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Influence of Planting Date, Maturity Group, Harvest aids and Fungicide Application on Soybean (*Glycine max* (L.) Seed Quality

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**INFLUENCE OF PLANTING DATE, MATURITY GROUP,
HARVEST AID, AND FUNGICIDE APPLICATION ON
SOYBEAN (*Glycine max* (L.) SEED QUALITY**

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Plant, Environmental, and Soil Sciences

by

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ABSTRACT

Field studies evaluated the influence of planting date, maturity group, and harvest timing on soybean yield and seed quality at the LSU AgCenter Northeast (NERS), Macon Ridge, and Dean Lee Research Stations in 2018-2020. In addition, the influence of harvest aid and fungicide application on seed quality impact from delayed harvest and environment was investigated at NERS in 2019 and 2020 in both field and environmentally controlled growth chambers.

Soybean yield was maximized when maturity group IV and V soybean varieties were planted between Mid-April and Mid-May. Earlier and later planting dates did not result in maximized yield. Planting date impacts on seed quality, however, were negligible. Soybean varieties within maturity group 4.5 to 5.3 can result in acceptable seed quality and maximized yield in Louisiana, assuming plants are harvested at the optimum harvest timing (when seed reach 13% moisture) and not delayed 14 to 28 days. At NERS, harvest aid application had no impact on soybean seed quality impacts from delayed harvest and saturated (100% relative humidity) environment.

Delaying harvest beyond approximately 20 days in the field past optimum harvest timing can result in reduced seed quality. In addition, seedpod exposure to high relative humidity conditions (100%) for as little as 48 hours after optimum harvest timing can result in poor seed quality. At NERS, fungicide application had no impact on seed quality impacts from delayed harvest and saturated environment in the absence of disease pressure. Delaying harvest beyond 20 days in the field past optimum harvest timing or 4 days in a completely saturated environment can result in significant seed quality reduction.

CHAPTER 1. Introduction and Literature Review

Soybean (*Glycine max* (L.) is one of the most important crops worldwide because of high oil and protein content and ability to fixate nitrogen. In 2019, worldwide production was approximately 333 million tons produced on 296 million acres (FAOSTAT 2021). The United States is the top soybean producer followed by Brazil and Argentina (FAOSTAT 2021). In 2020, the U.S. produced 4.14 billion bushels on 83 million acres, 16% more than the previous year. Average yield was 50.2 bushels per acre, a 5.9% increase from 2019 (USDA-NASS-2021). In 2020, Louisiana producers harvested 1.07 million acres of soybean averaging 55 bushels per acre, a 14.6% increase from the previous year (USDA-NASS-2021).

Late-season weather extremes and insect pressure can lead to loss of soybean seed quality (USB 2018). Discounts can exceed 3 dollars per bushel or even rejection of grain loads at the elevator (USB 2018). Factors such as variety selection, planting date, fungicide application, and desiccant application can influence soybean seed quality (Heatherly et al. 1999). Soybean continues to be a profitable crop in Louisiana, but seed quality and environmental issues in the past have resulted in negative impacts. In 2018, it was estimated that 130,000 to 140,000 acres of soybean remained unharvested, and an additional 60,000 hectares were harvested but unmarketable (USB 2018).

Numerous soybean varieties are commercially available to producers. Variety selection, judging variety yield results by performance and stability across environments, is one of the most important decisions a producer will make (LSU AgCenter 2020). Performance refers to varieties that show highest yield in an environment similar to that experienced by producers. Stability refers to how well a variety performs across multiple environments or locations. Other important characteristics to consider when selecting a variety are herbicide technology traits, disease

resistance, salt-chloride tolerance, maturity, lower pod height, tolerance to poor drainage, lodging resistance, plant height, and seed quality (LSU AgCenter 2020). Management factors such as fertilization, planting seeding rate and date, row spacing, and seeding depth should also be considered. Producers often utilize university official variety trial data, on farm variety trials, and company literature to determine which variety will be best suited for their location and environmental conditions.

University and private research have helped improve soybean yield and profits (Heatherly et al. 1999). Soybean yield, however, can be negatively impacted by various unpredictable abiotic factors such as humidity, precipitation, wind, and temperature (Heatherly et al. 1999). Biotic factors like insects, fungal and bacterial diseases, and weeds can also cause significant yield reduction. Production practices such as row spacing, variety, maturity group (MG) selection, chemical harvest aid, and pesticide application can also impact soybean yield. Harvested seed quality may also be affected by the above mentioned abiotic and biotic factors and production practices.

1.1. Soybean Biology

Soybean is produced worldwide and is desirable for high quality oil and protein content that provide components for human and animal feed; further, the ability to fix atmospheric nitrogen from air into plant usable forms in soil eliminates fertilizer inputs (Pratap et al. 2012). Soybean is an herbaceous, erect, and bushy crop with an average height of approximately 60 inches (Bernard and Weiss 1973). It is an annual crop and has two types of growth habits: determinate and indeterminate (Bernard and Weiss 1973). For determinate growth habit cultivars, the plant ceases growth soon after initiation of flowering. For indeterminate growth habit cultivars, the plant continues to produce vegetative growth through flowering.

Soybean growth can be divided into two distinct growth stages, vegetative and reproductive (Casteel 2011). The vegetative stage begins when the cotyledon and unifoliolate leaves fully expand. Nodes on a soybean plant are recognized when the leaflet edges of a trifoliolate are no longer touching on the node directly above it. The vegetative stages are numbered according to the number of fully developed trifoliolate leaves (Fehr and Caviness 1977). The vegetative stage begins with emergence (VE), where the cotyledons are showing above the soil surface, and followed by VC which is distinguished by the unrolled (leaf edges not touching) unifoliolate leaves (Fehr and Caviness 1977). The appearance of the unfolded first trifoliolate marks the V1 growth stage. The vegetative stages will continue developing in this manner until the reproductive (R) stages begin with initiation of flowering (R1) as described by Fehr and Caviness (1997). The R1 growth stage is distinguished once the plant has at least one flower on the plant mainstem. At R2 (full bloom or full flowering), there is an open flower on one of the two uppermost mainstem nodes. The uppermost node is determined using the same method as for distinguishing vegetative nodes; for a node to be considered the trifoliolate leaf immediately

above must be unrolled (leaflet margins of the trifoliolate no longer touching). The R3 growth stage, or beginning seedpod formation, is identified when a 5 mm long seedpod is located at one of the four uppermost mainstem nodes. At R4, or full seedpod, a 20 mm long seedpod must be located on one of the four uppermost mainstem nodes. At R5, or beginning seed, a seedpod in the upper four most mainstem nodes must contain seed 3 mm long. At R6, or full seed, a seedpod in the uppermost four mainstem nodes contains seed that are touching, and the seedpod capacity is completely filled. At R7 or beginning maturity, one seedpod anywhere on the main stem has reached its mature color of light gray to dark brown depending on the variety. At R8, or full maturity, 95% of the seedpods have reached mature color (Fehr and Caviness, 1977).

Approximately 80% of the atmosphere is nitrogen gas (N_2), which is unusable for protein production (New Mexico State University 2015). All organisms need the usable nitrogen form (ammonia NH_3) (New Mexico State University 2015). Biological nitrogen fixation is the process that changes unusable nitrogen (N_2) into useful nitrogen (NH_3). This process is possible by N-fixing rhizobia bacteria (New Mexico State University 2015; Sørensen and Sessitsch 2007). Soybean can utilize atmospheric nitrogen through its association with the bacterium, *Bradyrhizobia japonicum*. *Bradyrhizobia japonicum* lives in the soil and inhabit soybean roots, forming nodules where the N_2 is fixed. The relationship between soybean and *Bradyrhizobia japonicum* is symbiotic or mutually beneficial.

Nitrogen fixation in legumes starts with the formation of a nodule (New Mexico State University 2015). Soybean roots are colonized by the bacteria soon after germination. Once the bacteria is in the root, cells will multiply. The soybean plant supplies nutrients for the bacteria. Nodules are visible 2 to 3 weeks after planting. When nodules are not fixing, they are white or gray inside of the nodule. As nodules grow, they turn pink or reddish, indicating N_2 fixation has

started. The pink or red color is caused by leghemoglobin that is responsible for the oxygen flow to the bacteria. N₂ fixation normally begins at V2 to V3 (Fehr and Caviness 1977). Soybean nitrogen demand increases from R5 to R8 peaking at R5.5. Legumes lose their ability to fixate at seedpod fill. Any stresses that affect plant activity like hot or dry weather conditions can reduce nitrogen fixation. Poor nitrogen fixation can be corrected by inoculating soybean plants (New Mexico State University 2015). Soybean can fix up to 250 lb of N per acre and are not usually fertilized with N (Walley et al. 1996; Cash et al. 1981).

Photoperiod is the ability of a plant to flower in response to changes in relative length of day and night (Srivastava 2002). Plants are classified as followed: short, long and day neutral plants, long day plants, and day neutral plants depending on photoperiod requirements. Soybean is a short day plant, requiring a relatively short light period of 8 to 10 hours and a continuous dark period of 14 to 16 hours for flowering to begin. Phytochrome is the photo-receptor pigment affected by sunlight that allows plants to respond to the day/night length. Due to phytochrome, plants respond to day length by sending a signal to the meristem on nodes to initiate the reproductive growth stage. Phytochrome exists in two different forms: the red light (Pr), and the far red light (Pfr) (Srivastava 2002). When the Pr absorbs red light (660-665 nm), it is converted into the Pfr. When the Pfr absorbs far red light (730-735 nm), it is converted into the Pr form. The Pfr form changes into Pr form in dark. Pfr is considered the active form of phytochrome. During long days there is an accumulation of Pfr, whereas, short days/long nights allow the accumulated Pfr to convert back to Pr. At daytime, in short day plants, the Pfr is accumulated and will inhibit flowering but this is stimulatory in long day plants (Srivastava 2002). At dark period in short day plants, this changes into Pr, resulting in flowering. More than 12 hours of exposure with red light (660-665 nm wavelength) will convert Pr into Pfr and inhibit flowering.

