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# Use of harvest aid in soybean: application timing, economics and interactions in IPM programs

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# USE OF HARVEST AID IN SOYBEAN: APPLICATION TIMING, ECONOMICS AND INTERACTIONS IN IPM PROGRAMS

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## ABSTRACT

Indeterminate and determinate soybean (*Glycine max* (L). Merr.) cultivars were treated with the harvest aids, paraquat and sodium chlorate, when moisture of seed collected from the uppermost four nodes of plants averaged 60, 50, 40, 30, and 20% (± 2%). Harvest aid application at 60% seed moisture reduced yield of the Maturity Group (MG) IV indeterminate cultivar 15%, but yield was not affected with application at 50% seed moisture. For MG V and MG VI determinate cultivars, application at 60 and 50% seed moisture reduced yield 4 to 22%, but yield was not affected when harvest aid was applied at 40% seed moisture. Soybean treated with harvest aid was harvested 8 to 15 days before the non-treated. The value of paraquat harvest aid was also evaluated when used in fungicide and insecticide IPM programs. Fungicide (pyraclostrobin plus thiophanate-methyl at R3) application increased soybean green leaf retention, green stems, and seed moisture. Failure to control stink bug resulted in increased green pods, seed moisture, and seed damage. Application of harvest aid decreased green leaf retention, green stems, and seed moisture. When harvest aid was applied and stink bug was not controlled, seed quality deductions for moisture, foreign material, and damage were ≤ \$63.10/ha. When stink bug was controlled at the maximum level (acephate plus cyfluthrin when population reached 2 to 3 per 25 sweeps) or the intermediate level (lambda-cyhalothrin when population reached threshold of 8 to 9 per 25 sweeps), deductions were ≤ \$30.24/ha. When harvest aid was not applied, seed quality deductions across all fungicide/stink bug control programs were 3.8 to 6.4 times greater than when harvest aid was applied. Increase in net return due to harvest aid was greatest when fungicide was applied and stink bug was controlled at either level (\$171.49 and \$169.89/ha) and lowest when fungicide was not applied (\$94.81 and \$78.49/ha). Even so, net returns were more than enough to offset

the cost of a paraquat harvest aid application. At a second location, net returns, regardless of harvest aid application, tended to be highest when fungicide was applied and when stink bug was controlled.

# CHAPTER 1

# INTRODUCTION

Traditionally, harvest aids have been used to desiccate weeds and improve harvest efficiency (Griffin et al. 2010). In the past 10 years, the shift toward production of early-maturing soybean [*Glycine max* (L.) Merr.] cultivars has made harvest aids also important for crop desiccation.

## WEED RESPONSE TO HERBICIDE APPLIED AT HARVEST

In Mississippi, glufosinate or sodium chlorate combined with glyphosate, or paraquat applied near harvest effectively controlled late season weeds (Ellis et al. 1998a). Applying sodium chlorate plus glyphosate or paraquat to sicklepod (*Senna obtusifolia.* L) 14 days before harvest reduced sicklepod seed germination shoot emergence and growth (Bennett and Shaw 2000). Similarly, sicklepod seed production was inhibited when glyphosate, glufosinate, or paraquat was applied as a harvest aid to soybean at R5; seedling growth, emergence, and radical length of sicklepod were reduced when desiccant was applied to soybean at R5, R6, and R7 (Ratnayake and Shaw 1992a). Chlorimuron and imazaquin applied during the late fruit period (pods 9 cm in length or greater) of sicklepod reduced seed production 45 and 38% respectively (Isaacs et al. 1989). Glyphosate can be safely applied to soybean after senescence when pods have dried, to effectively control perennial weeds and reduce weed seed viability (Clay and Griffin 2000).

## CROP RESONSE TO HERBICIDE APPLIED AT HARVEST

Soybean yield is not affected by preharvest desiccation when application is made after seeds reach physiological maturity (R 6.5 and ~ 50% average seed moisture) (Griffin et al. 2010). Whigham and Stoller (1979) found that application of glyphosate, paraquat, or ametryn 3 and

4 weeks before harvest reduced soybean yield. Although paraquat was most effective for desiccation of soybean foliage, it had the greatest negative effect on yield and seed weight. Application of glyphosate at 23 and 29 days before harvest when 5 to 30% of the leaves had senesced, reduced yield 18% (Azlin and McWhorter 1981). Application of glyphosate before soybean physiological maturity reduced seed weight, caused seed discoloration, and drastically reduced progeny emergence, vigor and weight (Cerkauskas et al. 1982; Jeffery et al. 1981). In Mississippi, application of glufosinate or paraquat reduced soybean yield when applied at the R5 and R6 growth stages, but not at R7 or R8 (Ratnayake and Shaw 1992b). In dry bean (*Phaseolus vulgaris*), harvest aid of glyphosate, glufosinate, or paraquat applied when 7% of the pods had yellowed reduced seed yield 19 to 22 % (Wilson and Smith 2002). When glyphosate was applied to cowpea (*Vigna unguiculata*) 7 to11 days after flowering, pod width, seed dry weight, and seed length were reduced (Antonio et al. 1985). Applying paraquat to sensitive cultivars of peanut (*Arachis hypogaea* L.) negatively affected yield and grade by delaying maturity (Knauft et al. 1990).

Weeds present at harvest may not affect soybean seed production, but can have a negative effect on seed quality. The presence of redroot pigweed (*Amaranthus retroflexus* L.), sicklepod, ivyleaf morningglory (*Ipomoea hederacea* (L.) Jacq.), hemp sesbania (*Sesbania exaltata* (Raf.) Rydb. Ex A. W. Hill), and common cocklebur [*Xanthum strumarium* (L.)] at harvest increased soybean seed moisture, foreign material and seed damage and decreased test weight, especially where weed densities were high (Ellis et al. 1998b). Weeds, however, did not affect soybean yield, but did reduce combine speed. Where weed densities were greatest, soybean plants tended to be less susceptible to lodging, and were more easily gathered into the harvester, reducing losses from shattering (Burnside et al. 1969).

Even though weeds may not affect the ability of the combine to collect seeds, they can have a negative effect on harvest efficiency. The presence of smooth pigweed (*Amaranthus hybridus* L.) and giant foxtail *(Setaria faberii* Herrm.) at harvest resulted in threshing and separation losses when combine speed was increased from 1 to 2 and 3 mph, and soybean seed recovery was reduced in weedy plots compared to weed free plots (Nave and Wax 1971). Burnside et al. (1969) noted that when broadleaf weeds are controlled, cutting low, properly adjusting the combine, and harvesting early can reduce of soybean seed loss during harvest.

Desiccation of weeds with preharvest desiccants can also accelerate harvest. Glyphosate applied to grain sorghum [*Sorghum bicolor* (L.) Moench ssp. *Bicolor*] reduced grain, leaf, and stem moisture and harvest was 7 to 14 days earlier (Bovey et al. 1975). In another study, applying glyphosate or paraquat to grain sorghum at 30 and 35% seed moisture allowed harvest 5 to 7 days earlier, but negatively affected yield (Gigax and Burnside 1976). Leaving soybean plants in the field past harvest maturity exposes them to adverse weather conditions that can reduce yield and seed quality (Sidible et al. 1999). Yield losses of 0.2% per day which can be attributed to plant deterioration, grain losses, decreased harvest efficiency and reduction of net yield have been reported (Philbrook and Oplinger 1989).

**STINK BUG BIOLOGY AND CONTROL**

Stink bugs are an economically important pest in many cereral and grain crops in the mid-south. In 2001, Georgia producers spent $860,000 controlling green stink bug [*Acrosternum hilare* (Say)], southern green stink bug [*Nezara viridula* (L.)], and brown stink bug [*Euschistus servus* (Say)], with seed damage losses estimated at $120,000 (McPherson and Jones 2001). Soybean producers plant earlier maturing varieties to avoid late season insect infestations and drought stress during early August to mid-September (Heatherly and Bowers

1998). McPherson and Jones 2001 and McPherson et al. (2003) found that stink bugs were more abundant on early maturing varieties during the mid-season. The widespread adoption of an early soybean production system will provide an abundance of suitable host for early-season pests therefore, emphasizing the need for arthropod management (Baur et al. 2000).

Southern green stink bug oviposition begins shortly before soybean flowering with populations increasing during the R3, R4, R5 growth stages and peaking around the R6 (full pod) stage (Bundy and McPherson 2000; Schumann and Todd 1982). In determinate soybean feeding occurs preferentially in the upper half of plants until high infestation levels are reached (3.8 per m of row) forcing stink bugs to feed on the lower pods of plants (Russin et al. 1987). Stink bugs cause damage to seeds physically by puncturing the membrane which can expose seeds to secondary damage from pathogens (Clarke and Wilde 1970). In a cage study, green and southern green stink bug feeding during pod fill reduced seed size, weight, and oil content and increased seed damage (Brier and Rogers 1991; Daugherty et al. 1964; Todd and Turnipseed 1974; Yeargan 1977). When populations of green, southern green, brown and redbanded stink bugs [*Piezodorus guildinii* (Westwood)] reached treatment thresholds of 9 per 25 sweeps, significant reductions in soybean yield and quality were documented (McPherson et al. 1993). Identification, early detection, and monitoring are essential to the control of these insect pests.

Soybean seeds fed upbon by green stink bug nymphs is greatest in the 5$^{th}$ instar stage and is similar to adults with daily feeding frequencies of 3.4 times per day for at total of 5.1 hours (Simmons and Yeargan 1988). First instars do not feed while 2$^{nd}$ and 3$^{rd}$ instar feeding is relatively low. The growth stage of stink bugs as well as the length of time and frequency of feeding are important components of understanding their potential to damage soybean.

Feeding by southern green stink bug at a population of 6 per 0.3m of row for 7 to 14 days caused delays in soybean maturity (increased leaf retention) and reduced yields when infestation occurred during the R3-R5.5 growth stages, which is the most critical time for plant protection (Boethel et al. 2000). In other studies, an infestation of 2 stink bugs per 0.3m of row reduced both yield and seed quality (McPherson et al. 1979; Thomas et al. 1974). Yield loss caused by feeding of green stink bug has been attributed to reduced number of seeds or damaged seed (Simmons and Yeargan 1990; Jensen and Newsom 1971). McPherson (1996) reported that as stink bug increased seed damage, frequency of seed punctures, and the number of seeds punctured also increased. Stink bug also caused significant reductions in soybean 100-seed weight (McPherson 1996).

In soybean, total dry matter accumulation in seeds increases rapidly until 80% moisture (R3 early pod fill ) and then slows as seeds approach 60% moisture (R6 pod fill) (Fraser et al. 1982). Egli et al. (1985) showed an increase in photosynthate partitioning to developing seeds from less than 5% at R3 to 30% or more at R6. Therefore stink bug control would be especially important during soybean pod filling stages.

Over the past 50 years there has been limited research on delayed senescence of soybean affected by stink bug feeding. In recent years in the mid-south, a common occurrence in soybean is the retention of green leaves, pods, and/or stems when seed have matured and are ready to harvest. This occurrence has been labeled the “Green Plant Malady” (Griffin et al. 2010). The malady is likely caused by many factors, most likely interactive, including stress from water, temperature, and from pathogens and stink bugs.

## DELAYED MATURITY IN SOYBEAN

Plant disease management is an important component of Louisiana soybean production programs. Cercospera leaf blight (*Cercospora kukuchii*) and Asian soybean rust (*Phakopsora pachyrhizi*) are primary diseases in this state (Padgett 2007). Applications of foliar fungicides have been shown to increase the percentage of green stems and green leaves present at harvest (Padgett et al. 2003). Potter (2005) reported that triazole and strobilurin fungicides caused plants to retain lower canopy leaves several days longer than non-treated plants.

In the past, studies have investigated the cause of delayed maturity in soybean, with emphasis on green stems. The term green stem disorder is defined as a delayed senescence of stems with normal pod and seed maturation (Hobbs et al. 2006). In a study conducted in Illinois it was hypothesized that bean pod mottle virus (BPMV) was the casual agent of the green stem disorder. However, plants infected with the virus did not always have green stems, and conversely, many plants with green stems were not infected with BPMV (Hobbs et al. 2006). Previous work indicated that some soybean varieties are predisposed to the disorder with significant differences among cultivars (Hill et al. 2003; Hill et al. 2006). The exact causes of green leaf retention, green stems, and/or green pods have been linked to stink bug feeding (Boethel et al. 2000) and fungicide use (Padgett et al. 2003).

Research presented in this thesis focused on use of harvest aids to desiccate soybean with emphasis on application timing and harvest date. Research also addressed the value of harvest aid in soybean IPM programs that included stink bug control and fungicide application. Soybean green leaf retention and percentage green stems and pods were measured to help explain causes for the green plant malady. The effect of harvest aid on seed quality to include seed moisture, foreign material, and seed damage were assessed using economic analysis.

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## CHAPTER 2

## APPLICATION TIMING OF HARVEST AID HERBICIDES AFFECTS SOYBEAN HARVEST AND YIELD

### INTRODUCTION

Soybean is an economically important crop in the U.S. and in 2007, 25.9 million hectares were harvested (USDA 2009). Soybean cultivars are differentiated based on maturity group and adaptation to certain latitudes (McWilliams et al. 1999). Maturity groups range from 000 in the extreme northern U.S. to VIII in the southern Gulf Coast states. Cultivars with the lowest number designation (000 to IV) are considered indeterminate while MG V through X are determinate cultivars (Anonymous 2009). In the mid-South, introduction of glyphosate-resistant technology in the mid-1990's promoted a shift in soybean cultivar development toward MG IV and MG V cultivars. Use of glyphosate greatly improved weed control and the production of early maturing soybean cultivars in some years avoided late-season dry weather and insect problems (David Y. Lanclos, personal communication).

While both determinate and indeterminate soybean cultivars are photoperiod sensitive, they differ with respect to the extent of vegetative growth occurring after flower initiation (Pedersen et al. 2007). For determinate soybean, flowering is initiated in the middle portion of the plant and proceeds towards the top and bottom of the plant; terminal bud growth ceases when flowering begins. While there may be some slight difference in seed maturity on the plant, most seed mature at the same time. In contrast, flowering of indeterminate soybean is initiated in the lower portion of the plant and proceeds upward; terminal buds continue growing several weeks after flowering. There can be considerable difference in seed maturity with bottom seed reaching physiological maturity (when seed have reached maximum dry weight) first. With the variation in seed maturation, indeterminate plants tend to retain leaf material and stems remain green later into the growing season.

Traditionally harvest aids have been used to desiccate weeds and increase harvest efficiency (Burnside et al. 1969; Burnside 1973; Griffin et al. 2003). Increases in foreign material and seed moisture associated with green plants and weeds present at harvest can reduce soybean seed quality (Ellis et al. 1998; Willard and Griffin 1993). Reduction in seed quality can affect net returns to the grower. Additionally, leaving soybean plants in the field past maturity and awaiting harvest exposes seed to adverse weather conditions that can reduce yield and quality (Boudreaux and Griffin 2008). Philbrook and Oplinger (1989) reported that postponing soybean harvest after plant maturity resulted in yield losses of 0.2% per day, which was attributed to plant deterioration, grain losses, decreased harvest efficiency, and reduction of net yield.

With the shift toward earlier maturing soybean cultivars, the use of harvest aids has increased. A survey of extension soybean specialists in the mid-south during 2007 determined that 30 to 35% of soybean hectarage received a harvest aid application (David Y. Lanclos, personal communication). The increase in harvest aid use was related to late-season weed infestations but in many cases, desiccation of the crop expedited harvest. Earlier harvest may allow growers to take advantage of a higher market price for early delivery (Boudreaux and Griffin 2008).

Both paraquat and sodium chlorate are labeled as harvest aids/desiccants in soybean. For indeterminate varieties, the paraquat label states that application should be made when at least 65% of the seed pods have reached a mature brown color or when seed moisture is 30% or less. For determinate varieties, paraquat should be applied when plants are mature, i.e., soybeans are fully developed, half of the leaves have dropped, and remaining leaves are yellowing. For sodium chlorate, the label states that application should be made 7 to 10 days before anticipated harvest date when soybean is mature and ready to harvest. Statements on application timing for both paraquat and sodium chlorate are unclear and open to interpretation. If harvest aid is applied too early and foliage is removed before all seed on the soybean plant have reached physiological maturity, significant yield losses can occur (Pedersen et al. 2007). Application of paraquat three and four weeks before harvest was effective for desiccation of soybean foliage, but reduced soybean yield (Whigham and Stoller 1979). Ratnayake and Shaw (1992) in Mississippi, observed that application of glufosinate or paraquat at R5 (beginning seed; when seed is 3 mm long in the pod at one of the four uppermost nodes on the main stem) and R6 (full seed; when pods contain a green seed that fills the pod cavity at one of the four uppermost nodes on the main stem) (McWilliams et al. 1999) reduced yield, but yield loss did not occur with application at R7 (beginning maturity; when one normal pod on the main stem has reached mature pod color) or R8 (full maturity). Therefore, timing of harvest aid application to soybean is critical.

The objective of this research was to determine the effects of paraquat and sodium chlorate applied to indeterminate and determinate soybean, based on seed moisture in the top of the crop canopy, on yield, seed weight, and harvest date. Because in some cases harvest aids are applied to desiccate morningglory (*Ipomoea* spp.), paraquat was applied with carfentrazone to document any possible antagonism.

