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# Inducing Stress Early and Reducing Stress Late to Increase Soybean (Glycine max) Yield

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Gary L. Gregg, Student

Dr. Chad Lee, Major Professor

Dr. Mark Coyne, Director of Graduate Studies

# INDUCING STRESS EARLY AND REDUCING STRESS LATE TO INCREASE SOYBEAN (*Glycine max*) YIELD

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THESIS

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A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture, Food and the Environment
at the University of Kentucky

By

Gary Louis Gregg

Lexington, Kentucky

Director: Dr. Chad Lee, Professor of Extension

Lexington, Kentucky

2015

# ABSTRACT OF THESIS

## Inducing Stress Early and Reducing Stress late to Increase Soybean (*Glycine max*) Yield

Relatively little change in national soybean (*Glycine max*) yield over the previous years have led many farmers to creating management regimes focused on plant stress. Field experiments consisting of two different relative maturity (2.8RM and 4.5 RM) soybean cultivars were established at three locations across Kentucky in 2013 and 2014. Each maturity group received a single application, sequential applications, or a combination of the following treatments: N'N-diformyl urea, lactofen, lambda-cyhalothrin with thiamethoxam, and azoxystrobin with propiconazole. Relative maturity and yield environment*treatment interactions were observed to be significant (p 0≤.05). 4.5 RM soybean cultivars yielded significantly greater (800 kg ha$^{-1}$) than 2.8 RM cultivars. Compared to the untreated check, no treatment in the yield environment*treatment interaction significantly increased yield. Significant yield decrease varied across yield environment, but was observed for treatments containing a combination of lactofen and N'N-diformyl urea. Application of stress management practices was not a consistent approach to improving soybean yield.

KEYWORDS: Soybean Yield, Soybean Quality, Relative Maturity, Yield Environments, Stress Management

Gary Louis Gregg

March 2, 2015

# Inducing Stress Early and Reducing Stress late to Increase Soybean (*Glycine max*) Yield

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# Chapter 1

# Introduction

## 1.1 Soybean Production in Kentucky

Soybean (*Glycine Max)* is an important grain crop for Kentucky Farmers. In 2013, Soybean was number one in harvested area (6.6 x $10^5$ ha) and number two in total value of production ($1.04 billion). Soybean yield in Kentucky has risen from 741 kg $ha^{-1}$ in 1924 to 3221 kg $ha^{-1}$ in 2014, an average increase of 27.5 kg $ha^{-1}$ per year. The average price for soybean over the last ten years (2005-2014) has reached $.38 kg compared to $.215 kg in the previous nine years (1996-2004) (USDA-NASS, 2015). Nationally, approximately half of soybean production is exported, while the other half is used domestically primarily for the production of meal and oil (USDA-WASDE, 2015).

Soybean production in Kentucky is split between two systems: full-season and double-cropping with wheat (*Triticum aestivum*). In a full-season system, soybean planting begins at the end of April and continues until the middle of June. In a double-crop system, soybean planting begins following wheat harvest, around the beginning of June, continuing until the middle of July. The harvest in both systems begins the end of September and continues through the early part of December. Yield of double-crop soybean can be significantly less than yield produced from full-season soybean. It can be expected to see a yield loss in soybean from delaying planting after mid-June of 1.5% per day (Lee et. al, 2007).

## 1.2 Challenges Facing Kentucky Soybean Farmers

Over the previous 90 years, soybean yields in Kentucky have increase 435%, or approximately 4.8% per year. However, in the last ten years (2005-2014) increases in yields have become smaller and have only increased by 1% per year. In addition to the decline in yield increases, the cost of planting soybean has increased 171% in the last ten years, or an increase of 17% per year (Isaacs et al, 2006; Halich, 2015). The combination of declining yield increase and increase in seed cost has lead farmers to question how management practices can be improved to increase yield and profit.

## 1.3 Increases in Soybean Yield

Since 1924, national soybean yield has increased from 714 kg $ha^{-1}$ to 2965 kg $ha^{-1}$, an annual increase of 25 kg $ha^{-1}$. Yield is a function of the interaction between the genetic potential of the crop, the management practices used, and the weather received (Specht, 1990). Specht and Williams (1984) estimated that 50% of the increases (12.5 kg $ha^{-1}$ $yr^{-1}$) in yield has come from genetic gains, while larger genetic gains (22.7 kg $ha^{-1}$ $yr^{-1}$) have been estimated in Wisconsin (Rowntree et al., 2013).

The increase in yield coming from improved management have been a result of (1) optimizing planting date, (2) weed control, (3) row spacing, and (4) harvest efficiency (Specht, 1999). Villamil et al. (2012) estimated that approximately 54% of the variation of soybean yields in Illinois could be explained by management (e.g. planting date, row spacing, and tillage practices) and soil characteristics (e.g. soil pH, soil organic matter, cation exchange capacity, soil test levels for phosphorus (P) and potassium (K)). Planting date research in Iowa showed no difference in yield between late April and early May planting dates, but showed a significant decrease in yield for late May and early June planting dates (De Bruin and Pedersen, 2008a). Elmore (1990) showed similar results in Nebraska where early and mid-May planting dates resulted in similar yields, and were significantly higher yields than mid-June planting dates. In a summary of 28 planting date experiments between 1960 and 2005, Egli and Cornelius (2009) summarized that soybean yield was not increased by April or early-May planting dates, but suffered significant yield loss for planting after 30 May, 27 May, and 7 June in the Midwest, Deep South, and Upper South, respectively. Narrow row spacing (≤76 cm) has shown an increase in yield in the Midwest (De Bruin and Pedersen, 2008b; Elmore, 1998). However, an increase in yield across central and southern soybean growing regions is not always observed with narrower row spacing (Lee, 2006).

## 1.4 Yield Formation

Seed yield is a function of two components: seed number and seed mass. In order to increase yield, it is necessary to increase seed number, increase seed mass, or both. Seed number has been shown to have a higher correlation with total yield than seed size (Egli, 1974). Seed number is a function of post-flowering crop growth rate (CGR) (Jiang 1995). Seed size is determined by the rate and duration of dry matter accumulation in the seed (Egli, 1971). The rate of dry matter accumulation, or CGR, increases linearly with percent solar radiation intercepted. The maximum CGR is reached when the percent of light intercepted has also reached its maximum (Shibles, 1965). The specific growth stage when maximum light interception is necessary to achieve maximum yield is not clearly defined, but previous research shows it is important to achieve maximum light interception during early to mid-reproductive stages of growth (R1 to R5) (Fehr and Calivness, 1971; Lee et. al, 2008).

## 1.5 Fungicide and Insecticide Management

Insect and disease pressure are two late season stresses that can be managed by farmers. In Kentucky, three insect species may reach economically damaging levels before 1 June; eight different species may reach economically damaging populations after 1 July (Johnson et al., 2014). As the average size of grain crop farms continues to increase, farmers are trying to manage more acres in the same amount of time. As a result these changes, some farmers manage insect and disease stress based on plant growth stages instead of using economic thresholds (USDA-ERS, 2013).