This is due to the Pfr form converting back into Pr form after absorbing the far-red light.

Prolonging the continuous dark period for short day plants will initiate early flowering. The exposure to a few consecutive nights longer than the critical length will induce flowering. (Taiz et al. 2015).

1.2. Seed Quality

Crop production can be affected by seed quality (Bishaw et al. 2007). For varieties grown for commercial resale of plant seed, maintaining quality is essential. Genetic, physical, physiological, and health quality are the four attributes that are strongly associated with good seed quality. Genetic quality is the inherent genetics that provide the potential for maximum yield, better grain quality, and tolerance to biotic and abiotic stresses. Physiological quality is the viability, germination, and vigor inherent in the seed. Physical quality refers to seed size, weight and uniformity, and lack of other crop and weed seeds. Health quality is the absence of disease and insects. Environment and cultural practices employed play an important role in harvest seed quality.

According to Bishaw et al. (2007) high quality seed is defined as “seed of an adapted variety with high genetic varietal, species, and physical purity, high germination and vigor, free from seed-borne pests (fungi, bacteria, viruses, insects, nematodes, parasitic weeds), and properly cleaned, treated, tested and labeled”. Producers need to understand the requirements for producing high quality seed and guarantee quality in time (Bishaw et al. 2007). Producers should have access and availability to quality seeds and tools to achieve this goal. This availability contributes to increasing production, food security, and improving productivity by ensuring their livelihoods.

1.3. Soybean Planting Date and Maturity Group

Planting date and MG are two of the most important factors, along with variety selection, that can set the stage to maximize soybean yield potential. Maturity group can be a complex term, and understanding influencing factors can help with a proper decision.

Photoperiod and temperature are the primary factors that define soybean MG (Mourtzinis and Conley 2017). Soybean are classified as short-day plant, meaning, as the day length decreases plants will be induced to flower (Purcell et al. 2014). Maturity groups are adapted to certain areas depending on photoperiod and temperature requirements (Staton 2017). Varieties suitable for a given geographic area can range from one-half maturity group to one full maturity group.

One of the reasons day length varies among locations is the tilt of the Earth on its axis, and as a result, day length in the Midwest can range from nine hours in winter to 15 hours in summer (Johnston 2017). Scientists have identified and selected soybean varieties that differ in how phytochrome reacts to day length and have assigned maturity group numbers from 000 to 8 and developed corresponding zone maps to maximize production. Maturity Group 0 varieties are adapted to North Dakota, northwestern South Dakota and northern Minnesota (Mourtzinis et al. 2017). Maturity Group I varieties are adapted to central and north South Dakota, central Minnesota, northern Wisconsin, Michigan, and New York. Maturity Group II varieties are adapted to southern Michigan, Wisconsin, Minnesota, South Dakota, northern Iowa and Nebraska. Maturity Group III varieties are adapted to southern Nebraska and Iowa, central Illinois, central and northern Indiana, Ohio, and Pennsylvania, northern half of Missouri, and Kansas. Maturity Group IV varieties are adapted to the southern half of Kansas, Missouri, Illinois, Indiana, Oklahoma and Kentucky. Maturity Group V varieties are adapted to southern

states and MG VI varieties are adapted to the southern part of Georgia and South Carolina. These adaptation zones were delineated by collecting variety trial data that had differing MG's from 312 locations across the U.S. between 2005 to 2015 (Mourtzinis et al. 2017). Using these results, a new database was constructed including the location–year–specific optimum MG latitude, longitude, and elevation information. Finally, the data were extracted and used to develop a contour map of optimum soybean MG zones across the examined regions of the continental U.S. As the maturity scale increases from a group I to II and II to III and so on, the signal to initiate flowering is delayed, with each whole number increase adding approximately 10 days to maturity (Johnston 2017). In addition, soybean MGs are adapted to production zones that run east and west due to day length being governed by latitude and not longitude (north-south) (Hartwig et al. 1967).

Traditionally soybean in the Mid-South has been planted in the beginning of May through June using varieties from MG V, VI, and VII (Heatherly 1999). This production system resulted in low yields due to late season drought with most of the varieties requiring high amounts of water during reproductive stages (mid-July to mid-September) (Heatherly 1998). In the early 2000's, however, this common practice shifted to planting earlier maturing indeterminate varieties from MG IV and V with planting dates starting from March to Early-June (USDA-NASS-2020).

Research conducted in northeast Texas from 1986 to 1988 concluded that early maturing varieties planted in April had higher yield than later maturing varieties planted in May while early maturing varieties planted in May had higher yield than late maturing varieties planted the same month (Heatherly 1998). Research conducted in 2009 concluded that yield potential is reduced when soybean is planted after Late-May in the midwest and deep south and after Early-

June in the upper south, with the decrease at a faster rate in the deep south and upper south (Egli and Cornelius 2009). Early planting can also reduce insect and disease pressure and avoid drought stress ([Salmeron et al. 2014](#); Baur et al 2000). Producers can also face decreased yield due to reduced canopy closure and delayed seedling emergence associated with later plantings (Andales et al 2000; Boyer et al. 2015; Steele and Grabau 1997).

Mid-south U.S. research has shown that planting soybean in April and Early-May often results in greater yield and profits than those planted later (Heatherly et al. 1999). In the mid-south, MG IV and V soybean are best suited for early planting (late March to Early-May). When planted by Mid-April, group IV varieties will typically mature between September 1st and 5th and group V between September 10th and 15th. Non-irrigated Group IV varieties that are planted in April may reach harvest maturity 7 to 10 days earlier than those receiving adequate irrigation/rainfall (Heatherly et al. 1999).

According to the Variety Yields and Production Practices for Louisiana publication (LSU AgCenter 2020), when soybean are planted between April and May the date to maturity for MG III to early MG IV and MG 4.5 to 4.9 ranges from August 10 to August 19 and August 20 to September 10, respectively. For MG V varieties planted from March to May date of maturity ranges from September 11 to October 1. Recommended planting dates are April 15 to May 10 for MG III and IV varieties, March 25 to May 5 for MG V varieties, and from March 25 to April 30 for MG VI varieties. Varieties above MG V are no longer typically grown in Louisiana.

1.4. Harvest Aid application in Soybean

Desiccant type herbicides are commonly applied to enhance harvest efficiency in Louisiana. Both weeds and crop are desiccated with harvest aids resulting in less foreign matter in the soybean seed that could result in dockage, increased seed moisture content, and reduced seed quality (Heatherly et al. 1999; Willard and Griffin 1993). Late season weed control with the use of harvest aids may also result in reduced weed seed production (Clay and Griffin 2000).

Applying a harvest aid can also help to desiccate the crop and expedite harvest. Griffin et al. (2003) reported that the use of paraquat plus sodium chlorate pre-harvest decreased costs associated with labor and wear on harvest machinery in maturity group III soybean. Properly timed late season application of glyphosate has been shown to reduce weed seed production (Bennet and Shaw 2000; Clay and Griffin 2000; Ratnayake and Shaw 1992a). Carfentrazone and sodium chlorate are also herbicides used as harvest aids that are frequently applied in combination with paraquat for effective weed desiccation (Ellis et al. 1998; Griffin et al. 2003; Griffin et al. 2004)

In addition to weed desiccation, harvest aids have become an important soybean production practice in Louisiana to help desiccate the crop and expedite harvest. When harvest was delayed out to 42 days, soybean yield loss at a rate of 0.2% each day has been observed (Philbrook and Oplinger 1989). Soybean plants in the mid-south can retain green leaves, stems, and pods (green bean malady) on mature plants prior to harvest and has been linked to stink bug injury (Boethel et al. 2000). Additionally, it has been reported that soybean plants retain green leaves longer following foliar fungicide application (Padgett et al. 2003; Potter 2005).

Application of a harvest aid such as paraquat leads to rapid leaf desiccation and improved harvest efficiency if properly timed. Harvest aid applied at 7% yellow pod resulted in 19 to 22%

yield reduction (Wilson and Smith 2002) while application at 50% yellow pod did not reduce yield (Ratnayake and Shaw 1992b). Previous research in Louisiana reported that maturity group (MG) IV soybean can be safely desiccated with paraquat when seed moisture from the upper four main stem nodes averaged 50%, which corresponded to approximately 115 days after Mid-April to Mid-May planting date. Soybean was harvested 14 days earlier than those receiving no paraquat. For a determinate MG V variety, 40% moisture was considered safe and corresponded to 125 days after Mid-May planting date. This allowed 7 to 8 days expedited harvest. Expedited harvest can allow producers to take advantage of premium prices because of earlier deliveries to the grain elevator (Boudreaux et al. 2007; Boudreaux and Griffin 2008).

1.5. Fungicide Application in Soybean

Application of foliar fungicides has increased in the U.S. over the last decade as a means of maximizing yield in addition to protecting seed quality (Hershman et al. 2011). One reason foliar fungicides have increased is the development of broad-spectrum fungicides and manufacturers claiming maximized yield with application. A fungicide application can result in an economic gain when a yield-limiting disease is prevented or delayed, and research in Kentucky showed no economic benefit when disease pressure is low (Hershman et al. 2011). Fungicides can provide limited protection time because of degradation of the material on treated leaf surfaces and new leaves emerging after applications. Application timing is a critical factor because both fungi and plants have life/growth stages that could affect fungicide efficacy. In soybean, fungicide application usually is recommended in the early R3 growth stage, but can also be applied between R3 and R5 (Hershman et al. 2011).