## MATERIALS AND METHODS

Experiments were conducted in 2006 and 2007 at the Central Research Station, Ben Hur Research Farm in Baton Rouge, LA, on a Mhoon silty clay loam (fine-silty, mixed, nonacid, thermic Typic Fluavaquent) with 1.9% OM and a pH of 6.3. Experiments were conducted each year using MG IV indeterminate ‘Asgrow 4403RR’ and MG V ‘Asgrow 5903RR’ and MG VI ‘Asgrow 6202RR’ determinate soybean cultivars. In 2006, MG IV and V soybean were planted May 12 and MG VI soybean was planted on June 19. In 2007, MG IV soybean was planted on April 16 and MG V and VI soybean was planted May10. For each experiment both years, soybean was planted in prepared seedbeds following soybean the previous year. Row spacing consisted of 3 drills (38 cm apart) under the tractor with the outside drills 76 cm apart at a seeding rate of 56 kg/ha.

The experimental design was a randomized complete block with 16 treatments arranged in a 3 by 5 augmented factorial with a non-treated control (no harvest aid) included for comparison. Treatments were replicated four times and plot size was 1.5 by 9.1 m. Factor one consisted of the harvest aid treatments, paraquat at 0.28 kg ai/ha, paraquat at 0.28 kg ai/ha with carfentrazone at 0.014 kg ai/ha, and sodium chlorate at 6.72 kg ai/ha. A non-ionic surfactant at 0.25% v/v was added to all paraquat treatments. Treatments were applied at a spray volume of 140 l/ha with a $CO_2$-pressurized backpack sprayer at 172 kPa. The second factor was application timing. Harvest aid treatments were applied when moisture content of seed collected from pods at the four uppermost nodes of plants averaged 60, 50, 40, 30, and 20% (+ or – 2%). Application timing based on seed moisture was chosen because for indeterminate soybean, the paraquat label states that application should be made at seed moisture of 30% or less. For both the indeterminate and determinate varieties, the most immature seed would be located in the top of the crop canopy. To determine seed moisture, pods were hand shelled and green seed were weighed (wet weight), oven-dried for 24 hr at 80° C (dry weight), and re-weighed to calculate average moisture percentage. The three center rows of each plot were mechanically harvested with a plot combine when seed moisture was near 13% (harvest maturity). At harvest, 95% of the soybean leaves had dropped and 90% of stems had reached a mature brown color. Seed yield was adjusted to 13% moisture and expressed as a percent change compared to the yields of the respective non-treated controls (4,152 kg/ha for MG IV; 3,991 kg/ha for MG V; 3,809 kg/ha for MG VI). Seed weight expressed in g/100 seed was also determined. Because of late season problems with Cercospora leaf blight (*Cercospora kikuchii*), a fungicide application of pyraclostrobin (Headline®) at 219 g ai/ha + thiophanate-methyl (Topsin M®) at 784 g ai/ha was made in 2007 on both MG V and MG VI soybean at R3, (beginning pod; when a pod on the upper four nodes is 5 mm long) (McWilliams et al. 1999). Fungicide application in 2007 did not appear to delay senescence of soybean plants. In 2006, wet weather conditions delayed harvest of MG VI soybean treated with harvest aid at 20% and 30% seed moisture and for the non-treated control.

Because in this study a quantitative series of treatments (application timing based on seed moisture) were evaluated, data were analyzed initially using regression. To understand the nature of the response and also to predict responses for each soybean cultivar to timing of harvest aid application, sum of squares in the ANOVA was partitioned to determine linear and quadratic effects. From previous research and based on the paraquat label, soybean yield is not affected when paraquat harvest aid is applied to soybean at 30% seed moisture. Our interest was in determining if harvest aid can be applied earlier when seed moisture is greater than 30% without negatively affecting yield. Highly significant linear and quadratic responses were observed for each soybean cultivar. For the linear response, soybean yield decreased with increasing seed moisture leading one to conclude that it would never be safe to apply a harvest aid in soybean. Using the quadratic response one would conclude that soybean yield was greater when harvest aid was applied at 20, 30, and 40% seed moisture compared with no harvest aid application. The responses generated using regression analysis, although statistically significant, cannot be supported biologically.

Data for each of the soybean cultivars were subjected to the Mixed Procedure in SAS[1]. Years, replications, (nested within years) and all interactions containing either of these effects were considered random effects (Carmer et al. 1989). Harvest aid and application timing were considered fixed effects. Considering years as an environmental or random effect permits inferences about treatments to be made over a range of environments (Carmer et al. 1989; Hager et al. 2003). Type III statistics were used to test the fixed effects. For the seed yield and seed weight data for each experiment, there was no significant harvest aid treatment by application timing interaction, therefore, data were averaged across harvest aids. Least square means were used for mean separation at $P \leq 0.05$. Letter groupings were converted using the PDMIX800 macro in SAS (Saxton 1998).

**RESULTS AND DISCUSSION**

For both indeterminate and determinate soybean cultivars, the harvest aid treatment by application timing interaction was not significant and data for harvest aid treatments were averaged. Therefore, the harvest aid treatments were equally effective in desiccating soybean foliage and application of carfentrazone with paraquat was not antagonistic. Carfentrazone is active on broadleaf weeds, especially morningglory, and could be applied with paraquat to

[1] SAS institute. 2003. SAS User's Guide: Statistics. Version 9.1. SAS Institute Inc., SAS Campus Drive, Cary, NC 27513.

enhance control of morningglory and other troublesome broadleaf weeds not adequately controlled by paraquat (Griffin et al. 2004).

**MG IV Indeterminate Soybean**. Soybean was planted 26 d earlier in 2007 than in 2006. For the harvest aid timing treatments the 10% (+ or - 2) average loss in soybean seed moisture between applications occurred within 3 to 10 d depending on year and environmental conditions (Table 2.1). For the 60% average seed moisture application, harvest aid was applied on August 31 in 2006 and on July 26 in 2007; 36 d earlier in 2007. Although harvest aid application was 36 d earlier in 2007, there was only a 10 d difference between years in days after planting (DAP) to harvest aid application at 60% average seed moisture. When harvest aid was applied at 50% average seed moisture or less, the difference in DAP to harvest aid application between years was no more than 4 d.

When harvest aid was applied at 60% average seed moisture, yield was reduced an average of 15.4% and seed weight was reduced 1.8 g/100 seed (12.4%) (Table 2.1). Reduction in yield and seed weight indicates that not all seed within the top of the crop canopy had reached physiological maturity (R6.5) at the time of application. At R6.5, all normal pods on the four uppermost nodes would have pod cavities filled with seeds and the seeds would be separating from the white membrane inside the pod (Boudreaux and Griffin 2008). Moisture content of seed at physiological maturity would be around 50%. In this research, harvest aid application timing was based on average moisture of seed collected from the top four nodes of plants. At 60% average seed moisture, considerable variation in seed maturation was observed, and reduction in both yield and seed weight were expected. Additionally, at the 60% average seed moisture timing, few leaves had begun to turn yellow and all pods were green. In dry bean (*Phaseolus vulgaris* L.), a harvest aid applied when 7% of the pods had yellowed reduced

Table 2.1. Harvest aid application and harvest information for 2006 and 2007 and the effect of harvest aid application timing on yield and seed weight of MG IV 'Asgrow 4403RR' indeterminate soybean.[1]

| | 2006 | | | | 2007 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Application timing[2] | Date applied | DAP to application | Harvest date | DAA to harvest | Date applied | DAP to application | Harvest date | DAA to harvest | Yield[3] | Seed weight[3] |
| % moisture | | No. | | No. | | No. | | No. | % change | g 100 seed |
| 60 | Aug 31 | 111 | Sep 15 | 15 | Jul 26 | 101 | Aug 13 | 18 | -15.4 b[4] | 12.7 b[4] |
| 50 | Sep 5 | 116 | Sep 15 | 10 | Aug 6 | 112 | Aug 13 | 7 | -3.0 a | 14.0 a |
| 40 | Sep 12 | 123 | Sep 20 | 8 | Aug 15 | 121 | Aug 20 | 5 | -1.3 a | 14.2 a |
| 30 | Sep 19 | 130 | Sep 26 | 7 | Aug 20 | 126 | Aug 25 | 5 | -2.9 a | 13.9 a |
| 20 | Sep 22 | 133 | Sep 29 | 7 | Aug 24 | 130 | Aug 28 | 4 | +1.1 a | 13.9 a |
| Non-treated | - | - | Sep 29 | - | - | - | Aug 28 | - | 0 a | 14.5 a |

[1]Harvest aid treatments included paraquat at 0.28 kg ai/ha alone and with carfentrazone at 0.014 kg ai/ha, and sodium chlorate at 6.72 kg ai/ha. Data were averaged for the harvest aid treatments. DAP= days after planting and DAA = days after application. Soybean planted May 12, 2006 and April 16, 2007.

[2]Represents average seed moisture (+ or – 2%) for seed collected from the four uppermost nodes of plants. Seed moisture was determined based on weight loss for dried seed.

[3]Yield and seed weight data were averaged across two years.

[4] Means within a column followed by the same letter are not significantly different ($P \leq 0.05$). Yield for the non-treated control was 4,152 kg/ha.

seed yield 19 to 22% (Wilson and Smith 2002). When harvest aid application was delayed until 50% of soybean pods were yellow, crop yield reduction was not observed (Ratnayake and Shaw 1992). In the present study, application at 50% average seed moisture did not negatively affect soybean yield and seed weight. Soybean was harvested 10 and 7 d after application (DAA) in 2006 and 2007, respectively, and 14 and 15 d before the non-treated.

Delaying harvest aid application until 40% average seed moisture had no negative effect on yield and soybean was harvested both years approximately 9 d earlier than the non-treated. The paraquat label states that application should be made to indeterminate soybean at 30% seed moisture or less and 15 d before harvest. The sodium chlorate label states that application should be made 7 to 10 days before anticipated harvest date. In the present study, harvest aid application at 30% average seed moisture was safe to soybean but soybean was harvested, depending on year, 4 and 7 DAA, a violation of the paraquat label. Research shows that harvest aid can be safely applied at 50% average seed moisture accelerating harvest by 14 and 15 d, which in one year would have been in violation of the paraquat label. Strict adherence to the paraquat label with application at 30% seed moisture and harvest 15 d later in the present study would have eliminated any value in regard to earlier harvest. It should be noted that in this research, plots were weed free and harvest aid was applied to desiccate the crop and accelerate harvest. In situations where weeds are present, 15 d may be needed for weeds to completely dry down to improve harvest efficiency. There was no attempt in the present study to document the value of harvest aid for improvement in crop quality (decreased foreign material or seed damage) or harvest efficiency.

**MG V Determinate Soybean**. Soybean was planted both years in May within 2 d of one another. Fungicide applied at R3 in 2007 did not appear to delay senescence of soybean plants. Previous research has shown delayed maturity associated with late-season fungicide application in soybean (Padgett et al. 2003; Potter 2005). Depending on the year and environmental conditions, the 10% (+ or – 2) average loss in soybean seed moisture between the harvest aid timing treatments occurred within 4 to 13 d (Table 2.2). For the two years, DAP to application of individual harvest aid treatments differed by no more than 7 d. For the two years for each application timing treatment, soybean was harvested within 8 d of one another. Additionally for the two years, DAA to harvest for each of the application timing treatments was within 7 d of one another.

When harvest aid was applied at 60% average seed moisture, yield was reduced an average of 22% and seed weight was reduced 5.1 g/100 seed (33.3% reduction) (Table 2.2). Application at 50% average seed moisture reduced yield 15.6% and seed weight 4.1 g/100 seed (26.8%). Soybean yield was not negatively affected when harvest aid was applied at 40% average seed moisture or less, however, a seed weight reduction was observed. By delaying harvest aid application until 40% average seed moisture, soybean was harvested for the two years 14 and 12 DAA and 7 and 8 d before the non-treated. Soybean was harvested 7 DAA when harvest aid application was delayed until to 30% average seed moisture. The paraquat label states that for determinate soybean, application should be made when plants are mature with soybeans fully developed, half of the leaves have dropped, and remaining leaves are yellowing and that 15 d be allowed between application and harvest. As also noted for indeterminate soybean, delaying paraquat application for determinate soybean based on the label would negate any benefit to earlier harvest.

Table 2.2. Harvest aid application and harvest information for 2006 and 2007 and the effect of harvest aid application timing on yield and seed weight of 'Asgrow 5903 RR' MG V determinate soybean.[1]

| | 2006 | | | | 2007 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Application timing[2] | Date applied | DAP to application | Harvest date | DAA to harvest | Date applied | DAP to application | Harvest date | DAA to harvest | Yield[3] | Seed weight[3] |
| % moisture | | No. | | No. | | No. | | No. | % change | g 100 seed |
| 60 | Sep 1 | 112 | Sep 15 | 14 | Aug 22 | 105 | Sep 12 | 21 | -22.0 c[4] | 10.2 e[4] |
| 50 | Sep 5 | 116 | Sep 20 | 15 | Aug 31 | 114 | Sep 12 | 12 | -15.6 b | 11.2 d |
| 40 | Sep 12 | 123 | Sep 26 | 14 | Sep 13 | 127 | Sep 25 | 12 | -1.5 a | 12.9 c |
| 30 | Sep 19 | 130 | Sep 26 | 7 | Sep 22 | 136 | Sep 29 | 7 | +2.2 a | 13.6 c |
| 20 | Sep 26 | 137 | Oct 3 | 7 | Sep 27 | 141 | Oct 3 | 6 | +2.5 a | 14.3 b |
| Non-treated | - | - | Oct 3 | - | - | - | Oct 3 | - | 0 a | 15.3 a |

[1]Harvest aid treatments included paraquat at 0.28 kg ai/ha alone and with carfentrazone at 0.014 kg ai/ha, and sodium chlorate at 6.72 kg ai/ha. Data were averaged for the harvest aid treatments. DAP= days after planting and DAA = days after application. Soybean planted May 12, 2006 and April 16, 2007.

[2]Represents average seed moisture (+ or – 2%) for seed collected from the four uppermost nodes of plants. Seed moisture was determined based on weight loss for dried seed.

[3]Yield and seed weight data were averaged across two years.

[4]Means within a column followed by the same letter are not significantly different ($P \leq 0.05$). Yield for the non-treated control was 3,991 kg/ha.

**MG VI Determinate Soybean**. In 2006 because of wet weather, planting was delayed until June 19. Soybean was planted May 10 in 2007, 40 d earlier than in 2006. Fungicide applied at R3 in 2007 did not appear to delay senescence of soybean plants. For the harvest aid timing treatments, the 10% (+ or - 2) average loss in soybean seed moisture occurred within 4 to 10 d depending on year and environmental conditions (Table 2.3). For the two years DAP to application for individual harvest aid treatments differed by 30 to 34 d (Table 2.3). When harvest aid was applied at 60, 50, or 40% average seed moisture for the two years, soybean was harvested within 7 days of one another. When harvest aid was applied at 30% and 20% average seed moisture, harvest was delayed due to weather problems in 2006 and harvest date differed between the two years by 18 and 11 d.

When harvest aid was applied at 60% average seed moisture, yield was reduced an average of 18.1% and seed weight was reduced 3.2 g/100 seed (20.3%) (Table 2.3). Application at 50% average seed moisture reduced yield 4.0% and seed weight 1.4 g/100 seed (8.9%). However, soybean yield and seed weight were not negatively affected when harvest aid was applied at 40% average seed moisture or less. By delaying harvest aid application until 40% average seed moisture, soybean was harvested for the two years 7 d after application and 10 and 14 d before the non-treated. Because of wet weather, soybean treated with harvest aid at 30% average seed moisture in 2006 was harvested the same day as the non-treated and in 2007, 7 d before the non-treated. Based on this study, the paraquat harvest interval of 15 d was not met when harvest aid was applied at 40% average seed moisture or less.

Table 2.3. Harvest aid application and harvest information for 2006 and 2007 and the effect of harvest aid application timing on yield and seed weight of 'Asgrow 6202 RR' MG VI determinate soybean.[1]

| | 2006 | | | | 2007 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Application timing[2] | Date applied | DAP to application | Harvest date | DAA to harvest | Date applied | DAP to application | Harvest date | DAA to harvest | Yield[3] | Seed weight[3] |
| % moisture | | No. | | No. | | No. | | No. | % change | g 100 seed |
| 60 | Sep 19 | 92 | Oct 3 | 14 | Sep 10 | 123 | Sep 26 | 16 | -18.1 c[4] | 12.6 c[4] |
| 50 | Sep 26 | 99 | Oct 9 | 13 | Sep 16 | 129 | Sep 26 | 10 | -4.0 b | 14.4 b |
| 40 | Oct 3 | 106 | Oct 10 | 7 | Sep 26 | 139 | Oct 3 | 7 | +2.2 a | 15.1 ab |
| 30 | Oct 9 | 112 | Oct 24 | 15 | Oct 1 | 144 | Oct 6 | 5 | +1.2 a | 15.4 a |
| 20 | Oct 13 | 116 | Oct 24 | 11 | Oct 7 | 150 | Oct 13 | 6 | +1.2 a | 15.8 a |
| Non-treated | - | - | Oct 24 | - | - | - | Oct 13 | - | 0 a | 15.8 a |

[1]Harvest aid treatments included paraquat at 0.28 kg ai/ha alone and with carfentrazone at 0.014 kg ai/ha, and sodium chlorate at 6.72 kg ai/ha. Data were averaged for the harvest aid treatments. DAP= days after planting and DAA = days after application. Soybean planted May 12, 2006 and April 16, 2007.
[2]Represents average seed moisture (+ or – 2%) for seed collected from the four uppermost nodes of plants. Seed moisture was determined based on weight loss for dried seed.
[3]Yield and seed weight data were averaged across two years.
[4]Means within a column followed by the same letter are not significantly different ($P \leq 0.05$). Yield for the non-treated control was 3,809 kg/ha.

In conclusion, yield reductions were not observed when the harvest aid treatments of paraquat, paraquat plus carfentrazone, or sodium chlorate were applied to MG IV indeterminate soybean at 50% average seed moisture and to MG V and VI determinate soybean at 40% average seed moisture.  The greater flexibility in application with the indeterminate cultivar is because the most immature seed (seed that have not reached physiological maturity) are present in the top of the plant.  For determinate soybean the most immature seed would be present in both the top and bottom of the plant.

It is not practical that growers quantify soybean seed moisture by collecting and drying seed in order to determine the appropriate application timing for a harvest aid.  Regardless of whether an indeterminate or determinate cultivar is grown, yield reduction can be avoided if harvest aid is applied when on the uppermost nodes of the main stem, pod cavities have completely filled and all seed are separating from the white membrane inside the pod (about 50% seed moisture and at R6.5).  Delaying harvest aid application until all plants in the field have one normal pod on the main stem that has reached its mature pod color (R7) (McWilliams et al. 1999) would further assure that yield would not be reduced.

Paraquat and sodium chlorate can be used to desiccate weeds and the crop.  The product label states that soybean should not be harvested prior to 15 d after application of paraquat and 7 to 10 d after sodium chlorate.  The label for carfentrazone states that soybean can be harvested 3 d after application.  In situations where morningglory vines are present a combination of paraquat and carfentrazone can be effective in desiccating both the crop and weeds, but 15 d may be needed to fully desiccate vines (Griffin et al. 2004). In this study, when harvest aid was applied at the ideal application timing, the crop was harvested 7 to 14 d after application and depending on cultivar, 7 to 15 d before the non-treated.  Strict adherence to the 15 d harvest interval for parquat would negate the benefit of earlier harvest. Application of harvest aid can also improve harvest efficiency (Burnside et al. 1969; Burnside 1973; Griffin et al. 2003) and crop quality (Ellis et al. 1998; Willard and Griffin 1993) resulting in increased net return (Boudreaux and Griffin 2008).

In recent years in the mid-South, soybean production has shifted to early maturing cultivars. There has also been an increased incidence of the soybean green plant malady where although soybean seed are mature and ready to harvest, leaf retention and presence of green stems and pods can delay harvest (Griffin et al. 2010). It may be beneficial in a soybean production system that harvest aid be applied as a preventative measure to enhance desiccation of soybean and to decrease variability among plants within a field. Improved harvest efficiency and earlier harvest could also be added advantages to harvest aid application.

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# CHAPTER 3

# SOYBEAN IPM PROGRAMS AND HARVEST AID INTERACTIONS IN SOYBEAN

## INTRODUCTION

In Louisiana, soybean production in recent years has shifted toward use of maturity groups IV and V. Since these cultivars are harvested in August and escape late season droughts, pests, and plant diseases. Issues with Cercospera leaf blight (*Cercospora kukuchii*) and Asian soybean rust (*Phakopsora pachyrhizi*) epidemics have resulted in increased use of fungicides (Padgett 2007). To maximize soybean production especially in Louisiana, it is critical that an IPM program be implemented to include management of insects, diseases, and weeds. In recent years, soybean growers have experienced excessive green leaf retention and presence of green stems and pods when seed have dried down and reached harvest maturity. This condition is referred to as the "green plant malady" in Louisiana, and can delay harvest, decrease yield, and reduce seed quality (Griffin et al. 2010).

Harvest aids were initially used to desiccate weeds at harvest, but in recent years the role of desiccants has shifted to defoliation of the crop. Glyphosate applied to grain sorghum [*Sorghum bicolor* (L.) Moench ssp. *Bicolor*] reduced grain, leaf, and stem moisture and allowed for harvest 7 to 14 days earlier (Bovey et al. 1975). In another study, applying glyphosate or paraquat to grain sorghum at 30 and 35% seed moisture accelerated harvest by 5 to 7 days, but yield was negatively affected (Gigax and Burnside 1976). When harvest aid was applied at 50% average seed moisture for a MG 4 cultivar seed yield was not reduced and harvest was 14 days earlier than with no harvest aid (Boudreaux and Griffin 2008). Application of harvest aid to MG 5 and 6 cultivars at 50% average seed moisture reduced yield, but yield was not affected when applied at 40% average seed moisture. Soybean harvest was 7 to 14 days earlier than the control. Postponing harvest after soybean has reached maturity can expose plants to adverse weather conditions that can reduce yield and seed quality (Sidible et al. 1999). Philbrook and Oplinger (1989) reported yield losses of 0.2% per day which was attributed to plant deterioration, grain losses, decreased harvest efficiency, and reduction in net yield.

In the 1980's the green plant malady was reported to be caused by stink bug damage, viruses, microplasms or phytoplasmas (Boquet et al. 2010). In the 1990's, green plant problems became more wide spread and were attributed to changes in plant genetics and management practices that affected physiological responses, including stress imposed by insects.

In 2001, Georgia producers spent $860,000 controlling green stink bug [*Acrosternum hilare* (Say)], southern green stink bug [*Nezara viridula* (L.)], and brown stink bug [*Euschistus servus* (Say)], with seed damage losses estimated at $120,000 (McPherson and Jones 2001). McPherson and Jones (2001) and McPherson et al. (2003), found that stink bugs were more abundant on early maturing varieties during the mid-season. Insect management was emphasized when growers adopted early soybean production systems (Baur et al. 2000).

Stink bugs damage seed by puncturing the membrane exposing seeds to secondary damage from pathogens (Clarke and Wilde 1970). Green and southern green stink bug feeding during pod fill reduced seed yield, size, weight, and oil content and increased seed damage (Brier and Rogers 1991; Daugherty et al. 1964; Todd and Tunipseed 1974; Yeargan 1977). When populations of green, southern green, brown, and redbanded stink bugs [*Piezodorus guildinii* (Westwood)] combined reached treatment thresholds of 9 or more per 25 sweeps, significant reductions in soybean yield, 100 seed weight, and seed quality were documented due to increased percentage of damaged seeds from stink bug feeding (McPherson et al. 1993). Feeding by southern green stink bug at a population of 6 per 0.3 m of row for 7 to 14 days delayed soybean maturity as evidence when infestation occurred during the R3-R5.5 growth stages reducing soybean yield 15 to 28% (Boethel et al. 2000). In other studies, an infestation of 5 stink bugs per 0.3 m of row for 7 d reduced yield up to 26% and reduced seed quality McPherson et al. (1979), while infestation of 2 stink bugs per 0.3 m of row for 49 d reduced yield up to 40% and 100 seed weight 13.2% (Thomas et al. 1974). Simmons and Yeargan (1988) and Jensen and Newsom (1971) attributed yield loss from green stink bug feeding to fewer seeds or damaged seed.

Plant pathogens play an important role in Louisiana soybean production with Cercospera leaf blight and Asian soybean rust among the greatest concern (Padgett 2007). Improvement in plant health with foliar fungicides extend soybean growth which can contribute to green leaf retention and green stems (Padgett et al. 2003). Soybean plants treated with triazole and strobilurin fungicides retained lower canopy leaves several days longer than non-treated plants (Potter 2005). Research on delayed soybean maturity has focused on green stems. Bean pod mottle virus was suggested as the casual agent of this malady. However, many plants infected with the virus did not develop green stem disorder, and conversely, many plants that had green stem disorder were not infected with BPMV (Hobbs et al. 2006). It was reported that some soybean cultivars were predisposed to the green stem disorder (Hill et al. 2003; Hill et al. 2006).

The specific causes of the green plant malady including excessive green leaf retention, green stems, and/or green pods have not been determined, but most likely are related to the interaction of multiple biotic and abiotic factors. Research was conducted to investigate the effects of fungicide application and stink bug control on soybean green leaf retention, green stems and green pods at harvest maturity. In addition the effect of paraquat harvest aid to remediate the green plant problem and the subsequent effects on seed quality, yield, and economics were investigated.

## MATERIALS AND METHODS

**Baton Rouge Study.** Experiments were conducted in 2007 and 2008 at the Central Station, Ben Hur Research Farm in Baton Rouge, La. The soil type was a Mhoon silty clay loam (fine-silty, mixed, nonacid, thermic Typic Fluavaquent) with 1.9% OM and a pH of 6.3. `AsGrow 4403RR` soybean was planted on April 14, 2007 and April 30, 2008 at a seeding rate of 56 kg/ha with a row spacing of 38cm. The experimental design was a randomized complete block with a three-factor factorial treatment arrangement (fungicide, insecticide, and harvest aid treatments) and four replications. Plots size was 10.3 by 9.1 m and treatments applied using a tractor mounted pto sprayer delivering 140 L/ha at 220 kPa with 110003 flat fan teejet[1] nozzles. Fungicide and harvest aid applications were based on soybean growth stages according to Fehr and Caviness 1977.

Fungicide treatments included pyraclostrobin (Headline®) at 219 g ai/ha + thiophanate-methyl (Topsin M®) at 784 g ai/ha applied at R3 on June 26, 2007 and July 2, 2008, and no fungicide application control. Insecticide treatments included acephate (Orthene®) at 1,000 g ai/ha + cyfluthrin (Baythorid®) at 18 g ai/ha, lambda-cyhalothrin (Karate®) at 19 g ai/ha applied, and no insecticide control.

[1]Teejet Agricultural Spray Products. Spraying Systems Co. Wheaton, IL 60189.

Insecticide levels were chosen to simulate maximum control (acephate + cyfluthrin) and intermediate control (lambda-cyhalothrin) and no control (non-treated). Insecticide application timing was based on the aggregate of stink bugs per 25 sweeps and included both adults and nymphs of green stink bug, southern green stink bug, brown stink bug, and redbanded stink bug (*Piezodorus guildinii*). Insect populations were monitored weekly using a sweep net and for maximum control, insecticide was applied when insect numbers reached 2-3 per 25 sweeps. The intent was to keep stink bug numbers below an action threshold throughout the growing season. For the intermediate control, insecticide was applied when insect numbers reached an action threshold of 8-9 per 25 sweeps. For both years of the study two insecticide treatments were applied. In 2007, lambda-cyhalothrin was applied June 11 and August 1, and acephate + cyfluthrin was applied June 11 and June 25. In 2008, lambda-cyhalothrin was applied August 7 and August 20, and acephate + cyfluthrin was applied on July 22 and August 7.

Superimposed on the fungicide and insecticide treatments was a harvest aid application of paraquat at 280 g ai/ha plus 0.25% v/v nonionic surfactant along with a no harvest aid control. Paraquat was applied August 6, 2007 and August 26, 2008 when seeds from the top four nodes of the plant averaged 40% moisture (Boudreaux and Griffin 2008). For both years, plans were to harvest soybean when seed moisture was 13 to 14%. In some cases when soybean were at harvest maturity green leaves, stems, and/or pods were present. In 2007, plots receiving harvest aid were harvested two weeks earlier, August 15, than those not receiving harvest aid. The delay was due to leaf retention and presence of green pods and stems and intermittent rain that totaled 4.6 cm during the 2-week period. In 2008 when harvest aid was applied on August 26, soybean was ready to harvest 5 DAT, but because of rainfall (18.9 cm) associated with Hurricane Gustav which made landfall on September 1, all soybeans were harvested on September 10. To compare treatments, yield was adjusted to 13% moisture.

**Winnsboro Study.** Experiments were conducted at the Macon Ridge Research Station in Winnsboro, La, in 2007 and 2008. The soil type was a Gigger silt loam (fine-silty, mixed, active, thermic Typic Fragiudalfs) with 1.0% OM and a pH of 6.0. \`AsGrow 5606\` soybean was planted June 10, 2007 and \`Asgrow 5702\` soybean was planted June 16, 2008 at a seeding rate of 56 kg/ha with a row spacing of 102 cm. The experimental design and treatments evaluated were the same as described for the Baton Rouge study. Treatments were replicated 3 times and plot size was 7.7 by 9.1 m. Fungicide, insecticide, and harvest aid were applied using a $CO_2$ tractor mounted pressurized sprayer delivering 46 L/ha at 241 kPa with 8001 flat fan teejet[22] nozzles.

Fungicide was applied at R3 on July 24, 2007 and August 6, 2008. In 2007, lambda-cyhalothrin was applied August 18, September 7, September 15, and September 24, and acephate + cyfluthrin was applied August 18, September 7, September 15, and September 24. In 2008, lambda-cyhalothrin was applied August 20, September 10, September 17, and September 23 and acephate + cyfluthrin was applied September 10, September 17, and September 23. Paraquat harvest aid was applied October 8, 2007 and October 15, 2008. Plots were harvested as soon as possible after seed were mature and weather conditions permitted. Seed yield was adjusted to 13% moisture

At both locations on the day of harvest, plants in each plot were visually evaluated for percent green leaf retention, green stems, and green pods based on a scale of 0 to100 where 0=no green leaf retention, green stems, and green pods and 100=all plants in the plot on a

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[2] Teejet Agricultural Spray Products. Spraying Systems Co. Wheaton, IL 60189.

percentage basis having some level of green leaves, green stems, and green pods. At harvest sub-samples from each plot were collected and submitted to the Bunge Elevator, Lettsworth, LA to be graded for percent seed damage and foreign material using USDA AMS procedures (USDA 2004).

Because of differences in stink bug pressure, data were analyzed separately for the two locations by year. Weekly stink bug bug infestation data for the intermediate control, maximum control, and no control treatments were averaged across fungicide and harvest aid treatments, were not analyzed statistically, but represent changes for each treatment across the growing season compared with the threshold of 9 stink bugs/25 sweeps. Cumulative stink bug numbers were subjected to analysis of variance in SAS[3] with means separated using Fisher's protected LSD (P=0.05).

Because of the difference in cultivars and insect numbers, soybean plant data for Baton Rouge and Winnsboro were analyzed separately. Data for each location were subjected to the Mixed Procedure in SAS[3], and because there were no significant year effects, data were averaged across years. Years, replications (nested within years) and all interactions with either of these effects were considered random (Carmer et al.1989). All other variables were considered fixed. Considering years as environmental or random effects permit inferences about treatments to be made over a range of environments (Carmer et al. 1989; Hager et al. 2003). Although treatments were placed in a factorial arrangement, data were analyzed as individual fungicide/stink bug control programs (no fungicide/no stink bug control; no fungicide stink bug control intermediate; no fungicide/stink bug control maximized;

[3] SAS institute. 2003. SAS User's Guide: Statistics. Version 9.1. SAS Institute Inc., SAS Campus Drive, Cary, NC 27513.

fungicide/no stink bug control; fungicide/stink bug control intermediate; fungicide/stink bug control maximized). Analysis of variance was performed and least square means for fungicide and stink bug control programs with and without harvest aid were calculated and means separated using Fisher's protected LSD P=0.10. Letter groupings were converted using the PDMIX800 macro in SAS (Saxton 1998). For each parameter measured, comparisons were made among fungicide and stink bug control programs with or without harvest aid and between fungicide/stink bug control programs with and without harvest aid (Appendix Tables 2 and 3).

**Economic Analysis.** For the soybean yield data not adjusted for moisture, gross return for yield was calculated assuming a price of \$0.37/kg soybean. Using seed moisture of harvested grain and the data provided by Bunge Corporation, foreign material and seed damage deductions were determined using the Bunge "Soybean Discount Schedule" for moisture, foreign material, and damage (Appendix Table 1). Deductions for moisture and foreign material are based on a percentage of the gross yield; as seed moisture increases above 13% and foreign material above 1% deductions increase. For seed damage, deductions are based on a reduction in price; as seed damage increases \$/kg of yield decrease. Total seed quality loss was calculated and using gross return for yield, net return was determined. The increase in net return due to harvest aid application was calculated.

## RESULTS AND DISCUSSION

**Baton Rouge Study.** In 2007 and 2008, both the intermediate and maximum stink bug control programs maintained stink bug infestations below the action threshold of 9 stink bugs per 25 sweeps throughout the growing season (Figures 3.1 and 3.2). By July 19, 2007 and

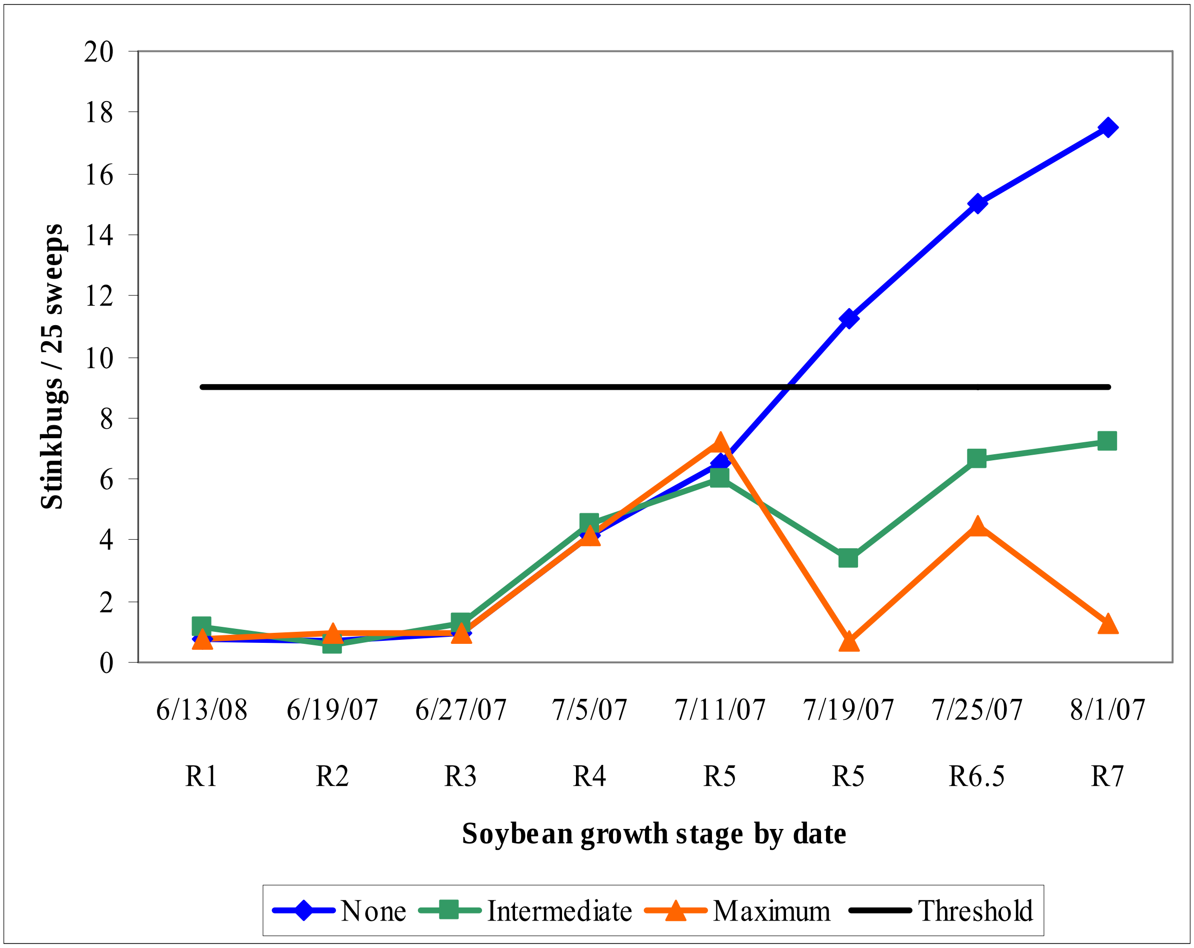


Figure 3.1. Stink bug numbers as affected by control programs at the Central Station, Ben Hur Research Farm, Baton Rouge, La in 2007.
Application timings were based on the total number of stink bugs per 25 sweeps which included: green stink bug, southern green stink bug, brown stink bug, redbanded stink bug, and nymphs. Insect populations were monitored weekly. For intermediate control, lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps on June 11 and August 1, 2007. For maximum control, acephate at 1,000 g ai/ha + cyfluthrin at 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps on June 11 and June 25, 2007.

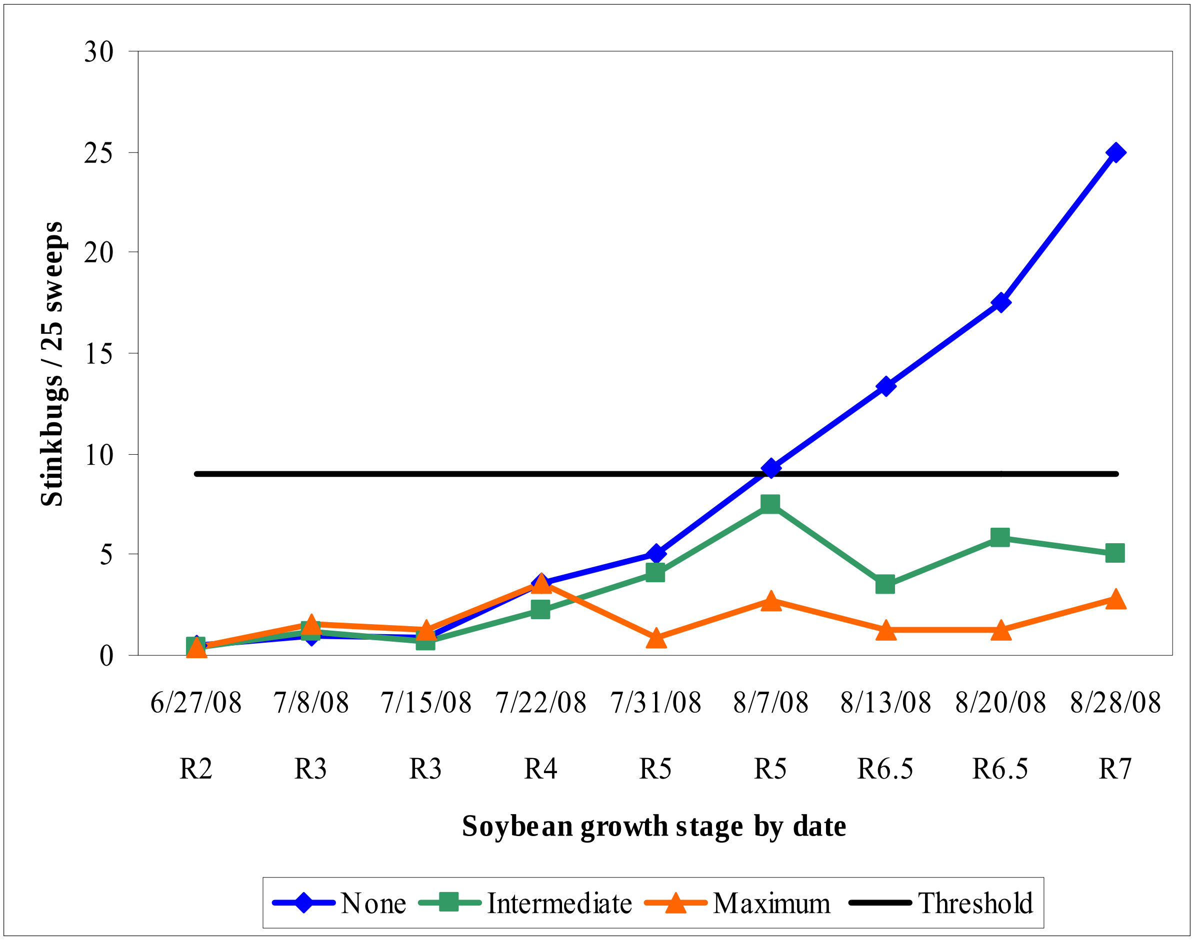


Figure 3.2. Stink bug numbers as affected by control programs at the Central Station, Ben Hur Research Farm, Baton Rouge, La in 2008.
Application timings were based on the total number of stink bugs per 25 sweeps which included: green stink bug, southern green stink bug, brown stink bug, redbanded stink bug, and nymphs. Insect populations were monitored weekly. For intermediate control, lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps on August 7 and August 20, 2008. For maximum control, acephate at 1,000 g ai/ha + cyfluthrin at 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps on July 22 and August 7, 2008.

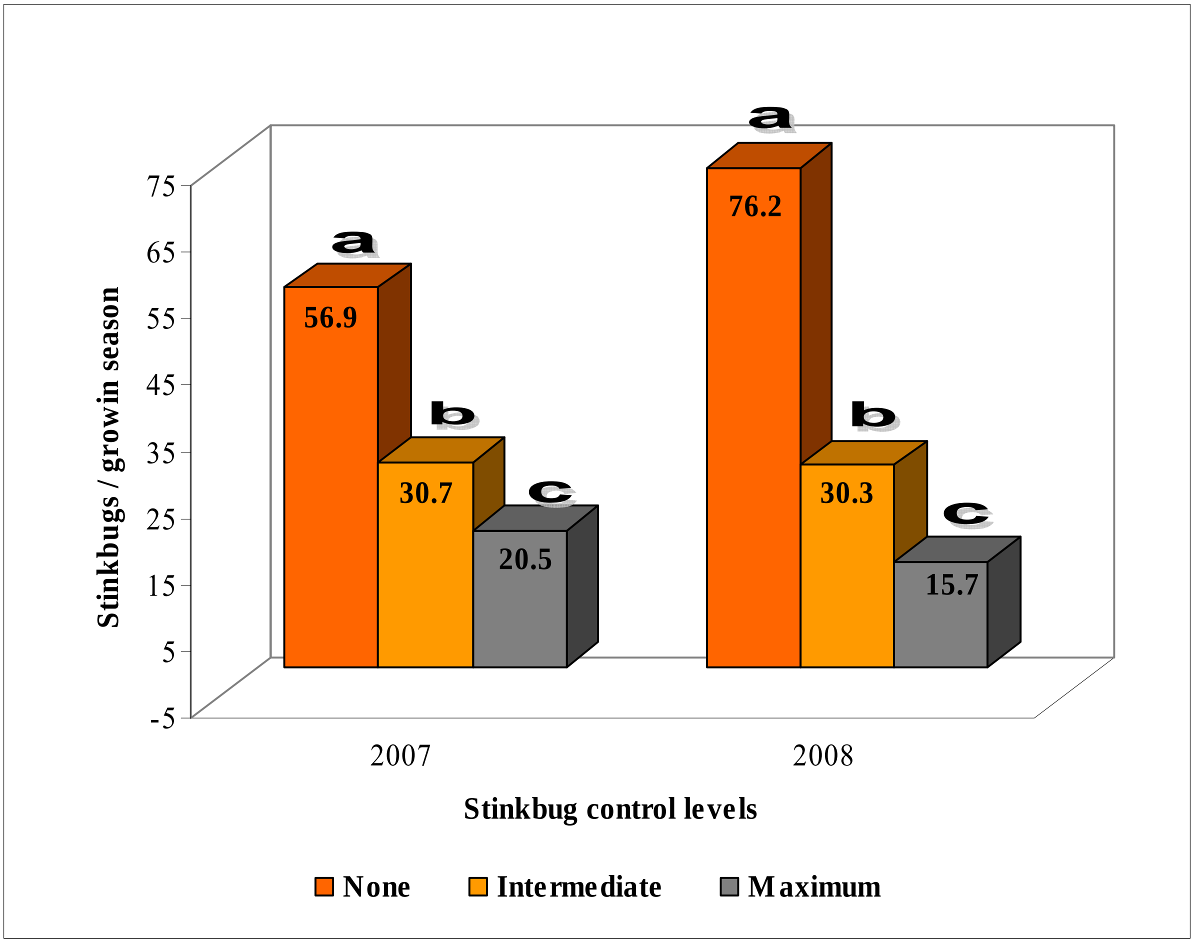


Figure 3.3. Cumulative stink bug numbers as affected by control programs at the Central Station, Ben Hur Research Farm Baton Rouge, La in 2007 and 2008.
Application timings were based on the total number of stink bugs per 25 sweeps which included: green stink bug, southern green stink bug, brown stink bug, redbanded stink bug, and nymphs. Insect populations were monitored weekly. For intermediate control, lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps on June 11 and August 1, 2007 and August 7 and August 20, 2008. For maximum control, acephate at 1,000 g ai/ha + cyfluthrin at 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps on June 11 and June 25, 2007 and July 22 and August 7, 2008. For each year bars with the same letter are not significantly different ($P \leq 0.05$). Data averaged across fungicide and harvest aid treatments.

July 31, 2008 stink bug infestation was lower in the maximum control program (two applications of acephate + cyfluthrin) than in the intermediate control program (lambda-cyhalothrin). Where bug stink was not controlled, the infestation exceeded the action threshold July 19, 2007 and August 7, 2008. By August 1, 2007 stink bugs in the non-treated control reached nearly 2 fold that of the action threshold. By August 28, 2008 stink bugs reached nearly 3 fold that of the action threshold. Cumulative stink bug numbers both years was greatest where stink bug was not controlled (57 in 2007 and 76 in 2008) and lowest for the maximum stink bug control program (21 in 2007 and 16 in 2008) (Figure 3.3).

Data for all parameters was compared among individual fungicide/stink bug control programs for harvest aid versus no harvest aid application. For pairwise comparison of all possible combinations of fungicide/stink bug control programs and harvest aid treatments using a T-test see Appendix Tables 2 and 3.

When paraquat harvest aid was applied, soybean green leaf retention at harvest was no more than 2% regardless of fungicide/stink bug control program (Table 3.1). When harvest aid was not applied, soybean green leaf retention for the fungicide/stink bug control programs was 3 to 9%, and was lowest when fungicide was not applied and stink bug control was intermediate or maximized (no more than 4%). For each of the fungicide/stink bug control programs, application of harvest aid reduced green leaf retention compared with no harvest aid.

When harvest aid was used in the no fungicide/no stink bug control program, percentage of green stems at harvest was 17% (Table 3.1). For the other programs, green stem percentage was 2 to 6% and less than the no fungicide/no stink bug control program. When harvest aid was not applied, green stem percentage (52%) in the no fungicide/no stink bug control program

Table 3.1. Effect of fungicide and insecticide programs followed by paraquat harvest aid (HA) application on percentage soybean green leaf retention, green stems, green pods, and seed moisture at harvest.[1]

| Fungicide/stink bug control program[2] | Green leaf retention | | Green stem | | Green pod | | Seed moisture | |
|---|---|---|---|---|---|---|---|---|
| | + HA | - HA | + HA | - HA | + HA | - HA | + HA | - HA |
| | % | | | | | | | |
| No fungicide/no stink bug control | 1* bc[3,4] | 6 bc | 17*a | 52 a | 5* a | 7 a | 13.9 | —[5] |
| No fungicide/stink bug control intermediate | 1* bc | 4 c | 5* b | 20 cd | 2 b | 3 bc | 13.0* | 15.0 b |
| No fungicide/stink bug control maximized | 0* c | 3 c | 2* b | 21 bcd | 1 b | 2 c | 13.2* | 15.3 b |
| Fungicide/no stink bug control | 2* ab | 9 a | 6* b | 35 b | 2* b | 6 ab | 13.9* | 18.0 a |
| Fungicide/stink bug control intermediate | 1* bc | 7 ab | 5 * b | 15 d | 1* b | 4 bc | 13.4* | 16.5 ab |
| Fungicide/stink bug control maximized | 2* ab | 8 ab | 4* b | 33 bc | 2 * b | 4 bc | 13.3* | 16.7 ab |
| P-value | 0.0267 | 0.0068 | 0.0001 | 0.0001 | 0.0025 | 0.0033 | 0.1076 | 0.0348 |

[1]Data collected on the day of harvest for `AsGrow 4403` soybean grown at the Central Station, Ben Hur Research Farm, Baton Rouge, La, and averaged across 2007 and 2008.

[2]Fungicide treatment was pyraclostrobin at 219 g ai/ha + thiophanate-methyl at 784 g ai/ha applied at R3. Insect numbers were monitored weekly, and for the intermediate stink bug control lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps. For maximum control acephate at 1,000 g ai/ha + cyfluthrin 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps. For both years of the study two applications of each insecticide treatment were made. Paraquat at 280 g ai/ha plus a nonionic surfactant at 0.25% v/v was applied at R6.5 on August 6, 2007 and August 26, 2008.

[3]Means for each of the fungicide/stink bug control programs within rows for percent green leaf retention, green stem, green pod, and seed moisture followed by an asterisk denotes a difference between application and no application of paraquat harvest aid ($P \leq 0.10$). Means without an asterisk are not significantly different ($P \leq 0.10$).

[4]Means for each of the fungicide/stink bug control programs within columns for the harvest aid or no harvest aid treatments followed by the same letter are not significantly different ($P \leq 0.10$). P-values are provided.

[5]Soybean could not be harvested.

was greater than the other programs (15 to 35% green stems).Green stem percentage was reduced by 35 percentage points with the addition of a harvest aid for the no fungicide/no stink bug control program. For the other programs, percentage green stems reductions ranged from10 to 29 percentage points with harvest aid application.

Percentage green pods for the no fungicide/no stink bug control was 5% when harvest aid was applied and was no more than 2% for the other programs (Table 3.1). When harvest aid was not applied, green pod percentage was 7% for the no fungicide/no stink bug control program and for the other programs green pod percentage was 2 to 6%. Green pod percentage was reduced when harvest aid was applied for all fungicide/stink bug control programs (2 to 4 percentage points) except where fungicide was not applied and stink bug control was intermediate or maximized.