Previous research on the effect of insecticide application based on plant growth stage on soybean yield has been mixed. A study in Ohio found that the application of an insecticide increased soybean yield in one year in eight out of nine locations, where soybean aphid (*Aphis glycines*) counts were between 181-3333 insects per plant. The same year, applications of an insecticide also increased soybean seed yields in two out of five locations where soybean aphids were not present. In a separate year, application of insecticide increased yield at one of ten locations, where soybean aphids were not present (Dorrance et al., 2010). In Indiana, application of lambda-cyhalothrin at R4 growth stage of growth increased yield by 5% with insect pressure below the economical threshold. When combined with a fungicide (pryraclostrobin), application of lambda-cyhalothrin increased yield 8-11% (Henry, 2011).

While foliar insecticides have been shown effective to reduce stress associated with insect pressure during the growing season, the use of foliar fungicides has also been proposed to help soybean manage environmental stress during the growing season. In Kentucky, early season disease pressure is limited to about four causal agents, while late season disease pressure can come from thirteen different causal agents. The most prevalent of those is *Circospora sojina*, the causal agent of Frogeye leaf spot (Johnson et al., 2014). The strobilurin family of fungicide is the primary class being marketed for disease control. Strobilurin fungicides have a mode of action that prevents fungal spore germination and are active against a wide range of pathogens (Grossman and Retzlaff, 1997). While these fungicides are effective at managing foliar diseases in soybean, strobilurin fungicides also cause physiological change in soybean that can help the plant deal with environmental stress (Grossman et al., 1999). A recent soybean study in Ontario found that the application of pyraclostrobin delayed soybean maturity, but the effect varied by cultivar (Mahoney et al., 2015).

Responses to the application of foliar fungicides have been mixed. In a study in Ohio, Dorrance et al. (2010) observed yield increases at 6 out of 28 locations after the application of a strobilurin type fungicide where brown spot (*Septoria glycines*) infected 1.6-42% of the leaf area in the lower to mid-canopy and concluded that the economic threshold for fungicide application varied due to yearly fluctuations in soybean prices. A study in Iowa examined the effect of two fungicides, tebuconazole and pyraclostrobin, a strobilurin, on soybean yield and yield components in an environment where disease infected 0-15% of the leaf area. The study found no differences in pod $m^{-2}$, seeds $m^{-2}$, seeds $pod^{-1}$ or seed yield between any treatments and the control and concluded that foliar fungicides should only be applied for disease management in soybean (Swoboda and Pedersen, 2009). Research in Indiana examined the interaction of soybean row spacing and foliar fungicide application and concluded fungicide application did not affect soybean seed yield (Hanna et al., 2008). A study at two locations in Missouri examined the effect of a strobilurin fungicide in conjunction with soil-applied and foliar fertilizers. The application of the strobilurin fungicide at the R4 growth state increased soybean seed yield between 0.23 and 0.36 Mg ha$^{-1}$ at one location but did not affect soybean seed yield at the other location (Nelson et al., 2010). A study in Indiana found that an R4 application of pyraclostrobin increased soybean seed yield by 0.1 Mg ha$^{-1}$. The increase in yield was derived primarily through 3% increase in seed mass (Henry et al., 2011). Similarly, researchers in Ontario found that the application of pyraclostrobin increased soybean seed yield by 4.1% compared to untreated plants when averaged across cultivars, but was generally not profitable due to the cost of fungicide application (Mahoney et al., 2015).

### 1.6 Effect of Lactofen Application on Yield

While much of the focus on in-season stress management has focused on reducing stress caused by environmental factors, it has been hypothesized that early-season stress can be beneficial to soybean yield production. While a number of options exist to subject soybeans to early season stress the most common method that has been proposed in the application of lactofen to soybean during early vegetative growth. Lactofen is a protoporphyringoen oxidase (PPO) herbicide registered for broadleaf weed control in soybean. While it is registered for use in soybean, lactofen causes burning and bronzing of the leaf tissue, leaf necrosis, and eventual leaf death (Wichert and Talber, 1993). Application of lactofen has also been shown to elevate the concentration of antioxidant compounds in the plant, especially glyceollin (Dann, 1999). Additionally, plants treated with lactofen show lower levels of infection by white mold [*Sclerotina* sclerotiorum] (Nelson, 2002; Dann, 1999). Lactofen has shown limited success in increasing soybean yields beyond its use for weed control. In a study in Michigan, Nelson (2002) showed an increase in yield for one of eight cultivars when soybeans were exposed to high pressure from white mold. The majority of published research has shown no effect on grain yield when lactofen is applied to early vegetative soybeans (Dann et al., 1999; Nelson et al., 2002; Harris et al., 1991; Edwards and Purcell, 2005; Wichert and Talbert, 1993).

### 1.7 Effect of Stress Management Products on Yield

In recent years, many products have come to the market claiming to help plants manage environmental stresses. One of these products is the compound N'N-diformyl urea, marketed as Bio-Forge (Stoller USA, Houston, TX). The label states that N'N-diformyl urea protects the plant from damage in response to drought, pesticide injury, nutrient deficiencies, and extreme temperatures (Stoller USA, Houston, TX). Peer-reviewed research about the effect of Bio-Forge on soybean yield has not yet been published. However, a small number of university extension reports outlining the results on independent studies that include Bio-Forge are available. A study at one location in Michigan found that the combination of Bio-Forge applied as a seed treatment plus a foliar application of Bio-Forge at growth stage V4 (Fehr and Caviness, 1971) increased soybean yield by 0.13 Mg $ha^{-1}$ and income by \$22.23 $ha^{-1}$ when compared to an untreated control (Staton, 2013). A study in Ohio evaluated Bio-Forge applied as a seed treatment and a foliar application at growth stage R1 and R 4.5 on both glyphosate resistant and non-GMO soybeans. Yield of soybean treated with the foliar applications were similar to that of the untreated control. However, it should be noted that this study was conducted under ideal environmental conditions, which the authors concluded may have limited the efficacy of products that help plants deal with environmental stress (Yost, et al., 2009). Another study in Ohio found no difference in yields between soybeans treated with a Bio-Forge, plus a foliar fertilizer, with glyphosate to soybean treated with glyphosate only (Bruynis, 2013). Research in Arkansas found an interaction between fertilizer rate and Bio-Forge application. When no fertilizer was applied, there was not a yield response to Bio-Forge, but increased yield when a high rate of fertilizer was applied (Slaton, 2013).

## 1.8 Research Question, Objectives, and Hypothesizes

Research has been conducted on the use of insecticides, fungicides, lactofen, and stress relievers in soybean management. The object of this research is to determine if introducing early season stress, relieving late season environmental stress, or a combination of early season introduction and late season relief of stress, will have an effect on soybean seed yield, seed quality, or soybean morphology. Our hypothesis is if we induce early season stress, relieve late season stress, or a combination, then we will increase soybean yield.

# Chapter 2

# Materials and Methods

## 2.1 Experimental Design

Field studies were established on three sites in Kentucky during 2013 and 2014. Each site was a randomized complete block design (RCBD) with three or four blocks. The sites were located at the Spindletop Research Farm in Lexington, Kentucky (LEX), a private farm near Hodgenville, Kentucky (HODG) and at the University of Kentucky Research and Education Center in Princeton, Kentucky (PRIN). Site description, soil texture, soil class and previous crops are summarized in table 2.1.

## 2.2 Materials

Specific equipment used in this study included a Hege research drill (Hege Equipment Inc. Colwich, KS) for LEX and HODG in 2013, a Wintersteiger DyanmicDisc research plot planter (Wintersteiger Inc. Salt Lake City, UT) for LEX and HODG in 2014, a Lilliston grain drill for PRIN 2013 and a Kinze 2600 planter (Kinze Manufacturing, Williamsburg, IA) for PRIN 2014.

Chemical treatments were applied with a $CO_2$ powered backpack sprayer with a hand boom (R & D Sprayers, Opelousas, LA) equipped with TeeJet XR 11003 nozzles (TeeJet Technologies, Wheaton, IL). The boom was calibrated to deliver 187 l $ha^{-1}$

Images of soybean canopy were captured with a basic digital camera (Canon Powershot, Canon USA, Melville, NY). A Crop Circle (Holland Scientific, Inc. Lincoln, NE) was used to determine plant NDVI. Soybean seed harvest was accomplished with a Wintersteiger Delta plot combine (Wintersteiger Inc. Salt Lake City, UT), equipped with a HarvestMaster weigh system (Juniper Systems, Logan, UT).

## 2.3 Methods

Soybean cultivars of different maturity were used in an attempt to create different climatic conditions during seed fill. Commercial varieties, “Asgrow 2830” (RM 2.8) and “Asgrow 4533” (RM 4.5) were used in 2013 and “Asgrow 2834” (RM 2.8) and “Asgrow 4534” (RM 4.5) were used in 2014. The same varieties were not commercially available for both years; however, RM was consistent across years. Target seeding rate was 309,000 seeds ha$^{-1}$ in 38-cm rows. Harvested plot size at LEX and HODG measured 3 m x 7 m. Plot size at PRN measured 3 m x 6 m.

Soybeans were seeded in either May or June each year (Table 2.2) once the combination of soil conditions and weather were favorable for planting.

In an effort to minimize competition with weeds and not affect soybean growth or canopy development, all sites received glyphosate plus a soil residual combination before planting (Table 2.1). The Hodgenville site differed in the pre-planting combination due to personal preference of the grower-cooperator. Plots were kept weed free with a combination of glyphosate + chloransulam, as well as hand weeding. Treatments were applied at soybean growth stages V2 (2 trifoliate), V4 (4 trifoliate), and R3 (beginning pod) (Fehr and Caviness, 1971) (Table 2.2). The treatments, timing, and rates for the study are included in table 2.3.

Initial stand counts (1 m of row) were taken in the four harvest rows between growth stages V2 and V4. Weekly measurements for light interception and NDVI were ecorded at LEX and HODG. Light interception was estimated from digital imagery of the soybean canopy according to Purcell (2000). Prior to harvest, final plant heights were taken by averaging the height of three randomly selected plants per plot. Final stand counts were taken from the same area as the initial stand counts. Plant lodging was also recorded prior to harvest.

Insect counts were taken prior to application of insecticide at R3 using the "shake cloth" method and a sweep net. Sweeps for insects were taken in the boarders surrounding the plots to prevent canopy damage or pod loss. Disease ratings were taken at growth stage R5.5, just prior to R6 (full seed) (Johnson et al., 2014).

At growth stage R8, all plants in 0.5 m of 1 harvest row were harvested by hand. In 2014, branches and main stems were separated from each other in the field. In 2013, branches and main stems were separated from each other in the lab. The change was implemented in 2014 to help preserve the integrity of the yield components from the stem and branches, respectively. Components that were measured in the lab included plant number, main stem nodes $m^{-2}$, branch nodes $m^{-2}$, main stem pods $m^{-2}$, branch pods $m^{-2}$, main stem seeds $m^{-2}$, branch seeds $m^{-2}$. Main stem seed size (mg $seed^{-1}$) and branch seed size were determined after drying the seed for 48 hours at 70° C then weighing the seed.

The center four soybean rows were harvested and yield was adjusted to 130g $kg^{-1}$ of water, using a test weight of 776 kg $m^{-3}$. Approximately 450 g seed samples were collected from each plot during harvest for analysis of oil and protein concentration.

Three sub-samples were pulled from each 450 g sample and oil and protein concentrations were determined using near infrared spectroscopy (NIR) (Perten DA7200, Perten Instruments, Springfield, IL). NIR regressions for oil and protein were created and validated by Perten Instruments.

## 2.4 Statistical Analysis

The data were analyzed with SAS 9.3 (SAS Institute Inc. Cary, NC). Seed yield and quality were analyzed using PROC MIXED a *P* value of 0.10 and 0.05, repectively. RM, treatment, and Yield Environment were considered fixed effects. Location, Year, and Block were considered random effects. Treatment means were separated from the check using Fisher's protected *t*-test with an alpha value of .10. Estimation of light interception (LI) was analyzed with using PROC MIXED with a REPEATED statement and the autoregressive covariance structure with a *P* value of 0.05. Treatment and Days after Treatment (DAT) were considered fixed effects. Block was considered a random effect. Block*treatment was used as the repeated effect. Differences amount treatments were separated using CONTRAST statements to compare plots with a V2 lactofen application to those plots not receiving a V2 lactofen application.

**Table 2.1.** Description of field sites for 2013 and 2014.

| **Site** | Lexington, Ky | Hodgenville, Ky | Princeton, Ky |
|---|---|---|---|
| **Abbreviation** | LEX | HODG | PRIN |
| **Location (lat, long)** | 38°7’ N, 84°29’W | 37°34’ N, 85°49’W | 37°5’ N, 87°51’W |
| **Soil Class** | Bluegrass-Maury silt loam: Fine, mixed, active, mesic Typic Argiudolls | Nicholson silt loam: Fine-silty, mixed, active, mesic, Ultic Hapludalfs | Crider silt loam: Fine-silty, mixed, active, mesic, Ultic Hapludalfs |
| **Previous Crop, 2013** | Corn (*Zea mays*) | Corn | Corn |
| **Previous Crop, 2014** | Corn | Corn | Corn followed by cover crop wheat |
| **Pre-plant herbicide, 2013** | Glyphosate + sulfentrazone +chloriuron ethyl | Glyphosate + metolachlor + metribuzin + imazethapyr | Glyphosate + sulfentrazone +chloriuron ethyl |
| **Tillage, 2013** | No-till | Minimum till (2 passes with a vertical tillage implement) | No-till |
| **Pre-plant herbicide, 2014** | Glyphosate + sulfentrazone +chloriuron ethyl | Glyphosate + metolachlor + metribuzin + imazethapyr | Glyphosate + sulfentrazone +chloriuron ethyl |
| **Tillage, 2014** | No-till | Minimum till (2 passes with a vertical tillage implement) | No-till |

**Table 2.2**. Planting date and growth stage progression for each experimental site.

| | **Lexington** | | **Hodgenville** | | **Princeton** | |
|---|---|---|---|---|---|---|
| | **2013** | **2014** | **2013** | **2014** | **2013** | **2014** |
| Planting | 16 May | 14 May | 28 May | 4 June | 2 May | 2 June |
| V2 growth stage | 12 Jun | 16 June | 21 June | 25 June | 30 May | 25 June |
| V4 growth stage | 20 Jun | 26 June | 2 July | 2 July | 11 June | -* |
| R3 (2.8RM†) growth stage | 8 July | 14 July | 17 July | 21 July | 1 July | 22 July |
| R3 (4.5RM) growth stage | 15 July | 21 July | 24 July | 1 Aug | 9 July | - |
| Harvest (2.8RM) | 20 Sept | 26 Sept | 24 Sept | 30 Sept | 19 Sept | 23 Oct |
| Harvest (4.5RM) | 21 Oct | 27 Oct | 11 Nov | 14 Nov | 24 Oct | - |

† RM = 2.8 RM includes “Asgrow 2830” and “Asgrow 2834”.
4.5 RM includes cultivars “Asgrow 4533” and “Asgrow 4534”.
* =PRIN, 2014, 4.5 RM was lost due to mechanical issues during planting.

**Table 2.3**. Chemical treatments and timing of application.

| **Treatment†** | **Treatment Type** | **Growth Stage** |
|---|---|---|
| Untreated Check (UTC) | | |
| Lambda-cyhalothrin, 30.81 g a.i. ha$^{-1}$ + Thiamethoxam, 41.31 g a.i. ha$^{-1}$ | Insecticide (I) | R3 |
| Azoxystrobin, 111.25 g a.i. ha$^{-1}$ + Propiconazole, 186.62 g a.i. ha$^{-1}$ | Fungicide (F) | R3 |
| Lambda-cyhalothrin, 30.81 g a.i. ha$^{-1}$ + Thiamethoxam, 41.31 g a.i. ha$^{-1}$ + Azoxystrobin, 111.25 g a.i. ha$^{-1}$ + Propiconazole, 186.62 g a.i. ha$^{-1}$ | I+F | R3 |
| N,N'-diformyl urea , 1.2 L ha$^{-1}$ | Stress reducer (SR) | R3 |
| N,N'-diformyl urea , 1.2 L ha$^{-1}$ + Lambda-cyhalothrin, 30.81 g a.i. ha$^{-1}$ + Thiamethoxam, 41.31 g a.i. ha$^{-1}$ | I+SR | R3 |
| N,N'-diformyl urea , 1.2 L ha$^{-1}$ + Azoxystrobin, 111.25 g a.i. ha$^{-1}$ + Propiconazole, 186.62 g a.i. ha$^{-1}$ | F+SR | R3 |
| N,N'-diformyl urea , 1.2 L ha$^{-1}$ + Azoxystrobin, 111.25 g a.i. ha$^{-1}$ + Propiconazole, 186.62 g a.i. ha$^{-1}$ + Lambda-cyhalothrin, 30.81 g a.i. ha$^{-1}$ + Thiamethoxam, 41.31 g a.i. ha$^{-1}$ | I + F+SR | R3 |
| lactofen , 210 g a.i. ha$^{-1}$ | Herbicide (H) | V2 |
| lactofen , 210 g a.i. ha$^{-1}$ fb N,N'-diformyl urea , 1.2 L ha$^{-1}$ | H fb SR | V2 fb R3 |
| lactofen , 210 g a.i. ha$^{-1}$ fb N,N'-diformyl urea , 1.2 L ha$^{-1}$ fb N,N'-diformyl urea , 1.2 L ha$^{-1}$ | H fb SR fb SR | V2 fb V4 fb R3 |
| N,N'-diformyl urea , 1.2 L ha$^{-1}$ | SR | V2 |
| N,N'-diformyl urea , 1.2 L ha$^{-1}$ fb N,N'-diformyl urea , 1.2 L ha$^{-1}$ | SR fb SR | V2 fb R3 |
| N,N'-diformyl urea , 1.2 L ha$^{-1}$ fb N,N'-diformyl urea , 1.2 L ha$^{-1}$ fb N,N'-diformyl urea , 1.2 L ha$^{-1}$ | SR fb SR fb SR | V2 fb V4 fb R3 |

† + = applied at the same time; fb = followed by.

# Chapter 3

# Results and Discussion

## 3.1 Yield

In 2013 and 2014, weather was favorable for soybean production (Table 3.1). Seed yield ranged between 2291 kg ha$^{-1}$ to 6020 kg ha$^{-1}$, with a study average of 4582 kg ha$^{-1}$. Spring conditions in 2013 and 2014 where ideal and allowed for timely planting. Two maturity groups were used to allow for two separate seed filling environments at each location each year. Lactofen at V2 caused visible plant injury to all exposed leaves and a delay in canopy development. Disease and insect pressure were low for both 2013 and 2014, across both maturity groups. The main effects of relative maturity and treatment did not interact, therefore data for these factors were analyzed independently (Table 3.2).

### 3.1.1 *Relative Maturity*

The 4.5 RM cultivar yielded significantly greater than the 2.8 RM cultivar (17%). (Table 3.3). Maturity group had a significant effect on stem nodes m$^{-2}$, stem pods m$^{-2}$, and stem seeds m$^{-2}$; total nodes m$^{-2}$, total pods m$^{-2}$, and total seeds m$^{-2}$. Branch nodes m$^{-2}$, branch pods m$^{-2}$, and branch seeds m$^{-2}$ and total seed size were not different between relative maturities (Table 3.5). The 4.5 RM cultivar showed an increase in stem nodes m$^{-2}$ of 21%, stem pods m$^{-2}$ of 25%, seeds m$^{-2}$ of 24%, total nodes m$^{-2}$ of 11%, total pods m$^{-2}$ of 15% and total seeds m$^{-2}$ of 28% compared with the 2.8 RM cultivar (Table 3.6).

The increase in yield of the 4.5 RM cultivar was a result of a 28% increase in total seeds per $m^{-2}$. With no difference in seed size, environmental conditions during early reproductive growth (R1-R5) favored higher yield for the 4.5 RM cultivars. A linear correlation ($R^2$=0.82) between seeds per $m^{-2}$ and crop growth rate (CGR) post-flowering has been defined in previous research (Jiang, 1995). The correlation between CGR and seeds per $m^{-2}$ indicates that the 4.5 RM cultivar experienced growing conditions that allowed for faster growth, a higher production of seeds, and higher yield compared with the 2.8 RM cultivar.

Weather conditions during seed fill (R5-R7) showed subtle differences between the 2.8 RM cultivar and 4.5 RM cultivar, but no difference in seed size was observed. The 2.8 RM cultivar experienced higher average daily temperatures (0.8 C in 2013, 1.5 C in 2014) than the 4.5 RM cultivar, and the 2.8 RM cultivar received slightly more rainfall (7.3 mm in 2013, 9.7 mm in 2014) than the 4.5 RM cultivar (Table 3.4). Previous research shows an increase in temperature can lead to a decrease in seed yield (Amani et al., 1995) and a decrease in the length of seed fill duration (Egli, 2004). However, the difference in yield in our study was from seed number and not seed size, indicating conditions during seed fill were not responsible for the difference in yield.

Higher yield potential in the 4.5 RM could be responsible for the increase in yield. However, Egli (1993) has shown under irrigation in Kentucky, early RM cultivars (1 and 3 RM cultivars) have equal yield potential as later RM cultivars (5 RM cultivar). More recently, multiple cultivars ranging from 1 RM to 4 RM have shown equal yield potential under irrigation (Edwards et al., 2003). Prior research under irrigation would indicate that the difference in yield observed in our study is not attributed to increased genetic potential of one maturity group compared with the other, but variations in weather conditions, specifically rainfall amounts and distribution, experienced during reproductive growth between the cultivars.

