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Impact of defoliation on yield of group IV soybeans in Mississippi

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ABSTRACT

Field experiments were conducted during 2009 and 2010 to evaluate the effects of defoliation on maturity group IV soybeans, *Glycine max* (L.) Merr., grown in Mississippi. During each year, two locations were planted with maturity group IV soybeans that were subjected to various levels of defoliation during R3, R5, and R6 growth stages. Soybeans were subjected to various levels of defoliation within the upper 50% of the plant canopy, lower 50% of the plant canopy, and whole-plant canopy. There was greater yield loss from defoliation occurring in the upper plant canopy compared with the lower plant canopy during R3 and R5 stages, but no difference between canopy regions during R6 stage. Yield loss from whole plant defoliation was greater than upper or lower canopy defoliation. Results confirmed that soybeans during R3 and R5 stages are more susceptible to yield loss than during R6. However, yield losses were not significantly different between R 3 and R5 until defoliation exceeded 63%. Dynamic economic injury levels were determined for each growth stage based on yield loss equations, value of the crop, and cost of control and can be used as a basis for developing action thresholds in high-yielding soybean production environments.

1. Introduction

Soybean, *Glycine max* (L.) Merr., production in Mississippi has increased from 640,000 ha in 2005 to 880,000 ha in 2009, generating an estimated 705 million U.S. dollars in revenue (NASS, 2010). This increase in soybean production has been primarily due to increased value of soybeans, along with increased insect control costs in other crops, particularly cotton, *Gossypium hirisutum* L. (Williams, 2005, 2011). An issue facing Mississippi soybean production is that increasing soybean production can lead to an increase in insect damage (Todd and Morgan, 1972).

Direct damage to soybeans from an insect pest occurs when the insect feeds on the seeds causing a reduction in yield. Examples of pests causing direct damage would be stink bug species (Pentatomidae) or corn earworm, *Helicoverpa zea* (Boddie). Indirect damage occurs when an insect feeds on other portions of the plant, such as stems, roots, or foliage. This feeding can also lead to reductions in yield by stressing the plant.

A very common type of soybean injury caused by insect pests is defoliation. Defoliation injury may reduce transpiration and photosynthesis in the plant. Furthermore, the capacity to compensate for nutrient deficiencies, water loss, and any other abiotic factor that could influence soybean yield is reduced. Fehr et al. (1985) reported that defoliation to soybean, especially when grown on calcareous soils, can reduce yield by reducing photosynthesis and increasing the potential for iron chlorosis (Froelich and Fehr, 1981; Fehr et al., 1983). Ostlie and Pedigo (1984) found that water loss of soybean increased as the amount of defoliation increased, which was in agreement with previous results found by Hammond and Pedigo (1981). Defoliation to soybeans is caused by a complex of insect species. Foliage feeders in this complex include the bean leaf beetle, *Ceratoma trifurcata* (Foster), green cloverworm, *Hypena scabra* (F.), velvetbean caterpillar, *Anticarsia gemmatalis* (Hübner), cabbage looper, *Trichoplusia ni* (Hübner), and soybean looper, *Chrysodeixis includens* (Walker). All of these species are commonly observed causing various levels of defoliation in soybean fields in Mississippi.

Most insect pest management thresholds are based on the number of insects sampled from a field or area within a field. However, when common damage can be caused by a number of insects, a threshold based on plant damage can be more useful. A

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defoliation threshold has been used in soybean for many years. In Mississippi and many other states, the threshold is based on research by Nettles et al. (1968), who suggested a threshold of 35% defoliation from emergence to flowering and 20% defoliation from flowering until maturity. Many researchers in the past (Dungun, 1939; Fuellman, 1944; Kalton et al., 1945; McAlister and Krober, 1958; