Investigation of Seed Treatment and Planting Date on Alabama Soybeans

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Abstract

Soybean (*Glycine max* L.) production in the southeastern United States is heavily influenced by interactions between insect pest pressure, agronomic practices, and environmental variability. Production practices such as planting date, threshold-based insecticide applications, and the use of seed treatments are commonly implemented to protect yield. However, effectiveness and economic return vary across production regions. Two field experiments were conducted across multiple environments in Alabama during the 2024 and 2025 growing seasons. The first evaluated the effects of fungicide and insecticide seed treatments on early-season insect pests, stand establishment, yield, and return on investment on six Alabama Agricultural Experiment Stations throughout the state. Across locations and years, seed treatments had limited effects on early-season insect pests, stand establishment, and yield. Economic benefits were inconsistent and primarily dependent on yield environment, with high yielding environments in mid-May planting dates producing the highest yield and economic return. The second experiment evaluated the effects of planting date and threshold-based insect management on insect pest populations and soybean yield in Prattville, AL. Planting date significantly influenced insect pressure, particularly for redbanded stink bug (*Piezodorus guildinii*) and kudzu bug (*Megacopta cribraria*). Threshold-based insecticide applications significantly reduced key pests and resulted in higher yields compared to non-treated plots. Soybeans planted in mid-May consistently produced higher yield and economic return across the state of Alabama. This research suggests that planting date is a primary factor in both insect pressure and soybean yield in

Alabama production systems, while benefits of seed treatments are often inconsistent and site-specific.

Artificial Intelligence (AI) Use Disclosure Statement

In the preparation of this thesis, the following Artificial Intelligence (AI) tools were used: ChatGPT and Microsoft Copilot. These tools were used primarily to assist in editing and reviewing the document. The author acknowledges full responsibility for the intellectual content of this work and has ensured that all AI-assisted sections have been reviewed and revised for accuracy and appropriate academic style. All AI-generated content was reviewed and validated for relevance, appropriateness, and accuracy before incorporation into the final document to maintain scholarly integrity of this research.

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The author acknowledges full responsibility for the intellectual content of this work and has made a good faith effort to comply with digital accessibility requirements in publishing, wherein the nature of the content does not significantly change in order to do so. Furthermore, all content has been reviewed and revised to meet these requirements prior to final publication.

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Table of Contents

Abstract……………………………………………………………………2
AI Statement……...……………………………………………………4
Digital Accessibility Disclosure……………………………………………5
Acknowledgements……………………………………………………...…6
List of Tables……………………………………………………………10
Chapter 1: Introduction and Review of Literature……………………………12
    Soybean………………………………………………………….……12
    Insect pests……………………………………………………...…13
    Pest Management……………………………………………….....……22
    Planting dates……………………………………………….…..………23
    Seed treatments……………………………………………………..…24
    References………………………………………………………..……26
Chapter 2: planting date influence on yield…………………………...……31
    Introduction……………………………………………………………31
    Materials and Methods…………………………………………….……33
    Results…………………………………………………………….....36
    Discussion………………………………………………………………...40
    References………………………………………………………………..43
    Tables...45
Chapter 3: seed treatment influence of yield…………………………..…….56
    Introduction……………………………………………………….....56

Materials and Methods……………………………………………………58
Results……………………………………………………………..……..59
Discussion…………………………………………………………..……60
References………………………………………………………………64
Tables...67

List of Tables

Table 2.1. Planting dates for soybeans planted with and without seed treatments at Alabama Agricultural Experiment Stations in 2024 and 2025 growing seasons.

Table 2.2. Precipitation totals at Alabama Agricultural Experiment Stations from April 15th to August 30th where soybeans were planted with and without seed treatments in 2024 and 2025.

Table 2.3. TCAH and TCAH damage in the 2025 season across three planting dates at the Prattville Agricultural Research Unit in Prattville, AL.

Table 2.4. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across April, May and June planting dates on six Alabama Agricultural Experiment Stations in 2024 and 2025.

Table 2.5. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across all April planting dates on six Alabama Agricultural Experiment Stations in the 2025 season.

Table 2.6. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across all May planting dates on six Alabama Agricultural Experiment Stations in the 2025 season.

Table 2.7. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across all June planting dates on six Alabama Agricultural Experiment Stations in the 2025 season.

Table 2.8. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across April high yield potential sites on two Alabama Agricultural Experiment Stations in the 2025 season.

Table 2.9. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across April moderate yield potential sites on two Alabama Agricultural Experiment Stations in the 2025 season.

Table 2.10. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across April low yield potential sites on two Alabama Agricultural Experiment Stations in the 2025 season.

Table 3.1. All planting dates for a soybean plant date experiment conducted at the Alabama Agricultural Experiment Station in Prattville, AL in the 2024 and 2025 season.

Table 3.2. Insecticide applications administered throughout a two year planting date study at the Prattville Agricultural Research Unit in Prattville, AL during the 2024 and 2025 growing season.

Table 3.3 Total kudzu bug populations (mean ± sem), recorded during the 2025 season at the Alabama Agricultural Experiment Station in Prattville, AL.

Table 3.4. Total redbanded stink bug populations (mean ± sem), in treated verses non-treated check across three planting dates in the 2025 season at an Alabama Agricultural Experiment Station in Prattville, AL.

Chapter 1: Introduction and Review of literature

Soybean

Soybean (*Glycine max.* (L.) Merr.) is a globally produced agronomic crop belonging to the family *Fabaceae*. The *Fabaceae* family (also called *Leguminosae*) is composed of legumes, with approximately 19,000 species distributed worldwide. The *Fabaceae* family is ranked second only after *Poaceae* in terms of economic importance (Shavanov 2021). Soybean is the leading oilseed crop in the United States, accounting for approximately 90 percent of oilseed production, with the remaining 10% including cottonseed, sunflower seed, canola, rapeseed, and peanuts (Bukowski and Swearingen 2025). In 2024, the United States ranked second in soybean production (28%) globally, producing 118.84 million metric tons (Soybeans | USDA Foreign Agricultural Service). Soybeans serve as a food source for both human and livestock consumption in a variety of products, as well as for industrial and consumer products such as biodiesel, building materials, lubricants, and other household items (USSOY Staff Writer2018). This crop is an essential source of protein (40-42%), edible oil (18-22%), minerals, and vitamins (Rahman et al. 2023). In the past, approximately 50% of soybeans produced in the United States were exported, however in recent years a shift has occurred as more soy is used for crush (the process of extracting soybean meal and oil from soybeans) in the United States (U.S. Department of Agriculture, Economic Research Service 2024). In the 2022-2023 marketing year 83.6 million acres (33.8 million hectares) were planted in the United States planted with total crop valued at $60.7 billion dollars. Soybeans are produced in 29 states throughout the U.S. with most acres produced in the Midwest. In 2023, there were 350,000 acres planted in Alabama with an average of 43.0 bushels per acre (American Soybean Association 2024). The soybean root system is characterized as diffuse, composed of three distinct components: the primary root, or taproot originating from the germinating seed, the lateral roots or secondary roots that emerge from the taproot, and the tertiary roots that emerge from the lateral roots (Torrion et al. 2012). Soybeans grow best in well-drained, high organic matter, and loamy soils with a pH of 6.0 to 7.5 (Cherlinka 2025). Optimum growing temperatures range from 70° to 90° F, and production ranges from tropical, sub-tropical, to cold-temperate regions, such as the U.S. and Canada (Coleman et al. 2021). Soybean development can be impacted by day length, temperature, variety, and other factors (Fehr and Caviness 1977). A wide range of maturity groups (MG) ranging from 000-10 exist in soybeans, allowing for production across a large latitudinal range. Soybean growth habit can be divided into two categories determinate, where variety stops vegetative and node growth on the main stem after flowering begins, and indeterminate, whereas varieties continue producing nodes on the main stem until the beginning of seed fill (Purcell et al. 2014).

Insect pests

Three hundred eighty insect species are considered pests of soybeans around the world, accounting for an estimated 25% yield loss annually worldwide (Rahman et al. 2023). Pest species include defoliators, pod feeders, stem and root borers, and sucking insects, which may cause damage to plant foliage, seeds, roots and stems (Roy et al. 2024). In a report from 18 states, including Alabama, the stink bug complex, corn earworm, and soybean lopper are considered the most economically important insect pests of soybeans, respectively (Musser et al. 2025). In conjunction with current management practices, insect pests are estimated to cause ~1.6% of all yield losses across soybean producing states in US. Greater loses may be observed in high pest pressure areas such as the southeast (Musser et al. 2025) In 2023, the stink bug complex was reported to reduce yield more than any other insect pest at 12.562 million bushels (Sisson et al. 2024). In the southern region, the armyworm complex, bean leaf beetle (*Cerotoma trifurcate*), corn earworm (*Helicoverpa zea*), green clover worm (*Hypena scabra*), kudzu bug (*Megacopta cribraria*), soybean looper (*Chrysodeixis includens*), stink bug complex including the brown stink bug (*Euschistus servus*), brown marmorated stink bug (*Halyomorpha halys*), green stink bug (*Chinavia hilaris*), southern green stink bug (*Nezara viridula*), red banded stink bug (*Piezodorus guildinii*), threecornered alfalfa hopper (*Spissistilus festinus*), and velvetbean caterpillar (*Anticarsia gemmatalis*) are identified as causing economic damage across production areas (Musser et al. 2025).

The complex of seed-feeding stink bugs (Hemiptera: Pentatomidae) accounted for the majority of insect costs and losses amongst 18 states in the US (Musser et al. 2023). Since the beginning of soybean production in the United States, stink bugs have been prevalent, especially in southern producing states (Michel et al. 2013). Members of the Pentatomidae family, both nymphal and adult, are phytophagous, obtaining nutrients from plants, particularly pods and seeds in the case of soybeans, by piercing plant tissues with their mandibular and maxillary stylets (McPherson 2018). Stink bug adults are shield-shaped insects, typically 0.5 inch in length, with the ability to overwinter in most conditions (Michel et al. 2013). Stink bugs are late-season pests attracted to seeds, fruits, and growing shoots (Hesler et al. 2018). Adults move between host plants over the season, leaving host plants as they mature and colonizing new hosts when favorable feeding stages become available (McPherson 2018). All species go through gradual metamorphosis, consisting of egg, nymph, and adults, immature stink bugs of all species will go through five nymphal instars (Hartman et al. 2015). Development from egg to adult varies from 40 to 60 days pending environmental conditions and species.

Southern green stink bugs, *Nezara viridula,* are green and can be distinguished from green stink bugs by the three light dots typically found along the front edge of the pronotum (Bush et al. 2025). Females lay eggs in masses of approximately 20 to 30 eggs on the underside of leaves, with females producing up to 260 eggs over their lifespan. Instars take approximately 3 to 7 days each, with the overall life cycle being completed in 65 to 70 days (Squitier 2025). Instars of southern green stink bug can be discerned from the green stink bug due to the black and white spots visible on their dorsal side (Bush et al. 2025).

The green stink bug, *Chinavia hilaris*, is a native pentatomid that is bright green in coloration and 0.5 to 0.75 inch in length (Cloyd 2022). While similar to southern green stink bug, green stink bugs may be differentiated due to the black bands on the antennae and a pointed abdominal spine, while southern green stink bugs possess red bands on their antennae and a rounded abdominal spine (Kamminga et al. 2012). The green stink bug life cycle from egg to adult is shorter than other species typically being completed in only 30 to 45 days (Gomez and Mizell 2023). Females lay egg masses on the underside of leaves, with an average of 32 eggs per mass but upwards of 130 have been observed; Eggs are deposited vertically and are barrel-shaped, changing in color from light green to yellow to light pink before hatching in approximately seven days after deposition (Kamminga et al. 2012). In the southeast, green stink bugs are likely to have two generations per year due to favorable weather conditions (Kamminga et al. 2012).

Brown marmorated stink bug, *Halyomorpha halys*, is an invasive pentatomid that is highly damaging to a variety of agronomic crops (Bush et al. 2025). Adults are larger than most species at approximately 0.7 inches long with mottled brown coloration on the dorsal side with distinct alternating dark and light bands on the dorsal part of the abdomen that extends past the wings and white bands on the legs and antennae (Toews et al. 2022). Early instar nymphs have an abdomen that is red and orange with black stripes running down the middle. However, in later instars nymphs are brown with distinct white bands on antennae and legs similar to adults (Michel et al. 2013). Females lay egg masses of 20-30 light green to yellow or light blue elliptical-shaped eggs on the underside of leaves (US EPA 2015). Females may produce five to nine egg masses in their lifetime with up to 250 eggs in total. The life cycle from oviposition to adult ranges from 33 to 62 days (Medal et al. 2013).

The redbanded stink bug, *Piezodorus guildinii*, is marginally smaller than other species of stink bugs at approximately 0.4 inches in length, they are yellowish-green in coloration with a yellow, red, or brown band across the anterior of the scutellum (Okosun et al. 2024). This stink bug can be confused with the redshouldered stink bug (*Thyanta spp*.) but can easily be distinguished as the redbanded stink bug possesses a spine on the abdomen (Akin et al. 2011). Redbanded stink bugs typically complete a life cycle in 37-39 days under optimal conditions, with the possibility of four to eight generations per year (Vyavhare et al. 2024). This species is not only more damaging than other stink bug species but is also more tolerant to insecticide applications, causing significant increases in insecticide applications where present (Vyavhare et al. 2014). Females lay an average of 15 eggs per mass, with preference to oviposition on pods (Panizzi and Smith 1977). This species reaches maturity quicker than some species, only taking 37 to 38 days to develop from egg to adult (Panizzi and Smith 1977). While it is common amongst stink bug nymphs to aggregate as first instar nymphs and not feed until the second instar, redbanded nymphs continue to have this gregarious behavior until the fourth instar where populations begin to disperse throughout soybean plants (Panizzi and Slansky 1985).

Kudzu bug, *Megacopta cribraria* (F.) (Hemiptera: plataspidae), also known as bean plataspid, lablab bug, or globular stink bug, are “true bugs,” approximately 0.2 inches in length and almost square or shield-like in shape with distinctive olive-green coloration with brown speckles (NC State Extension 2012). Kudzu bugs primarily feed on leguminous host plants, with kudzu and soybean being preferred reproductive hosts. This species typically feeds on main stems, leaf petioles, and leaf veins; however, early instars appear to also feed on leaves (Zhang et al. 2012). Kudzu bugs are generally aggregate on soybean main stems (Seiter et al. 2014). Kudzu bug has two peak oviposition windows, the first between April to early June and second July to August, this suggests two generations per year. Eggs are laid in masses, primarily in two rows, containing approximately 16 eggs in the southeastern United States (McPherson 2018). Typically, females lay egg masses on the underside of leaves (Zhang et al. 2012). Eggs are oval-shaped and white after oviposition, becoming off-white or pink closer to hatching (Dhammi et al.2016). Similar to other members of the Pentatomidae family, kudzu bugs undergo five nymphal instars with late season adults overwintering (Zhang et al. 2012). From egg to adult, development takes an average of 24 to 56 days to complete, with adult longevity ranging from 23 to 77 days, with variation attributed to environmental and nutritional factors (Dhammi et al.2016).

Several insect orders are recognized as defoliators of soybeans including Coleoptera (beetles), Lepidoptera (moths and butterflies), and Orthoptera (grasshoppers), with the most significant being Coleoptera and Lepidoptera (O’Neal and Johnson 2010). Soybeans are resilient to the caterpillar pest complex (Lepidoptera) as the crop can withstand up to 30 percent foliage loss before the early pod development stage (R3) with minimal yield reduction (Carter-Wientjes et al. 2004).

Green cloverworm, *Hypena scabra* (Lepidoptera: Noctuidae), adults are migratory moths that likely migrate from the south-central United States to the Midwest. Adults are described as having charcoal-colored bodies with brown and silver patches on the forewings, and a triangular in shape at rest (Hodgson et al. 2021). The green cloverworm is one of the most widespread sporadic pests of soybean (Pedigo et al. 1973). Early instar green cloverworms are often confused with soybean looper caterpillars, however, distinction can easily be made between the two as green cloverworms have a narrow white stripe along each side on their body and three pairs of abdominal prolegs whereas soybean looper caterpillars have two pairs of abdominal prolegs. Green cloverworm also displays a dramatic jumping action when disturbed (Troesser 2023). Green cloverworms undergo complete metamorphosis (egg, larva, pupa, adult), with larvae going through six instars before pupation (Hodgson et al. 2021). Completion of metamorphosis takes an average of 28.5 days at an average temperature of 85°F, with males taking significantly longer, and additional 2.4 days, than females (Hammond et al. 1979). Females lay individual eggs on the underside of leaves, with three or four generations typically found in the southern United States each year (Vyavhare et al. 2015). Egg production peaks when soybeans are at the R2 (full bloom) stage and continues until R5 (beginning pod fill), eggs are rarely found on VE-V4 plants (Hodgson et al. 2021). Early instar larvae are mobile and may feed throughout the plant, however, larvae are typically found in the upper half to one-third of the canopy Pedigo et al. 1973). Green cloverworms generally feed in the middle of leaflets instead of on leaf margins leaving a tattered appearance on leaves with only main leaf veins remaining (Hodgson et al. 2021).

The soybean looper, *Chrysodeixis includens* (Lepidoptera: Noctuidae), is an economically important defoliating pest of the southeastern United States soybean production (Nagoshi et al. 2023). Soybean looper adults (moths) overwinter in south Florida and Texas, Central or South America, and the Caribbean islands (Carter-Wientjes et al. 2004). Adults are tawny-black to grey with a distinctive ‘figure eight’ pattern present in the middle of the forewings; Larvae are pale to dark green with a longitudinal white stripes along each side and dorsum (Hodgson et al. 2021). Larvae have two pair of abdominal prolegs causing them to loop while crawling (Vyavhare et al. 2015). Soybean looper is a polyphagous pest feeding on a large variety of host species including but not limited to soybeans, cabbage (*Brassica oleracea*), common bean (*Phaseolus vulgaris*), Palmer amarantha (*Amaranthus palmeri*), sweetpotato (*Ipomea batatas*), and tomato (*Solanum lycopersicum*) among others (Hodgson et al. 2021). Females often feed on cotton flower nectar before migrating into soybean field to lay their eggs (white to opaque) singly on the underside of soybean leaves in the lower two thirds of the canopy (Carter-Wientjes et al. 2004). Larvae develop through six larval instars, typically completed in 27 to 34 days, with up to four generations per growing season (Carter-Wientjes et al. 2004). Soybean looper feeding begins in the lower two thirds and progresses upward and outward on the plant (Debnath et al. 2024). Larvae feed on lower leaf surface with lateral leaf veins often not fed on giving a ‘lacelike’ appearance to damaged plants, 97 percent of leaf consumption by the soybean looper occurs during the later instars (Hodgson et al. 2021).

Velvetbean caterpillar, *Anticarsia gemmatalis* (Lepidoptera: Noctuidae) is a migratory defoliating pest of mid to late soybean from the Caribbean and Central and South America where it can occur year round but may overwinter in the southern tip of Florida (CABI 2019). Adults (moths) are highly variable in coloration, typically a variation of brown, with a diagonal black line across the forewings and hind wings, and a row of light-colored spots near the margin of the hind wings (Hodgson et al. 2021). While given the name velvetbean caterpillar, a clear preference for leguminous hosts, particularly soybean, has been observed within the species (Hinds and Osterberger 1931). Females may lay eggs individually or in groups of two or three on the underside of leaves, pods, or stems of soybean plants (Vyavhare et al. 2015). Females can lay upwards of 960 eggs within their lifetime (Moscardi et al. 1981). Eggs are prominently ribbed and white to light green until one day before hatching when eggs will turn pink in coloration (CABI 2019). Larvae go through complete metamorphosis, going through six instars before pupating, with development from egg hatch to adult lasting approximately 22 to 24 days (Moscardi et al. 1981). Velvetbean caterpillars vary greatly in coloration from pale yellow-green to brown and black, with white or yellow stripes running lengthwise; four pairs of abdominal prolegs also help to distinguish this pest from others in the caterpillar complex (Vyavhare et al. 2015). Caterpillars feed in the upper one-half to one-third of the soybean leaf canopy (Herzog and Todd 1980). After the upper canopy has been consumed, velvetbean caterpillars feed down the plant until all foliage has been consumed, then begin to eat tender portions of the stems (Herzog and Todd 1980). The number of generations per year varies on arrival of the first migratory generation and environmental conditions (Barbara 2024).

Threecornered alfalfa hopper, *Spissistilus festinus* (Say) (Hemiptera: Membracidae), are wedge shaped pests approximately 0.25 inches in length and light green in coloration (Beyer et al. 2017). Adults and nymphs have piercing-sucking mouthparts and prefer leguminous crops including alfalfa, bean, cowpea, peanut, soybean, and sweet clover. The host range also includes cotton, tomato, sugarcane, potato, Bermuda grass, Johnson grass, wheat, barley, and oats (Mueller and Dumas 1987). Eggs are white, oblong (0.9-1.3 mm), and oviposited within a slit in the plant tissue near the base on the main stem in soybeans. Up to six eggs may be laid per slit in soybean (Wildermuth 1915). TCAH are hemimetabolous, typically undergoing five nymphal stages in total. Nymphs possess dorsal spine-like protrusions and become progressively greener with time (Moore and Mueller 1976). Multiple generations can be seen within a growing season, with adults overwintering in a state of reproductive diapause (Wildermuth 1915). Adults and nymphs feed by sporadic probing and series of lateral punctures around stems, often leading to a gall-like growth or girdle on main stems and branches. Girdling impairs the flow of nutrients, ultimately impacting structural stability of the plant, and leading to lodging at later stages (Beyer et al. 2017). Heavy feeding (lodging) may lead to associated yield losses, reduced forage quality, and increased levels of detergent fibers (Russin et al. 1986).

Pest management

In 2023, invertebrate pests accounted for $669.3 million USD in management costs the United States, with pests reducing soybean bushels by approximately 1.6% (Sisson et al. 2024). Within the southern United States, 81% of soybean acres were scouted for insect pests, 76% received an insecticide seed treatment (IST), and fields were treated with an average of 1.65 foliar applications (Musser et al. 2025). Earlier surveys reported that 30% of soybean acres in the southeast were scouted for insect pests in 2022 and 33% were planted with an IST(Musser et al. 2022). However, insecticidal management remains one of the most effective means for reducing pest populations in soybean (O’Neal and Johnson 2010). Many soybean producers scout and apply insecticides only once pest populations have reached an economic threshold as this practice has proven to be more cost-effective than preventative practices, such as automatic insecticide applications by growth stage (O’Neal and Johnson 2010).

Within the framework of scouting and using economic thresholds, some pest group require more attention than others. The stink bug complex, for example, has much lower thresholds than most insect pests because feeding results in direct seed injury and significant reductions in seed quality (Michel et al. 2013). Among these species, redbanded stink bug, *Piezodorus guildinii,* (RBSB) causes more damage per insect than any other stink bug species in soybean (Vyahare et al. 2024). RBSB infestations can reduce yield and seed quality as well as delay soybean maturity. This is likely to to destructive salivary enzymes (Vyahare et al. 2024). Additionally, RBSB is difficult to control because it has developed resistance to many commonly used insecticides (Okosun et al. 2024).

Another pest of increasing importance in southern soybean production is the kudzu bug *Megacopta cribraria*. Similar to RBSB, kudzu bug feeding can result in substantial yield loss, up to 50% documented in unmanaged fields (Dhammi et al. 2016). Kudzu bugs primarily feed on stems, nodes, and petioles, causing plant stress and reducing photosynthetic capacity (Lahiri and Reisig 2016). Management of kudzu bug relies on pyrethroids and neonicotinoid insecticides, as they have provided the most reliable control infestations (Dhammi et al. 2016). Neonicotinoid seed treatments, such as thiamethoxam, imidacloprid, and clothianidin, have also been documented to provide protection against early-season establishment of populations (O'Neal and Johnson 2010).

Planting date

Planting date plays a key role in soybean growth, yield potential and exposure to biotic and abiotic stress. As soybean production expanded across the southern US, planting windows expanded substantially, spanning from late March through late June (Bateman et al. 2020). The Early Soybean Production System (ESPS), introduced in the early 2000s encouraged growers to shift to earlier planting dates and to adopt early maturity groups (MG IV-V) to avoid drought and high temperatures during reproductive stages, conditions known to induce stress and yield loss (Heatherly 2005).

Both planting date and seed treatment significantly impact soybean growth, yield and seed quality (Siler and Singh, 2023). Early planting may boost yield potential by allowing longer vegetative period and better alignment of reproductive stages with favorable environmental conditions. However, early planting can also increase risk of early season disease and insect pressure, while late planting may shorten overall growing season duration and may limit yield potential (Kandel et al., 2016).

In the Mid-South, maturity group IV cultivars planted April to mid-May have consistently done well within the ESPS framework (Bruns 2011). Beatty et al. (1982) found that seed weight, oil content, and protein percentage was highest in soybeans planted on 15 April; later planting dates (15 May, 15 June, 15 July) showed progressive declines in the parameters (Beatty et al. 1982). In the southern region, Chen and Wiatrak (2010) observed that vegetative stage duration decreased as planting date was delayed across MG IV-VIII, and this reduced vegetative period was identified as the primary factor to cause yield reduction within later plantings. Additionally, soybeans planted between mid-May and mid-June have been observed to have higher incidence of lodging, mostly due to excessive plant heights, leading to possible yield losses (Bateman et al. 2020).

Seed treatments

Seed treatments are widely used in soybean production to mitigate early season stressors, particularly those associated with seedling insect pests and pathogens. These treatments have been shown to improve stand establishment and reduce early pest and disease pressure; however, these benefits vary with environmental conditions, pest incidence, and planting window (Gaspar et al., 2014). Yield gains are most consistently observed in high early season pest pressure areas, while in low-pressure environments, return on investment is often minimal (Cox and Cherney, 2014). Impacts of seed-applied insecticides are limited by how active ingredients remain within the plant, as concentrations decline with plant growth and increasing vegetative biomass (O’Neal and Johnson 2010). Recent work emphasizes the need to integrate planting date and seed treatments into production systems to optimize profitability and reduce risk, especially under variable environmental conditions (Mourtzinis et al., 2023). Seed treatments are expected to improve early season stand establishment by protecting against insect feeding and seedling disease, though their effectiveness is influenced by local pest pressure, environmental variability, and soil conditions (Hurry et al., 2024). Previous studies demonstrate the extent of yield benefits from seed treatments may vary greatly by environment and year, suggesting different locations in Alabama will have different requirements across regions (Cox et al., 2008).Due to the variable nature of insect pest pressure and planting date influence further region-specific research is needed to determine management recommendations for soybean producers throughout the state of Alabama. Limited information currently exists addressing the topic of seed treatments and planting date on Alabama soybeans. Therefore, these experiments serve to help producers evaluate the impact of seed treatments and planting date on insect pressure, yield, and economic return on soybeans in Alabama production regions.

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Chapter 2: Seed Treatment Influence on Yield

Introduction

Soybeans are a key row crop produced in Alabama annually. In 2025, approximately 295,000 acres of soybeans were planted in Alabama with the National Agricultural Statistics Service (NASS 2026) reporting an average price of $10.20 per bushel. Over the past few years, tight profit margins and overall reduced yields have led to a decrease in planted acres across Alabama.

Soybean production in the United States is influenced by a variety of agronomic practices, among which planting date and seed treatments play an important role in crop establishment, plant growth, yield, and seed quality (Siler and Singh 2023). Early planting can extend the vegetative growth period and improve alignment with favorable environmental conditions, which in turn leads to increased yield potential (Heatherly 2005). However, early planted soybeans are often subjected to higher early season disease and insect pressure, which can negatively impact stand establishment and seedling vigor (Kandel et al. 2016). Due to this, seed treatments are widely used in soybean production systems to help mitigate stressors on seedling stands. The effectiveness of seed treatments, however, vary greatly based on environmental conditions, pest incidence, and planting window (Gaspar et al. 2014). In the Mid-South region of the US, approximately 68% of soybean seed planted will be treated with an insecticide seed treatment (Musser et al. 2025). In Alabama, approximately 35% of soybean seed are treated with an insecticide seed treatment (Musser et al. 2025) and approximately 75% of soybean seed are treated with a fungicide seed treatment (S. Graham, personal communication).

Insect pest infestations during the soybean seedling stage are typically more detrimental to yield in the Early Soybean Production System (Baur et al. 2000). Common early season pests in the mid-south include bean leaf beetle (*Cerotoma trifurcata*, lesser cornstalk borer (*Elasmopalpus lignosellus*), grape colaspis (*Colaspis brunnea*), pea leaf weevil (*Sitona lineatus*), threecornered alfalfa hopper (*Spissistilus festinus*), white grubs (multiple spp.), wireworms (multiple spp.), and thrips (multiple spp.). Neonicotinoid seed treatments have been documented to provide significant increases in yield relative to non-treated soybeans by suppressing early season pests below and above ground with their systemic activity (Baur et al. 2000, North et al. 2016). Specifically, imidacloprid and thiamethoxam provided a significant yield increase over a fungicide seed treatment alone in the midsouth (Maienfisch et al. 2001).

However, effectiveness of seed treatments is limited to a short timeframe after plant emergence, and their value is influenced by planting date and environmental conditions (Cox and Cherney 2011). Additionally, Reisig et al. (2012) reported that while adult thrips populations were reduced by neonicotinoid seed treatments in soybeans, no differences in yield were observed. Despite the widespread usage of seed treatments in soybean production systems, results vary in terms of economic return of seed treatments across planting dates. Especially in the southeastern US where pest pressure and environmental conditions vary substantially by year.

While previous studies have been conducted in surrounding regions such as the midsouth, there is currently a lack of information for the southeast, with no prior studies being conducted in Alabama. Alabama soybean producers currently plant the majority of soybeans within a different planting window than neighboring regions with differing pest pressures. The objective of this study was to evaluate the effects of seed treatments on early season insect pressure, soybean yield and economic return across multiple planting dates in Alabama soybean production systems.

Materials and Methods

Experiments were conducted at six Alabama Agricultural Experiment Stations (AAES) to evaluate how fungicide and insecticide seed treatments influence soybean yield and return of investment from 2024-2025. Locations included the Tennessee Valley Research Extension Center (TVREC; Belle Mina, Alabama), Prattville Agricultural Research Unit (PARU; Prattville, AL), E.V. Smith Field Crops Unit (EVS; Shorter, AL), Brewton Agricultural Research Unit (BARU; Brewton, AL), Black Belt Research Extension Center (BBREC; Marion Junction, AL), and Gulf Coast Research Extension Center (GCREC; Fairhope, AL). Soybeans, Asgrow 48XF3 (Bayer CropScience, St. Louis, MO, USA) were used in all locations and in both years.

All seed were weighed and separated into 5 lb. increment bags and then treated with seed treatments. Treatments included: a non-treated check, fungicide seed treatment (FST) only: Evergol Energy 1.5 ml per 5 lbs. (1oz/cwt) (active ingredients: Prothioconazole 7.18%, Penflufen 3.59%, Metalaxyl 5.74%) and Allegiance FL 0.75 ml per 5 lbs. (0.5oz/cwt) (active ingredients: Metalaxyl 28.35%) with 0.75 ml colorant, an insecticide seed treatment (IST) only: Gaucho 600 3.0 ml per 5 lbs. (2oz/cwt) (active ingredient: Imidacloprid 48.75%) with 0.75 ml colorant, and a combination of the FST + IST. Treatments were applied using a Gustafson laboratory-scale seed treater for approximately 5 minutes, or until seed treatment had dried completely. Seed was then sorted into packets by treatment for each plot using a Seedburo 801 count-a-pak seed counter, for a targeted seeding rate of ≈100,000 seed per acre.

Treatments were arranged in a randomized complete block design (RCBD) with four replications at each location. Plot dimensions varied slightly by location but consisted of four rows spaced 30-to-36-inch apart and 25 to 30 feet in length. Winter vegetation was terminated at least one month prior to planting to remove cover crop or winter weed residue from the trial area plot.

In 2024, a single planting date within the first week of May was targeted at each location. The planting date was chosen to replicate Alabama's current production practices as the majority of all soybean acres are planted within the first week of May currently. This targeted plant date was accomplished at three locations including: EVS, TVREC, and PARU. Due to excessive rainfall, planting was delayed by two weeks in the remaining locations: BARU, BBREC, and GCREC (Table 2.1).

In 2025, a planting date factor was added to the experiment, with targeted dates in April, May, and June across locations. All three planting dates were established at TVREC, PARU, and BARU. Due to excessive rain, planting was delayed or plant dates were missed at EVS (April), BBREC and GCREC (Table 2.1).

Data Collection

All plots were evaluated 28 days after planting (DAP) for stand establishment, insect counts, and threecornered alfalfa hopper (TCAH) damage ratings. Stand counts were estimated by counting all plants in rows two and three of each plot and converted to plants per acre to determine the percent stand established.

Insect population densities were evaluated using a 38.1-cm diameter sweep-net, with 15 sweeps per plot. Although multiple insect pests, including kudzu bug and bean leaf beetle were observed during this trial, they were found sporadically in some locations and planting dates but not others; therefore, these species were excluded from statistical analysis. Only TCAH density and injury are reported.

Threecornered alfalfa hopper damage ratings were assessed by applying light pressure to all seedlings in a one-meter section 3-4 inches above the soil using a one-meter ruler in four locations per plot (two one-meter assessments each in rows two and three). Plants damaged by TCAH exhibited girdling on the mainstem and would snap under applied pressure. All broken seedlings were counted and recorded within each plot to determine TCAH damage per plot.