The difference in growth patterns of the maturity groups resulted in an increase in stem nodes m$^{-2}$. The 4.5RM cultivar had a longer period of vegetative growth (Emergence-R5) compared with the 2.8 RM cultivar. These results are similar to previous research which also has shown an increase in duration of vegetative growth resulting in more stem nodes m$^{-2}$ for later maturing varieties (Egli, 1993).

### 3.1.2 *Treatment*

Treatment did not have a significant effect on seed yield (Table 3.2). Treatment also did not have a significant effect on yield components (Table 3.5). Lactofen at V2 resulted in a reduction of percent light interception (LI) between 2 and 27% seven DAT. In 2013, LI was less for lactofen treatments until 31 DAT for HODG and until 50 DAT at LEX. In 2014, LI was less for lactofen treatments until 15 DAT for HODG, but LI was not affected at LEX (Figure 3.1).

Inducing early season stress with a V2 application of lactofen did not lead to a yield increase. No yield response was observed with an application of lactofen because there were no differences in yield components. Application of lactofen did not result in an increase in branch nodes m$^{-2}$, branch pods m$^{-2}$, or branch seeds m$^{-2}$.

The application of lactofen at V2 did not lead to a yield decrease. Soybean treated with lactofen reached equal LI to untreated plots by R3 at all sites, except for LEX in 2013. NDVI from growth stage R5 was not different among treatments, indicating treated and not treated soybean had reach equal LI. (data not shown). In 2013, the 2.8 RM reached R3 by 26 DAT at both LEX and HODG; the 4.5 RM reached R3 by 33 DAT at both HODG and LEX. In 2014, the 2.8 RM reached R3 by 26 and 28 DAT at HODG and LEX, respectively; the 4.5 RM reached R3 by 37 and 35 DAT at HODG and LEX, respectively (Figure 3.1). LI has shown a strong linear correlation to yield at growth stages R1 and R5, (Lee et al., 2008; Board et al. 2004). Lee et al. (2008) showed that at R1, a linear correlation between yield and LI did not hold true for all cultivars. Lee et al. (2008) determined if LI approached 90% at R1 and reached 95% by R5, maximum yield would result. The 2013 Lexington site was the only site not to reach equal canopy closure of all treatments by R3, but equal canopy closure was reached by R5. Even though lactofen treatments did not have LI equal to the non-treated plots at R1, they still had similar yields. These results for lactofen application during early vegetative growth are similar to previous research showing no yield differences (Edwards and Purcell, 2005; Wichert and Talber, 1993; Harris et al., 1991; Nelson, 2002). Delay in canopy development could be more influential on yield in shorter season varieties because they reach reproductive growth quicker. However, previous research by Edwards and Purcell (2005) found similar results in an ultra-short-season production system where yield in short-season cultivars was not reduced by lactofen application during early vegetative growth.

Attempting to relieve plant stress by applying a purported stress reliever at V4 and R3, or R3 alone following lactofen at V2 did not significantly increase seed yield above the V2 lactofen treatment or the UTC. An application of a purported stress reliever at V4 did not lead to an increase in LI, nor did it result in achieving canopy closure at an earlier date compared to the V2 lactofen treatments. By the time of the R3 application of a stress reliever, equal canopy closure was reached at all sites, except Lexington in 2013.

Application of an insecticide, fungicide, or a combination also did not affect yield. Insect and disease ratings were not significantly different among the maturity groups (data not shown). Green cloverworm (*Hypena scabra*) was present at a level of 0.82-3.28 insects per m row and green stink bug (*Acrosternum hilare*) was present at a level of 1 bug per 25 sweeps. These levels of disease pressure are below threshold levels in Kentucky (Johnson et al., 2014). Brown spot and downy mildew (*Peronospora manshurica*) were present, but infected less than 10% of the total leaf area.

Our results are similar to previous studies on fungicide effects with similarly disease pressure and pathogens (Swombode and Pedersen, 2009; Hanna et al., 2008; Nelson et al., 2010). Our research does not show a yield increase when using a fungicide with low levels of disease pressure. Additionally, combining a purported stress reliever with fungicide did not result in a yield difference.

The application of an insecticide did not have an effect on soybean yield. Insect pressure was almost non-existent and well below threshold limits. In the absence of insect pressure, insecticide applications do not appear to have any physiological effects that would lead to an increase in soybean yield. Applying a purported stress reliever with an insecticide did not lead to an increase in yield. A response to insecticide when insect pressure is below economic threshold level has been previously reported (Henry et al., 2011; Dorrance et al., 2010). The economic threshold level for insect pressure is an indicator of when application of an insecticide will yield an economic benefit, not the level of pest pressure needed to see a yield response for an application of an insecticide.

A combined application of an insecticide and a fungicide did not have an effect on yield. While neither insect nor disease pressure was high enough to induce a response from individual applications of insecticide or fungicide, the combined pressure from low levels of insect and disease was still not high enough to trigger a response from using control practices. Adding a purported stress reliever to the combination of an insecticide and fungicide did not have any additional effect on yield.

Single application of a claimed stress reliever or sequential applications of a stress reliever were unsuccessful in significantly increasing yield. Both 2013 and 2014 were relatively low stress years, with lower seasonal temperatures and adequate to near-adequate rainfall. Additionally, combining a stress reliever with an insecticide, fungicide, or both did not have any effect on yield. In 2012, when a large part of the soybean growing region experienced water stress, application of a stress reliever increase soybean yield across nine states (John Orlowski, unpublished data). Perhaps more severe stress is required for a stress reliever to have an effect on yield.

### 3.1.3 *Yield Environment*

Four out of eleven growing environments (site, year, and maturity group combination) had a whole plot average yields of over 5360 kg ha$^{-1}$: 1) LEX 4.5RM 2013; 2) PRIN 4.5RM 2013; 3) HODG 2.8RM 2014; and 4) HODG 4.5RM 2014. Dann et al. (1999) showed yield response to lactofen varied across environmental conditions. To assess whether the yield level of an environment influences lactofen’s effect on yield the four higher-yielding (HIGH) environments were grouped together. Six other growing environments were grouped into a MODERATE environment, with an average yield of 4390 kg ha$^{-1}$. One growing environment was placed in a LOW environment, with an average yield of 2292 kg ha$^{-1}$. The HIGH, MODERATE, and LOW environments were analyzed as a main effect. With this analysis, treatment interacted with yield environment ($P$<0.10).

In the HIGH yield environment, application of a stress reliever at V2 followed by V4 followed by R3 reduced yield by 8% compared with the UTC. In the MODERATE environment, lactofen at V2 followed by a stress reliever at V4 and R3 resulted in a 10% reduction in yield when compared with the UTC. No treatments significantly increased yield compared with the UTC in either the HIGH or MODERATE yield environment. In the LOW yield environment, an application of lactofen at V2 followed by a stress reliever at V4 and R3 increased yield by 22% (Table 3.3).