Differences among the fungicide/stink bug control programs for seed moisture were not observed with harvest application (13.5%) (Table 3.1). When harvest aid was not applied, soybean could not be harvested due to excessive green stems for the no fungicide/no stink bug control program. For the fungicide/no stink bug control program without harvest aid, soybean seed moisture was 18%, but was no more than 15.3% when fungicide was not applied and stink bug was controlled at either level.

For all fungicide/stink bug control programs without harvest aid, seed moisture was at least 2 percentage points greater than when harvest aid was applied. Programs with the highest seed moisture were fungicide/no stink bug control, fungicide/stink bug control intermediate, and fungicide/stink bug control maximized (3.1 to 4.1 percentage points greater with no harvest aid) were the same programs in general that promoted greater green leaf retention, green stems, and green pods. It has been reported that fungicides used in soybean can contribute to leaf retention and presence of green stems (Padgett 2003, Potter 2005). In this study harvest aid was especially beneficial in reducing percentage green stems and their subsequent effect on seed moisture. In a practical sense, soybean delivered to the elevator with seed moisture of 16 to 18% would be rejected or would receive a high dockage (6-10.8% of gross yield) based on the soybean discount schedule (Appendix table 1).

Foreign material in soybean harvested for the fungicide/stink bug control programs with or without harvest aid was no more than 1.5% (Table 3.2). Statistical differences among most of the IPM programs were not observed for foreign material. However values greater than 1% would result in a deduction based on the Bunge Corporation soybean discount schedule (Appendix Table 1).

Seed damage where harvest aid was applied for the no fungicide/no stink bug control program was 9.0% and greater than for the other programs (Table 3.2). Seed damage for the other fungicide/stink bug control programs ranged from 3.1% (no fungicide/stink bug control maximized) to 5.4% (fungicide/no stink bug control). When harvest aid was not applied seed damage ranged from 3.9% (no fungicide/stink bug control maximized) to 7.1% (fungicide/no stink bug control). The greater seed damage observed where stink bugs were not controlled was not unexpected and emphasizes the importance of stink bug control in an IPM program showing that even though stink bug was controlled with insecticide treatments (Figures 3.1, 3.2, and 3.3), some damage to seed still occurred. Application of harvest aid reduced seed damage for the fungicide/no stink bug control program1.7 percentage points, and for the fungicide/stink bug control intermediate program 2 points. Seed damage is most often associated with stink bug (Todd and Turnipseed 1974), but can also be attributed to pathogens such as purple seed stain (*Cercospora kikuchii*), seed decay (*Bacillus subtilis, Pseudomonas*

Table 3.2. Effect of fungicide and insecticide programs followed by paraquat harvest aid (HA) application on percentage foreign material and seed damage, and soybean yield.[1]

| Fungicide/stink bug control program[2] | Foreign material | | Seed damage | | Yield[3] | |
|---|---|---|---|---|---|---|
| | + HA | - HA | + HA | - HA | + HA | - HA |
| | % | | | | Kg/ha | |
| No fungicide/no stink bug control | 1.0 | —[4] | 9.0 a[5] | —[4] | 3950 a | —[4] |
| No fungicide/stink bug control intermediate | 1.1 | 1.4 | 4.3 bc | 5.0 abc | 4400 b | 4290 |
| No fungicide/stink bug control maximized | 1.0 | 1.3 | 3.1 c | 3.9 c | 4380 b | 4220 |
| Fungicide/no stink bug control | 0.9 | 1.5 | 5.4*b[6] | 7.1 a | 4450 b | 4320 |
| Fungicide/stink bug control intermediate | 1.0 | 1.2 | 4.1* bc | 6.1 ab | 4540* b | 4260 |
| Fungicide/stink bug control maximized | 0.7 | 1.3 | 3.7 bc | 5.2 ab | 4550 b | 4310 |
| P-value | 0.6499 | 0.9983 | < 0.0001 | 0.0185 | 0.0146 | 0.4685 |

[1]Data collected on combine harvested samples for \`AsGrow 4403\` soybean grown at the Central Station, Ben Hur Research Farm, Baton Rouge, La, and averaged across 2007 and 2008.

[2]Fungicide treatment was pyraclostrobin at 219 g ai/ha + thiophanate-methyl at 784 g ai/ha applied at R3. Insect numbers were monitored weekly, and for the intermediate stink bug control lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps. For maximum control acephate at 1,000 g ai/ha + cyfluthrin 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps. For both years of the study two applications of each insecticide treatment were made. Paraquat at 280 g ai/ha plus a nonionic surfactant at 0.25% v/v was applied at R6.5 on August 6, 2007 and August 26, 2008.

[3]Yield adjusted to 13% moisture to allow for comparison among treatments.

[4]Soybean could not be harvested.

[5]Means for each of the fungicide/stink bug control programs within columns for the harvest aid or no harvest aid treatments followed by the same letter are not significantly different ($P \leq 0.10$). P-values are provided.

[6]Means for each of the fungicide/stink bug control programs within rows for percent green leaf retention, green stem, green pod, and seed moisture followed by an asterisk denotes a difference between application and no application of paraquat harvest aid ($P \leq 0.10$). Means without an asterisk are not significantly different ($P \leq 0.10$).

*syringae pv. glycinea*, *Althernaria* spp., and *Aspergillus* spp., *Penicillium* spp., and *Phomopsis longicolla*) and Yeast spot (*Nematospora coryli Pegl*.) (Sinclair 1993). In this study where harvest aid was not applied, seed damage numerically was greatest where stink bug was not controlled whether or not fungicide was applied. This suggests that stink bug was primarily responsible for seed damage observed. Although, statistical differences were not always observed among the fungicide/insect control programs,
seed damage of 2% or more would receive a deduction based on the Bunge Corporation soybean discount schedule (Appendix Table 1). In the present study a deduction would be accessed for all of the fungicide/stink bug control programs.

When harvest aid was applied, soybean yield (adjusted for 13% moisture) for the no fungicide/no stink bug control program was 3,950 kg/ha (Table 3.2). For the other IPM programs soybean yield was equivalent and averaged 13% more than the no fungicide/no stink bug control program. When harvest aid was not applied yield differences were not observed among the fungicide/stink bug control programs. Harvest aid application resulted in increased soybean yield only for the fungicide/stink bug control intermediate program 6.6%.

**Economic Analysis.** Deductions for soybean seed moisture are assessed when moisture levels exceed 13%. Deductions are based on a schedule that increases as percent moisture increases (Appendix Table 1). Seed moisture deductions were assessed for all IPM programs except the no fungicide/stink bug control intermediate program with harvest aid (Table 3.3). Deductions ranged from $16.24 to $181.26/ha and were greater when harvest aid was not applied. Foreign material greater than 1% is deducted by that percentage from gross yield. Where harvest aid was applied deduction for foreign material was assessed only for the fungicide/stink bug control intermediate program (1.1% foreign material and $1.63/ha deduction) (Table 3.3).

Table 3.3. Effect of fungicide and insecticide programs followed by paraquat harvest aid (HA) application on deduction for soybean seed moisture, foreign material, and seed damage.[1]

| Fungicide/stink bug control program[2] | Deduction for seed moisture | | Deduction for foreign material | | Deduction for seed damage | | Total seed quality loss[3] | |
|---|---|---|---|---|---|---|---|---|
| | + HA | - HA | + HA | - HA | + HA | - HA | + HA | - HA |
| | $/ha | | | | | | | |
| No fungicide/no stink bug control | $29.49 | —[4] | $0.00 | —[4] | $33.61 | —[4] | $63.10 | —[4] |
| No fungicide/stink bug control intermediate | $0.00 | $64.76 | $1.63 | $6.48 | $12.91 | $12.84 | $14.54 | $84.08 |
| No fungicide/stink bug control maximized | $16.24 | $79.87 | $0.00 | $4.79 | $8.05 | $7.91 | $24.29 | $92.57 |
| Fungicide/no stink bug control | $33.23 | $181.26 | $0.00 | $8.39 | $18.11 | $31.60 | $51.34 | $221.25 |
| Fungicide/stink bug control intermediate | $16.87 | $117.46 | $0.00 | $3.26 | $13.37 | $24.25 | $30.24 | $144.97 |
| Fungicide/stink bug control maximized | $16.89 | $138.91 | $0.00 | $4.96 | $8.37 | $18.03 | $25.26 | $161.90 |

[1]See Table 1 for seed moisture data and Table 2 for foreign material and seed damage data. Data collected for `AsGrow 4403` soybean grown at the Central Station, Ben Hur Research Farm, Baton Rouge, La, and averaged across 2007 and 2008.

[2]Fungicide treatment was pyraclostrobin at 219 g ai/ha + thiophanate-methyl at 784 g ai/ha applied at R3. Insect numbers were monitored weekly, and for the intermediate stink bug control lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps. For maximum control acephate at 1,000 g ai/ha + cyfluthrin 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps. For both years of the study two applications of each insecticide treatment were made. Paraquat at 280 g ai/ha plus a nonionic surfactant at 0.25% v/v was applied at R6.5 on August 6, 2007 and August 26, 2008.

[3]Total seed quality loss = deduction for moisture, foreign material, and damage.

[4]Soybean could not be harvested.

Deductions due to foreign material ($3.26/ha to $8.39/ha) were assessed for all fungicide/stink bug control programs where harvest aid was not applied. For soybean delivered to the elevator seed damage up to 2% is allowed. As seed damage increases, deductions increase following a schedule (Appendix Table 1). The deduction for seed damage was $33.61/ha in the no fungicide/no stink bug control program with harvest aid (Table 3.3). Deductions due to seed damage were also observed for the other fungicide/stink bug control programs regardless of harvest aid application. When harvest aid was applied, the deduction was lowest when stink bug control was maximized with no fungicide ($8.05/ha reduction) and with a fungicide ($8.37/ha reduction). When stink bug was not controlled or controlled at an intermediate level and harvest aid was applied, deductions were $18.11/ha and $13.37/ha, respectively, when fungicide was applied and $12.91 when fungicide was not applied and stink bug control was intermediate.

When harvest aid was not applied, deductions were lowest for no fungicide/stink bug control maximized program ($7.91/ha) and greatest for fungicide/no stink bug control program ($31.60) (Table 3.3). For all programs with/without fungicide deductions due to seed damage were greatest where stink bug was not controlled and lowest where bug stink control was maximized. This observation is supported by cumulative stink bug numbers which show in both years that stink bug infestation was greatest where stink bug was not controlled, intermediate for the intermediate control program, and lowest for the maximum control program (Figure 3.3).

Total seed quality loss (deductions for seed moisture, foreign material, and seed damage) was $63.10/ha and greatest for the no fungicide/no stink bug control program when harvest aid was applied (Table 3). For the other programs, losses ranged from $14.54/ha for the no fungicide/stink bug control intermediate program to $51.34/ha for the fungicide/no stink bug control program. When harvest aid was not applied, losses due to seed quality ranged from $84.08/ha for the no fungicide/intermediate stink bug control program to $221.25/ha for the fungicide/no stink bug control program. The greatest benefit from the harvest aid application in reducing seed quality loss was for the fungicide/no stink bug control program ($169.91/ha less reduction when harvest aid was applied). For this treatment, seed quality losses were due high deductions for seed moisture and damage where harvest aid was not applied. For the fungicide/stink bug control maximized program, harvest aid reduced seed quality loss by $136.64/ha.

To allow for comparison of deductions due to seed moisture, gross return for yield was based on yield at the unadjusted harvest moisture. Using the yield data, gross return was calculated assuming a price of $0.37/kg (Table 3.4). A gross return of $1,474.65 to $1,688.55/ha was obtained for the fungicide/stink bug control programs where harvest aid was applied. Where harvest aid was not applied, gross returns ranged from $1,597.31 to $1,678.32/ha. Gross return with harvest aid application was higher for all individual fungicide/stink bug control programs except the fungicide/no stink bug control program. For this program, the high gross return for yield for the no harvest aid treatment was due to seed moisture of 18% compared to 13.9% when harvest aid was applied (Table 3.1).

Net return was increased for all fungicide/stink bug control programs when harvest aid was applied compared with no harvest aid (Table 3.4). Loss in net return due to seed quality when harvest aid was not applied ranged from $68.28 to $114.73/ha for the no fungicide/stink bug control intermediate and maximized programs and for the fungicide/stink bug control

Table 3.4. Effect of fungicide and insecticide programs followed by paraquat harvest aid (HA) application on gross return for yield, net return, and increase due to harvest aid.[1]

| Fungicide/stink bug control program[2] | Gross return for yield[3] | | Net return[4] | | Increase due to HA[5] |
|---|---|---|---|---|---|
| | + HA | - HA | + HA | - HA | |
| | $/ha | | | | |
| No fungicide/no stink bug control | $1,474.65 | —[6] | $1,411.55 | —[6] | —[6] |
| No fungicide/stink bug control intermediate | $1,628.00 | $1,619.05 | $1,613.46 | $1,534.97 | $78.49 |
| No fungicide/stink bug control maximized | $1,623.84 | $1,597.31 | $1,599.55 | $1,504.74 | $94.81 |
| Fungicide/no stink bug control | $1,661.32 | $1,678.32 | $1,609.98 | $1,457.07 | $152.91 |
| Fungicide/stink bug control intermediate | $1,686.52 | $1,631.37 | $1,656.28 | $1,486.40 | $169.89 |
| Fungicide/stink bug control maximized | $1,688.55 | $1,653.70 | $1,663.29 | $1,491.80 | $171.49 |

[1]Data collected for `AsGrow 4403` soybean grown at the Central Station, Ben Hur Research Farm, Baton Rouge, La, and averaged across 2007 and 2008.

[2]Fungicide treatment was pyraclostrobin at 219 g ai/ha + thiophanate-methyl at 784 g ai/ha applied at R3. Insect numbers were monitored weekly, and for the intermediate stink bug control lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps. For maximum control acephate at 1,000 g ai/ha + cyfluthrin 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps. For both years of the study two applications of each insecticide treatment were made. Paraquat at 280 g ai/ha plus a nonionic surfactant at 0.25% v/v was applied at R6.5 on August 6, 2007 and August 26, 2008.

[3]Gross return for yield was not adjusted for moisture. Gross return for yield = yield x price ($0.37/kg).

[4]Net return = gross return for yield – total seed quality loss (see Table 3).

[5]Increase due to harvest aid = net return due to harvest aid application for each fungicide/stink bug control program.

[6]Soybean could not be harvested.

intermediate program. The increase in net return due to harvest aid application was greatest for the fungicide/stink bug control maximized program ($171.49/ha), and lowest for the no fungicide/stink bug control intermediate program ($78.49/ha). It is estimated that harvest aid cost including surfactant and aerial application would be $23.65/ha. Increase in net return due to harvest aid application for all fungicide/stink bug control programs would more than pay for the cost of a harvest aid application.

Results from the Baton Rouge study show that the combined seed quality deductions due to seed moisture, foreign material, and seed damage for all fungicide and stink bug control programs were at least 3.8 times greater when harvest aid was not applied (Table 3.3). When considering crop yield and deductions, the percentage increase in net return due to harvest aid application was greatest in an IPM program where fungicide was applied (10.5 to 11.5% increase in net return). This compared with 5.1 and 6.3 % increase in net return for IPM programs where fungicide was not applied.