Application of foliar fungicides has increased in the U.S. as a means of maximizing yield in addition to protecting seed quality (Hershman et al. 2011). Pathogens that infect leaves reduce

photosynthesis by reducing green leaf area leading to increased disease infection (Bassanezi et al. 2001). Fungicides that are broad-spectrum have become popular because of benefits such as optimizing processes in the plant, improved host plant tolerance to the environment, uniform seed size and better seed quality, improved plant utilization of nitrogen and photosynthesis, and increased plant defenses (Padgett et al. 2011).

How a soybean plant will respond to a foliar fungicide depends on many factors such as environmental conditions, the susceptibility of the host regarding the pathogen, and the effectiveness of the product. Before applying any foliar fungicide it is important to monitor and correctly identify the disease and pathogen (Dekalb 2019). Research has shown that foliar fungicide application not only benefits disease management but can also improve yield. Pioneer research conducted from 2007 to 2014 both on-farm and in small-plot research to understand the potential of using foliar fungicides in soybean alone or co-applied with an insecticide found that a broad spectrum fungicide with or without insecticide applied at R3 resulted in higher yield response (Jeschke and Ahlers 2008). In Ohio it was reported that one application of fungicide increased yield significantly, however, environmental conditions and insect pressure can affect foliar fungicide efficacy (Dorrance et al. 2011). Other research has shown that foliar fungicides do not impact yield (Swoboda and Pedersen 2009; Hershman et al. 2011). In addition, it has been reported that use of a foliar fungicide can play a role in green bean malady impacting harvest (Hershman et al. 2011; Padgett et al. 2003; Potter 2005).

1.6.Objectives

Multiple factors will continue to affect harvest seed quality and yield loss. However, understanding how planting date, variety selection, harvest aid and fungicide application affect soybean seed quality will aid producer decisions helping maximize yield and profits. Therefore, this research focuses on impact of these factors to maintain optimum soybean seed quality at harvest.

1. Evaluate the influence of planting date and maturity group on soybean yield and seed quality.
2. Evaluate the influence of harvest aid on soybean seed quality impact from delayed harvest and environment.
3. Evaluate the influence of fungicide on soybean seed quality impact from delayed harvest and environment.

CHAPTER 2. Influence of Planting Date, Maturity Group, and Harvest Timing on Soybean Yield and Seed Quality

2.1 Introduction

Planting date can be one of the most important soybean management decisions a producer can make as it can greatly influence vegetative growth period, flowering, pod set, and seed fill (Salmerón et al. 2017). Choosing an earlier planting date within the optimum planting interval can help seed development, avoid hot and humid weather, and maximize yield (Sweeney et al. 1995; Steele and Grabau 1997). Planting late within or outside the optimum planting interval may not achieve maximum yield potential (Zhang et al. 2007). Early planting can also reduce insect and disease pressure and avoid drought stress (Salmeron et al. 2014). It has also been reported that later planted soybean tends to have more incidence of defoliating insects compared to early planted soybean during vegetative and reproductive growth stages (Baur et al. 2000). Producers can also face a decrease in yield due to reduced canopy closure and delayed seedling emergence associated with late planting (Andales et al. 2000; Boyer et al. 2015; Steele and Grabau 1997). Egli and Cornelius (2009) reported that yield potential is reduced when soybean is planted after Late-May in the Midwest and deep south and after Early-June in the upper south, with yield decrease occurring at a faster rate in the deep and upper south.

Research conducted in northeast Texas from 1986 to 1988 concluded that early maturing varieties planted in April had higher yield than later maturing varieties planted in May while early maturing varieties planted in May had higher yield than later maturing varieties when planted in the same month (Heatherly 1998). Research conducted in Arkansas during 2016 and 2017 evaluated soybean maturity group (MG) and planting date influence on grain yield and nitrogen dynamics (Carrie et al. 2020). The optimal planting dates in 2016 and 2017 were considered to be May 7th and 10th while the late planting dates were July 4th and 7th, respectively.

It was reported that choosing an early planting date and a well-suited MG for the environment allows the crop to achieve maximum biomass accumulation and N uptake, thereby preparing the crop to produce a high grain yield with adequate N allocated in the grain.

In the later part of the 20th century, soybean production in the mid-south included planting dates from beginning of May through June using varieties from MG's V, VI, and VII (Heatherly 1999). Soybean MG's V, VI, VII are well adapted to the mid-south growing region, however, water availability and drought stress during the growing season can affect yield. In this regard, early maturing varieties have been shown to help the producer (Popp et al. 2004). This standard practice of planting later MG soybean resulted in low yields over the years due to late season drought with most varieties requiring high amounts of water in reproductive growth stages (mid-July to mid-September) (Heatherly 1998). In the early 2000's, however, this production practice shifted to utilization of earlier maturing indeterminate varieties from MG IV and V, with planting dates starting from March to Early-June (USDA-NASS-2020).

Mid-south U.S. research has shown that planting soybean in April and Early-May in this region often results in greater yield and profits than those which are planted later (Heatherly et al. 1999). In the mid-south, MG IV and V soybean are best suited for early planting (late March to Early-April). When planted by Mid-April, group IV varieties will typically mature between September 1st and 5th and group V between September 10th and 15th. Non-irrigated group IV varieties that are planted in April may reach harvest maturity 7 to 10 days earlier than those receiving adequate irrigation/rainfall (Heatherly et al. 1999). According to the Variety Yields and Production Practices for Louisiana publication, when soybean is planted between Mid-April and Mid-May, the date to maturity for MG III to early MG IV and MG 4.5 to 4.9 ranges from August 10 to August 19 and August 20 to September 10, respectively (LSU AgCenter 2020). For MG V

varieties planted from March to May, date of maturity ranges from September 11 to October 1. Recommended planting dates are April 15 to May 10 for MG III and IV varieties, March 25 to May 5 for MG V varieties, and from March 25 to April 30 for MG VI varieties. Varieties above MG V are not typically grown in Louisiana.

Previous research has identified both planting dates and MG's that can maximize soybean production in growing regions similar to Louisiana. This research, however, focused on yield potential and ability to mitigate impact of biotic and abiotic factors. Little to no research has reported on impact of abiotic factors like planting date, MG, and harvest timings on seed quality. The current research is focused on these potential impacts on seed quality.

2.2 Materials and Methods

Planting Date Study. Research was conducted from 2018 to 2020 at the LSU AgCenter Northeast Research Station near Saint Joseph, Louisiana to evaluate soybean planting date effects on soybean yield and seed quality. The study was conducted in a randomized complete block design with a factorial arrangement of planting date and varieties replicated four times. In 2018 and 2019, soybean was planted into a Commerce silt loam soil, while in 2020 planting was into a Sharkey clay soil. Varieties were chosen to represent MG differences and based on availability each year. Plots were four rows on 40-inch centers with a length of 45 ft for 2018 and 2020 and length between 22 and 30 feet for 2019.

Plots were maintained free from weeds and insect pests, and harvest aid was applied utilizing normal recommended production practices (Josh Copes, Personal communication). Fungicide applications were not included in management decisions so as not to confound seed quality impact from pathogens.

Variety, MG, planting date, harvest aid application timing, harvest date, and rainfall amount and number of rainfall events from harvest aid application to harvest for each year are presented in Tables 1 to 3. At least fifteen days were allowed between harvest aid application and harvest according to label restrictions. Depending on environmental conditions, greater than 15 days could have elapsed prior to harvest. Following machine harvest of the center two rows of each plot, seed samples were collected, and moisture content and test weight recorded. Plot weight was adjusted to 13% moisture. In 2018, seed quality ratings were conducted by counting number of damaged seed in a 100 seed subsample using USDA reference images (USDA 2016). In 2019, two separate seed quality measurements were recorded, one similar to 2018 (SQ 1) and one which used a 1 to 10 scale, with 1 being seed in good condition and 10 poor seed condition using USDA reference images (SQ 2). In 2020 two seed quality ratings methods were utilized. The first method (SQ 1) was the same method used in 2019, using the 1 to 10 rating scale in a 100 seed sample. The second method (SQ 2) utilized the 1 to 10 rating scale in a 0.5 cup sample using USDA reference images. Weather related issues such as mold or heat damage were considered for seed quality ratings. Stink bug damaged and purple stained seed were recorded but not considered for seed quality rating, unless there were also weathering damages.

Table 2.1. Soybean variety, maturity group, planting date, harvest aid application date, harvest date, and amount and number of rainfall events from harvest aid application to harvest at St. Joseph, LA in 2018.

Variety	Maturity Group	Planting Date	Harvest Aid ^a Application Date	Harvest Date	Rainfall Amount ^b	Rainfall Events ^c
REV 41A18	IV	April 20	August 21	September 4	1.35	5
AG 46X6	IV	April 20	August 31	September 21	2.16	8
AG 51X8	V	April 20	August 31	September 13	2.09	7
REV 41A18	IV	May 3	August 21	September 4	1.35	5
AG 46X6	IV	May 3	August 31	September 13	2.09	7
AG 51X8	V	May 3	September 7	September 21	1.71	4
REV 41A18	IV	May 17	September 7	September 21	1.71	4
AG 46X6	IV	May 17	September 14	October 2	4.70	6
AG 51X8	V	May 17	September 14	October 2	4.70	6

^aParaquat at 16 oz/a plus crop oil concentrate at 1% v/v according to label directions.

^bRainfall amount in inches following harvest aid application to harvest.

^cNumber of rainfall events following harvest aid application to harvest.

Table 2.2. Soybean variety, maturity group, planting date, harvest aid application date, harvest date, and amount and number of rainfall events from harvest aid application to harvest at St. Joseph, LA in 2019.

Variety	Maturity Group	Planting Date	Harvest Aid ^a Application Date	Harvest Date	Rainfall Amount ^b	Rainfall Events ^c
REV 4310X	IV	April 17	September 3	September 18	0	0
AG 45X8	IV	April 17	September 3	September 18	0	0
P48A60X	IV	April 17	September 3	September 18	0	0
REV 4310X	IV	May 2	September 3	September 18	0	0
AG 45X8	IV	May 2	September 3	September 18	0	0
P48A60X	IV	May 2	September 10	September 26	0.02	1
REV 4310X	IV	May 15	September 10	September 26	0.02	1
AG 45X8	IV	May 15	September 10	September 26	0.02	1
P48A60X	IV	May 15	September 10	September 26	0.02	1
REV 4310X	IV	May 17	September 18	October 3	0.02	1
AG 45X8	IV	May 17	September 18	October 3	0.02	1
P48A60X	IV	May 17	September 18	October 3	0.02	1

^aParaquat at 16 oz/a plus crop oil concentrate at 1% v/v according to label directions.

^bRainfall amount in inches following harvest aid application to harvest.

^cNumber of rainfall events following harvest aid application to harvest.

Table 2.1. Soybean variety, maturity group, planting date, harvest aid application date, harvest date, and amount and number of rainfall events from harvest aid application to harvest at St. Joseph, LA in 2020.

Variety	Maturity Group	Planting Date	Harvest Aid ^a Application Date	Harvest Date	Rainfall amount ^b	Rainfall Events ^c
Pioneer 42A96X	IV	April 7	August 18	September 2	2.13	5
AG 47X9	IV	April 7	August 18	September 2	2.13	5
AG 56X8	V	April 7	August 18	September 2	2.13	5
Pioneer 42A96X	IV	May 5	August 18	September 2	2.13	5
AG 47X9	IV	May 5	September 1	September 18	0.87	3
AG 56X8	V	May 5	September 14	October 6	5.15	6
Pioneer 42A96X	IV	May 19	September 1	September 18	0.87	3
AG 47X9	IV	May 19	September 14	October 6	5.15	6
AG 56X8	V	May 19	September 14	October 6	5.15	6
Pioneer 42A96X	IV	June 12	September 14	October 6	5.15	6
AG 47X9	IV	June 12	September 21	October 6	5.15	6
AG 56X8	V	June 12	September 21	October 6	5.15	6
Pioneer 42A96X	IV	June 23	October 1	October 19	4.96	2
AG 47X9	IV	June 23	October 1	October 19	4.96	2
AG 56X8	V	June 23	October 1	October 19	4.96	2

^aParaquat at 16 oz/a plus crop oil concentrate at 1% v/v according to label directions.

^bRainfall amount in inches following harvest aid application to harvest.

^cNumber of rainfall events following harvest aid application to harvest.

All data were subjected to an ANOVA using the PROC GLM procedure in the statistical software SAS 9.4 (SAS Institute, Cary NC) with means separated following Tukey post-hoc procedure at $\alpha = 0.05$. Fixed effects were variety and planting date. Year was considered as a random effect.

Maturity Group and Harvest Timings Study. Research was conducted in 2019 and 2020 to evaluate the impact of MG and harvest timing on soybean seed quality. The study was conducted as a randomized complete block design with a factorial arrangement of MG and harvest timing replicated four times. The location in 2019 was the LSU AgCenter Northeast Research Station near St. Joseph, LA (NERS) and the LSU AgCenter Macon Ridge Research Station near Winnsboro, LA (MRRS) and NERS and the LSU AgCenter Dean Lee Research

Station near Alexandria, LA (DLRS) in 2020. Each MG consisted of all varieties within the official LSU AgCenter Variety Trial at each location. Maturity group, planting date, harvest aid application date, harvest date, and rainfall amount and number of rainfall events from harvest aid application to optimum harvest timing and optimum harvest timing to delayed harvest timing of each year are presented in Tables 4 and 5. Following machine harvest of the center two rows of each plot, seed quality for 2019 was determined as described for SQ2 in the same year for the planting date study and as previously described in the planting date study for 2020.

Table 2.2. Maturity group, planting date, harvest aid application date, harvest date, and rainfall amount and number of rainfall events from harvest aid application date to optimum harvest and optimum harvest to delayed harvest in 2019 at St. Joseph and Winnsboro, LA.

Maturity Group	NERS	MRRS	NERS	MRRS	NERS	MRRS	NERS	MRRS	NERS	MRRS
	Planting Date	Harvest Aid ^b Application Date	Harvest Date ^c	Rainfall Amount/Number of Events ^d	Rainfall Amount/Number of Events ^e					
5.0 – 4.4	April 30	April 29	Sept. 12	Sept 12.	Sept. 27	Sept. 27	0.02 (1)	0.07 (1)	2.47 (6)	5.59 (8)
4.5 – 4.7	April 30	April 29	Sept. 12	Sept. 12	Sept. 27	Sept. 27	0.02 (1)	0.07 (1)	2.47 (6)	5.59 (8)
4.8 – 4.9	April 30	April 29	Sept. 12	Sept 12	Sept. 28	Sept. 28	0.02 (1)	0.07 (1)	2.47 (6)	5.59 (8)
5.0 – 5.3	April 30	April 29	Sept. 25	Sept 12	Oct. 10	Oct. 10	0.26 (2)	0.94 (2)	2.21 (4)	4.63 (7)
5.4 – 6.0	April 30	April 29	Sept 25.	Sept 12	Oct. 10	Oct. 10	0.26 (2)	0.94 (2)	2.21 (4)	4.63 (7)

^aAbbreviations: NERS, LSU AgCenter Northeast Research Station near St. Joseph, LA; MRRS, LSU AgCenter Macon Ridge Research Station, near Winnsboro, LA.

^bParaquat at 16 oz/a plus Firezone at 1% v/v according to label directions.

^cOptimum harvest date; delayed harvest date for all groups was October 24.

^dRainfall amount in inches and number of events from harvest aid application to optimum harvest.

^eRainfall amount in inches and number of events from optimum to delayed harvest.

Table 2.3. Maturity group, planting date, harvest aid application date, harvest date, and rainfall amount and number of rainfall events from harvest aid application date to optimum harvest and optimum harvest to delayed harvest in 2020 at St. Joseph and Alexandria, LA.

Maturity Group	NERS	DLRS	NERS	DLRS	NERS	DLRS	NERS	DLRS	NERS	DLRS
	Planting Date		Harvest Aid ^b Application Date		Harvest Date ^c		Rainfall Amount/Number of Events ^d		Rainfall Amount/Number of Events ^e	
3.0 – 4.4	May 11	May 4	Sept. 18	Sept. 3	Oct. 8	Sept. 18	5.15 (6)	0.96 (4)	6.3 (5)	4.33 (4)
4.5 – 4.7	May 11	May 4	Sept. 18	Sept. 16	Oct. 8	Oct. 1	5.15 (6)	4.33 (4)	6.3 (5)	11.98 (3)
4.8 – 4.9	May 12	May 4	Sept. 18	Sept. 16	Oct. 8	Oct. 1	5.15 (6)	4.33 (4)	6.3 (5)	11.98 (3)
5.0 – 5.3	May 12	May 4	Oct. 5	Sept. 16	Oct. 20	Oct. 5	4.96 (2)	4.33 (4)	1.34 (3)	11.98 (3)
5.4 – 6.0	May 12	May 4	Oct. 5	Sept. 30	Oct. 21	Oct. 6	4.96 (2)	0.00	1.34 (3)	12.81 (4)

^aAbbreviations: NERS, LSU AgCenter Northeast Research Station near St. Joseph, LA; DLRS, LSU AgCenter Dean Lee Research Station, near Alexandria, LA.

^bParaquat at 16 oz/a plus Firezone at 1% v/v according to label directions.

^cOptimum harvest date; delayed harvest dates at NERS: November 3 (MG 3.0 – 4.4), November 4 (MG 4.5 – 4.7), and November 5 (MG 4.8 – 6.0); at DLRS was October 2 (MG 3.0 – 4.4), October 20 (MG 4.5 – 5.3) and October 27 for the last MG.

^dRainfall amount in inches and number of events from harvest aid application to optimum harvest.

^eRainfall amount in inches and number of events from optimum to delayed harvest.

Delayed harvest was not initiated until rainfall events occurred. Soil type for NERS was Commerce silt loam, a Gigger-Gilbert silt loam at MRRS, and a Coushatta silt loam at DLRS. Plots were four rows on 40 inches centers with a length of 45 feet. Plots were maintained free from weeds and insects utilizing normal production practices (Josh Copes, Personal Communication). Fungicide application was not included in management decisions as to not confound seed quality impact from pathogens.

All data were subjected to an ANOVA using the PROC GLM procedure in the statistical software SAS 9.4 (SAS Institute, Cary NC) with means separated following Tukey post-hoc procedure at $\alpha = 0.05$. Fixed effects were MG and harvest timing, while year was considered a random effect.

2.3. Results and Discussion

Planting date Study. In 2018, a significant planting date effect was observed for soybean yield while soybean variety and planting date by variety interactions were insignificant. Averaged across varieties, the earliest planting date of Mid-April resulted in yield of 80 bu/A, which was 10 and 18% greater than that observed for the Early-May (73 bu/A) and Mid-May (68 bu/A) planting date, respectively (Table 6). Seed quality ratings ranged from 3 to 4 with no significant effect observed for planting date, variety, or their interaction (data not shown).

Table 2.4. Planting date and soybean variety impact on yield and seed quality at St. Joseph, LA, 2018 to 2020.

Planting Date ^b	Soybean Yield (bu/A) ^a			Seed Quality ^a
	2018	2019	2020	2019 ^d
Early-April	-	-	43 b	-
Mid-April	80 a	61 b	-	2.16 a
Early-May	73 b	74 a	49 a	1.16 b
Mid-May	68 b	66 ab	49 a	1 b
Late-May	-	58 b	-	1.33 b
Mid-June	-	-	40 b	-
Late-June	-	-	34 c	-
Variety ^c				
AG47X9			47 a	
AG56X8	NS	NS	41 b	NS
P42A96X			41 b	

^aMeans in a column followed by the same letter are not significantly different using Tukey's mean separation test ($P \leq 0.05$).