In a HIGH yield environment, multiple applications of the stress reliever appeared to cause some antagonism and decrease plant yield. It is not clear why this difference only occurs in high yield environments and not across all environments. In the MODERATE yield environment, it is unclear why application of lactofen at V2 followed by a stress reliever at V4 and R3 decreased yield in only a moderate yield environment and not all environments. Both decreases in yield across environments receive and application of a stress reliever at V4 followed by R3. There could be antagonism with the timing and multiple applications of a stress reliever, but the response is not observed across all environments. Also, if there was an antagonist effect, it wouldn’t explain why the treatment decreased yield in a MODERATE environment, but increased yield in a LOW environment.

### 3.1.4 *Conclusion*

Across maturity group, application of stress management did not lead to significant differences in yield. The practice of applying stress and attempting to relieve stress with stress management products was only successful in increasing soybean yield in low yielding environments. Stress management varied across yield environments, but none of the treatments, or their combination, increased yield above the UTC in a moderate or high yielding environment. Our research suggests stress management for maximum yield does not differ across high and moderate yield environments, or early and late reproductive growth environments, but is important in low yielding environments.

## 3.2 Seed Quality

Because of the difference in varieties used each year, seed protein and oil were analyzed by year.

### 3.2.1 *2013*

A significant relative maturity*treatment interaction was observed for seed oil in 2013 (Table 3.7). In the 4.5 RM cultivar, no treatment resulted in a significant difference from the UTC. In the 2.8 RM, compared to the UTC, insecticide, purported stress reliever at R3, purported stress reliever at V2 followed by R3, and purported stress reliever at V2 followed by V4 followed by R3 increased seed oil by 0.010%, 0.015%, 0.020%, and

0.015%, respectively (Table 3.8). It is unclear why treatment increased seed oil concentration in the 2.8 RM cultivar and not in the 4.5 RM cultivar. Three of the four treatments that resulted in an increase in oil concentration in the 2.8 RM cultivar was an application of a purported stress releiver at R3. However, R3 applications of a purported stress reliever following an V2 application of lactofen did not increase seed oil concentration. Additionally, when a purported stress reliever was applied in combination with a fungicide or insecticide no increase in seed oil concentration was observed.

The main effect treatment had a significant effect on seed protein concentration (Table 3.7). The combination of a purported stress reliever and a fungicide at R3 increase seed protein concentration by 0.011% compared with the UTC (Table 3.8). Nelson (2010) reported increase in seed protein with an application of fungicide with low disease pressure. However, it is unclear why only one of the four treatments including a fungicide resulted in an increase in seed protein concentration.

### **3.2.2** ***2014***

In 2014, a significant variety*treatment interaction was observed for seed protein (Table 3.7). In the 4.5 RM, no treatment resulted in a significant difference in seed protein concentration compared with the UTC. In the 2.8 RM cultivar, a purported stress reliever applied at V2 resulted in an increase seed protein concentration of 0.011% compared with the UTC (Table 3.9).

Treatment had a significant effect on seed oil (Table 3.7). Application of a purported stress reliever at R3 increased seed oil concentration by 0.010% (Table 3.9).

### 3.2.3 *Conclusion*

There were no treatments that consistently increased seed oil or protein across year or relative maturity. In 2013, the treatments that resulted in an increase in seed oil concentration did not result in an increase in seed oil concentration in 2014. Similarly, those that had an effect on seed protein concentration in 2013 did not have the same effect in 2014. Seed quality was increase with some applications including a purported stress reliever at R3; however, not all applications including a purported stress reliever at R3 resulted in an increase in oil or protein concentration.

This research supports previous research by Nelson (2010) that chemical applications to soybeans can result in a change in seed oil and protein concentration. However, the differences in oil and protein concentration were very small. While the differences were statistically significant, these small differences are not economically significant. Further, with little consistency with treatment differences across year and relative maturity assessing what is causing the differences is difficult and remains uncertain.

**Table 3.1** Summary of growing season temperature and precipitation for experimental locations in 2013 and 2014.

| | Lexington | | Hodgenville | | Princeton | |
|---|---|---|---|---|---|---|
| Year/month | Precip. | Temp. | Precip. | Temp. | Precip. | Temp. |
| | mm | ° C | mm | ° C | | |
| 2013 | | | | | | |
| May | 143 | 18.1 | 152 | 18.7 | 108 | 18.7 |
| June | 166 | 22.4 | 121 | 22.3 | 192 | 23.2 |
| July | 233 | 22.9 | 147 | 22.8 | 113 | 23.3 |
| August | 181 | 23.1 | 103 | 23.2 | 142 | 23.8 |
| September | 36 | 20.3 | 62 | 20.7 | 136 | 21.2 |
| October | 102 | 13.8 | 86 | 14.2 | 106 | 14.6 |
| Total | 861 | 20.1 | 671 | 20.3 | 797 | 20.8 |
| | | | | | | |
| 2014 | | | | | | |
| May | 108 | 18.4 | 124 | 19.2 | 50 | 19.9 |
| June | 116 | 22.9 | 86 | 23.2 | 103 | 23.9 |
| July | 68 | 22.3 | 78 | 22.2 | 40 | 22.3 |
| August | 164 | 23.3 | 135 | 23.7 | 237 | 25.0 |
| September | 89 | 19.9 | 17 | 20.2 | 25 | 20.2 |
| October | 116 | 13.3 | 114 | 14.1 | 111 | 14.8 |
| Total | 661 | 20.1 | 554 | 20.4 | 565 | 21.0 |
| | | | | | | |
| | | | State-wide | | | |
| | | | Precip. | Temp. | | |
| | | | mm | ° C | | |
| 30 Year Average | | | | | | |
| May | | | 129 | 18.2 | | |
| June | | | 108 | 22.7 | | |
| July | | | 115 | 24.6 | | |
| August | | | 89 | 24.0 | | |
| September | | | 90 | 20.1 | | |
| October | | | 86 | 13.9 | | |
| Total | | | 618 | 20.6 | | |

**Table 3.2** ANOVA for the main effects of maturity group and treatment on seed yield.

| **Effect** | **Num DF**[†] | **Den DF**[+] | **F-value** | ***P*-value** |
|---|---|---|---|---|
| relative maturity (RM) | 1 | 26 | 27.93 | **<.0001** |
| treatment (TRT) | 13 | 26 | 1.16 | **0.3559** |
| RM*TRT | 13 | 26 | 0.54 | **0.8782** |

[†]=numerator degrees of freedom.

[+]=denominator degrees of freedom.

