SOYBEAN YIELD AND YIELD COMPONENTS AS AFFECTED BY PLANTING DATE AND MATURITY GROUP IN OKLAHOMA

By

ALEXANDRE STEFANI BARREIRO

Bachelor of Science in Agronomic Engineering

Sao Paulo State University (UNESP)

Botucatu, Sao Paulo, Brazil

2008

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 2011

SOYBEAN YIELD AND YIELD COMPONENTS AS

AFFECTED BY PLANTING DATE AND

MATURITY GROUP IN OKLAHOMA

Thesis Approved:

Dr. Chad Godsey

Thesis Adviser

Dr. Jeff Edwards

Dr. Joe Armstrong

Dr. Sheryl Tucker

Dean of the Graduate College

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

SOYBEAN YIELD AND YIELD COMPONENTS AS AFFECTED BY PLANTING DATE AND MATURITY GROUP IN OKLAHOMA

ABSTRACT

Soybean [*Glycine max* (L.) Merr.] is normally planted between early April and early May using maturity groups (MG) III and IV, or from May through June using MG IV and V in Oklahoma. Planting date (PD) and MG can greatly impact yield components and consequently seed yield. Our objectives were to determine the effects of PD and MG on yield in an effort to assist Oklahoma soybean producers in making better decisions in choosing the correct MG for a specific planting period. Five MGs ranging between 3.8 and 5.6 were sown at five PDs between early April and July in Stillwater, OK, in 2009. Split Block Design was used as the experimental design, with 3 replications, having PD as the main plot and MG cultivar as the sub plot. Soybean yield components and canopy closure were assessed and correlated to seed yield. With early-season PDs (from April to late May) using early MGs, seed yield was greater compared to late-season PDs (from late May to late July) using later MGs. Early season MGs 4.4 and 4.8 produced higher yields compared to MG 3.8. No difference was found in seed yield among MGs IV and V planted in late season, which was lower than in early plantings, and reduced significantly as planting dates were delayed. This reduction in yield was 160 kg ha^{-1} per week after 10-Jun. This reduction in yield was attributed to lower canopy closure and consequently a reduced light use efficiency that resulted in a lower number of pods m^{-2}, followed by seeds m^{-2}, and reproductive nodes m^{-2}.

For the 2010 growing season, five MGs were sown at all six PDs in Stillwater, OK, and four of these MGs were sown in the same PDs in Lahoma, OK. For the Stillwater location, late MG IV and MG V cultivars produced higher yields compared to MG 3.8 and early MG IV cultivars when planted from April to late May. For Lahoma,

MGs 4.4, 4.8 and 5.6, presented an exponential increase in seed yield when planted until early June, and MG 5.2 did not change in yield for these early PDs. For both locations, no difference in yield was observed among MGs, in late planting and yield decreased significantly as planting dates were delayed after middle of June, losing an average of 235 kg ha^{-1} per week in Stillwater and 190 kg ha^{-1} in Lahoma. Number of reproductive nodes m^{-2}, followed by number of pods and seeds m^{-2} were again the yield components which most affected seed yield. Selection of MG was less important when compared to PD. Planting before the middle of June was important to maintain yield potential.

CHAPTER I

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is considered one of the most valuable oilseed crops in the world due to the diversity of possible uses. Soybean seeds contain high levels of protein and oil, compared to other oilseed crops, and these components are very important for human consumption (Brummer et al., 1997). In addition, soybean can be used as animal feed and is very useful in several industrial applications. Processed soybean is the largest source of protein feed and the second largest source of vegetable oil in the world (USDA, 2011). Moreover, soybean is the dominant oilseed produced in the United States, accounting for 90% of total oilseed produced in the country, and it is the second most planted field crop in the U.S. after corn, with 31.4 million hectares planted in 2009 (USDA, 2011). The United States is the world`s leading soybean producer and exporter (USDA, 2011).

Recently, higher prices and an increased demand for soybean products have attracted producers to increase acres planted to soybean. For instance, in Oklahoma, soybean production has increased from 77,000 ha planted in 2007 to 202,000 ha planted in 2010. (USDA, 2011). This production in Oklahoma has been concentrated in the eastern part of the state due to greater and more frequent precipitation. In the western half of the state, precipitation decreases and soybean production management decisions become critical to maximize seed yield. Two management practices that might differ for western OK as opposed to eastern are planting date and maturity group selection. Currently, a minimum amount of data exists regarding these management practices for western Oklahoma.

Planting date has been considered the most important and least expensive cultural practice affecting soybean production (Robinson et al., 2009). Therefore, choosing the optimum planting date with an adequate maturity group is a critical factor to avoid heat and drought stresses during sensitive growth stages and to maximize seed yield.

Producers in the southern US, including Oklahoma, often choose a double-cropping system to increase profitability. In this system, soybean is planted after winter wheat harvest (Egli and Bruening, 2000). Consequently, this alternative system usually leads to delayed soybean plantings and consequently, with less time to complete its cycle during the growing season, this double-crop presents reduced yield (Egli and Bruening, 2000; Wesley, 1999). This reduction in yield is related to shorter days, lower insolation and temperatures at the end the growing stage, and also less soil moisture availability (Egli and Bruening, 2000; Knapp et al., 1980).

For the southern U.S., early maturity group (MG) soybean cultivars range from III to IV and are considered short-season cultivars, and usually are planted from early April to late May. Late or full season cultivars, for southern U.S. are represented by MGs V to VII, commonly planted from late May to late June. Historically for Oklahoma, it is believed that planting after 15 June will decrease yield. Late planting dates with late MG may cause a delay in the reproductive development and greater risks of decreased grain yield due to drought, pest attacks, and late-season seed and foliar diseases (Heatherly et al., 2005). For MG V to VII, the duration of the vegetative, flowering and pod-set stages is shorter, which is the main factor affecting yield (Chen and Wiatrak, 2010). All these aspects justify our research to determine the best soybean system for Oklahoma production areas. Selection of the proper MG and planting date will enable soybean producers to better manage their production system, improve yield and consequently increase their profitability.

CHAPTER II

REVIEW OF LITERATURE

Soybean Crop Overall.

Soybean [*Glycine max* (L.) Merr.] is considered one of the most valuable oilseed crops in the world due to the diversity of possible uses. Soybean seeds contain high levels of protein and oil, compared to other oilseed crops, and these components are very important for human consumption (Brummer et al., 1997). In addition, soybean can be used as animal feed and is very useful in several industrial applications. Processed soybean is the largest source of protein feed and the second largest source of vegetable oil in the world (USDA, 2011). Moreover, soybean is the dominant oilseed produced in the United States, accounting for 90% of total oilseed produced in the country, and it is the second most planted field crop in the U.S. after corn, with 31.4 million hactares planted in 2009 (USDA, 2011). The United States is the world`s leading soybean producer and exporter (USDA, 2011).

Higher prices paid to soybean producers, and an increased demand for soybean products, have attracted more producers every year in several states. For instance, in Oklahoma, soybean production has increased from 77,000 ha planted in 2007 to 202,000 ha planted in 2010. (USDA, 2011). This production in Oklahoma has been concentrated in the eastern part of the state due to a greater and more frequent precipitation. In the western half of the state, precipitation decreases and soybean production management decisions become critical to maximize seed yield. Two management practices that might differ for western OK as opposed to eastern are planting date and maturity group selection. Currently, a minimum amount of data exists regarding these management practices for western Oklahoma.

Photoperiod and Temperature

When selecting a planting date and maturity group, the two most important environmental factors that must be considered are the photoperiod requirement and temperature. The time of exposure to day light and the temperature is well known to directly affect soybean development stages (Zhang et al., 2001). This interaction has a great influence in how soybean producers must manage their soybean crop to be able to predict flowering date, maturity date and finally predicting the yield (Alliprandini et al., 2009). Soybean is classified as a short-day photoperiod-sensitive plant, meaning they remain in a vegetative stage during long daylight hours and begin to flower when day length becomes shorter (Caviness and Thomas, 1979). In other words, flowering initiates after the period of darkness become equal to or greater than the critical daylength (Board and Hall, 1984). The longest day of the year for the north hemisphere is June 21^{st}, and therefore, after this date, the nights become longer than the days (Withrow, 1959). The plants will flower during this period of longer nights when a certain number of uninterrupted hours of darkness (critical daylength) is reached. In Oklahoma, this daylength is around 14 hours, meaning that the plants will flower when daylength is shorter than the critical number (Board and Hall, 1984). Figure 1 shows three examples of daylength according to the location, and helps to explain this interaction between photoperiod and time of the year, and why soybean producers must take it in consideration before planting their crop.

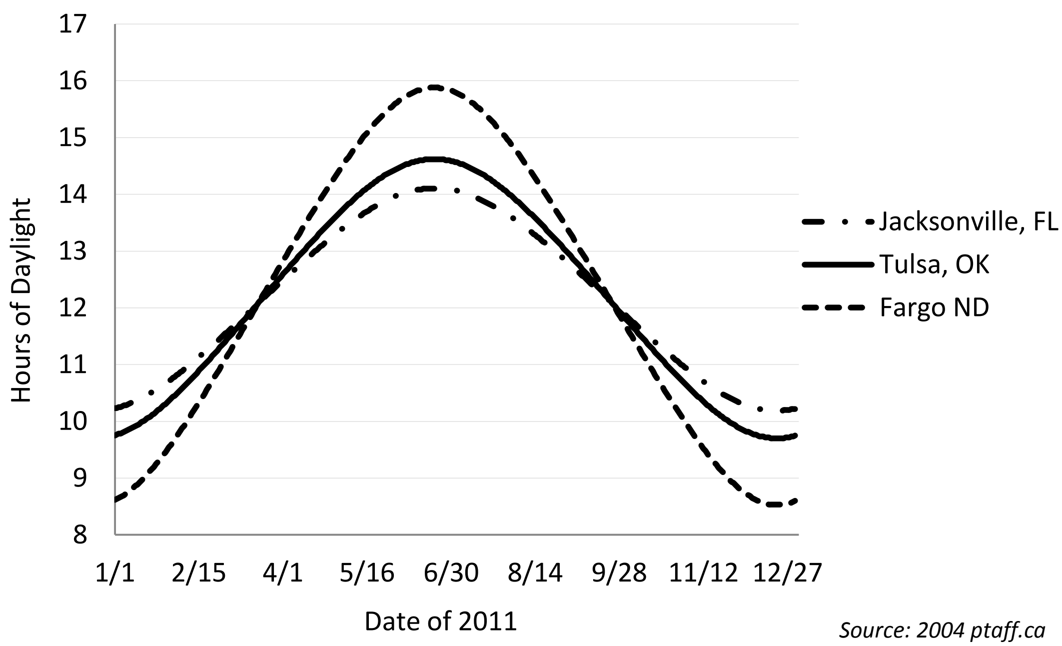


Figure 1. Relationship between daylength and time of the year for three locations in US.

For all three locations (Figure 1), around March 20th the daylight period becomes greater and night period becomes shorter. On June 21st, nights start to become longer and then on September 23rd, nighttime hours exceed daylight hours. Between June 21st and Sep 23rd, period of longer nights and shorter days is when soybean plants receive their stimulus to flower by reaching the critical daylength. For example, soybean varieties grown in Tulsa, OK usually require a critical daylength of 14 hours, so they would flower around July 27^{th}.

As stated before, along with photoperiod, temperature is a very critical factor as well affecting soybean production. The optimum temperature for soybean growth and development is approximately 30˚C (Schlenker and Roberts, 2008). Soybean plants exposed for a few days to temperatures between 32 ˚C and 36 ˚C can survive this heat stress if well supplied with water, otherwise, heat injuries start to appear. However, frequent days over 37 ˚C and without water supply can have a severe negative impact on the yield potential for the soybean crop (Godsey, 2011). According to Foroud et al. (1993), excessive heat and drought stress at late reproductive stages of soybean development can cause reduction of the number of pods per plant, which will lead to a reduction in yield.

Planting Date

Considering the direct effect of photoperiod in the growth and development of soybean plants, a maximum seed yield could be obtained by choosing the optimum planting date with an adequate maturity group, which are important strategies to avoid heat and drought stresses during critical growth stages. Planting date has been considered the most important and least expensive cultural practice affecting soybean production (Robinson et al., 2009). Cartter and Hartwig (1962) also concluded that there is no other single practice more important than planting date for soybean production.

Planting date and other management practices such as row-spacing, population, and variety selection have been studied for decades; however, yield response to planting date can vary widely from year to year according to environmental conditions such as rainfall amount and distribution (Chen and Wiatrak, 2010). Therefore, extrapolation outside the areas where research is conducted is difficult and often unreliable. For instance, in the Midwest, by the mid-20th century, recommended planting dates for soybean ranged from 1 to 23 May (Torrie and Briggs, 1995). However, over the past 35 years, (Pendleton and Hartwig, 1973; Heatherly and Elmor, 2004; Egli and Cornelius, 2009), planting dates have extended into early June in the Midwest. In one of the earliest-known planting date studies in the Midsouthern USA, higher soybean yield was found in plantings from mid-June through early July (Mooers, 1908). However, some researchers such as Bastidas et al. (2008), Egli and Cornelius (2009), and Heatherly and Spurlock (1999), stated that higher yields can be achieved when planted mid-March through early-May in the Midsouthern United States. Although Popp et al., (2002) found that early soybean plantings can result in lower yields compared to full-season soybeans due to typical mid-season drought in this region, early-season production has been viewed as an interesting alternative for growers since soil moisture deficit could be avoided during reproductive stages of the crop (Kane et al., 1997). Also, Edwards et al. (2003), stated that irrigation requirements, which normally occur during late-season, can be reduced using short-season cultivars with early planting dates. However, a limit must be placed to very early planting dates. Plant population and yield can be significantly lower than the maximum potential if planted too early in soils with low temperatures and excessive moisture, due to a reduction and delay of seedling emergence (Lee et al., 2008).

Date of planting also affects soybean yield components (Robinson et al., 2009), which are physiological measurements in the plant that directly affect yield (Egli, 2005).

Board and Modali (2005), described yield components in soybean as seeds m^{-2}, seed size, seeds per pod, pods m^{-2}, pods per reproductive node, reproductive node m^{-2}, percent of reproductive nodes, and nodes m^{-2}. Environmental conditions during critical growth stages influence the level of dry matter (produced from the sunlight), which consequently affects yield components (Board et al., 2010).

Several studies can be found stating that yield components of determinate and indeterminate lines are affected by planting dates (Akhter and Sneller, 1996). In general, higher numbers of nodes can be found in early planting dates as stated by Wilcox and Frankenberger (1987) and Robinson et al. (2009).The number of pod m^{-2} and seeds per pod are also increased in early plantings (Pedersen and Lauer, 2004; Robinson et al., 2009) .Considering late planting, Heitholt et al. (1986) reported that there is a greater rate of floral abortion. Consequently, plants will have lower number of pods and seeds m^{-2}, but as an attempt to compensate for this, seed weight will often be greater (Robinson et al., 2009; Spaeth and Sinclair, 1984). Also, several investigators (Cartter and Hartwing, 1962; Egli et al., 1987; Wilcox and Frankenberger, 1987; Egli and Bruening, 2000; Bastidas et al., 2008) stated that for late planting dates the period for vegetative and flowering stages is shorter, due to the photoperiod; however the duration for seed-fill is not consistently shorter, although not enough to overcome yield losses.

Robinson et al. (2009) reported that early planting dates from late April through early May will increase soybean yield mainly due to a greater number of pods m^{-2}. Studies by Wit (1967) and Egli at al. (1999) showed that in the US mid-south region, climate conditions present higher solar radiation, which is favorable for crop production because there is a longer growing season when compared to northern regions. In these conditions with greater solar radiation, soybean will have sufficient time to achieve maximum growth development, which in general represents higher yield potential.

Producers in the southern US, including Oklahoma, often choose a double-cropping system to increase profitability. In this system soybean is planted after winter wheat harvest (Egli, 1999). However, this alternative system usually leads to delayed soybean plantings and consequently, with less time to complete its cycle during the growing season, this double-crop presents reduced yield (Egli, 1999; Kane et al., 1997; Wesley et al., 1991). This reduction in yield is related to shorter days, lower insolation and temperatures at the end the growing stage, and also less soil moisture availability (Bowers, 1995; Egli, 1999; Heatherly and Spurlock, 1999).

Maturity Group

Early maturity group (MG) soybean cultivars range from III to IV and are considered short-season cultivars in the southern U.S., and usually are planted from early April to late May. Late or full season cultivars, for southern U.S. are represented by MG's V to VII, commonly planted from late May to late June. Soybean production in the Mid-Southern US has typically used MG V and VI cultivars, however, MG III and IV have become popular alternatives among soybean producers to be used in early plantings (Heatherly and Hodges, 1999). This popularity of early-season cultivars can be attributed to the possibility of yield increases usually due to greater exposure to in-season rainfalls, and also because they allow producers to better allocate labor and equipment.

