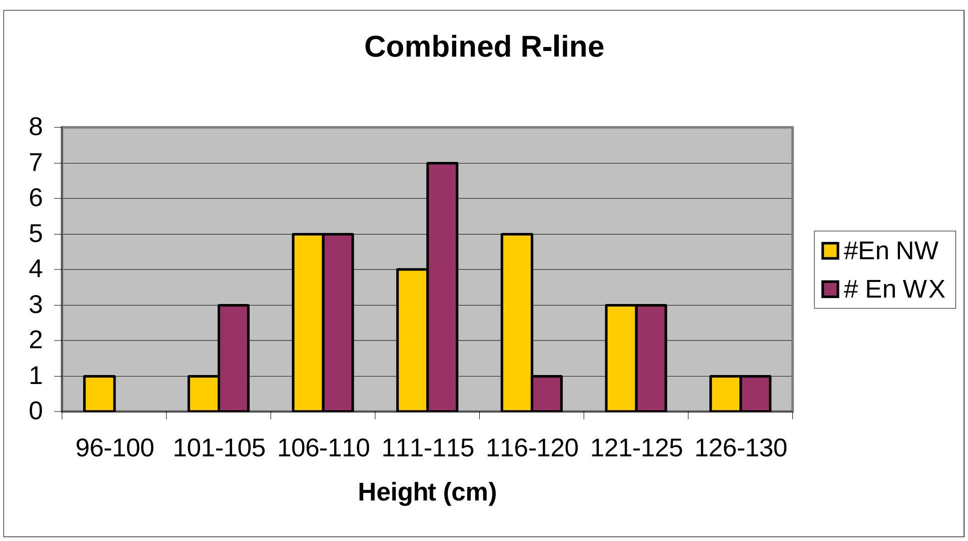

Figure 11. Distribution of combined plant height (cm) for R-line genotypes classed as waxy and non-waxy in five different environments.

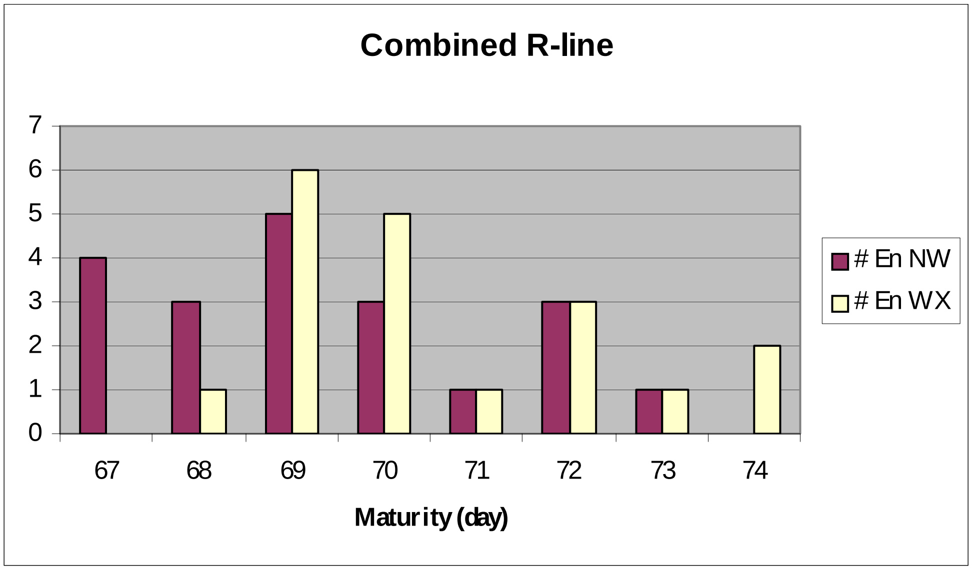

Figure 12. Distribution of combined days to anthesis for R-line genotypes classed as waxy and non-waxy in three different environments.

Table 44. Means of the ten highest entries for grain yield (kg/ha^{-1}), the ten tallest entries for plant height (cm), and the ten latest and ten earliest entries for days to anthesis in the combined R-line analysis from up to five environments. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

Rank	Entry	Yield	Entry	Plant Height	Latest Entry	Days to Flower	Earliest Entry	Days to Flower
1	15	4,009	1	128.1	23	74.2	16	67.2
2	17	3,961	28	127.5	36	74.0	14	67.5
3	9	3,953	8	124.4	7	73.3	10	67.8
4	6	3,841	9	123.2	31	73.2	17	67.8
5	4	3,801	30	123.2	11	72.6	9	68.3
6	14	3,777	6	122.2	2	72.5	28	68.6
7	10	3,777	34	121.9	33	72.5	18	68.6
8	35	3,653	36	120.1	34	72.5	8	68.8
9	16	3,600	4	119.1	37	72.5	27	69.0
10	8	3,467	7	119.1	39	72.5	35	69.0
L.S.D.		1,155		11.5		4.0		4.0

CHAPTER V

HYBRID LINE RESULTS

Hybrid B-line Population

Individual Environment Analysis in Hybrid B-line Population

Model I: Analysis of variance of each environment with hybrid B -line population did not detect any significant variation for yield due to endosperm (Tables 45 and 46). Significant variation among genotypes within endosperm type was detected in only one of the three environments (Table 45).

In hybrid B-line population, the significant variation for height among endosperm types was detected in only one location (Table 47). In each location, non-waxy endosperm types were taller than waxy endosperm lines (Table 48). Statistical differences in plant height among hybrids within endosperm were detected in two locations (Table 47).

Data on days to anthesis were taken only in College Station and Weslaco. No data were taken in the Lubbock location. However, there were no statistical differences for days to anthesis due to endosperm (Tables 49 and 50).

Table 45. Mean squares from the analysis of variance for grain yield of 50 testcross hybrids from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5) grown in three environments in Texas.

	2000 Hybrid Trials		
Source	College Station	Lubbock	Weslaco
Replication	636,925	6,157,326**	1,949,801
Endosperm	1,114	175,851	211,376
Entry(Endosperm)	921,102**	1,866,981	520,693
Error	501,145	1,227,462	624,455

** Significance at P < .05

Table 46. Means for grain yield (kg/ha^{-1}) for testcross hybrids (A3Tx436*(BTxArg-1* BTx623)-F_5) classified by the endosperm type of the pollinator parent and grown in three environments in Texas.

	2000 Hybrid Trials		
Endosperm Type	College Station	Lubbock	Weslaco
Waxy	4,322	5,643	3,938
Non-Waxy	4,315	5,559	3,846
L.S.D.	ns	ns	ns

Table 47. Mean squares from the analysis of variance for plant height of 50 testcross hybrids from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5) grown in three environments in Texas.

	2000 Hybrid Trials		
Source	College Station	Lubbock	Weslaco
Rep	402**	23	2
Endosperm	272	18	256**
Entry(Endosperm)	92**	29	35**
Error	32	21	21

** Significance at P < .05

Table 48. Means for plant height (cm) for testcross hybrids (A3Tx436*(BTxArg-1* BTx623)-F5) classified by the endosperm type of the pollinator parent and grown in three environments in Texas.

	2000 Hybrid Trials		
Endosperm Type	College Station	Lubbock	Weslaco
Waxy	129	109	114
Non-Waxy	132	110	118
L.S.D.	ns	ns	3.6

Table 49. Mean squares from the analysis of variance for plant maturity of 50 testcross hybrids from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5) grown in two environments in Texas.

	2000 Hybrid Trials	
Source	College Station	Weslaco
Rep	0.3	1.0
Endosperm	0.1	4.8
Entry(Endosperm)	1.6**	1.6
Error	0.4	1.1

** Significance at P < .05

Table 50. Means for plant maturity for testcross hybrids (A3Tx436*(BTxArg-1* BTx623)-F_5) classified by the endosperm type of the pollinator parent and grown in two environments in Texas.

	2000 Hybrid Trials	
Endosperm Type	College Station	Weslaco
Waxy	58.3	67.3
Non-Waxy	58.2	67.7
L.S.D.	ns	ns

Model II: When endosperm type is removed from the model, significant variation among hybrids for grain yield was detected in only one of three environments (Table 51). The distribution of entries was normal for both types of endosperm. (Figure 13). In addition, in every environment, the top yielding lines were not specifically from one endosperm type (Table 52).

In plant height, significant variation was detected in two of three environments for genotypes with ANOVA model II (Table 53). The distribution of waxy endosperm hybrids were slightly skewed to shorter heights compared to hybrids from non-waxy pollinators (Figure 14). In addition, in every environment, non-waxy endosperm genotypes were consistently taller (Table 54).

Variation for days to anthesis was detected only in one environment (Table 55). The distribution by endosperm type was similar in both endosperm types (Figure 15), however, the latest hybrids were dominated by hybrids from non-waxy lines (Table 56). The earliest hybrid lines almost evenly distributed from waxy and non-waxy lines (Table 57).

Table 51. Mean squares of plant yield from the analysis of variance of 50 hybrid lines from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5) grown in three environments in Texas.

	2000 Hybrid Trials		
Source	College Station	Lubbock	Weslaco
Replication	636,925	6,157,326**	1,949,801
Entry	902,327**	1,832,468	514,380
Error	501,145	1,227,462	624,455

** Significance at P < .05

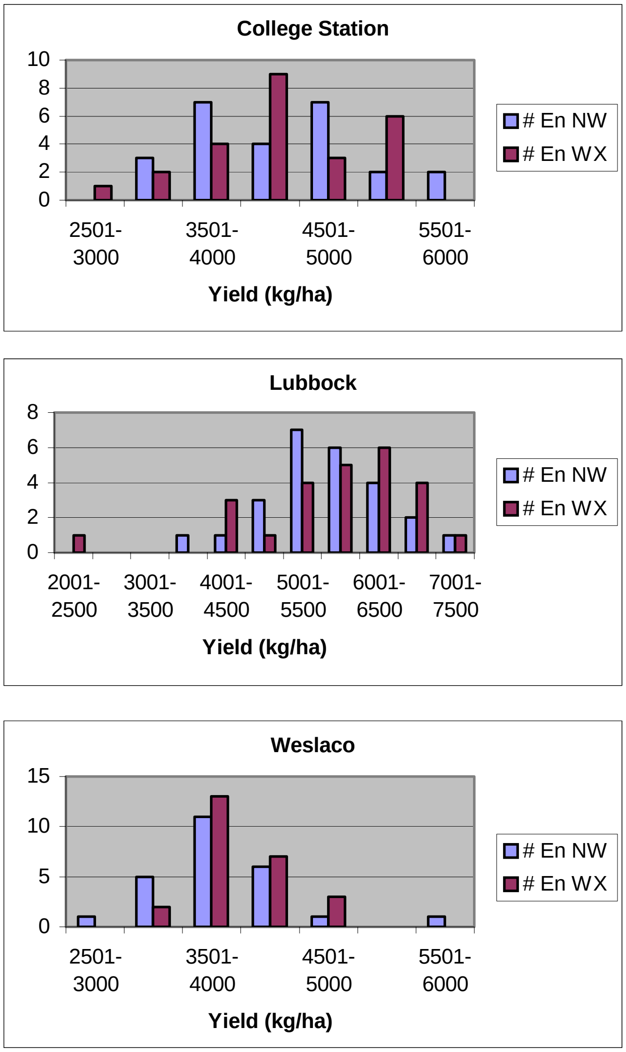

Figure 13. Distribution of grain yield (kg/ha^{-1}) for hybrid B-line genotypes classed as waxy and non-waxy in three different environments. A. College Station. B. Lubbock. C. Weslaco.

Table 52. Genotype and grain yield (kg/ha^{-1}) of ten highest yielding hybrid B-lines in College Station, Lubbock, and Weslaco. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	College Station		Lubbock		Weslaco	
Rank	Entry	Yield	Entry	Yield	Entry	Yield
1	1	5,678	49	7,212	1	5,997
2	16	5,624	25	7,044	30	4,750
3	7	5,408	30	6,933	25	4,721
4	35	5,262	31	6,709	41	4,648
5	41	5,259	10	6,709	32	4,536
6	27	5,190	33	6,653	10	4,316
7	36	5,128	7	6,597	18	4,314
8	46	5,103	37	6,597	26	4,312
9	19	5,087	1	6,485	44	4,288
10	42	5,049	35	6,429	21	4,194
L.S.D.		2,845		ns		ns

Table 53. Mean squares of plant height from the analysis of variance of 50 hybrid lines from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5) grown in three environments in Texas.

	2000 Hybrid Trials		
Source	College Station	Lubbock	Weslaco
Replication	402.6**	23.3	1.6
Entry	95.9**	28.9	39.2**
Error	32.3	21.3	20.8

** Significance at P < .05

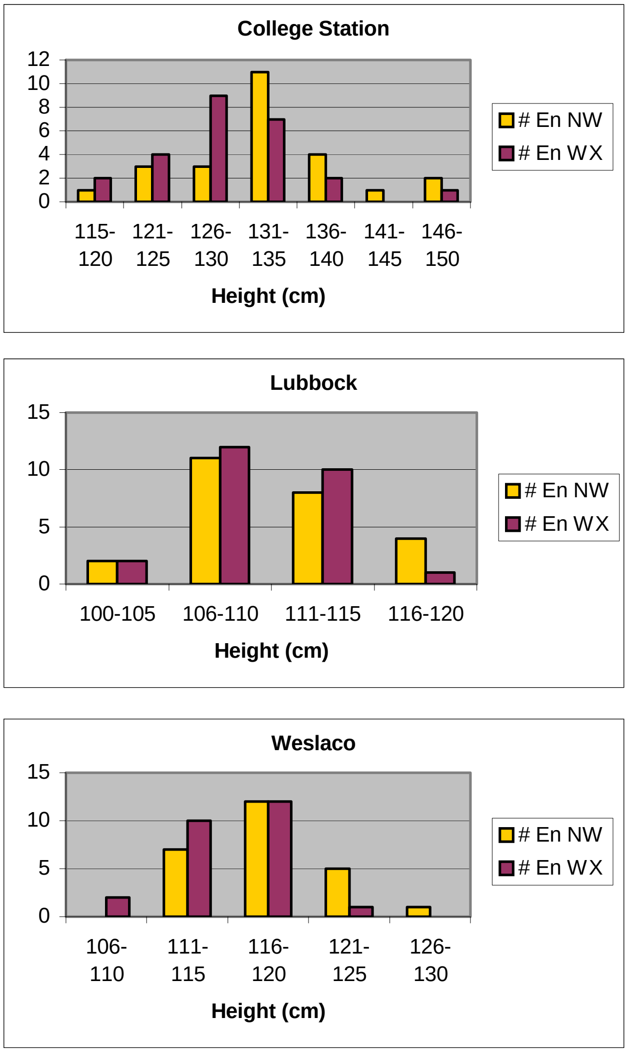

Figure 14. Distribution of plant height (cm) for hybrid B-line genotypes classed as waxy and non-waxy in three different environments. A. College Station. B. Lubbock. C. Weslaco.

Table 54. Genotype and plant height (cm) of ten highest hybrid B-lines in College Station, Lubbock, and Weslaco. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	College Station		Lubbock		Weslaco	
Rank	Entry	Plant Height	Entry	Plant Height	Entry	Plant Height
1	20	147.3	1	119.4	4	127.0
2	22	147.3	37	116.8	7	124.4
3	36	147.3	4	115.5	18	124.4
4	1	142.2	10	115.5	44	124.4
5	4	138.4	16	115.5	1	123.2
6	45	138.4	2	114.3	10	121.9
7	3	137.2	27	114.3	15	121.9
8	35	137.2	31	114.3	5	119.4
9	8	135.9	32	114.3	16	119.4
10	9	135.9	15	113.1	25	119.4
L.S.D.		22.8		ns		18.3

Table 55. Mean squares of plant maturity from the analysis of variance of 50 hybrid lines from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5) grown in three environments in Texas.

	2000 Hybrid Trials	
Source	College Station	Weslaco
Rep	0.3	1.0
Entry	1.6**	1.7
Error	0.3	1.1

** Significance at P < .05

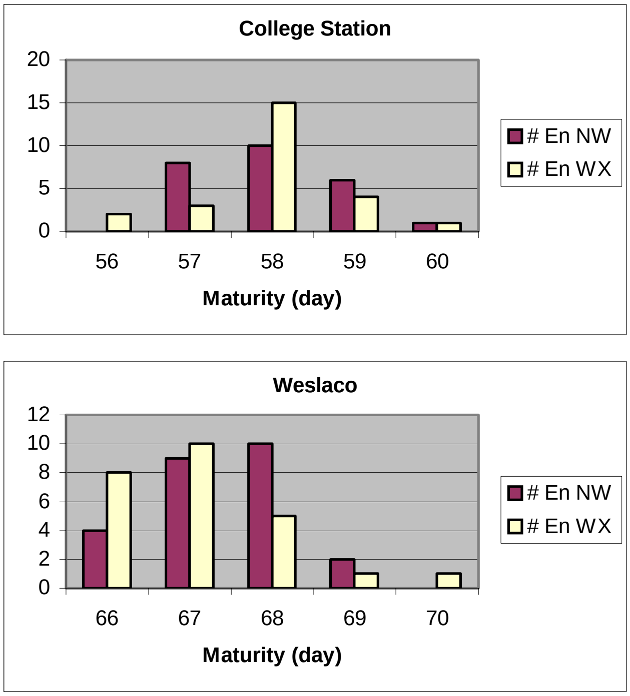

Figure 15. Distribution of plant maturity for hybrid B-line genotypes classed as waxy and non-waxy in two different environments. A. College Station. B. Weslaco.

Table 56. Genotype and plant maturity of ten latest maturity hybrid B-lines in College Station and Weslaco. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	College Station		Weslaco	
		Days to		Days to
Rank	Entry	Flower	Entry	Flower
1	17	60.0	38	70.0
2	38	60.0	3	69.5
3	1	59.5	9	69.0
4	2	59.5	27	69.0
5	6	59.5	2	68.5
6	8	59.5	6	68.5
7	29	59.5	10	68.5
8	31	59.5	12	68.5
9	44	59.5	17	68.5
10	50	59.5	20	68.5
L.S.D.		2.3		ns

Table 57. Genotype and plant maturity of ten earliest maturity hybrid B-lines in College Station and Weslaco. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

	College Station		Weslaco	
		Days to		Days to
Rank	Entry	Flower	Entry	Flower
1	28	56.5	31	66.0
2	35	56.5	34	66.0
3	4	57.0	35	66.0
4	11	57.0	42	66.0
5	12	57.0	4	66.5
6	23	57.0	5	66.5
7	47	57.0	15	66.5
8	3	57.5	18	66.5
9	5	57.5	30	66.5
10	7	57.5	39	66.5
L.S.D.		2.3		ns

Combined Analysis in Hybrid B-line Population

Model I: Test of homogeneity of variance indicated that the variances for grain yield were not heterogeneous. Therefore, the data was combined across environments. In the combined analysis of model I, significant variation among endosperm or hybrids was not detected for yield (Table 58), but the waxy parents had produced hybrids with a numerically higher yield (Table 59).

Test of homogeneity of variance indicated that the variances for plant height were not heterogeneous. Therefore, the data was combined across environments. In the combined analysis, hybrids of non-waxy pollinators were taller than those from waxy pollinators (Tables 58 and 59). In addition, significant variation for plant height among hybrids within an endosperm was detected (Table 58).

Test of homogeneity of variance indicated that the variances for days to anthesis were not heterogeneous. Therefore, the data was combined across environments. Analysis with combined plant maturity data did not detect any significant variation between endosperm types for plant maturity (Table 58). However, as expected, significant variation among hybrids was detected. (Table 59). Also significant interaction between entry within endosperm and environments was detected, but the interaction between endosperm types and the environments was not statistically significant (Table 58).

Table 58. Combined analysis of the 50 hybrid lines from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5). Data from three environments were combined in this analysis for model I.

Source	Yield	Maturity	Plant Height
Environment	79,171,962**	4 297**	11,530**
Replication (Environment)	2,914,684**	1.0	143**
Endosperm	277,548	1.8	452.1**
Endosperm*Environment	55,397	3.1	47.5
Entry(Endosperm)	1,115,332	2.1**	67.4**
Entry(Endosperm)*Environment	1,096,722**	1.2**	44.3**
Error	784,354	0.7	24.8
C.V.	26.4%	7.5%	9.1%

** Significance at P < .05

Table 59. Means for waxy and non-waxy endosperm classes of sorghum from a set of 50 hybrid B-lines evaluated in three environments.

Class	Grain Yield kg/ha^{-1}	Maturity day	Plant Height cm
Waxy	4,634	62.8	117.5
Non-Waxy	4,574	62.9	120.1
L.S.D.	ns	ns	2.2

Model II: Variation for grain yield among genotypes was not detected in the combined analysis although some of the interaction terms were significant (Table 60). The standard deviation around the mean is not high in the hybrid B-line. This might be an explanation why there is no significant variation among the entries (Table 58). In the combined analysis, the yield distribution of all genotypes is normal, but when they are distributed based on endosperm types, the waxy endosperm types are very slightly skewed toward higher yield (Figure 16). Of the ten highest yielding hybrids, six are hybrids from a waxy pollinator (Table 61). This result seems to indicate that the yield difference between endosperm is related to some other factors in hybrid B-line population.

Analysis of plant height detected significant variation among genotypes (Table 60). Several interactions terms were significant as well (Table 60). In the combined analysis, the plant height distribution of genotypes was normal, but when they are distributed by endosperm types, the non-waxy lines are slightly skewed to higher plant height (Figure 17). This effect was detected in the Model I analysis. Of the ten tallest hybrids, seven were derived from non-waxy pollinators, implying that the waxy endosperm may reduce plant height of the hybrids (Table 61).

For plant maturity the variation among the genotype was statistically significant (Table 60). The average days to maturity in the combined analysis showed that there was no skewing of either endosperm type in the histogram. (Figure 18 and Table 61).

Table 60. Combined analysis of the 50 hybrid lines from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5). Data from three environments were combined in this analysis for model II.

Source	Yield	Maturity	Plant Height
Environment	79,171,961**	4,296**	11,529**
Replication (Environment)	2,914,684**	0.6	142.5**
Entry	1,098,234	2.1**	75.3**
Entry*Environment	1,075,471**	1.2**	44.4**
Error	784,354	0.7	24.8
C.V.	26.4%	7.6%	9.1%

** Significance at P < .05

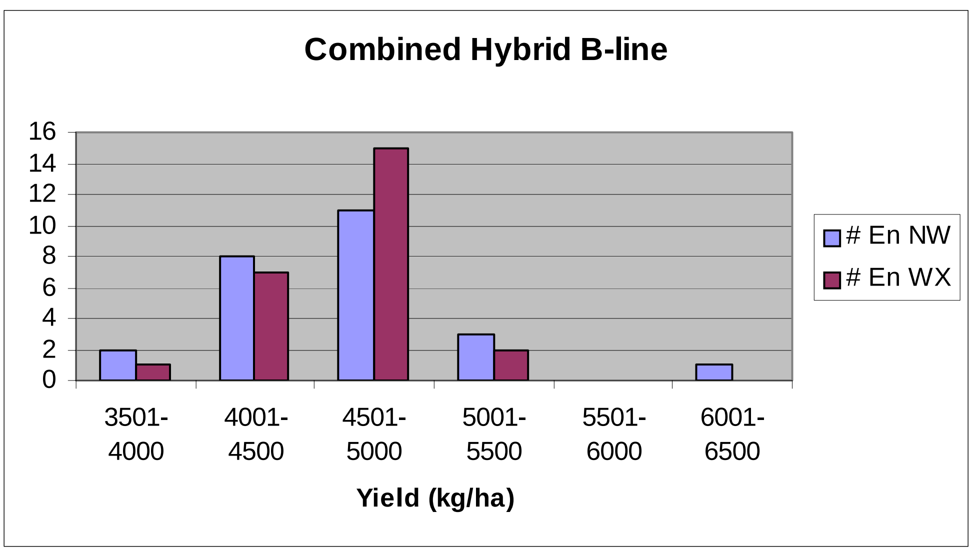

Figure 16. Distribution of combined hybrid B-line grain yield (kg/ha^{-1}) for genotypes classed as waxy and non-waxy in three different environments.

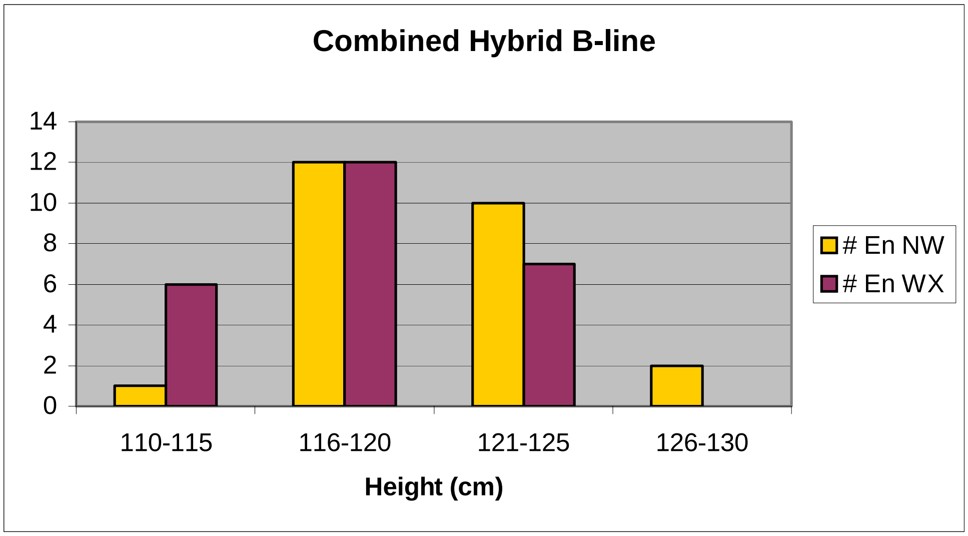

Figure 17. Distribution of combined hybrid B-line plant height (cm) for genotypes classed as waxy and non-waxy in three different environments.

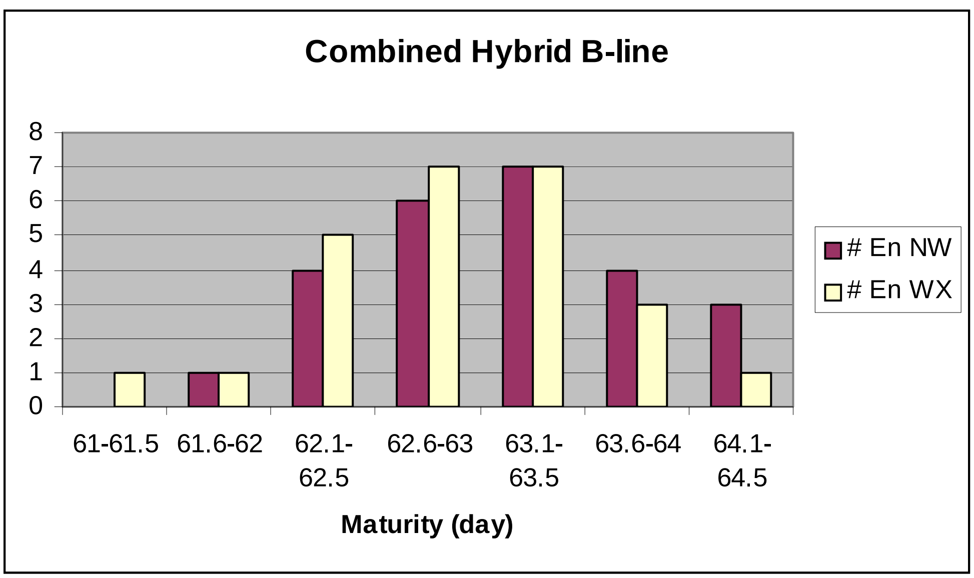

Figure 18. Distribution of combined hybrid B-line plant maturity for genotypes classed as waxy and non-waxy in two different environments.

Table 61. Means of the ten highest entries for grain yield (kg/ha^{-1}), the ten tallest entries for plant height (cm), and the ten latest and ten earliest entries for days to anthesis in the combined hybrid B-line analysis from up to three environments. Entries numbered one through 25 are non-waxy endosperm while entries numbered 26 through 50 are waxy endosperm.

Rank	Entry	Yield	Entry	Plant Height	Latest Entry	Days to Flower	Earliest Entry	Days to Flower
1	1	6,053	1	128.3	38	65.0	35	61.3
2	30	5,311	4	127.0	17	64.2	4	61.8
3	7	5,273	20	123.6	2	64.0	34	61.8
4	25	5,149	7	122.7	6	64.0	5	62.0
5	16	5,017	37	122.7	1	63.7	28	62.0
6	35	5,000	16	122.7	27	63.7	42	62.0
7	46	4,991	15	122.3	44	63.7	47	62.0
8	44	4,941	36	122.3	50	63.7	11	62.3
9	36	4,931	44	121.9	3	63.5	15	62.3
10	32	4,913	22	121.5	8	63.5	23	62.3
L.S.D.		ns		11.3		2.4		2.4

Hybrid R-line Population

Individual Environment Analysis in Hybrid R-line Population

Model I: Analysis by environments detected significant variation for yield among endosperm types only in the 2000 Lubbock environment. No significant variation was detected among entry within an endosperm in any environment (Table 62). Although differences in yield were significant in only one environment, the non-waxy endosperm types were numerically higher in yield than waxy endosperm lines (Table 63).

Analysis by environments did not detect any difference in height due to endosperm in any environments. Significant variation among genotypes for plant height was detected two of three environments (Table 64). In environments where differences were detected, there was no trend in height with relationship to endosperm type (Table 65). For plant maturity, there was no significant variation detected due to endosperm or among genotypes within an endosperm type. (Table 66). In addition, the average plant maturity data clearly showed that there were not any significant differences among genotypes, and the means are almost the same for endosperm types (Table 67).

Table 62. Mean squares from the analysis of variance for grain yield of 40 testcross hybrids from the cross of ($ATx631*(Tx2907*RTx430)-CF_2$) grown in three environments in Texas.

	2000 Hybrid Trials		
Source	College Station	Lubbock	Weslaco
Replication	1,165,525	16,246,798**	436,258
Endosperm	555	3,442,168**	686,911
Entry(Endosperm)	1,271,242	363,054	753,361
Error	835,474	338,434	519,950

** Significance at P < .05

Table 63. Means for grain yield (kg/ha^{-1}) for testcross hybrids ($ATx631*(Tx2907*RTx430)-CF_2$) classified by the endosperm type of the pollinator parent and grown in three environments in Texas.

	2000 Hybrid Trials		
Endosperm Type	College Station	Lubbock	Weslaco
Waxy	6,380	6,114	4,329
Non-Waxy	6,386	6,529	4,514
L.S.D.	ns	526	ns

Table 64. Mean squares from the analysis of variance for plant height of 40 testcross hybrids from the cross of (ATx631*(Tx2907*RTx430)-CF_2) grown in three environments in Texas.

	2000 Hybrid Trials		
Source	College Station	Lubbock	Weslaco
Replication	0.1	99	774**
Endosperm	50	88	1
Entry(Endosperm)	95**	42	39**
Error	39	33	17

** Significance at P < .05

Table 65. Means for plant height (cm) for testcross hybrids (ATx631*(Tx2907*RTx430)-CF_2) classified by the endosperm type of the pollinator parent and grown in three environments in Texas.

	2000 Hybrid Trials		
Endosperm Type	College Station	Lubbock	Weslaco
Waxy	144	122	132
Non-Waxy	143	124	131
L.S.D.	ns	ns	ns

Table 66. Mean squares from the analysis of variance for plant maturity of 40 testcross hybrids from the cross of (ATx631*(Tx2907*RTx430)-CF_2) grown in two environments in Texas.

	2000 Hybrid Trials	
Source	College Station	Weslaco
Replication	0.2	0.01
Endosperm	1.2	0.6
Entry(Endosperm)	2.4	0.9
Error	1.8	0.9

** Significance at P < .05

Table 67. Means for plant maturity for testcross hybrids (ATx631*(Tx2907*RTx430)-CF_2) classified by the endosperm type of the pollinator parent and grown in two environments in Texas.

	2000 Hybrid Trials	
Endosperm Type	College Station	Weslaco
Waxy	82.5	70.3
Non-Waxy	82.3	70.2
L.S.D.	ns	ns

Model II: When endosperm type is removed from the model, no significant variation due to genotype was detected for yield in any environment (Table 68). When classified by endosperm the distribution of waxy lines were slightly shifted, but not significantly, to lower yielding (Figure 19). In addition, in every environment, non-waxy endosperm genotypes composed the majority of the top yielding lines (Table 69).

Significant variation was detected for plant height in two environments for genotypes (Table 70). The classified distribution by endosperm showed that there might be a slight shift, resulting in non-waxy pollinators producing slightly taller hybrids (Figure 20). In addition, the non-waxy endosperm genotypes dominated the tallest hybrids (Table 71).

As in the other experiment, there was no significant variation detected for genotypes for plant day to flowering (Table 72). The distribution and average plant maturity indicated that there was no difference between the endosperm types (Figure 21) (Table 73). However, the earliest hybrids were dominated by hybrids from non-waxy lines (Table 74).

Table 68. Mean squares of plant yield from the analysis of variance of 40 hybrid lines from the cross of (ATx631*(Tx2907*RTx430)-CF_2) grown in three environments in Texas.

	2000 Hybrid Trials		
Source	College Station	Lubbock	Weslaco
Replication	1,165,525	16,246,797**	436,258
Entry	1,238,660	442,005	751,657
Error	835,474	338,433	519,949

** Significance at P < .05

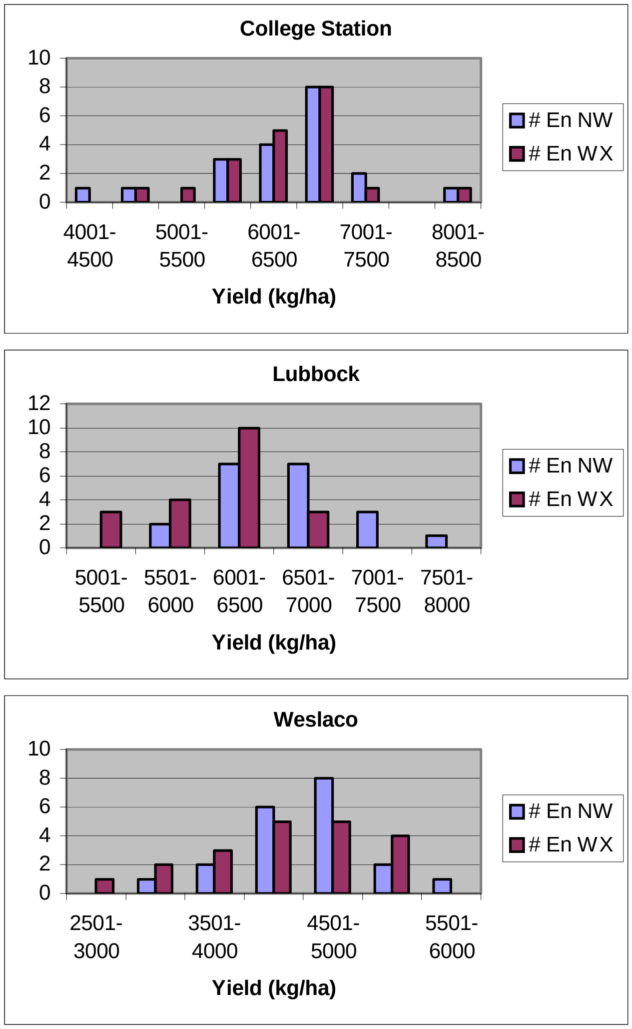

Figure 19. Distribution of grain yield (kg/ha^{-1}) for hybrid R-line genotypes classed as waxy and non-waxy in three different environments. A. College Station. B. Lubbock. C. Weslaco.

Table 69. Genotype and grain yield (kg ha^{-1}) of ten highest yielding hybrid R-lines in College Station, Lubbock, and Weslaco. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	College Station		Lubbock		Weslaco	
Rank	Entry	Yield	Entry	Yield	Entry	Yield
1	20	8,050	7	7,509	5	5,533
2	23	8,039	16	7,156	34	5,384
3	4	7,138	6	7,044	15	5,358
4	40	7,066	3	7,005	8	5,195
5	13	7,019	17	6,877	25	5,177
6	7	6,963	10	6,821	27	5,075
7	31	6,929	20	6,709	22	5,020
8	16	6,919	13	6,653	21	4,977
9	1	6,917	35	6,653	17	4,872
10	24	6,858	2	6,620	39	4,868
L.S.D.		ns		ns		ns

Table 70. Mean squares of plant height (cm) from the analysis of variance of 40 hybrid lines from the cross of (ATx631*(Tx2907*RTx430)-CF_2) grown in three environments in Texas.

	2000 Hybrid Trials		
Source	College Station	Lubbock	Weslaco
Rep	0.1	98.8	774.5**
Entry	94.2**	43.4	37.8**
Error	39.8	32.9	17.1

** Significance at $P < .05$

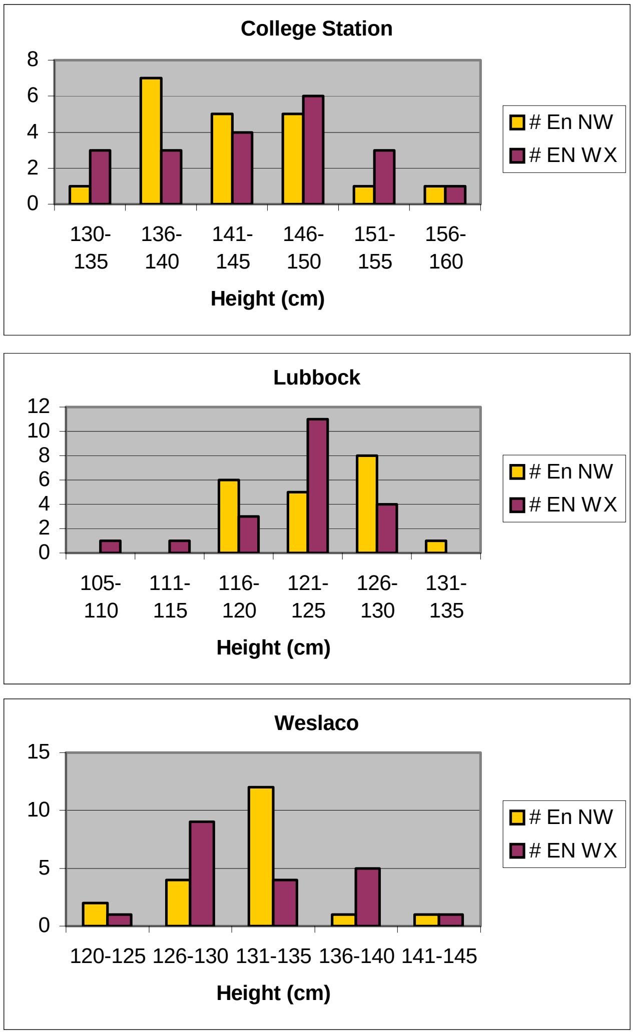

Figure 20. Distribution of plant height (cm) for hybrid R-line genotypes classed as waxy and non-waxy in three different environments. A. College Station. B. Lubbock. C. Weslaco.

Table 71. Genotype and plant height (cm) of ten highest hybrid R-lines in College Station, Lubbock, and Weslaco. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	College Station		Lubbock		Weslaco	
Rank	Entry	Plant Height	Entry	Plant Height	Entry	Plant Height
1	4	158.7	3	132.1	7	140.9
2	23	156.2	6	129.5	31	140.9
3	28	154.9	20	129.5	21	137.2
4	31	153.6	10	128.3	23	137.2
5	9	152.4	12	128.3	25	137.2
6	30	151.1	4	127.0	27	137.2
7	21	149.8	7	127.0	4	135.9
8	29	149.8	8	127.0	29	135.9
9	10	148.6	9	127.0	8	134.6
10	12	148.6	21	127.0	9	134.6
L.S.D.		25.5		ns		16.6

Table 72. Mean squares of plant maturity from the analysis of variance of 40 hybrid lines from the cross of (Atx631*(Tx2907*Rtx430)-CF2) grown in two environments in Texas.

	2000 Hybrid Trials	
Source	College Station	Weslaco
Replication	0.2	0.1
Entry	2.4	0.9
Error	1.8	0.9

** Significance at P < .05

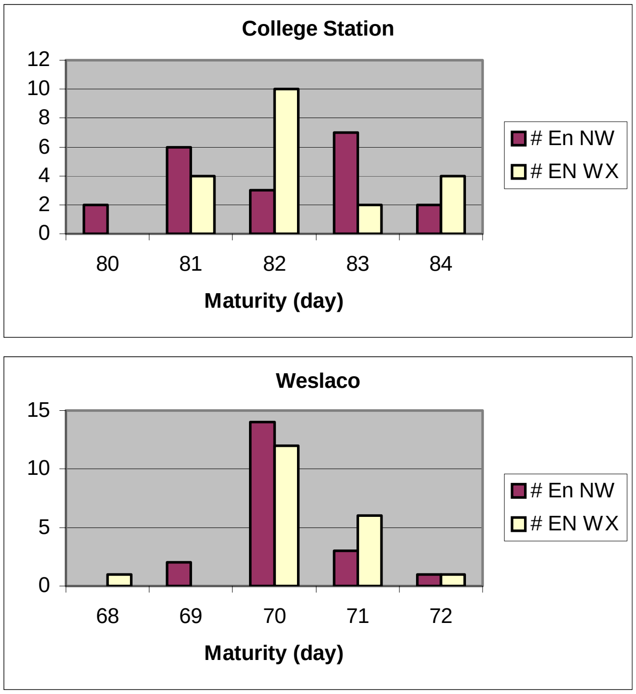

Figure 21. Distribution of plant maturity for hybrid R-line genotypes classed as waxy and non-waxy in two different environments. A. College Station. C. Weslaco.

Table 73. Genotype and plant maturity of ten latest hybrid R-lines in College Station, and Weslaco. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	College Station		Weslaco	
Rank	Entry	Days to Flower	Entry	Days to Flower
1	29	84.5	20	72.0
2	33	84.5	33	72.0
3	2	84.0	40	71.0
4	7	84.0	13	71.0
5	26	84.0	18	71.0
6	32	84.0	19	71.0
7	6	83.5	24	71.0
8	11	83.5	26	71.0
9	18	83.5	31	71.0
10	35	83.5	32	71.0
L.S.D.		ns		ns

Table 74. Genotype and plant maturity of ten earliest hybrid R-lines in College Station, and Weslaco. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

	College Station		Weslaco	
		Days to		Days to
Rank	Entry	Flower	Entry	Flower
1	4	80.5	27	68.5
2	9	80.5	6	69.0
3	1	81.0	8	69.0
4	14	81.0	1	70.0
5	30	81.0	2	70.0
6	8	81.5	3	70.0
7	12	81.5	4	70.0
8	16	81.5	5	70.0
9	20	81.5	7	70.0
10	23	81.5	9	70.0
L.S.D.		ns		ns

Combined Analysis in Hybrid R-line Population

Model I: For all traits the Levene test of homogeneity of variance was conducted and no heterogeneity of error mean squares was detected. Therefore, the data from each environment were combined for analysis. As previous, two statistical models were used. In model I, significant variation was not detected for yield and among entries within an endosperm (Table 75). Likewise, the effect of endosperm was not significant with hybrid R-line population. In the hybrids, there was no effect of waxy endosperm allele.

Test of homogeneity of variance was conducted for plant height and the result from the statistical analysis indicated that the variances were equal to combine the data from all environments. Combined analysis detected no significant variation for plant height in endosperm types but significant variation was detected among entries within endosperm (Table 75). In addition, some other factors were significant to account for the variation as well (Table 75). The average plant height was very similar for endosperm types (Table 76).

Combined analysis of model I did not detect any significance variation in days to anthesis due to the endosperm types, or entries within endosperm (Table 75). The means of waxy and non-waxy hybrids were essentially the same for days to anthesis. (Table 76).

Table 75. Combined analysis of the 40 hybrid lines from the cross of (ATx631*(Tx2907*RTx430)-CF_2). Data from three environments were combined in this analysis for model I.

Source	Yield	Maturity	Plant Height
Environment	99,450,228**	5,941	8,635**
Replication (Environment)	5,949,527**	0.1	291**
Endosperm	2,443,828	2	0.4
Endosperm*Environment	842,903	0.1	69
Entry(Endosperm)	731,019	2	117**
Entry(Endosperm)*Environment	828,319**	1.5	30
Error	564,619	1.3	30
C.V.	22.1%	8.2%	2%

** Significance at P < .05

Table 76. Means for waxy and non-waxy endosperm classes of sorghum from a set of 40 hybrid R-lines evaluated in three environments.

	Grain Yield	Maturity	Plant Height
Class	kg/ha^{-1}	day	Cm
Waxy	5,608	76.4	132.5
Non-Waxy	5,809	76.2	132.5
L.S.D.	ns	ns	ns

Model II: There was no significant variation for genotype effect in the combined analysis, but some other sources of variation were significant such as environments, replications, and entry (endosperm) by environments interaction (Table 77). In the combined analysis, the yield distribution of genotypes was normal, but when they are classified according to endosperm, the non-waxy endosperm types are very slightly skewed toward higher yield (Figure 22). In detailed analysis of average yields in the combined analysis, nine of the top ten yielding lines are non-waxy (Table 78).

For plant height, the significant variation was not found among genotypes (Table 77). In the top ten highest line analyses, seven of the ten lines were from the non-waxy lines (Table 78). It is saying that the endosperm type is slightly effecting the plant height. Also the distribution of plant height based on endosperm types shows very similar pattern (Figure 23).

For days to anthesis, significant variation was not found among genotypes (Table 77). Histograms indicated that the distribution of non-waxy and waxy genotypes for days to maturity were very similar (Figure 24). Most of the latest maturity lines were from waxy endosperm pollinators (Table 78).

Table 77. Combined analysis of the 40 hybrid R-lines from the cross of (ATx631*(Tx2907*RTx430)-CF_2). Data from three environments were combined in this analysis for model II.

Source	Yield	Maturity	Plant Height
Environment	99,450,227**	5,941	8,635**
Replication (Environment)	5,949,527**	0.1	291.1**
Entry	774,937	1.9	113.9**
Entry*Environment	828,692**	1.4	30.8
Error	564,619	1.3	29.9
C.V.	22.1%	8.1%	8.24%

** Significance at P < .05

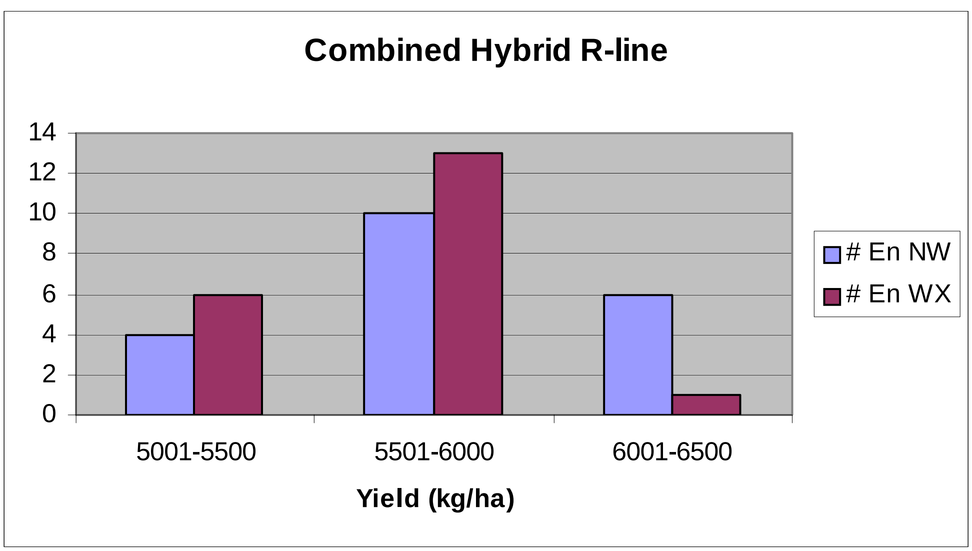

Figure 22. Distribution of combined hybrid R-line grain yield (kg/ha^{-1}) for genotypes classed as waxy and non-waxy in three different environments.

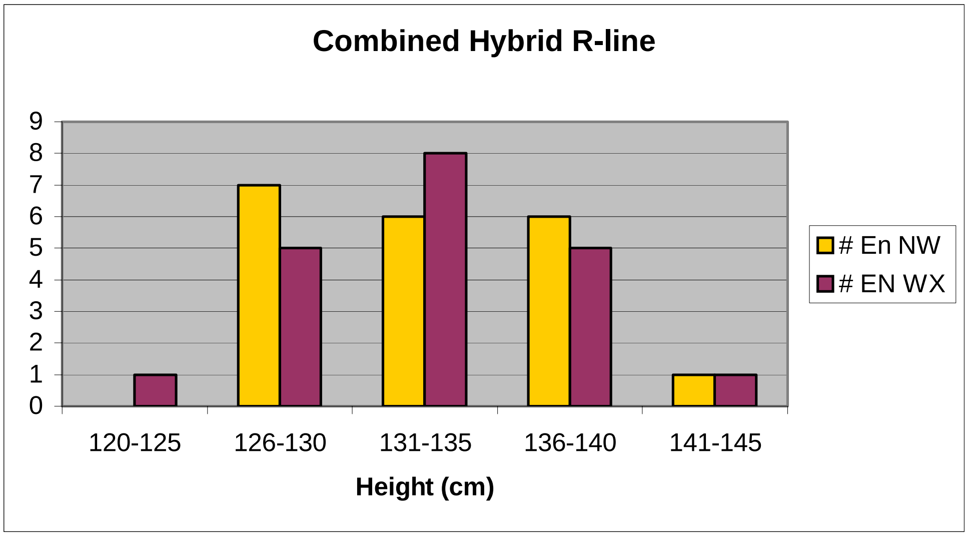

Figure 23. Distribution of combined hybrid R-line plant height (cm) for genotypes classed as waxy and non-waxy in three different environments.

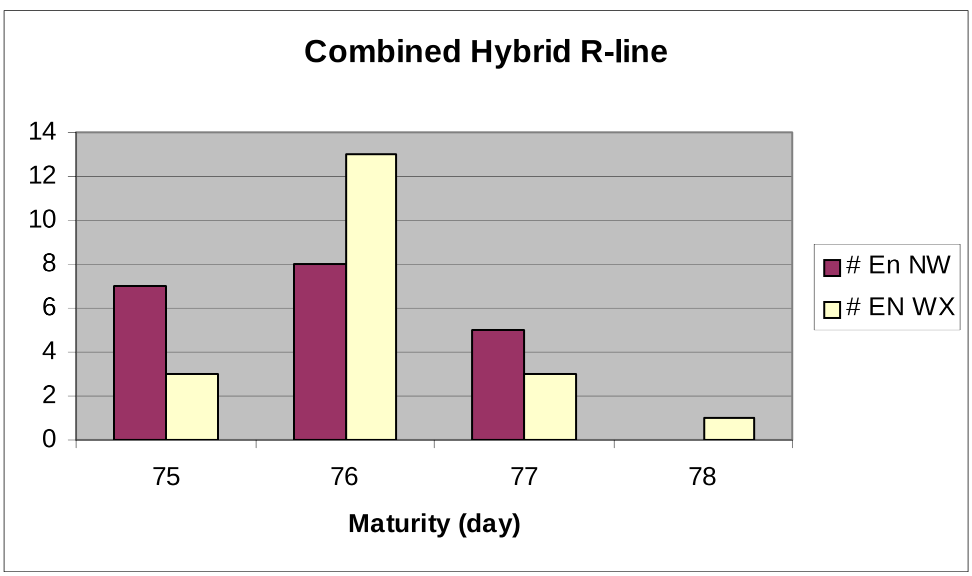

Figure 24. Distribution of combined hybrid R-line plant maturity for genotypes classed as waxy and non-waxy in two different environments.

Table 78. Means of the ten highest entries for grain yield (kg/ha^{-1}), the ten tallest entries for plant height (cm), and the ten latest and ten earliest entries for days to anthesis in the combined analysis from up to three environments. Entries numbered one through 20 are non-waxy endosperm while entries numbered 21 through 40 are waxy endosperm.

Rank	Entry	Yield	Entry	Plant Height	Latest Entry	Days to Flower	Earliest Entry	Days to Flower
1	20	6,394	4	140.5	33	78.3	4	75.3
2	7	6,330	23	140.1	26	77.5	8	75.3
3	16	6,314	31	139.7	32	77.5	9	75.3
4	15	6,103	7	138.0	18	77.3	27	75.3
5	21	6,089	21	138.0	29	77.3	1	75.5
6	8	6,084	9	138.0	2	77.0	14	75.5
7	4	6,059	28	137.5	7	77.0	30	75.5
8	27	5,985	29	137.1	13	77.0	12	75.8
9	17	5,955	8	136.3	19	77.0	16	75.8
10	22	5,955	10	136.3	11	76.8	23	75.8
L.S.D.		ns		12.5		ns		ns

CHAPTER VI

DISCUSSION AND SUMMARY

For the inbred B-line population, the average yield difference between waxy and non-waxy lines was greatest in College Station (Table 8). In Lubbock, waxy lines yielded numerically but not statistically less than the non-waxy group. In all four environments, the waxy lines yielded numerically less than the non-waxy lines and in two of those environments, the difference was statistically significant (Table 7). This trend was further accentuated in the combined analysis, where the difference between the waxy and non-waxy groups was highly significant (Table 22). In the inbred R-line population, the waxy lines as a group yielded numerically less than the group of non-waxy lines and the reduction in yield was significant in three of the four environments (Tables 26 and 27). This trend was further accentuated in the combined analysis, where the difference between the waxy and non-waxy groups was highly significant (Table 41).

In both inbred line populations, the presence of waxy endosperm resulted in a significant reduction in grain yield in five out of eight environments. In the combined analysis for both populations, grain yield was reduced in the waxy endosperm group compared to the non-waxy group. If this data from the two populations were further combined, additional significance in the differences would be identified. Thus, the data clearly imply that the waxy trait has a negative impact on grain yield.

Similar trends were not observed in the hybrid trials. In the testcross hybrids of the B-line population, there was no difference in yield in any single environment or in the combined analysis (Tables 45 and 58). In testcross hybrids of the R-line population, the hybrids created with non-waxy lines were numerically higher in yield in all four environments, but only marginally statistically significant in a single environment (Table 62). In the combined analysis, there was no statistical difference in yield (Table 75). These results indicate that the waxy trait does not influence yield potential in hybrid sorghums. However, there were additional factors that must be considered when evaluating the yield data from the testcross hybrids.

In the testcross hybrids from the B-line population, the $F_{2:5}$ lines were hybridized to A3Tx436. Because this hybrid was made using A3 cytoplasm, all of the testcross hybrids will be male sterile and required the use of a male pollinator for seed set. Because most pollen in the yield trial block was from non-waxy hybrids and lines, almost 100% of the pollen that pollinated the experimental hybrids possessed a dominant *Wx* allele. Due to the xenia effect (expression of that allele in the developing grain) the endosperm phenotype will be non-waxy for every testcross hybrid, regardless of the genotype of line in the hybrid. This effectively masks and makes any other comparison of the performance across lines impossible.

In testcross hybrids from the R-line population, the $F_{2:5}$ lines were hybridized onto ATx631 (Miller, 1986). Because these hybrids were made in the A1 cytoplasmic male sterile (CMS) system, each pollinator fully restored the fertility of the hybrid. ATx631 is a non-waxy parental line and in combination with the waxy pollinator lines, the grain on the resultant F_1 hybrids is heterowaxy, as it is segregating for waxy endosperm. Therefore, the comparison in this trial is between a set of non-waxy endosperm hybrids and a set of heterowaxy hybrids. Since heterowaxy hybrids are approximately 75% non-waxy and only 25% waxy, any yield disparity between the waxy and non-waxy traits per se would be diluted. While they certainly do not confirm this, the yield from the R-line testcross hybrids seems to support the concept of a dilution effect.

To effectively test the effect of the *wx* allele in hybrid combination, it will be necessary to use additional testers and specific pollinators to test the combinations. In the B-line populations where male sterile hybrids are tested, testcross hybrids should be isolated and pollinated with a waxy parental line and/or waxy fertile hybrid. In the R-line population, the best situation for testing would be through the use of a waxy A-line tester such as ATxArg-1. In both situations, this would result in a more appropriate comparison of a waxy hybrid with a heterowaxy hybrid, which will reduce the effect of dominance in the comparison.

While the hybrid data is inconclusive due to the factors previously discussed, the inbred line data clearly indicate that waxy endosperm is associated with a general reduction in yield. However, the cause of the yield reduction is not determined by the previous analysis. The yield reduction could be a pleiotrophic effect specifically associated with the wx allele or it could be due to undesirable alleles associated with waxy through genetic linkages.

If the latter option is occurring, it should be possible to disrupt those linkages and produce individual waxy lines that have high yield potential. The second analysis in this study (model II) addressed this question. In the B-line population, the highest yielding line was entry 17, which was a non-waxy line, but the highest yielding waxy line was entry 43 which ranked second in the combined analysis with ranks in individual environment ranging from first to fifteenth (Table 25). The stability of both of these lines was similar and the yield differences between the two were not significantly different. In the combined analysis, three of the top ten lines were waxy endosperm.

For the R-line population, the performance of the waxy lines was not as strong. Entry 35 was had the highest average yield for a waxy R-line, but in the combined analysis that ranked eighth, behind seven non-waxy lines (Table 44). Entry 35 ranked in the top ten in three of the five environments ranging in rank from third to twenty-second (Tables 33 and 34). In the combined analysis, only entry 35 was in the top ten; the remaining nine lines were all non-waxy (Table 44).

Results from the B-line population indicate that high yielding waxy endosperm lines can be developed while the results from the R-line population are less optimistic about the possibility of developing high-yielding waxy endosperm sorghum. In corn, systematic efforts to improve waxy endosperm corn have resulted in substantial improvement in yield, however, continual improvements in the yields of non-waxy corn still result in a yield gap between the two types. Waxy endosperm rice cultivars, desirable for certain food products do not yield competitively with non-waxy cultivars. In both cases, market factors such as food use or processing needs, and not grain yield, drive the production of these specialty type cultivars and hybrids. While waxy endosperm sorghum may also provide benefits to the end-user, the end-users have traditionally been unwilling to compensate the producer using any measure besides yield. Consequently, if yields are even slightly lower, then producers must take a cut in profit simply to grow the product. This is something that they are obviously not willing to do.

In conclusion, it appears that the waxy endosperm phenotype is associated with a grain yield reduction. Whether this is in fact due to pleiotrophy or linkage remains unclear, as there is evidence of both occurring in different populations. Additional and more descriptive trials are needed to determine if the same effect is detectable in hybrid combinations. Initial circumstantial evidence indicates that it is, but further testing is needed. Regardless of the cause, the reductions in yield associated with waxy endosperm in sorghum will preclude its production and use until market prices for the product are based some factor other than grain yield.

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APPENDIX A

Table 79. The inbred B-line collected data for grain yield (kg/ha^{-1}), plant height (cm), and days to anthesis from the cross of (BTxArg-1*BTx623) grown in five environments in Texas.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
1	College Station	1	Non waxy	1	1998	2275.33	134.62	77
2	College Station	1	Non waxy	1	1998	3374.90	124.46	79
3	College Station	1	Non waxy	1	1998	834.46	119.38	77
4	College Station	1	Non waxy	1	1998	1352.81	124.46	74
5	College Station	1	Non waxy	1	1998	4074.02	132.08	74
6	College Station	1	Non waxy	1	1998	2853.50	124.46	73
7	College Station	1	Non waxy	1	1998	2773.02	127.00	75
8	College Station	1	Non waxy	1	1998	2224.31	142.24	73
9	College Station	1	Non waxy	1	1998	2786.91	127.00	78
10	College Station	1	Non waxy	1	1998	3653.20	129.54	76
11	College Station	1	Non waxy	1	1998	2477.24	139.70	77
12	College Station	1	Non waxy	1	1998	2344.31	129.54	77
13	College Station	1	Non waxy	1	1998	5478.24	127.00	74
14	College Station	1	Non waxy	1	1998	3155.51	129.54	74
15	College Station	1	Non waxy	1	1998	3596.92	137.16	72
16	College Station	1	Non waxy	1	1998	3698.71	132.08	75
17	College Station	1	Non waxy	1	1998	5902.40	134.62	74
18	College Station	1	Non waxy	1	1998	4161.19	132.08	74
19	College Station	1	Non waxy	1	1998	2870.02	134.62	74
20	College Station	1	Non waxy	1	1998	1496.70	124.46	82

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	1	Non waxy	1	1998	3944.92	124.46	76
22	College Station	1	Non waxy	1	1998	1965.89	124.46	80
23	College Station	1	Non waxy	1	1998	3641.23	134.62	76
24	College Station	1	Non waxy	1	1998	4502.73	127.00	70
25	College Station	1	Non waxy	1	1998	3622.55	137.16	71
26	College Station	1	Waxy	1	1998	1355.15	121.92	79
27	College Station	1	Waxy	1	1998	2151.04	129.54	80
28	College Station	1	Waxy	1	1998	1841.34	119.38	72
29	College Station	1	Waxy	1	1998	1113.91	111.76	80
30	College Station	1	Waxy	1	1998	3093.48	124.46	73
31	College Station	1	Waxy	1	1998	1884.93	129.54	81
32	College Station	1	Waxy	1	1998	4004.08	127.00	73
33	College Station	1	Waxy	1	1998	1868.41	129.54	77
34	College Station	1	Waxy	1	1998	3292.51	124.46	71
35	College Station	1	Waxy	1	1998	2828.58	127.00	75
36	College Station	1	Waxy	1	1998	2280.83	134.62	68
37	College Station	1	Waxy	1	1998	1261.26	134.62	80
38	College Station	1	Waxy	1	1998	1829.37	142.24	78
39	College Station	1	Waxy	1	1998	2288.74	132.08	77
40	College Station	1	Waxy	1	1998	4247.42	121.92	74
41	College Station	1	Waxy	1	1998	3908.51	139.70	74
42	College Station	1	Waxy	1	1998	3667.10	127.00	79
43	College Station	1	Waxy	1	1998	4628.72	111.76	72
44	College Station	1	Waxy	1	1998	4262.27	129.54	80
45	College Station	1	Waxy	1	1998	2137.13	121.92	76

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	College Station	1	Waxy	1	1998	1409.99	129.54	78
47	College Station	1	Waxy	1	1998	2838.40	121.92	76
48	College Station	1	Waxy	1	1998	2394.36	121.92	80
49	College Station	1	Waxy	1	1998	4389.44	119.38	74
50	College Station	1	Waxy	1	1998	1542.92	127.00	80
1	College Station	1	Non waxy	2	1998	3020.19	134.62	79
2	College Station	1	Non waxy	2	1998	1578.13	119.38	80
3	College Station	1	Non waxy	2	1998	1105.82	137.16	79
4	College Station	1	Non waxy	2	1998	1064.63	127.00	76
5	College Station	1	Non waxy	2	1998	4810.97	137.16	74
6	College Station	1	Non waxy	2	1998	3765.53	127.00	74
7	College Station	1	Non waxy	2	1998	5151.80	127.00	77
8	College Station	1	Non waxy	2	1998	4619.13	147.32	75
9	College Station	1	Non waxy	2	1998	3646.73	132.08	75
10	College Station	1	Non waxy	2	1998	5366.62	137.16	73
11	College Station	1	Non waxy	2	1998	4022.76	132.08	77
12	College Station	1	Non waxy	2	1998	3285.32	124.46	80
13	College Station	1	Non waxy	2	1998	5831.75	132.08	79
14	College Station	1	Non waxy	2	1998	3575.61	132.08	73
15	College Station	1	Non waxy	2	1998	5286.40	137.16	78
16	College Station	1	Non waxy	2	1998	4036.18	132.08	76
17	College Station	1	Non waxy	2	1998	4079.53	137.16	74
18	College Station	1	Non waxy	2	1998	3860.37	132.08	78
19	College Station	1	Non waxy	2	1998	3562.19	157.48	75
20	College Station	1	Non waxy	2	1998	1475.38	124.46	81

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	1	Non waxy	2	1998	2856.85	121.92	74
22	College Station	1	Non waxy	2	1998	2735.90	132.08	77
23	College Station	1	Non waxy	2	1998	3032.89	134.62	75
24	College Station	1	Non waxy	2	1998	5677.99	129.54	74
25	College Station	1	Non waxy	2	1998	6050.17	139.70	75
26	College Station	1	Waxy	2	1998	1205.45	119.38	78
27	College Station	1	Waxy	2	1998	1304.85	129.54	80
28	College Station	1	Waxy	2	1998	1153.96	104.14	72
29	College Station	1	Waxy	2	1998	739.61	119.38	82
30	College Station	1	Waxy	2	1998	4629.43	129.54	74
31	College Station	1	Waxy	2	1998	1960.38	132.08	81
32	College Station	1	Waxy	2	1998	3638.60	134.62	76
33	College Station	1	Waxy	2	1998	1507.71	134.62	77
34	College Station	1	Waxy	2	1998	4508.00	114.30	74
35	College Station	1	Waxy	2	1998	3952.35	139.70	74
36	College Station	1	Waxy	2	1998	4342.26	127.00	71
37	College Station	1	Waxy	2	1998	2981.15	142.24	81
38	College Station	1	Waxy	2	1998	3368.20	124.46	72
39	College Station	1	Waxy	2	1998	3750.21	127.00	74
40	College Station	1	Waxy	2	1998	3002.47	129.54	74
41	College Station	1	Waxy	2	1998	5249.99	139.70	75
42	College Station	1	Waxy	2	1998	5966.83	132.08	77
43	College Station	1	Waxy	2	1998	5774.74	132.08	72
44	College Station	1	Waxy	2	1998	3653.45	129.54	78
45	College Station	1	Waxy	2	1998	2370.41	124.46	79

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	College Station	1	Waxy	2	1998	1955.11	134.62	79
47	College Station	1	Waxy	2	1998	2602.74	129.54	74
48	College Station	1	Waxy	2	1998	2114.86	132.08	78
49	College Station	1	Waxy	2	1998	3823.97	129.54	76
50	College Station	1	Waxy	2	1998	2892.29	132.08	81
1	Lubbock	2	Non waxy	3	1998	2062.57	106.68	No Data
2	Lubbock	2	Non waxy	3	1998	2561.43	111.76	No Data
3	Lubbock	2	Non waxy	3	1998	2725.32	116.84	No Data
4	Lubbock	2	Non waxy	3	1998	1505.38	116.84	No Data
5	Lubbock	2	Non waxy	3	1998	3331.35	111.76	No Data
6	Lubbock	2	Non waxy	3	1998	3963.28	111.76	No Data
7	Lubbock	2	Non waxy	3	1998	1776.55	116.84	No Data
8	Lubbock	2	Non waxy	3	1998	3530.29	116.84	No Data
9	Lubbock	2	Non waxy	3	1998	1141.16	111.76	No Data
10	Lubbock	2	Non waxy	3	1998	2689.05	121.92	No Data
11	Lubbock	2	Non waxy	3	1998	2079.40	127.00	No Data
12	Lubbock	2	Non waxy	3	1998	2550.49	121.92	No Data
13	Lubbock	2	Non waxy	3	1998	1927.97	121.92	No Data
14	Lubbock	2	Non waxy	3	1998	3562.45	116.84	No Data
15	Lubbock	2	Non waxy	3	1998	1679.56	121.92	No Data
16	Lubbock	2	Non waxy	3	1998	1148.59	121.92	No Data
17	Lubbock	2	Non waxy	3	1998	3518.90	116.84	No Data
18	Lubbock	2	Non waxy	3	1998	2399.07	116.84	No Data
19	Lubbock	2	Non waxy	3	1998	3030.49	116.84	No Data
20	Lubbock	2	Non waxy	3	1998	1882.17	101.60	No Data

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	Lubbock	2	Non waxy	3	1998	4361.13	111.76	No Data
22	Lubbock	2	Non waxy	3	1998	1551.40	116.84	No Data
23	Lubbock	2	Non waxy	3	1998	1906.20	116.84	No Data
24	Lubbock	2	Non waxy	3	1998	2324.34	106.68	No Data
25	Lubbock	2	Non waxy	3	1998	4059.77	116.84	No Data
26	Lubbock	2	Waxy	3	1998	2615.70	106.68	No Data
27	Lubbock	2	Waxy	3	1998	1314.12	111.76	No Data
28	Lubbock	2	Waxy	3	1998	1439.56	101.60	No Data
29	Lubbock	2	Waxy	3	1998	1015.23	101.60	No Data
30	Lubbock	2	Waxy	3	1998	4874.78	111.76	No Data
31	Lubbock	2	Waxy	3	1998	1432.88	111.76	No Data
32	Lubbock	2	Waxy	3	1998	4304.22	116.84	No Data
33	Lubbock	2	Waxy	3	1998	1849.78	106.68	No Data
34	Lubbock	2	Waxy	3	1998	4307.69	111.76	No Data
35	Lubbock	2	Waxy	3	1998	3085.42	111.76	No Data
36	Lubbock	2	Waxy	3	1998	1872.06	106.68	No Data
37	Lubbock	2	Waxy	3	1998	1328.96	121.92	No Data
38	Lubbock	2	Waxy	3	1998	2752.39	111.76	No Data
39	Lubbock	2	Waxy	3	1998	1444.01	121.92	No Data
40	Lubbock	2	Waxy	3	1998	2389.67	111.76	No Data
41	Lubbock	2	Waxy	3	1998	5089.54	116.84	No Data
42	Lubbock	2	Waxy	3	1998	2782.08	116.84	No Data
43	Lubbock	2	Waxy	3	1998	4542.24	111.76	No Data
44	Lubbock	2	Waxy	3	1998	4030.08	116.84	No Data
45	Lubbock	2	Waxy	3	1998	736.39	111.76	No Data

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	Lubbock	2	Waxy	3	1998	1181.50	106.68	No Data
47	Lubbock	2	Waxy	3	1998	1838.41	101.60	No Data
48	Lubbock	2	Waxy	3	1998	1140.18	106.68	No Data
49	Lubbock	2	Waxy	3	1998	2788.51	111.76	No Data
50	Lubbock	2	Waxy	3	1998	2979.02	121.92	No Data
1	Lubbock	2	Non waxy	4	1998	2661.83	114.30	No Data
2	Lubbock	2	Non waxy	4	1998	3040.88	116.84	No Data
3	Lubbock	2	Non waxy	4	1998	4428.93	109.22	No Data
4	Lubbock	2	Non waxy	4	1998	2679.65	111.76	No Data
5	Lubbock	2	Non waxy	4	1998	3288.30	114.30	No Data
6	Lubbock	2	Non waxy	4	1998	3401.13	106.68	No Data
7	Lubbock	2	Non waxy	4	1998	2447.56	114.30	No Data
8	Lubbock	2	Non waxy	4	1998	3712.88	116.84	No Data
9	Lubbock	2	Non waxy	4	1998	1367.31	111.76	No Data
10	Lubbock	2	Non waxy	4	1998	2845.91	124.46	No Data
11	Lubbock	2	Non waxy	4	1998	3013.67	121.92	No Data
12	Lubbock	2	Non waxy	4	1998	2659.85	111.76	No Data
13	Lubbock	2	Non waxy	4	1998	2008.63	116.84	No Data
14	Lubbock	2	Non waxy	4	1998	2309.49	111.76	No Data
15	Lubbock	2	Non waxy	4	1998	3377.38	119.38	No Data
16	Lubbock	2	Non waxy	4	1998	2937.95	114.30	No Data
17	Lubbock	2	Non waxy	4	1998	3187.85	114.30	No Data
18	Lubbock	2	Non waxy	4	1998	3141.34	111.76	No Data
19	Lubbock	2	Non waxy	4	1998	2396.59	111.76	No Data
20	Lubbock	2	Non waxy	4	1998	2441.12	109.22	No Data

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	Lubbock	2	Non waxy	4	1998	3930.62	116.84	No Data
22	Lubbock	2	Non waxy	4	1998	1383.15	116.84	No Data
23	Lubbock	2	Non waxy	4	1998	3794.03	119.38	No Data
24	Lubbock	2	Non waxy	4	1998	5339.44	114.30	No Data
25	Lubbock	2	Non waxy	4	1998	3343.23	114.30	No Data
26	Lubbock	2	Waxy	4	1998	3499.11	109.22	No Data
27	Lubbock	2	Waxy	4	1998	2458.45	109.22	No Data
28	Lubbock	2	Waxy	4	1998	3199.72	104.14	No Data
29	Lubbock	2	Waxy	4	1998	2090.77	104.14	No Data
30	Lubbock	2	Waxy	4	1998	3513.96	109.22	No Data
31	Lubbock	2	Waxy	4	1998	2573.25	116.84	No Data
32	Lubbock	2	Waxy	4	1998	3185.38	114.30	No Data
33	Lubbock	2	Waxy	4	1998	1843.84	106.68	No Data
34	Lubbock	2	Waxy	4	1998	2906.78	106.68	No Data
35	Lubbock	2	Waxy	4	1998	2525.25	114.30	No Data
36	Lubbock	2	Waxy	4	1998	2894.41	106.68	No Data
37	Lubbock	2	Waxy	4	1998	2674.20	121.92	No Data
38	Lubbock	2	Waxy	4	1998	3280.39	111.76	No Data
39	Lubbock	2	Waxy	4	1998	1913.12	116.84	No Data
40	Lubbock	2	Waxy	4	1998	3933.59	109.22	No Data
41	Lubbock	2	Waxy	4	1998	3346.21	109.22	No Data
42	Lubbock	2	Waxy	4	1998	3539.19	119.38	No Data
43	Lubbock	2	Waxy	4	1998	3919.23	104.14	No Data
44	Lubbock	2	Waxy	4	1998	2024.47	111.76	No Data
45	Lubbock	2	Waxy	4	1998	826.94	109.22	No Data

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	Lubbock	2	Waxy	4	1998	3693.58	104.14	No Data
47	Lubbock	2	Waxy	4	1998	2429.25	109.22	No Data
48	Lubbock	2	Waxy	4	1998	1287.64	111.76	No Data
49	Lubbock	2	Waxy	4	1998	3699.03	119.38	No Data
50	Lubbock	2	Waxy	4	1998	3628.26	114.30	No Data
1	College Station	3	Non waxy	5	1999	4061.83	144.78	71
2	College Station	3	Non waxy	5	1999	3726.29	116.84	75
3	College Station	3	Non waxy	5	1999	3108.84	132.08	75
4	College Station	3	Non waxy	5	1999	3799.82	144.78	71
5	College Station	3	Non waxy	5	1999	4639.52	132.08	72
6	College Station	3	Non waxy	5	1999	4915.20	132.08	73
7	College Station	3	Non waxy	5	1999	3853.71	121.92	75
8	College Station	3	Non waxy	5	1999	4665.39	137.16	72
9	College Station	3	Non waxy	5	1999	3931.78	124.46	75
10	College Station	3	Non waxy	5	1999	4620.36	132.08	75
11	College Station	3	Non waxy	5	1999	3311.94	129.54	77
12	College Station	3	Non waxy	5	1999	4852.93	132.08	74
13	College Station	3	Non waxy	5	1999	4003.39	124.46	75
14	College Station	3	Non waxy	5	1999	4174.64	137.16	70
15	College Station	3	Non waxy	5	1999	4640.25	132.08	74
16	College Station	3	Non waxy	5	1999	3611.33	134.62	71
17	College Station	3	Non waxy	5	1999	4424.93	129.54	70
18	College Station	3	Non waxy	5	1999	5293.61	129.54	72
19	College Station	3	Non waxy	5	1999	4855.56	137.16	71
20	College Station	3	Non waxy	5	1999	5080.70	121.92	72

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	3	Non waxy	5	1999	4561.92	129.54	69
22	College Station	3	Non waxy	5	1999	6509.11	124.46	72
23	College Station	3	Non waxy	5	1999	4809.34	132.08	71
24	College Station	3	Non waxy	5	1999	4140.39	124.46	70
25	College Station	3	Non waxy	5	1999	5228.47	137.16	70
26	College Station	3	Waxy	5	1999	3453.49	116.84	71
27	College Station	3	Waxy	5	1999	4123.87	137.16	72
28	College Station	3	Waxy	5	1999	3022.86	121.92	70
29	College Station	3	Waxy	5	1999	3962.68	134.62	69
30	College Station	3	Waxy	5	1999	3639.83	137.16	70
31	College Station	3	Waxy	5	1999	3201.76	132.08	72
32	College Station	3	Waxy	5	1999	4109.74	132.08	70
33	College Station	3	Waxy	5	1999	5052.43	121.92	71
34	College Station	3	Waxy	5	1999	2705.52	124.46	74
35	College Station	3	Waxy	5	1999	3864.48	119.38	74
36	College Station	3	Waxy	5	1999	3289.91	121.92	72
37	College Station	3	Waxy	5	1999	4732.45	134.62	75
38	College Station	3	Waxy	5	1999	2070.34	134.62	80
39	College Station	3	Waxy	5	1999	3446.79	121.92	74
40	College Station	3	Waxy	5	1999	2506.96	124.46	76
41	College Station	3	Waxy	5	1999	3650.60	137.16	74
42	College Station	3	Waxy	5	1999	3316.01	121.92	72
43	College Station	3	Waxy	5	1999	4806.22	121.92	70
44	College Station	3	Waxy	5	1999	1510.61	119.38	80
45	College Station	3	Waxy	5	1999	3158.89	127.00	75

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	College Station	3	Waxy	5	1999	3381.40	121.92	71
47	College Station	3	Waxy	5	1999	2975.20	109.22	73
48	College Station	3	Waxy	5	1999	4378.70	114.30	75
49	College Station	3	Waxy	5	1999	3532.53	121.92	75
50	College Station	3	Waxy	5	1999	3490.38	124.46	76
1	College Station	3	Non waxy	6	1999	3805.57	144.78	72
2	College Station	3	Non waxy	6	1999	3298.29	119.38	75
3	College Station	3	Non waxy	6	1999	3830.24	137.16	75
4	College Station	3	Non waxy	6	1999	3675.99	147.32	75
5	College Station	3	Non waxy	6	1999	4460.85	134.62	72
6	College Station	3	Non waxy	6	1999	5718.50	132.08	70
7	College Station	3	Non waxy	6	1999	3055.67	127.00	80
8	College Station	3	Non waxy	6	1999	5130.03	142.24	70
9	College Station	3	Non waxy	6	1999	3948.07	124.46	75
10	College Station	3	Non waxy	6	1999	2648.75	132.08	78
11	College Station	3	Non waxy	6	1999	4732.21	129.54	76
12	College Station	3	Non waxy	6	1999	4942.50	127.00	74
13	College Station	3	Non waxy	6	1999	4129.14	129.54	72
14	College Station	3	Non waxy	6	1999	4188.30	132.08	76
15	College Station	3	Non waxy	6	1999	4218.23	129.54	71
16	College Station	3	Non waxy	6	1999	5155.66	129.54	72
17	College Station	3	Non waxy	6	1999	5181.77	134.62	70
18	College Station	3	Non waxy	6	1999	4920.95	129.54	74
19	College Station	3	Non waxy	6	1999	7078.66	147.32	72
20	College Station	3	Non waxy	6	1999	1620.31	111.76	81

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	3	Non waxy	6	1999	4028.78	124.46	71
22	College Station	3	Non waxy	6	1999	4711.38	116.84	77
23	College Station	3	Non waxy	6	1999	5040.46	134.62	74
24	College Station	3	Non waxy	6	1999	4337.51	129.54	72
25	College Station	3	Non waxy	6	1999	3066.21	132.08	75
26	College Station	3	Waxy	6	1999	3629.28	116.84	71
27	College Station	3	Waxy	6	1999	3577.79	134.62	75
28	College Station	3	Waxy	6	1999	3080.58	116.84	72
29	College Station	3	Waxy	6	1999	5838.49	137.16	72
30	College Station	3	Waxy	6	1999	2856.40	127.00	75
31	College Station	3	Waxy	6	1999	3374.70	129.54	75
32	College Station	3	Waxy	6	1999	3565.82	127.00	70
33	College Station	3	Waxy	6	1999	3303.79	129.54	70
34	College Station	3	Waxy	6	1999	2743.84	119.38	74
35	College Station	3	Waxy	6	1999	3120.34	119.38	79
36	College Station	3	Waxy	6	1999	2685.63	119.38	68
37	College Station	3	Waxy	6	1999	4869.21	132.08	70
38	College Station	3	Waxy	6	1999	2898.79	129.54	76
39	College Station	3	Waxy	6	1999	4707.54	134.62	72
40	College Station	3	Waxy	6	1999	2882.74	119.38	75
41	College Station	3	Waxy	6	1999	2290.69	129.54	79
42	College Station	3	Waxy	6	1999	4802.39	127.00	72
43	College Station	3	Waxy	6	1999	5508.94	132.08	74
44	College Station	3	Waxy	6	1999	2270.08	116.84	79
45	College Station	3	Waxy	6	1999	4003.87	119.38	76

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	College Station	3	Waxy	6	1999	3629.05	121.92	73
47	College Station	3	Waxy	6	1999	4111.89	119.38	71
48	College Station	3	Waxy	6	1999	4464.68	116.84	75
49	College Station	3	Waxy	6	1999	4407.44	124.46	73
50	College Station	3	Waxy	6	1999	2447.32	124.46	74
1	Lubbock	4	Non waxy	7	1999	1703.07	127.00	No Data
2	Lubbock	4	Non waxy	7	1999	1115.69	127.00	No Data
3	Lubbock	4	Non waxy	7	1999	2131.61	124.46	No Data
4	Lubbock	4	Non waxy	7	1999	2531.19	129.54	No Data
5	Lubbock	4	Non waxy	7	1999	3576.31	127.00	No Data
6	Lubbock	4	Non waxy	7	1999	1815.89	116.84	No Data
7	Lubbock	4	Non waxy	7	1999	3299.69	116.84	No Data
8	Lubbock	4	Non waxy	7	1999	1999.24	124.46	No Data
9	Lubbock	4	Non waxy	7	1999	2566.33	116.84	No Data
10	Lubbock	4	Non waxy	7	1999	3862.34	119.38	No Data
11	Lubbock	4	Non waxy	7	1999	1883.94	111.76	No Data
12	Lubbock	4	Non waxy	7	1999	2069.01	111.76	No Data
13	Lubbock	4	Non waxy	7	1999	3071.57	121.92	No Data
14	Lubbock	4	Non waxy	7	1999	2814.25	116.84	No Data
15	Lubbock	4	Non waxy	7	1999	2810.54	119.38	No Data
16	Lubbock	4	Non waxy	7	1999	2536.15	114.30	No Data
17	Lubbock	4	Non waxy	7	1999	2802.12	119.38	No Data
18	Lubbock	4	Non waxy	7	1999	2026.20	116.84	No Data
19	Lubbock	4	Non waxy	7	1999	1261.66	119.38	No Data
20	Lubbock	4	Non waxy	7	1999	583.97	109.22	No Data

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	Lubbock	4	Non waxy	7	1999	2715.28	119.38	No Data
22	Lubbock	4	Non waxy	7	1999	1868.59	106.68	No Data
23	Lubbock	4	Non waxy	7	1999	3010.71	116.84	No Data
24	Lubbock	4	Non waxy	7	1999	1004.10	109.22	No Data
25	Lubbock	4	Non waxy	7	1999	1317.33	124.46	No Data
26	Lubbock	4	Waxy	7	1999	2956.27	114.30	No Data
27	Lubbock	4	Waxy	7	1999	1888.14	119.38	No Data
28	Lubbock	4	Waxy	7	1999	1552.14	104.14	No Data
29	Lubbock	4	Waxy	7	1999	2113.80	127.00	No Data
30	Lubbock	4	Waxy	7	1999	2853.10	109.22	No Data
31	Lubbock	4	Waxy	7	1999	2355.03	111.76	No Data
32	Lubbock	4	Waxy	7	1999	1574.16	111.76	No Data
33	Lubbock	4	Waxy	7	1999	1626.37	114.30	No Data
34	Lubbock	4	Waxy	7	1999	1960.63	109.22	No Data
35	Lubbock	4	Waxy	7	1999	1529.37	119.38	No Data
36	Lubbock	4	Waxy	7	1999	1377.95	109.22	No Data
37	Lubbock	4	Waxy	7	1999	1503.15	116.84	No Data
38	Lubbock	4	Waxy	7	1999	2791.73	109.22	No Data
39	Lubbock	4	Waxy	7	1999	1923.03	124.46	No Data
40	Lubbock	4	Waxy	7	1999	1742.66	106.68	No Data
41	Lubbock	4	Waxy	7	1999	2066.28	121.92	No Data
42	Lubbock	4	Waxy	7	1999	3075.77	116.84	No Data
43	Lubbock	4	Waxy	7	1999	2813.01	109.22	No Data
44	Lubbock	4	Waxy	7	1999	3261.59	114.30	No Data
45	Lubbock	4	Waxy	7	1999	2092.02	114.30	No Data

