THE EFFECT OF PLANTING STRATEGIES, IMAZETHAPYR RATES, AND APPLICATION TIMINGS ON CLEARFIELD® HYBRID RICE INJURY

A Thesis

by

AARON LYLES TURNER

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

MASTER OF SCIENCE

December 2011

Major Subject: Agronomy

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ABSTRACT

The Effect of Planting Strategies, Imazethapyr Rates, and Application Timings on CLEARFIELD® Hybrid Rice Injury. (December 2011)

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CLEARFIELD® rice, which is a non-genetically modified crop that is tolerant to herbicides in the imidazolinone family, has helped producers combat red rice problems in rice since its introduction in 2002. Recently, breeders introduced hybrid CLEARFIELD® lines hoping to maintain the desired herbicide-resistant traits while having the added benefits of a hybrid. Soon after the hybrid line was released, farmers noticed herbicide injury to these new varieties while following the label recommendations. Research was performed to test the hybrids on the effect of planting date, planting density, and imazethapyr application rate on visual plant injury in Beaumont and Eagle Lake, TX in 2008 and 2009. A secondary experiment was designed to test the effect of imazethapyr application timing and rate on plant height, fresh weight, and dry weight in Eagle Lake and Beaumont, TX in 2010 with a greenhouse experiment in College Station, TX in 2009.

The 2008 and 2009 field trials were planted at three different densities, (28, 39, and 50 kg ha^{-1}) with two different planting dates representing the

months of March and April. Herbicide treatments consisted of four 1- to 2-leaf rates of imazethapyr that included 0.035, 0.07, 0.105, and 0.14 kg $ha^{-1,}$ followed by two 4- to 6-leaf rates of imazethapyr of 0.07 and 0.105 kg ha^{-1}. Rice showed injury symptoms two weeks after the second application of imazethapyr but was able to recover soon after nitrogen fertilizer application and flood establishment. Grain yield was not significantly different in plots that received a full labeled rate of imazethapyr or more for either location in either year.

The 2009 greenhouse study and 2010 field studies included treatments that had one early post at 1- to 2-leaf and one of two different late post applications that included either a 3- to 4-leaf or a 5- to 6-leaf treatment. The three rates included in the early 1- to 2-leaf application were 0, 0.035 and 0.07 kg ai ha^{-1}. The four rates included in the late application were 0, 0.07, 0.105, and 0.14 kg ai ha^{-1}. Plants treated with the labeled rate, 0.07 to 0.105 kg ai ha^{-1} at each 1- to 2-leaf and 3- to 6-leaf stage, showed no significant differences in yield, or quality; however, significant differences were recorded in height. According to this data, hybrid rice seems to be tolerant to imazethapyr applications and timings.

DEDICATION

This thesis is dedicated to my wife, Sarah. Without her unconditional love, patience and support this would not have been possible. She has stayed by my side through thick and thin.

ACKNOWLEDGEMENTS

I would like to express my appreciation to all those who made contributions toward this journey: Dr. Tom Cothren, Dr. Mike Chandler, and Dr. Garry McCauley for their support, encouragement, and guidance as they served on my graduate committee. The Texas Rice Belt Warehouse and the Texas Rice Research Foundation are recognized for providing the necessary funding for these projects. Appreciation is extended as well to: Jason Samford, Jack Vawter, Benjamin McKnight, Edinalvo Camargo, Antonio Manriquez and the Eagle Lake support staff for their help in completing this task. Hinze's Barbeque is acknowledged for providing a place of comfort on long days. A special thanks is extended to my mentor Dr. Scott Senseman for providing purpose, direction, and many words of wisdom.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa L.*) is an important commodity in the United States and world wide. In 2009, the United States planted 1.3 million hectares (ha) of rice with an average yield of 7,941 kg ha^{-1} (USDA 2010). Rice in the United States is grown mainly in Arkansas, Mississippi, Louisiana, Texas, and California. In 2009, Texas planted almost 71,500 ha of rice and 73,000 ha in 2008 (USDA 2010) across 21 counties. Most of the rice grown in Texas is in the southeast coastal region, with Wharton County having the most area in production with almost 17,500 ha planted in 2009 (Wilson et al. 2010).

Red rice (*Oryza spp.*) is a native annual grass from the Far East that has been considered a weed in rice fields across the United States for more than 150 years (Steele et al. 2002). The presence of red rice in a rice crop can reduce yield up to 45% (Shivrain et al. 2009). In Arkansas, 5 red rice plants m^{-2} have been shown to reduce rice grain yield 22% (Diarra et al. 1985). The plant also adversely affects the commercial value of the crop by reducing milling value and grade (Smith 1992). These adverse effects make controlling red rice imperative to rice producers.

This thesis follows the style and format of Weed Technology.

Traditionally in developing countries, red rice was controlled using various methods of crop rotations along with cultural and mechanical practices. A typical crop rotation consisted of one year of rice and two years of a different crop, normally sorghum or soybeans. Farmers are able to initiate red rice germination by tillage in preparation for these crops and were then able to easily remove the seedlings from the ground by hand. After many hours of labor were expended in two rotation years, rice crops would have a much lower percentage of viable red rice seed in the soil. Farmers took great care to make sure that rice seed was free of red rice by going through the seed by hand. The irrigation source was sometimes screened during irrigation because of the tendency of red rice to travel through waterways. Producers also had to clean equipment thoroughly because plows and combines could transport red rice seed from an infected field to a non-infected field.

There are many visual differences between red rice and commercial rice. Typically, red rice grows taller than commercial rice, which in turn leads to lodging of red rice plants that ultimately creates lodging problems of neighboring commercial rice plants. Red rice plants are lighter green in color and have more tillering. The leaves and seeds of red rice are rough and hairy to the touch compared to smooth leaves and seeds of commercial rice. Some of the red rice seeds also have a colored pericarp ranging from a dark red color to a light straw color. The color differences are apparent after rice has been milled because the color of the red rice will be darker than the almost pure white commercial rice.

The most important difference is that red rice is photosensitive which means that the plant is able to reach full maturity over a broader period depending on emergence. This characteristic makes red rice very difficult to control (Smith 1992).

Botanically and traditionally, red rice is classified as *Oryza sativa ssp. indica*. However, recent research has shown that there can be different ecotypes such as *O. sativa ssp. indica*, *O. sativa ssp. japonica* and *O. nivara*. Commercial rice grown in the United States is classified as *O. sativa ssp. indica* or *O. sativa ssp. japonica* (Vaughan et al. 2001). These genetic similarities make the control practices of red rice a challenge and time consuming while likely providing inadequate results. Fortunately, commercial rice is 99.9% self-pollinated (Smith 1992). However, genetic crosses and hybrids are known to exist both in nature and in a controlled environment (Smith 1992; Vaughan et al. 2001). Though in nature the outcrosses are rare, they pose a serious threat to the future of red rice control (Vaughan et al. 2001). A producer must incorporate cultural, biological, mechanical, and chemical practices to maintain control of red rice.

Red rice control is labor intensive and requires a thorough knowledge of the biology and ecology of the plant. Producers must rotate their crops and make sure that their seed and irrigation water are free of red rice. Herbicides have made the process more efficient, especially during seasons when rice is not present. Research has shown that flooding the rice field during the winter will encourage water fowl to land on the field. The fowl eat the red rice seed that is left over from the harvest and reduce the amount that is left at the start of the next season.

Early flood and maintenance is also effective in reducing red rice emergence. One of the most popular methods of incorporating water as a weed control measure includes water seeding pre-germinated commercial rice seed. The producers may either keep the flood after rice is planted or drain the field followed by flushing every few days until emergence and then flooded (Smith 1992).

Some red rice plants have shown natural tolerance to acetolactate synthase (ALS) inhibiting herbicides. This tolerance is believed to have developed before the introduction of imidazolinone-tolerant crops due to intense herbicide selection pressure, such as imazethapyr (Kuk et al. 2008). Imidazolinone-tolerant rice has been developed within the past decade. The technology is referred to as CLEARFIELD® technology and is tolerant of herbicides from the imidazolinone family (Croughan 2003). Unlike other herbicide-tolerant plants that have been genetically altered in a laboratory, CLEARFIELD® rice was discovered through selection screening of many different rice ecotypes (Croughan 2003). Once the tolerant parent plant was identified, breeders passed the mutant gene into other lines.

The most common active ingredient used in the CLEARFIELD® system is imazethapyr [2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid] (Figure 1) and is sold commercially as NewPath™ (BASF 2010). This chemical was effective up to 95% in controlling red rice in commercial rice when used according to the CLEARFIELD® system (Steele et al. 2002).