Historically, for Oklahoma, it is believed that planting after 15 June will decrease yield (Soybean Production Guide, 2009). According to Heatherly (2005), 36% of the total soybean produced in Arkansas is planted prior to May 1st. However, from April through late June planting, maturity group (MG) IV soybean cultivars can produce great yields in the mid-south. (Akhter and Sneller, 1996). Late planting dates with late MG may cause a delay in the reproductive development and greater risks of decreased grain yield due to drought, pest attacks, and late-season seed and foliar diseases (Heatherly et al., 2005). From MG V to VI, the duration of the vegetative, flowering and pod-set stages is shorter, which is the main factor affecting yield (Chen and Wiatrak, 2010). Moreover, Kane and Grabau (1992) also stated that early MG's planted late in the season could have a premature flowering affecting the yield due to the shorter plants and reduced canopy closure. These short plants with reduced canopy closure decreases the efficiency of soybean plants to intercept solar radiation (Egli and Bruening, 2000) and reduces important yield components, such as number of nodes (Pendleton and Hartwig, 1973) which consequently would reduce yield.

In eastern Oklahoma, Sholar and Edwards (1997) found that these negative factors, including heat and drought stresses, could be avoided during flowering stage when planting MG III and IV in April. In another study by Keim et al. (1999) in the eastern part of Oklahoma, the results showed that maximum yield was reached when MG IV, V and VI were planted around mid-May and mid-June with average yields of 2518 Kg ha^{-1}, 2882 Kg ha^{-1}, and 2801 Kg ha^{-1}, respectively. However, between these two periods and after June 22nd, yields were significantly low.

A recent review of soybean trial data from around Oklahoma indicates that recommendations related to planting date and maturity group (MG) need to be revisited. With a broad range of planting dates and a wide selection of new soybean varieties available for Oklahoma, it is necessary to investigate what are the actual effects of planting dates and certain MG cultivars on soybean yield. Determining seed yield and yield components (nodes m^{-2}, reproductive nodes m^{-2}, pods reprod. $node^{-1}$, seeds pod^{-1}, seed mass (grams per 100 seeds), pods m^{-2}, seeds m^{-2}, percentage reproductive nodes, and harvest index as affected by PD and MG, will help to guide planting recommendations for Oklahoma. Selection of the proper MG and PD will enable producers to manage better their production system and consequently increase their profitability. The objectives of this study were to determine the effects of PD and MG on seed yield and yield components in an effort to assist Oklahoma soybean producers in making better decisions in choosing the optimum MG for a specific planting period.

CHAPTER III

METHODOLOGY

General Methodology

This study was conducted during the 2009 growing season at one location in Stillwater, OK, and in 2010 at two locations (Stillwater, OK, and Lahoma, OK). At all the locations, the established plots were 3.0 m wide by 9.1 m long. Pre-plant soil samples were taken and a routine soil analysis was conducted with the results shown in Appendix A. Precipitation and air temperature records were obtained from weather stations located near each site. All soybean varieties used in the study were glyphosate-resistant. Plots were planted with a Monosem vacuum planter (Monosem, Inc. Edwardsville, KS) with four rows spaced at 0.76 m and calibrated to plant a population of 310,000 plants ha^{-1} at 2.5 cm deep.

Inoculants, soil fertility, and pest management practices were conducted according to Oklahoma State University recommended practices (Pratt et al., 2009). To control weeds, the plot area was sprayed as needed with 1.12 kg ai ha^{-1}glyphosate. To control insect pests, the Stillwater plots were treated with 0.028 kg ai ha^{-1} lambda-cyhalothrin.

2009 Growing Season

The experimental design was a Split Block Design with three replications. This study was established at the Oklahoma State University Agronomy Research Station in Stillwater, Oklahoma (36°07'52.25" N, 97°06'13.79" W, elevation 270 m) on Easpur Loam (fine loamy, mixed, superactive, thermic Fluventic Haplustolls) soils. The planting dates were established from early April through late July. One soybean variety from MG III and two from MG IV were planted in all three PDs from early April through late May, and two soybean varieties from late MG IV and three MG V were planted in all PDs from late May through late July. All these varieties were selected based on yield performance tests in previous years in Oklahoma (Soybean Variety Performance Tests, 2008). Table 1 provides a list of all planting dates, maturity groups and varieties used in 2009.

Table 1. Varieties and maturity groups tested on early and late planting dates in 2009.

Planting Date	Maturity Groups	Varieties†
Early Season		
9-Apr		DG 35G38 (*I*) ‡
24-Apr	3.8 – 4.4 – 4.8	DG 37A44 (*I*)
20-May		DG 36Y48 (*I*)
Late-Season		
20-May		RT4485N (*I*) – TV49R17 (*I*)
10-Jun	4.4 – 4.9 – 5.2 – 5.5 – 5.6	HBKR522 (*D*) – TV55R15 (*D*)
20-Jul		GMA 56511R (*D*)

†Varieties described on each season were planted on each planting date of that given season.
‡ Varieties followed by (*I*) have indeterminate growth habit and varieties followed by (*D*) have determinate growth habit.

Prior to this field experiment, the plot location was used for winter wheat and fallowed for 9-mo period. Pre-plant tillage operations were made for weed control and to incorporate crop residues.

2010 Growing Season

The 2010 growing season was established at two experimental sites, one located at the Oklahoma State University Agronomy Research Station in Stillwater, OK (36°23’21.28” N, 97°06’34.69” W, elevation 268 m) on Ashport Silt Clay Loam (fine-silty, mixed, superactive, thermic Fluventic Haplustolls) and one at the Oklahoma State University North Central Research Station near Lahoma, OK. (36°07’03.15” N, 97°05’47.85” W, elevation 390 m) on Grant Silt Loam (fine-silty, mixed, superactive, thermic Udic Argiustolls). The experimental design for these two sites was a split block design with three replications. The planting dates were established from early April through late July for both sites. One soybean variety from MG III, four varieties from MG IV and three varieties from MG V were planted at all six planting dates at the Stillwater site. For the Lahoma site, two soybean varieties from MG IV and two from MG V were planted at all 6 plantings dates. Varieties were also selected based on yield performance tests in previous years in Oklahoma. Table 2 provides a list of all planting dates, maturity groups and varieties used in 2010.

Table 2. Varieties and maturity groups for each planting date at Stillwater and Lahoma in 2010.

Location	Planting Date	Maturity Groups	Varieties†
	13 – April		
	29 – April		DG 35G38 (*I*) ‡
Stillwater, OK	25 – May	3.8 – 4.4 – 4.8	S42-T4 (*I*) - RC 4417 (*I*)
	21 – June	5.2 – 5.6	RTS 4824 (*I*) – 4807 RR (*I*)
	13 – July		R2 520 (*D*) – 5218 RR (*D*)
	29-Jul		AG 5605 (*D*) – 5622 RR (*D*)
	15 – April		
	05 – May		RC 4417 (*I*)
Lahoma, OK	02 – June	4.4 – 4.8	RTS 4824 (*I*)
	22 – June	5.2 – 5.6	5218 RR (*D*)
	13 – July		AG 5605 (*D*)
	29-Jul		

†Varieties described on each season were planted on each planting date of that given season.
‡ Varieties followed by (*I*) have indeterminate growth habit and varieties followed by (*D*) have determinate growth habit.

Prior to this experiment, the Stillwater plot location was used for sorghum in the 2009 growing season and followed by a 4-mo fallow period. For Lahoma, sunflower was grown and followed by 4-mo fallow period. Pre-plant tillage operations were made at both locations for weed control and to incorporate crop residues. All evaluations prior to harvesting were similar to 2009.

Harvest and Yield Analysis

To determine seed yield, for all site-years, the two inner rows were harvested when the soybean plants reached maturity (R8), using a Wintersteiger Delta plot combine (WINTERSTEIGER Inc., Salt Lake City, UT). This combine simultaneously recorded seed yield, seed moisture and test weight of each plot. Seed yield was recorded and adjusted to a moisture content of 13 %. Yield losses after mid-June were calculated for all locations by dividing the yield difference between the late June PD and last PD (late July) by the number of weeks between these PDs to determine what would be the yield loss per week.

Relative yield was obtained across all PDs by finding the highest yield considering all PDs, locations and years, and then dividing the maximum yield from each PD by this highest yield.

Yield Components

Hand harvesting was used to obtain yield components and plant growth characteristics. Plants were randomly harvested at R8 from 1 m^2 area in each plot. From these hand-harvested samples, ten plants were randomly selected to determine the following yield components: no. of seeds m^{-2}, seed mass (grams 100seeds^{-1}), no. of pods m^{-2}, no. of seeds pod^{-1}, no. of pods reproductive node^{-1}, no. of reproductive nodes m^{-2}, no. of nodes m^{-2}, percent of reproductive nodes, and harvest index (HI). All yield components were calculated by the method described by Board and Modali (2005). These evaluations were done at Stillwater locations in both years.

Canopy Closure

Digital photographs of 1 m^2 from each plot were taken once per week, between emergence (VE) and the R7 stage, using a method similar to that described by Purcell

(2000). Pictures were taken from 1 m above the soil surface and the camera was mounted on a monopod attached to a piece of PVC pipe with the camera lens pointing down covering approximately 1 m^2. These digital photographs were analyzed using a computer program called SigmaScan Pro (v. 5.0, systat software, Point Richmond, CA). This program selects the green pixels in the digital image and divides them by the total number of pixels in the image photo, providing a percentage indicating the total percent cover of the plants in the 1 m^2. (Purcell, 2000). Thermal units (*Tu*) or growing degree day units (*GDD*) were calculated using the following equation:

$$Tu = \left[\frac{(T_{MAX} + T_{MIN})}{2}\right] - T_{BASE}$$

where T_{MAX} is the daily maximum air temperature, T_{MIN} is the daily minimum air temperature, and T_{BASE} is the temperature below which the plant do not progress in growth (McMaster and Wilhelm, 1997). The base temperature for soybean is 10°C. Daily maximum and minimum temperatures for each location were obtained from the Oklahoma Mesonet website (http://agweather.mesonet.org/). The fractional coverage and *Tu* were plotted to estimate canopy closure of each planting date.

Statistical Analysis

Seed yield data and yield components data were analyzed using SAS software version 9.2 (SAS, 2008). Analyses of variance (ANOVA) was performed using PROC GLIMMIX to determine differences in seed yield between planting dates, maturity groups, and the correlation of planting dates and maturity groups for both early-season and late-season plantings in 2009, and for the whole 2010 growing season in Stillwater and Lahoma. Least significant differences (LSDs) were determined at 0.05 significance level. For yield components analysis of variance, the same SAS function (PROC GLIMMIX) and the same LSD was used to determine differences between each yield component, according to the PD, for Stillwater in 2009 and 2010. Log Transform was used in the yield analysis of Stillwater and Lahoma 2010 to address problems with normal distribution. In the text all discussion of seed yield is done after it was transformed back to kg ha^{-1}.

Path analysis was used in yield components to determine direct and indirect effects of primary (No. of seeds m^{-2} and seed mass (grams $100seeds^{-1}$)), secondary (No. of seeds pod^{-1} and No. of pods m^{-2}), tertiary (No. of pods reproductive $node^{-1}$ and No. of reproductive nodes m^{-2}), and quaternary (No. of nodes m^{-2} and % of reproductive nodes) on seed yield, using the SAS function PROC CORR and PROC IML.

CHAPTER IV

RESULTS AND DISCUSSION

Adequate environmental conditions are important for soybean plants to achieve maximum growth and yield potential. These conditions can vary according to year and location. Figure 2 shows the rainfall and temperature records for 2009 and 2010, and 30-yr average rainfall and temperature for Stillwater, OK.

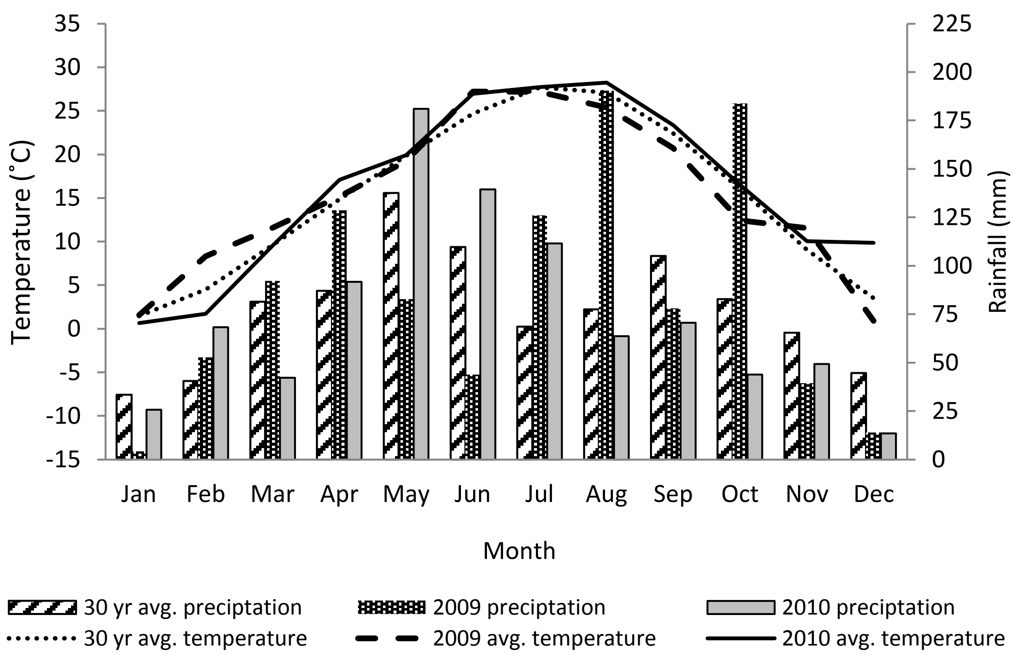


Figure 2. Average monthly temperature and rainfall for Stillwater, OK in 2009, 2010 and 30-yr averages.

Seed Yield – Stillwater 2009

As shown in Figure 2, in 2009, Stillwater, OK weather conditions were exceptional during soybean reproductive stages with greater amounts of rainfall late in the season (from July through October) and lower temperatures during the summer compared to the 30-yr average. Most seed yields from early plantings in 2009 were observed to be numerically higher compared to the state average in the past 10-yr which was (1,640 kg ha^{-1}) (USDA, 2011).

For early-season, planting date and maturity group interaction (PD*MG) was not observed, so individual main effects were considered separately. Both planting date ($p < 0.01$) and maturity group ($p = 0.04$) had significant effects on mean yield. As shown in Table 3, the first two planting dates (13-Apr and 24-Apr) had higher yields when compared to the 20-May PD. Yield loss of 1150 kg ha^{-1} was observed when comparing 24-Apr to 20-May. This reduction in yield can be explained by the typical short time of these early MGs to complete their growth and reproductive stages. In general, higher yields were obtained in early-season compared to late season. In agreement with these results, Robinson (2009) found that higher yields were obtained on planting dates between late April and early May near West Lafayette, IN. Moreover, Boquet (1998), Heatherly (1999) and Edwards (2003) also concluded that for the midsouthern US, early MGs (III and IV) when planted early in the season can avoid mid-season drought stresses during seed fill, which can result in higher yields.

As stated previously, differences in MG was significant for early-season where both MGs 4.4 and 4.8 produced greater yields compared to MG 3.8 (Table 4).

For late-season plantings, no PD*MG interaction was observed ($p = 0.87$). There was significant effect on seed yield due to PD ($p = 0.01$), but no significant effect was found for MG ($p = 0.06$). Yields of each planting date when averaged across MGs in 2009 are shown in Table 3. Mainly due to the photoperiod sensitivity of soybean, seed yields decreased as planting date was delayed (Table 3). The last PD (20-July) had significantly lower yield compared to PD's 20-May and 10-June. Considering the average yield across MGs within the same planting date, after May-20 the yield loss was 120 kg ha^{-1} per week. These findings agree with others (Egli, 1999; Kane et al., 1997; and Wesley et al., 1991) that observed that late planting dates showed reduced yields due to the critical photoperiod being reached sooner and consequently less time for the plants to complete adequate vegetative growth.

Table 3. Least square means for soybean seed yield among planting dates in both early and late season trials at Stillwater 2009.

Season	Planting Date	Seed Yield Across MG
		Kg ha^{-1}
	13–Apr	2789 a†
Early	24–Apr	2530 a
	20–May	1381 b
	20–May	2240 a
Late	10–Jun	1907 a
	20–Jul	1308 b

† Values followed by same letter within same season do not differ ($p > 0.05$).

Table 4. Least square means among maturity groups in both early and late season trials at Stillwater 2009.