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	Lubbock	4	Waxy	7	1999	1892.85	116.84	No Data
47	Lubbock	4	Waxy	7	1999	2080.89	96.52	No Data
48	Lubbock	4	Waxy	7	1999	3307.86	109.22	No Data
49	Lubbock	4	Waxy	7	1999	1389.83	119.38	No Data
50	Lubbock	4	Waxy	7	1999	2183.81	119.38	No Data
1	Lubbock	4	Non waxy	8	1999	1722.37	121.92	No Data
2	Lubbock	4	Non waxy	8	1999	1146.61	119.38	No Data
3	Lubbock	4	Non waxy	8	1999	2447.81	116.84	No Data
4	Lubbock	4	Non waxy	8	1999	1360.63	127.00	No Data
5	Lubbock	4	Non waxy	8	1999	1631.07	119.38	No Data
6	Lubbock	4	Non waxy	8	1999	2238.49	114.30	No Data
7	Lubbock	4	Non waxy	8	1999	1583.07	111.76	No Data
8	Lubbock	4	Non waxy	8	1999	3310.83	127.00	No Data
9	Lubbock	4	Non waxy	8	1999	1323.77	116.84	No Data
10	Lubbock	4	Non waxy	8	1999	2172.43	114.30	No Data
11	Lubbock	4	Non waxy	8	1999	1085.99	116.84	No Data
12	Lubbock	4	Non waxy	8	1999	2987.70	116.84	No Data
13	Lubbock	4	Non waxy	8	1999	3187.61	121.92	No Data
14	Lubbock	4	Non waxy	8	1999	2419.60	116.84	No Data
15	Lubbock	4	Non waxy	8	1999	1358.40	116.84	No Data
16	Lubbock	4	Non waxy	8	1999	2463.65	116.84	No Data
17	Lubbock	4	Non waxy	8	1999	1988.35	119.38	No Data
18	Lubbock	4	Non waxy	8	1999	1451.44	116.84	No Data
19	Lubbock	4	Non waxy	8	1999	2712.55	127.00	No Data
20	Lubbock	4	Non waxy	8	1999	624.06	106.68	No Data

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	Lubbock	4	Non waxy	8	1999	2731.12	109.22	No Data
22	Lubbock	4	Non waxy	8	1999	2359.73	116.84	No Data
23	Lubbock	4	Non waxy	8	1999	2544.80	106.68	No Data
24	Lubbock	4	Non waxy	8	1999	2017.54	109.22	No Data
25	Lubbock	4	Non waxy	8	1999	1911.15	116.84	No Data
26	Lubbock	4	Waxy	8	1999	3106.71	111.76	No Data
27	Lubbock	4	Waxy	8	1999	1802.28	124.46	No Data
28	Lubbock	4	Waxy	8	1999	2240.97	101.60	No Data
29	Lubbock	4	Waxy	8	1999	3087.90	116.84	No Data
30	Lubbock	4	Waxy	8	1999	2540.84	116.84	No Data
31	Lubbock	4	Waxy	8	1999	2421.83	111.76	No Data
32	Lubbock	4	Waxy	8	1999	1696.39	114.30	No Data
33	Lubbock	4	Waxy	8	1999	2077.18	114.30	No Data
34	Lubbock	4	Waxy	8	1999	2004.18	106.68	No Data
35	Lubbock	4	Waxy	8	1999	1163.93	111.76	No Data
36	Lubbock	4	Waxy	8	1999	971.43	104.14	No Data
37	Lubbock	4	Waxy	8	1999	2031.90	121.92	No Data
38	Lubbock	4	Waxy	8	1999	3320.24	124.46	No Data
39	Lubbock	4	Waxy	8	1999	2706.12	124.46	No Data
40	Lubbock	4	Waxy	8	1999	1693.91	106.68	No Data
41	Lubbock	4	Waxy	8	1999	2991.16	127.00	No Data
42	Lubbock	4	Waxy	8	1999	1955.94	116.84	No Data
43	Lubbock	4	Waxy	8	1999	3407.57	109.22	No Data
44	Lubbock	4	Waxy	8	1999	1224.80	114.30	No Data
45	Lubbock	4	Waxy	8	1999	1502.16	116.84	No Data

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	Lubbock	4	Waxy	8	1999	1201.05	109.22	No Data
47	Lubbock	4	Waxy	8	1999	2373.34	104.14	No Data
48	Lubbock	4	Waxy	8	1999	1195.11	114.30	No Data
49	Lubbock	4	Waxy	8	1999	876.92	116.84	No Data
50	Lubbock	4	Waxy	8	1999	2084.11	111.76	No Data
1	College Station	5	Non waxy	9	2000	2661.16	157.48	56
2	College Station	5	Non waxy	9	2000	4575.95	116.84	56
3	College Station	5	Non waxy	9	2000	4463.17	137.16	57
4	College Station	5	Non waxy	9	2000	4264.18	134.62	56
5	College Station	5	Non waxy	9	2000	5036.98	137.16	56
6	College Station	5	Non waxy	9	2000	5413.61	137.16	56
7	College Station	5	Non waxy	9	2000	3904.10	142.24	60
8	College Station	5	Non waxy	9	2000	3904.03	139.70	59
9	College Station	5	Non waxy	9	2000	4517.54	139.70	58
10	College Station	5	Non waxy	9	2000	4517.43	149.86	59
11	College Station	5	Non waxy	9	2000	2834.96	134.62	59
12	College Station	5	Non waxy	9	2000	3341.12	134.62	59
13	College Station	5	Non waxy	9	2000	3371.78	139.70	58
14	College Station	5	Non waxy	9	2000	5233.15	134.62	58
15	College Station	5	Non waxy	9	2000	4576.11	137.16	60
16	College Station	5	Non waxy	9	2000	4683.45	134.62	60
17	College Station	5	Non waxy	9	2000	6238.75	134.62	58
18	College Station	5	Non waxy	9	2000	5731.82	137.16	59
19	College Station	5	Non waxy	9	2000	4502.32	152.40	61
20	College Station	5	Non waxy	9	2000	2311.05	127.00	62

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	5	Non waxy	9	2000	4528.03	127.00	59
22	College Station	5	Non waxy	9	2000	5602.49	142.24	59
23	College Station	5	Non waxy	9	2000	4631.04	137.16	60
24	College Station	5	Non waxy	9	2000	5879.43	127.00	59
25	College Station	5	Non waxy	9	2000	5117.88	132.08	59
26	College Station	5	Waxy	9	2000	2311.00	119.38	60
27	College Station	5	Waxy	9	2000	1708.60	124.46	64
28	College Station	5	Waxy	9	2000	5258.91	119.38	57
29	College Station	5	Waxy	9	2000	3433.42	129.54	61
30	College Station	5	Waxy	9	2000	5736.82	124.46	60
31	College Station	5	Waxy	9	2000	2698.69	114.30	63
32	College Station	5	Waxy	9	2000	5802.96	129.54	57
33	College Station	5	Waxy	9	2000	4292.81	116.84	59
34	College Station	5	Waxy	9	2000	3593.44	124.46	58
35	College Station	5	Waxy	9	2000	4098.84	129.54	58
36	College Station	5	Waxy	9	2000	3262.73	137.16	56
37	College Station	5	Waxy	9	2000	3516.00	142.24	59
38	College Station	5	Waxy	9	2000	1906.11	121.92	61
39	College Station	5	Waxy	9	2000	3267.00	139.70	60
40	College Station	5	Waxy	9	2000	4553.57	129.54	59
41	College Station	5	Waxy	9	2000	4293.92	139.70	59
42	College Station	5	Waxy	9	2000	3335.48	139.70	61
43	College Station	5	Waxy	9	2000	2321.36	116.84	58
44	College Station	5	Waxy	9	2000	3831.29	137.16	61
45	College Station	5	Waxy	9	2000	5664.17	154.94	61

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	College Station	5	Waxy	9	2000	2939.79	132.08	61
47	College Station	5	Waxy	9	2000	2470.76	124.46	58
48	College Station	5	Waxy	9	2000	4398.14	137.16	60
49	College Station	5	Waxy	9	2000	4596.68	132.08	58
50	College Station	5	Waxy	9	2000	3588.37	137.16	62
1	College Station	5	Non waxy	10	2000	5298.88	152.40	59
2	College Station	5	Non waxy	10	2000	3186.97	119.38	61
3	College Station	5	Non waxy	10	2000	4272.40	142.24	60
4	College Station	5	Non waxy	10	2000	3769.63	147.32	58
5	College Station	5	Non waxy	10	2000	4784.78	134.62	56
6	College Station	5	Non waxy	10	2000	4898.70	139.70	59
7	College Station	5	Non waxy	10	2000	4764.27	139.70	61
8	College Station	5	Non waxy	10	2000	3937.27	144.78	58
9	College Station	5	Non waxy	10	2000	2767.16	137.16	61
10	College Station	5	Non waxy	10	2000	3961.89	144.78	61
11	College Station	5	Non waxy	10	2000	4219.86	142.24	60
12	College Station	5	Non waxy	10	2000	2968.88	137.16	61
13	College Station	5	Non waxy	10	2000	2980.62	134.62	59
14	College Station	5	Non waxy	10	2000	4540.20	134.62	59
15	College Station	5	Non waxy	10	2000	4344.80	139.70	61
16	College Station	5	Non waxy	10	2000	4847.79	137.16	60
17	College Station	5	Non waxy	10	2000	4927.89	137.16	60
18	College Station	5	Non waxy	10	2000	3455.63	137.16	60
19	College Station	5	Non waxy	10	2000	3323.49	154.94	60
20	College Station	5	Non waxy	10	2000	2649.90	121.92	63

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	5	Non waxy	10	2000	3658.04	134.62	58
22	College Station	5	Non waxy	10	2000	3882.49	144.78	61
23	College Station	5	Non waxy	10	2000	2963.34	134.62	60
24	College Station	5	Non waxy	10	2000	5286.47	132.08	58
25	College Station	5	Non waxy	10	2000	4967.44	142.24	58
26	College Station	5	Waxy	10	2000	3883.90	116.84	60
27	College Station	5	Waxy	10	2000	3356.51	134.62	60
28	College Station	5	Waxy	10	2000	4874.93	127.00	58
29	College Station	5	Waxy	10	2000	3030.16	127.00	61
30	College Station	5	Waxy	10	2000	3210.37	124.46	59
31	College Station	5	Waxy	10	2000	1748.80	116.84	63
32	College Station	5	Waxy	10	2000	3982.00	139.70	59
33	College Station	5	Waxy	10	2000	4995.11	124.46	59
34	College Station	5	Waxy	10	2000	5222.69	121.92	59
35	College Station	5	Waxy	10	2000	3164.05	127.00	58
36	College Station	5	Waxy	10	2000	4570.35	121.92	55
37	College Station	5	Waxy	10	2000	3616.99	142.24	59
38	College Station	5	Waxy	10	2000	2756.38	147.32	61
39	College Station	5	Waxy	10	2000	2598.22	134.62	60
40	College Station	5	Waxy	10	2000	3538.34	111.76	59
41	College Station	5	Waxy	10	2000	5152.84	139.70	60
42	College Station	5	Waxy	10	2000	2599.28	129.54	60
43	College Station	5	Waxy	10	2000	3315.24	129.54	59
44	College Station	5	Waxy	10	2000	2957.03	129.54	61
45	College Station	5	Waxy	10	2000	4923.08	149.86	60

Table 79. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
46	College Station	5	Waxy	10	2000	4739.31	134.62	61
47	College Station	5	Waxy	10	2000	3882.96	121.92	57
48	College Station	5	Waxy	10	2000	4821.32	134.62	59
49	College Station	5	Waxy	10	2000	4103.52	132.08	59
50	College Station	5	Waxy	10	2000	2012.78	127.00	60

APPENDIX B

Table 80. The inbred R-line collected data for grain yield (kg/ha^{-1}), plant height (cm), and days to anthesis from the cross of (Tx2907*RTx430) grown in five environments in Texas.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
1	College Station	1	Non Waxy	1	1998	3572.49	132.08	78
2	College Station	1	Non Waxy	1	1998	2647.04	114.30	79
3	College Station	1	Non Waxy	1	1998	2918.88	124.46	78
4	College Station	1	Non Waxy	1	1998	4450.28	124.46	78
5	College Station	1	Non Waxy	1	1998	2269.34	114.30	78
6	College Station	1	Non Waxy	1	1998	4143.71	132.08	75
7	College Station	1	Non Waxy	1	1998	2338.80	119.38	84
8	College Station	1	Non Waxy	1	1998	1625.79	132.08	76
9	College Station	1	Non Waxy	1	1998	5513.92	121.92	73
10	College Station	1	Non Waxy	1	1998	3641.47	121.92	75
11	College Station	1	Non Waxy	1	1998	1488.32	93.98	83
12	College Station	1	Non Waxy	1	1998	2321.32	96.52	76
13	College Station	1	Non Waxy	1	1998	1679.68	99.06	83
14	College Station	1	Non Waxy	1	1998	3734.16	109.22	75
15	College Station	1	Non Waxy	1	1998	3836.90	101.60	75
16	College Station	1	Non Waxy	1	1998	2394.84	121.92	74
17	College Station	1	Non Waxy	1	1998	3380.41	111.76	75
18	College Station	1	Non Waxy	1	1998	1322.33	104.14	75
19	College Station	1	Non Waxy	1	1998	4479.26	116.84	75
20	College Station	1	Non Waxy	1	1998	1057.68	93.98	79

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	1	Waxy	1	1998	2419.27	91.44	80
22	College Station	1	Waxy	1	1998	2358.19	114.30	78
23	College Station	1	Waxy	1	1998	2483.22	114.30	83
24	College Station	1	Waxy	1	1998	953.49	91.44	78
25	College Station	1	Waxy	1	1998	2461.90	104.14	79
26	College Station	1	Waxy	1	1998	2426.45	99.06	81
27	College Station	1	Waxy	1	1998	3777.75	109.22	77
28	College Station	1	Waxy	1	1998	3381.85	142.24	75
29	College Station	1	Waxy	1	1998	2095.46	124.46	76
30	College Station	1	Waxy	1	1998	4008.63	144.78	75
31	College Station	1	Waxy	1	1998	3683.87	132.08	78
32	College Station	1	Waxy	1	1998	1335.27	101.60	83
33	College Station	1	Waxy	1	1998	1518.25	109.22	81
34	College Station	1	Waxy	1	1998	3643.63	134.62	81
35	College Station	1	Waxy	1	1998	3863.49	132.08	75
36	College Station	1	Waxy	1	1998	2552.43	142.24	80
37	College Station	1	Waxy	1	1998	2223.59	109.22	81
38	College Station	1	Waxy	1	1998	2346.94	104.14	78
39	College Station	1	Waxy	1	1998	3436.21	93.98	82
40	College Station	1	Waxy	1	1998	847.85	111.76	77
1	College Station	1	Non Waxy	2	1998	2032.95	132.08	79
2	College Station	1	Non Waxy	2	1998	1687.58	93.98	84
3	College Station	1	Non Waxy	2	1998	2076.78	121.92	81
4	College Station	1	Non Waxy	2	1998	6096.16	109.22	78
5	College Station	1	Non Waxy	2	1998	1355.87	109.22	79

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
6	College Station	1	Non Waxy	2	1998	2509.33	111.76	79
7	College Station	1	Non Waxy	2	1998	3073.84	127.00	84
8	College Station	1	Non Waxy	2	1998	3583.74	119.38	77
9	College Station	1	Non Waxy	2	1998	5143.89	124.46	74
10	College Station	1	Non Waxy	2	1998	4433.28	121.92	73
11	College Station	1	Non Waxy	2	1998	1731.41	96.52	82
12	College Station	1	Non Waxy	2	1998	2181.20	104.14	75
13	College Station	1	Non Waxy	2	1998	1894.03	114.30	75
14	College Station	1	Non Waxy	2	1998	4166.46	106.68	73
15	College Station	1	Non Waxy	2	1998	4882.83	101.60	75
16	College Station	1	Non Waxy	2	1998	3193.83	106.68	73
17	College Station	1	Non Waxy	2	1998	5512.49	109.22	75
18	College Station	1	Non Waxy	2	1998	1711.05	114.30	75
19	College Station	1	Non Waxy	2	1998	4856.96	124.46	74
20	College Station	1	Non Waxy	2	1998	1681.36	111.76	79
21	College Station	1	Waxy	2	1998	1457.90	104.14	78
22	College Station	1	Waxy	2	1998	2540.23	134.62	76
23	College Station	1	Waxy	2	1998	1355.85	104.14	88
24	College Station	1	Waxy	2	1998	729.32	99.06	81
25	College Station	1	Waxy	2	1998	1701.23	99.06	79
26	College Station	1	Waxy	2	1998	2429.33	119.38	78
27	College Station	1	Waxy	2	1998	3513.81	124.46	75
28	College Station	1	Waxy	2	1998	4542.25	132.08	75
29	College Station	1	Waxy	2	1998	2271.98	116.84	78
30	College Station	1	Waxy	2	1998	3441.49	137.16	75

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
31	College Station	1	Waxy	2	1998	2539.98	109.22	83
32	College Station	1	Waxy	2	1998	1635.37	106.68	78
33	College Station	1	Waxy	2	1998	1193.48	99.06	85
34	College Station	1	Waxy	2	1998	3892.95	134.62	82
35	College Station	1	Waxy	2	1998	4365.97	129.54	73
36	College Station	1	Waxy	2	1998	3270.24	111.76	85
37	College Station	1	Waxy	2	1998	1497.17	116.84	78
38	College Station	1	Waxy	2	1998	5160.90	106.68	77
39	College Station	1	Waxy	2	1998	3280.77	106.68	80
40	College Station	1	Waxy	2	1998	740.32	101.60	78
1	Lubbock	2	Non Waxy	3	1998	4215.64	106.68	No Data
2	Lubbock	2	Non Waxy	3	1998	1944.80	96.52	No Data
3	Lubbock	2	Non Waxy	3	1998	1657.79	111.76	No Data
4	Lubbock	2	Non Waxy	3	1998	4072.64	99.06	No Data
5	Lubbock	2	Non Waxy	3	1998	3271.97	101.60	No Data
6	Lubbock	2	Non Waxy	3	1998	3899.44	106.68	No Data
7	Lubbock	2	Non Waxy	3	1998	2603.44	114.30	No Data
8	Lubbock	2	Non Waxy	3	1998	3302.66	109.22	No Data
9	Lubbock	2	Non Waxy	3	1998	4775.32	114.30	No Data
10	Lubbock	2	Non Waxy	3	1998	4164.19	106.68	No Data
11	Lubbock	2	Non Waxy	3	1998	822.49	96.52	No Data
12	Lubbock	2	Non Waxy	3	1998	813.58	101.60	No Data
13	Lubbock	2	Non Waxy	3	1998	2105.63	96.52	No Data
14	Lubbock	2	Non Waxy	3	1998	3210.62	104.14	No Data
15	Lubbock	2	Non Waxy	3	1998	4520.97	101.60	No Data

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
16	Lubbock	2	Non Waxy	3	1998	4586.78	101.60	No Data
17	Lubbock	2	Non Waxy	3	1998	4048.39	104.14	No Data
18	Lubbock	2	Non Waxy	3	1998	3534.25	106.68	No Data
19	Lubbock	2	Non Waxy	3	1998	4291.85	106.68	No Data
20	Lubbock	2	Non Waxy	3	1998	2258.04	93.98	No Data
21	Lubbock	2	Waxy	3	1998	1551.40	101.60	No Data
22	Lubbock	2	Waxy	3	1998	2772.68	96.52	No Data
23	Lubbock	2	Waxy	3	1998	1223.31	109.22	No Data
24	Lubbock	2	Waxy	3	1998	907.60	104.14	No Data
25	Lubbock	2	Waxy	3	1998	3107.19	99.06	No Data
26	Lubbock	2	Waxy	3	1998	2638.08	104.14	No Data
27	Lubbock	2	Waxy	3	1998	4074.12	114.30	No Data
28	Lubbock	2	Waxy	3	1998	3596.60	119.38	No Data
29	Lubbock	2	Waxy	3	1998	2432.22	109.22	No Data
30	Lubbock	2	Waxy	3	1998	3417.95	114.30	No Data
31	Lubbock	2	Waxy	3	1998	3561.46	96.52	No Data
32	Lubbock	2	Waxy	3	1998	3683.69	81.28	No Data
33	Lubbock	2	Waxy	3	1998	568.88	99.06	No Data
34	Lubbock	2	Waxy	3	1998	3090.86	109.22	No Data
35	Lubbock	2	Waxy	3	1998	3755.94	101.60	No Data
36	Lubbock	2	Waxy	3	1998	3307.60	111.76	No Data
37	Lubbock	2	Waxy	3	1998	2976.56	101.60	No Data
38	Lubbock	2	Waxy	3	1998	3225.95	96.52	No Data
39	Lubbock	2	Waxy	3	1998	1780.51	91.44	No Data
40	Lubbock	2	Waxy	3	1998	986.27	91.44	No Data