^bMeans are averaged across soybean varieties.

^cMeans are averaged across planting dates of Early-April, Early-May, Mid-May, Mid-June, and Late-June in 2020.

^dSeed quality ratings based on 100 seed sample using a 1 to 10 scale with 1 being seed in good condition and 10 in poor condition based on USDA reference images.

In 2019, as was observed the previous year, the only significant effect on soybean yield was planting date. Unlike 2018, the Early-May planting date resulted in a yield of 74 bu/A

averaged across soybean varieties, which was equal to the 66 bu/A observed for the Mid-May planting date and greater than that for the Mid-April (61 bu/A) and Late-May (58 bu/A) plantings (Table 6). Equivalent yield was observed for the Mid-April and mid/Late-May planting dates. The only significant effect with respect to seed quality in 2019 was for planting date and the SQ 2 rating. Averaged across varieties, a slightly higher rating (lower quality) of 2.16 was observed for the Mid-April planting date in comparison to all other planting dates which resulted in equivalent seed quality ratings (1 to 1.33) (Table 6).

In 2020, a significant effect was observed with respect to soybean yield for both planting date and soybean variety. Averaged across varieties, early and Mid-May planting dates resulted in a yield of 49 bu/A, which was greater than all other planting dates (Table 6). Early-April and mid-June plantings resulted in similar yields of 43 and 40 bu/A, respectively, while the lowest yield was observed for the latest planting date of Late-June (34 bu/A). Averaged across planting dates, soybean variety AG47X9 yielded 47 bu/A, compared to 41 bu/A observed for varieties P42A95X and AG56X8 (Table 6). With respect to SQ1 and SQ 2 ratings, a significant planting date by soybean variety interaction was observed. For the SQ 1 and SQ 2 ratings, soybean variety P42A96X planted in Early-April resulted in a seed quality rating of 7 and 5, respectively, which was greater than that observed for all the planting dates and varieties which resulted in equal ratings ranging from 1 to 3 (Table 7).

Table 2.5. Planting date and soybean variety interaction impact on seed quality at St. Joseph, LA in 2020.

	Early-April	Early-May	Mid-May	Mid-June	Late-June
Variety	Seed Quality 1 ^{ab}				
AG47X9	3 b	2 b	1 b	1 b	1 b
AG56X8	1 b	1 b	1 b	1 b	1 b
P42A96X	7 a	1 b	1 b	1 b	2 b
Variety	Seed Quality 2 ^{ac}				
AG47X9	3 b	2 b	1 b	1 b	1 b
AG56X8	1 b	1 b	1 b	1 b	1 b
P42A96X	5 a	2 b	1 b	1 b	2 b

^aMeans in a column followed by the same letter are not significantly different using Tukey's mean separation test ($P \leq 0.05$).

^bSeed quality ratings based on 100 seed sample using a 1 to 10 scale with 1 being seed in good condition and 10 in poor condition based on USDA reference images.

^cSeed quality ratings based on 0.5 cup seed sample using a 1 to 10 scale with 1 being seed in good condition and 10 in poor condition based on USDA reference images.

Our results indicate that planting MG IV and V soybean varieties between Mid-April and Mid-May can maximize yield in Louisiana. Later planting resulted in less-than-maximum yields. A regional analysis conducted in 2009 also showed that planting in Late-May or Early-June can result in low yield in the Midwest, deep south, and upper south (Egli & Cornelius 2009). Research conducted in Mississippi also indicated that delaying planting past Mid-May can result in decreased yield in comparison to earlier planting dates (B.H. Arnold 2011). Salmeron et al (2016) found that yield declined in the U.S. midsouth if planting was delayed from Mid-May to June in MG III, IV, V, and VI, especially in southern locations. In addition, they reported that MG IV cultivars yielded highest at all locations. Planting date impacts in our seed quality studies were negligible and limited to only one variety planted in Early-April in one year.

Maturity Group and Harvest Timing Study. For all locations and years significant MG and harvest timing effects were observed. Poorest seed quality, averaged across harvest timing, was observed for the earliest (3.0 – 4.4) MG at NERS in 2019 (5.5) and 2020 (4.27 and 4.1 for SQ1 and SQ2, respectively), at MRRS (5.04), and with MG 5.0 – 5.3 at DLRS (4.9) (Table 8). At NERS both years and MRRS the best seed quality ranging from 1.6 to 2.02 was observed with the latest MG 5.4 – 6.0. Seed quality ratings for MGs 4.5 – 5.3 was good and ranged from 2.2 to 3.4 with only minor differences observed at the locations. At DLRS, greatest seed quality was also observed for the latest MG, however, other MGs resulted in ratings of 3.7 to 4.1. Averaged across MGs, optimum harvest timing at every location and year resulted in greater seed quality (1.5 – 3.7) (Table 8). Delayed harvest timing resulted in a 25 to 50% decrease in seed quality rating depending on year and location.

Our results indicate that greatest soybean quality can be obtained when planting MG 5.4 – 6.0 soybean; however, as indicated in the planting date study, yield would not be maximized. Planting MG 3.0 – 4.4 soybean varieties in Louisiana can result in less-than-optimal seed quality. Soybean in MG 4.5 – 5.3 can result in acceptable seed quality while also maximizing yield.

Table 2.6. Influence of maturity group and harvest timing on soybean seed quality at St. Joseph, Winnsboro, and Alexandria, LA in 2019 and 2020.

Maturity Group ^c	2019		2020		
	NERS ^a	MRRS ^a	NERS ^a	DLRS ^a	DLRS ^a
	Seed Quality ^b		SQ 1 ^b	SQ2 ^b	SQ2 ^b
3.0 - 4.4	5.5 a	5.0 a	4.3 a	4.1 a	-
4.5 - 4.7	2.6 c	3.4 b	2.6 b	2.6 c	4.1 b
4.8 - 4.9	2.7 c	2.8 c	2.4 c	2.3 d	3.7 c
5.0 - 5.3	3.4 b	2.2 d	2.5 bc	3.1 b	4.9 a
5.4 - 6.0	2.0 d	1.6 e	1.9 d	1.8 d	2.8 d
Harvest Timings ^{de}					
Optimal	2.5 b	2.0 b	1.5 b	1.7 b	3.7 b
Delayed	3.6 a	4.1 a	3.9 a	3.8 a	4.9 a

^aAbbreviations: NERS, LSU AgCenter Northeast Research Station near St. Joseph, LA; MRRS, LSU AgCenter, Macon Ridge Research Station near Winnsboro, LA; DLRS, LSU AgCenter Dean Lee Research Station near Alexandria, LA.

^bMeans in a column followed by the same letter are not significant different using Tukey's mean separation ($P \leq 0.05$).

^cMeans are averaged across harvest timings.

^dMeans are averaged across maturity group.

^eOptimum harvest dates for 2019 at NERS and MRRS: September 27 for MG 3.0 – 4.7, September 28 for MG 4.8 – 4.9, and October 11 for last MG; Harvest dates for 2020 at NERS: October 8 for MG 3.0 – 4.9, and October 20 and 21 for MG 5.0 – 5.3 and 5.4 – 6.0, respectively. For DLRS: September 18 for MG 3.0 – 4.4, October 1 for MG 4.5 – 4.9, October 5 for MG 5.0 – 5.3, and October 6 for the last MG. Delayed harvest for all MGs at NERS and MRRS in 2019 was October 24; for 2020 at NERS: November 3 (MG 3.0 – 4.4), November 4 (MG 4.5 – 4.7), and November 5 (MG 4.8 -6.0); at DLRS for all MGs was October 27.

CHAPTER 3. Influence of Harvest Aid on Seed Quality Impact from Delayed Harvest and Environment

3.1. Introduction

Desiccant type herbicides are often used as harvest aids in soybean to desiccate weeds, thereby improving harvest efficiency and crop quality. Weeds present at harvest can increase seed moisture and foreign material (Ellis et al. 1998; Willard and Griffin 1993). A 19% increase in losses in soybean as a result of broadleaf weed presence at harvest has been reported in previous research (Burnside 1973).

Griffin et al. (2003) reported that the use of paraquat plus sodium chlorate pre-harvest decreased costs associated with labor and wear on harvest machinery in maturity group III soybean. When properly timed late season application of glyphosate has been shown to reduce weed seed production (Bennet and Shaw 2000; Clay and Griffin 2000; Ratnayake and Shaw 1992a). Carfentrazone and sodium chlorate are also herbicides used as harvest aids that are frequently applied in combination with paraquat for effective weed desiccation (Ellis et al. 1998; Griffin et al. 2003; Griffin et al. 2004)

In addition to weed desiccation, harvest aids have become an important soybean production practice in Louisiana to help desiccate the crop and expedite harvest. When harvest was delayed out to 42 days, soybean yield loss at a rate of 0.2% each day has been observed (Philbrook and Oplinger 1989). Soybean plants in the mid-south can retain green leaves, stems, and pods (green bean malady) on mature plants prior to harvest and has been linked to stink bug injury (Boethel et al. 2000). Additionally, it has been reported that soybean plants retain green leaves longer following foliar fungicide application (Padgett et al. 2003; Potter 2005).