Season	Maturity Group	Seed Yield Across PDs
		Kg ha^{-1}
Early	3.8	1790 b†
	4.4	2295 a
	4.8	2371 a
Late	4.4	1518 a
	4.9	1804 a
	5.2	1806 a
	5.5	1933 a
	5.6	1841 a

† Values followed by same letter within same season do not differ.

2010 Seed Yield – Stillwater, OK

In 2010, the Stillwater site had different environmental conditions compared to 2009 (Figure 3). A more common weather pattern for Oklahoma with greater rainfall was observed at the beginning of the growing season and decreased significantly after July, and also showed higher average temperatures during the mid-season, similar to the 30-yr averages.

No differences were observed between varieties within the same MG ($p = 0.43$), so averages for each MG are presented in Figure 3. The interaction between PD*MG on yield was significant ($p = 0.02$), so only the interaction will be discussed. The interaction appears to indicate that with earlier planting dates MG selection was more important but with later PD's, regardless of MG, yields decreased, so MG selection was less of a factor. On the three first PDs, MG 4.8, 5.2 and 5.6 soybean had the highest yields from this trial with averages of 2626 kg ha^{-1}, 2906 kg ha^{-1}, and 3101 kg ha^{-1}, respectively. The lowest average yield obtained on these three first PD's was from MG 3.8 soybean with 1458 kg ha^{-1}. Yields were probably higher in this period due to greater rainfall and moderate temperatures during the vegetative stages, flowering dates, and beginning of the reproductive stages. For the planting dates established from middle of June through late July, the opposite occurred. The vegetative growth stage was shortened due to daylength, which resulted in fewer reproductive nodes. Similar results were found in several other studies (Egli, 1999; Kane et al., 1997; Wesley et al., 1991) that indicated delayed soybean plantings resulted in reduced yield due to shorter days, lower insolation and temperatures, and less soil moisture available, which are typical factors for late soybean growing season.

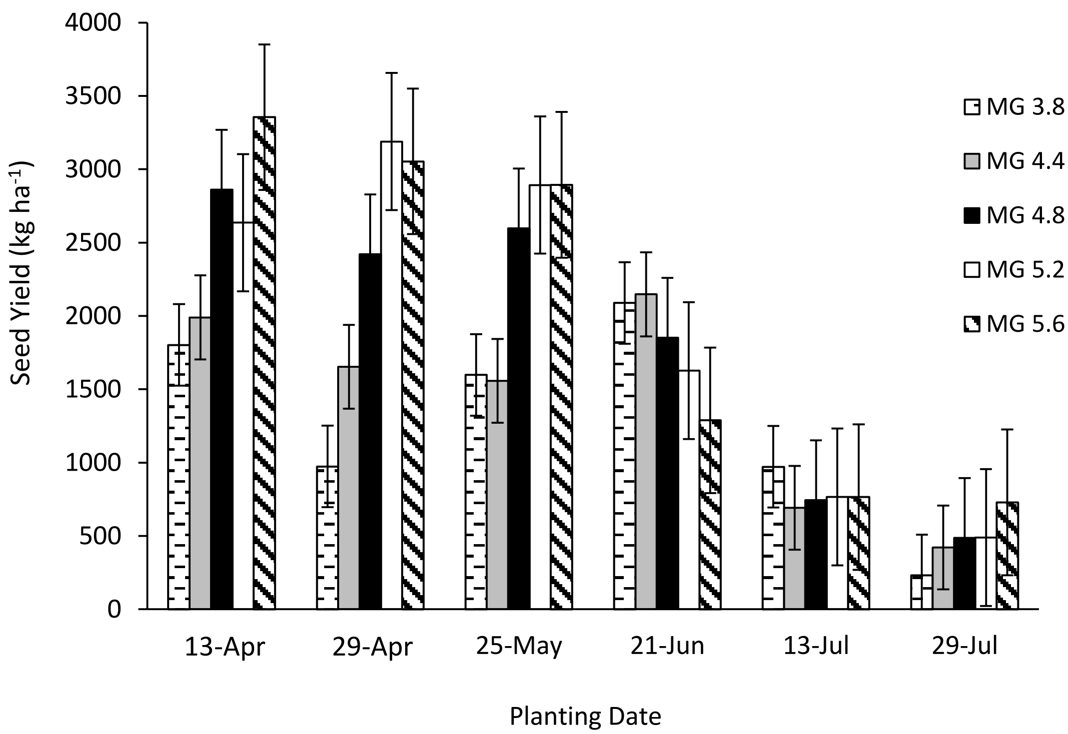


Figure 3. Soybean seed yield for all planting dates and maturity groups for Stillwater, 2010.

Seed Yield – Lahoma 2010

Growing season weather conditions in Lahoma, OK are given in Figure 4. Annual rainfall is less when compared to Stillwater, therefore analysis of Lahoma was considered separately.

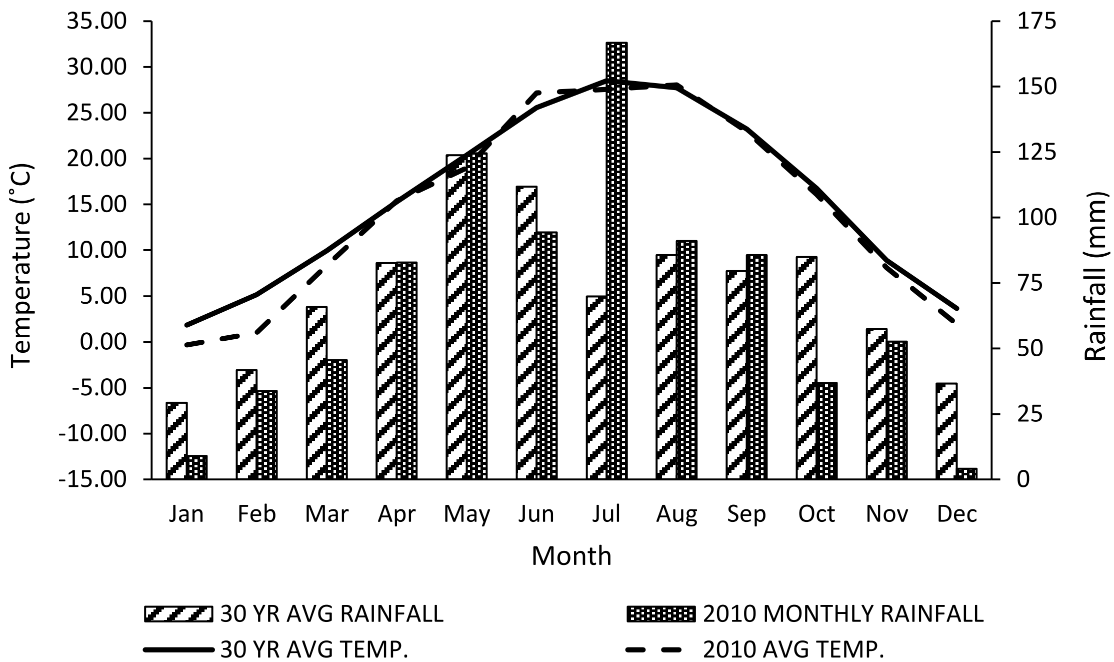


Figure 4. Average temperature and monthly rainfall for Stillwater, OK in 2009, 2010 and 30 years averages. "AVG" = average.

During the 2010 growing season at Lahoma, near normal temperatures and rainfall were observed when compared to the 30-yr averages. In July, the rainfall was more than two times higher compared to the 30-yr average. This greater rainfall amount favored the soybean cultivars planted in 02-Jun, which had higher yields compared to the other PDs. The reason would be the greater soil moisture present at the flowering stage until beginning of the pod set, which are critical period for soybean plants. Table 5 shows the seed yield obtained according to the PD and MG at Lahoma in 2010.

No interaction between PD*MG was observed on yield ($p = 0.50$), so individual main effects are discussed. Planting date ($p < .0001$) presented significant effect on mean yield, however maturity group ($p = 0.05$), did not. Taking the average across MGs within each PD and evaluating only the PD effect, PDs 05-May and 02-Jun had greater yields compared to all PDs after mid-June. However, PD 15-Apr did not differ in yield from either PD 05-May, 22-Jun and 13-Jul. Planting date 02-Jun had the highest yield being statistically different from all other PDs as well as the last PD (29-Jul) which presented the lowest yield for this location. Analysis of variance among MGs across PDs with Alpha=0.05 showed that MG 4.8 had the greatest yield and it was different from MG 4.4 and 5.2, but not different from MG 5.6, which also had no difference from MGs 4.4 and 5.2. Least square means for each MG among PDs were different as well showing $p<0.001$ for all of them, reinforcing the PD effect on each MG.

Generally comparing Lahoma and Stillwater locations, the average seed yield across all six PDs was 18% lower for Lahoma than the same average for Stillwater. This is probably due to the lower rainfall obtained in Lahoma during the early season compared to Stillwater which had higher amounts of rainfall than the 30-yr average in all months until July. This fact did not happen for the Lahoma location. The average temperatures had no differences between both locations during the growing season. The poor yield for soybean in late PDs (from 22-Jun to 29-Jul) can be explained following again the same results found by Egli, (1999); Kane et al., (1997); and Wesley et al., (1991), when they stated that typical factors from late growing season, such as shorter days, lower insolation, cooler temperatures and less soil moisture were responsible for significant reductions in seed yield as plantings are delayed. For this location, these yield losses across MGs were close to 195 kg ha^{-1} per week of planting delay after middle of June. Therefore, these significant losses justify the importance in selecting the appropriate planting date, which cannot be after mid-June considering all MGs tested in this study.

Table 5. Means for seed yield across maturity groups and across planting date at Lahoma 2010.

PD	Yield	MG	Yield
Seed yield by planting date		Seed yield by maturity group	
	Kg ha^{-1}		Kg ha^{-1}
15-Apr	1758 abc†		
05-May	1903 ab	4.4	1359 b†
02-Jun	2422 a	4.8	1694 a
22-Jun	1300 bc	5.2	1314 b
13-Jul	1252 c	5.6	1636 ab
29-Jul	370 d		

† Values followed by same letter within same column do not differ at $\alpha = 0.05$.

Relative Yield

All PDs from both years and locations were plotted together as shown in Figure 5 according to their yield which was converted to relative yield as function of days of year to provide an overview about the yield potential according to the planting date.

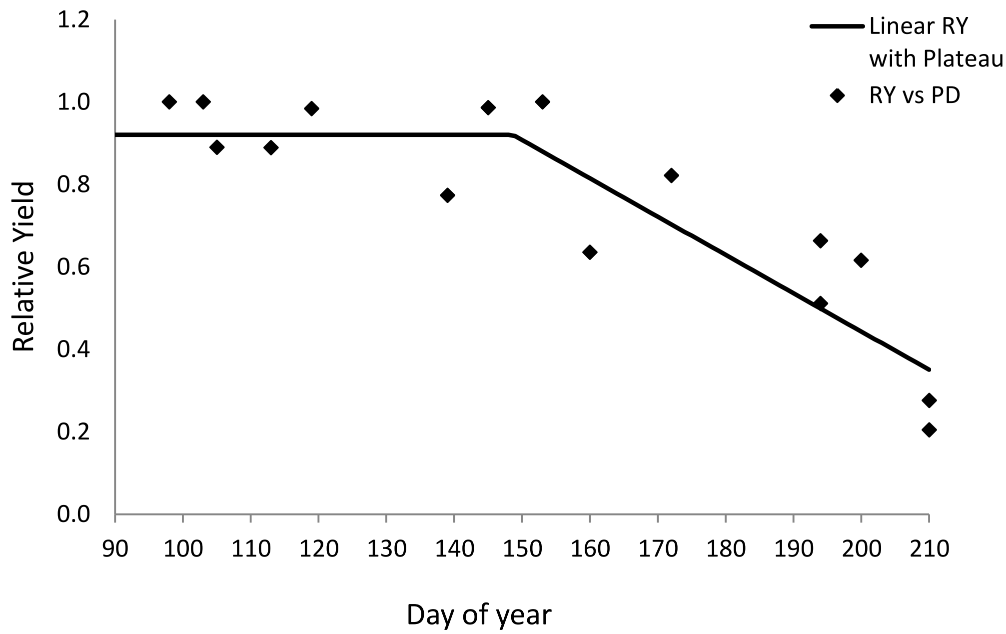


Figure 5. Relative Yield with Plateau using all PDs from all locations and both years. "RY" = Relative Yield and "PD" = Planting Date

Planting date selection prior to DOY 151 did not appear to affect yield. However, once PD was delayed after DOY 151 (June 1) yield decreased linearly regardless of MG. A seed yield reduction of approximately 215 kg ha^{-1} per week of delay in planting was observed. Again, this significant reduction in seed yield for plantings after the middle of June is explained as discussed before due to days becoming shorter, lower insolation, and consequently lower temperatures and less soil moisture available due to the lack of sufficient rainfall on this period. In contrast to these results, Keim (1999) found that late May PDs showed low seed yield, and that optimum yield can be reached in mid-May and mid- to late June PDs.

Yield Components

Table 6 shows the mean values for each yield components by planting date.

Table 6. Least square means for yield components by planting date in early and late season at Stillwater in 2009.

Planting Date	seeds pod^{-1}		pods m^{-2}		seeds m^{-2}		pods repnd^{-1}		repnds m^{-2}		nds m^{-2}		perc. repnds		seedmass		HI	
Early season															(g 100seeds-1)			
9-Apr	2.32	a	1406	a	3262	a	1.98	b	712	a	963	a	74.2	b	14.0	a	46.7	a
24-Apr	2.37	a	1170	a	2773	ab	1.99	b	589	b	782	b	75.7	ab	15.2	a	45.9	a
20-May	2.41	a	869	b	2094	a	2.20	a	370	c	467	c	79.7	a	14.8	a	44.6	a
Late-season																		
20-May	2.30	a	1200	a	2739	a	2.08	b	507	a	642	a	79.4	a	14.2	a	43.6	a
10-Jun	2.27	a	803	b	1764	b	2.51	a	408	b	547	ab	78.6	a	12.6	b	43.1	a
20-Jul	2.24	a	744	b	1666	b	2.02	b	367	b	459	b	74.8	b	14.2	a	40.4	b

† Values followed by the same letter within the same season do not differ at $\alpha = 0.05$.

Pods m^{-2}, seeds m^{-2}, and repnds m^{-2} were the three yield components most affected by planting dates, decreasing in later PD. These three yield components were directly related to seed yield as shown in Table 7.

Table 7 provides the path analysis for 2009 yield components at Stillwater. The path analysis was used to identify the indirect and direct effect of each yield component on seed yield. Results are shown as coefficient representing the level of effect on seed yield.

Table 7. Indirect and direct path coefficients of (a) primary, (b) secondary, (c) tertiary, and (d) quaternary yield components showing the effect on yield according to the PD at Stillwater, 2009.

	Planting Date					
Indirect effect on yield	**9-Apr**	**24-Apr**	**20-May**	**20-May**	**10-Jun**	**20-Jul**
(a) Primary yield components						
Seed mass (g 100 seeds^{-1})	-0.72	0.18	-0.55	-0.24	0.16	-0.21
Seeds m^{-2}	-0.04	-0.03	0.05	-0.04	-0.03	0.01
(b) Secondary yield components						
Seeds pod^{-1}	0.08	0.03	-0.50	-0.56	-0.32	-0.30
Pods m^{-2}	-0.16	0.01	0.01	-0.01	0.01	-0.02
(c) Tertiary yield components						
Pods per rep. node	-0.02	0.01	-0.40	-0.69	-0.73	-0.67
Rep. node m^{-2}	-0.01	0.01	-0.39	-0.25	-0.37	-0.34
(d) Quaternary yield components						
Node m^{-2}	-0.19	-0.55	-0.84	0.06	0.13	-0.05
Percent repr. Node	-0.16	-0.46	-0.87	0.07	0.17	-0.07
Direct effect on yield						
Seed mass (g 100 seeds^{-1})	0.06	-0.18	-0.09	0.14	-0.21	-0.05
Seeds m^{-2}	0.93	0.96	0.88	0.94	0.98	0.92
Seeds pod^{-1}	-0.21	0.16	-0.02	0.01	-0.04	0.05
Pods m^{-2}	1.08	0.92	0.96	0.92	0.95	0.97
Pods per rep. node	0.43	0.63	0.92	0.58	0.61	0.58
Rep. nodes m^{-2}	0.82	0.71	0.93	1.04	1.20	1.15
Nodes m^{-2}	0.67	0.89	1.24	0.54	0.61	0.75
Percent rep. nodes	0.79	1.05	1.20	0.53	0.45	0.53

The indirect path coefficients (Table 7) for each PD are the measurement of the indirect effect of that given yield component through the other yield component within the same category. For instance, the first number in the top left side (-0.72) is the coefficient representing the indirect effect of seed mass (g 100 seeds^{-1}) through seed m^{-2} on yield for the PD 9-Apr. The number below (-0.04) is the opposite, meaning the indirect effect of seed m^{-2} on yield through seed mass (g 100 seeds^{-1}). Indirect effects were generally negative or close to zero since very little correlation between yield components within the same category was found to affect yield. No trends were observed in the values across PDs. Board et al. (2003) and Robinson et al. (2009) found similar results when they stated that the variation between positive and negative correlations according to PDs are due to other yield component compensation, for example, a low seed mass being compensated with high number of seeds m^{-2}.

The direct effect of each yield component on yield (Table 7) reveals the importance of these yield components on seed yield. This path analysis demonstrated that the three most important yield components across PDs were pods m^{-2} (r^2 = 0.94) followed by seeds m^{-2} (r^2 = 0.92) and then rep. node m^{-2} (r^2 = 0.75). The effect on yield by pods m^{-2} also was observed in studies by Robinson et al. (2009) when he found that pods m^{-2} was the most important yield component directly affecting the yield, mainly in early PDs. In agreement, Singer (2004) found that pods m^{-2} differences is highly related to yield differences (r^2 = 0.92). For seeds m^{-2} other authors also found similar results where seeds m^{-2} was highly correlated to seed yield. De Bruin and Pederson (2008) found that seed m^{-2} was the yield component that drove yield with a strong linear relationship (r^2 = 0.89). Seed mass had little or no effect on yield, which agrees with the authors previously cited, however it contradicts Robinson et al. (2009) when he stated which showed that seed number was a poor yield predictor on his study, but no data was shown.

For PDs in late-season, rep. node m^{-2} had slightly greater effect on yield compared to pods m^{-2} and seeds m^{-2}. The least important yield component throughout the growing season was seed mass followed by seeds pod^{-1}. Unlike our findings, Robinson et al. (2009) stated that seed mass was the second most important yield component affecting yield. Pedersen and Lauer (2004), also showed a greater effect on seed yield by seed mass compared to seed number, pod number and seeds pod^{-1}.

For 2010 yield component results, Table 8 shows the mean values for each yield components by PD.

Table 8. Least square means for yield components by planting date at Stillwater in 2010.

Plant Date	seeds pod^{-1}		pods m^{-2}		seeds m^{-2}		pods repnd^{-1}		repnds m^{-2}		nds m^{-2}		perc. repnds		seedmass (g 100seeds-1)		HI	
13-Apr	2.3	a†	1029.1	b†	2362.0	b†	2.46	a†	418.6	b†	549.0	b†	44.4	b†	12.5	a†	37.9	a†
29-Apr	2.2	a	1182.7	ab	2649.2	ab	2.46	a	483.6	ab	613.6	ab	44.9	b	11.0	b	36.8	a
25-May	2.2	a	1321.3	a	2870.8	a	2.46	a	544.3	a	682.8	a	47.6	a	11.6	ab	36.7	a
21-Jun	2.1	a	998.6	b	2133.5	c	2.53	a	397.6	b	510.3	b	45.4	ab	11.7	ab	37.2	a
13-Jul	2.3	a	673.9	bc	1536.6	d	2.56	a	267.3	c	368.3	c	44.2	b	12.3	a	39.6	a
29-Jul	2.1	a	380.3	c	815.1	e	1.99	b	191.0	c	282.2	c	35.7	c	10.8	b	42.3	a

† Values followed by the same letter within the same column do not differ at $\alpha = 0.05$.

Similar to 2009, pods m^{-2}, seeds m^{-2}, and repnds m^{-2} were again the three yield components most affected by planting dates, decreasing as PD was delayed past 21-Jun. Path analysis was also done (Table 9) to determine the indirect and direct effect of each yield component across planting dates. Results are shown as coefficient representing the level of effect on seed yield.

Table 9. Indirect and direct path coefficients of (a) primary, (b) secondary, (c) tertiary, and (d) quaternary yield components showing the effect on yield according to the PD at Stillwater, 2010.

	Planting Date					
Indirect effect on yield	**13-Apr**	**29-Apr**	**25-May**	**21-Jun**	**13-Jul**	**29-Jul**
(a) Primary yield components						
Seed mass (g 100 seeds^{-1})	-0.52	-0.72	-0.22	-0.17	0.16	-0.04
Seeds m^{-2}	-0.24	-0.25	-0.10	-0.03	0.05	-0.02
(b) Secondary yield components						
Seeds pod^{-1}	-0.25	0.55	0.22	-0.43	0.20	0.20
Pods m^{-2}	-0.04	0.04	0.15	-0.13	0.05	0.05
(c) Tertiary yield components						
Pods per rep. node	-0.28	-0.51	-0.76	-0.44	-0.77	-0.21
Rep. nodes m^{-2}	-0.37	-0.24	-0.74	-0.12	-0.39	-0.15
(d) Quaternary yield components						
Nodes m^{-2}	-0.01	0.09	0.03	0.04	0.04	-0.04
Percent repr. Nodes	-0.05	0.15	0.05	0.32	0.26	-0.08
Direct effect on yield						
Seed mass (g 100 seeds^{-1})	0.51	0.42	0.44	0.20	0.30	0.38
Seeds m^{-2}	1.12	1.19	0.98	1.01	0.90	0.94
Seeds pod^{-1}	0.16	0.06	0.45	0.33	0.23	0.21
Pods m^{-2}	0.93	0.91	0.63	1.06	0.87	0.85
Pods per rep. node	0.90	0.51	0.96	0.27	0.59	0.58
Rep. nodes m^{-2}	0.69	1.07	1.18	1.00	1.17	0.86
Nodes m^{-2}	0.33	0.67	0.38	0.85	0.76	0.65
Percent rep. nodes	0.04	0.41	0.20	0.11	0.12	0.36

The indirect effects of the yield components analyzed (Table 9) were similar to the 2009 observations, alternating from positive to negative according to the PD due to the yield compensation by other yield components being more important to seed yield at a specific PD. All coefficients representing direct effect on seed yield were positive, but the greatest effect on yield came from seeds m^{-2} and rep. node m^{-2} with no difference in effect between them, followed by pod m^{-2}. This greater effect from seeds m^{-2} and rep.

node m^{-2} on yield was close to 2.5 times greater than seed mass effect. In the last two PDs, with exception of seed mass and seeds pod^{-1}, all other yield components were negatively impacted by late plantings and directly affected seed yield.

Canopy Closure

Figure 6 illustrates the linear plateau models that were created by fitting the data collected from estimates of canopy closure for each planting date when averaged across MG's. The rate of canopy closure for each planting date was similar but the plateau point was different for the PDs. Figures illustrating the same model but considering thermal units (*Tu*) are shown in the appendices N and P.

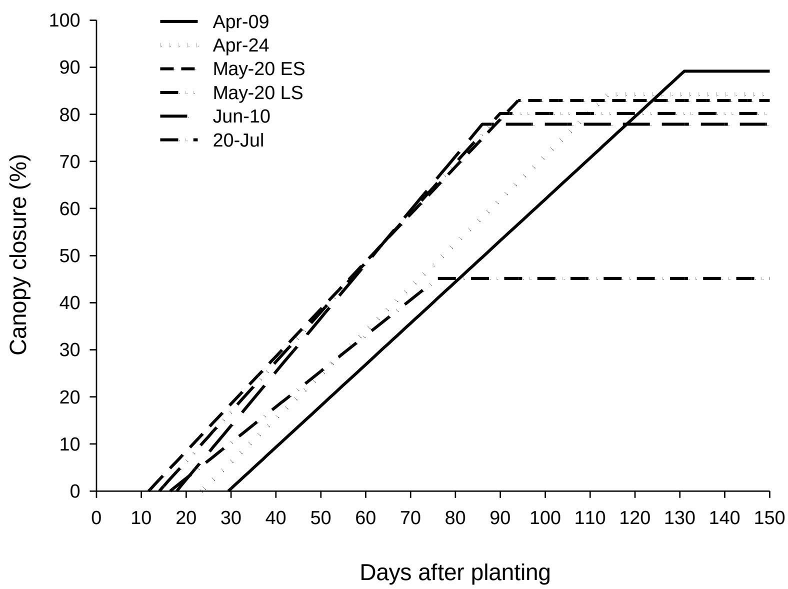


Figure 6. Maximum canopy closure reached by each planting date with averaged maturity groups in Stillwater 2009.

Least square means analysis shown in Table 10 provides the differences among maximum canopy closure among PDs in both early and late season in 2009.

Table 10. Least square means grouping planting dates in early and late season in 2009 to compare maximum canopy closures at Stillwater.

Early-Season			Late-Season		
PD	Maximum canopy closure	Differences	PD	Maximum canopy closure	Differences
	%			%	
9-Apr	89.2	A†	20-May	80.2	A
24-Apr	84.2	A	10-Jun	77.9	B
20-May	82.9	A	20-Jul	45.2	C

† Different planting dates (PD) displaying the same letter within the same season do not differ at $\alpha = 0.05$.

Early season PD had no significant effect on the maximum canopy closure ($p = 0.57$). However, late season PD's had significantly lower plateau points ($p < 0.01$). Planting date 20-May had the greatest canopy closure compared to the later PDs 10-Jun and 20-Jul, which were also different from each other. The latest PD (20-July) had the lowest maximum canopy closure (45%), indicating ineffectiveness in light interception which no doubt negatively affected crop growth and seed yield as seen previously in Table 5. This negative effect obtained on crop growth and yield due to a reduced light interception in soybean plants is well documented (Shibles and Weber,1966; Manson et al., (1980); Parvez et al., (1989); Board and Harville, (1996); and Flenet et al., (1996);

Similar to the previous year, with exception of having only one growing season, results from 2010 in Figure 7 were similar to what was observed in 2009. Focusing in the maximum canopy closure reached, PD showed significant effect on maximum canopy closure ($p < 0.001$).

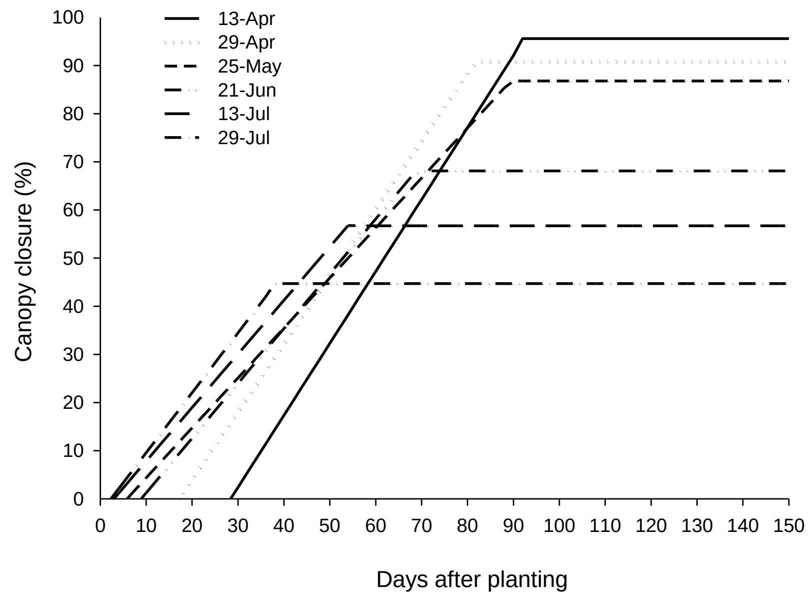


Figure 7. Maximum canopy closure reached by each planting date with averaged maturity groups in Stillwater 2010.

Least square means analysis shown in Table 11 provides the differences among maximum canopy closure across PDs in 2010.

Table 11. Least square means grouping planting dates in 2010 to compare maximum canopy closure at Stillwater.

Planting Date	Maximum canopy closure	Differences
	%	
13-Apr	95.6	A
29-Apr	90.2	AB
25-May	86.7	B
21-Jun	68.1	C
13-Jul	56.6	D
29-Jul	44.7	E

Different planting dates displaying the same letter within the same season do not differ at $\alpha = 0.05$.

Early plantings (prior to middle of June) showed greater values for canopy closure compared to late plantings (after middle of June). This decreased growth and reduced canopy coverage observed in late season is mainly due to, as discussed before, the lack of moisture, shorter days, and consequently less time for the soybean plants to complete their vegetative stage. As shown in Table 11, PD 13-Apr was not different from 29-Apr ($p = 0.13$), but it did have a greater maximum canopy closure when compared to all the other later PDs. After the 25-May PD, the maximum canopy closure decreased as PD was delayed.

These results from both years indicate a poor ability to intercept solar radiation by soybean plants planted late in the season, thus having a negative impact on seed yield. Besides those studies cited previously, our findings can also be confirmed by similar results obtained by Shibles and Weber (1966), when they observed that seed yield can be increased by increasing canopy coverage. Increased canopy coverage intercepts more solar radiation, increasing the production of photosynthate and its use in seed production.

CHAPTER V

CONCLUSION

For Oklahoma conditions, soybean planting dates affect seed yield during the growing season. Our findings indicate that greater seed yield can be achieved when soybean is planted from middle of April until early June, when using an appropriate maturity group. Planting soybean after early June, seed yield is reduced and decreases as planting date is delayed regardless of the maturity group being used. This yield reduction by late plantings can be explained by the insufficient time to establish a complete canopy development during the vegetative stage. Therefore, important yield components are greatly affected on these shorter soybean plants, having then a limited seed yield as consequence.

Maturity group selection demonstrated to be important mainly in early planting soybean system. In this case, MGs from 4.8 to 5.6 had greater seed yields (average of 2700 kg ha^{-1}) compared to MGs from 3.8 to 4.4 (1600 kg ha^{-1}). This superior yield performance by later MGs was due to the longer vegetative stage and appropriate environmental conditions until maturation.

Canopy closure was similar between planting dates prior to early June when greater coverage was reached compared to plantings after this period. On these late planting dates canopy closure decreased as planting dates were delayed, and consequently had lower light use efficiency, which is directly related to seed yield.

The yield components most affected by late planting dates were reproductive nodes m^{-2}, followed by pods m^{-2} and seeds m^{-2}, which showed to have higher direct correlation to seed yield. Seed mass and seeds pod^{-1} had little correlation with seed yield. Their little increase in late planting dates was not enough to compensate losses by the three highly correlated yield components mentioned previously.

Selection of soybean variety within the MG IV to V and planting prior to June 1 provides the greatest chance to maximize soybean seed yield in Oklahoma, however, environmental factors greatly influence the yield potential of soybean in Oklahoma.

REFERENCES

Akhter M., Sneller C.H. (1996) Yield and yield components of early maturing soybean genotypes in the mid-south. Crop Science 36:877-882.

Alliprandini L.F., Abatti C., Bertagnolli P.F., Cavassim J.E., Gabe H.L., Kurek A., Matsumoto M.N., de Oliveira M.A.R., Pitol C., Prado L.C., Steckling C. (2009) Understanding Soybean Maturity Groups in Brazil: Environment, Cultivar Classification, and Stability. Crop Science 49:801-808. DOI: DOI 10.2135/cropsci2008.07.0390.

Board J.E., Hall W. (1984) Premature Flowering in Soybean Yield Reductions at Nonoptimal Planting Dates as Influenced by Temperature and Photoperiod. Agronomy Journal 76:700-704.

Board J.E., Harville B.G. (1996) Growth dynamics during the vegetative period affects yield of narrow-row, late-planted soybean. Agronomy Journal 88:567-572.

Board J.E., Modali H. (2005) Dry matter accumulation predictors for optimal yield in soybean. Crop Science 45:1790-1799. DOI: DOI 10.2135/cropsci2004.0602.

Board J.E., Kang M.S., Bodrero M.L. (2003) Yield components as indirect selection criteria for late-planted soybean cultivars. Agronomy Journal 95:420-429.

Board J.E., Kumudini S., Omielan J., Prior E., Kahlon C.S. (2010) Yield Response of Soybean to Partial and Total Defoliation during the Seed-Filling Period. Crop Science 50:703-712. DOI: DOI 10.2135/cropsci2009.03.0128.

Bowers G.R. (1995) An Early Soybean Production System for Drought Avoidance. Journal of Production Agriculture 8:112-119.

Brummer E.C., Graef G.L., Orf J., Wilcox J.R., Shoemaker R.C. (1997) Mapping QTL for seed protein and oil content in eight soybean populations. Crop Science 37:370-378.

Caviness C.E., Thomas J.D. (1979) Influence of Planting Date on 3 Soybean Varieties. Arkansas Farm Research 28:8-8.

Chen G.H., Wiatrak P. (2010) Soybean Development and Yield Are Influenced by Planting Date and Environmental Conditions in the Southeastern Coastal Plain, United States. Agronomy Journal 102:1731-1737. DOI: DOI 10.2134/agronj2010.0219.

De Bruin J.L., Pedersen P. (2008) Soybean seed yield response to planting date and seeding rate in the upper Midwest. Agronomy Journal 100:696-703. DOI: DOI 10.2134/agronj2007.0115.

Edwards, J. T., Purcell, L. C., Vories, E. D., Shannon, J. G., and Ashlock, L. O. 2003. Short-season soybean cultivars have similar yields with less irrigation than longer-season cultivars. Online. Crop Management doi:10.1094/CM-2003-0922-01-RS.

Egli D.B. (1999) Variation in leaf starch and sink limitations during seed filling in soybean. Crop Science 39:1361-1368.

Egli D.B. (2005) Flowering, pod set and reproductive success in soya bean. Journal of Agronomy and Crop Science 191:283-291.

Egli D.B., Bruening W.P. (2000) Potential of early-maturing soybean cultivars in late plantings. Agronomy Journal 92:532-537.

Flenet F., Kiniry J.R., Board J.E., Westgate M.E., Reicosky D.C. (1996) Row spacing effects on light extinction coefficients of corn, sorghum, soybean, and sunflower. Agronomy Journal 88:185-190.

Foroud N., Mundel H.H., Saindon G., Entz T. (1993) Effect of Level and Timing of Moisture Stress on Soybean Plant Development and Yield Components. Irrigation Science 13:149-155.

Heatherly L.G., Spurlock S.R. (1999) Yield and economics of traditional and early soybean production system (ESPS) seedings in the midsouthern United States. Field Crops Research 63:35-45.

Heatherly L.G., Reddy K.N., Spurlock S.R. (2005) Weed management in glyphosate-resistant and non-glyphosate-resistant soybean grown continuously and in rotation. Agronomy Journal 97:568-577.

Heitholt J.J., Egli D.B., Leggett J.E. (1986) Characteristics of Reproductive Abortion in Soybean. Crop Science 26:589-595.

Kane M.V., Grabau L.J. (1992) Early Planted, Early Maturing Soybean Cropping System - Growth, Development, and Yield. Agronomy Journal 84:769-773.

Kane M.V., Steele C.C., Grabau L.J. (1997) Early-maturing soybean cropping system .2. Growth and development responses to environmental conditions. Agronomy Journal 89:459-464.

Keim K.R., Eren A., Edwards L.H. (1999) Long-term study of planting date effects on seed yield in soybean. Journal of Production Agriculture 12:288-292.

Lee C.D., Egli D.B., TeKrony D.M. (2008) Soybean response to plant population at early and late planting dates in the Mid-South. Agronomy Journal 100:971-976. DOI: DOI 10.2134/agronj2007.0210.

Mason W.K., Taylor H.M., Bennie A.T.P., Rowse H.R., Reicosky D.C., Jung Y., Righes A.A., Yang R.L., Kaspar T.C., Stone J.A. (1980) Soybean Row Spacing and Soil-Water Supply - Their Effect on Growth, Development, Water Relations, and Mineral Uptake. Science and Education Administration Publications Aat:1-59.

McMaster G.S., Wilhelm W.W. (1997) Growing degree-days: one equation, two interpretations. Agricultural and Forest Meteorology 87:291-300.

Parvez A.Q., Gardner F.P., Boote K.J. (1989) Determinate-Type and Indeterminate-Type Soybean Cultivar Responses to Pattern, Density, and Planting Date. Crop Science 29:150-157.

Pedersen P., Lauer J.G. (2004) Response of soybean yield components to management system and planting date. Agronomy Journal 96:1372-1381.

Popp M.P., Keisling T.C., McNew R.W., Oliver L.R., Dillon C.R., Wallace D.M. (2002) Planting date, cultivar, and tillage system effects on dryland soybean production. Agronomy Journal 94:81-88.

Pratt P., Patricia B., Godsey C.B. (2010) Soybean proction Guide. Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University. E-967.

Purcell L.C. (2000) Soybean canopy coverage and light interception measurements using digital imagery. Crop Science 40:834-837.

Robinson A.P., Conley S.P., Volenec J.J., Santini J.B. (2009) Analysis of High Yielding, Early-Planted Soybean in Indiana. Agronomy Journal 101:131-139. DOI: DOI 10.2134/agronj2008.0014x.

Shibles R.M., Weber C.R. (1966) Interception of Solar Radiation and Dry Matter Production by Various Soybean Planting Patterns. Crop Science 6:55-&.

Sholar, R., L. Edwards, and B. Heister. 1997. Soybean variety tests–1996. Full season (Group V). PT97–8 9(8). Oklahoma CSREES, Stillwater, OK.

Singer J.W., Malone R.W., Meek D.W., Drake D. (2004) Predicting yield loss in indeterminate soybean from pod density using simulated damage studies. Agronomy Journal 96:584-589.

Spaeth S.C., Sinclair T.R. (1984) Soybean Seed Growth .2. Individual Seed Mass and Component Compensation. Agronomy Journal 76:128-133.

Wesley R.A., Heatherly L.G., Elmore C.D. (1991) Cropping Systems for Clay Soil - Crop-Rotation and Irrigation Effects on Soybean and Wheat Doublecropping. Journal of Production Agriculture 4:345-352.

Wilcox J.R., Frankenberger E.M. (1987) Indeterminate and Determinate Soybean Responses to Planting Date. Agronomy Journal 79:1074-1078.

Zhang L.X., Wang R.F., Hesketh J.D. (2001) Effects of photoperiod on growth and development of soybean floral bud in different maturity. Agronomy Journal 93:944-948.

APPENDICES

Appendix A. Soil pH and nutrients (NPK) collected at the first planting date from the experiment areas in both locations and years.

Location/Year		Spoil pH†	Nutrients		
			NO_3-N‡	P‡	K‡
Stillwater				kg ha-1	
	2009	6.8	33.7	65.5	261.0
	2010	6.2	26.8	41.5	249
Lahoma					
	2010	6.5	29.5	47.4	301

† Soil pH values were obtained by the method 1:1.

‡ NO_3-N, P and K values were obtained using the method Mehlich-3.

Appendix B. Seed yield of each maturity group and variety on early-season planting dates for Stillwater, OK in 2009.

Planting Date	Variety	Maturity Group	Rep	Yield
				kg ha^{-1}
9-Apr	DG35G38	3.8	1	2148.8
			2	2747.0
			3	2323.3
	37A44	4.4	1	2693.3
			2	3654.8
			3	2559.6
	36Y48	4.8	1	2983.7
			2	2979.2
			3	3323.9
24-Apr	DG35G38	3.8	1	2091.5
			2	2275.8
			3	1383.8
	37A44	4.4	1	2928.8
			2	2837.5
			3	3013.3
	36Y48	4.8	1	2838.9
			2	3249.6
			3	2792.2
5-May	DG35G38	3.8	1	1624.9
			2	1663.2
			3	774.3
	37A44	4.4	1	1990.6
			2	1080.6
			3	1301.9
	36Y48	4.8	1	1753.5
			2	1258.6
			3	1412.1

Appendix C. Seed yield of each maturity group and variety on late-season planting dates for Stillwater, OK in 2009.

Planting Date	Variety	Maturity Group	Rep	Yield
				kg ha^{-1}
5-May	TV49R17	4.9	1	2263.2
			2	2293.8
			3	2817.9
	TV55R15	5.5	1	2826.3
			2	1785.4
			3	2561.8
	RT4485N	4.4	1	1923.3
			2	2285.7
			3	1693.4
	HBKR522	5.2	1	2472.0
			2	2030.6
			3	1989.1
	56511R	5.6	1	2419.7
			2	2168.7
			3	2437.9
10-Jun	TV49R17	4.9	1	2110.8
			2	2078.0
			3	1660.8
	TV55R15	5.5	1	1921.9
			2	1981.7
			3	2188.8
	RT4485N	4.4	1	1292.2
			2	1594.7
			3	2322.0
	HBKR522	5.2	1	1510.0
			2	2160.3
			3	2011.0
	56511R	5.6	1	2166.6
			2	1830.4
			3	2124.5
20-Jul	TV49R17	4.9	1	799.5
			2	1746.5
			3	1362.3
	TV55R15	5.5	1	1400.3
			2	1701.3
			3	1466.9
	RT4485N	4.4	1	898.6
			2	1216.9
			3	1097.9
	HBKR522	5.2	1	1046.6
			2	2250.4
			3	1326.5
	56511R	5.6	1	1071.1
			2	1359.1
			3	1549.7

Appendix D. Average yield in early-season PDs by maturity group in Stillwater 2009.

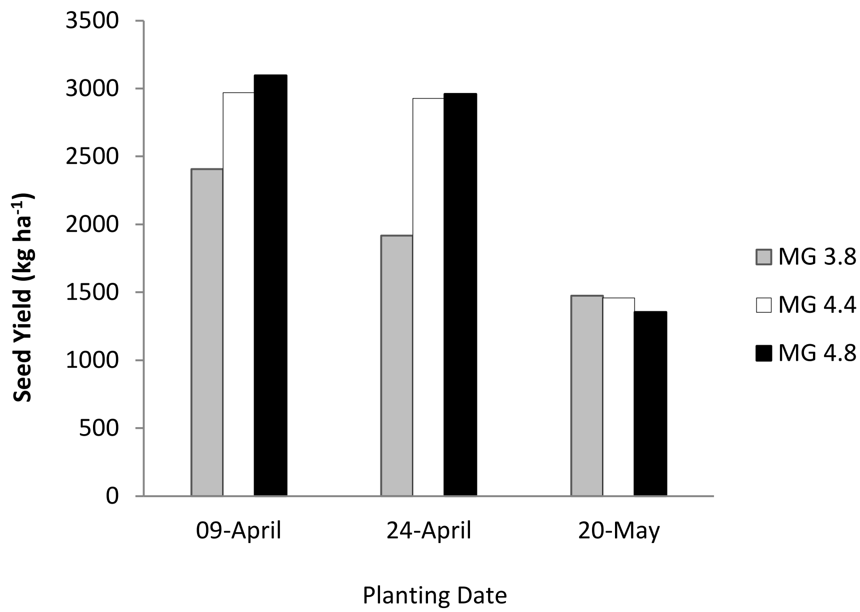
Planting Date	Maturity Group	Yield
		Kg ha^{-1}
9-Apr	3.8	2406.4 b†
	4.4	2969.2 a
	4.8	3095.6 a
24-Apr	3.8	1917.0 b
	4.4	2926.5 a
	4.8	2960.2 a
20-May	3.8	1474.7 a
	4.4	1457.7 a
	4.8	1354.1 a

† Values followed by same lowercase letters within the same planting date do not differ between MGs ($p > 0.05$).

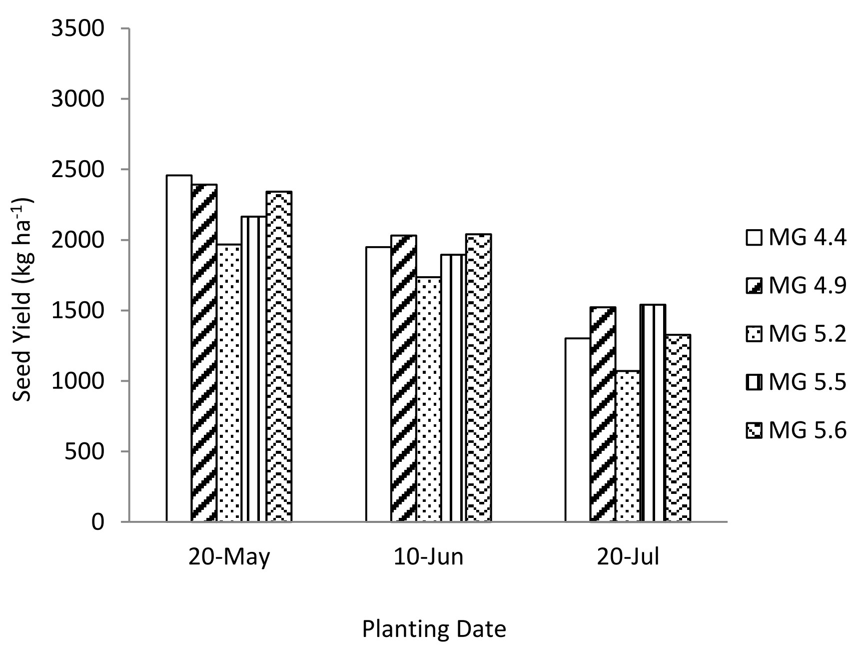
Appendix E. Average yield for late-season PDs by maturity group in Stillwater 2009.

Planting Date	Maturity Group	Yield
		Kg ha^{-1}
20-May	4.4	2458.3 a†
	4.9	2391.2 a
	5.2	1967.5 b
	5.5	2163.9 ab
	5.6	2342.1 a
10-Jun	4.4	1949.9 a
	4.9	2030.8 a
	5.2	1736.3 b
	5.5	1893.7 ab
	5.6	2040.5 a
20-Jul	4.4	1302.7 a
	4.9	1522.8 a
	5.2	1071.1 b
	5.5	1541.2 a
	5.6	1326.6 a

† Values followed by same lowercase letters within the same PD do not differ between MGs ($p > 0.05$).



Appendix E. Soybean seed yield for early-season planting dates by maturity groups in Stillwater 2009.



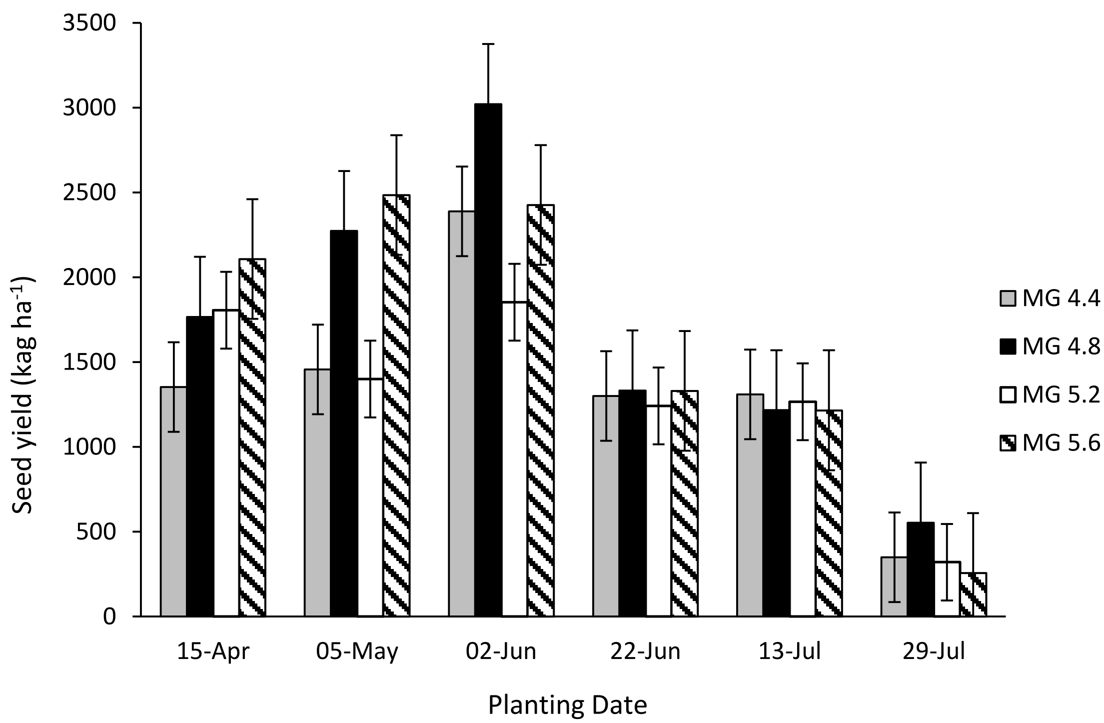
Appendix F. Soybean seed yield for late-season planting dates by maturity group in Stillwater 2009.

Appendix G. Seed yield for each variety and maturity group in all PDs in Stillwater 2010.

Planting Date	Maturity Group	Variety	Yield
			kg ha^{-1}
13-Apr	3.8	DG-35G38	1800.4
	4.2	42-T4	1932.0
	4.4	RC-4417	2045.4
	4.8	RTS-4824	2307.8
		4807-RR	3408.6
	5.2	R2-520	2534.9
		5218-RR	2732.8
	5.6	AG-5605	4053.0
		5622-RR	2652.7
29-Apr	3.8	DG-35G38	973.5
	4.2	42-T4	1687.8
	4.4	RC-4417	1617.4
	4.8	RTS-4824	2846.3
		4807-RR	1990.3
	5.2	R2-520	3028.0
		5218-RR	3345.5
	5.6	AG-5605	3689.5
		5622-RR	2412.0
25-May	3.8	DG-35G38	1597.1
	4.2	42-T4	1766.0
	4.4	RC-4417	1346.9
	4.8	RTS-4824	3036.3
		4807-RR	2154.2
	5.2	R2-520	2296.6
		5218-RR	3484.1
	5.6	AG-5605	2546.2
		5622-RR	3237.3
21-Jun	3.8	DG-35G38	2086.7
	4.2	42-T4	2453.1
	4.4	RC-4417	1838.0
	4.8	RTS-4824	1549.5
		4807-RR	2151.9
	5.2	R2-520	1894.5
		5218-RR	1357.5
	5.6	AG-5605	764.2
		5622-RR	1811.2
13-Jul	3.8	DG-35G38	1781.9
	4.2	42-T4	1026.7
	4.4	RC-4417	357.5
	4.8	RTS-4824	1039.2
		4807-RR	446.6
	5.2	R2-520	1280.8
		5218-RR	248.1
	5.6	AG-5605	750.1
		5622-RR	779.3
29-Jul	3.8	DG-35G38	231.2
	4.2	42-T4	521.0
	4.4	RC-4417	322.5
	4.8	RTS-4824	417.3
		4807-RR	554.9
	5.2	R2-520	439.8
		5218-RR	536.8
	5.6	AG-5605	803.0
		5622-RR	654.1

Appendix H. Seed yield for each variety and maturity group in all PDs in Lahoma 2010.