Imazethapyr controls some annual broadleaf weeds and several annual grasses. Among these, the most significant are morningglory (*Ipomoea spp.*), johnsongrass (*Sorghum halepense*), red rice (*Oryza sativa*), and nutsedge (*Cyperus spp.*). Imazethapyr inhibits the production of branched chain amino acids, leucine, isoleucine, and valine through the inhibition of the enzyme ALS or acetohydroxy acid synthase (AHAS). Plant growth is inhibited within a few hours after the application but injury symptoms usually appear after 1 to 2 weeks. Meristematic areas become chlorotic followed by slow foliar chlorosis and necrosis (Senseman 2007).

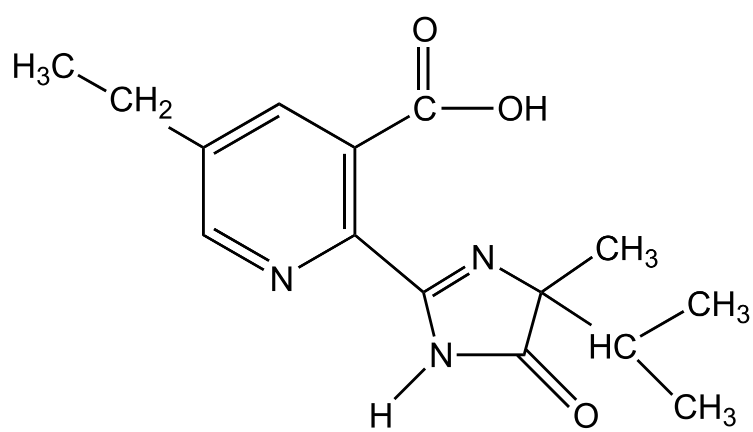

Figure 1. Imazethapyr chemical structure.

Within the last decade, hybrid rice has become available and grown in the United States. It has been used in China since 1976 with India, Vietnam, and the Philippines initiating wide-spread commercial hybrid use in 1994. Hybrid rice, like most hybrid crops, is obtained through crossing two or three different inbred lines. The resulting seed is then used as an F1 hybrid (Atlin et al. 2006). There are many reasons why producers prefer hybrid rice. These include a 20% greater yield, lower seeding rates, more tillering, better lodging resistance, and better performance on marginal land. Unfortunately, farmers cannot use saved seed for the next season, and the seed is priced higher than conventional inbred varieties (Vijayalakshmi and Hopper 2000). RiceTec released a hybrid CLEARFIELD® variety in 2004 (Muzzi 2003). These hybrid varieties are made by crossing an inbred line containing the CLEARFIELD® trait with an inbred line that does not contain the CLEARFIELD® trait (R. Miller, personal communication). Some producers believe that these hybrids do not tolerate imazethapyr as well as their inbred counter parts, particularly with later applications (G. N. McCauley, personal communication). Herbicide absorption has been shown to increase as plants mature (Pline et al. 2001). In order to determine the effect of imazethapyr on the hybrid lines, research was conducted to evaluate the visual injury caused by different imazethapyr application rates and different seeding rates of CLEARFIELD® hybrid rice at two different planting dates. Additional research was conducted to study the visual injury caused by different imazethapyr application rates to CLEARFIELD® hybrid rice applied at different plant growth stages.

CHAPTER II

MATERIALS AND METHODS

The Texas A&M AgriLife Research Centers near Beaumont and Eagle Lake, TX were the two locations chosen for the field research with greenhouse research in College Station, TX. The plot area in Beaumont was a Morey silty clay loam (fine-silty, siliceous, superactive, hyperthermic Oxyaquic Argiudolls) soil. This soil had a pH of 7.3 and contained 19.4% sand, 45.3% silt, and 35.5% clay. The plot area in Eagle Lake had a Nada fine sandy loam (fine-loamy, siliceous, active, hyperthermic Albaquic Hapludalfs) soil which had a pH of 6.1 and is 61.4% sand, 31.2% silt, and 7.4% clay. All field plots were dry-seeded using a grain drill with 6 rows spaced 19 cm apart at a depth of 1.3 cm and 3.2 cm for Beaumont and Eagle Lake, respectively, at planting rates of 28, 39, and 50 kg of seed ha^{-1}. Field plots were 1.5 x 5.5 m separated by a 0.3 m alley.

II.1 The effect of planting date, planting density, and imazethapyr rates on CLEARFIELD® hybrid rice injury

The experimental design was a randomized complete block design with 24 treatments and 4 replications. A flood was established at the 6- to 8-leaf stage and was maintained until harvest. Plots were fertilized according to soil testing recommendations.

Plots in Beaumont were planted on March 26 and April 23 in 2008, and March 12 and April 9 in 2009. Eagle Lake was planted on March 24 and April 16 in 2008, and March 23 and April 15 in 2009. The recommended planting date for Eagle Lake is between March 15 and April 21, and March 21 to April 21 for Beaumont (Dou and Tarpley 2010). The variety used at each location was CLXL 730 for both years.

The plots were treated with imazethapyr in a split application. The first application was sprayed at the 1- to 2-leaf stage and the second application was sprayed at the 4- to 6-leaf stage. The rates used were 0.035, 0.07, 0.105, or 0.14 kg ha^{-1} for the first application, and 0.07 or 0.14 kg ha^{-1} for the second application. The plots were sprayed with a CO_2 backpack sprayer at 4.8 km h^{-1} at 187 L ha^{-1} spray volume using three 8002 XR[1] spray tips.

Treatments were evaluated every 2 weeks for six weeks after the first application for visual injury. Ratings were assigned based on height and yellowing of the plant population within the plot compared to an untreated plot. A rating of 0 indicated that the plot did not have any visual injury at the time of the rating; a rating of 100 indicated complete death. Subsequent evaluations were made based on any changes or observations in plant height. The rice was harvested with a Mitsubishi[2] small plot combine and weighed for grain yield. Milling data, percent whole grain and total milling yield was collected to assess if grain quality was affected by imazethapyr treatments.

The collected data was entered into Agriculture Research Manager (ARM)[3]. It was analyzed using ARM by location for each year. March plantings for Eagle Lake were able to be combined for 2008 and 2009 using Statistical Analysis Software (SAS)[4]. The means were separated using Tukey's Honest Significant Difference at $\alpha = 0.05$.

II.2 The effect of imazethapyr rate and application timing on CLEARFIELD® hybrid rice injury

II.2.1 Greenhouse experiment

Rice was planted in 25 x 51-cm flats using a divider to separate the flats into two 25 x 25-cm sections and arranged in a randomized complete block design with three replications. CL151 was randomly planted on one side of the divider while CLXL745 was planted on the other side of the divider. The rice was planted in QUIKRETE® washed sand (QUIKRETE® in Atlanta, GA) and fertilized with a slow-release multi-nutrient fertilizer. The rice was sprayed with imazethapyr at rates of 0, 0.035, or 0.07 kg ai ha^{-1} for the first application, and rates of 0, 0.07, 0.105, or 0.14 kg ai ha^{-1} for the second application. The first application was applied at the 1- to 2-leaf growth stage. The second application was applied in two different segments. Half of the treatments were sprayed at the 3- to 4-leaf growth stage, the other half was sprayed at the 5- to 6-leaf growth stage. Flats were sprayed using a spray chamber set to apply 187 L ha^{-1} using a travel speed of 4.8 km h^{-1}. The plants were evaluated for visual injury on a scale from

0 to 100 with 0 being no injury present and 100 being total plant death. The data were analyzed using ARM[3] and the means were separated by Student-Newman-Kuels at α=0.05.

II.2.2 Field experiment

Experiments were planted at the Texas A&M Research and Extension Center in Beaumont and Eagle Lake, TX in 2010. CLXL 745 was planted at 39 kg ha^{-1} and the plots were arranged in a randomized complete block design with four replications. The plot area in Eagle Lake was a Nada fine sandy loam (fine-loamy, siliceous, active, hyperthermic Albaquic Hapludalfs) soil with a pH of 6.1 and a texture of 61.4% sand, 31.2% silt, and 7.4% clay. The soil in Beaumont was a Morey silty clay loam (fine-silty, siliceous, superactive, hyperthermic Oxyaquic Argiudolls) soil. The soil had a pH of 7.3 and contained 19.4% sand, 45.3% silt, and 35.5% clay. Plots in both locations were fertilized according to soil test recommendations. Plots were sprayed with 0, 0.035, or 0.07 kg ai ha^{-1} of imazethapyr for the first application, and the second application consisted of rates of 0, 0.07, 0.105, or 0.14 kg ai ha^{-1} imazethapyr for each location. The first application was applied when rice reached the 1- to 2-leaf growth stage. For the second application, half of the plots received imazethapyr when rice reached the 3- to 4-leaf growth stage, while the other half received the second application when rice reached the 5- to 6-leaf growth stage. The plots were sprayed with a CO_2 backpack sprayer. The sprayer was calibrated to deliver 140 L ha^{-1} at 4.8

km h^{-1} with 3 nozzles. The plants were measured at the panicle initiation growth stage for plant height using a meter stick and averaging three plant heights from the plot. Crop yield and grain quality were also collected at the end of the season.

The data were analyzed using ARM[3] and the means were separated using Tukey's Honest Significant Difference at $\alpha=0.05$.

CHAPTER III

RESULTS AND DISCUSSION

III.1 The effect of planting date, planting density and imazethapyr rates on CLEARFIELD® hybrid rice injury

Due to relatively warm weather conditions in Beaumont there were no visual injury symptoms for either the March or April plantings in 2008 or 2009 nor were any differences recorded for the April planting in Eagle Lake 2009 (See Appendix).

Significant differences in injury were recorded in Eagle Lake for each planting in 2008 and the March planting in 2009. Data for March plantings were able to be combined for 2008 and 2009 for Eagle Lake. Injury or yield was not affected by planted rice density (Table 1). Visual injury was more severe for the March plantings compared to the April 2008 planting (Table 2). Cooler temperatures in March at the time of the first and second imazethapyr applications increased the visual injury. This is similar to the findings of a study involving acetolactate synthase inhibiting herbicides applied to plant foliage in cooler weather (Green and Strek 2001).

Table 1. Percent visual injury to rice treated with various split-application rates of imazethapyr at Eagle Lake, TX, in March 2008 and 2009.

Rate 1st/2nd[a]	Visual Injury[b]
——kg ha^{-1}——	——%——
0.035/0.07	3 e
0.07/0.07	8 d
0.105/0.07	12 c
0.14/0.07	17 ab
0.035/0.105	3 e
0.07/0.105	8 d
0.105/0.105	14 bc
0.14/0.105	19 a

[a] Rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

[b] Ratings taken two weeks after second application.

Table 2. Percent visual injury to rice planted at three densities and treated with various split-application rates of imazethapyr at Eagle Lake, TX, April 2008.

		Weeks After Treatment[b]	
Plant density	Rate 1st/2nd[a]	2	4
kg ha^{-1}		%	
28	0.035/0.07	15 abc	0 a
	0.07/0.07	15 abc	0 a
	0.105/0.07	15 abc	0 a
	0.14/0.07	20 a	0 a
	0.035/0.105	10 a-d	0 a
	0.07/0.105	13 a-d	0 a
	0.105/0.105	18 ab	0 a
	0.14/0.105	18 ab	0 a
39	0.035/0.07	3 cd	0 a
	0.07/0.07	10 a-d	0 a
	0.105/0.07	3 cd	0 a
	0.14/0.07	13 a-d	0 a
	0.035/0.105	0 d	0 a
	0.07/0.105	5 bcd	0 a
	0.105/0.105	15 abc	0 a
	0.14/0.105	15 abc	0 a
50	0.035/0.07	0 d	0 a
	0.07/0.07	5 bcd	0 a
	0.105/0.07	8 a-d	0 a
	0.14/0.07	8 a-d	0 a
	0.035/0.105	0 d	0 a
	0.07/0.105	5 bcd	0 a
	0.105/0.105	8 a-d	0 a
	0.14/0.105	13 a-d	0 a

[a] Rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

[b] Weeks after the second treatment applied at the 4- to 6-leaf stage.

Injury was noticeable in the plots two weeks after the second application of imazethapyr. Plots receiving the highest rates of imazethapyr had the most visual injury in the March 2008 planting. Visual injury was no longer present four weeks after the second chemical application for all treatments. The plots received the second application of imazethapyr at the 4- to 6-leaf stage. Soon after the plots received an application of nitrogen fertilizer and a flood was established and maintained through the growing season. Plant recovery is attributed to the combination of the fertilizer and water application.

Injury symptoms were significantly different among plots that received a minimum labeled rate of 0.07 kg ha^{-1} for the first and second application and treatments that received a full labeled rate of 0.105 kg ha^{-1} for each application in the March plantings at Eagle Lake.

There were no significant differences in yield at Eagle Lake in 2008 or 2009 (Table 3), or in the March planting at Beaumont in 2009 (Table 4) among treatments that received a labeled rate of imazethapyr. Significant differences were noted in the March 2008 planting and the April 2009 planting at Beaumont. These differences were attributed to increased weed pressure due to less chemical application and a lower planting density. The visual injury symptoms at Eagle Lake did not translate into a significant yield loss.

Table 3. Rice grain yield from rice planted at three different densities and treated with various split-application rates of imazethapyr at Eagle Lake, TX, 2008 and 2009.

		2008		2009	
Plant density	Rate 1st/2nd[a]	March Planting	April Planting	March Planting	April Planting
		kg ha^{-1}			
28	0.035/0.07	9471 a	9884 a	10645 a	11529 a
	0.07/0.07	9940 a	10380 a	10572 a	11756 a
	0.105/0.07	9649 a	10429 a	10144 a	11836 a
	0.14/0.07	9657 a	10635 a	9270 a	12464 a
	0.035/0.105	9754 a	10571 a	9676 a	11368 a
	0.07/0.105	9435 a	9983 a	8834 a	11505 a
	0.105/0.105	9334 a	10690 a	10202 a	11771 a
	0.14/0.105	9573 a	10697 a	9807 a	11711 a
39	0.035/0.07	9075 a	10004 a	10953 a	11463 a
	0.07/0.07	9596 a	10158 a	10801 a	11607 a
	0.105/0.07	9400 a	10661 a	9841 a	11763 a
	0.14/0.07	9690 a	10126 a	9762 a	11616 a
	0.035/0.105	9504 a	10316 a	10343 a	12257 a
	0.07/0.105	9143 a	10107 a	10721 a	11690 a
	0.105/0.105	9850 a	10169 a	10639 a	12537 a
	0.14/0.105	9076 a	9823 a	10426 a	11508 a
50	0.035/0.07	9428 a	10471 a	10588 a	11379 a
	0.07/0.07	9720 a	10478 a	11144 a	12060 a
	0.105/0.07	9434 a	10346 a	10572 a	11845 a
	0.14/0.07	9775 a	10848 a	10116 a	11946 a
	0.035/0.105	9397 a	10326 a	10509 a	11476 a
	0.07/0.105	9237 a	10719 a	10076 a	12411 a
	0.105/0.105	9156 a	10218 a	10601 a	11491 a
	0.14/0.105	9359 a	10612 a	10495 a	11630 a

[a] Rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

Table 4. Rice grain yield from rice planted at three different densities and treated with various split-application rates of imazethapyr at Beaumont, TX, 2008 and 2009.

		2008		2009	
Plant density	Rate 1st/2nd[a]	March Planting	April Planting	March Planting	April Planting
		kg ha^{-1}			
28	0.035/0.07	3899 b	4008 a	5906 a	6658 b
	0.07/0.07	4439 ab	4184 a	6414 a	7882 ab
	0.105/0.07	4624 ab	4104 a	6300 a	7509 ab
	0.14/0.07	4688 ab	4583 a	6612 a	7852 ab
	0.035/0.105	4214 ab	4233 a	6413 a	6594 b
	0.07/0.105	4746 ab	4160 a	6333 a	7306 ab
	0.105/0.105	4834 ab	4846 a	6438 a	7707 ab
	0.14/0.105	4666 ab	4358 a	6015 a	7659 ab
39	0.035/0.07	4760 ab	3714 a	6266 a	7012 ab
	0.07/0.07	4720 ab	4318 a	6264 a	7521 ab
	0.105/0.07	5064 ab	4471 a	6461 a	8022 a
	0.14/0.07	5183 a	4291 a	6684 a	7851 ab
	0.035/0.105	4948 ab	4307 a	6901 a	7421 ab
	0.07/0.105	4664 ab	4531 a	5645 a	7931 ab
	0.105/0.105	5021 ab	4579 a	5609 a	7499 ab
	0.14/0.105	4917 ab	4283 a	6229 a	7881 ab
50	0.035/0.07	4868 ab	4297 a	6033 a	7176 ab
	0.07/0.07	4799 ab	4308 a	6085 a	8056 a
	0.105/0.07	4996 ab	4691 a	6677 a	8134 a
	0.14/0.07	5192 a	4827 a	7089 a	8138 a
	0.035/0.105	4824 ab	4495 a	6119 a	7354 ab
	0.07/0.105	5015 ab	4889 a	6228 a	7688 ab
	0.105/0.105	4813 ab	4655 a	6136 a	7452 ab
	0.14/0.105	5072 ab	4710 a	6201 a	7622 ab

[a] rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

III.2 The effect of imazethapyr rate and application timing on CLEARFIELD® hybrid rice injury

Due to unfavorable growing conditions in the greenhouse experiment at College Station, TX in 2009, visual injury recorded was highly variable. Visual injury recorded in CL 151 ranged from 10 to 80% while CLXL 745 ranged from 10 to 83%. There were no significant differences among treatments (Table 5).

III.2.1 Plant height

The height range for Beaumont, TX was from 23 to 27 cm when measured at the panicle initiation (PI) stage. The average height for treatments that received the second imazethapyr application at the 3- to 4-leaf growth stage was 25 cm. The average height for treatments that received the second imazethapyr application at the 5- to 6-leaf growth stage was 24 cm. All treatments receiving a labeled application of imazethapyr were not significantly different from each other (Table 6).

The height range for Eagle Lake, TX was 29 to 32 cm when measured at the panicle initiation stage. Average height for treatments receiving a 3- to 4-leaf stage second application of imazethapyr was 30.4 cm, and the average height for treatments receiving a 5- to 6-leaf second application of imazethapyr was also 30.4 cm. Significant differences were recorded; however, the results do not follow a consistent pattern. Some plots sprayed at the later 5- to 6-leaf stage

Table 5. Percent visual injury to two rice varieties in greenhouse study treated with various split application rates of imazethapyr at different growth stages for the second application. Injury was recorded two weeks after second application, College Station, TX, 2009.

Growth stage at 2nd application	Rate 1st/2nd[a]	CL 151	CLXL 745
	—kg ha^{-1}—	—%—	
3- to 4-leaf	untreated	40 a	37 a
	0/0.07	20 a	40 a
	0/0.105	48 a	38 a
	0/0.14	27 a	43 a
	0.035/0	33 a	18 a
	0.035/0.07	30 a	55 a
	0.035/0.105	20 a	43 a
	0.035/0.14	43 a	25 a
	0.07/0	60 a	63 a
	0.07/0.07	20 a	45 a
	0.07/0.105	40 a	53 a
	0.07/0.14	22 a	60 a
5- to 6-leaf	untreated	35 a	42 a
	0/0.07	40 a	40 a
	0/0.105	62 a	62 a
	0/0.14	80 a	83 a
	0.035/0	53 a	53 a
	0.035/0.07	50 a	72 a
	0.035/0.105	23 a	20 a
	0.035/0.14	40 a	62 a
	0.07/0	33 a	47 a
	0.07/0.07	10 a	10 a
	0.07/0.105	33 a	70 a
	0.07/0.14	45 a	58 a

[a] Rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

Table 6. Rice plant height at panicle initiation when treated with various split application rates of imazethapyr at two different second application times at Beaumont, TX, 2010.

Growth stage at 2nd application	Rate 1st/2nd[a]	Height
	—kg ha^{-1}—	—cm—
	untreated	27 a
3- to 4-leaf	0/0.07	25 ab
	0/0.105	25 ab
	0/0.14	26 ab
	0.035/0	26 ab
	0.035/0.07	26 ab
	0.035/0.105	26 ab
	0.035/0.14	25 ab
	0.07/0	25 ab
	0.07/0.07	25 ab
	0.07/0.105	26 ab
	0.07/0.14	25 ab
5- to 6-leaf	0/0.07	23 b
	0/0.105	24 ab
	0/0.14	24 ab
	0.035/0	25 ab
	0.035/0.07	24 ab
	0.035/0.105	24 ab
	0.035/0.14	23 b
	0.07/0	25 ab
	0.07/0.07	25 ab
	0.07/0.105	25 ab
	0.07/0.14	24 ab

[a] Rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

Table 7. Rice plant height at panicle initiation when treated with various split application rates of imazethapyr at two different second application times at Eagle Lake, TX, 2010.

Growth stage at 2nd application	Rate 1st/2nd[a]	Height
	—kg ha^{-1}—	—cm—
	untreated	29 d
3- to 4-leaf	0/0.07	30 c
	0/0.105	30 c
	0/0.14	31 b
	0.035/0	30 c
	0.035/0.07	32 a
	0.035/0.105	30 c
	0.035/0.14	31 b
	0.07/0	30 c
	0.07/0.07	31 b
	0.07/0.105	30 c
	0.07/0.14	31 b
5- to 6-leaf	0/0.07	31 b
	0/0.105	31 b
	0/0.14	30 c
	0.035/0	32 a
	0.035/0.07	30 c
	0.035/0.105	30 c
	0.035/0.14	31 b
	0.07/0	30 c
	0.07/0.07	30 c
	0.07/0.105	30 c
	0.07/0.14	30 c

[a] Rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

second application were significantly shorter than plots that received similar treatments at the 3- to 4-leaf stage second application. However, some of the plots did not exhibit differences between the two second application timings. Some late second application plots were taller than plots that received similar treatments with an early second application (Table 7). Ultimately no definitive conclusions regarding injury could be made from these plant height data. Most of the height differences recorded between similar treatments were less than 2 cm at each location.

III.2.2 Rice grain yield

Grain yield in Beaumont ranged from 4,243 to 8,371 kg ha^{-1} (Table 8). Significant differences were not recorded in treatments that received at least a full labeled rate of imazethapyr (0.07-0.105 kg ha^{-1} for both first and second applications (BASF 2010)). Significant differences were recorded in one treatment that received less than a recommended rate. This difference is likely due to increased weed pressure in the plot .

Grain yield in Eagle Lake ranged from 7,834 to 9,225 kg ha^{-1} (Table 9). Yield was not significantly different in treatments that received an application of imazethapyr. A significant difference was noted in the untreated check which is attributed to weed competition. The significant differences in visual injury or plant height that were recorded did not translate into significant yield loss.

Significant differences were not found in average total milling percentage or average whole milling percentage in plots that received at least a full labeled rate of imazethapyr in Beaumont (Table 8) and Eagle Lake (Table 9).

Table 8. Grain yield, percent of total mill grain weight, and percent whole mill grain weight of rice treated with various split application rates of imazethapyr at two different second application timings at Beaumont, TX, 2010.

Growth stage at 2nd application	Rate 1st/2nd[a]	Grain yield	Total mill grain	Whole mill grain
	——kg ha^{-1}——		——%——	
	untreated	4243 c	73 a	68 a
3- to 4-leaf	0/0.07	6335 b	74 a	68 a
	0/0.105	7297 ab	73 a	67 ab
	0/0.14	7397 ab	73 a	68 ab
	0.035/0	7635 ab	73 a	68 a
	0.035/0.07	8234 ab	73 a	68 ab
	0.035/0.105	8109 ab	73 a	67 ab
	0.035/0.14	8358 a	73 a	67 ab
	0.07/0	6875 ab	74 a	68 ab
	0.07/0.07	8090 ab	74 a	68 ab
	0.07/0.105	8732 a	74 a	68 ab
	0.07/0.14	8379 a	74 a	67 ab
5- to 6-leaf	0/0.07	7792 ab	74 a	67 ab
	0/0.105	6985 ab	73 a	67 ab
	0/0.14	7447 ab	73 a	67 ab
	0.035/0	7357 ab	73 a	68 ab
	0.035/0.07	7731 ab	74 a	67 ab
	0.035/0.105	8157 ab	73 a	66 b
	0.035/0.14	7971 ab	73 a	67 ab
	0.07/0	7851 ab	74 a	68 a
	0.07/0.07	7974 ab	74 a	67 ab
	0.07/0.105	8484 a	73 a	67 ab
	0.07/0.14	8007 ab	74 a	68 ab

[a] Rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

Table 9. Grain yield, percent of total mill grain weight, and percent whole mill grain weight of rice treated with various split application rates of imazethapyr at two different second application timings at Eagle Lake, TX, 2010.

Growth stage at 2nd application	Rate 1st/2nd[a]	Grain yield	Total mill grain	Whole mill grain
	——kg ha^{-1}——		——%——	
	untreated	7835 b	73 a	66 a
3- to 4-leaf	0/0.07	8643 ab	73 a	66 a
	0/0.105	8460 ab	73 a	66 a
	0/0.14	8524 ab	73 a	65 a
	0.035/0	8904 ab	73 a	65 a
	0.035/0.07	8626 ab	73 a	65 a
	0.035/0.105	9226 a	73 a	65 a
	0.035/0.14	8354 ab	73 a	66 a
	0.07/0	8635 ab	73 a	66 a
	0.07/0.07	8088 ab	73 a	65 a
	0.07/0.105	8935 ab	73 a	65 a
	0.07/0.14	8522 ab	73 a	66 a
5- to 6-leaf	0/0.07	9181 a	73 a	65 a
	0/0.105	8210 ab	73 a	65 a
	0/0.14	8541 ab	73 a	66 a
	0.035/0	8688 ab	73 a	66 a
	0.035/0.07	8608 ab	73 a	66 a
	0.035/0.105	8399 ab	73 a	66 a
	0.035/0.14	8510 ab	73 a	66 a
	0.07/0	8390 ab	73 a	66 a
	0.07/0.07	8785 ab	73 a	66 a
	0.07/0.105	8086 ab	73 a	66 a
	0.07/0.14	8234 ab	73 a	66 a

[a] Rate of 1st imazethapyr application/rate of 2nd imazethapyr application in kg ha^{-1}.

CHAPTER IV

CONCLUSIONS

Visually, rice response to imazethapyr was greater in March planting compared to April planting at Eagle Lake; however, no differences were recorded at Beaumont. Injury was present two weeks after the second 4- to 6-leaf application of imazethapyr. After nitrogen fertilizer was applied and the plots were flooded the plants were able to recover from the injury. Injury was not significantly different in plots that received similar treatments planted at different densities. Yield was not significantly different among treatments that received a full labeled rate of imazethapyr (0.07 - 0.105 kg ha^{-1} applied at the 1- to 2-leaf stage and again at the 3- to 6-leaf stage) or more at either location in either year.

Rice response to imazethapyr was minimally affected by application rate and timing of second application. Significant height differences were recorded in plots sprayed with a full labeled rate (0.07 to 0.105 kg ha^{-1} applied at the 1- to 2-leaf stage and at the 3- to 6-leaf stage) in treatments that received the second application at a 5- to 6-leaf stage compared to a 3- to 4-leaf stage; however, differences did not translate into significant yield or quality loss. Based on these data, CLXL 745 and CLXL 730 seem tolerant to imazethapyr regardless of timing of spray application.

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APPENDIX A

SOURCES OF MATERIALS

[1] TeeJet XR 8002, TeeJet, Wheaton, IL.

[2] Mitsubishi VY60 combine, Mitsubishi Agricultural Machinery Co., LTD., Higashiizumo, Shimane, Japan.

[3] Agriculture Research Manager version 8, Gylling Data Management, Inc., Brookings, SD.

[4] Statistical Analysis Software, SAS, Cary, NC.

APPENDIX B

Climate data for the 2008 growing season at the Texas AgriLife Research and Extension Center in Eagle Lake, TX.

Date	Air Temp Max	Air Temp Min	Air Temp Avg	Rainfall
	———————	F°	——————-	——in—-
Mar 15, 2008	87	55	71	0
Mar 16, 2008	82	50	66	0
Mar 17, 2008	72	64	68	0
Mar 18, 2008	82	67	74.5	0.02
Mar 19, 2008	82	67	74.5	*
Mar 20, 2008	75	39	57	0
Mar 21, 2008	73	40	56.5	0
Mar 22, 2008	76	45	60.5	0
Mar 23, 2008	78	50	64	0
Mar 24, 2008	70	40	55	0
Mar 25, 2008	69	42	55.5	0
Mar 26, 2008	74	46	60	0
Mar 27, 2008	76	63	69.5	0
Mar 28, 2008	81	64	72.5	0
Mar 29, 2008	80	58	69	0.03
Mar 30, 2008	81	70	75.5	0.01
Mar 31, 2008	81	71	76	0.01
Apr 1, 2008	81	71	76	0.01
Apr 2, 2008	86	63	74.5	0
Apr 3, 2008	82	65	73.5	0
Apr 4, 2008	83	70	76.5	0
Apr 5, 2008	80	45	62.5	0.02
Apr 6, 2008	80	45	62.5	*
Apr 7, 2008	83	47	65	0
Apr 8, 2008	83	65	74	0
Apr 9, 2008	86	67	76.5	0
Apr 10, 2008	78	68	73	0
Apr 11, 2008	79	62	70.5	0.04
Apr 12, 2008	80	51	65.5	0
Apr 13, 2008	73	45	59	0
Apr 14, 2008	75	39	57	0
Apr 15, 2008	75	39	57	0
Apr 16, 2008	76	43	59.5	0
Apr 17, 2008	78	53	65.5	0
Apr 18, 2008	81	50	65.5	0.95
Apr 19, 2008	72	49	60.5	0

Apr 20, 2008	82	52	67	0
Apr 21, 2008	80	68	74	0
Apr 22, 2008	86	70	78	0
Apr 23, 2008	87	69	78	0
Apr 24, 2008	89	70	79.5	0
Apr 25, 2008	85	70	77.5	0
Apr 26, 2008	84	64	74	1.02
Apr 27, 2008	79	62	70.5	0
Apr 28, 2008	75	49	62	0
Apr 29, 2008	74	47	60.5	0
Apr 30, 2008	80	49	64.5	0
May 1, 2008	81	57	69	0
May 2, 2008	82	70	76	0.01
May 3, 2008	87	69	78	0
May 4, 2008	77	53	65	0
May 5, 2008	82	67	74.5	0
May 6, 2008	72	63	67.5	0.08
May 7, 2008	80	67	73.5	0.04
May 8, 2008	82	65	73.5	0
May 9, 2008	90	68	79	0
May 10, 2008	90	70	80	0
May 11, 2008	89	71	80	0
May 12, 2008	80	59	69.5	0
May 13, 2008	81	62	71.5	0
May 14, 2008	85	73	79	0.08
May 15, 2008	87	67	77	0.01
May 16, 2008	82	62	72	0.04
May 17, 2008	77	59	68	0
May 18, 2008	77	57	67	0.02
May 19, 2008	89	62	75.5	0
May 20, 2008	95	66	80.5	0
May 21, 2008	95	71	83	0
May 22, 2008	92	75	83.5	0
May 23, 2008	90	77	83.5	0
May 24, 2008	94	77	85.5	0
May 25, 2008	94	77	85.5	0
May 26, 2008	94	76	85	0
May 27, 2008	93	76	84.5	0
May 28, 2008	93	67	80	0
May 29, 2008	93	67	80	*
May 30, 2008	89	67	78	0.02
May 31, 2008	91	69	80	0
Jun 1, 2008	94	71	82.5	0

Jun 2, 2008	94	72	83	0
Jun 3, 2008	95	73	84	0
Jun 4, 2008	95	74	84.5	0
Jun 5, 2008	95	74	84.5	*
Jun 6, 2008	92	78	85	0
Jun 7, 2008	94	74	84	0
Jun 8, 2008	94	74	84	0
Jun 9, 2008	94	75	84.5	0
Jun 10, 2008	95	74	84.5	0
Jun 11, 2008	96	73	84.5	0
Jun 12, 2008	96	72	84	0
Jun 13, 2008	94	73	83.5	0
Jun 14, 2008	95	73	84	0
Jun 15, 2008	95	73	84	0
Jun 16, 2008	97	74	85.5	0
Jun 17, 2008	98	73	85.5	0
Jun 18, 2008	99	72	85.5	0
Jun 19, 2008	98	74	86	0
Jun 20, 2008	98	71	84.5	0
Jun 21, 2008	97	71	84	0.06
Jun 22, 2008	96	70	83	0
Jun 23, 2008	97	72	84.5	0
Jun 24, 2008	97	72	84.5	0
Jun 25, 2008	93	74	83.5	0
Jun 26, 2008	98	74	86	0
Jun 27, 2008	99	74	86.5	0
Jun 28, 2008	94	72	83	0
Jun 29, 2008	96	72	84	0
Jun 30, 2008	98	74	86	0
Jul 1, 2008	96	72	84	0
Jul 2, 2008	95	71	83	0
Jul 3, 2008	94	73	83.5	0
Jul 4, 2008	92	73	82.5	0
Jul 5, 2008	95	72	83.5	0.02
Jul 6, 2008	92	66	79	0.37
Jul 7, 2008	93	71	82	0.02
Jul 8, 2008	94	70	82	0
Jul 9, 2008	93	72	82.5	0.14
Jul 10, 2008	93	72	82.5	*
Jul 11, 2008	94	72	83	0.18
Jul 12, 2008	96	72	84	0
Jul 13, 2008	96	71	83.5	0
Jul 14, 2008	98	73	85.5	0

Jul 15, 2008	100	75	87.5	0
Jul 16, 2008	100	75	87.5	*
Jul 17, 2008	96	73	84.5	0
Jul 18, 2008	97	72	84.5	0
Jul 19, 2008	96	70	83	0
Jul 20, 2008	97	72	84.5	0
Jul 21, 2008	98	73	85.5	0
Jul 22, 2008	98	71	84.5	0
Jul 23, 2008	97	75	86	0
Jul 24, 2008	88	72	80	0.6
Jul 25, 2008	86	73	79.5	1.03
Jul 26, 2008	94	74	84	0
Jul 27, 2008	95	72	83.5	0
Jul 28, 2008	97	74	85.5	0
Jul 29, 2008	97	72	84.5	0
Jul 30, 2008	96	73	84.5	0
Jul 31, 2008	97	75	86	0
Aug 1, 2008	99	75	87	0
Aug 2, 2008	99	75	87	0
Aug 3, 2008	100	75	87.5	0
Aug 4, 2008	100	70	85	0.42
Aug 5, 2008	97	74	85.5	0
Aug 6, 2008	86	73	79.5	0.15
Aug 7, 2008	92	74	83	0.01
Aug 8, 2008	99	74	86.5	0.01
Aug 9, 2008	96	74	85	0
Aug 10, 2008	99	75	87	0
Aug 11, 2008	99	75	87	0
Aug 12, 2008	96	77	86.5	0
Aug 13, 2008	91	76	83.5	0
Aug 14, 2008	97	74	85.5	0
Aug 15, 2008	98	74	86	0

* data not available

APPENDIX C

Climate data for the 2009 growing season at the Texas AgriLife Research and Extension Center in Eagle Lake, TX.

Date	Air Temp Max	Air Temp Min	Air Temp Avg	Rainfall
	————	——F°——	————-	——in——-
Mar 15, 2009	49	44	46.5	0.14
Mar 16, 2009	54	44	49	0.26
Mar 17, 2009	77	45	61	0.01
Mar 18, 2009	74	48	61	0
Mar 19, 2009	79	56	67.5	0
Mar 20, 2009	76	49	62.5	0
Mar 21, 2009	80	50	65	0
Mar 22, 2009	80	57	68.5	0
Mar 23, 2009	82	64	73	0
Mar 24, 2009	80	65	72.5	0
Mar 25, 2009	75	59	67	0.09
Mar 26, 2009	80	56	68	0.17
Mar 27, 2009	72	57	64.5	0.26
Mar 28, 2009	80	38	59	0
Mar 29, 2009	68	38	53	0
Mar 30, 2009	73	38	55.5	0
Mar 31, 2009	75	55	65	0.02
Apr 1, 2009	71	44	57.5	0.11
Apr 2, 2009	73	46	59.5	0.16
Apr 3, 2009	74	44	59	0
Apr 4, 2009	82	66	74	0
Apr 5, 2009	82	66	74	0
Apr 6, 2009	73	46	59.5	0
Apr 7, 2009	63	33	48	0
Apr 8, 2009	73	35	54	0
Apr 9, 2009	84	46	65	0
Apr 10, 2009	84	67	75.5	0
Apr 11, 2009	79	58	68.5	0
Apr 12, 2009	70	64	67	0.22
Apr 13, 2009	83	56	69.5	0.52
Apr 14, 2009	75	47	61	0
Apr 15, 2009	78	48	63	0
Apr 16, 2009	79	53	66	0
Apr 17, 2009	77	62	69.5	0
Apr 18, 2009	74	60	67	1.37
Apr 19, 2009	70	61	65.5	1.6

Apr 20, 2009	75	53	64	0
Apr 21, 2009	78	55	66.5	0
Apr 22, 2009	90	58	74	0
Apr 23, 2009	90	61	75.5	0
Apr 24, 2009	83	66	74.5	0
Apr 25, 2009	83	66	74.5	*
Apr 26, 2009	83	66	74.5	*
Apr 27, 2009	83	67	75	0.06
Apr 28, 2009	76	68	72	1.72
Apr 29, 2009	84	71	77.5	0.01
Apr 30, 2009	82	70	76	0
May 1, 2009	84	71	77.5	0.01
May 2, 2009	85	73	79	0
May 3, 2009	85	73	79	0
May 4, 2009	83	62	72.5	0
May 5, 2009	83	63	73	0
May 6, 2009	88	73	80.5	0
May 7, 2009	89	73	81	0
May 8, 2009	89	75	82	0
May 9, 2009	90	71	80.5	0
May 10, 2009	90	71	80.5	0
May 11, 2009	90	72	81	0
May 12, 2009	90	71	80.5	0
May 13, 2009	90	71	80.5	0
May 14, 2009	87	69	78	0
May 15, 2009	89	73	81	0
May 16, 2009	89	68	78.5	0
May 17, 2009	89	65	77	0.19
May 18, 2009	75	56	65.5	0.03
May 19, 2009	77	53	65	0
May 20, 2009	77	46	61.5	0
May 21, 2009	82	58	70	0
May 22, 2009	87	64	75.5	0
May 23, 2009	86	65	75.5	0
May 24, 2009	84	66	75	0
May 25, 2009	82	65	73.5	0.68
May 26, 2009	90	73	81.5	0
May 27, 2009	91	73	82	0
May 28, 2009	84	68	76	0.06
May 29, 2009	88	65	76.5	0
May 30, 2009	89	68	78.5	0
May 31, 2009	91	69	80	0
Jun 1, 2009	89	68	78.5	0

Jun 2, 2009	90	67	78.5	0
Jun 3, 2009	93	69	81	0
Jun 4, 2009	94	68	81	0
Jun 5, 2009	87	63	75	0
Jun 6, 2009	90	67	78.5	0
Jun 7, 2009	92	66	79	0
Jun 8, 2009	89	69	79	0
Jun 9, 2009	92	71	81.5	0
Jun 10, 2009	92	73	82.5	0
Jun 11, 2009	93	73	83	0
Jun 12, 2009	93	74	83.5	0
Jun 13, 2009	94	75	84.5	0
Jun 14, 2009	96	73	84.5	0
Jun 15, 2009	97	71	84	0
Jun 16, 2009	96	72	84	0
Jun 17, 2009	96	74	85	0
Jun 18, 2009	96	74	85	0
Jun 19, 2009	95	73	84	0
Jun 20, 2009	96	73	84.5	0
Jun 21, 2009	96	74	85	0
Jun 22, 2009	97	72	84.5	0
Jun 23, 2009	99	74	86.5	0
Jun 24, 2009	99	74	86.5	*
Jun 25, 2009	102	76	89	0
Jun 26, 2009	102	75	88.5	0
Jun 27, 2009	101	77	89	0
Jun 28, 2009	101	76	88.5	0
Jun 29, 2009	101	75	88	0
Jun 30, 2009	101	77	89	0.02
Jul 1, 2009	97	74	85.5	0
Jul 2, 2009	100	74	87	0
Jul 3, 2009	100	74	87	0
Jul 4, 2009	99	77	88	0
Jul 5, 2009	101	77	89	0
Jul 6, 2009	101	79	90	0
Jul 7, 2009	97	74	85.5	0.39
Jul 8, 2009	92	74	83	0.04
Jul 9, 2009	92	74	83	*
Jul 10, 2009	101	76	88.5	0
Jul 11, 2009	101	74	87.5	0
Jul 12, 2009	99	75	87	0
Jul 13, 2009	99	75	87	*
Jul 14, 2009	100	75	87.5	0

Jul 15, 2009	100	74	87	0
Jul 16, 2009	100	75	87.5	0
Jul 17, 2009	101	76	88.5	0
Jul 18, 2009	100	71	85.5	0.32
Jul 19, 2009	98	70	84	0.87
Jul 20, 2009	97	76	86.5	0
Jul 21, 2009	95	77	86	0
Jul 22, 2009	96	77	86.5	0
Jul 23, 2009	100	77	88.5	0
Jul 24, 2009	100	75	87.5	0
Jul 25, 2009	100	75	87.5	*
Jul 26, 2009	100	75	87.5	*
Jul 27, 2009	100	75	87.5	*
Jul 28, 2009	98	77	87.5	0
Jul 29, 2009	98	78	88	0
Jul 30, 2009	98	80	89	0
Jul 31, 2009	100	80	90	0
Aug 1, 2009	101	80	90.5	0
Aug 2, 2009	102	77	89.5	0
Aug 3, 2009	102	74	88	0
Aug 4, 2009	101	74	87.5	0
Aug 5, 2009	101	75	88	0
Aug 6, 2009	101	76	88.5	0
Aug 7, 2009	100	75	87.5	0
Aug 8, 2009	101	75	88	0
Aug 9, 2009	98	73	85.5	0
Aug 10, 2009	98	76	87	0.04
Aug 11, 2009	101	75	88	0
Aug 12, 2009	101	74	87.5	0
Aug 13, 2009	102	73	87.5	0.96
Aug 14, 2009	97	73	85	1
Aug 15, 2009	96	73	84.5	0

* data not available

APPENDIX D

Climate data for the 2008 growing season at the Texas AgriLife Research and Extension Center in Beaumont, TX.