**Winnsboro Study.** In 2007, only the maximum stink bug control program kept stink bug infestation below the action threshold throughout the growing season (Figure 3.4). For the intermediate stink bug control program, stink bug numbers exceeded threshold between the September 7 and 18 sampling dates and threshold was exceeded in the non-treated between August 7 and September 7 sampling dates. Stink bug numbers for these treatments for the remainder of the growing season exceeded threshold and for the non-treated, population reached 34 stink bugs per 25 sweeps on September 27. In contrast in 2008, stink bug population for all levels of stink bug control exceeded threshold between the August 28 and September 10 sampling dates (Figure 5). For the intermediate and maximum stink bug control

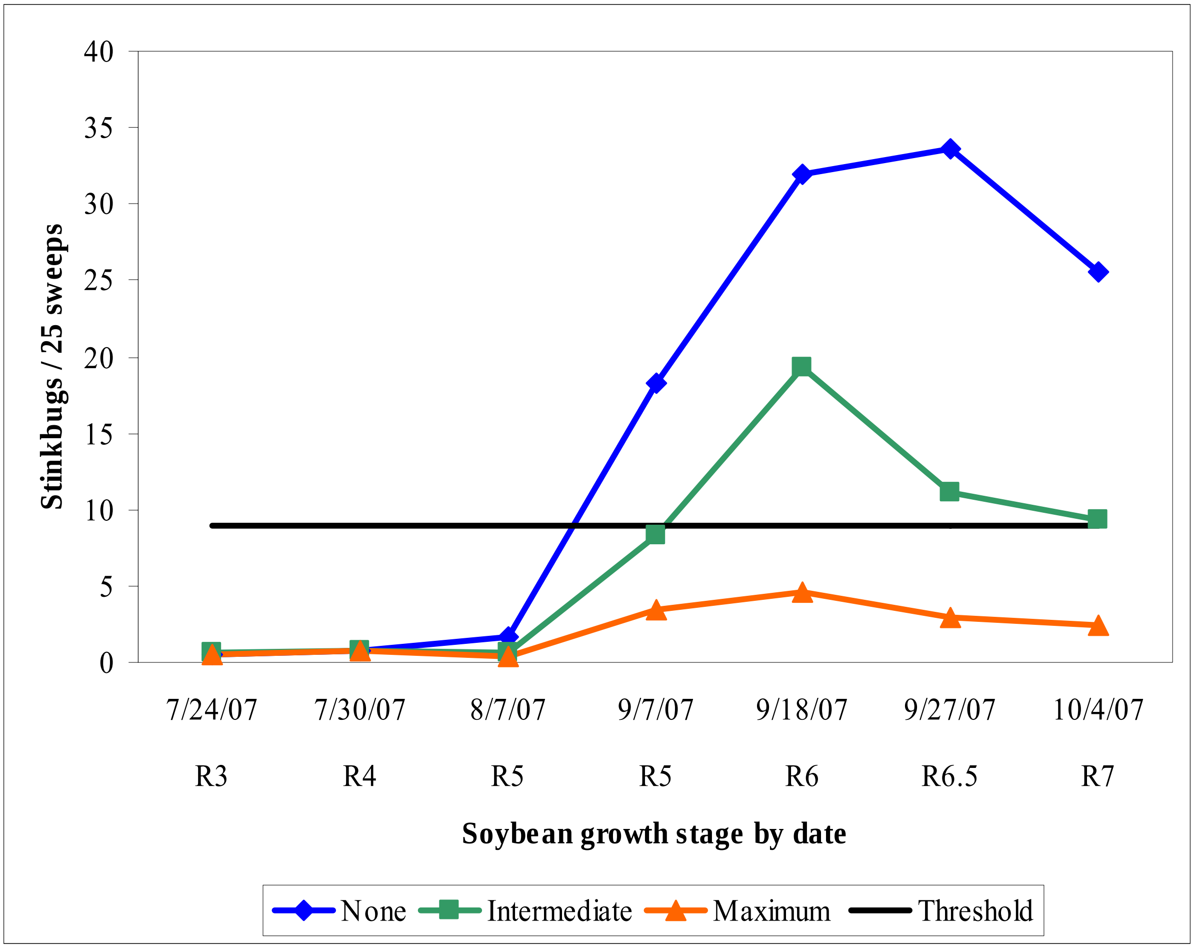


Figure 3.4. Stink bug numbers as affected by control programs at the Macon Ridge Research Station, Winnsboro, La in 2007.
Application timings were based on the total number of stink bugs per 25 sweeps which included: green stink bug, southern green stink bug, brown stink bug, redbanded stink bug, and nymphs. Insect numbers were monitored weekly. For intermediate control, lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps on August 18, September 7, September 15, and September 24, 2007. For maximum control, acephate at 1,000 g ai/ha + cyfluthrin at 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps on August 18, September 7, September 15, and September 24, 2007.

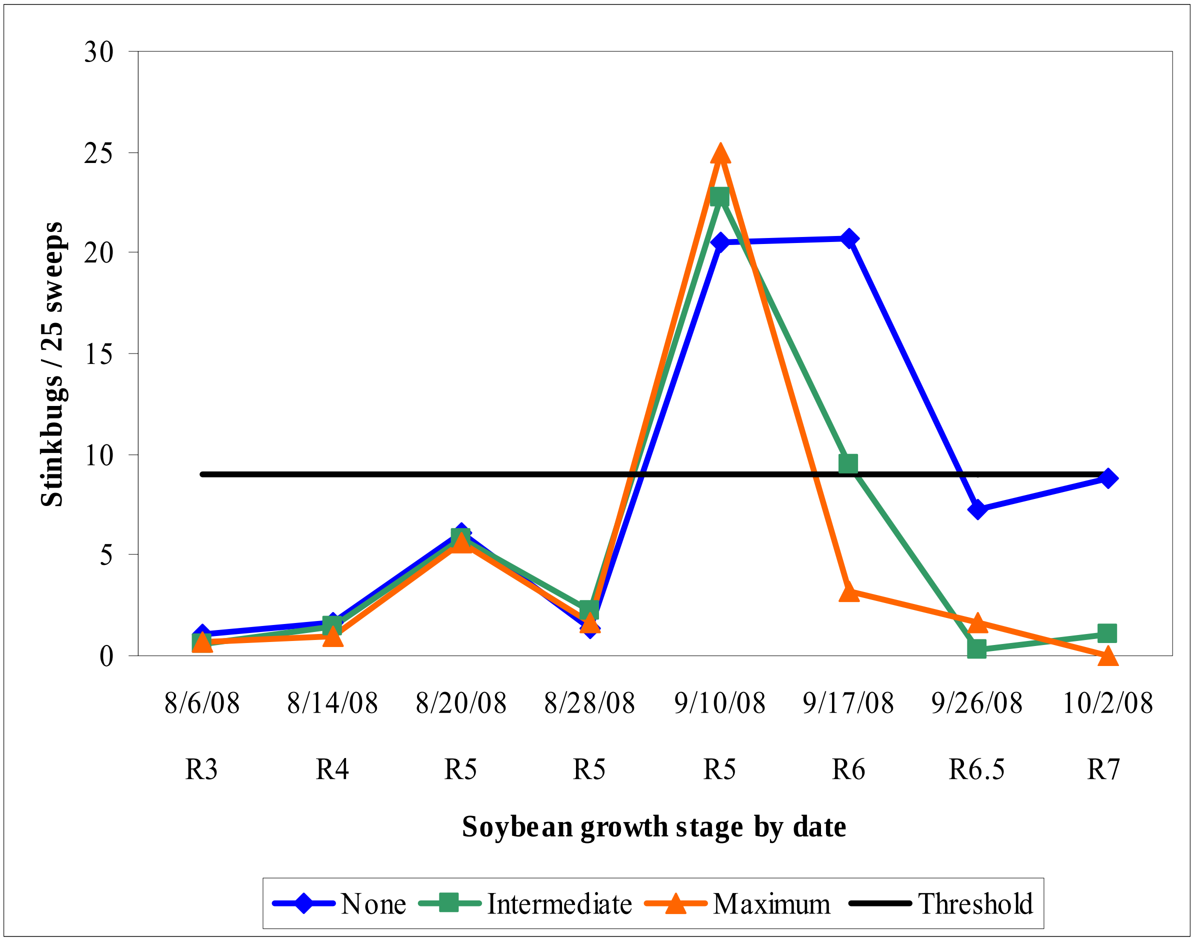


Figure 3.5. Stink bug numbers as affected by control programs at the Macon Ridge Research Station, Winnsboro, La in 2008.
Application timings were based on the total number of stink bugs per 25 sweeps which included: green stink bug, southern green stink bug, brown stink bug, redbanded stink bug, and nymphs. Insect numbers were monitored weekly. For intermediate control, lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps on August 20, September 10, September 17, and September 23, 2008. For maximum control, acephate at 1,000 g ai/ha + cyfluthrin at 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps on September 10, September 17, and September 23, 2008.

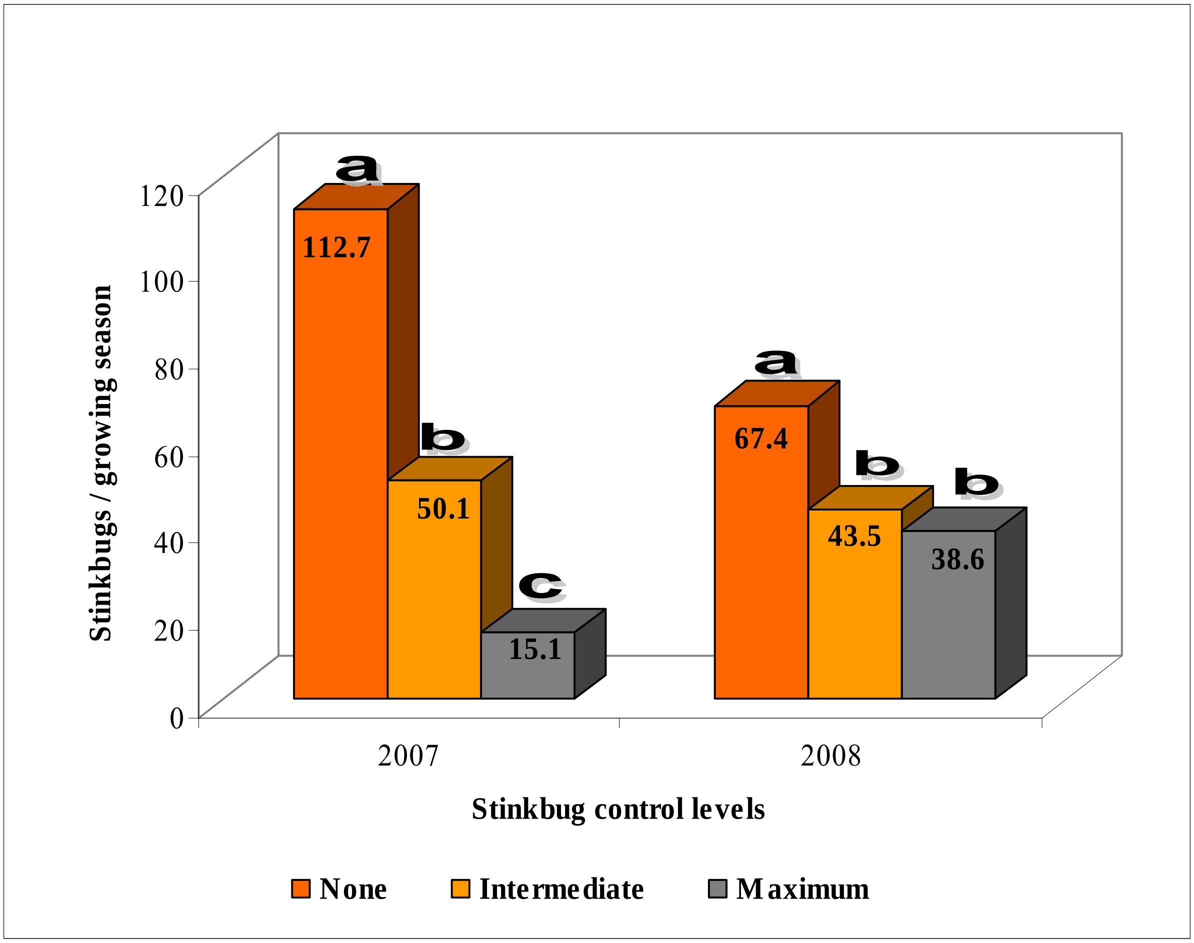


Figure 3.6. Cumulative stink bug numbers as affected by control programs at Macon Ridge Research Station, Winnsboro, La in 2007 and 2008.
Application timings were based on the total number of stink bugs per 25 sweeps which included: green stink bug, southern green stink bug, brown stink bug, redbanded stink bug, and nymphs. Insect numbers were monitored weekly. For intermediate control, lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps August 18, September 7, September 15, and September 24, 2007 and August 20, September 10, September 17, and September 23, 2008. For maximum control, acephate at 1,000 g ai/ha + cyfluthrin at 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps on August 18, September 7, September 15, and September 24, 2007 and September 10, September 17, and September 23, 2008. For each year bars with the same letter are not significantly different ($P \leq 0.05$). Data averaged across fungicide and harvest aid treatments.

programs, stink bug numbers decreased below threshold between the September 10 and 17 for the maximum control program and between September 17 and 26 for the intermediate control program. For the non-treated, stink bug infestation decreased below threshold on September 26 and reached threshold again October 2. Cumulative stink bug numbers both years were greatest where stink bug was not controlled and totaled 113 in 2007 and 67 in 2008 (Figure 3.6). In 2007 cumulative stink bug population was lowest for the maximum control program (87% less than the non-treated), but in 2008 population was equivalent for the intermediate and maximum control programs and averaged 39% less than the non-treated.

Paraquat harvest aid application did not reduce green leaf retention for any of the fungicide/stink bug control programs except for the fungicide/no stink bug control program where green leaf retention was reduced from 55% to 3% (Table 3.5). When harvest aid was applied green leaf retention was equivalent for all fungicide/stink bug control programs. In contrast, when harvest aid was omitted green leaf retention was 37% for the fungicide/stink bug control intermediate program and less than for no fungicide/stink bug control intermediate or maximized programs (73 and 68%), respectively.

Application of paraquat harvest aid reduced green stem percentage only for the fungicide/no stink bug control program (66 to 26%) (Table 3.5). When harvest aid was applied, green stem percentage was 83% for the no fungicide/stink bug control maximized program and greater than when fungicide was applied and stink bug control was maximized (44%) and where stink bug was not controlled (26%). When harvest aid was not applied green stem percentage was equivalent for the fungicide/stink bug control programs (31 to 86%). Percentage green pods for the fungicide/stink bug control programs ranged from 6 to 20% and differences were not

Table 3.5. Effect of fungicide and insecticide programs followed by paraquat harvest aid (HA) application on percentage soybean green leaf retention, green stems, green pods, and seed moisture at harvest.[1]

| Fungicide/stink bug control program[2] | Green leaf retention | | Green stem | | Green pod | | Seed moisture | |
|---|---|---|---|---|---|---|---|---|
| | + HA | - HA | + HA | - HA | + HA | - HA | + HA | - HA |
| | % | | | | | | | |
| No fungicide/no stink bug control | 49 | 53 ab[4] | 55 abc | 65 | 10 | 16 | 12.6 | 12.9 a |
| No fungicide/stink bug control intermediate | 32 | 73 a | 63 abc | 86 | 14 | 20 | 11.6 | 11.8 abc |
| No fungicide/stink bug control maximized | 57 | 68 a | 83 a | 68 | 12 | 10 | 11.3 | 11.3 c |
| Fungicide/no stink bug control | 3*[3] | 55 ab | 26* c | 66 | 6 | 10 | 11.6 | 12.7 ab |
| Fungicide/stink bug control intermediate | 51 | 37 b | 66 ab | 31 | 12 | 6 | 11.7 | 11.6 bc |
| Fungicide/stink bug control maximized | 29 | 38 ab | 44 bc | 60 | 8 | 11 | 11.5 | 11.3 c |
| P-value | 0.1286 | 0.0917 | 0.0934 | 0.2320 | 0.7434 | 0.3448 | 0.7057 | 0.0416 |

[1]Data collected on day of harvest for `AsGrow 5606` soybean grown in 2007 and `AsGrow 5702` in 2008 at the Macon Ridge, Research Station, Winnsboro, La, and averaged across 2007 and 2008.

[2]Fungicide treatment was pyraclostrobin at 219 g ai/ha + thiophanate-methyl at 784 g ai/ha applied at R3. Insect numbers were monitored weekly, and for the intermediate stink bug control lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps. For maximum control acephate at 1,000 g ai/ha + cyfluthrin 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps. Paraquat at 280 g ai/ha plus a nonionic surfactant at 0.25% v/v was applied at R6.5 on October 8, 2007 and October 15, 2008.

[3]Means for each of the fungicide and stink bug control programs within rows for percent green leaf retention, green stem, green pod, and seed moisture followed by an asterisk denotes a difference between application and no application of paraquat harvest aid ($P \leq 0.10$). Means without an asterisk are not significantly different ($P \leq 0.10$).

[4]Means for each of the fungicide and stink bug control programs within columns for the harvest aid or no harvest aid treatments followed by the same letter are not significantly different ($P \leq 0.10$). P-values are provided.

observed whether or not harvest aid was applied (Table 3.5). Soybean seed moisture ranged from 11.3 to 12.6% when harvest aid was applied and differences among the fungicide/stinkbug control programs were no observed (Table 3.5). When harvest aid was not applied, seed moisture was 12.9% for the no fungicide/no stink bug control program and greater than the no fungicide/stink bug control maximized program and for the fungicide/stink bug control intermediate and fungicide/stink bug control maximized programs (11.3 to 11.8%). Both years of the study weather conditions were such that all plots were harvested at the same time. Therefore, there was no difference in seed moisture for individual treatments due to harvest aid application, as was the case for the Baton Rouge study. Because seed moisture for all treatments was < 13% there would be no deduction at the elevator.

For each of the individual fungicide/stink bug control programs, use of harvest aid did not affect foreign material (Table 3.6). When harvest aid was applied foreign material ranged from 1.7 to 3.9% and differences among fungicide/insect control programs were not observed. When harvest aid was not applied foreign material was 3.3% for the fungicide/no stink bug control program and greater than when fungicide was applied and stink bug control was intermediate (1.5%) or maximized (1.9%). For all of the fungicide/stink bug control programs because foreign material was greater than 1%, a deduction would be assessed whether or not a harvest aid was applied.