Planting Date	Maturity group	Variety	Yield
			kg ha^{-1}
15-Apr	4.4	RC-4417	1477.6
	4.8	M-4824	2044.2
	5.2	R2-520	1806.1
	5.6	AG-5605	2107.3
5-May	4.4	RC-4417	1457.0
	4.8	M-4824	2272.4
	5.2	R2-520	1398.7
	5.6	AG-5605	2484.3
2-Jun	4.4	RC-4417	2388.8
	4.8	M-4824	3021.2
	5.2	R2-520	1853.1
	5.6	AG-5605	2426.3
22-Jun	4.4	RC-4417	1299.4
	4.8	M-4824	1332.4
	5.2	R2-520	1240.7
	5.6	AG-5605	1329.4
13-Jul	4.4	RC-4417	1309.3
	4.8	M-4824	1216.4
	5.2	R2-520	1265.2
	5.6	AG-5605	1215.9
29-Jul	4.4	RC-4417	349.7
	4.8	M-4824	553.0
	5.2	R2-520	319.9
	5.6	AG-5605	257.3



Appendix I. Soybean seed yield by planting dates and maturity groups for Lahoma, 2010.

Appendix J. Soybean yield components of each planting date and maturity group replication for early and late-season in Stillwater 2009.

Plant Date	MG	Variety	Rep	repnds pl^{-1}	nds pl^{-1}	pods pl^{-1}	seeds pod^{-1}	pls m^{-2}	pods m^{-2}	seeds m^{-2}	pods $repnd^{-1}$	repnds m^{-2}	nds m^{-2}	repnds	seedmass	HI
														%	g $seed^{-1}$ *100	
9-Apr	3.8	DG35G38	1	25.6	38.6	44.3	2.1	19.5	863.9	1779.5	1.7	499.2	752.7	66.3	16.1	48.9
		DG35G38	2	32.0	38.3	62.0	2.3	19.1	1184.2	2700.0	1.9	611.2	731.5	83.6	14.4	54.7
		DG35G38	3	38.8	46.8	71.0	2.2	19.5	1384.5	3045.9	1.8	756.6	912.6	82.9	14.0	54.5
	4.4	37A44	1	40.8	54.3	99.5	2.4	16.0	1592.0	3804.9	2.4	652.8	868.8	75.1	14.3	33.7
		37A44	2	52.0	62.8	106.0	2.4	17.3	1833.8	4474.5	2.0	899.6	1086.4	82.8	13.3	49.9
		37A44	3	44.4	59.1	89.0	2.4	15.5	1379.5	3338.4	2.0	688.2	916.1	75.1	12.9	54.0
	4.8	36Y48	1	30.0	46.7	64.3	2.5	20.8	1337.4	3316.9	2.1	624.0	971.4	64.2	13.7	41.1
		36Y48	2	45.7	66.2	87.3	2.5	20.0	1746.0	4277.7	1.9	914.0	1324.0	69.0	13.3	44.3
		36Y48	3	40.8	59.2	71.8	2.2	18.6	1335.5	2938.1	1.8	758.9	1101.1	68.9	13.9	39.4
24-Apr	3.8	DG35G38	1	31.3	38.1	68.3	2.6	17.3	1181.6	3036.7	2.2	541.5	659.1	82.2	14.5	49.5
		DG35G38	2	28.4	34.1	61.7	2.4	19.5	1203.2	2887.6	2.2	553.8	665.0	83.3	15.2	51.0
		DG35G38	3	25.0	37.0	45.0	2.2	24.4	1098.0	2426.6	1.8	610.0	902.8	67.6	16.9	45.5
	4.4	37A44	1	37.6	49.0	76.6	2.5	17.8	1363.5	3354.2	2.0	669.3	872.2	76.7	16.9	37.4
		37A44	2	37.9	49.6	79.8	2.3	16.9	1348.6	3074.9	2.1	640.5	838.2	76.4	13.7	51.6
		37A44	3	38.3	49.7	73.2	2.5	12.0	878.4	2204.8	1.9	459.6	596.4	77.1	13.6	50.9
	4.8	36Y48	1	36.8	55.7	72.5	2.4	15.1	1094.8	2638.3	2.0	555.7	841.1	66.1	16.1	40.9
		36Y48	2	33.8	43.7	64.7	2.3	21.8	1410.5	3272.3	1.9	736.8	952.7	77.3	15.0	44.4
		36Y48	3	31.0	41.3	55.2	2.2	17.3	955.0	2053.2	1.8	536.3	714.5	75.1	14.6	42.1
20-May	3.8	DG35G38	1	34.7	46.2	70.0	2.2	15.1	1079.7	2418.4	2.9	374.5	450.0	83.2	15.4	44.2
		DG35G38	2	30.3	40.2	52.2	2.4	16.9	833.2	1991.3	2.7	307.6	368.4	83.5	14.2	41.7
		DG35G38	3	24.8	32.0	56.6	2.5	10.6	671.0	1684.2	2.6	256.5	312.7	82.0	17.1	50.6
	4.4	37A44	1	36.5	44.5	90.8	2.6	10.2	926.2	2380.2	2.5	372.3	453.9	82.0	12.6	44.8
		37A44	2	34.3	41.1	85.2	2.4	10.6	903.1	2122.3	2.5	363.6	435.7	83.5	12.9	42.0
		37A44	3	30.8	40.8	68.2	2.3	17.3	1179.9	2678.3	2.2	532.8	705.8	75.5	13.1	47.8
	4.8	36Y48	1	24.8	29.8	71.5	2.6	11.5	805.0	2101.1	2.0	399.1	531.3	75.1	16.7	47.9
		36Y48	2	18.2	21.8	49.3	2.4	12.9	673.4	1589.2	1.7	390.9	518.6	75.4	16.1	38.4
		36Y48	3	24.2	29.5	63.3	2.4	13.3	752.8	1799.1	2.3	329.8	425.6	77.5	15.0	43.8
20-May	4.4	RT4485N	1	36.0	44.0	83.5	2.5	18.2	1519.7	3753.7	2.3	655.2	800.8	81.8	13.3	41.4
		RT4485N	2	37.7	56.0	78.3	2.4	15.1	1182.3	2825.8	2.1	569.3	845.6	67.3	13.7	57.2
		RT4485N	3	31.3	38.2	87.0	2.4	16.0	1392.0	3354.7	2.8	500.8	611.2	81.9	12.3	50.3
	4.9	TV49R17	1	30.3	38.5	56.6	2.3	18.8	1064.1	2468.7	1.9	569.6	723.8	78.7	14.1	34.2

Plant Date	MG	Variety	Rep	repnds pl^{-1}	nds pl^{-1}	pods pl^{-1}	seeds pod^{-1}	pls m^{-2}	pods m^{-2}	seeds m^{-2}	pods $repnd^{-1}$	repnds m^{-2}	nds m^{-2}	repnds	seedmass	HI
														%	g $seed^{-1}$ *100	
		TV49R17	2	42.8	49.8	97.1	2.4	21.3	2068.2	4901.7	2.3	911.6	1060.7	85.9	14.7	40.2
		TV49R17	3	30.0	37.8	56.6	2.2	20.0	1132.0	2524.4	1.9	600.0	756.0	79.4	13.9	44.1
	5.2	HBKR522	1	18.9	30.6	46.1	2.1	19.6	901.3	1856.6	2.4	369.5	598.2	61.8	12.9	44.0
		HBKR522	2	22.5	32.1	59.8	2.4	19.5	1166.1	2787.0	2.7	438.8	626.0	70.1	13.5	38.4
		HBKR522	3	15.8	22.3	53.7	2.1	18.7	1004.2	2149.0	3.4	295.5	417.0	70.9	15.7	39.4
	5.5	TV55R15	1	28.7	36.3	56.7	2.2	14.7	831.2	1812.1	2.0	420.7	532.2	79.1	16.2	39.9
		TV55R15	2	27.3	37.3	60.4	2.2	17.8	1075.1	2333.0	2.2	485.9	663.9	73.2	16.4	45.8
		TV55R15	3	40.3	36.0	60.4	2.3	18.2	1099.3	2528.3	1.5	733.5	655.2	111.9	15.1	43.3
	5.6	56511R	1	28.9	35.9	115.6	2.3	10.2	1179.1	2735.6	4.0	294.8	366.2	80.5	13.7	43.7
		56511R	2	23.1	31.6	81.8	2.5	16.4	1341.5	3300.1	3.5	378.8	518.2	73.1	14.5	42.4
		56511R	3	30.6	36.9	84.2	2.4	12.4	1044.1	2464.0	2.8	379.4	457.6	82.9	13.7	41.9
10-Jun	4.4	RT4485N	1	25.4	31.4	71.4	2.4	9.7	692.6	1648.3	2.8	246.4	304.6	80.9	14.1	41.8
		RT4485N	2	24.5	31.5	45.7	2.4	16.9	772.3	1822.7	1.9	414.1	532.4	77.8	14.6	45.5
		RT4485N	3	33.5	44.5	70.0	2.3	10.2	714.0	1627.9	2.1	341.7	453.9	75.3	16.1	45.5
	4.9	TV49R17	1	34.7	43.8	77.9	2.3	10.2	794.6	1851.4	2.2	353.9	446.8	79.2	14.9	44.7
		TV49R17	2	27.9	34.3	57.4	2.2	17.3	993.0	2174.7	2.1	482.7	593.4	81.3	13.3	43.8
		TV49R17	3	35.5	38.5	61.2	2.2	13.3	814.0	1798.9	1.7	472.2	512.1	92.2	13.3	41.7
	5.2	HBKR522	1	33.8	39.6	69.3	2.2	14.2	984.1	2115.7	2.1	480.0	562.3	85.4	14.3	46.4
		HBKR522	2	22.0	27.6	42.0	2.3	11.5	483.0	1106.1	1.9	253.0	317.4	79.7	11.7	31.4
		HBKR522	3	31.2	40.0	66.5	2.3	13.3	884.5	1990.0	2.1	415.0	532.0	78.0	13.8	43.5
	5.5	TV55R15	1	20.8	30.0	49.0	2.2	8.5	416.5	920.5	2.4	176.8	255.0	69.3	13.9	41.6
		TV55R15	2	36.3	43.7	83.0	2.2	8.9	738.7	1654.7	2.3	323.1	388.9	83.1	13.6	40.0
		TV55R15	3	45.7	53.0	72.7	2.3	10.2	741.5	1727.8	1.6	466.1	540.6	86.2	12.9	46.1
	5.6	56511R	1	21.6	30.5	59.2	2.3	13.7	811.0	1824.8	2.7	295.9	417.9	70.8	15.7	47.0
		56511R	2	25.7	32.3	44.2	2.3	12.9	570.2	1317.1	1.7	331.5	416.7	79.6	15.2	48.9
		56511R	3	29.0	40.0	48.2	2.3	15.5	747.1	1695.9	1.7	449.5	620.0	72.5	15.4	45.2
20-Jul	4.4	RT4485N	1	20.7	24.9	41.7	2.5	14.2	592.1	1468.5	2.0	293.9	353.6	83.1	11.9	45.1
		RT4485N	2	17.2	22.2	31.2	2.3	20.4	636.5	1470.3	1.8	350.9	452.9	77.5	12.3	52.8
		RT4485N	3	21.8	33.8	43.0	2.1	11.1	477.3	997.6	2.0	242.0	375.2	64.5	12.2	42.6
	4.9	TV49R17	1	28.2	35.8	48.2	2.2	16.9	814.6	1775.8	1.7	476.6	605.0	78.8	14.3	45.4
		TV49R17	2	17.1	22.0	40.1	2.4	20.0	802.0	1924.8	2.3	342.0	440.0	77.7	13.8	47.7
		TV49R17	3	14.3	18.1	26.8	2.3	20.0	536.0	1238.2	1.9	286.0	362.0	79.0	13.5	37.2
	5.2	HBKR522	1	19.8	27.2	42.0	2.2	22.2	932.4	2014.0	2.1	439.6	603.8	72.8	12.0	41.3
		HBKR522	2	18.2	31.8	42.1	2.3	16.9	711.5	1636.4	2.3	307.6	537.4	57.2	13.4	28.5
		HBKR522	3	19.6	23.7	45.6	2.3	20.9	953.0	2172.9	2.3	409.6	495.3	82.7	13.0	40.6

Plant Date	MG	Variety	Rep	repnds pl^{-1}	nds pl^{-1}	pods pl^{-1}	seeds pod^{-1}	pls m^{-2}	pods m^{-2}	seeds m^{-2}	pods $repnd^{-1}$	repnds m^{-2}	nds m^{-2}	repnds	seedmass	HI
														%	g $seed^{-1}$ *100	
	5.5	TV55R15	1	28.6	40.3	48.3	2.2	17.8	859.7	1908.6	1.7	509.1	717.3	71.0	13.4	36.6
		TV55R15	2	31.7	41.0	46.8	2.1	24.4	1141.9	2363.8	1.5	773.5	1000.4	77.3	11.8	40.2
		TV55R15	3	24.7	33.0	44.3	2.1	20.0	886.0	1878.3	1.8	494.0	660.0	74.8	12.8	41.1
	5.6	56511R	1	21.4	26.7	55.0	2.1	16.0	880.0	1848.0	2.6	342.4	427.2	80.1	11.5	38.7
		56511R	2	31.5	43.0	63.2	2.3	17.3	1093.4	2536.6	2.0	545.0	743.9	73.3	11.3	32.1
		56511R	3	23.2	32.0	52.8	2.3	13.8	728.6	1654.0	2.3	320.2	441.6	72.5	12.4	35.7

Appendix K. Correlation coefficients between yield components within the same category and their correlation with seed yield for Stillwater 2009.

Planting Date	Primary yield components			Secondary yield components			Tertiary yield components			Quaternary yield components		
	Index†	seed mass‡	seeds m^{-2}‡	Index	seeds pod^{-1}‡	pod m^{-2}‡	Index	pods $rep.nds^{-1}$‡	rep.nds m^{-2}‡	Index	nds m^{-2}‡	% rep.nds‡
9-Apr	-0.77	-0.66	0.89	0.75	0.60	0.92	-0.02	0.41	0.81	-0.24	0.49	0.63
24-Apr	0.19	0.00	0.93	0.04	0.19	0.93	0.01	0.64	0.72	-0.52	0.33	0.59
20-May ES	-0.62	-0.63	0.93	-0.52	-0.52	0.97	-0.43	0.52	0.54	-0.70	0.40	0.32
20 May LS	-0.26	-0.10	0.91	0.60	0.56	0.92	-0.66	-0.10	0.79	0.12	0.60	0.59
10-Jun	0.17	-0.05	0.94	-0.34	-0.36	0.96	-0.61	-0.12	0.83	0.29	0.73	0.62
20-Jul	-0.23	-0.26	0.94	-0.31	-0.25	0.95	-0.59	-0.09	0.81	-0.09	0.71	0.46

† Index = the correlation between yield components within the same category.

‡ Correlation between the given yield component and seed yield.

Appendix L. Soybean yield components of each planting date and maturity group replication in Stillwater 2010.