Date	Air Temp Max	Air Temp Min	Air Temp Avg	Rainfall
	——————F°—————-			——in—-
Mar 15, 2008	78.7	62.3	69.3	0
Mar 16, 2008	87.4	56.5	69.9	0
Mar 17, 2008	77.3	60.7	70.1	0
Mar 18, 2008	80.8	72	74.8	0
Mar 19, 2008	77	55.6	66.7	0.04
Mar 20, 2008	67.6	41	54.7	0
Mar 21, 2008	72.2	43.1	56.8	0
Mar 22, 2008	72.4	50	60.7	0
Mar 23, 2008	77.8	53.5	64.7	0
Mar 24, 2008	70.1	40.2	56.4	0
Mar 25, 2008	67.2	43.2	53.9	0
Mar 26, 2008	71.2	55.6	63.5	0
Mar 27, 2008	75.6	63.1	68.1	0
Mar 28, 2008	78	64.7	70.3	0
Mar 29, 2008	81.1	62.3	70.8	0
Mar 30, 2008	83.1	69.4	74.7	0
Mar 31, 2008	81.8	65.4	72.8	0.18
Apr 1, 2008	78.8	70.2	73.1	0
Apr 2, 2008	83.1	66.7	73.8	0
Apr 3, 2008	80.4	66.8	72.4	0
Apr 4, 2008	81.1	72.8	75.3	0
Apr 5, 2008	82.9	55.4	64.3	0.27
Apr 6, 2008	66.6	51.4	57.7	0
Apr 7, 2008	79.1	56.4	66.1	0
Apr 8, 2008	80.9	63.3	70.8	0
Apr 9, 2008	82.1	68.8	74.2	0
Apr 10, 2008	82.1	73.4	76.3	0
Apr 11, 2008	82.3	72.2	76.2	0
Apr 12, 2008	80.8	53.3	67.7	0.01
Apr 13, 2008	74.9	44.1	60.7	0
Apr 14, 2008	72.7	39.1	57.5	0
Apr 15, 2008	67.2	41.2	53.5	0
Apr 16, 2008	69.3	45	56.7	0
Apr 17, 2008	74.7	61.3	66.8	0
Apr 18, 2008	79.2	61.4	71.5	0.57
Apr 19, 2008	71.8	45.9	58.3	0.01

Apr 20, 2008	80.2	49.2	64.3	0
Apr 21, 2008	81.3	61.9	70.7	0
Apr 22, 2008	84.3	69.5	74.9	0
Apr 23, 2008	84.5	69.9	75.5	0
Apr 24, 2008	87.1	68.4	76.4	0
Apr 25, 2008	83.6	69.4	75.3	0
Apr 26, 2008	83.1	69.3	74.9	0
Apr 27, 2008	81.7	63.2	71	0
Apr 28, 2008	78.1	51.9	64.3	0.03
Apr 29, 2008	75.7	46.8	61	0
Apr 30, 2008	80.4	52.5	66.7	0
May 1, 2008	80	68.8	73.3	0
May 2, 2008	79.7	73.6	75.8	0
May 3, 2008	84.7	69.3	77.4	0
May 4, 2008	81.9	53.9	67.8	0
May 5, 2008	83.5	64.7	72.9	0.45
May 6, 2008	67.3	57.8	61.8	1.09
May 7, 2008	81	66.9	73.3	0
May 8, 2008	81.2	72.6	76.6	0
May 9, 2008	87.6	70.5	78	0
May 10, 2008	88.4	71.5	78.9	0
May 11, 2008	86.4	69.2	78.1	0
May 12, 2008	82.1	54.5	68.9	0
May 13, 2008	80.2	65.3	73.5	0
May 14, 2008	84	76	78.6	0
May 15, 2008	84.2	65.4	76.5	1.69
May 16, 2008	84.9	63.4	73.3	0
May 17, 2008	75.8	58.3	66	0
May 18, 2008	75.8	54.8	63.3	0
May 19, 2008	85.6	66.2	74.5	0
May 20, 2008	91.6	70	78.9	0
May 21, 2008	91.5	74	80.4	0
May 22, 2008	89.8	75.4	80.8	0
May 23, 2008	87.1	78.3	81.4	0
May 24, 2008	89.4	78.5	82.5	0
May 25, 2008	89.1	76	81.9	0
May 26, 2008	90	73.8	81.3	0
May 27, 2008	89.4	74.2	81.1	0
May 28, 2008	90.3	72.2	79.9	0
May 29, 2008	91	70.6	77.3	0.8
May 30, 2008	89.2	70.1	78.3	0.01
May 31, 2008	88.6	69.8	79.7	0
Jun 1, 2008	90.9	71.6	81.3	0

Jun 2, 2008	91.5	72.3	81.3	0
Jun 3, 2008	91.9	74.6	82.7	0
Jun 4, 2008	91.5	77.8	83.5	0
Jun 5, 2008	90	79.6	83.5	0.03
Jun 6, 2008	89.7	78.2	82.9	0
Jun 7, 2008	89.7	77.5	82.4	0.09
Jun 8, 2008	90.6	75	82.5	0.01
Jun 9, 2008	90.7	73.4	82.1	0
Jun 10, 2008	90.2	74.7	81.9	0
Jun 11, 2008	84.7	71	76	0.14
Jun 12, 2008	90.1	71.5	80.9	0
Jun 13, 2008	90.1	73	81.7	0
Jun 14, 2008	89.5	72.8	80.7	0.46
Jun 15, 2008	89.5	73.4	81	0
Jun 16, 2008	93.6	72.8	81.3	0.41
Jun 17, 2008	93.9	74.6	82.5	0.33
Jun 18, 2008	93.4	70.1	77.7	0.29
Jun 19, 2008	94.9	74.4	82.9	0
Jun 20, 2008	93.2	70.9	78.1	1.54
Jun 21, 2008	89.7	73.8	80.4	0.07
Jun 22, 2008	91	71.7	77.5	0.46
Jun 23, 2008	91.9	72.7	82.1	0
Jun 24, 2008	91.3	72.8	80.9	0
Jun 25, 2008	85.9	73.9	79.2	0
Jun 26, 2008	88.2	70.5	76	0.96
Jun 27, 2008	87.6	71.5	76.7	0.4
Jun 28, 2008	90.7	74.4	82.4	0.05
Jun 29, 2008	89.4	70.9	78.6	1.88
Jun 30, 2008	93	73.2	80.3	0
Jul 1, 2008	90.8	69.2	79.6	0
Jul 2, 2008	89.4	69.9	79.4	0
Jul 3, 2008	88.3	72.7	79.4	0
Jul 4, 2008	90.9	72.4	81	0
Jul 5, 2008	86.7	72.2	77.3	0.01
Jul 6, 2008	89.4	73.5	80.6	0
Jul 7, 2008	92.1	73.5	82.3	0
Jul 8, 2008	92	74	82.4	0.27
Jul 9, 2008	93	74	82.9	0
Jul 10, 2008	92.7	73.9	80.5	0.29
Jul 11, 2008	91.2	74	81.4	0.06
Jul 12, 2008	93.3	74.6	83.3	0
Jul 13, 2008	93.6	71.9	82.4	0
Jul 14, 2008	93.9	75.5	83.2	0

Jul 15, 2008	92.9	76.3	81.9	0.02
Jul 16, 2008	91.4	73.9	82.5	0
Jul 17, 2008	95.7	70.8	83	0
Jul 18, 2008	94	70.9	81.8	0
Jul 19, 2008	91.5	72.6	80.6	0.04
Jul 20, 2008	94.2	73	83.4	0
Jul 21, 2008	94.9	74.1	84.1	0
Jul 22, 2008	97.3	74.8	84.8	0.35
Jul 23, 2008	89.3	76	81.6	0.03
Jul 24, 2008	84.8	74.8	77.6	0.79
Jul 25, 2008	83.2	72.7	77.2	4.09
Jul 26, 2008	91.5	75.8	83	0
Jul 27, 2008	95	72.6	83.3	0
Jul 28, 2008	95.5	73.4	83.1	0
Jul 29, 2008	94.5	73.6	82.5	0
Jul 30, 2008	93.7	75.2	83.1	0
Jul 31, 2008	90.6	76.5	81.9	0
Aug 1, 2008	94.7	75.3	84	0
Aug 2, 2008	95.6	76.9	84.8	0
Aug 3, 2008	97	73.1	84.7	0
Aug 4, 2008	96	71.2	79.4	0.12
Aug 5, 2008	94.8	73.2	83.4	0.99
Aug 6, 2008	82.4	74.6	77.3	0.09
Aug 7, 2008	89.7	74.6	80.1	0.29
Aug 8, 2008	94.4	75.9	83.7	0
Aug 9, 2008	92.5	73	79.5	1.23
Aug 10, 2008	90.5	76.1	82	0
Aug 11, 2008	92.5	77.3	83.8	0
Aug 12, 2008	91.3	79.9	84.2	0
Aug 13, 2008	88.9	75	81.5	0.49
Aug 14, 2008	92.2	75	81.7	0
Aug 15, 2008	94.8	74.6	83	0

APPENDIX E

Climate data for the 2009 growing season at the Texas AgriLife Research and Extension Center in Beaumont, TX.