Harvest aid application reduced seed damage for only the no fungicide/stink bug control intermediate program (reduction from 21.1 to 7.5%) (Table 3.6). Whether or not harvest aid was applied differences among the fungicide/stink bug control programs were not observed and seed damage ranged from 5.3 to 21.1%. Because deductions would be assessed for seed damage greater than 2%, all fungicide/stink bug control programs in this study would receive

Table 3.6. Effect of fungicide and insecticide programs followed by paraquat harvest aid (HA) application on percentage soybean foreign material and seed damage, and soybean yield.[1]

| Fungicide/stink bug control program[2] | Foreign material | | Seed damage | | Yield[3] | |
|---|---|---|---|---|---|---|
| | + HA | - HA | + HA | - HA | + HA | - HA |
| | % | | | | Kg/ha | |
| No fungicide/no stink bug control | 1.8 | 2.0 ab[4] | 6.3 | 7.3 | 1940 | 1810 |
| No fungicide/stink bug control intermediate | 2.1 | 2.4 ab | 7.5*[5] | 21.1 | 1820 | 1990 |
| No fungicide/stink bug control maximized | 2.1 | 1.4 b | 12.2 | 5.4 | 1730 | 1840 |
| Fungicide/no stink bug control | 3.9 | 3.3 a | 13.1 | 9.4 | 1920 | 1770 |
| Fungicide/stink bug control intermediate | 1.7 | 1.5 b | 7.4 | 5.3 | 1880 | 2110 |
| Fungicide/stink bug control maximized | 1.7 | 1.9 b | 8.2 | 8.4 | 1940 | 2090 |
| P-value | 0.4318 | 0.0658 | 0.5151 | 0.1571 | 0.9080 | 0.2651 |

[1]Data collected on day of harvest for `AsGrow 5606` soybean grown in 2007 and `AsGrow 5702` in 2008 at the Macon Ridge, Research Station, Winnsboro, La, and averaged across 2007 and 2008.
[2]Fungicide treatment was pyraclostrobin at 219 g ai/ha + thiophanate-methyl at 784 g ai/ha applied at R3. Insect numbers were monitored weekly, and for the intermediate stink bug control lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps. For maximum control acephate at 1,000 g ai/ha + cyfluthrin 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps. Paraquat at 280 g ai/ha plus a nonionic surfactant at 0.25% v/v was applied at R6.5 on October 8, 2007 and October 15, 2008.
[3]Yield adjusted to 13% moisture to allow for comparison among treatments.
[4]Means for each of the fungicide and stink bug control programs within columns for the harvest aid or no harvest aid treatments followed by the same letter are not significantly different ($P \leq 0.10$). P-values are provided.
[5]Means for each of the fungicide and stink bug control programs within rows for % foreign material, seed damage, and yield followed by an asterisk denotes a difference between paraquat harvest aid application ($P \leq 0.10$). Means without an asterisk are not significantly different ($P \leq 0.10$).

a deduction. The high levels of damage observed in this study are not unexpected because of the high stink bug infestation (figure 3.6). The inability to detect differences among the fungicide/stink bug control programs for seed damage is probably due to variability in stink bug control with the insecticide treatments. Stink bug threshold was exceeded for the intermediate control treatment in 2007 (Figure 3.4) and for both the intermediate and maximum control treatments in 2008 (Figure 3.5). This occurrence was not a factor in the Baton Rouge study (Figure 3.1 and 3.2).

Soybean yield differences (adjusted for moisture) were not observed among the fungicide/stink bug control programs or between each program when harvest aid was applied (Table 3.6). Yields ranged from 1,730 to 2,110 kg/ha and were around half of what was observed at Baton Rouge. Differences between locations were attributed to planting date, insect pressure, and effectiveness of insecticide treatments, and rainfall.

**Economic Analysis.** Because seed moisture was no more than 13% for any of the fungicide/stink bug control programs (Table 3.5), deductions for moisture were not assessed. Foreign material deductions were assessed for all fungicide/stink bug control programs (Table 3.7). When harvest aid was applied, deduction for the fungicide/no stink bug control program was $20.59/ha and when harvest aid was not applied the deduction was $15.05/ha. Deductions for the other treatments ranged from $3.91 to $10.32/ha. Economic loss due to seed damage was $79.61/ha and greatest for the no fungicide/stink bug control intermediate program when harvest aid was not applied (Table 3.7). When harvest aid was applied, deductions were $29.83/ha for the no fungicide/stink bug control maximized program and $37.29/ha for the fungicide/no stink bug control program. For the remaining fungicide/stink bug control programs, deductions for damage ranged from $7.44 to $18.81/ha. Total seed quality loss was

Table 3.7. Effect of fungicide and insecticide programs followed by paraquat harvest aid (HA) application on deduction for soybean foreign material, and seed damage. [1]

| Fungicide/stink bug control program[2] | Deduction for foreign material | | Deduction for seed damage | | Total seed quality loss[3] | |
|---|---|---|---|---|---|---|
| | + HA | - HA | + HA | - HA | + HA | - HA |
| | $/ha | | | | | |
| No fungicide/no stink bug control | $5.73 | $6.71 | $10.65 | $12.64 | $16.38 | $19.35 |
| No fungicide/stink bug control intermediate | $7.41 | $10.32 | $12.69 | $79.61 | $20.10 | $89.93 |
| No fungicide/stink bug control maximized | $7.05 | $2.73 | $29.83 | $7.44 | $36.88 | $10.17 |
| Fungicide/no stink bug control | $20.59 | $15.05 | $37.29 | $18.81 | $57.88 | $33.86 |
| Fungicide/stink bug control intermediate | $4.88 | $3.91 | $13.13 | $8.53 | $18.00 | $12.44 |
| Fungicide/stink bug control maximized | $5.03 | $6.97 | $17.81 | $17.81 | $22.84 | $26.14 |

[1]See Table 5 for treatment foreign material seed damage and yield data. Data collected for `AsGrow 5606` soybean grown in 2007 and `AsGrow 5702` in 2008 at the Macon Ridge, Research Station, Winnsboro, La, and averaged across 2007 and 2008.
[2]Fungicide treatment was pyraclostrobin at 219 g ai/ha + thiophanate-methyl at 784 g ai/ha applied at R3. Insect numbers were monitored weekly, and for the intermediate stink bug control lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps. For maximum control acephate at 1,000 g ai/ha + cyfluthrin 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps. Paraquat at 280 g ai/ha plus a nonionic surfactant at 0.25% v/v was applied at R6.5 on October 8, 2007 and October 15, 2008.
[3]Total seed quality loss = deduction for foreign material and seed damage.

greatest for the no fungicide/stink bug control intermediate program when harvest aid was not applied ($89.93/ha) followed by a loss of $57.88/ha for the fungicide/no stink bug control program where harvest aid was applied (Table 3.7). For the remaining programs total seed quality losses ranged from $12.44 to $36.88/ha.

Based on yield unadjusted for harvest moisture, gross returns assuming a price of $0.37/kg ranged from $640.47 to $718.91/ha when harvest aid was applied and $654.53 to $782.18/ha when harvest aid was not applied (Table 3.8). Application of harvest aid increased gross returns only for programs where stink bug was not controlled. This was because the no stink bug control programs were the only programs where harvest aid increased yield. When harvest aid was not applied, gross return was $774.04 for the fungicide/stink bug control maximized program and $782.18/ha for the fungicide/stink bug control intermediate program.

When harvest aid was applied, net return was highest for the no fungicide/no stink bug control program ($699.94/ha) followed by the fungicide/stink bug control maximized program ($696.07/ha) (Table 8). Where harvest aid was not applied, net return was highest for the fungicide/stink bug control intermediate program ($769.71/ha) followed by the fungicide/stink bug control maximized program ($747.90/ha). Increase in net return due to harvest aid application was observed for only the no fungicide/no stink bug control program, the no fungicide/stink bug control intermediate program, and the fungicide/no stink bug control program ($6.56 to $48.11/ha increase) (Table 3.8). For the other programs, use of harvest aid reduced net return $51.83 to $90.66/ha.Whether or not harvest aid was applied, net returns tended to be highest when fungicide was applied and where stink bug was controlled at the intermediate or maximum level; net returns were also highest for these treatments at Baton Rouge when harvest aid was applied.

Table 3.8. Effect of fungicide and insecticide programs followed by paraquat harvest aid (HA) application on gross return for yield, net return, and increase due to harvest aid.[1]

| Fungicide/stink bug control program[2] | Gross return for yield[3] | | Net return[4] | | Increase due to HA[5] |
|---|---|---|---|---|---|
| | + HA | - HA | + HA | - HA | |
| | $/ha | | | | |
| No fungicide/no stink bug control | $716.32 | $671.18 | $699.94 | $651.83 | $48.11 |
| No fungicide/stink bug control intermediate | $673.77 | $737.04 | $653.67 | $647.11 | $6.56 |
| No fungicide/stink bug control maximized | $640.47 | $682.65 | $603.59 | $672.48 | -$68.89 |
| Fungicide/no stink bug control | $710.03 | $654.53 | $652.15 | $620.67 | $31.48 |
| Fungicide/stink bug control intermediate | $697.08 | $782.18 | $679.08 | $769.74 | -$90.66 |
| Fungicide/stink bug control maximized | $718.91 | $774.04 | $696.07 | $747.90 | -$51.83 |

[1]Data collected for `AsGrow 5606` soybean grown in 2007 and `AsGrow 5702` in 2008 at the Macon Ridge, Research Station, Winnsboro, La, and averaged across 2007 and 2008.
[2]Fungicide treatment was pyraclostrobin at 219 g ai/ha + thiophanate-methyl at 784 g ai/ha applied at R3. Insect numbers were monitored weekly, and for the intermediate stink bug control lambda-cyhalothrin at 19 g ai/ha was applied when insect numbers reached 8-9 per 25 sweeps. For maximum control acephate at 1,000 g ai/ha + cyfluthrin 18 g ai/ha was applied when insect numbers reached 2-3 per 25 sweeps. Paraquat at 280 g ai/ha plus a nonionic surfactant at 0.25% v/v was applied at R6.5 on October 8, 2007 and October 15, 2008.
[3]Gross return for yield was not adjusted for moisture. Gross return for yield = yield x price ($0.37/kg).
[4]Net return = gross return for yield – total seed quality loss (see Table 7).
[5]Increase due to harvest aid = net return due to harvest aid application for each fungicide/stink bug control program.

In the Winnsboro study, net returns were around half those observed in the Baton Rouge study (Tables 3.4 and 3.8), and were attributed primarily to yield differences at the locations. Increase in net return due to harvest aid was observed for all fungicide/stink bug control programs at Baton Rouge, but not at Winnsboro. Implementation of IPM programs i.e., use of fungicide and insect management should be included in an overall management program that emphasizes maximum soybean yield production. In Louisiana, environmental conditions are conducive to disease development and in most years, stink bug can be a limiting factor to maximizing yield potential. In planning a soybean production program, a cultivar with high yield potential should be selected and emphasis placed on pest management.

With many fungicides, improved plant health can result in plants with green leaves and green stems later in the growing season. In addition, where stink bugs are not controlled soybean with green stems and pods can be present when seeds are mature and ready for harvest. The adverse effects of fungicide application and stress due to stink bug feeding on developing seed can contribute to the green plant malady, which can delay harvest and increase seed moisture, foreign material, and seed damage. Paraquat harvest aid can decrease green leaf retention and presence of green stems associated with the green plant malady. Improvement in seed quality (decreased deduction for moisture, foreign material, and seed damage) along with earlier harvest can more than offset the cost of a harvest aid application.

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# CHAPTER 4

## SUMMARY

Research was conducted to determine the effect of application timing of harvest aid treatments on soybean seed yield and seed weight and harvest date. Soybean maturity groups (MG) IV (indeterminate) and MG V and VI (determinate) were treated with paraquat at 0.28 kg ai/ha, paraquat with carfentrazone at 0.014 kg ai/ha, or sodium chlorate at 6.72 kg ai/ha when moisture of seed collected from the uppermost four nodes of plants averaged 60, 50, 40, 30, and 20% (+ or – 2%).

When harvest aid was applied at 60% average seed moisture for the MG IV indeterminate cultivar, yield was reduced 15.4%. Application at 50% average seed moisture or less did not negatively affect soybean yield, and allowed for harvest 15 and 14 days earlier than the non-treated. When harvest aid was applied at 60% and 50% average seed moisture for the MG V and MG VI cultivars, yield was reduced 4 to 22%. Soybean yield was not negatively affected when harvest aid was applied at 40% average seed moisture or less and soybean harvest was 7 to 14 days earlier than the non-treated. Differences in response to harvest aid timing for the indeterminate and determinate cultivars are related to the extent of vegetative growth occurring after flower initiation and the effect on seed maturity.

For indeterminate soybean, flowering begins on the lower nodes of the plant and progresses upwards to the top of the plant. Pod growth and seed development follow in a similar pattern, therefore, the most immature seeds would be in the top of the plant. For determinate soybean flowering begins in the middle of the plant and progresses both upwards and downwards. Pod growth and seed development would follow in a similar pattern, therefore, the most immature seeds would be both in the top and bottom of the plant. The negative effect of application at

50% average seed moisture on determinate cultivars but not on indeterminate cultivars was due to an increased percentage of immature seeds and reduced seed weight.

The paraquat harvest aid label states for both indeterminate and determinate soybean, that 15 days be allowed between application and harvest. In this study soybean treated with harvest aid at 50% average seed moisture (indeterminate) and 40% (determinate) had dried down and were ready for harvest, depending on year, 7 to 15 days earlier than the non-treated. Soybean was harvested 7 and 10 days after application for the indeterminate cultivar and 7 to 14 days after application for the determinate cultivars. Strict adherence to the paraquat 15 day pre-harvest interval would negate any benefit of earlier harvest.

In another study, experiments were conducted at two locations, Baton Rouge and Winnsboro, La, to determine the value of paraquat harvest aid when used in an IPM program that included fungicide application at R3 and stink bug control; maximum control when insecticide was applied prior to the action threshold (9 stink bugs per 25 sweeps) and intermediate control when insecticide was applied at the action threshold. The effect of the fungicide and stink bug control programs on soybean green leaf retention and green stems and pods was determined and paraquat was evaluated as a desiccant. The subsequent effects of the fungicide and stink bug control programs and harvest aid application on soybean seed yield and seed quality (seed moisture, seed damage, and foreign material) were measured.

At the Baton Rouge location, paraquat harvest aid reduced percentage green leaf retention, green stems, and seed moisture for all fungicide/stink bug control programs. Seed damage was greatest when stink bug was not controlled. Soybean yield when harvest aid was applied was reduced an average of 11.5% for the no fungicide/no stink bug control program compared to all other programs. Deductions for seed moisture and seed damage were observed in most cases for all fungicide/stink bug control programs whether or not a harvest aid was applied. Deductions for foreign material were assessed for all fungicide/stink bug control programs where harvest aid was not applied. Combined deductions due to seed moisture, foreign material, and seed damage for all fungicide/stink bug control programs were 3.8 to 6.4 times greater when harvest aid was not applied. When considering crop yield and deductions, increase in net return due to harvest aid application was greatest in programs where fungicide was applied regardless of stink bug control level ($152.91 to 171.49/ha) compared with no fungicide application ($78.49 and $94.81/ha). Results clearly show the value of both fungicide application and stink bug control in an IPM program. Furthermore, application of harvest aid can be especially important in mediation of green plant issues often associated with fungicide application.

At the Winnsboro location, stink bug control programs were less effective compared with Baton Rouge. Soybean yield differences at Winnsboro were not observed among the fungicide/stink bug control programs and there was no effect observed due to harvest aid. Yields were around 50% of those observed at Baton Rouge. Application of harvest aid at Winnsboro with the exception of the fungicide/no stink bug control program did not reduce leaf retention or green stems. Harvest aid also did not affect percentage green pods or seed moisture. Foreign material was greater for the fungicide/no stink bug control program with harvest aid (3.9%) compared with no harvest aid (3.3%); no differences between harvest aid and no harvest aid were observed for any of the fungicide/stink bug control programs. Application of harvest aid reduced seed damage for only the no fungicide/stink bug control intermediate program. Deductions were assessed for both foreign material and seed damage for all fungicide/stink bug control programs. Unlike at Baton Rouge when harvest aid application resulted in a positive net return at Winnsboro, an increase due to harvest aid was not observed for the no fungicide/stink bug control maximized program, and for the fungicide/stink bug control intermediate or maximized program. Data for the Winnsboro location does not agree with the Baton Rouge location. Differences may be attributed to soybean variety, planting date, environmental conditions, and insect control levels.

# APPENDIX: SOYBEAN IPM PROGRAMS STUDY

Appendix Table 1. Soybean Discount Schedule for seed moisture, seed damage and foreign material Bunge Corporation.[1]

| Seed moisture | Deduction | Seed damage | Deduction |
|---|---|---|---|
| % | % of gross weight | % | $/Bu |
| 13.1-13.5 | 1.0 | <2 | $0.00 |
| 13.6-14.0 | 2.0 | 2.1-3.0 | $0.02 |
| 14.1-14.5 | 3.0 | 3.1-4.0 | $0.05 |
| 14.6-15.0 | 4.0 | 4.1-5.0 | $0.08 |
| 15.1-15.5 | 5.0 | 5.1-6.0 | $0.11 |
| 15.6-16.0 | 6.0 | 6.1-7.0 | $0.15 |
| 16.1-16.5 | 7.2 | 7.1-8.0 | $0.19 |
| 16.6-17.0 | 8.4 | 8.1-9.0 | $0.23 |
| 17.1-17.5 | 9.6 | 9.1-10.0 | $0.29 |
| 17.6-18.0 | 10.8 | 10.0-11.0 | $0.35 |
| | | 11.1-12.0 | $0.41 |
| | | 12.1-13.0 | $0.47 |
| | | 13.1-14.0 | $0.53 |
| | | 14.1-15.0 | $0.59 |
| | | 15.1-16.0 | $0.65 |
| | | 16.1-17.0 | $0.71 |
| | | 17.1-18.0 | $0.77 |
| | | 18.1-19.0 | $0.83 |
| | | 19.1-20.0 | $0.89 |
| | | 20.1-21.0 | $0.99 |
| | | 21.1-22.0 | $1.09 |
| | | 22.1-23.0 | $1.19 |
| | | 23.1-24.0 | $1.29 |
| | | 24.1-25.0 | $1.39 |

[1]Foreign material in excess of 1% will be deducted as a percentage of total weight.