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
1	Lubbock	2	Non Waxy	4	1998	4943.07	121.92	No Data
2	Lubbock	2	Non Waxy	4	1998	1166.90	101.60	No Data
3	Lubbock	2	Non Waxy	4	1998	2955.27	106.68	No Data
4	Lubbock	2	Non Waxy	4	1998	2958.73	116.84	No Data
5	Lubbock	2	Non Waxy	4	1998	2026.94	106.68	No Data
6	Lubbock	2	Non Waxy	4	1998	3717.83	111.76	No Data
7	Lubbock	2	Non Waxy	4	1998	3904.39	111.76	No Data
8	Lubbock	2	Non Waxy	4	1998	1659.28	106.68	No Data
9	Lubbock	2	Non Waxy	4	1998	4572.93	111.76	No Data
10	Lubbock	2	Non Waxy	4	1998	4697.13	111.76	No Data
11	Lubbock	2	Non Waxy	4	1998	876.67	93.98	No Data
12	Lubbock	2	Non Waxy	4	1998	883.10	106.68	No Data
13	Lubbock	2	Non Waxy	4	1998	3163.11	106.68	No Data
14	Lubbock	2	Non Waxy	4	1998	3604.51	106.68	No Data
15	Lubbock	2	Non Waxy	4	1998	3778.21	101.60	No Data
16	Lubbock	2	Non Waxy	4	1998	4569.47	106.68	No Data
17	Lubbock	2	Non Waxy	4	1998	3441.71	101.60	No Data
18	Lubbock	2	Non Waxy	4	1998	2600.97	106.68	No Data
19	Lubbock	2	Non Waxy	4	1998	4262.16	111.76	No Data
20	Lubbock	2	Non Waxy	4	1998	3102.25	96.52	No Data
21	Lubbock	2	Waxy	4	1998	2258.53	96.52	No Data
22	Lubbock	2	Waxy	4	1998	2210.03	101.60	No Data
23	Lubbock	2	Waxy	4	1998	2490.61	96.52	No Data
24	Lubbock	2	Waxy	4	1998	1489.05	96.52	No Data
25	Lubbock	2	Waxy	4	1998	2516.84	101.60	No Data

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
26	Lubbock	2	Waxy	4	1998	3757.92	96.52	No Data
27	Lubbock	2	Waxy	4	1998	4255.73	106.68	No Data
28	Lubbock	2	Waxy	4	1998	2809.29	121.92	No Data
29	Lubbock	2	Waxy	4	1998	2835.03	111.76	No Data
30	Lubbock	2	Waxy	4	1998	2820.67	121.92	No Data
31	Lubbock	2	Waxy	4	1998	3439.23	111.76	No Data
32	Lubbock	2	Waxy	4	1998	3195.27	91.44	No Data
33	Lubbock	2	Waxy	4	1998	636.92	106.68	No Data
34	Lubbock	2	Waxy	4	1998	1616.21	111.76	No Data
35	Lubbock	2	Waxy	4	1998	5392.39	96.52	No Data
36	Lubbock	2	Waxy	4	1998	2392.64	116.84	No Data
37	Lubbock	2	Waxy	4	1998	2394.61	106.68	No Data
38	Lubbock	2	Waxy	4	1998	2180.83	91.44	No Data
39	Lubbock	2	Waxy	4	1998	4032.56	91.44	No Data
40	Lubbock	2	Waxy	4	1998	1234.70	91.44	No Data
1	College Station	3	Non Waxy	5	1999	4397.05	127.00	71
2	College Station	3	Non Waxy	5	1999	3451.47	121.92	74
3	College Station	3	Non Waxy	5	1999	2642.91	119.38	75
4	College Station	3	Non Waxy	5	1999	4680.87	132.08	71
5	College Station	3	Non Waxy	5	1999	4156.82	109.22	71
6	College Station	3	Non Waxy	5	1999	5294.24	132.08	71
7	College Station	3	Non Waxy	5	1999	2743.97	116.84	76
8	College Station	3	Non Waxy	5	1999	5073.42	139.70	70
9	College Station	3	Non Waxy	5	1999	2787.81	124.46	71
10	College Station	3	Non Waxy	5	1999	4519.43	121.92	70

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
11	College Station	3	Non Waxy	5	1999	3891.21	111.76	75
12	College Station	3	Non Waxy	5	1999	3409.33	129.54	71
13	College Station	3	Non Waxy	5	1999	3994.44	111.76	71
14	College Station	3	Non Waxy	5	1999	3303.22	111.76	71
15	College Station	3	Non Waxy	5	1999	3736.25	99.06	72
16	College Station	3	Non Waxy	5	1999	4023.89	104.14	70
17	College Station	3	Non Waxy	5	1999	5030.78	104.14	71
18	College Station	3	Non Waxy	5	1999	3226.10	106.68	72
19	College Station	3	Non Waxy	5	1999	3726.29	121.92	72
20	College Station	3	Non Waxy	5	1999	2887.92	96.52	74
21	College Station	3	Waxy	5	1999	4186.53	106.68	72
22	College Station	3	Waxy	5	1999	936.89	104.14	75
23	College Station	3	Waxy	5	1999	2565.30	111.76	71
24	College Station	3	Waxy	5	1999	1829.06	121.92	71
25	College Station	3	Waxy	5	1999	3055.57	109.22	71
26	College Station	3	Waxy	5	1999	2116.47	91.44	75
27	College Station	3	Waxy	5	1999	2880.25	106.68	71
28	College Station	3	Waxy	5	1999	3536.98	129.54	71
29	College Station	3	Waxy	5	1999	1583.09	101.60	71
30	College Station	3	Waxy	5	1999	3026.35	111.76	73
31	College Station	3	Waxy	5	1999	2074.07	106.68	75
32	College Station	3	Waxy	5	1999	3426.33	99.06	71
33	College Station	3	Waxy	5	1999	1674.34	104.14	73
34	College Station	3	Waxy	5	1999	1742.12	116.84	72
35	College Station	3	Waxy	5	1999	3942.46	109.22	72

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
36	College Station	3	Waxy	5	1999	2224.97	116.84	76
37	College Station	3	Waxy	5	1999	2169.40	119.38	75
38	College Station	3	Waxy	5	1999	2091.08	106.68	74
39	College Station	3	Waxy	5	1999	1113.41	104.14	75
40	College Station	3	Waxy	5	1999	4828.64	111.76	73
1	College Station	3	Non Waxy	6	1999	5239.15	132.08	71
2	College Station	3	Non Waxy	6	1999	3123.83	116.84	75
3	College Station	3	Non Waxy	6	1999	3549.92	116.84	75
4	College Station	3	Non Waxy	6	1999	3548.48	121.92	74
5	College Station	3	Non Waxy	6	1999	4144.61	111.76	71
6	College Station	3	Non Waxy	6	1999	5089.70	129.54	74
7	College Station	3	Non Waxy	6	1999	2235.51	121.92	75
8	College Station	3	Non Waxy	6	1999	5467.65	127.00	71
9	College Station	3	Non Waxy	6	1999	3526.20	134.62	74
10	College Station	3	Non Waxy	6	1999	5603.20	119.38	71
11	College Station	3	Non Waxy	6	1999	3556.87	96.52	74
12	College Station	3	Non Waxy	6	1999	2412.74	111.76	74
13	College Station	3	Non Waxy	6	1999	2814.63	106.68	71
14	College Station	3	Non Waxy	6	1999	4415.25	106.68	71
15	College Station	3	Non Waxy	6	1999	3956.12	106.68	74
16	College Station	3	Non Waxy	6	1999	4939.77	121.92	71
17	College Station	3	Non Waxy	6	1999	5451.83	111.76	71
18	College Station	3	Non Waxy	6	1999	3914.68	104.14	71
19	College Station	3	Non Waxy	6	1999	1264.79	114.30	80
20	College Station	3	Non Waxy	6	1999	1596.26	93.98	75

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	3	Waxy	6	1999	1985.46	104.14	74
22	College Station	3	Waxy	6	1999	1394.12	109.22	74
23	College Station	3	Waxy	6	1999	1198.44	109.22	81
24	College Station	3	Waxy	6	1999	1943.31	109.22	74
25	College Station	3	Waxy	6	1999	2593.33	114.30	72
26	College Station	3	Waxy	6	1999	3791.58	101.60	75
27	College Station	3	Waxy	6	1999	3869.66	116.84	71
28	College Station	3	Waxy	6	1999	2327.95	116.84	75
29	College Station	3	Waxy	6	1999	3096.76	111.76	76
30	College Station	3	Waxy	6	1999	1611.59	99.06	81
31	College Station	3	Waxy	6	1999	2324.37	114.30	81
32	College Station	3	Waxy	6	1999	3094.13	101.60	70
33	College Station	3	Waxy	6	1999	1370.89	124.46	76
34	College Station	3	Waxy	6	1999	2886.00	116.84	79
35	College Station	3	Waxy	6	1999	3709.42	106.68	75
36	College Station	3	Waxy	6	1999	1265.51	119.38	80
37	College Station	3	Waxy	6	1999	1186.45	116.84	82
38	College Station	3	Waxy	6	1999	1784.04	104.14	75
39	College Station	3	Waxy	6	1999	1941.87	104.14	80
40	College Station	3	Waxy	6	1999	4101.26	109.22	74
1	Lubbock	4	Non Waxy	7	1999	1503.39	127.00	No Data
2	Lubbock	4	Non Waxy	7	1999	1793.37	111.76	No Data
3	Lubbock	4	Non Waxy	7	1999	1034.28	111.76	No Data
4	Lubbock	4	Non Waxy	7	1999	3591.16	129.54	No Data
5	Lubbock	4	Non Waxy	7	1999	2844.68	114.30	No Data

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
6	Lubbock	4	Non Waxy	7	1999	3119.57	129.54	No Data
7	Lubbock	4	Non Waxy	7	1999	1538.78	121.92	No Data
8	Lubbock	4	Non Waxy	7	1999	3341.02	129.54	No Data
9	Lubbock	4	Non Waxy	7	1999	2335.73	132.08	No Data
10	Lubbock	4	Non Waxy	7	1999	1422.82	111.76	No Data
11	Lubbock	4	Non Waxy	7	1999	2166.25	116.84	No Data
12	Lubbock	4	Non Waxy	7	1999	1567.97	127.00	No Data
13	Lubbock	4	Non Waxy	7	1999	2559.65	104.14	No Data
14	Lubbock	4	Non Waxy	7	1999	3545.14	114.30	No Data
15	Lubbock	4	Non Waxy	7	1999	2502.00	109.22	No Data
16	Lubbock	4	Non Waxy	7	1999	2146.70	104.14	No Data
17	Lubbock	4	Non Waxy	7	1999	2352.06	114.30	No Data
18	Lubbock	4	Non Waxy	7	1999	2067.28	119.38	No Data
19	Lubbock	4	Non Waxy	7	1999	1566.99	119.38	No Data
20	Lubbock	4	Non Waxy	7	1999	2279.07	99.06	No Data
21	Lubbock	4	Waxy	7	1999	2398.08	101.60	No Data
22	Lubbock	4	Waxy	7	1999	1453.91	109.22	No Data
23	Lubbock	4	Waxy	7	1999	955.84	116.84	No Data
24	Lubbock	4	Waxy	7	1999	1143.89	114.30	No Data
25	Lubbock	4	Waxy	7	1999	1278.73	104.14	No Data
26	Lubbock	4	Waxy	7	1999	1497.22	106.68	No Data
27	Lubbock	4	Waxy	7	1999	1521.95	114.30	No Data
28	Lubbock	4	Waxy	7	1999	1519.97	101.60	No Data
29	Lubbock	4	Waxy	7	1999	1051.35	121.92	No Data
30	Lubbock	4	Waxy	7	1999	827.18	121.92	No Data

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
31	Lubbock	4	Waxy	7	1999	641.62	109.22	No Data
32	Lubbock	4	Waxy	7	1999	3401.63	116.84	No Data
33	Lubbock	4	Waxy	7	1999	661.41	119.38	No Data
34	Lubbock	4	Waxy	7	1999	1185.95	119.38	No Data
35	Lubbock	4	Waxy	7	1999	1600.88	101.60	No Data
36	Lubbock	4	Waxy	7	1999	754.44	106.68	No Data
37	Lubbock	4	Waxy	7	1999	1539.27	106.68	No Data
38	Lubbock	4	Waxy	7	1999	2018.29	109.22	No Data
39	Lubbock	4	Waxy	7	1999	834.86	109.22	No Data
40	Lubbock	4	Waxy	7	1999	2185.54	116.84	No Data
1	Lubbock	4	Non Waxy	8	1999	1435.85	127.00	No Data
2	Lubbock	4	Non Waxy	8	1999	1210.45	101.60	No Data
3	Lubbock	4	Non Waxy	8	1999	684.92	116.84	No Data
4	Lubbock	4	Non Waxy	8	1999	1782.00	127.00	No Data
5	Lubbock	4	Non Waxy	8	1999	2528.72	116.84	No Data
6	Lubbock	4	Non Waxy	8	1999	2586.62	116.84	No Data
7	Lubbock	4	Non Waxy	8	1999	1088.97	114.30	No Data
8	Lubbock	4	Non Waxy	8	1999	3125.26	119.38	No Data
9	Lubbock	4	Non Waxy	8	1999	2652.93	127.00	No Data
10	Lubbock	4	Non Waxy	8	1999	2207.56	114.30	No Data
11	Lubbock	4	Non Waxy	8	1999	1953.71	111.76	No Data
12	Lubbock	4	Non Waxy	8	1999	825.95	114.30	No Data
13	Lubbock	4	Non Waxy	8	1999	1365.08	101.60	No Data
14	Lubbock	4	Non Waxy	8	1999	3447.90	114.30	No Data
15	Lubbock	4	Non Waxy	8	1999	2981.26	114.30	No Data

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
16	Lubbock	4	Non Waxy	8	1999	1737.46	114.30	No Data
17	Lubbock	4	Non Waxy	8	1999	1693.66	119.38	No Data
18	Lubbock	4	Non Waxy	8	1999	2187.03	114.30	No Data
19	Lubbock	4	Non Waxy	8	1999	1666.20	127.00	No Data
20	Lubbock	4	Non Waxy	8	1999	1929.71	106.68	No Data
21	Lubbock	4	Waxy	8	1999	1432.14	104.14	No Data
22	Lubbock	4	Waxy	8	1999	1360.14	99.06	No Data
23	Lubbock	4	Waxy	8	1999	1033.05	111.76	No Data
24	Lubbock	4	Waxy	8	1999	1180.51	114.30	No Data
25	Lubbock	4	Waxy	8	1999	1754.29	114.30	No Data
26	Lubbock	4	Waxy	8	1999	2218.20	116.84	No Data
27	Lubbock	4	Waxy	8	1999	924.92	104.14	No Data
28	Lubbock	4	Waxy	8	1999	2280.80	127.00	No Data
29	Lubbock	4	Waxy	8	1999	1471.73	119.38	No Data
30	Lubbock	4	Waxy	8	1999	1161.71	127.00	No Data
31	Lubbock	4	Waxy	8	1999	719.81	96.52	No Data
32	Lubbock	4	Waxy	8	1999	3133.92	109.22	No Data
33	Lubbock	4	Waxy	8	1999	637.17	124.46	No Data
34	Lubbock	4	Waxy	8	1999	1341.82	124.46	No Data
35	Lubbock	4	Waxy	8	1999	1480.89	114.30	No Data
36	Lubbock	4	Waxy	8	1999	1176.79	127.00	No Data
37	Lubbock	4	Waxy	8	1999	870.74	104.14	No Data
38	Lubbock	4	Waxy	8	1999	1659.03	124.46	No Data
39	Lubbock	4	Waxy	8	1999	1203.51	109.22	No Data
40	Lubbock	4	Waxy	8	1999	1778.04	116.84	No Data

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
1	College Station	5	Non Waxy	9	2000	1530.40	137.16	60
2	College Station	5	Non Waxy	9	2000	1884.52	116.84	62
3	College Station	5	Non Waxy	9	2000	1860.26	116.84	60
4	College Station	5	Non Waxy	9	2000	2916.74	114.30	59
5	College Station	5	Non Waxy	9	2000	3512.95	111.76	58
6	College Station	5	Non Waxy	9	2000	3774.97	127.00	57
7	College Station	5	Non Waxy	9	2000	2530.52	127.00	60
8	College Station	5	Non Waxy	9	2000	3676.91	119.38	58
9	College Station	5	Non Waxy	9	2000	3762.20	121.92	59
10	College Station	5	Non Waxy	9	2000	3750.33	121.92	59
11	College Station	5	Non Waxy	9	2000	2614.38	88.90	62
12	College Station	5	Non Waxy	9	2000	2894.03	114.30	60
13	College Station	5	Non Waxy	9	2000	4493.64	109.22	58
14	College Station	5	Non Waxy	9	2000	4363.13	116.84	57
15	College Station	5	Non Waxy	9	2000	5019.38	119.38	59
16	College Station	5	Non Waxy	9	2000	4705.99	121.92	57
17	College Station	5	Non Waxy	9	2000	3556.67	106.68	56
18	College Station	5	Non Waxy	9	2000	2780.04	106.68	60
19	College Station	5	Non Waxy	9	2000	5282.42	119.38	60
20	College Station	5	Non Waxy	9	2000	2869.35	101.60	60
21	College Station	5	Waxy	9	2000	2838.69	101.60	60
22	College Station	5	Waxy	9	2000	3044.04	119.38	58
23	College Station	5	Waxy	9	2000	1210.77	114.30	61
24	College Station	5	Waxy	9	2000	3021.29	109.22	56
25	College Station	5	Waxy	9	2000	2420.89	114.30	59

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
26	College Station	5	Waxy	9	2000	4421.28	106.68	59
27	College Station	5	Waxy	9	2000	3027.77	119.38	60
28	College Station	5	Waxy	9	2000	4291.08	139.70	58
29	College Station	5	Waxy	9	2000	4248.79	121.92	57
30	College Station	5	Waxy	9	2000	4585.57	134.62	56
31	College Station	5	Waxy	9	2000	1567.90	101.60	61
32	College Station	5	Waxy	9	2000	4288.08	109.22	57
33	College Station	5	Waxy	9	2000	2923.53	111.76	60
34	College Station	5	Waxy	9	2000	1988.48	124.46	60
35	College Station	5	Waxy	9	2000	4583.18	119.38	59
36	College Station	5	Waxy	9	2000	2224.03	119.38	62
37	College Station	5	Waxy	9	2000	3230.03	121.92	60
38	College Station	5	Waxy	9	2000	3219.44	111.76	60
39	College Station	5	Waxy	9	2000	3229.34	114.30	59
40	College Station	5	Waxy	9	2000	2518.47	109.22	59
1	College Station	5	Non Waxy	10	2000	3481.68	137.16	61
2	College Station	5	Non Waxy	10	2000	901.30	109.22	61
3	College Station	5	Non Waxy	10	2000	1164.97	111.76	63
4	College Station	5	Non Waxy	10	2000	3917.74	116.84	60
5	College Station	5	Non Waxy	10	2000	3370.34	109.22	61
6	College Station	5	Non Waxy	10	2000	4279.11	124.46	61
7	College Station	5	Non Waxy	10	2000	1425.92	116.84	61
8	College Station	5	Non Waxy	10	2000	3818.18	142.24	61
9	College Station	5	Non Waxy	10	2000	4465.14	119.38	59
10	College Station	5	Non Waxy	10	2000	3335.87	119.38	59

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
11	College Station	5	Non Waxy	10	2000	2317.60	99.06	60
12	College Station	5	Non Waxy	10	2000	3558.55	121.92	59
13	College Station	5	Non Waxy	10	2000	3088.04	104.14	60
14	College Station	5	Non Waxy	10	2000	3985.41	109.22	58
15	College Station	5	Non Waxy	10	2000	4879.36	116.84	60
16	College Station	5	Non Waxy	10	2000	3709.79	111.76	58
17	College Station	5	Non Waxy	10	2000	5142.40	106.68	59
18	College Station	5	Non Waxy	10	2000	4189.52	119.38	59
19	College Station	5	Non Waxy	10	2000	2691.79	119.38	62
20	College Station	5	Non Waxy	10	2000	2084.28	96.52	59
21	College Station	5	Waxy	10	2000	3923.04	99.06	58
22	College Station	5	Waxy	10	2000	1463.59	114.30	61
23	College Station	5	Waxy	10	2000	2038.48	119.38	61
24	College Station	5	Waxy	10	2000	2720.93	109.22	58
25	College Station	5	Waxy	10	2000	2762.73	109.22	62
26	College Station	5	Waxy	10	2000	3136.56	109.22	60
27	College Station	5	Waxy	10	2000	2939.07	111.76	60
28	College Station	5	Waxy	10	2000	3818.49	144.78	58
29	College Station	5	Waxy	10	2000	1112.94	114.30	60
30	College Station	5	Waxy	10	2000	2758.07	119.38	59
31	College Station	5	Waxy	10	2000	1845.76	127.00	61
32	College Station	5	Waxy	10	2000	2928.02	101.60	59
33	College Station	5	Waxy	10	2000	1170.11	109.22	60
34	College Station	5	Waxy	10	2000	1188.82	127.00	61
35	College Station	5	Waxy	10	2000	3844.91	121.92	60

Table 80. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
36	College Station	5	Waxy	10	2000	1754.90	129.54	61
37	College Station	5	Waxy	10	2000	3679.70	116.84	59
38	College Station	5	Waxy	10	2000	1891.43	96.52	58
39	College Station	5	Waxy	10	2000	2039.16	109.22	59
40	College Station	5	Waxy	10	2000	2314.46	109.22	59