PD	MG	Variety	Rep	repnds pl^{-1}	nds pl^{-1}	pods pl^{-1}	seeds pod^{-1}	pls m^{-2}	pods m^{-2}	seeds m^{-2}	pods $repnd^{-1}$	repnds m^{-2}	nds m^{-2}	repnds	seedmass	HI
														%	g $seed^{-1}$ *100	
13-Apr	3.8	DG35G38	1	20.0	26.9	55.3	2.4	15.0	829.5	1974.2	2.8	300.0	403.5	74.3	12.6	35.3
			2	21.8	30.1	54.5	2.3	19.0	1035.5	2371.3	2.5	414.2	571.9	72.4	12.3	35.3
			3	17.0	21.5	41.6	2.3	21.0	873.6	1965.6	2.4	357.0	451.5	79.1	13.5	36.1
	4.2	42-T4	1	23.1	30.8	49.9	2.3	19.0	948.1	2142.7	2.2	438.9	585.2	75.0	12.9	44.1
			2	25.1	31.8	56.1	2.2	20.0	1122.0	2490.8	2.2	502.0	636.0	78.9	12.2	39.5
			3	21.1	27.8	48.2	2.2	16.8	809.8	1757.2	2.3	354.5	467.0	75.9	12.7	41.5
	4.4	RC4417	1	27.3	33.3	36.8	2.4	20.0	736.0	1729.6	1.3	546.0	666.0	82.0	13.1	42.0
			2	23.3	28.2	51.4	2.3	19.0	976.6	2246.2	2.2	442.7	535.8	82.6	11.9	38.5
			3	24.8	31.1	40.2	2.3	17.0	683.9	1566.2	1.6	421.6	528.7	79.7	14.3	48.8
	4.8	RTS4824	1	16.6	20.5	49.4	2.4	21.5	1062.1	2549.0	3.0	356.9	440.8	81.0	12.1	34.2
			2	15.6	20.0	47.2	2.3	22.4	1057.3	2442.3	3.0	349.4	448.0	78.0	12.3	32.6
			3	16.6	22.0	50.6	2.3	21.6	1093.0	2524.7	3.0	358.6	475.2	75.5	11.9	33.5
	4.8	4807RR	1	17.2	21.7	45.6	2.4	23.0	1048.8	2538.1	2.7	395.6	499.1	79.3	13.1	33.5
			2	18.3	23.9	46.6	2.5	24.2	1127.7	2762.9	2.5	442.9	578.4	76.6	11.9	32.3
			3	14.2	19.4	39.8	2.4	23.0	915.4	2206.1	2.8	326.6	446.2	73.2	12.9	33.0
	5.2	R2520	1	18.6	27.4	47.8	2.5	22.5	1075.5	2710.3	2.6	418.5	616.5	67.9	11.8	33.8
			2	21.0	27.4	50.7	2.5	23.6	1196.5	3027.2	2.4	495.6	646.6	76.6	10.4	30.7
			3	16.5	24.5	43.3	2.4	20.1	870.3	2088.8	2.6	331.7	492.5	67.3	13.4	34.4
	5.2	5218RR	1	22.0	32.0	64.6	1.9	21.0	1356.6	2604.7	2.9	462.0	672.0	68.8	13.3	36.5
			2	24.0	35.0	67.1	2.1	23.0	1543.3	3163.8	2.8	552.0	805.0	68.6	11.7	35.0
			3	19.3	26.9	61.5	2.1	20.0	1230.0	2570.7	3.2	386.0	538.0	71.7	12.2	36.3
	5.6	AG5605	1	18.8	22.6	62.0	2.3	24.0	1488.0	3422.4	3.3	451.2	542.4	83.2	13.9	48.9
			2	17.5	23.1	58.2	2.2	25.0	1455.0	3186.5	3.3	437.5	577.5	75.8	12.6	36.5
			3	16.5	21.4	54.4	2.1	23.0	1251.2	2677.6	3.3	379.5	492.2	77.1	12.8	34.0
	5.6	5622RR	1	21.9	29.7	55.7	2.5	22.5	1253.3	3158.2	2.5	492.8	668.3	73.7	11.5	47.5
			2	25.6	31.3	57.0	2.5	23.5	1339.5	3335.4	2.2	601.6	735.6	81.8	10.2	39.7
			3	19.3	26.1	52.4	2.3	20.5	1074.2	2513.6	2.7	395.7	535.1	73.9	9.7	36.6
29-Apr	3.8	DG35G38	1	18.0	25.0	34.9	2.0	25.5	890.0	1815.5	1.9	459.0	637.5	72.0	11.2	39.7
			2	21.0	29.2	39.6	2.1	27.3	1081.1	2291.9	1.9	573.3	797.2	71.9	11.5	35.8
			3	19.0	24.5	36.2	2.2	23.3	843.5	1872.5	1.9	442.7	570.9	77.6	11.8	43.1
	4.2	42-T4	1	13.0	16.2	36.6	2.3	21.0	768.6	1767.8	2.8	273.0	340.2	80.2	11.4	36.9
			2	16.6	21.2	48.5	2.2	20.2	979.7	2174.9	2.9	335.3	428.2	78.3	10.8	34.2
			3	17.2	21.7	49.3	2.3	21.1	1040.2	2361.3	2.9	362.9	457.9	79.3	10.5	34.1
	4.4	RC4417	1	21.6	26.0	61.4	2.2	21.2	1301.7	2837.7	2.8	457.9	551.2	83.1	11.2	35.7
			2	22.1	28.4	52.4	2.3	22.0	1152.8	2605.3	2.4	486.2	624.8	77.8	11.3	32.2
			3	20.4	25.6	54.7	2.1	20.3	1110.4	2376.3	2.7	414.1	519.7	79.7	11.2	41.0

PD	MG	Variety	Rep	repnds pl^{-1}	nds pl^{-1}	pods pl^{-1}	seeds pod^{-1}	pls m^{-2}	pods m^{-2}	seeds m^{-2}	pods $repnd^{-1}$	repnds m^{-2}	nds m^{-2}	repnds	seedmass	HI
														%	g seed-1 *100	
	4.8	RTS4824	1	28.2	33.4	63.0	2.1	22.0	1386.0	2952.2	2.2	620.4	734.8	84.4	13.1	47.5
			2	30.3	37.6	65.0	2.3	21.8	1417.0	3244.9	2.1	660.5	819.7	80.6	11.4	47.8
			3	26.4	33.4	55.3	2.2	21.8	1205.5	2628.1	2.1	575.5	728.1	79.0	12.2	43.9
	4.8	4807RR	1	17.4	22.2	51.4	2.1	24.5	1259.3	2669.7	3.0	426.3	543.9	78.4	11.5	34.8
			2	24.0	29.5	56.4	2.3	26.9	1517.2	3519.8	2.4	645.6	793.6	81.4	9.9	33.6
			3	17.4	23.3	49.1	2.1	22.5	1104.8	2297.9	2.8	391.5	524.3	74.7	11.1	32.9
	5.2	R2520	1	25.6	30.2	56.0	2.4	25.0	1400.0	3416.0	2.2	640.0	755.0	84.8	10.6	38.1
			2	30.1	34.9	62.0	2.3	26.1	1618.2	3673.3	2.1	785.6	910.9	86.2	10.4	36.0
			3	21.4	28.4	53.6	2.3	22.1	1184.6	2771.9	2.5	472.9	627.6	75.4	10.2	34.6
	5.2	5218RR	1	17.0	21.0	43.0	2.2	27.0	1161.0	2507.8	2.5	459.0	567.0	81.0	12.1	36.3
			2	16.7	22.8	42.2	2.2	28.4	1198.5	2624.7	2.5	474.3	647.5	73.2	12.0	34.7
			3	17.6	21.9	36.3	2.2	24.6	893.0	1973.5	2.1	433.0	538.7	80.4	12.4	33.7
	5.6	AG5605	1	21.6	25.4	57.6	2.6	28.5	1641.6	4202.5	2.7	615.6	723.9	85.0	10.3	36.2
			2	24.6	31.4	56.7	2.5	27.2	1542.2	3824.8	2.3	669.1	854.1	78.3	10.6	34.3
			3	19.4	24.6	54.2	2.4	25.3	1371.3	3277.3	2.8	490.8	622.4	78.9	9.9	34.2
	5.6	5622RR	1	22.6	28.0	61.4	2.4	27.5	1688.5	3984.9	2.7	621.5	770.0	80.7	9.9	35.0
			2	23.2	29.1	63.4	2.4	26.1	1654.7	4004.5	2.7	605.5	759.5	79.7	9.2	37.1
			3	19.6	26.7	58.3	2.3	23.4	1364.2	3096.8	3.0	458.6	624.8	73.4	10.1	34.3
25-May	3.8	DG35G38	1	22.7	26.3	48.3	2.0	24.0	1159.2	2341.6	2.1	544.8	631.2	86.3	11.2	33.6
			2	26.0	32.4	55.2	2.1	26.3	1451.8	2990.6	2.1	683.8	852.1	80.2	10.4	34.8
			3	21.8	27.1	47.1	2.0	22.7	1069.2	2084.9	2.2	494.9	615.2	80.4	11.6	40.2
	4.2	42-T4	1	28.4	32.8	61.8	1.9	21.0	1297.8	2478.8	2.2	596.4	688.8	86.6	12.0	33.7
			2	27.4	36.7	63.2	2.1	21.2	1339.8	2827.1	2.3	580.9	778.0	74.7	11.2	33.2
			3	23.1	31.0	54.2	2.2	20.0	1084.0	2384.8	2.3	462.0	620.0	74.5	12.1	36.5
	4.4	RC4417	1	30.4	42.0	60.8	2.3	21.5	1307.2	2980.4	2.0	653.6	903.0	72.4	11.0	38.1
			2	31.2	36.1	62.7	2.4	24.2	1517.3	3565.7	2.0	755.0	873.6	86.4	11.4	36.9
			3	34.3	40.3	58.2	2.3	23.8	1385.2	3199.7	1.7	816.3	959.1	85.1	12.3	33.7
	4.8	RTS4824	1	24.6	29.6	71.6	2.3	18.5	1324.6	3020.1	2.9	455.1	547.6	83.1	12.7	42.3
			2	27.1	33.3	79.1	2.3	20.7	1637.4	3798.7	2.9	561.0	689.3	81.4	11.0	40.4
			3	26.6	32.5	81.2	2.2	20.1	1632.1	3509.1	3.1	534.7	653.3	81.8	10.9	39.2
	4.8	4807RR	1	23.6	29.6	74.6	2.1	17.0	1268.2	2713.9	3.2	401.2	503.2	79.7	11.6	38.6
			2	26.3	31.8	71.4	2.3	19.0	1356.6	3093.0	2.7	499.7	604.2	82.7	11.7	44.3
			3	21.1	26.8	70.2	2.1	18.0	1263.6	2590.4	3.3	379.8	482.4	78.7	11.0	33.0
	5.2	R2520	1	18.2	23.8	60.2	2.3	23.5	1414.7	3310.4	3.3	427.7	559.3	76.5	11.7	37.5
			2	21.0	26.7	53.6	2.4	24.1	1291.8	3139.0	2.6	506.1	643.5	78.7	12.6	33.8
			3	16.2	21.6	44.0	2.3	22.0	968.0	2207.0	2.7	356.4	475.2	75.0	11.2	38.1
	5.2	5218RR	1	20.6	25.0	59.8	2.0	20.5	1225.9	2500.8	2.9	422.3	512.5	82.4	14.8	36.8
			2	22.5	29.2	69.1	2.2	22.5	1554.8	3342.7	3.1	506.3	657.0	77.1	11.3	38.6
			3	19.0	24.6	57.1	2.0	19.0	1084.9	2213.2	3.0	361.0	467.4	77.2	12.2	33.4

PD	MG	Variety	Rep	repnds pl^{-1}	nds pl^{-1}	pods pl^{-1}	seeds pod^{-1}	pls m^{-2}	pods m^{-2}	seeds m^{-2}	pods $repnd^{-1}$	repnds m^{-2}	nds m^{-2}	repnds	seedmass	HI
														%	g seed-1 *100	
	5.6	AG5605	1	23.2	29.8	56.0	2.3	26.0	1456.0	3334.2	2.4	603.2	774.8	77.9	12.1	36.5
			2	18.3	24.4	52.5	2.2	23.0	1207.5	2632.4	2.9	420.9	561.2	75.0	12.0	38.2
			3	18.3	24.4	52.5	2.2	23.0	1207.5	2632.4	2.9	420.9	561.2	75.0	12.0	38.2
	5.6	5622RR	1	28.6	38.4	75.8	2.2	21.0	1591.8	3502.0	2.7	600.6	806.4	74.5	10.8	38.3
			2	28.2	33.8	71.7	2.3	22.4	1606.1	3694.0	2.5	631.7	757.1	83.4	11.9	40.5
			3	25.5	33.6	74.2	2.1	19.0	1409.8	2988.8	2.9	484.5	638.4	75.9	11.2	38.7
21-Jun	3.8	DG35G38	1	19.2	22.2	52.2	2.2	21.0	1096.2	2433.6	2.7	403.2	466.2	86.5	11.7	33.5
			2	24.1	30.3	55.6	2.3	20.5	1139.8	2632.9	2.3	494.1	621.2	79.5	12.2	34.8
			3	17.6	22.4	44.0	2.2	20.3	893.2	1920.4	2.5	357.3	454.7	78.6	10.7	42.2
	4.2	42-T4	1	13.2	20.8	36.2	2.2	24.5	886.9	1951.2	2.7	323.4	509.6	63.5	12.8	32.9
			2	16.6	23.9	47.2	2.3	25.4	1198.9	2769.4	2.8	421.6	607.1	69.5	12.1	35.7
			3	12.6	19.1	36.2	2.2	23.0	832.6	1798.4	2.9	289.8	439.3	66.0	11.7	36.6
	4.4	RC4417	1	34.8	39.6	76.2	1.9	21.0	1600.2	2976.4	2.2	730.8	831.6	87.9	12.0	46.0
			2	32.0	38.2	78.1	2.0	20.7	1616.7	3152.5	2.4	662.4	790.7	83.8	11.2	45.5
			3	32.1	39.6	71.9	1.9	22.0	1581.8	2973.8	2.2	706.2	871.2	81.1	11.4	42.2
	4.8	RTS4824	1	17.6	23.4	39.6	2.0	17.0	673.2	1359.9	2.3	299.2	397.8	75.2	12.1	34.0
			2	21.9	28.1	43.2	2.1	18.4	794.9	1701.0	2.0	403.0	517.0	77.9	12.8	34.8
			3	18.2	24.5	52.1	2.0	16.0	833.6	1700.5	2.9	291.2	392.0	74.3	11.6	38.5
	4.8	4807RR	1	30.4	37.2	71.0	2.3	13.5	958.5	2242.9	2.3	410.4	502.2	81.7	11.3	41.7
			2	31.8	37.5	59.0	2.3	17.0	1003.0	2266.8	1.9	540.6	637.5	84.8	12.7	32.9
			3	28.5	34.3	68.0	2.2	14.0	952.0	2132.5	2.4	399.0	480.2	83.1	11.0	38.5
	5.2	R2520	1	14.4	18.4	36.2	1.9	21.0	760.2	1459.6	2.5	302.4	386.4	78.3	11.4	37.7
			2	19.2	24.6	44.7	2.3	25.1	1122.0	2524.4	2.3	481.9	617.5	78.0	11.2	30.9
			3	12.6	17.2	37.6	2.0	20.0	752.0	1504.0	3.0	252.0	344.0	73.3	10.3	33.0
	5.2	5218RR	1	11.2	16.0	23.0	2.4	14.0	322.0	779.2	2.1	156.8	224.0	70.0	13.1	33.1
			2	14.7	22.5	39.0	2.4	17.2	670.8	1623.3	2.7	252.8	387.0	65.3	12.2	32.0
			3	12.2	17.1	30.0	2.3	15.0	450.0	1030.5	2.5	183.0	256.5	71.3	12.7	37.9
	5.6	AG5605	1	16.8	20.0	49.4	2.2	14.0	691.6	1535.4	2.9	235.2	280.0	84.0	10.7	33.5
			2	21.9	25.5	58.2	2.3	16.3	948.7	2191.4	2.7	357.0	415.7	85.9	12.8	47.1
			3	19.9	24.7	61.7	2.2	13.0	802.1	1724.5	3.1	258.7	321.1	80.6	10.3	38.5
	5.6	5622RR	1	24.2	31.6	75.6	2.1	15.5	1171.8	2437.3	3.1	375.1	489.8	76.6	10.4	32.1
			2	27.3	33.4	77.4	2.4	17.9	1385.5	3269.7	2.8	488.7	597.9	81.7	11.5	39.6
			3	22.2	27.5	59.6	2.1	16.0	953.6	1993.0	2.7	355.2	440.0	80.7	10.8	34.1
13-Jul	3.8	DG35G38	1	21.8	27.0	50.3	2.3	13.0	653.9	1504.0	2.3	283.4	351.0	80.7	11.8	41.4
			2	27.4	35.2	52.8	2.4	15.1	797.3	1921.4	1.9	413.7	531.5	77.8	12.5	38.3
			3	19.1	26.3	51.9	2.2	15.0	778.5	1720.5	2.7	286.5	394.5	72.6	12.5	44.8
	4.2	42-T4	1	12.4	18.0	37.8	2.4	19.0	718.2	1709.3	3.0	235.6	342.0	68.9	11.1	39.9
PD	MG	Variety	Rep	repnds	nds pl^{-1}	pods	seeds	pls m^{-}	pods m^{-2}	seeds m^{-2}	pods	repnds m^{-2}	nds m^{-2}	repnds	seedmass	HI