**Table 3.3** Seed yield means. LSD valid for comparisons within each column.

| **Main Effect** | | **All Site Years** | **High Yield Site Years** | **Moderate Yield Site Years** | **Low Yield Site Years** |
|---|---|---|---|---|---|
| | | Yield kg ha$^{-1}$ | | | |
| **Relative Maturity** | | | | | |
| 2.8 | | 4642b | | | |
| 4.5 | | 5442a | | | |
| LSD (0.10) | | 226 | | | |
| | | | | | |
| **Treatment Type** | **Growth Stage** | | | | |
| Untreated Check (UTC) | | 5111 | 4427 | 5832 | 2130 |
| Insecticide (I) | R3 | 5003 | 4386 | 5604 | 2511 |
| Fungicide (F) | R3 | 5142 | 4558 | 5800 | 1712 |
| I+F | R3 | 5126 | 4708 | 5555 | 1997 |
| Stress reducer (SR) | R3 | 5107 | 4320 | 5864 | 2519 |
| I+SR | R3 | 5219 | 4423 | 6051 | 2382 |
| F+SR | R3 | 5037 | 4428 | 5627 | 2337 |
| I + F+SR | R3 | 5294 | 4585 | 6046 | 2317 |
| lactofen | V2 | 4896 | 4168 | 5555 | 2541 |
| lactofen fb SR | V2 fb R3 | 4800 | 4143 | 5502 | 2392 |
| lactofen fb SR fb SR | V2 fb V4 fb R3 | 4939 | 4004[x] | 5957 | 2718[x] |
| SR | V2 | 5067 | 4511 | 5628 | 2507 |
| SR fb SR | V2 fb R3 | 4995 | 4457 | 5686 | 2244 |
| SR fb SR fb SR | V2 fb V4 fb R3 | 4875 | 4376 | 5361[x] | 1782 |
| LSD(0.10) | | NS | 329 | 342 | 472 |
| Average | | 5046 | 4392 | 5719 | 2292 |

Different letters represent separate statistical groupings *P*=0.10.

[x]= significantly different from the UTC at $p \leq 0.10$.

**Table 3.4** Average daily temperature and total precipitation during seed fill (R5-R7) for 2013 and 2014.

| | **2013** | | **2014** | |
|---|---|---|---|---|
| **Location/ Relative Maturity** | Avg Daily Temp (°C) | Total Precipitation (mm) | Avg Daily Temp (°C) | Total Precipitation (mm) |
| HODG, 2.8RM | 22.0 | 77 | 23.9 | 114 |
| HODG, 4.5RM | 21.2 | 75 | 22.1 | 77 |
| LEX, 2.8RM | 21.9 | 108 | 24.7 | 233 |
| LEX, 4.5RM | 20.9 | 105 | 24.7 | 278 |
| PRINC, 2.8RM | 23.6 | 195 | 24.6 | 154 |
| PRINC, 4.5RM | 23.1 | 174 | 21.9 | 117 |
| Average, 2.8RM | 22.5 | 126.7 | 24.4 | 167.2 |
| Average, 4.5RM | 21.7 | 118.0 | 22.9 | 157.5 |

**Table 3.5** ANOVA for the main effects of relative maturity and treatment on yield components.

| | Stem | | | Branch | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Main Effect** | Node $m^{-2}$ | Pods $m^{-2}$ | Seeds $m^{-2}$ | Node $m^{-2}$ | Pods $m^{-2}$ | Seeds $m^{-2}$ | Node $m^{-2}$ | Pods $m^{-2}$ | Seeds $m^{-2}$ | mg $seed^{-1}$ |
| RM | ** | ** | ** | - | - | - | * | * | * | - |
| TRT | - | - | - | - | - | - | - | - | - | - |
| RM* TRT | - | - | - | - | - | - | - | - | - | - |

-=not significantly different.
*= significantly different at *P*= 0.05.
**= significantly different at *P*= 0.01.
***= significantly different at *P*= 0.001.

**Table 3.6** Relative maturity yield component means averaged across treatment.

| **Relative Maturity** | **Stem** | | | **Branch** | | | **Total** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nodes $m^{-2}$ | Pods $m^{-2}$ | Seeds $m^{-2}$ | Nodes $m^{-2}$ | Pods $m^{-2}$ | Seeds $m^{-2}$ | Nodes $m^{-2}$ | Pods $m^{-2}$ | Seeds $m^{-2}$ | mg $seed^{-1}$ |
| 2.8 | 440b | 897b | 1600b | 259 | 369 | 630 | 697b | 1265b | 2263a | 136 |
| 4.5 | 557a | 1190a | 2419a | 216 | 286 | 634 | 785a | 1486a | 3132b | 139 |

Different letters represent separate statistical groupings $P \leq 0.05$.

**Table 3.7** ANOVA for 2013 and 2014 Seed Quality.

| | **Seed Protein** | | **Seed Oil** | |
|---|---|---|---|---|
| **Source** | **DF** | **Pr>F** | **DF** | **Pr>F** |
| *2013* | | | | |
| Relative Maturity (RM) | 1 | 0.0904 | 1 | 0.2681 |
| Treatment (TRT) | 13 | 0.0474 | 13 | 0.3060 |
| RM*TRT | 13 | 0.4331 | 13 | 0.0134 |
| | | | | |
| *2014* | | | | |
| Relative Maturity (RM) | 1 | <.0001 | 1 | <.0001 |
| Treatment (TRT) | 13 | 0.8465 | 13 | 0.0487 |
| RM*TRT | 13 | 0.0393 | 13 | 0.5092 |

**Table 3.8** 2013 seed quality means.

| Main Effect | Oil Concentration g kg$^{-1}$ 2.8 RM | Oil Concentration g kg$^{-1}$ 4.5 RM | Protein Concentration$^{\dagger}$ g kg$^{-1}$ |
|---|---|---|---|
| **Relative Maturity** | | | |
| 2.8 | | | 360 |
| 4.5 | | | 367 |
| | | | |
| **Treatment** | | | |
| Untreated Check (UTC) | 192 | 190 | 362 |
| Insecticide (I) | 194$^{x}$ | 191 | 363 |
| Fungicide (F) | 194 | 190 | 365 |
| I+F | 191 | 190 | 364 |
| Stress reducer (SR) | 195$^{x}$ | 191 | 362 |
| I+SR | 192 | 191 | 363 |
| F+SR | 193 | 188 | 366$^{x}$ |
| I + F+SR | 192 | 190 | 364 |
| lactofen | 193 | 191 | 363 |
| lactofen fb SR | 192 | 191 | 363 |
| lactofen fb SR fb SR | 194 | 190 | 364 |
| SR | 192 | 189 | 363 |
| SR fb SR | 196$^{x}$ | 190 | 363 |
| SR fb SR fb SR | 195$^{x}$ | 190 | 361 |

$^{\dagger}$=Seed protein concentration averaged over secondary main effect.

$^{x}$= significantly different at $P \leq 0.05$.