APPENDIX C

Table 81. The hybrid B-line collected data for grain yield (kg/ha^{-1}), plant height (cm), and days to anthesis from the cross of (A3Tx436*(BTxArg-1*BTx623)-F_5) grown in three environments in Texas.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
1	College Station	1	Non Waxy	1	2000	6053.90	139.70	60
2	College Station	1	Non Waxy	1	2000	3535.64	129.54	60
3	College Station	1	Non Waxy	1	2000	4178.02	142.24	57
4	College Station	1	Non Waxy	1	2000	5318.88	139.70	56
5	College Station	1	Non Waxy	1	2000	4440.10	129.54	57
6	College Station	1	Non Waxy	1	2000	3217.02	132.08	59
7	College Station	1	Non Waxy	1	2000	5940.69	132.08	57
8	College Station	1	Non Waxy	1	2000	4224.26	134.62	60
9	College Station	1	Non Waxy	1	2000	4804.98	134.62	58
10	College Station	1	Non Waxy	1	2000	3175.91	129.54	58
11	College Station	1	Non Waxy	1	2000	4327.04	132.08	57
12	College Station	1	Non Waxy	1	2000	4070.09	139.70	57
13	College Station	1	Non Waxy	1	2000	4054.68	134.62	58
14	College Station	1	Non Waxy	1	2000	3535.64	132.08	58
15	College Station	1	Non Waxy	1	2000	4846.09	129.54	59
16	College Station	1	Non Waxy	1	2000	5483.33	129.54	59
17	College Station	1	Non Waxy	1	2000	3808.01	134.62	60
18	College Station	1	Non Waxy	1	2000	4296.21	119.38	58
19	College Station	1	Non Waxy	1	2000	4892.33	119.38	58

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
20	College Station	1	Non Waxy	1	2000	4758.72	147.32	58
21	College Station	1	Non Waxy	1	2000	3751.47	127.00	59
22	College Station	1	Non Waxy	1	2000	3525.36	147.32	58
23	College Station	1	Non Waxy	1	2000	4183.15	101.60	57
24	College Station	1	Non Waxy	1	2000	4291.08	116.84	58
25	College Station	1	Non Waxy	1	2000	3756.62	124.46	59
26	College Station	1	Waxy	1	2000	4167.74	121.92	58
27	College Station	1	Waxy	1	2000	4959.15	127.00	58
28	College Station	1	Waxy	1	2000	3833.70	121.92	57
29	College Station	1	Waxy	1	2000	2523.26	116.84	60
30	College Station	1	Waxy	1	2000	3792.59	121.92	59
31	College Station	1	Waxy	1	2000	3710.36	121.92	60
32	College Station	1	Waxy	1	2000	2615.76	114.30	58
33	College Station	1	Waxy	1	2000	3730.92	119.38	59
34	College Station	1	Waxy	1	2000	4548.03	116.84	57
35	College Station	1	Waxy	1	2000	5005.39	132.08	56
36	College Station	1	Waxy	1	2000	5082.48	147.32	58
37	College Station	1	Waxy	1	2000	3813.14	132.08	58
38	College Station	1	Waxy	1	2000	4506.91	132.08	60
39	College Station	1	Waxy	1	2000	3576.75	127.00	58
40	College Station	1	Waxy	1	2000	3258.13	119.38	59
41	College Station	1	Waxy	1	2000	5288.04	132.08	59
42	College Station	1	Waxy	1	2000	3895.37	121.92	58
43	College Station	1	Waxy	1	2000	2980.62	121.92	59
44	College Station	1	Waxy	1	2000	4393.86	129.54	60

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
45	College Station	1	Waxy	1	2000	5796.80	134.62	59
46	College Station	1	Waxy	1	2000	5067.06	124.46	58
47	College Station	1	Waxy	1	2000	3561.34	129.54	57
48	College Station	1	Waxy	1	2000	4095.79	121.92	58
49	College Station	1	Waxy	1	2000	4039.26	129.54	58
50	College Station	1	Waxy	1	2000	5257.21	134.62	59
1	College Station	1	Non Waxy	2	2000	5303.45	144.78	59
2	College Station	1	Non Waxy	2	2000	4095.79	132.08	59
3	College Station	1	Non Waxy	2	2000	4414.41	132.08	58
4	College Station	1	Non Waxy	2	2000	4465.80	137.16	58
5	College Station	1	Non Waxy	2	2000	4059.82	132.08	58
6	College Station	1	Non Waxy	2	2000	3191.33	132.08	60
7	College Station	1	Non Waxy	2	2000	4876.92	132.08	58
8	College Station	1	Non Waxy	2	2000	4846.09	137.16	59
9	College Station	1	Non Waxy	2	2000	3145.07	137.16	58
10	College Station	1	Non Waxy	2	2000	3777.18	124.46	58
11	College Station	1	Non Waxy	2	2000	3427.72	134.62	57
12	College Station	1	Non Waxy	2	2000	5308.60	129.54	57
13	College Station	1	Non Waxy	2	2000	4142.04	124.46	58
14	College Station	1	Non Waxy	2	2000	3489.39	129.54	58
15	College Station	1	Non Waxy	2	2000	4691.92	134.62	57
16	College Station	1	Non Waxy	2	2000	5765.97	137.16	58
17	College Station	1	Non Waxy	2	2000	2857.29	134.62	60
18	College Station	1	Non Waxy	2	2000	3222.16	127.00	59
19	College Station	1	Non Waxy	2	2000	5282.90	121.92	57

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
20	College Station	1	Non Waxy	2	2000	3396.89	147.32	58
21	College Station	1	Non Waxy	2	2000	4157.46	134.62	59
22	College Station	1	Non Waxy	2	2000	5632.35	147.32	58
23	College Station	1	Non Waxy	2	2000	5128.73	137.16	57
24	College Station	1	Non Waxy	2	2000	5036.23	127.00	59
25	College Station	1	Non Waxy	2	2000	3607.58	127.00	59
26	College Station	1	Waxy	2	2000	4589.14	132.08	58
27	College Station	1	Waxy	2	2000	5421.66	132.08	59
28	College Station	1	Waxy	2	2000	3874.81	132.08	56
29	College Station	1	Waxy	2	2000	3324.94	121.92	59
30	College Station	1	Waxy	2	2000	4712.47	132.08	58
31	College Station	1	Waxy	2	2000	4383.58	139.70	59
32	College Station	1	Waxy	2	2000	5046.50	137.16	58
33	College Station	1	Waxy	2	2000	4404.13	124.46	58
34	College Station	1	Waxy	2	2000	5149.28	132.08	58
35	College Station	1	Waxy	2	2000	5519.29	142.24	57
36	College Station	1	Waxy	2	2000	5174.99	147.32	58
37	College Station	1	Waxy	2	2000	4589.14	137.16	57
38	College Station	1	Waxy	2	2000	3921.07	129.54	60
39	College Station	1	Waxy	2	2000	5401.10	134.62	58
40	College Station	1	Waxy	2	2000	4476.08	116.84	58
41	College Station	1	Waxy	2	2000	5231.51	134.62	58
42	College Station	1	Waxy	2	2000	6202.79	132.08	58
43	College Station	1	Waxy	2	2000	3206.74	127.00	58
44	College Station	1	Waxy	2	2000	4491.49	127.00	59

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
45	College Station	1	Waxy	2	2000	3818.29	142.24	58
46	College Station	1	Waxy	2	2000	5139.01	132.08	58
47	College Station	1	Waxy	2	2000	4974.56	134.62	57
48	College Station	1	Waxy	2	2000	2754.51	119.38	58
49	College Station	1	Waxy	2	2000	3011.46	124.46	59
50	College Station	1	Waxy	2	2000	3808.01	132.08	60
1	Lubbock	2	Non Waxy	3	2000	5591.26	119.38	No Data
2	Lubbock	2	Non Waxy	3	2000	6150.39	114.30	No Data
3	Lubbock	2	Non Waxy	3	2000	5255.79	106.68	No Data
4	Lubbock	2	Non Waxy	3	2000	5814.91	114.30	No Data
5	Lubbock	2	Non Waxy	3	2000	4249.36	104.14	No Data
6	Lubbock	2	Non Waxy	3	2000	6150.39	109.22	No Data
7	Lubbock	2	Non Waxy	3	2000	6150.39	109.22	No Data
8	Lubbock	2	Non Waxy	3	2000	5591.26	109.22	No Data
9	Lubbock	2	Non Waxy	3	2000	6150.39	114.30	No Data
10	Lubbock	2	Non Waxy	3	2000	5926.74	111.76	No Data
11	Lubbock	2	Non Waxy	3	2000	5479.44	111.76	No Data
12	Lubbock	2	Non Waxy	3	2000	3131.11	116.84	No Data
13	Lubbock	2	Non Waxy	3	2000	4584.83	106.68	No Data
14	Lubbock	2	Non Waxy	3	2000	4316.45	109.22	No Data
15	Lubbock	2	Non Waxy	3	2000	4372.37	109.22	No Data
16	Lubbock	2	Non Waxy	3	2000	4025.71	114.30	No Data
17	Lubbock	2	Non Waxy	3	2000	4025.71	106.68	No Data
18	Lubbock	2	Non Waxy	3	2000	5378.80	116.84	No Data
19	Lubbock	2	Non Waxy	3	2000	3802.06	111.76	No Data

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
20	Lubbock	2	Non Waxy	3	2000	4383.54	106.68	No Data
21	Lubbock	2	Non Waxy	3	2000	6374.04	106.68	No Data
22	Lubbock	2	Non Waxy	3	2000	3913.88	101.60	No Data
23	Lubbock	2	Non Waxy	3	2000	5703.09	104.14	No Data
24	Lubbock	2	Non Waxy	3	2000	5814.91	109.22	No Data
25	Lubbock	2	Non Waxy	3	2000	6597.69	109.22	No Data
26	Lubbock	2	Waxy	3	2000	6150.39	114.30	No Data
27	Lubbock	2	Waxy	3	2000	6374.04	114.30	No Data
28	Lubbock	2	Waxy	3	2000	5255.79	96.52	No Data
29	Lubbock	2	Waxy	3	2000	5703.09	109.22	No Data
30	Lubbock	2	Waxy	3	2000	7156.81	114.30	No Data
31	Lubbock	2	Waxy	3	2000	6597.69	114.30	No Data
32	Lubbock	2	Waxy	3	2000	6262.21	114.30	No Data
33	Lubbock	2	Waxy	3	2000	6374.04	114.30	No Data
34	Lubbock	2	Waxy	3	2000	5255.79	114.30	No Data
35	Lubbock	2	Waxy	3	2000	6709.51	114.30	No Data
36	Lubbock	2	Waxy	3	2000	4696.66	109.22	No Data
37	Lubbock	2	Waxy	3	2000	6709.51	119.38	No Data
38	Lubbock	2	Waxy	3	2000	5479.44	116.84	No Data
39	Lubbock	2	Waxy	3	2000	5479.44	109.22	No Data
40	Lubbock	2	Waxy	3	2000	5367.61	109.22	No Data
41	Lubbock	2	Waxy	3	2000	3779.70	101.60	No Data
42	Lubbock	2	Waxy	3	2000	6038.56	109.22	No Data
43	Lubbock	2	Waxy	3	2000	4473.01	109.22	No Data
44	Lubbock	2	Waxy	3	2000	5032.14	109.22	No Data

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
45	Lubbock	2	Waxy	3	2000	4473.01	106.68	No Data
46	Lubbock	2	Waxy	3	2000	5479.44	101.60	No Data
47	Lubbock	2	Waxy	3	2000	6262.21	111.76	No Data
48	Lubbock	2	Waxy	3	2000	5703.09	101.60	No Data
49	Lubbock	2	Waxy	3	2000	6374.04	111.76	No Data
50	Lubbock	2	Waxy	3	2000	1565.55	109.22	No Data
1	Lubbock	2	Non Waxy	4	2000	7380.47	119.38	No Data
2	Lubbock	2	Non Waxy	4	2000	3466.58	114.30	No Data
3	Lubbock	2	Non Waxy	4	2000	4025.71	101.60	No Data
4	Lubbock	2	Non Waxy	4	2000	6262.21	116.84	No Data
5	Lubbock	2	Non Waxy	4	2000	6597.69	109.22	No Data
6	Lubbock	2	Non Waxy	4	2000	6374.04	106.68	No Data
7	Lubbock	2	Non Waxy	4	2000	7044.99	114.30	No Data
8	Lubbock	2	Non Waxy	4	2000	6150.39	109.22	No Data
9	Lubbock	2	Non Waxy	4	2000	5703.09	104.14	No Data
10	Lubbock	2	Non Waxy	4	2000	7492.29	119.38	No Data
11	Lubbock	2	Non Waxy	4	2000	6262.21	104.14	No Data
12	Lubbock	2	Non Waxy	4	2000	3913.88	106.68	No Data
13	Lubbock	2	Non Waxy	4	2000	7044.99	106.68	No Data
14	Lubbock	2	Non Waxy	4	2000	6933.16	114.30	No Data
15	Lubbock	2	Non Waxy	4	2000	5814.91	116.84	No Data
16	Lubbock	2	Non Waxy	4	2000	7268.64	116.84	No Data
17	Lubbock	2	Non Waxy	4	2000	6709.51	101.60	No Data
18	Lubbock	2	Non Waxy	4	2000	7268.64	104.14	No Data
19	Lubbock	2	Non Waxy	4	2000	6262.21	106.68	No Data

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
20	Lubbock	2	Non Waxy	4	2000	6262.21	109.22	No Data
21	Lubbock	2	Non Waxy	4	2000	4584.83	109.22	No Data
22	Lubbock	2	Non Waxy	4	2000	4361.18	109.22	No Data
23	Lubbock	2	Non Waxy	4	2000	3578.41	109.22	No Data
24	Lubbock	2	Non Waxy	4	2000	4808.49	111.76	No Data
25	Lubbock	2	Non Waxy	4	2000	7492.29	111.76	No Data
26	Lubbock	2	Waxy	4	2000	3880.34	104.14	No Data
27	Lubbock	2	Waxy	4	2000	5143.96	114.30	No Data
28	Lubbock	2	Waxy	4	2000	3242.93	106.68	No Data
29	Lubbock	2	Waxy	4	2000	5255.79	101.60	No Data
30	Lubbock	2	Waxy	4	2000	6709.51	104.14	No Data
31	Lubbock	2	Waxy	4	2000	6821.34	114.30	No Data
32	Lubbock	2	Waxy	4	2000	6485.86	114.30	No Data
33	Lubbock	2	Waxy	4	2000	6933.16	106.68	No Data
34	Lubbock	2	Waxy	4	2000	5926.74	106.68	No Data
35	Lubbock	2	Waxy	4	2000	6150.39	106.68	No Data
36	Lubbock	2	Waxy	4	2000	7156.81	109.22	No Data
37	Lubbock	2	Waxy	4	2000	6485.86	114.30	No Data
38	Lubbock	2	Waxy	4	2000	4920.31	104.14	No Data
39	Lubbock	2	Waxy	4	2000	6150.39	101.60	No Data
40	Lubbock	2	Waxy	4	2000	4920.31	99.06	No Data
41	Lubbock	2	Waxy	4	2000	5032.14	111.76	No Data
42	Lubbock	2	Waxy	4	2000	5591.26	106.68	No Data
43	Lubbock	2	Waxy	4	2000	7604.12	114.30	No Data
44	Lubbock	2	Waxy	4	2000	7156.81	116.84	No Data

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
45	Lubbock	2	Waxy	4	2000	4361.18	106.68	No Data
46	Lubbock	2	Waxy	4	2000	6821.34	109.22	No Data
47	Lubbock	2	Waxy	4	2000	2907.46	101.60	No Data
48	Lubbock	2	Waxy	4	2000	6933.16	109.22	No Data
49	Lubbock	2	Waxy	4	2000	8051.42	114.30	No Data
50	Lubbock	2	Waxy	4	2000	2795.63	109.22	No Data
1	Weslaco	3	Non Waxy	5	2000	7433.36	119.38	70
2	Weslaco	3	Non Waxy	5	2000	3690.23	119.38	69
3	Weslaco	3	Non Waxy	5	2000	2392.34	119.38	70
4	Weslaco	3	Non Waxy	5	2000	3084.01	127.00	67
5	Weslaco	3	Non Waxy	5	2000	3995.38	121.92	67
6	Weslaco	3	Non Waxy	5	2000	3865.18	119.38	69
7	Weslaco	3	Non Waxy	5	2000	2754.45	127.00	69
8	Weslaco	3	Non Waxy	5	2000	2058.72	116.84	68
9	Weslaco	3	Non Waxy	5	2000	3983.17	111.76	69
10	Weslaco	3	Non Waxy	5	2000	4267.98	121.92	70
11	Weslaco	3	Non Waxy	5	2000	2982.29	111.76	68
12	Weslaco	3	Non Waxy	5	2000	4394.10	114.30	69
13	Weslaco	3	Non Waxy	5	2000	2848.03	119.38	69
14	Weslaco	3	Non Waxy	5	2000	3328.13	116.84	69
15	Weslaco	3	Non Waxy	5	2000	3743.12	121.92	67
16	Weslaco	3	Non Waxy	5	2000	3364.74	116.84	68
17	Weslaco	3	Non Waxy	5	2000	2774.79	111.76	69
18	Weslaco	3	Non Waxy	5	2000	4451.06	127.00	67
19	Weslaco	3	Non Waxy	5	2000	3185.72	116.84	67

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
20	Weslaco	3	Non Waxy	5	2000	2970.09	121.92	68
21	Weslaco	3	Non Waxy	5	2000	5004.39	116.84	66
22	Weslaco	3	Non Waxy	5	2000	2839.89	109.22	68
23	Weslaco	3	Non Waxy	5	2000	3462.39	116.84	68
24	Weslaco	3	Non Waxy	5	2000	4613.81	111.76	67
25	Weslaco	3	Non Waxy	5	2000	4711.45	119.38	67
26	Weslaco	3	Waxy	5	2000	3686.16	116.84	68
27	Weslaco	3	Waxy	5	2000	3905.87	111.76	67
28	Weslaco	3	Waxy	5	2000	3873.32	114.30	68
29	Weslaco	3	Waxy	5	2000	4626.01	111.76	67
30	Weslaco	3	Waxy	5	2000	4202.88	114.30	66
31	Weslaco	3	Waxy	5	2000	3470.53	119.38	66
32	Weslaco	3	Waxy	5	2000	4918.95	116.84	67
33	Weslaco	3	Waxy	5	2000	3507.15	101.60	67
34	Weslaco	3	Waxy	5	2000	3995.38	111.76	66
35	Weslaco	3	Waxy	5	2000	3047.39	114.30	66
36	Weslaco	3	Waxy	5	2000	3962.83	101.60	68
37	Weslaco	3	Waxy	5	2000	3767.54	116.84	68
38	Weslaco	3	Waxy	5	2000	4646.36	116.84	68
39	Weslaco	3	Waxy	5	2000	3079.94	114.30	66
40	Weslaco	3	Waxy	5	2000	2599.84	111.76	68
41	Weslaco	3	Waxy	5	2000	4300.52	116.84	69
42	Weslaco	3	Waxy	5	2000	3267.10	114.30	66
43	Weslaco	3	Waxy	5	2000	3560.04	109.22	67
44	Weslaco	3	Waxy	5	2000	4756.21	127.00	67

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
45	Weslaco	3	Waxy	5	2000	2742.25	119.38	66
46	Weslaco	3	Waxy	5	2000	4048.27	111.76	66
47	Weslaco	3	Waxy	5	2000	4235.43	114.30	67
48	Weslaco	3	Waxy	5	2000	3397.29	106.68	68
49	Weslaco	3	Waxy	5	2000	4125.57	116.84	67
50	Weslaco	3	Waxy	5	2000	3710.58	119.38	67
1	Weslaco	3	Non Waxy	6	2000	4560.92	127.00	66
2	Weslaco	3	Non Waxy	6	2000	3828.57	114.30	68
3	Weslaco	3	Non Waxy	6	2000	3462.39	109.22	69
4	Weslaco	3	Non Waxy	6	2000	4235.43	127.00	66
5	Weslaco	3	Non Waxy	6	2000	4003.52	116.84	66
6	Weslaco	3	Non Waxy	6	2000	4516.16	104.14	68
7	Weslaco	3	Non Waxy	6	2000	4874.20	121.92	67
8	Weslaco	3	Non Waxy	6	2000	4483.61	116.84	67
9	Weslaco	3	Non Waxy	6	2000	3515.28	119.38	69
10	Weslaco	3	Non Waxy	6	2000	4365.62	121.92	67
11	Weslaco	3	Non Waxy	6	2000	4243.56	116.84	67
12	Weslaco	3	Non Waxy	6	2000	3210.14	111.76	68
13	Weslaco	3	Non Waxy	6	2000	4394.10	116.84	67
14	Weslaco	3	Non Waxy	6	2000	4829.44	119.38	67
15	Weslaco	3	Non Waxy	6	2000	4483.61	121.92	66
16	Weslaco	3	Non Waxy	6	2000	4198.81	121.92	67
17	Weslaco	3	Non Waxy	6	2000	3275.23	111.76	68
18	Weslaco	3	Non Waxy	6	2000	4178.47	121.92	66
19	Weslaco	3	Non Waxy	6	2000	2917.20	114.30	68