Appendix Table 2. T-Test comparison of selected treatments with and without a harvest aid for percent green leaf retention, green stem, green pod, seed moisture, foreign material, seed damage and yield at Central Station, Ben Hur Research Farm, Baton Rouge, La.

| Program + HA[1] | | | Program - HA | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | F0 I0 | F0 I1 | F0 I2 | F1 I0 | F1 I1 | F1 I2 |
| | | | % Green Leaves | | | | | |
| | | Mean | 5.8 | 3.9 | 3.3 | 9.4 | 7.0 | 7.9 |
| 1 | F0 I0 | 1.0 | <0.0001 | 0.0514 | 0.1175 | <0.0001 | 0.0002 | <0.0001 |
| 2 | F0 I1 | 0.5 | <0.0001 | 0.0228 | 0.0591 | <0.0001 | <0.0001 | <0.0001 |
| 3 | F0 I2 | 0.4 | <0.0001 | 0.0184 | 0.0492 | <0.0001 | <0.0001 | <0.0001 |
| 4 | F1 I0 | 2.3 | 0.0002 | 0.2667 | 0.4541 | <0.0001 | 0.0022 | 0.0002 |
| 5 | F1 I1 | 1.1 | <0.0001 | 0.0621 | 0.1377 | <0.0001 | 0.0002 | <0.0001 |
| 6 | F1 I2 | 1.5 | <0.0001 | 0.1061 | 0.2148 | <0.0001 | 0.0005 | <0.0001 |
| | | | % Green Stems | | | | | |
| | | Mean | 51.6 | 19.6 | 19.3 | 34.8 | 14.8 | 33.3 |
| 1 | F0 I0 | 5.8 | <0.0001 | 0.6427 | 0.5201 | 0.0021 | 0.6817 | 0.0046 |
| 2 | F0 I1 | 3.9 | <0.0001 | 0.0102 | 0.0077 | <0.0001 | 0.0832 | <0.0001 |
| 3 | F0 I2 | 3.3 | <0.0001 | 0.0022 | 0.0017 | <0.0001 | 0.0244 | <0.0001 |
| 4 | F1 I0 | 9.4 | <0.0001 | 0.0130 | 0.0097 | <0.0001 | 0.0999 | <0.0001 |
| 5 | F1 I1 | 7.0 | <0.0001 | 0.0115 | 0.0086 | <0.0001 | 0.0912 | <0.0001 |
| 6 | F1 I2 | 7.9 | <0.0001 | 0.0057 | 0.0043 | <0.0001 | 0.0531 | <0.0001 |
| | | | % Green Pods | | | | | |
| | | Mean | 7.3 | 3.4 | 1.8 | 5.8 | 3.6 | 4.1 |
| 1 | F0 I0 | 4.7 | 0.0186 | 0.2354 | 0.0116 | 0.3156 | 0.3382 | 0.6190 |
| 2 | F0 I1 | 1.9 | <0.0001 | 0.1675 | 0.9328 | 0.0006 | 0.1081 | 0.0399 |
| 3 | F0 I2 | 0.9 | <0.0001 | 0.0228 | 0.4193 | <0.0001 | 0.0126 | 0.0034 |
| 4 | F1 I0 | 1.6 | <0.0001 | 0.1081 | 0.8894 | 0.0003 | 0.0670 | 0.0228 |
| 5 | F1 I1 | 1.3 | <0.0001 | 0.0795 | 0.7763 | 0.0002 | 0.0480 | 0.0156 |
| 6 | F1 I2 | 2.3 | <0.0001 | 0.2993 | 0.6751 | 0.0017 | 0.2048 | 0.0855 |
| | | | % Seed Moisture | | | | | |
| | | Mean | - | 15.0 | 15.3 | 18.0 | 16.5 | 16.7 |
| 1 | F0 I0 | 13.9 | - | 0.2640 | 0.1158 | <0.0001 | 0.0046 | 0.0022 |
| 2 | F0 I1 | 13.0 | - | 0.0608 | 0.0177 | <0.0001 | 0.0005 | 0.0002 |
| 3 | F0 I2 | 13.2 | - | 0.0677 | 0.0017 | <0.0001 | 0.0003 | 0.0001 |
| 4 | F1 I0 | 13.9 | - | 0.2341 | 0.0978 | <0.0001 | 0.0036 | 0.0017 |
| 5 | F1 I1 | 13.4 | - | 0.1189 | 0.0406 | <0.0001 | 0.0012 | 0.0006 |
| 6 | F1 I2 | 13.3 | - | 0.0922 | 0.0269 | <0.0001 | 0.0006 | 0.0003 |

Appendix Table 2. continued

| Program + HA | | | Program - HA F0 I0 | F0 I1 | F0 I2 | F1 I0 | F1 I1 | F1 I2 |
|---|---|---|---|---|---|---|---|---|
| | | | % Foreign Material | | | | | |
| | | Mean | - | 1.4 | 1.3 | 1.5 | 1.2 | 1.3 |
| 1 | F0 I0 | 1.0 | - | 0.3408 | 0.3885 | 0.1582 | 0.6219 | 0.3885 |
| 2 | F0 I1 | 1.1 | - | 0.5294 | 0.6037 | 0.2838 | 0.8820 | 0.5887 |
| 3 | F0 I2 | 1.0 | - | 0.3936 | 0.4368 | 0.1843 | 0.6833 | 0.4368 |
| 4 | F1 I0 | 0.9 | - | 0.2809 | 0.3006 | 0.1138 | 0.5048 | 0.3006 |
| 5 | F1 I1 | 1.0 | - | 0.4111 | 0.4588 | 0.1967 | 0.7107 | 0.4588 |
| 6 | F1 I2 | 0.7 | - | 0.1058 | 0.0982 | 0.0286 | 0.1967 | 0.0982 |
| | | | % Seed Damage | | | | | |
| | | Mean | - | 5.0 | 3.9 | 7.1 | 6.1 | 5.2 |
| 1 | F0 I0 | 9.0 | - | 0.0001 | <0.0001 | 0.0288 | 0.0016 | <0.0001 |
| 2 | F0 I1 | 4.3 | - | 0.5319 | 0.6262 | 0.0026 | 0.0423 | 0.3381 |
| 3 | F0 I2 | 3.1 | - | 0.0727 | 0.3816 | <0.0001 | 0.0010 | 0.0225 |
| 4 | F1 I0 | 5.4 | - | 0.6587 | 0.0900 | 0.0633 | 0.4045 | 0.7913 |
| 5 | F1 I1 | 4.1 | - | 0.3929 | 0.8237 | 0.0012 | 0.0225 | 0.2228 |
| 6 | F1 I2 | 3.7 | - | 0.2483 | 0.9002 | 0.0004 | 0.0091 | 0.1187 |
| | | | Yield Kg/ha | | | | | |
| | | Mean | - | 4290 | 4220 | 4320 | 4260 | 4310 |
| 1 | F0 I0 | 3950 | - | 0.0697 | 0.0910 | 0.0245 | 0.0568 | 0.0257 |
| 2 | F0 I1 | 4400 | - | 0.5201 | 0.2586 | 0.5816 | 0.3627 | 0.5680 |
| 3 | F0 I2 | 4380 | - | 0.6080 | 0.3263 | 0.6880 | 0.3227 | 0.6734 |
| 4 | F1 I0 | 4450 | - | 0.3726 | 0.1581 | 0.4030 | 0.2327 | 0.3920 |
| 5 | F1 I1 | 4540 | - | 0.1707 | 0.0511 | 0.1662 | 0.0825 | 0.1602 |
| 6 | F1 I2 | 4550 | - | 0.1499 | 0.0424 | 0.1429 | 0.0694 | 0.1377 |

[1]Fungicide/stink bug control programs receiving a harvest aid are denoted using +HA and those not receiving a harvest aid are denoted by –HA. IPM programs where fungicide was not applied are coded F0, and F1 when fungicide was applied. Stink bug control levels are none (I0), intermediate (I1), and maximum I(2).

Appendix Table 3. T-Test comparison of selected treatments with and without a harvest aid for percent green leaf retention, green stem, green pod, seed moisture, foreign material, seed damage and yield at Macon Ridge Research Farm Winnsboro, La.

| Program + HA[1] | | | Program - HA | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | F0 I0 | F0 I1 | F0 I2 | F1 I0 | F1 I1 | F1 I2 |
| | | | % Green Leaves | | | | | |
| | | Mean | 53 | 73 | 68 | 55 | 37 | 38 |
| 1 | F0 I0 | 49 | 0.8784 | 0.2904 | 0.4038 | 0.7890 | 0.1028 | 0.5676 |
| 2 | F0 I1 | 32 | 0.3439 | 0.0712 | 0.1103 | 0.2019 | 0.3831 | 0.9086 |
| 3 | F0 I2 | 57 | 0.8484 | 0.4700 | 0.6200 | 0.9390 | 0.0524 | 0.3632 |
| 4 | F1 I0 | 3 | 0.0325 | 0.0040 | 0.0069 | 0.0254 | 0.6745 | 0.1360 |
| 5 | F1 I1 | 51 | 0.9390 | 0.3254 | 0.4473 | 0.8484 | 0.0889 | 0.5175 |
| 6 | F1 I2 | 29 | 0.2904 | 0.0566 | 0.0889 | 0.2431 | 0.4473 | 0.7310 |
| | | | % Green Stems | | | | | |
| | | Mean | 65 | 86 | 68 | 66 | 31 | 60 |
| 1 | F0 I0 | 55 | 0.6048 | 0.1216 | 0.4912 | 0.5753 | 0.2178 | 0.7954 |
| 2 | F0 I1 | 63 | 0.9311 | 0.2535 | 0.7954 | 0.8968 | 0.1020 | 0.8627 |
| 3 | F0 I2 | 83 | 0.3462 | 0.9036 | 0.4394 | 0.3682 | 0.0115 | 0.2335 |
| 4 | F1 I0 | 26 | 0.0518 | 0.0047 | 0.0362 | 0.0474 | 0.7954 | 0.0866 |
| 5 | F1 I1 | 66 | 0.9655 | 0.3090 | 0.8968 | 0.9652 | 0.0797 | 0.7623 |
| 6 | F1 I2 | 44 | 0.2859 | 0.0403 | 0.2178 | 0.2675 | 0.4912 | 0.4147 |
| | | | % Green Pods | | | | | |
| | | Mean | 16 | 20 | 10 | 10 | 6 | 11 |
| 1 | F0 I0 | 10 | 0.3199 | 0.0950 | 0.8652 | 0.9632 | 0.4570 | 0.8631 |
| 2 | F0 I1 | 14 | 0.7740 | 0.3199 | 0.4750 | 0.4750 | 0.1601 | 0.5862 |
| 3 | F0 I2 | 12 | 0.4750 | 0.1601 | 0.7740 | 0.7740 | 0.3199 | 0.9085 |
| 4 | F1 I0 | 6 | 0.0950 | 0.0217 | 0.4570 | 0.5742 | 0. 7523 | 0.3772 |
| 5 | F1 I1 | 12 | 0.4750 | 0.1601 | 0.7521 | 0.6348 | 0.3162 | 0.9235 |
| 6 | F1 I2 | 8 | 0.2042 | 0.5040 | 0.5623 | 0.7542 | 0.6670 | 0.6464 |
| | | | % Seed Moisture | | | | | |
| | | Mean | 12.9 | 11.8 | 11.3 | 12.7 | 11.6 | 11.3 |
| 1 | F0 I0 | 12.6 | 0.6085 | 0.2715 | 0.0779 | 0.8508 | 0.1911 | 0.0706 |
| 2 | F0 I1 | 11.6 | 0.0577 | 0.7599 | 0.7068 | 0.1137 | 0.9250 | 0.6723 |
| 3 | F0 I2 | 11.3 | 0.0256 | 0.5109 | 0.9812 | 0.0548 | 0.6552 | 0.9437 |
| 4 | F1 I0 | 11.6 | 0.0706 | 0.8324 | 0.6384 | 0.1361 | 0.9532 | 0.6052 |
| 5 | F1 I1 | 11.7 | 0.0900 | 0.9250 | 0.5571 | 0.1688 | 0.9064 | 0.5261 |
| 6 | F1 I2 | 11.5 | 0.0444 | 0.6723 | 0.7959 | 0.0900 | 0.8324 | 0.7599 |

Appendix Table 3. continued

| Program + HA | | | Program - HA F0 I0 | F0 I1 | F0 I2 | F1 I0 | F1 I1 | F1 I2 |
|---|---|---|---|---|---|---|---|---|
| | | | % Foreign Material | | | | | |
| | | Mean | 2.0 | 2.4 | 1.4 | 3.3 | 1.5 | 1.9 |
| 1 | F0 I0 | 1.8 | 0.8127 | 0.5092 | 0.6749 | 0.1285 | 0.7823 | 0.8971 |
| 2 | F0 I1 | 2.1 | 0.9685 | 0.7093 | 0.4799 | 0.2152 | 0.5809 | 0.8737 |
| 3 | F0 I2 | 2.1 | 0.9434 | 0.7186 | 0.4395 | 0.2040 | 0.5449 | 0.8428 |
| 4 | F1 I0 | 3.9 | 0.0653 | 0.1296 | 0.0098 | 0.5406 | 0.0190 | 0.0404 |
| 5 | F1 I1 | 1.7 | 0.6950 | 0.3984 | 0.7731 | 0.0816 | 0.8862 | 0.7731 |
| 6 | F1 I2 | 1.7 | 0.7593 | 0.4502 | 0.7052 | 0.0980 | 0.8190 | 0.8428 |
| | | | % Seed Damage | | | | | |
| | | Mean | 7.3 | 21.1 | 5.4 | 9.4 | 5.3 | 8.4 |
| 1 | F0 I0 | 6.3 | 0.8675 | 0.0098 | 0.8659 | 0.5749 | 0.8703 | 0.7082 |
| 2 | F0 I1 | 7.5 | 0.9700 | 0.0253 | 0.7195 | 0.7465 | 0.7278 | 0.8820 |
| 3 | F0 I2 | 12.2 | 0.3744 | 0.0953 | 0.2002 | 0.6011 | 0.2220 | 0.4725 |
| 4 | F1 I0 | 13.1 | 0.2967 | 0.1328 | 0.1447 | 0.4882 | 0.1675 | 0.3745 |
| 5 | F1 I1 | 7.4 | 0.9869 | 0.0116 | 0.7060 | 0.6966 | 0.7185 | 0.8466 |
| 6 | F1 I2 | 8.2 | 0.8647 | 0.0175 | 0.5902 | 0.8194 | 0.6073 | 0.9747 |
| | | | Yield Kg/ha | | | | | |
| | | Mean | 1810 | 1990 | 1850 | 1770 | 2110 | 2090 |
| 1 | F0 I0 | 1940 | 0.5500 | 0.7843 | 0.5672 | 0.4138 | 0.3843 | 0.4430 |
| 2 | F0 I1 | 1820 | 0.9724 | 0.4036 | 0.9046 | 0.7983 | 0.1544 | 0.1859 |
| 3 | F0 I2 | 1730 | 0.9828 | 0.2033 | 0.5736 | 0.8509 | 0.0604 | 0.0796 |
| 4 | F1 I0 | 1920 | 0.6073 | 0.7203 | 0.7189 | 0.4631 | 0.3405 | 0.3951 |
| 5 | F1 I1 | 1880 | 0.7321 | 0.5966 | 0.8519 | 0.5736 | 0.2615 | 0.3075 |
| 6 | F1 I2 | 1940 | 0.5273 | 0.8110 | 0.6324 | 0.3945 | 0.4033 | 0.4637 |

[1]Fungicide/stink bug control programs receiving a harvest aid are denoted using +HA and those not receiving a harvest aid are denoted by –HA. IPM programs where fungicide was not applied are coded F0, and F1 when fungicide was applied. Stink bug control levels are none (I0), intermediate (I1), and maximum I(2).

## VITA

Joseph Michael Boudreaux is the son of Gayle and Ike Boudreaux. Born November 1983, he was raised on a family farm in northern St. Landry parish near the town of Lebeau, Louisiana. He attended St. Joseph's Catholic School for 13 years until high school graduation in May of 2002. Joseph went on to study at Louisiana State University where he graduated with a bachelor's degree in agronomy in 2006. He was then accepted into the graduate school program where he pursued a Mater of Science degree in the School of Plant, Environmental, and Soil Sciences under the direction of Dr. James Griffin. He is currently a candidate for graduation with a degree in agronomy with an emphasis in weed science. After graduation Joseph plans to return to the family farm in Lebeau, Louisiana.