Application of a harvest aid such as paraquat leads to rapid leaf desiccation and improved harvest efficiency; further, one study showed that a properly timed harvest aid applied at 7% yellow pod resulted in 19 to 22% yield reduction, (Wilson and Smith 2002) while another study indicated that application at 50% yellow pod did not reduce yield (Ratnayake and Shaw 1992b). Previous research in Louisiana reported that maturity group (MG) IV soybean can be safely desiccated with paraquat when seed moisture from the upper four main stem nodes averaged 50%, which corresponded to approximately 115 days after Mid-April to Mid-May planting date (Boudreaux et al. 2007; Boudreaux and Griffin 2008). Soybean was harvested 14 days earlier than those receiving no paraquat. For a determinate MG V variety, 40% moisture was considered safe and corresponded to 125 days after Mid-May planting date. This allowed 7 to 8 days expedited harvest. Expedited harvest can allow producers to take advantage of premium prices because of earlier deliveries to the grain elevator.

Previous research has shown the effectiveness of harvest aids to increase soybean harvest efficiency through weed and soybean desiccation. This research has focused on efficiency and yield impacts. The current research focuses on the impact of harvest aids on mitigating impacts of factors such as delayed harvest and less-than-optimum environmental conditions that may negatively affect seed quality.

3.2. Materials and Methods

Field Study. An experiment was conducted at the LSU AgCenter Northeast Research Station, near St. Joseph, LA in 2019 and repeated twice in 2020 to evaluate the impact of harvest aids on mitigating delayed harvest and environmental effects on soybean seed quality. In both years, experiments were conducted in a randomized complete block design with a factorial arrangement of harvest aids and harvest timings. Soybean variety AG 46X6 was planted into a Commerce silt loam soil on May 3 in 2019, while varieties P46A86 and AG46X6 were planted at separate locations into a Commerce silt loam soil on May 7 in 2020. In 2019, harvest aid treatments consisted of no harvest aid, paraquat at 10.7 oz/A, or sodium chlorate at 4.8 qt/A, while in 2020 salflufenacil was added at 2 oz/A. Plots were maintained free from weed and insect impacts utilizing normal recommended production practices (Josh Copes, Personal communication). Fungicide applications were not included in management decisions so as not to confound seed quality impact from pathogens. Harvest aids were applied at the R6.5 – 7 growth stage. The middle two rows of each four row 45 ft plot were machine harvested at 13% seed moisture on October 3 (optimum) and 23 (delayed harvest (DH) 1) and November 4 (DH2) and 18 (DH3) in 2019 and September 19 (optimum), October 7 (DH1) and 16 (DH2), and November 2 (DH3) in 2020.

Seed quality ratings (SQ) were conducted in 2019 utilizing a 100 seed sub sample and a rating scale of 1 to 10 with 1 being seed in good condition and 10 seed in poor condition based on USDA reference images (USDA 2016). In 2020, two SQ ratings were utilized, one as described in 2019 (SQ1) and one with a 0.5 cup subsample using the same rating scale (SQ2). Weather related issues such as mold or heat damage were considered for seed quality ratings.

Stink bug and purple stain damaged were recorded but not considered for seed quality rating, unless they were weathered damages also.

All data were subjected to an ANOVA using the PROC GLM procedure in the statistical software SAS 9.4 (SAS Institute, Cary NC) with means separated following Tukey post-hoc procedure at $\alpha = 0.05$. Fixed effects were harvest aid treatment and harvest timing and year and location considered random effects.

Growth Chamber Study. A separate experiment evaluated the impact of harvest aids on mitigation of seed quality issues under varying controlled simulated environments in growth chambers. The experiments were conducted in a randomized complete block design with a factorial arrangement of harvest aid, simulated environment, and length of seedpod exposure. Field method details prior to harvest were the same as previously described in the field study except for a single harvest of soybean variety AG 46X6. At the R8 growth stage, soybean plants were removed from the center two rows of each plot. Ten pods were collected for each harvest aid treatment and placed on plastic trays. In 2019, pods were placed in environmentally controlled growth chambers at 79 or 90 °F with 30 or 100% relative humidity (RH) and exposed for 24, 48, 72, or 96 hours. In 2020, seed pods were exposed to the same environments replicated three times with exposure times of 48, 96, or 144 hours. After exposure time was complete, seedpods were hand shelled and SQ ratings were determined in a similar manner to that described in the previous study using a 30 seed subsample. Weather related issues such as mold or heat damage were considered for seed quality ratings. Stink bug damaged and purple stained seed were recorded but not considered for seed quality ratings unless they also were weather damaged.

All data were subjected to an ANOVA using the PROC GLM procedure in the statistical software SAS 9.4 (SAS Institute, Cary NC) with means separated following Tukey post-hoc procedure at $\alpha = 0.05$. Fixed effects were harvest aid treatment, environment, and exposure time while year was considered a random effect.

3.3 Results and Discussion

Field Study. For the 2019 and 2020 field experiments, a significant harvest time effect was noted with respect to yield and seed quality. In 2019, averaged across harvest aid treatments, a significant stepwise reduction in soybean yield was observed for each harvest timing delay from 54 down to 49 bu/A (Table 9). Equivalent seed quality ratings of 2 to 2.2 were observed for the optimum and first two DH timings and increased to 5.5 for the latest harvest timing. In 2020, electronic soybean yield data was lost for the two latest DH timings at both locations (Table 9). At location one, yield was similar for the optimum timing and DH1 (59 and 58 bu/A) while in location two, DH reduced yield 9.9% (71 to 64 bu/A). Greatest seed quality was observed with both SQ ratings at location one (1 – 2.1) and location two (1 – 1.5) at the optimum harvest timing. Seed quality ratings for DH 1 ranged from 1 to 3 for all methods and locations and was higher (poorer seed quality) than that for the optimum timing for both methods in location one but not two. The two latest harvest timings resulted in similar poor seed quality with ratings ranging from 7.2 to 9 for location one and 3.5 to 4.0 for location two across both rating methods.

Table 3.1. Impact of delayed harvest on soybean yield and seed quality near St. Joseph, LA in 2019 and 2020.

Harvest Timing ^{bcd}	2019		Location 1			Location 2		
	Yield ^a	SQ ^a	2020			Yield	SQ1 ^a	SQ2 ^a
			Yield ^a	SQ1 ^a	SQ2 ^a			
Optimum	54 a	2.0 b	59 a	1.0 c	2.1 d	71 a	1.0 b	1.5 b
DH 1	52 b	2.0 b	58 a	1.9 b	3.0 c	64 b	1.0 b	1.0 c
DH 2	50 c	2.2 b	-	8.8 a	7.2 b	-	3.8 a	4.0 a
DH 3	49 d	5.5 a	-	9.0 a	8.0 a	-	3.5 a	3.8 a

^aMeans in a column followed by the same letter are not significantly different using Tukey's mean separation test ($P < 0.05$). SQ1: seed quality ratings based on 100 seed sample using a 1 to 10 scale with 1 being seed in good condition and 10 poor condition based on USDA reference images. SQ 2: Seed quality ratings based on 0.5 cup seed sample using a 1 to 10 scale with 1 being seed in good condition and 10 poor condition based on USDA reference images.

^bMeans are averaged across harvest aid treatments of none, paraquat (16 oz/A for 2019 and 10.7 oz/A for 2020), sodium chlorate at 4.8 qt/A, and all of these plus salflunacil at 2 oz/A in 2020.

^cHarvest Timings: October 3(optimum) and 23(DH1) and November 4 (DH2) and 18 (DH3) in 2019 and September 19 (optimum), October 7 (DH1)and 16 (DH2), and November 2(DH3) in 2020.

^dAbbreviation: DH: delayed harvest.

For the 2019 growth chamber study, a significant environment by seedpod exposure time interaction was observed. At the 24-hour exposure time seed quality ranged from 1.16 to 1.8 and was similar for all environments (Table 10). At 48 hours a poor seed quality rating of 6.6 was noted for environment three which was greater than seed quality ratings for all other environments (1 to 1.8). At the 72- and 96-hour exposure times, samples from environment three were accidentally discarded. At 72 hours, equal seed quality from 1 to 2.6 was observed for all environmental conditions. At 96 hours, the longest exposure time poorest seed quality was observed for environment four (8.6 vs 1 to 1.1). Increased exposure time did not reduce seed quality at the lower RH environments. Of interest was that seed quality deteriorated at the 48-hour exposure time in the lower temperature 100% RH environment but at the 96 hour time for the 90 ° temperature at the same RH.

Table 3.2. Impact of environment and seedpod exposure time following harvest aid application in 2019.

Environment ^c	Seed Quality ^{ab}			
	24 hr	48 hr	72 hr	96 hr
1	1.16 c	1.0 c	1.0 c	1.0 c
2	1.16 c	1.8c	1.1 c	1.1 c
3	1.8 c	6.6 b	-	-
4	1.5 c	1.3 c	2.6 c	8.6 a

^aMeans in a column followed by the same letter are not significantly different using Tukey’s mean separation test ($P < 0.05$). Seed quality rating using a 1 to 10 scale, 1 being seed in good condition and 10 seed in poor condition using a 30 seed subsample and visual USDA reference images.

^bMeans averaged across harvest aid treatments of none, paraquat at 10.7 oz/A, and sodium chlorate at 4.8 qt/A.

^cEnvironment: 1 (79 °F, 30% relative humidity (RH)), 2 (90 °F, 30% RH), 3 (79 °F, 100% RH), 4 (90 °F, 100% RH).

In 2020, a significant interaction of all factors was observed. With both low humidity environments good seed quality ratings of 1 to 1.6 were observed for all harvest aid treatments and seed pod exposure times (Table 11). For environment three and four at the 96-hour exposure time, seed quality was poor ranging from 3.6 to 8.3 with the vast majority ranging from 6 to 8.3 and only minor differences noted. At the longest exposure time, poor seed quality ranging from 8.6 to 10 was observed for all harvest aid treatments and conditions of 100% RH (environments three and four).

Table 3.3. Impact of environment, harvest aid treatment, and seedpod exposure time interaction on seed quality in 2020.