After 28 DAP, all plots were monitored on a weekly basis for insect pests (Table 2.11) by performing 15 sweep-net samples per plot. All insect pests present within the stand were recorded by plot and separated by adult and immatures of each species. Insecticide applications were made uniformly across all treatments when pest populations exceeded action thresholds according to the Alabama Soybean IPM Guide until soybean maturity. The center two rows of each plot were harvested and total pounds of seed per plot were converted to bushels per acre using a standard of 60 lbs per bushel. Finally, an economic analysis was conducted to estimate the return of investment (ROI) compared to the non-treated check. Treatment costs were estimated at $5.00 per acre for the FST, $9.00 per acre for the IST, and $14.00 per acre for the FST + IST. The value of soybeans (bu/A) used was $10.50 across both growing seasons. Gross revenue for each treatment was calculated as mean yield (bu/A) x

$10.50 and treatment costs were subtracted to determine the net economic return relative to the non-treated control.

Data collected at 28 DAP were analyzed using a linear mixed model of analysis in PROC GLIMMIX (SAS Version 9.4; SAS Institute, Cary, NC). Due to the addition of planting date as a factor in 2025, data were analyzed separately by year. In 2024, seed treatment was included as the fixed effect. In 2025, seed treatment and planting date were treated as fixed effects. Location, replication, and replication nested within location were treated as random effects to allow inference across environments, consistent with recommendations for multi-environment experiments from Blouin et al. (2011). Yield data were analyzed similarly, except location was considered a main effect due to variable rainfall and yield potential variation across locations (Table 2.2). Degrees of freedom were estimated using the Kenward–Roger method. Means were obtained using LSMEANS and separated using Fisher's protected LSD at $\alpha = 0.05$, following the mean comparison framework described by Carmer et al. (1989).

Results

In the 2024 season, no significant differences were observed in threecornered alfalfa hopper (TCAH) populations (F=0.95; df = 3, 54; P = 0.4238), threecornered alfalfa hopper damage ratings (F=3.64; df=3, 54; P = 0.7252), or stand counts (F=0.58; df=3, 69; P=0.6325). No significant difference was observed for yield by treatment (F=1.68; df=3, 67; P=0.1789), however, the FST+IST had the highest overall yield (44.6±4.3 bu/A), followed by the FST (44.2±4.3 bu/A) then IST (43.9±4.2 bu/A) then by the check (42.6±4.3 bu/A). All treatments also provided a positive ROI over the check.

Averaged across all locations, the highest ROI was observed when using the FST ($11.80/A) followed by the FST + IST ($7.00/A) and IST ($4.65/A).

In the 2025 season, no significant differences were observed in TCAH populations (F=0.45; df=3, 196; P = 0.7162) or stand counts (F=0.54; df=3, 230; P = 0.9846) among seed treatment. However, there was a difference in TCAH damage ratings (F=2.77; df=3, 196; P = 0.0426) among seed treatment, soybeans treated with the FST + IST (8.9±0.7) had more TCAH damage than all other treatments. There were also significant differences for TCAH populations (F = 3.56; df=2, 197; P=0.0304) and for TCAH damage ratings (F = 13.85; df=2, 197; P<0.0001). Significantly more TCAH and TCAH damage were found in May and June planting dates than April planting dates (Table 2.3). There was also a significant difference for stand counts across planting dates (F=35.15; df=2, 219; P<0.0001) where higher stands were observed for April (121.5±4.2) planted soybeans than May (105.2±3.5) planted soybeans which was higher than June (92.4±1.8) planted soybeans. This could be due to increased TCAH damage as the season progressed.

In 2025 there was a significant impact of planting date (F=100.93; df=2, 246; P<0.0001), location (F=188.71; df=5, 246; P<0.0001) and their interaction (F=21.37; df=9, 246; P<0.0001) on yield. Soybeans planted in May (42.3±1.4 bu/A) yielded significantly higher than those planted in April (29.5±1.4 bu/A) and June (25.2±1.4 bu/A). Soybeans planted at GCREC (54.9±1.1 bu/a /A) had the highest yields, followed by TNVREC (40.3±1.3 bu /A), then PARU (27.9±1.1 bu /A) and EVS (27.8±1.4 bu /A), and finally BARU (18.2±0.7 bu /A) and BBREC (15.5±0.9 bu /A) had the lowest.

There was no impact of seed treatment (F=1.37; df=3, 246; P=0.2529) on yield when analyzed across all locations and planting dates in 2025. Additionally, no, significant interactions were observed for planting date by seed treatment (F=0.87; df=6, 246; P=0.5201), location by seed treatment (F=0.39; df=15, 246; P=0.9804), or three-way interaction of seed treatment by location by planting date (F=0.23 df=21.37, 246; P=1.0).

When data were analyzed by planting date and averaged across locations, responses differed among planting windows. Significant differences in yield among seed treatments were observed in the April planting date (F=5.46; df=3, 69; P=0.0019) (Table 2.5). In contrast, no yield differences were detected among seed treatments in May (F=0.19; df=3, 115; P=0.9063) (Table 2.6) or June (F=0.34; df=3, 56; P=0.7964) (Table 2.7) planting dates.

Despite the lack of significant overall yield differences in the full model, economic returns varied by treatment and planting dates. When averaged across locations and planting dates, all seed treatments resulted in no significant differences observed for yield, although a positive $1.50-12.25 ROI was observed (Table 2.4). When averaged across locations for each planting date, there was a significant difference in yield between treatments in April (Table 2.5), but not in May (Table 2.6) or June (Table 2.7). Significant differences were found for yield for seed treatment and planting date but not their interaction and a positive ROI was observed when seed treatments were used. When averaged across all locations and planting dates, highest return over untreated check was observed for FST only at $13.67 per acre, followed by the FST + IST ($8.20) and IST ($3.31). Similarly, all treatments provided a positive ROI (Table 2.4). Averaged across all April plantings, the FST + IST provided the highest ROI at $45.85 per acre, followed by the FST at $34.90 per acre, and finally the IST at $2.55 per acre (Table 2.5). In May, returns were modest, with the FST providing the highest ROI at $7.60 per acre, and minimal return observed for other treatments (Table 2.6). In June planting dates it was observed that insecticide only was the only treatment with positive return on investment at $2.55 per acre (Table 2.7).

The April planting date had the only observable significance in yield (Table 2.5). Due to variation in yield across locations, a second analysis was conducted in the 2025 season looking at variation of yield potential by locality in the April planting date. Locations were divided into high yield potential (GC, TNV), moderate yield potential (PARU, EVS) and low yield potential (BARU, BBREC). These different yield potential sites were then analyzed to determine differences in return on investment within each environment.

Within the high yield potential sites, all seed treatments had significant increases on return on investment, fungicide plus insecticide seed treatment had the highest return on investment over untreated check at $186.55 per acre, followed by fungicide only ($158.80), and insecticide only ($107.55) respectively (Table 2.8). In the moderate yield potential sites, the fungicide only ($21.25) and fungicide plus insecticide ($18.55) seed treatments had positive returns, while no return was found in an insecticide only seed treatment (-$1.65) (Table 2.9). Averaged across all low yield potential sites a positive return on investment was found over the untreated check, with fungicide plus insecticide seed treatment having the highest return at $29.05 (Table 2.10).

Discussion

Across locations and years, seed treatments had limited effects on insect pressure, stand establishment, and yield supporting previous findings that the value of seed treatments in soybean is variable and highly dependent on pest pressure and environmental conditions (Mourtzinis et al. 2019). Large, multi-location studies have demonstrated that insecticide and fungicide seed treatments often provide inconsistent or negligible benefits in soybean production systems, particularly under low pest pressure (Labrie et al. 2019).

In 2024 no significant differences were observed among treatments for TCAH populations or damage, stand establishment, or yield. These results suggest pest pressure in 2024 may have been insufficient to elicit a response to either fungicide or insecticide seed treatments. Similar results have been reported in locations where pest populations remained below economic thresholds, limiting the agronomic benefits of prophylactic seed treatments (Mourtzinis et al. 2019, Labrie et al. 2019). In other studies, reductions in early-season pest populations did not consistently increase yield, reinforcing the context-dependent nature of seed treatment efficacy (Cox and Cherney 2011, Reisig et al. 2012).

Although yield differences among treatments were not significantly different in 2024, the FST+IST numerically resulted in the highest mean yield, and all seed treatments provided a positive ROI relative to the non-treated check. Economic benefits in the absence of statistical yield gains have been reported and may reflect early season plant health, protection from lack of subthreshold pest pressure, or reduced early stress that is not captured through insect population estimates alone (North et al. 2016, Gaspar et al. 2017).

Similar trends were observed in 2025, where no significant seed treatment effects were detected for stand establishment, TCAH populations, or yield in the overall analysis. Despite no significant main effects or interactions involving seed treatments, the FST+IST again numerically produced the highest mean yield. These findings further support previous research indicating that soybean responses to seed treatments are often small and relative to environmental variability and may not be statistically detectable at the field scale (Mourtzinis et al. 2019).

In contrast to seed treatment effects, planting date significantly influenced yield in 2025. Soybeans planted in May yielded higher than those planted in April or June, this indicated that mid-season plantings were better aligned with environmental conditions. Planting date study also observed that a May planting window produced highest overall yield (Table 2.6). These observations are consistent with Bruns (2011), who reported that a maturity group IV soybeans in the midsouth could achieve high yields when planted in mid-May. The primary driver for yield potential in soybeans across the Southeastern US and yield penalties are expected when soybeans are planted too early or too late in most cases (Heatherly 2005, Bateman et al. 2020). In Alabama, production windows may be more favorable in mid-May than in an early planting window.

Further analysis of April plantings showed that economic returns from seed treatments were strongly influenced by yield environment. In high-yield potential locations, seed treatments generated substantial positive returns, particularly when fungicide and insecticide seed treatments were combined. Prior research has shown that seed treatment profitability is tied to yield potential, as the fixed cost of seed treatments can be offset more readily in high yield environments, whereas economic returns are often inconsistent or reduced under lower yield conditions (Gaspar et al. 2017). On the other hand, returns were inconsistent in moderate and low yield environments, supporting that yield potential plays a critical role in determining the economic feasibility of seed treatment inputs.

These findings indicate that seed treatments provide inconsistent benefits in Alabama soybean production systems. In our study, seed treatments provided the most valuable return on investment in systems with early planting conditions and high yield environments. However, return was limited in areas with moderate to low pest pressures. Planting date had more consistent influence on yield, indicating that optimal planting windows may play a more significant role in improving yield and return on investment than seed treatments. Overall, planting date had more consistent influence on yield than seed treatments, with the highest yields experienced for soybeans planted in May.

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Tables

Table 2.1. Planting dates for soybeans planted with and without seed treatments at Alabama Agricultural Experiment Stations in 2024 and 2025 growing seasons.

Planting dates by location	TNV	PARU	EVS	BBREC	BARU	GCREC
2024	5 May	8 May	30 April	20 May	20 May	23 May
2025 Early	16 April	11 April	April 22	17 April	8 April	-
2025 Mid	16 May	12 May	-	19 May	6 May	28 May
2025 Late	12 June	3 June	-	25 June	13 June	12 June

Table 2.2. Precipitation totals at Alabama Agricultural Experiment Stations from April 15th to August 30th where soybeans were planted with and without seed treatments in 2024 and 2025.

Precipitation (in) by location	TNV	PARU	EVS	BBREC	BARU	GCREC
2024	16.63	15.8	22.02	18.20	19.06	29.47
2025	20.86	32.41	19.34	27.74	20.09	27.7

Table 2.3. Threecornered alfalfa hopper population estimates (mean ± sem) and damage (mean ± sem) for soybeans planted in April, May and June 2025 at the Prattville Agricultural Research Unit in Prattville, AL.

Planting Date	TCAH population	TCAH Damage
April 2025	1.12 (±0.2) b	5.69 (±0.6) c
May 2025	1.19 (±0.3) ba	7.45 (±0.8) b
June 2025	1.79 (±0.2) a	9.48 (±0.7) a

Means followed by a common letter are not significantly different (Fisher's Protected LSD, α=0.05).

Table 2.4. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across April, May and June planting dates on six Alabama Agricultural Experiment Stations in 2024 and 2025.

Treatment	Yield Bu/A	Gross Income $ per A	Cost of Trt $ per A	Net Profits $ per A	ROI vs Check $ per A
Fungicide[1] + Insecticide[2]	33.3 (1.9) a	$349.65	$14.00	$335.62	$12.25
Fungicide[1] Only	32.4 (2.1) a	$340.20	$5.00	$335.20	$11.80
Insecticide[2] Only	31.8 (1.6) a	$333.90	$9.00	$324.90	$1.50
Check	30.8 (1.9) a	$323.40	-	$323.40	-

[1] Evergol Energy (1 oz/cwt) + Allegiance FL (0.5 oz/cwt)

[2] Gaucho 600 (2 oz/cwt)

Means followed by a common letter are not significantly different (Fisher's Protected LSD, α=0.05).

Table 2.5. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across all April planting dates on six Alabama Agricultural Experiment Stations in the 2025 season.

	Yield	Gross Income	Cost of Trt	Net Profits	ROI vs Check
Treatment	**Bu/A**	**$ per A**	**$ per A**	**$ per A**	**$ per A**
Fungicide[1] + Insecticide[2]	28.3 (±3.1) a	$297.15	$14.00	$283.15	$45.85
Fungicide[1] Only	26.4 (±2.9) a	$277.20	$5.00	$272.20	$34.90
Insecticide[2] Only	23.7 (±2.7) a	$248.85	$9.00	$239.85	$2.55
Check	22.6 (±2.6) a	$237.30	-	$337.30	-

[1] Evergol Energy (1 oz/cwt) + Allegiance FL (0.5 oz/cwt)

[2] Gaucho 600 (2 oz/cwt)

Means followed by a common letter are not significantly different (Fisher's Protected LSD, α=0.05).

Table 2.6. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across all May planting dates on six Alabama Agricultural Experiment Stations in the 2025 season.

Treatment	Yield Bu/A	Gross Income $ per A	Cost of Trt $ per A	Net Profits $ per A	ROI vs Check $ per A
Fungicide[1] + Insecticide[2]	40.1 (±3.1) a	$421.05	$14.00	$407.05	$3.85
Fungicide[1] Only	39.6 (±3.2) a	$415.80	$5.00	$410.80	$7.60
Insecticide[2] Only	39.8 (±3.1) a	$417.90	$9.00	$408.90	$5.70
Check	38.4 (±3.1) a	$403.20	-	$403.20	-

[1] Evergol Energy (1 oz/cwt) + Allegiance FL (0.5 oz/cwt)

[2] Gaucho 600 (2 oz/cwt)

Means followed by a common letter are not significantly different (Fisher's Protected LSD, α=0.05).

Table 2.7. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across all June planting dates on six Alabama Agricultural Experiment Stations in the 2025 season.

Treatment	Yield Bu/A	Gross Income $ per A	Cost of Trt $ per A	Net Profits $ per A	ROI vs Check $ per A
Fungicide[1] + Insecticide[2]	29.8 (±4.4) a	$312.90	$14.00	$298.90	-$1.40
Fungicide[1] Only	28.8 (±4.1) a	$302.40	$5.00	$297.40	-$2.90
Insecticide[2] Only	29.7 (±4.2) a	$311.85	$9.00	$302.85	$2.55
Check	29.8 (±3.9) a	$300.30	-	$300.30	-

[1] Evergol Energy (1 oz/cwt) + Allegiance FL (0.5 oz/cwt)

[2] Gaucho 600 (2 oz/cwt)

Means followed by a common letter are not significantly different (Fisher’s Protected LSD, α=0.05).

Table 2.8. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across April high yield potential sites on two Alabama Agricultural Experiment Stations in the 2025 season.

Treatment	Yield Bu/A	Gross Income $ per A	Cost of Trt $ per A	Net Profits $ per A	ROI vs Check $ per A
Fungicide[1] + Insecticide[2]	42.9 (±2.9) a	$450.45	$14.00	$436.45	$186.55
Fungicide[1] Only	39.4 (±3.4) a	$413.70	$5.00	$408.70	$158.80
Insecticide[2] Only	34.9 (±3.1) a	$366.70	$9.00	$357.45	$107.55
Check	23.8 (±1.9) a	$249.90	-	$249.90	-

[1] Evergol Energy (1 oz/cwt) + Allegiance FL (0.5 oz/cwt)

[2] Gaucho 600 (2 oz/cwt)

Means followed by a common letter are not significantly different (Fisher’s Protected LSD, α=0.05).

Table 2.9. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across April moderate yield potential sites on two Alabama Agricultural Experiment Stations in the 2025 season.

Treatment	Yield Bu/A	Gross Income $ per A	Cost of Trt $ per A	Net Profits $ per A	ROI vs Check $ per A
Fungicide[1] + Insecticide[2]	29.9 (±3.5) a	$313.95	$14.00	$299.95	$18.55
Fungicide[1] Only	29.3 (±3.8) a	$307.65	$5.00	$302.65	$21.25
Insecticide[2] Only	27.5 (±3.1) a	$288.75	$9.00	$279.75	-$1.65
Check	26.8 (±3.7) a	$281.40	-	$281.40	-

[1] Evergol Energy (1 oz/cwt) + Allegiance FL (0.5 oz/cwt)

[2] Gaucho 600 (2 oz/cwt)

Means followed by a common letter are not significantly different (Fisher’s Protected LSD, α=0.05).

Table 2.10. Effect of seed treatments on soybean yield (mean ± sem), gross income and return of investment (ROI) averaged across April low yield potential sites on two Alabama Agricultural Experiment Stations in the 2025 season.

Treatment	Yield Bu/A	Gross Income $ per A	Cost of Trt $ per A	Net Profits $ per A	ROI vs Check $ per A
Fungicide[1] + Insecticide[2]	11.8 (±1.6) a	$123.90	$14.00	$104.90	$29.05
Fungicide[1] Only	10.5 (±0.8) a	$110.25	$5.00	$105.25	$24.40
Insecticide[2] Only	8.6 (±1.4) a	$90.30	$9.00	$81.30	$0.45
Check	7.7 (±0.9) a	$80.85	-	$80.85	-

[1] Evergol Energy (1 oz/cwt) + Allegiance FL (0.5 oz/cwt)

[2] Gaucho 600 (2 oz/cwt)

Means followed by a common letter are not significantly different (Fisher's Protected LSD, α=0.05).

Table 2.11. Insect populations present and recorded within a two year seed treatment study conducted at the six Alabama Agricultural Research Units in Alabama during the 2024 and 2025 growing season.

Insect populations present	
Bean leaf beetle	*Cerotoma trifurcate*
Corn earworm	*Helicoverpa zea*
Green clover worm	*Hypena scabra*
Soybean looper	*Chrysodeixis includens*
Velvetbean caterpillar	*Anticarsia gemmatalis*
Kudzu bug	*Megacopta cribraria*
Brown stink bug	*Euschistus servus*
Brown marmorated stink bug	*Halyomorpha halys*
Green stink bug	*Chinavia hilaris*
Southern green stink bug	*Nezara viridula*
Redbanded stink bug	*Piezodorus guildinii*
Pea leaf weevil	*Sitona lineatus*
Threecornered alfalfa hopper	*Spissistilus festinus*

Chapter 3: Planting date influence on yield

Introduction

The United States produces soybeans in 29 states and produces 28% of all soybeans in the world. This accounts for 90% of all oilseed production in the United States (Bukowski and Swearingen 2025). Development of soybean is impacted by temperature, day length, variety, and maturity group (Fehr and Caviness 1977). This makes planting date an important factor to consider in production systems. Planting date is variable based on geographic location and maturity group within a production system. However, it can be one of the most impactful factors in growth, yield potential, and exposure to abiotic and biotic stressors within a production system. Planting in the southern US generally ranges from late March through late June (Bateman et al. 2020). Since the early 2000s the majority of growers have adopted earlier planting dates and the use of early maturity groups (MG IV-V), to mitigate stress from drought and high temperatures during reproductive stages of the crop (Heatherly 2005). The midsouth has seen MG IV cultivars to consistently produce high yields when planted from April to mid-May. However, after 15 April a reduction in seed oil content, protein, and weight has been observed across the region (Bruns 2011, Beatty et al.1982). Early planting dates are highly utilized in the midsouth to minimize inclement weather conditions, drought, and insect pressure as higher incidence has been reported in late season soybeans (Heatherly and Hodges 1998, Bateman et al. 2020). However, according to the USDA Crop Progress Report, Alabama producers typically utilize later planting windows with the majority planted in May (~64%) and June (~30%) and relatively few April (~2%).

In conjunction with current management practices, insect pests are estimated to cause ~1.6% of all yield losses across soybean producing states in US. Greater loses may be observed in high pest pressure areas such as the southeast (Musser et al. 2025). Multiple insect species are known to impact soybean production in Alabama, most notably the redbanded stink bug (*Piezodorus guildinii*) along with the "traditional" stink bug complex of the green stink bug (*Chinavia hilaris*), southern green stink bug (*Nezara viridula*) and brown stink bug (*Euschistus servus*), and the kudzu bug (*Megacopta cribraria*) (Musser et al. 2025). In recent years, the redbanded stink bug has become a more consistent contributor to soybean damage in Alabama. This pest causes more damage per insect than the traditional stink bug complex (Reddy et al. 2024, Vyavhare et al. 2024). Insecticidal management is one of the most effective means for reducing pest populations in soybeans (O'Neal and Johnson 2010). It has been observed that pyrethroids insecticide applications have significantly reduced populations of these pests in soybeans (Marques et al. 2019). However, the redbanded stink bug is less susceptible to commonly used insecticides used to control stink bug populations, this has resulted in increased insecticide applications in regions where redbanded stink bug is present. A combination of pyrethroid and organophosphate or neonicotinoid has shown significant suppression of this pest (Okosun et al. 2024).

Due to limited information on soybean planting date effects in Alabama production systems, the objective of this study was to evaluate the effects of planting date and threshold-based IPM practices on insect pest populations, soybean yield, and economic return.

Materials and Methods

An experiment was conducted at the Prattville Agricultural Research Unit (PARU) in Prattville, Alabama in 2024-25 to evaluate the impact of planting date on insect management and soybean yield. Soybeans, Pioneer 48A14 (Corteva Agriscience, Indianapolis, IN, USA) were used both years of the trial and planted at a seeding rate of ≈100,000 plants per acre. Treatments were organized in a split-plot design with planting date assigned to whole plots and insect-management treatment assigned to subplots with four replications. Soybeans were planted on 36-inch row spacings and plots were 8 rows wide and 25 feet long. Winter vegetation was terminated at least one month prior to planting to remove any crop residue from the plot. In both years, soybeans were planted the second week of April, May, and June (Table 3.1). Treatments included: a non-managed check and managed plots sprayed at threshold for all insect pests. All plots were scouted on a weekly basis from emergence through maturity (R7 stage) with visual examination and sweeping. Insect populations were estimated by making 25 sweeps per plot using a 38.1 cm diameter sweep-net. All insect pests present (Table 3.5) were identified and recorded. When the action threshold was reached for any insect pest within management plots applications were made according to the Alabama IPM guide until soybeans reached maturity (Table 3.2). The center two rows of each plot were harvested at maturity to determine impacts of planting date and management threshold applications on yield. Total pounds of seed per plot were then converted to bushels per acre using a standard of 60 lbs per bushel.

An economic analysis was done to determine the impact of insecticide applications across planting dates on return of investment (ROI). To estimate insecticide costs, we solicited current price quotes from several agricultural input retailers and independent crop consultants who supply products and services across Alabama. These sources provided representative market prices for the active ingredients used in this trial. In addition to the insecticide cost, an average application cost of $8.00 per acre was added to reflect cost of the sprayer. The value of soybeans (bu/A) was estimated at $10.50 across growing years. The total cost of each treatment was then subtracted from the average value of each treatment (avg. bu/A X $10.50) to determine the economic ROI compared to the non-treated check.

Data were analyzed using a linear mixed model of analysis in PROC GLIMMIX (SAS 9.4). Treatment and planting date were treated as fixed effects. Year, replication and replication nested in year were designated as random effects. Degrees of freedom were estimated using the Kenward-Roger method. Means were obtained using LSMEANS and separated using Fisher's protected LSD at $\alpha = 0.05$, following the mean comparison framework described by Carmer et al. (1989).

Results

Unless specified, interactions of planting date and management were not significant and are not discussed. Sporadic insect populations were observed throughout the season (Table 3.5), but analysis focused on consistent pest populations found throughout the season. A significant difference was observed between kudzu bug populations for planting date ($F=17.81$, $df=2, 421$, $p<0.0001$), populations steadily increased as the season progressed with highest overall population observed in the late planting date (June) (Table 3.3). A significant reduction in kudzu bug population was observed between threshold plots (14.2 ± 1.3) and non-treated check (21.4 ± 1.7)

(F=12.20, df= 1, 421, p=0.0005). No significant difference was observed between stink bug population across plant dates (F=1.68, df=1, 421, p=0.1873). A significant difference was observed between treatment and stink bug populations (F=16.55, df=1, 421, p<0.0001) with management plots (1.2 ± 0.2) having fewer stink bugs than the non-managed check (2.4 ± 0.3). Because redbanded stink bugs are considered more damaging than other stink bug species and have a lower threshold, they were analyzed separately from the other species. There was a significant interaction for planting date and treatment for immature redbanded stink bugs (F=6.10, df=2, 421, p=0.0024) and the total number (F=5.95, df=2, 421, p=0.0028) of redbanded stink bugs (adult + immature) observed. Regardless of treatment, significantly more redbanded stink bugs were found in the late planted non-managed check than all other treatments. For the total number of redbanded stink bugs, the most were observed in the non-managed late planting date, followed by the early planted non-managed check (Table 3.4).

For yield, there was no significant difference across planting dates (F=0.59, df=2, 27, p=0.5613), however there was a significant difference for treatment (F=34.42, df= 1, 27, p<0.0001). Regardless of planting date, soybeans treated for insect pests at threshold (32.6±0.9 bu) yielded significantly higher than soybeans not treated for insect pests (24.7±1.1 bu).