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
20	Weslaco	3	Non Waxy	6	2000	3450.18	109.22	69
21	Weslaco	3	Non Waxy	6	2000	3385.09	114.30	68
22	Weslaco	3	Non Waxy	6	2000	4093.03	114.30	67
23	Weslaco	3	Non Waxy	6	2000	4353.42	116.84	67
24	Weslaco	3	Non Waxy	6	2000	2526.61	114.30	67
25	Weslaco	3	Non Waxy	6	2000	4731.80	119.38	67
26	Weslaco	3	Waxy	6	2000	4939.30	109.22	68
27	Weslaco	3	Waxy	6	2000	3352.54	121.92	71
28	Weslaco	3	Waxy	6	2000	4243.56	116.84	67
29	Weslaco	3	Waxy	6	2000	3437.98	109.22	67
30	Weslaco	3	Waxy	6	2000	5297.34	121.92	67
31	Weslaco	3	Waxy	6	2000	3828.57	114.30	66
32	Weslaco	3	Waxy	6	2000	4154.05	121.92	68
33	Weslaco	3	Waxy	6	2000	4288.32	116.84	67
34	Weslaco	3	Waxy	6	2000	4166.26	106.68	66
35	Weslaco	3	Waxy	6	2000	3568.17	106.68	66
36	Weslaco	3	Waxy	6	2000	3515.28	119.38	67
37	Weslaco	3	Waxy	6	2000	3970.97	116.84	67
38	Weslaco	3	Waxy	6	2000	2925.33	114.30	72
39	Weslaco	3	Waxy	6	2000	3873.32	116.84	67
40	Weslaco	3	Waxy	6	2000	4874.20	109.22	67
41	Weslaco	3	Waxy	6	2000	4996.26	121.92	67
42	Weslaco	3	Waxy	6	2000	4223.22	106.68	66
43	Weslaco	3	Waxy	6	2000	4455.13	111.76	68
44	Weslaco	3	Waxy	6	2000	3820.43	121.92	69

Table 81. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
45	Weslaco	3	Waxy	6	2000	4430.72	114.30	67
46	Weslaco	3	Waxy	6	2000	3393.22	111.76	67
47	Weslaco	3	Waxy	6	2000	3612.93	109.22	67
48	Weslaco	3	Waxy	6	2000	4666.70	116.84	68
49	Weslaco	3	Waxy	6	2000	3299.65	114.30	68
50	Weslaco	3	Waxy	6	2000	4145.92	119.38	69

APPENDIX D

Table 82. The hybrid R-line collected data for grain yield (kg/ha^{-1}), plant height (cm), and days to anthesis from the cross of (ATx631*(Tx2907*RTx430)-CF$_2$) grown in three environments in Texas.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
1	College Station	1	Non Waxy	1	2000	5411.38	139.70	80
2	College Station	1	Non Waxy	1	2000	5858.47	129.54	84
3	College Station	1	Non Waxy	1	2000	2703.12	134.62	83
4	College Station	1	Non Waxy	1	2000	6588.21	147.32	80
5	College Station	1	Non Waxy	1	2000	6269.59	142.24	82
6	College Station	1	Non Waxy	1	2000	5935.56	147.32	82
7	College Station	1	Non Waxy	1	2000	6947.94	147.32	83
8	College Station	1	Non Waxy	1	2000	6464.87	149.86	80
9	College Station	1	Non Waxy	1	2000	6259.31	149.86	80
10	College Station	1	Non Waxy	1	2000	6320.98	149.86	83
11	College Station	1	Non Waxy	1	2000	5699.16	144.78	84
12	College Station	1	Non Waxy	1	2000	6978.77	147.32	81
13	College Station	1	Non Waxy	1	2000	6850.30	129.54	84
14	College Station	1	Non Waxy	1	2000	6048.62	134.62	83
15	College Station	1	Non Waxy	1	2000	6819.47	144.78	83
16	College Station	1	Non Waxy	1	2000	7348.78	149.86	82
17	College Station	1	Non Waxy	1	2000	6038.34	142.24	82
18	College Station	1	Non Waxy	1	2000	6706.41	134.62	84
19	College Station	1	Non Waxy	1	2000	5683.74	139.70	82
20	College Station	1	Non Waxy	1	2000	7919.21	142.24	82

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	College Station	1	Waxy	1	2000	6413.48	149.86	82
22	College Station	1	Waxy	1	2000	6495.70	139.70	82
23	College Station	1	Waxy	1	2000	8551.31	154.94	82
24	College Station	1	Waxy	1	2000	6490.57	144.78	83
25	College Station	1	Waxy	1	2000	5411.38	144.78	84
26	College Station	1	Waxy	1	2000	5509.02	144.78	84
27	College Station	1	Waxy	1	2000	6680.71	124.46	83
28	College Station	1	Waxy	1	2000	5652.91	152.40	82
29	College Station	1	Waxy	1	2000	5801.94	142.24	85
30	College Station	1	Waxy	1	2000	5735.13	147.32	82
31	College Station	1	Waxy	1	2000	6480.29	157.48	82
32	College Station	1	Waxy	1	2000	5966.39	149.86	84
33	College Station	1	Waxy	1	2000	5683.74	142.24	85
34	College Station	1	Waxy	1	2000	4835.81	147.32	82
35	College Station	1	Waxy	1	2000	6762.93	142.24	84
36	College Station	1	Waxy	1	2000	6377.51	152.40	83
37	College Station	1	Waxy	1	2000	6989.05	142.24	84
38	College Station	1	Waxy	1	2000	6768.08	147.32	82
39	College Station	1	Waxy	1	2000	5416.51	129.54	79
40	College Station	1	Waxy	1	2000	7616.01	134.62	81
1	College Station	1	Non Waxy	2	2000	8422.84	152.40	82
2	College Station	1	Non Waxy	2	2000	6932.53	144.78	84
3	College Station	1	Non Waxy	2	2000	5401.10	137.16	83
4	College Station	1	Non Waxy	2	2000	7687.95	170.18	81
5	College Station	1	Non Waxy	2	2000	5236.65	129.54	84

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
6	College Station	1	Non Waxy	2	2000	5113.32	134.62	85
7	College Station	1	Non Waxy	2	2000	6978.77	144.78	85
8	College Station	1	Non Waxy	2	2000	7184.33	144.78	83
9	College Station	1	Non Waxy	2	2000	6942.80	154.94	81
10	College Station	1	Non Waxy	2	2000	6660.15	147.32	82
11	College Station	1	Non Waxy	2	2000	6947.94	137.16	83
12	College Station	1	Non Waxy	2	2000	2353.67	149.86	82
13	College Station	1	Non Waxy	2	2000	7189.48	144.78	82
14	College Station	1	Non Waxy	2	2000	7292.26	139.70	79
15	College Station	1	Non Waxy	2	2000	6783.49	142.24	81
16	College Station	1	Non Waxy	2	2000	6490.57	132.08	81
17	College Station	1	Non Waxy	2	2000	6197.64	134.62	82
18	College Station	1	Non Waxy	2	2000	6362.09	134.62	83
19	College Station	1	Non Waxy	2	2000	6213.06	134.62	84
20	College Station	1	Non Waxy	2	2000	8181.30	147.32	81
21	College Station	1	Waxy	2	2000	7194.61	149.86	82
22	College Station	1	Waxy	2	2000	6670.43	142.24	82
23	College Station	1	Waxy	2	2000	7528.65	157.48	81
24	College Station	1	Waxy	2	2000	7225.44	134.62	82
25	College Station	1	Waxy	2	2000	6670.43	144.78	81
26	College Station	1	Waxy	2	2000	5200.67	147.32	84
27	College Station	1	Waxy	2	2000	7004.47	137.16	81
28	College Station	1	Waxy	2	2000	7466.98	157.48	82
29	College Station	1	Waxy	2	2000	7050.72	157.48	84
30	College Station	1	Waxy	2	2000	4054.68	154.94	80

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
31	College Station	1	Waxy	2	2000	7379.61	149.86	82
32	College Station	1	Waxy	2	2000	5894.45	142.24	84
33	College Station	1	Waxy	2	2000	7019.88	134.62	84
34	College Station	1	Waxy	2	2000	6238.75	144.78	82
35	College Station	1	Waxy	2	2000	6511.13	139.70	83
36	College Station	1	Waxy	2	2000	5884.17	142.24	82
37	College Station	1	Waxy	2	2000	5596.38	134.62	80
38	College Station	1	Waxy	2	2000	6490.57	139.70	85
39	College Station	1	Waxy	2	2000	5976.67	134.62	84
40	College Station	1	Waxy	2	2000	6516.26	132.08	82
1	Lubbock	2	Non Waxy	3	2000	5703.09	129.54	No Data
2	Lubbock	2	Non Waxy	3	2000	6083.29	121.92	No Data
3	Lubbock	2	Non Waxy	3	2000	6485.86	132.08	No Data
4	Lubbock	2	Non Waxy	3	2000	6910.80	132.08	No Data
5	Lubbock	2	Non Waxy	3	2000	5926.74	121.92	No Data
6	Lubbock	2	Non Waxy	3	2000	6485.86	134.62	No Data
7	Lubbock	2	Non Waxy	3	2000	7637.66	124.46	No Data
8	Lubbock	2	Non Waxy	3	2000	5792.55	132.08	No Data
9	Lubbock	2	Non Waxy	3	2000	6150.39	121.92	No Data
10	Lubbock	2	Non Waxy	3	2000	6485.86	127.00	No Data
11	Lubbock	2	Non Waxy	3	2000	5367.61	114.30	No Data
12	Lubbock	2	Non Waxy	3	2000	6374.04	124.46	No Data
13	Lubbock	2	Non Waxy	3	2000	6262.21	121.92	No Data
14	Lubbock	2	Non Waxy	3	2000	6608.87	121.92	No Data
15	Lubbock	2	Non Waxy	3	2000	5479.44	116.84	No Data

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
16	Lubbock	2	Non Waxy	3	2000	6709.51	119.38	No Data
17	Lubbock	2	Non Waxy	3	2000	6485.86	121.92	No Data
18	Lubbock	2	Non Waxy	3	2000	4696.66	114.30	No Data
19	Lubbock	2	Non Waxy	3	2000	5647.18	119.38	No Data
20	Lubbock	2	Non Waxy	3	2000	6150.39	127.00	No Data
21	Lubbock	2	Waxy	3	2000	5479.44	121.92	No Data
22	Lubbock	2	Waxy	3	2000	5703.09	116.84	No Data
23	Lubbock	2	Waxy	3	2000	4808.49	124.46	No Data
24	Lubbock	2	Waxy	3	2000	4584.83	124.46	No Data
25	Lubbock	2	Waxy	3	2000	4584.83	111.76	No Data
26	Lubbock	2	Waxy	3	2000	5479.44	119.38	No Data
27	Lubbock	2	Waxy	3	2000	5143.96	104.14	No Data
28	Lubbock	2	Waxy	3	2000	5591.26	116.84	No Data
29	Lubbock	2	Waxy	3	2000	5591.78	124.46	No Data
30	Lubbock	2	Waxy	3	2000	5479.44	116.84	No Data
31	Lubbock	2	Waxy	3	2000	6038.56	119.38	No Data
32	Lubbock	2	Waxy	3	2000	5591.26	119.38	No Data
33	Lubbock	2	Waxy	3	2000	5367.61	119.38	No Data
34	Lubbock	2	Waxy	3	2000	6485.86	121.92	No Data
35	Lubbock	2	Waxy	3	2000	5814.91	124.46	No Data
36	Lubbock	2	Waxy	3	2000	5814.91	119.38	No Data
37	Lubbock	2	Waxy	3	2000	5143.96	116.84	No Data
38	Lubbock	2	Waxy	3	2000	6262.21	124.46	No Data
39	Lubbock	2	Waxy	3	2000	5703.09	111.76	No Data
40	Lubbock	2	Waxy	3	2000	6709.51	127.00	No Data

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
1	Lubbock	2	Non Waxy	4	2000	7000.26	119.38	No Data
2	Lubbock	2	Non Waxy	4	2000	7156.81	119.38	No Data
3	Lubbock	2	Non Waxy	4	2000	7525.84	132.08	No Data
4	Lubbock	2	Non Waxy	4	2000	6150.39	121.92	No Data
5	Lubbock	2	Non Waxy	4	2000	6374.04	116.84	No Data
6	Lubbock	2	Non Waxy	4	2000	7604.12	124.46	No Data
7	Lubbock	2	Non Waxy	4	2000	7380.47	129.54	No Data
8	Lubbock	2	Non Waxy	4	2000	6675.97	121.92	No Data
9	Lubbock	2	Non Waxy	4	2000	6374.04	132.08	No Data
10	Lubbock	2	Non Waxy	4	2000	7156.81	129.54	No Data
11	Lubbock	2	Non Waxy	4	2000	6374.04	121.92	No Data
12	Lubbock	2	Non Waxy	4	2000	6575.33	132.08	No Data
13	Lubbock	2	Non Waxy	4	2000	7044.99	121.92	No Data
14	Lubbock	2	Non Waxy	4	2000	6485.86	109.22	No Data
15	Lubbock	2	Non Waxy	4	2000	6821.34	124.46	No Data
16	Lubbock	2	Non Waxy	4	2000	7604.12	116.84	No Data
17	Lubbock	2	Non Waxy	4	2000	7268.64	116.84	No Data
18	Lubbock	2	Non Waxy	4	2000	6374.04	124.46	No Data
19	Lubbock	2	Non Waxy	4	2000	6485.86	124.46	No Data
20	Lubbock	2	Non Waxy	4	2000	7268.64	132.08	No Data
21	Lubbock	2	Waxy	4	2000	7492.29	132.08	No Data
22	Lubbock	2	Waxy	4	2000	6821.34	121.92	No Data
23	Lubbock	2	Waxy	4	2000	6150.39	129.54	No Data
24	Lubbock	2	Waxy	4	2000	6150.39	116.84	No Data
25	Lubbock	2	Waxy	4	2000	7156.81	137.16	No Data

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
26	Lubbock	2	Waxy	4	2000	6374.04	124.46	No Data
27	Lubbock	2	Waxy	4	2000	6933.16	114.30	No Data
28	Lubbock	2	Waxy	4	2000	7481.10	129.54	No Data
29	Lubbock	2	Waxy	4	2000	5367.61	127.00	No Data
30	Lubbock	2	Waxy	4	2000	7268.64	127.00	No Data
31	Lubbock	2	Waxy	4	2000	6933.16	129.54	No Data
32	Lubbock	2	Waxy	4	2000	6821.34	129.54	No Data
33	Lubbock	2	Waxy	4	2000	6709.51	114.30	No Data
34	Lubbock	2	Waxy	4	2000	6150.39	121.92	No Data
35	Lubbock	2	Waxy	4	2000	7492.29	127.00	No Data
36	Lubbock	2	Waxy	4	2000	6821.34	124.46	No Data
37	Lubbock	2	Waxy	4	2000	6597.69	119.38	No Data
38	Lubbock	2	Waxy	4	2000	5591.26	121.92	No Data
39	Lubbock	2	Waxy	4	2000	7380.47	116.84	No Data
40	Lubbock	2	Waxy	4	2000	5479.44	116.84	No Data
1	Weslaco	3	Non Waxy	5	2000	4040.13	134.62	67
2	Weslaco	3	Non Waxy	5	2000	3657.68	129.54	67
3	Weslaco	3	Non Waxy	5	2000	4638.22	132.08	67
4	Weslaco	3	Non Waxy	5	2000	4548.71	137.16	67
5	Weslaco	3	Non Waxy	5	2000	4984.05	134.62	70
6	Weslaco	3	Non Waxy	5	2000	4015.72	134.62	65
7	Weslaco	3	Non Waxy	5	2000	4829.44	147.32	67
8	Weslaco	3	Non Waxy	5	2000	5036.94	139.70	65
9	Weslaco	3	Non Waxy	5	2000	4927.09	139.70	65
10	Weslaco	3	Non Waxy	5	2000	4516.16	137.16	67

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
11	Weslaco	3	Non Waxy	5	2000	3177.59	134.62	67
12	Weslaco	3	Non Waxy	5	2000	4520.23	137.16	67
13	Weslaco	3	Non Waxy	5	2000	4581.26	127.00	67
14	Weslaco	3	Non Waxy	5	2000	4503.96	127.00	67
15	Weslaco	3	Non Waxy	5	2000	5264.79	139.70	67
16	Weslaco	3	Non Waxy	5	2000	4874.20	132.08	70
17	Weslaco	3	Non Waxy	5	2000	4927.09	129.54	70
18	Weslaco	3	Non Waxy	5	2000	4178.47	132.08	70
19	Weslaco	3	Non Waxy	5	2000	4560.92	132.08	72
20	Weslaco	3	Non Waxy	5	2000	4451.06	137.16	72
21	Weslaco	3	Waxy	5	2000	5744.88	139.70	70
22	Weslaco	3	Waxy	5	2000	4113.37	134.62	70
23	Weslaco	3	Waxy	5	2000	4731.80	144.78	70
24	Weslaco	3	Waxy	5	2000	3185.72	132.08	72
25	Weslaco	3	Waxy	5	2000	5134.59	139.70	70
26	Weslaco	3	Waxy	5	2000	3222.34	137.16	72
27	Weslaco	3	Waxy	5	2000	4601.60	144.78	67
28	Weslaco	3	Waxy	5	2000	4646.36	139.70	70
29	Weslaco	3	Waxy	5	2000	3417.64	137.16	70
30	Weslaco	3	Waxy	5	2000	4007.58	132.08	70
31	Weslaco	3	Waxy	5	2000	2839.89	144.78	72
32	Weslaco	3	Waxy	5	2000	2807.34	121.92	72
33	Weslaco	3	Waxy	5	2000	2970.09	129.54	72
34	Weslaco	3	Waxy	5	2000	4939.30	134.62	70
35	Weslaco	3	Waxy	5	2000	3503.08	134.62	70

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
36	Weslaco	3	Waxy	5	2000	4874.20	127.00	70
37	Weslaco	3	Waxy	5	2000	5236.31	127.00	70
38	Weslaco	3	Waxy	5	2000	4267.98	132.08	70
39	Weslaco	3	Waxy	5	2000	5004.39	132.08	72
40	Weslaco	3	Waxy	5	2000	4430.72	124.46	72
1	Weslaco	3	Non Waxy	6	2000	4638.22	129.54	70
2	Weslaco	3	Non Waxy	6	2000	4621.95	127.00	70
3	Weslaco	3	Non Waxy	6	2000	5081.70	132.08	70
4	Weslaco	3	Non Waxy	6	2000	4471.41	134.62	70
5	Weslaco	3	Non Waxy	6	2000	6082.58	127.00	70
6	Weslaco	3	Non Waxy	6	2000	4198.81	127.00	70
7	Weslaco	3	Non Waxy	6	2000	4211.02	134.62	70
8	Weslaco	3	Non Waxy	6	2000	5354.30	129.54	70
9	Weslaco	3	Non Waxy	6	2000	4560.92	129.54	72
10	Weslaco	3	Non Waxy	6	2000	4548.71	127.00	70
11	Weslaco	3	Non Waxy	6	2000	4528.37	132.08	70
12	Weslaco	3	Non Waxy	6	2000	4463.27	127.00	70
13	Weslaco	3	Non Waxy	6	2000	2331.32	132.08	72
14	Weslaco	3	Non Waxy	6	2000	3787.88	121.92	70
15	Weslaco	3	Non Waxy	6	2000	5451.94	121.92	70
16	Weslaco	3	Non Waxy	6	2000	4857.92	132.08	70
17	Weslaco	3	Non Waxy	6	2000	4817.24	124.46	70
18	Weslaco	3	Non Waxy	6	2000	2917.20	116.84	72
19	Weslaco	3	Non Waxy	6	2000	5016.60	127.00	70
20	Weslaco	3	Non Waxy	6	2000	4398.17	127.00	72

Table 82. Continued.

Entry	Location	Environment	Endosperm	Reps	Year	Yield	Height	Maturity
21	Weslaco	3	Waxy	6	2000	4211.02	134.62	70
22	Weslaco	3	Waxy	6	2000	5927.97	134.62	70
23	Weslaco	3	Waxy	6	2000	3763.47	129.54	70
24	Weslaco	3	Waxy	6	2000	4996.26	121.92	70
25	Weslaco	3	Waxy	6	2000	5220.03	134.62	70
26	Weslaco	3	Waxy	6	2000	4540.57	127.00	70
27	Weslaco	3	Waxy	6	2000	5549.59	129.54	70
28	Weslaco	3	Waxy	6	2000	2799.21	129.54	70
29	Weslaco	3	Waxy	6	2000	3470.53	134.62	70
30	Weslaco	3	Waxy	6	2000	4145.92	121.92	70
31	Weslaco	3	Waxy	6	2000	5159.00	137.16	70
32	Weslaco	3	Waxy	6	2000	3763.47	129.54	70
33	Weslaco	3	Waxy	6	2000	2852.10	127.00	72
34	Weslaco	3	Waxy	6	2000	5830.32	124.46	70
35	Weslaco	3	Waxy	6	2000	5346.16	132.08	70
36	Weslaco	3	Waxy	6	2000	4581.26	132.08	70
37	Weslaco	3	Waxy	6	2000	3840.77	121.92	70
38	Weslaco	3	Waxy	6	2000	3918.08	121.92	70
39	Weslaco	3	Waxy	6	2000	4731.80	124.46	70
40	Weslaco	3	Waxy	6	2000	4833.51	127.00	70

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