Environment ^b	Harvest Aid ^c	Seed Quality ^a		
		48 hr	96 hr	144 hr
1	Non-Treated	1.0 e	1.0 e	1.0 e
	Paraquat	1.0 e	1.0 e	1.0 e
	Salflunacil	1.0 e	1.0 e	1.0 e
	Sodium Chlorate	1.0 e	1.3 e	1.0 e
2	Non-Treated	1.6 e	1.0 e	1.3 e
	Paraquat	1.0 e	1.0 e	1.0 e
	Salflunacil	1.3 e	1.0 e	1.0 e
	Sodium Chlorate	1.0 e	1.3 e	1.3 e
3	Non-Treated	1.3 e	3.6 dc	10.0 a
	Paraquat	1.3 e	6.6 b	9.6 a
	Salflunacil	1.0 e	8.3 a	9.3 a
	Sodium Chlorate	1.0 e	6.3 b	9.0 a
4	Non-Treated	1.0 e	6.0 bc	10.0 a
	Paraquat	1.0 e	7.0 ab	8.6 a
	Salflunacil	1.0 e	7.3 ab	9.3 a
	Sodium Chlorate	1.0 e	4.0 c	10.0 a

^aMeans in a column followed by the same letter are not significantly different using Tukey's mean separation test ($P < 0.05$). Seed quality rating using a 1 to 10 scale, 1 being seed in good condition and 10 seed in poor condition using a 30 seed subsample and visual USDA reference images.

^bEnvironment: 1 (79 °F – 30% relative humidity(RH)), 2 (90 °F – 30% RH), 3 (79 °F - 100% RH), 4 (90 °F – 100% RH).

^cParaquat at 10.7 oz/A, salflunacil at 2 oz/A, and sodium chlorate at 4.8 qt/A.

At the 48-hour exposure time, good seed quality ranging from 1 to 1.6 was observed for all harvest aid treatments and environments (Table 3). For both the 96- and 144-hour exposure times, for all harvest aid treatments seed quality was better at 30 (1 to 1.3) vs 100% RH (3.6 to 10, with the vast majority ranging from 6 to 10. In no instance did application of harvest aid result in better seed quality.

Our results indicate that delayed harvest past approximately 20 days beyond optimum (seed at 13% moisture) can result in reduced seed quality regardless of harvest aid application. In addition, plant exposure to high RH conditions for as little as 48 hours after optimum harvest timing can result in severe seed quality issues regardless of harvest aid used.

CHAPTER 4. Influence of Fungicide on Seed Quality Impact from Delayed Harvest and Environment

4.1. Introduction

Over the past decade in the U.S., there has been a trend for utilizing fungicide seed treatments in soybean, however, some questions continue as to whether it is economically advantageous (Hershman 2011). Producers sometimes choose not to utilize fungicide treated seed thinking planting with high quality seed in sufficiently warm soils (60F or above) will minimize fungal infection. Research has found, however, that soybean seed treated with fungicide can be beneficial in the following situations: planting in Mid-April to Early-May, planting in minimum till fields or poorly drained fields and/or fields where *Phytophthora* has been a problem, planting in soil types prone to crusting, flooding, and/or compaction, when low seeding rates are used, and when seed germination is moderate or unknown (LSU AgCenter 2020; Hershman 2011).

Application of foliar fungicides has increased in the U.S. as a means of maximizing yield in addition to protecting seed quality (Hershman et al. 2011). Application timing is a critical factor because both fungi and plants have life/growth stages that could affect fungicide efficacy. Pathogens that affect leaves reduce photosynthesis by reducing green leaf area leading to increased disease infection (Bassanezi et al. 2001). In soybean, fungicide application usually is recommended at early R3 growth stage (Hershman et al. 2011). Fungicides that are broad-spectrum have become more popular due to their benefits such as optimizing processes in the plant, improved host plant tolerance to the environment, uniform seed size and better seed quality, improved plant utilization of nitrogen and photosynthesis, and increased plant defenses (Padgett et al. 2011).

How a soybean plant will respond to a foliar fungicide depends on many factors such as environmental conditions, the susceptibility of the host regarding the pathogen, and the effectiveness of the product. Before applying any foliar fungicide it is important to monitor and correctly identify the disease and pathogen (Dekalb 2019). Research has shown that foliar fungicide application not only benefits disease management but can also improve yield. Pioneer research conducted from 2007 to 2014 both on-farm and in small-plot research to understand the potential of using foliar fungicides in soybean alone or co-applied with an insecticide found that a broad spectrum fungicide with or without insecticide applied at R3 resulted in higher yield response (Jeschke & Ahlers 2008). In Ohio it was reported that one application of fungicide increased yield significantly, however, environmental conditions and insect pressure can affect foliar fungicide efficacy (Dorrance et al. 2011). Other research has shown that foliar fungicides do not impact yield (Swoboda and Pedersen 2009; Hershman et al. 2011). In addition, it has been reported that use of foliar fungicide can lead to soybean plants getting more green beans and impacting harvest (Hershman et al. 2011; Padgett et al. 2003; Potter 2005).

Previous research has identified fungicides that can preserve soybean yields in the presence of yield-limiting diseases in growing regions similar to Louisiana. Little to no research has reported on impact of abiotic factors like fungicide application, harvest timings, and environmental conditions on seed quality. The current research is focused on these potential impacts on seed quality.

4.2. Materials and Methods

Field Study. An experiment was conducted at the LSU AgCenter Northeast Research Station, near St. Joseph, LA in 2019 and repeated twice in 2020 to evaluate the impact of fungicides on mitigating environmental effects on soybean seed quality at harvest. In both years, experiments were conducted in a randomized complete block design with a factorial arrangement of fungicide treatments and harvest timings. Soybean variety AG 46X6 was planted into a Commerce silt loam soil on May 3 in 2019 while varieties P46A86 and AG46X6 were planted at separate locations into a Commerce silt loam soil on May 7 in 2020.

In 2019, fungicide treatments consisted of no fungicide, pydiflumetofen plus difenoconazole at 13.7 oz/A (Miravis[®] Top) at R6 growth stage, and pydiflumetofen plus difenoconazole at 13.7 oz/A co-applied with paraquat at 16 oz/A at R6.5 – 7 growth stage, while in 2020 pydiflumetofen plus difenoconazole at 13.7 oz/A only at R6 changed to R6.5 and two treatments were added: pydiflumetofen plus difenoconazole at 13.7 oz/A at R3 or R3 followed by R6.5 growth stages. Paraquat at 16 oz/A was applied at the R6.5 – 7 growth stage to the no fungicide and pydiflumetofen plus difenoconazole alone plots both years. In 2020, soybean variety AG46X6 received pydiflumetofen plus difenoconazole at 13.7 oz/A and 10.7 oz/A of paraquat as the fungicide alone or plus harvest aid treatments, while variety P46A86 was treated with mefentrifluconazole plus pyraclostrobin plus fluxapyroxad at 8 oz/A (Revytek[™]) and paraquat at 10.7 oz/A as the fungicide alone or plus harvest aid treatments. The middle two rows of each four row 45 ft plot were machine harvested at 13% seed moisture on October 3 (optimum) and 23 (delayed harvest (DH) 1) and November 4 (DH2) and 18 (DH3) in 2019 and September 19 (optimum), October 7 (DH1) and 16 (DH2), and November 2 (DH3) in 2020.

Seed quality ratings (SQ) were conducted in 2019 utilizing a 100 seed sub sample and a rating scale of 1 to 10 with 1 being seed in good condition and 10 seed in poor condition based on USDA reference images (USDA 2016). In 2020, two SQ ratings were utilized, one as described in 2019 (SQ2) and one with a 0.5 cup subsample using the same rating scale (SQ2). Weather related issues such as mold or heat damage were considered for seed quality ratings. Stink bug and purple stain damaged were recorded but not considered for seed quality rating, unless they were weathered damages also.

All data were subjected to an ANOVA using the PROC GLM procedure in the statistical software SAS 9.4 (SAS Institute, Cary NC) with means separated following Tukey post-hoc procedure at $\alpha = 0.05$. Fixed effects were fungicide treatment and harvest timing while year and location were considered random effects.

Growth Chamber Study. A separate study evaluated the impact of fungicides on mitigating seed quality issues under varying controlled environments in growth chambers. The experiments were conducted in a randomized complete block design with a factorial arrangement of fungicides treatments, environments, and length of seedpod exposure. Field method details were the same prior to harvest as previously described in the field study except for a single harvest date of soybean variety AG 46X6. At the R8 growth stage, soybean plants were removed from the center two rows of each plot. Ten pods were collected for each fungicide treatment and placed on plastic trays. In 2019, pods were placed in environmentally controlled growth chambers at 79 or 90 F with 30 or 100% relative humidity (RH) and exposed for 24, 48, 72, or 96 hours. In 2020, seed pods were exposed to the same environmental conditions and replicated three times with exposure times of 48, 96, or 144 hours. SQ ratings were determined in a similar manner to that described in the previous study using 30 seed sample. Weather related issues such

as mold or heat damage were considered for seed quality ratings. Stink bug and purple stain damaged were recorded but not considered for seed quality rating, unless they were weathered damages also.

All data were subjected to an ANOVA using the PROC GLM procedure in the statistical software SAS 9.4 (SAS Institute, Cary NC) with means separated following Tukey's post-hoc procedure at $\alpha = 0.05$. Fixed effects were fungicide treatment, environment, and seedpod exposure time while year was considered a random effect.