				pl^{-1}		pl^{-1}	pod^{-1}	^{2}			$repnd^{-1}$					
														%	g seed-1 *100	
			2	15.2	23.4	42.9	2.4	20.3	870.9	2124.9	2.8	308.6	475.0	65.0	12.4	44.0
			3	10.1	16.4	29.0	2.3	16.0	464.0	1071.8	2.9	161.6	262.4	61.6	10.2	33.3
	4.4	RC4417	1	13.4	17.4	32.2	2.3	17.0	547.4	1237.1	2.4	227.8	295.8	77.0	12.3	42.6
			2	18.2	26.1	41.5	2.3	22.0	913.0	2127.3	2.3	400.4	574.2	69.7	13.6	47.0
			3	11.3	15.7	30.8	2.2	16.0	492.8	1059.5	2.7	180.8	251.2	72.0	11.4	47.2
	4.8	RTS4824	1	20.4	26.0	46.8	2.6	16.0	748.8	1946.9	2.3	326.4	416.0	78.5	11.3	41.7
			2	25.1	33.7	51.4	2.5	17.5	899.5	2230.8	2.0	439.3	589.8	74.5	10.2	36.6
			3	17.1	24.5	50.4	2.4	14.0	705.6	1714.6	2.9	239.4	343.0	69.8	11.0	42.1
	4.8	4807RR	1	9.8	15.0	25.2	2.0	17.0	428.4	856.8	2.6	166.6	255.0	65.3	11.4	38.3
			2	12.7	18.0	31.7	2.1	21.1	668.9	1404.6	2.5	268.0	379.8	70.6	12.3	35.6
			3	8.9	14.4	23.3	1.9	15.0	349.5	674.5	2.6	133.5	216.0	61.8	11.6	30.7
	5.2	R2520	1	10.2	17.1	30.6	2.2	22.0	673.2	1501.2	3.0	224.4	376.2	59.6	11.5	46.2
			2	10.0	16.5	26.2	2.4	23.0	602.6	1452.3	2.6	230.0	379.5	60.6	11.6	35.7
			3	9.0	12.2	28.4	2.4	20.0	568.0	1368.9	3.2	180.0	244.0	73.8	11.2	43.8
	5.2	5218RR	1	17.0	24.0	43.8	2.1	22.0	963.6	1975.4	2.6	374.0	528.0	70.8	10.1	36.3
			2	19.3	25.5	41.4	2.2	21.1	873.5	1878.1	2.1	407.2	538.1	75.7	11.3	34.1
			3	15.0	20.3	39.8	2.0	19.0	756.2	1504.8	2.7	285.0	385.7	73.9	11.5	40.5
	5.6	AG5605	1	11.6	18.6	22.6	2.4	18.0	406.8	956.0	1.9	208.8	334.8	62.4	9.8	47.3
			2	14.5	22.2	28.4	2.3	22.4	636.2	1456.8	2.0	324.8	497.3	65.3	11.1	53.5
			3	10.4	16.5	26.1	2.3	16.0	417.6	948.0	2.5	166.4	264.0	63.0	10.3	37.0
	5.6	5622RR	1	21.2	26.0	35.8	2.2	19.0	680.2	1523.6	1.7	402.8	494.0	81.5	10.4	39.7
			2	24.9	33.5	47.0	2.3	21.6	1015.2	2355.3	1.9	537.8	723.6	74.3	11.1	31.9
			3	20.5	24.1	47.4	2.2	17.0	805.8	1748.6	2.3	348.5	409.7	85.1	9.6	35.9
29-Jul	3.8	DG35G38	1	8.0	14.0	14.4	2.2	19.0	273.6	596.4	1.8	152.0	266.0	57.1	11.2	41.4
			2	10.0	16.2	18.3	2.2	19.6	358.7	792.7	1.8	196.0	317.5	61.7	9.6	43.1
			3	10.0	12.1	20.6	2.0	18.5	381.1	773.6	2.1	185.0	223.9	82.6	10.8	39.3
	4.2	42-T4	1	12.0	15.8	22.4	2.1	17.9	401.0	822.0	1.9	214.8	282.8	75.9	12.0	45.9
			2	13.0	17.6	24.7	2.1	15.8	390.3	835.2	1.9	205.4	278.1	73.9	12.5	48.9
			3	10.0	15.8	20.6	2.0	21.5	442.9	881.4	2.1	215.0	339.7	63.3	11.7	41.7
	4.4	RC4417	1	10.0	16.4	19.8	2.2	14.5	287.1	617.3	2.0	145.0	237.8	61.0	10.9	51.6
			2	11.3	16.9	18.4	2.2	16.5	303.6	671.0	1.6	186.5	278.9	66.9	11.6	44.9
			3	9.0	12.9	17.8	2.2	18.4	327.5	730.4	2.0	165.6	237.4	69.8	10.2	42.6
	4.8	RTS4824	1	11.2	14.8	25.2	2.2	18.6	468.7	1031.2	2.3	208.3	275.3	75.7	10.2	41.9
			2	12.8	17.1	27.4	2.1	17.4	476.8	1006.0	2.1	222.7	297.5	74.9	10.4	41.5
			3	10.2	14.5	28.7	2.3	18.0	516.6	1167.5	2.8	183.6	261.0	70.3	10.1	46.8
	4.8	4807RR	1	12.4	18.4	23.2	2.2	17.0	394.4	875.6	1.9	210.8	312.8	67.4	11.6	34.1
			2	14.2	19.9	25.5	2.3	18.0	459.0	1046.5	1.8	255.6	358.2	71.4	12.2	39.4
			3	10.7	16.2	26.2	2.1	15.0	393.0	841.0	2.4	160.5	243.0	66.0	10.7	38.7
PD	MG	Variety	Rep	repnds	nds pl^{-1}	pods	seeds	pls m^{-}	pods m^{-2}	seeds m^{-2}	pods	repnds m^{-2}	nds m^{-2}	repnds	seedmass	HI

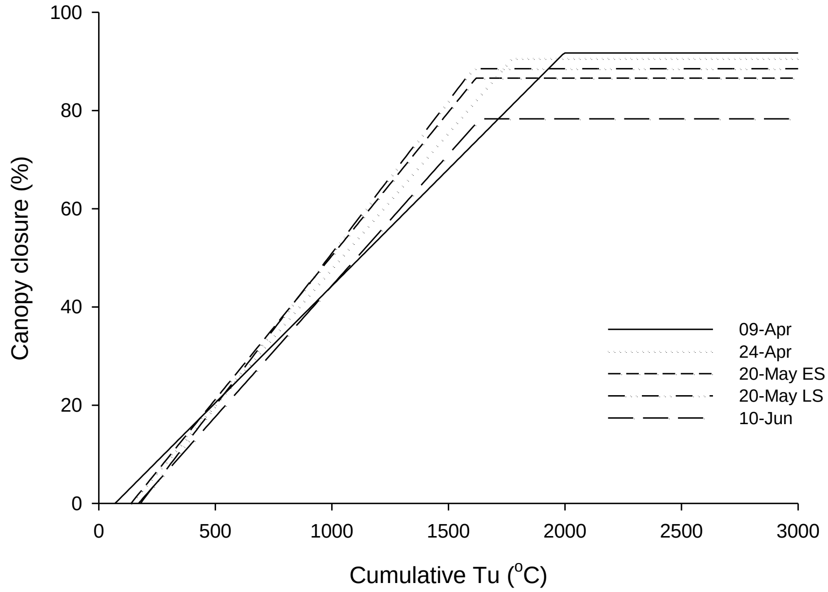
			pl^{-1}		pl^{-1}	pod^{-1}	^{2}			$repnd^{-1}$					
													%	g seed-1 *100	
5.2	R2520	1	8.2	15.2	18.6	2.2	19.0	353.4	773.9	2.3	155.8	288.8	53.9	10.5	38.9
		2	10.3	15.8	19.2	2.3	20.0	384.0	864.0	1.9	206.0	316.0	65.2	10.0	45.5
		3	8.4	13.6	19.1	2.3	17.0	324.7	750.1	2.3	142.8	231.2	61.8	10.6	44.5
5.2	5218RR	1	9.0	12.2	17.2	1.9	17.0	292.4	558.5	1.9	153.0	207.4	73.8	10.2	33.5
		2	11.2	16.9	20.1	2.0	19.0	381.9	760.0	1.8	212.8	321.1	66.3	11.4	33.8
		3	8.0	12.3	15.9	2.1	19.3	306.9	629.1	2.0	154.4	237.4	65.0	9.8	33.6
5.6	AG5605	1	11.8	16.4	28.2	2.2	17.5	493.5	1100.5	2.4	206.5	287.0	72.0	9.4	39.4
		2	13.7	21.2	30.8	2.3	16.4	505.1	1166.8	2.2	224.7	347.7	64.6	10.3	44.4
		3	10.3	15.5	26.7	2.2	18.0	480.6	1057.3	2.6	185.4	279.0	66.5	9.5	38.5
5.6	5622RR	1	11.2	16.4	20.4	2.1	20.5	418.2	886.6	1.8	229.6	336.2	68.3	10.7	42.1
		2	13.4	19.5	24.3	2.1	22.0	534.6	1095.9	1.8	294.8	429.0	68.7	10.4	51.8
		3	10.5	15.2	17.0	2.0	18.0	306.0	599.8	1.6	189.0	273.6	69.1	8.5	37.8

Appendix M. Correlation coefficients between yield components within the same category and their correlation with seed yield for Stillwater 2010.

Planting Date	Primary yield components			Secondary yield components			Tertiary yield components			Quaternary yield components		
	Index†	seed mass‡	seeds m^{-2}‡	Index	seeds pod^{-1}‡	pod m^{-2}‡	Index	pods $rep.nds^{-1}$‡	rep.nds m^{-2}‡	Index	nds m^{-2}‡	% rep.nds‡
PD 1	-0.47	-0.01	0.89	-0.27	-0.09	0.89	-0.41	0.62	0.33	-0.14	0.33	-0.01
PD 2	-0.60	-0.30	0.94	0.60	0.61	0.95	-0.47	0.00	0.83	0.22	0.76	0.56
PD 3	-0.23	0.22	0.89	0.34	0.67	0.78	-0.76	0.06	0.44	0.13	0.41	0.25
PD 4	-0.17	0.03	0.98	-0.40	-0.10	0.93	-0.44	-0.17	0.88	0.38	0.89	0.43
PD 5	0.18	0.46	0.95	0.23	0.43	0.92	-0.66	-0.19	0.79	0.34	0.80	0.38
PD 6	-0.04	0.34	0.92	0.24	0.41	0.90	-0.25	0.37	0.71	-0.12	0.61	0.28

† Index = the correlation between yield components within the same category.

‡ Correlation between the given yield component and seed yield.



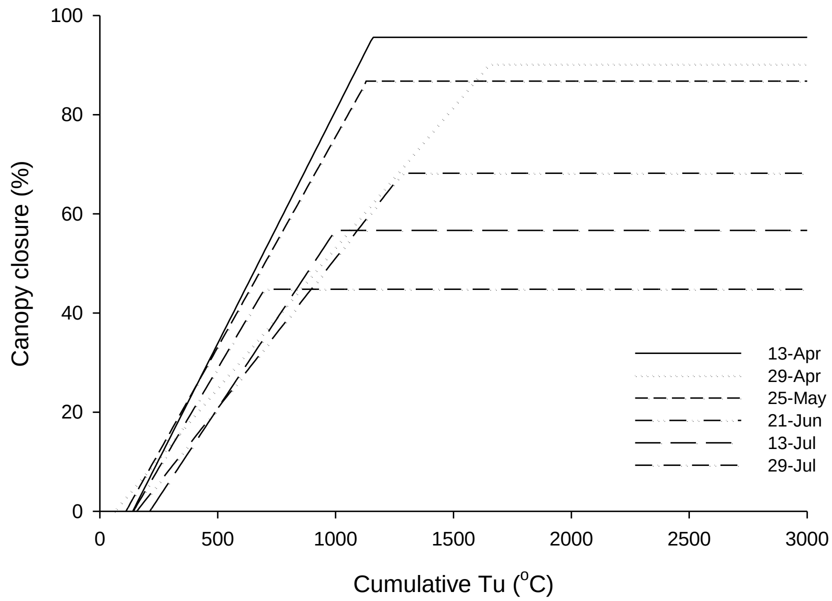
Appendix N. Maximum canopy closure reached by each planting date with averaged maturity groups in Stillwater 2009.

Appendix O. Regression equation for canopy closure and the coefficient of determination for each planting date in Stillwater 2009.

Planting date	Canopy closure (y) †		R^2
	Slope (a)	Interception (b)‡	
9-Apr	0.048	-3.326	0.99
24-Apr	0.055	-7.586	0.99
20-May ES	0.058	-8.115	0.98
20-May LS	0.058	-8.115	0.98
10-Jun	0.053	-9.1016	0.94
20-Jul	0.062	-11.103	0.97

† Regression equation for canopy closure (y) = ax + b, where “x” is the thermal unit (*Tu*).

‡ Values for “b” are the origin of canopy closure from the day of planting.



Appendix P. Maximum canopy closure reached by each planting date with averaged maturity groups in Stillwater 2010.

Appendix Q. Regression equation for canopy closure and the coefficient of determination for each planting date in Stillwater 2010.

Planting date	Canopy closure (y) †		R^2
	Slope (a)	Interception (b)‡	
13-Apr	0.094	-13.101	0.96
29-Apr	0.057	-3.468	0.94
25-May	0.085	-9.417	0.96
21-Jun	0.061	-9.486	0.98
13-Jul	0.072	-15.288	0.96
29-Jul	0.081	-11.466	0.98

† Regression equation for canopy closure (y) = ax + b, where "x" is the thermal unit (*Tu*).

‡ Values for "b" are the origin of canopy closure from the day of planting.

VITA

Alexandre Stefani Barreiro

Candidate for the Degree of

Master of Science

Thesis: SOYBEAN YIELD AND YIELD COMPONENTS AS AFFECTED BY PLANTING DATE AND MATURITY GROUP IN OKLAHOMA

Major Field: Plant and Soil Sciences

Biographical: Born in Sao Joao da Boa Vista, Sao Paulo, Brazil.

Education:

Completed the requirements for the Master of Science in Plant and Soil Sciences at Oklahoma State University, Stillwater, Oklahoma in December, 2011.

Completed the requirements for the Bachelor of Science in Agronomical Engineering at Sao Paulo State University - College of Agronomical Sciences, Botucatu, Sao Paulo, Brazil in 2008.

Experience:

Graduate Research Assistant: Oklahoma State University – Fall 2009 - current

Professional Memberships:

American Society of Agronomy
Crop Science Society of America
Soil Science Society of America

Name: Alexandre Stefani Barreiro
Date of Degree: December, 2011

Institution: Oklahoma State University
Location: Stillwater, Oklahoma

Title of Study: SOYBEAN YIELD AND YIELD COMPONENTS AS AFFECTED BY PLANTING DATE AND MATURITY GROUP IN OKLAHOMA

Pages in Study: 67
Candidate for the Degree of Master of Science

Major Field: Plant and Soil Sciences

Scope and Method of Study:

Planting date (PD) and maturity group (MG) can greatly impact yield components and consequently seed yield due to soybean photoperiod sensitivity. Determining the effects of PD and MG on soybean yields would allow us to assist Oklahoma soybean producers in making better decisions in choosing the correct MG for a specific planting period. This study was established at Stillwater in 2009 and 2010 and at Lahoma in 2010.The experimental design was Split Block Design, with three replications, six PDs (from early April to late July), and three MGs (III, IV and V). Varieties (glyphosate-resistant) were selected based on yield performance tests in previous years in Oklahoma. At all the sites, the plots were 3.0 m wide by 9.1 m long. Plots were planted with 4 rows spaced at 0.76 m and population of 310,000 plants ha^{-1} at 2.5 cm deep. Soybean yield components and canopy closure were assessed and correlated to seed yield.

Findings and Conclusions:

Greater seed yield can be achieved when soybean is planted from middle of April until early June, when using an appropriate maturity. Planting soybean after early June, seed yield is reduced and decreases as planting date is delayed regardless of the maturity group being used. MGs from 4.8 to 5.6 had greater seed yields (average of 2700 kg ha^{-1}) compared to MGs from 3.8 to 4.4 (1600 kg ha^{-1}). Canopy closure reached greater coverage prior to early June compared to plantings after this period where it decreased as planting dates were delayed, which directly affected seed yield. The yield components most affected by late planting dates were rep. nodes m^{-2}, followed by pods m^{-2} and seeds m^{-2}, which showed to have higher direct correlation to seed yield. Selection of soybean variety within the MG IV to V and planting prior to June 1 provides the greatest chance to maximize soybean seed yield in Oklahoma, however, environmental factors greatly influence the yield potential of soybean in Oklahoma.

ADVISER'S APPROVAL: Chad B. Godsey