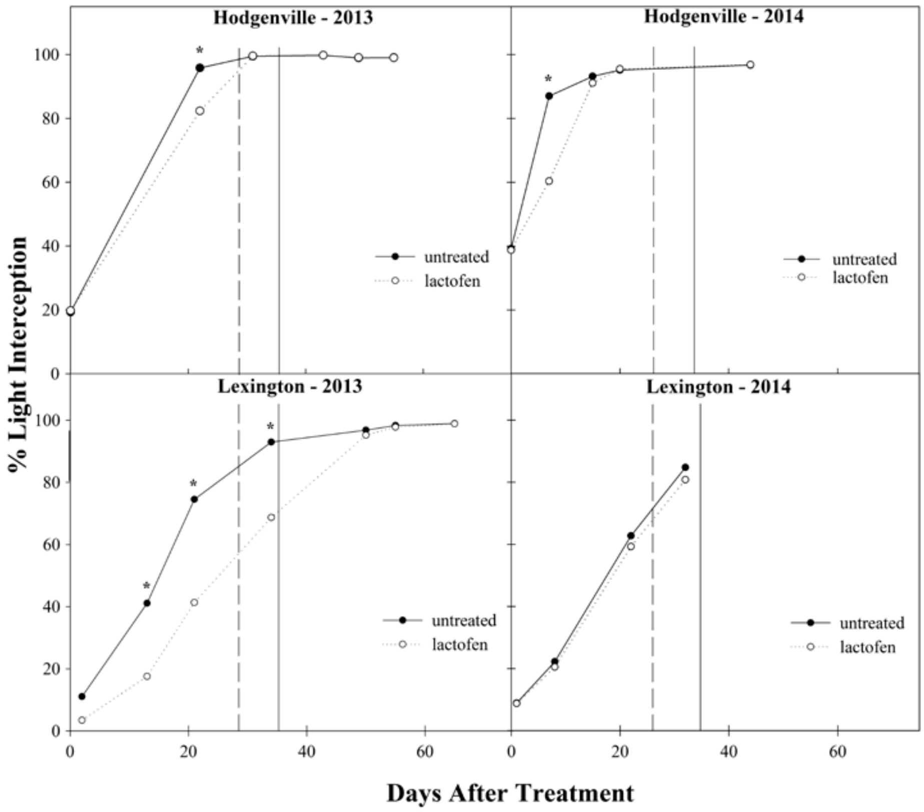
**Table 3.9** 2014 seed quality means.

| **Main Effect** | **Oil Concentration**[†] g kg$^{-1}$ | **Protein Concentration** g kg$^{-1}$ 2.8 RM | **Protein Concentration** g kg$^{-1}$ 4.5 RM |
|---|---|---|---|
| **Relative Maturity** | | | |
| 2.8 | 212a | | |
| 4.5 | 188b | | |
| | | | |
| **Treatment** | | | |
| Untreated Check (UTC) | 191 | 350 | 378 |
| Insecticide (I) | 193 | 348 | 378 |
| Fungicide (F) | 192 | 353 | 377 |
| I+F | 191 | 352 | 378 |
| Stress reducer (SR) | 193[x] | 350 | 376 |
| I+SR | 191 | 351 | 379 |
| F+SR | 190 | 351 | 379 |
| I + F+SR | 191 | 351 | 378 |
| lactofen | 192 | 351 | 380 |
| lactofen fb SR | 191 | 351 | 378 |
| lactofen fb SR fb SR | 192 | 351 | 376 |
| SR | 191 | 354[x] | 379 |
| SR fb SR | 193 | 353 | 380 |
| SR fb SR fb SR | 193 | 353 | 379 |

[†]=Seed protein concentration averaged over secondary main effect.

[x]= significantly different at $P \leq 0.05$.

**Figure 3.1** Light interception for HODG and LEX in 2013 and 2014.



*= Denotes days with occurrence of significant difference in light interception $P \leq 0.05$. Dashed vertical lines represent day after treatment when 2.8 RM cultivars reached growth stage R3.

Solid vertical lines represent day after treatment when 4.5 RM cultivars reached growth stage R3.

# Chapter 4

# Conclusion

Neither of the initial hypothesizes were verified. Inducing stress early by applying lactofen at V2 was ineffective for increasing soybean yield. While lactofen application did not have an effect on yield, lactofen is a very effective herbicide for post emergence broadleaf weed control in soybean fields. With the increased difficulties of managing herbicide resistant weeds, lactofen could be an important herbicide used as a part of a resistant weed management strategy. Attempting to reduce stress late was also ineffective for increasing soybean yield. Insect and disease were present at very low levels during both years. Additionally, weather was favorable for soybean production both years and experienced very low levels of water stress. Applying insecticides and fungicides should be based on threshold levels and scouting, not growth staging. Applying a purported stress reliever was not an effect way to increase soybean yield in this study. While preliminary data did show an increase in during the drought in 2012, the weather during 2013 and 2014 was very different. As soybean prices decline from record highs, farmers will need to evaluate if their stress management practices are the most profitable for their farming operation.

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# Vita

**Name**

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**Education**

B.S. Agronomy, Magna Cum Laude, Focus: Crop Production and Business Management. Iowa State University, Ames, Iowa

**Research Experience**

Graduate Research Assistant: University of Kentucky, Lexington, Kentucky, 2013-2015

Undergraduate Research Assistant: Soybean Extension Program, Iowa State University, Ames, Iowa, 2011-2013

Undergraduate Research Assistant: Weed Science Extension Program, Iowa State University, Ames, Iowa, 2011, 2013

**Non-Research Professional Experience**

General Laborer: Glenfolye Station, Cromwell, New Zealand, 2012

General Laborer: Oliver & Sons Dairy, Umawera, New Zealand, 2012

Sales Intern: Heartland Co-op, Marshalltown, Iowa, 2010

Farm Hand: Phoenix Holding Company, Fredericktown, Ohio, 2001-present

**Grants**

Lee, C.D., G.L. Gregg and J.M. Orlowski. 2014. Kentucky Soybean Promotion Board. Reducing Soybean Stress to Increase Yield. Total funded: $53,000.

**Extension Publications**

Lee, C.D., G.L. Gregg and J.M. Orlowski. 2014. Stressing Soybeans to Increase Yield. Kentucky Soybean Association. The Soybean Sentinel. 5(3): p.36-27.

**Published Abstracts and Proceedings**

Orlowski, J.M., B.J. Haverkamp, R.G. Laurenz, D.A Marburger, E.W. Wilson, S. Casteel, S.P Conley, C.D. Lee, E.D. Nafziger, K.L. Roozeboom, W.J. Ross, K.D. Thelen, S.L. Naeve and G.L. Gregg. Agronomic Maximization of Soybean Yield and Quality: Management Interactions. Joint Annual Meeting of the ASA-CSSA-SSSA, Tampa, FL. November 3-6, 2013. Abstract# 104-21.

G.L. Gregg and C.D. Lee. Stressing Soybeans to Increase Yield. Joint Annual Meeting of the ASA-CSSA-SSSA, Long Beach, California. November 2-5, 2014. Abstract#114-6.

Orlowski, J.M., C.D. Lee and G.L. Gregg. Early season lactofen application affects soybean yield and yield components. Joint Annual Meeting of the ASA-CSSA-SSSA, Long Beach, California. November 2-5, 2014. Abstract# 87454.

Orlowski,J.M., C.D. Lee and G.L. Gregg. 2015. Early season lactofen application on effects on soybean physiology. In GoverA.E.(ed) Proceedings of the 69th Annual Meeting of the Northeastern Weed Science Society: 69

## Teaching Experience

Teaching Assistant: University of Kentucky, PLS 366- Fundamentals of Soil Science, 2014

Teaching Assistant: University of Kentucky, PLS 104- Plants, Soils, & People: Science Perspective, 2014

## Awards, Honors, and Leadership

President, University of Kentucky Integrated Plant and Soil Science Grad. Student Assoc.- 2014

North Central Weed Society 2013 Weed Science Contest- 1st place written calibration

University of Kentucky 2013 3 Minute Thesis- 2nd place masters division.

University of Kentucky 2014 3 Minute Thesis- 2nd place masters division.

## Professional Memberships

American Society of Agronomy

Crop Science Society of Agronomy

Soil Science Society of Agronomy