4.3 Results and Discussion

Field Study. In both 2019 and 2020, a significant harvest timing effect was noted. Averaged across fungicide treatments in 2019, a significant stepwise reduction in yield was observed as harvest was delayed (54 down to 49 bu/A) (Table 12). Seed quality for the optimum harvest timing, DH1, and DH 2 timings was equivalent (2) and greater than the 5.0 observed at the latest harvest timing. In 2020, electronic yield data for DH1 and DH3 at both field locations was lost. Averaged across fungicide treatments, yield in location one was similar among optimum harvest timing and DH 1 (62 vs 59 bu/A) while in location two, harvest delay resulted in a 9.1% yield reduction (Table 12). Seed quality ratings were similarly good for the optimum timing and DH 1 in both locations for both seed quality rating methods (1.0 to 2.4) (Table 12). Seed quality of the two latest delayed harvest timings was significantly decreased at location one (7.1 to 8.1) and two (3.7 – 4.5) in comparison to DH 1 and optimum timing regardless of rating method.

Table 4.1. Impact of harvest timings on soybean seed quality near St. Joseph, LA in 2019 and 2020.

Harvest Timings ^{bcd}	2019		Location 1			Location 2		
	Yield ^a	SQ ^a	2020			Yield ^a	SQ 1 ^a	SQ 2 ^a
			Yield ^a	SQ 1 ^a	SQ 2 ^a			
Optimum	54 a	2.0 a	62 a	1.0 b	1.2 c	66 a	1.0 b	1.3 c
DH1	53 b	2.0 a	59 a	1.5 b	2.4 b	60 b	1.0 b	1.3 c
DH2	50 c	2.0 a		8.1 a	7.1 a		4.0 a	4.5 a
DH3	49 d	5.0 b		8.0 a	7.6 a		3.7 a	3.9 b

^aMeans in a column followed by the same letter are not significantly different using Tukey's mean separation test ($P < 0.05$). SQ1: seed quality ratings based on 100 seed sample using a 1 to 10 scale with 1 being seed in good condition and 10 poor condition based on USDA reference images. SQ 2: Seed quality ratings based on 0.5 cup seed sample using a 1 to 10 scale with 1 being seed in good condition and 10 poor condition based on USDA reference images.

^bMeans are averaged across fungicide treatment: no fungicide, pydiflumetofen plus difenoconazole at 13.7 oz/A at R6 growth stage, and pydiflumetofen plus difenoconazole at 13.7 oz/A co-applied with paraquat at 16 oz/A at R6.5 – 7 growth stage in 2019, no fungicide, mefentrifluconazole plus pyraclostrobin plus fluxapyroxad at 8 oz/A at R3, R6.5, or R3 followed by R6.5 growth stage, and mefentrifluconazole plus pyraclostrobin plus fluxapyroxad at 8 oz/A plus paraquat 10.7 oz/A at R6.5 at location one in 2020, no fungicide, pydiflumetofen plus difenoconazole at 13.7 oz/A at R3, R6.5, or R3 followed by R6.5 growth stage, and pydiflumetofen plus difenoconazole at 13.7 oz/A plus paraquat at 10.7 oz/A at R6.5 at location two in 2020.

^cHarvest Timings: October 3(optimum) and 23(DH1) and November 4 (DH2) and 18 (DH3) in 2019 and September 19 (optimum), October 7 (DH1)and 16 (DH2), and November 2(DH3) in 2020.

^dAbbreviation: DH: delayed harvest.

Growth Chamber Study. In 2019, a significant interaction of all factors was observed. For all seedpod exposure timings, seed quality ratings ranged from 1.0 to 1.5 for environment one and two with no differences among fungicide treatments (Table 13). For environment three at the lower temperature, samples from the growth chamber for the 72- and 96-hour exposure timings were accidentally discarded, as was the no fungicide treatment at the 48 hour exposure time. For the 24-hour exposure time, seed quality rating was good (1.0 to 2.0) and similar in all environments. At the 48-hour exposure time, seed quality was similar for pydyflumetofen alone

in environment three and in combination with paraquat in environment 4 (3 vs 3.5) and lower than all other treatments regardless of environment (1 to 1.5). At the two longest exposure timings, poor seed quality of 3.5 to 10 was observed, respectively, and was worse than low humidity environments (1 to 1.5). In no instance did fungicide application result in a positive impact on seed quality.

Table 4.2. Impact of environment and seedpod exposure times on soybean seed quality following harvest aid application in 2019.

Environment ^b	Fungicide ^c	Seed Quality ^a			
		24 hr	48 hr	72 hr	96 hr
1	No Fungicide	1.0 d	1.0 d	1.0 d	1.0 d
	Pydiflumetofen plus difenoconazole	1.0 d	1.0 d	1.0 d	1.0 d
	Pydiflumetofen plus difenoconazole with Desiccant	1.0 d	1.0 d	1.0 d	1.0 d
2	No Fungicide	1.0 d	1.0 d	1.0 d	1.0 d
	Pydiflumetofen plus difenoconazole	1.5 d	1.0 d	1.0 d	1.5 d
	Pydiflumetofen plus difenoconazole with Desiccant	1.5 d	1.5 d	1.0 d	1.0 d
3	No Fungicide	2 d	-	-	7.0 b
	Pydiflumetofen plus difenoconazole	1.5 d	3 c	-	-
	Pydiflumetofen plus difenoconazole with Desiccant	1.0 d	1.5 d	-	-
4	No Fungicide	1.1 d	1.0 d	3.5 c	7.5 b
	Pydiflumetofen plus difenoconazole	1.0 d	1.0 d	5.0 c	10.0 a
	Pydiflumetofen plus difenoconazole with Desiccant	1.0 d	3.5 c	5.0 c	9.0 a

^aMeans in a column followed by the same letter are not significantly different using Tukey's mean separation test ($P < 0.05$). Seed quality rating using a 1 – 10 scale, 1 being seed in good condition and 10 seed in poor condition using a 30 seed subsample and visual USDA reference images.

^bControlled environments: 1 (79 F – 30% relative humidity(RH)), 2 (90 F – 30% RH), 3 (79% - 100% RH), 4 (90 F – 100% RH).

^cNo fungicide, pydiflumetofen plus difenoconazole at 13.7 oz/A at R6 growth stage, and pydiflumetofen plus difenoconazole at 13.7 oz/A or co-applied with paraquat at 16 oz/A at R6.5 – 7 growth stage.

In 2020, an environment by seedpod exposure time interaction was the only significance noted. At the shortest exposure time, equivalent seed quality ratings of 1.0 to 1.2 was observed

for all environments when averaged across fungicide treatments (Table 14). At both the 96- and 144-hour exposure times, seed quality was significantly worse in environment three and four (4.9 and 5.2, and 8.9 and 9.2, respectively) than environment one and two (1.0 and 1.0, and 1.0 and 1.1, respectively). Length of exposure time had no impact on seed quality at the lowest RH environments (1 to 1.2). At the highest RH environments, however, a stepwise decrease in seed quality from 1.0 to 8.9 and 1.0 to 9.2 was observed as exposure time was increase from 48 to 96 to 144 hours.

Table 4.3. Impact of environment and seedpod exposure time in seed quality in 2020.

Environment ^c	Seed Quality ^{ab}		
	48 hr	96 hr	144 hr
1	1.1 c	1.0 c	1.0 c
2	1.2 c	1.0 c	1.1 c
3	1.0 c	4.9 b	8.9 a
4	1.0 c	5.2 b	9.2 a

^aMeans in a column followed by the same letter are not significantly different using Tukey’s mean separation test ($P < 0.05$). Seed quality rating using a 1 – 10 scale, 1 being seed in good condition and 10 seed in poor condition using a 30 seed subsample and visual USDA reference images.

^bMeans averaged across fungicide treatments of no fungicide, pydiflumetofen plus difenoconazole at 13.7 oz/A at R3, R6.5, or R3 followed by R6.5 growth stage, and pydiflumetofen plus difenoconazole at 13.7 oz/A plus paraquat at 10.7 oz/A at R6.5.

^cEnvironment: 1 (79 F, 30% relative humidity (RH)), 2 (90 F, 30% RH), 3 (79F, 100% RH), 4 (90 F, 100% RH).

Overall results indicate that foliar fungicide application has no impact on minimizing seed quality issues in the absence of disease. Benefits from fungicide application may have been more pronounced with significant disease pressure. Delaying harvest beyond 20 days under natural conditions or 4 days in saturated environment conditions can result in significantly reduced seed quality.

CHAPTER 5. Summary and Conclusion

Research was conducted from 2018 to 2020 at the LSU AgCenter Northeast Research Station (NERS) near Saint Joseph, LA, to evaluate soybean planting date effects on soybean yield and seed quality (SQ). In addition, research was also conducted in 2019 and 2020 to evaluate the impact of soybean maturity group (MG) and harvest timing on soybean seed quality.

Our results indicate that planting MG IV and V soybean varieties between Mid-April and Mid-May can maximize yield in Louisiana. Later planting did not result in maximum yield. Delayed harvest timing resulted in a 25 to 50% decrease in seed quality rating depending on year and location. Our results indicate that greatest soybean quality can be obtained when planting MG 5.4 – 6.0 soybean, however, as indicated in the planting date study, in the current research yield would not be maximized. Planting MG 3.0 – 4.4 soybean varieties in Louisiana can result in less than optimal seed quality. Soybean in MG 4.5 – 5.3 can result in acceptable seed quality while also maximizing yield.

An experiment was conducted at the LSU AgCenter Northeast Research Station, near St. Joseph, La. in 2019 and repeated twice in 2020 to evaluate the impact of harvest aids and foliar fungicides application on mitigating delayed harvest (DH) and environment effects on soybean seed quality at harvest. A separate experiment evaluated the impact of harvest aids on mitigation of seed quality issues under varying controlled simulated environments in growth chambers.

Overall results indicate that harvest aids and foliar fungicide application has no impact on minimizing seed quality issues. Delaying harvest beyond 20 days in field under natural conditions or 4 days in saturated environment conditions can result in significantly reduced seed quality.

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