Discussion

Planting date significantly influenced kudzu bug populations, with populations steadily increasing as the season progressed, and overall populations peaking in the June planting date (late). This trend is consistent with prior research indicating higher infestation of kudzu bug can be found as the growing season progresses due to overlapping generations and aggregating tendencies of kudzu bug (Seiter et al. 2013). Kudzu bug undergoes multiple generations per year in the southeastern United States, with oviposition beginning in April and often lasting through July. This extended migration and oviposition leads to multiple generations being present in fields at the same time (Zhang et al.2012). In our study, we applied bifenthrin (6.4 oz per A) when kudzu bug populations reached economic thresholds. This significantly reduced kudzu bug populations compared to non-managed plots. However, we did not always see yield increases, supporting the effectiveness of threshold-based insect pest management. These findings support IPM recommendations and agree with prior studies that observed pyrethroids (Maio et al. 2016) or organophosphates (Wu et al. 1992) are an effective control of kudzu bug populations (Lahiri and Reisig 2016).

We did not see an impact of planting date on the traditional stink bug complex, however, insecticide application had a significant impact. Overall, this complex was found at low populations, however, they were likely suppressed by applications targeting other pests, like redbanded stink bug. Redband stink bugs (RBSB) are considered the most damaging species of stink bug to soybean (Depieri and Panizzi 2011). RBSB population had a significant interaction between planting date and treatment. Highest populations were observed in the late planted (June) non-treated plots, indicating that later planted soybeans are at higher risk of infestation and damage if not properly managed. In addition to yield loss and reduced quality, high populations of RBSB are correlated with delayed soybean maturity (Vyavhare et al.2015). While we did not directly evaluate this, we did observe that non-managed plots remained green longer.

This could have been “green stem syndrome” which is a result of delayed maturity and complicates harvest (Boethel et al. 2000). Similar to other research, we found that RBSB populations increased as soybeans reached later reproductive stages (Vyavhare et al. 2014). In our study, RBSB required 1-3 insecticide applications, depending on planting date and year. In production areas where RBSB are present, an increase in insecticide applications has been observed due to resistance and/or higher tolerance compared to other stink bug species (Temple et al. 2013). Because of this, we chose to use tank-mixtures of acephate and bifenthrin, which has been documented to provide better control than either insecticide alone (Cook and Gore 2018).

Planting date had a significant effect on soybean yield and return on investment of insect management (Table 3.6). Soybeans planted in May had the highest overall yield and economic return during this study. Early planting is often associated with increased yield potential in most production regions, however, several studies have shown optimal planting windows vary on a year-to-year basis and depend on environmental conditions (Bastidas et al. 2008, Rowntree et al. 2013). In the mid-south early planting date is utilized to minimize inclement weather conditions, late season drought stress, and insect pressure (Heatherly and Hodges 1998). It has also been noted in the midsouth that the highest insect pressure is present in late planting dates (July) (Bateman et al. 2020). Interestingly, we did not see a similar trend. Our study had several key differences from Bateman et al. (2020). In our study, an “early” planting date was made in mid-April, which is several weeks later than Bateman et al. (2020). This was done to replicate Alabama’s current production practices, as the majority of all acres are planted within the first week of May currently. We also had increased insecticide applications in early planted soybeans because of kudzu bug infestations. While this increased the number of applications and cost of control, we did not see yield increases to justify multiple applications for migratory adults in vegetative stage soybeans. Additionally, RBSB infestations were worst in our early and late planted soybeans, with populations highest overall in the later planted. While Bateman et al. (2020) experienced high stink bug pressure, they did not report high pressure from RBSB. Often, RBSB are often found to infest the earliest reproductive soybean fields (i.e. earliest planted) first, albeit at lower numbers, then heavily congregate in the latest reproductive soybean (i.e. latest planted) fields at the end of the year, with soybeans planted in the middle experiencing the lowest pressure (S. Graham, personal observation). Another difference compared to Bateman et al. (2020) is that late planting dates were in July in that study, while ours were in mid-June. We did not experience populations of defoliating caterpillars, such as soybean looper, reaching economic thresholds as Bateman et al. 2020 did. May planting date had highest overall yield and return on investment, this may be due to better environmental factors and minimal insect pressure within the May planting window.

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Tables

Table 3.1. Planting dates for a soybean plant date experiment conducted at the Alabama Agricultural Experiment Station in Prattville, AL in the 2024 and 2025 season.

Planting dates	Early PD	Mid PD	Late Pd
2024	8 May	28 May	18 June
2025	11 April	12 May	3 June

Table 3.2. Insecticide applications administered throughout a two year planting date study at the Prattville Agricultural Research Unit in Prattville, AL during the 2024 and 2025 growing season.

Plant Date	Insecticide	Rate	Application Date	Target Insect
Early-2024	Bifenthrin	6.4 oz	18-June*	Kudzu Bug
Mid-2024	Bifenthrin	6.4 oz	18-June*	Kudzu Bug
Early-2024	Bifenthrin	6.4 oz	28-June	Kudzu Bug
Early-2024	Bifenthrin	6.4 oz	10-July	Kudzu Bug
Mid-2024	Bifenthrin	6.4 oz	10-July	Kudzu Bug
Early-2024	Bifenthrin	6.4 oz	17-July	Kudzu Bug
Mid-2024	Bifenthrin	6.4 oz	17-July	Kudzu Bug
Early-2024	Bifenthrin Acephate	6.4 oz 0.5 lb	16-August	RBSB
Late-2024	Bifenthrin Acephate	6.4 oz 0.5 lb	24-September	RBSB
Late-2024	Bifenthrin Acephate	6.4 oz 0.5 lb	8-October	RBSB
Early-2025	Bifenthrin	6.4 oz	30-June	Stink Bug
Early-2025	Bifenthrin Acephate	6.4 oz 0.5 lb	14-July	RBSB
Early-2025	Bifenthrin Acephate	6.4 oz 0.5 lb	22-July	RBSB
Mid-2025	Bifenthrin Acephate	6.4 oz 0.5 lb	4-August	RBSB
Mid-2025	Bifenthrin Acephate	6.4 oz 0.5 lb	22-August	RBSB

Late-2025	Bifenthrin Acephate	6.4 oz 0.5 lb	22-August	RBSB
Late-2025	Bifenthrin Acephate	6.4 oz 0.5 lb	3-September	RBSB

(*) Indicates that both managed and non-managed plots received insecticide applications.

Table 3.3 Total kudzu bug populations (mean ± sem), recorded during the 2025 season at the Alabama Agricultural Experiment Station in Prattville, AL.

Planting Date	Early (April)	Mid (May)	Late (June)
Kudzu Bug Total	10.1 (±1.5) C	17.3 (±1.8) B	25.9 (±2.0) A

Means followed by a common letter are not significantly different (Fisher's Protected LSD, α=0.05).

Table 3.4. Total redbanded stink bug populations (mean ± sem), in treated verses non-treated check across three planting dates in the 2025 season at an Alabama Agricultural Experiment Station in Prattville, AL.

Total RBSB Population	Non-treated Check	Threshold
Early (April)	4.3 (±0.6) b	1.7 (±0.7) c
Mid (May)	3.5 (±0.4) c	1.3 (±0.2) c
Late (June)	6.1 (±0.5) a	1.4 (±0.2) c

Means followed by a common letter are not significantly different (Fisher's Protected LSD, α=0.05).

Table 3.5. Insect populations present within a two year planting date study at the Prattville Agricultural Research Unit in Prattville, AL during the 2024 and 2025 growing season.

Insect populations present	
Bean leaf beetle	*Cerotoma trifurcate*
Corn earworm	*Helicoverpa zea*
Green clover worm	*Hypena scabra*
Soybean looper	*Chrysodeixis includens*
Velvetbean caterpillar	*Anticarsia gemmatalis*
Kudzu bug	*Megacopta cribraria*
Brown stink bug	*Euschistus servus*
Brown marmorated stink bug	*Halyomorpha halys*
Green stink bug	*Chinavia hilaris*
Southern green stink bug	*Nezara viridula*
Redbanded stink bug	*Piezodorus guildinii*
Pea leaf weevil	*Sitona lineatus*
Threecornered alfalfa hopper	*Spissistilus festinus*

Table 3.6. Return on investment on insect management calculated for three planting dates averaged across the 2024 and 2025 season at an Alabama Agricultural Experiment Station in Prattville, AL.

Planting Date	Return on Investment
Early (April)	-$18.75
Mid (May)	$80.03
Late (June)	$67.22

Return on investment of insecticide application by planting date calculated by cost of material plus $8.00 application cost, with a soybean price of $10/bushel.