Date	Air Temp Max	Air Temp Min	Air Temp Avg	Rainfall
	——F°——			——in—-
Mar 15, 2009	48.6	42.6	46.8	0.34
Mar 16, 2009	54.4	48.1	52.7	0.43
Mar 17, 2009	74.3	47.6	58.8	0
Mar 18, 2009	71.5	48.4	57.6	0.01
Mar 19, 2009	77.2	47.7	60.9	0
Mar 20, 2009	80	53.7	65.3	0
Mar 21, 2009	78.2	53.2	64.5	0
Mar 22, 2009	78.8	52.9	64.6	0
Mar 23, 2009	77.3	63.7	69	0
Mar 24, 2009	78.5	67.3	71.7	0
Mar 25, 2009	77.7	56.8	70.2	0
Mar 26, 2009	79.9	58	66.8	1
Mar 27, 2009	78.5	60.7	67.2	0.88
Mar 28, 2009	81.4	41.7	62	0.35
Mar 29, 2009	61.1	41.1	50.8	0
Mar 30, 2009	69.9	47.8	57.1	0
Mar 31, 2009	71.7	61.4	68.4	0
Apr 1, 2009	74.6	47.1	61.1	0
Apr 2, 2009	69.1	53.8	65.2	0.14
Apr 3, 2009	75.9	46.8	61	0.29
Apr 4, 2009	73.4	52.5	60.5	0
Apr 5, 2009	76.9	63.8	70.2	0
Apr 6, 2009	80	46	62.5	0
Apr 7, 2009	62.9	36.4	50.2	0
Apr 8, 2009	66.3	43.2	54.1	0
Apr 9, 2009	76.7	59.2	68	0
Apr 10, 2009	74.4	68.3	70.8	0
Apr 11, 2009	84.9	56.9	70.6	0
Apr 12, 2009	72.9	58.8	68.3	0
Apr 13, 2009	78.4	55.6	65.8	0.35
Apr 14, 2009	79.4	47.1	63.1	0
Apr 15, 2009	74.9	48.8	61.1	0
Apr 16, 2009	75.5	55.7	64.3	0
Apr 17, 2009	75.8	61.1	68.1	0
Apr 18, 2009	73.4	63.1	68.5	1.49
Apr 19, 2009	72.2	57.7	66.2	2.69

Apr 20, 2009	76.9	55.9	66.2	0
Apr 21, 2009	76.4	57.1	65.8	0
Apr 22, 2009	84.7	60.7	72.2	0
Apr 23, 2009	85.3	65.6	74	0
Apr 24, 2009	81.9	66.6	73.7	0
Apr 25, 2009	81.8	70.1	74.5	1.3
Apr 26, 2009	80.3	71.1	74.7	0
Apr 27, 2009	79	71.9	74.9	0.01
Apr 28, 2009	81.8	64.8	72.1	2.61
Apr 29, 2009	80.2	70.1	74.1	0
Apr 30, 2009	81.1	68.8	74.3	0
May 1, 2009	80.3	73.2	75.4	0.01
May 2, 2009	83.6	72.6	76.4	0.01
May 3, 2009	83.5	74.6	77.5	0
May 4, 2009	82.1	64	70.2	0.24
May 5, 2009	83.9	66.3	75.1	0
May 6, 2009	84.7	75.1	78.3	0
May 7, 2009	85.2	74.8	78.9	0
May 8, 2009	85.5	73.1	78.7	0
May 9, 2009	86.1	75	79.2	0
May 10, 2009	88.4	75	80	0
May 11, 2009	87	71.8	79.4	0
May 12, 2009	88.2	67.5	75.5	0
May 13, 2009	87.3	71	78.3	0
May 14, 2009	88.1	69.7	78.8	0
May 15, 2009	89.4	70.7	78.9	0
May 16, 2009	88.6	67.5	78	0
May 17, 2009	87.9	68.3	74.2	0.62
May 18, 2009	72	52.6	62.2	0
May 19, 2009	76.8	54.3	65	0
May 20, 2009	80.3	55.1	67.6	0
May 21, 2009	82.8	66.3	73.5	0
May 22, 2009	85	65.2	75.3	0
May 23, 2009	83.8	68.7	74.4	0
May 24, 2009	83.9	68	75.7	0
May 25, 2009	82.7	66.6	71.3	0.29
May 26, 2009	88.3	68.1	76.3	0
May 27, 2009	88.2	70.2	76.8	0.5
May 28, 2009	83.2	67.8	76.1	0
May 29, 2009	87	63.8	75.2	0
May 30, 2009	87.9	62.5	75.4	0
May 31, 2009	89.7	64.7	77	0
Jun 1, 2009	88.3	63.8	76.6	0

Jun 2, 2009	87.6	66.8	77	0
Jun 3, 2009	85.9	68.6	75.8	0
Jun 4, 2009	87.5	66.2	72.3	1.14
Jun 5, 2009	78.8	64.4	72.1	0
Jun 6, 2009	84	63.1	73.4	0
Jun 7, 2009	87.4	65.6	76.1	0
Jun 8, 2009	87.6	69.4	78.6	0
Jun 9, 2009	89.9	72.3	80.5	0
Jun 10, 2009	90.6	74.2	81.7	0
Jun 11, 2009	90.6	74.9	82.1	0
Jun 12, 2009	91	74	82.5	0
Jun 13, 2009	91.6	74.6	82.2	0
Jun 14, 2009	91.6	72.6	81.8	0
Jun 15, 2009	92.4	73.6	82.3	0
Jun 16, 2009	92.9	75	82.9	0
Jun 17, 2009	92.7	73.6	82.7	0
Jun 18, 2009	93.3	75.3	83	0
Jun 19, 2009	93.8	73.4	83.2	0
Jun 20, 2009	94.8	73.9	83.5	0
Jun 21, 2009	93.6	74.5	83.7	0
Jun 22, 2009	94.2	72.6	83.1	0
Jun 23, 2009	96.6	74	84.1	0
Jun 24, 2009	97.2	74.9	84.5	0
Jun 25, 2009	101.4	78.2	88.6	0
Jun 26, 2009	100.5	75.9	85.9	0
Jun 27, 2009	100.8	76.8	87	0
Jun 28, 2009	99	76.2	85.6	0.02
Jun 29, 2009	99.1	77.3	87.1	0
Jun 30, 2009	99.3	74	82.5	0.03
Jul 1, 2009	95.7	73.7	81.2	0.2
Jul 2, 2009	90.9	75.8	82.9	0
Jul 3, 2009	98.4	72.8	85.3	0
Jul 4, 2009	97.4	76.6	86.5	0
Jul 5, 2009	96.8	78.5	86.3	0
Jul 6, 2009	96.9	78.2	85.5	0
Jul 7, 2009	97	78.4	85.5	0.15
Jul 8, 2009	90.7	75.3	81	0.06
Jul 9, 2009	96.3	74.5	83.6	0.9
Jul 10, 2009	96	76.5	85.5	0
Jul 11, 2009	96.6	74.5	85.3	0
Jul 12, 2009	95.7	75.7	84.5	0
Jul 13, 2009	95.8	76.2	84.9	0
Jul 14, 2009	97.4	75.2	85.4	0

Jul 15, 2009	96.7	75.7	84.9	0
Jul 16, 2009	97.6	77.3	85.5	0.01
Jul 17, 2009	94.6	75.9	83.8	0
Jul 18, 2009	92.1	73	82.8	0
Jul 19, 2009	97.8	69.1	77.7	1.82
Jul 20, 2009	90.7	74.5	79.8	0.03
Jul 21, 2009	88.2	73.9	79.3	0.58
Jul 22, 2009	89.7	71.8	81	0.65
Jul 23, 2009	93	75.9	81.1	0.18
Jul 24, 2009	91.5	72.5	78	0.06
Jul 25, 2009	92.9	74.4	81.3	0
Jul 26, 2009	93.4	75.7	83.1	0
Jul 27, 2009	92.5	75	82.5	0.02
Jul 28, 2009	91.4	78.8	83.3	0.02
Jul 29, 2009	92.4	79.1	84.7	0
Jul 30, 2009	93.4	77.6	84.9	0
Jul 31, 2009	91.3	74.3	83.6	0.36
Aug 1, 2009	84.9	73.6	79.8	0.01
Aug 2, 2009	91.5	76.8	83	0
Aug 3, 2009	93.3	77.9	83.6	0
Aug 4, 2009	94.5	74	83.1	0
Aug 5, 2009	95.2	74.4	84.2	0
Aug 6, 2009	94.8	75.7	84.8	0
Aug 7, 2009	96.3	75.4	84.4	0
Aug 8, 2009	94.9	73.9	83.9	0
Aug 9, 2009	94.1	75.4	83.9	0
Aug 10, 2009	91.6	76.8	83.4	0.32
Aug 11, 2009	95	74.7	83.5	0
Aug 12, 2009	95.5	75.3	84.2	0
Aug 13, 2009	96	73.1	83.3	0
Aug 14, 2009	96.9	73.6	82.7	0
Aug 15, 2009	94.6	72.9	82.3	0

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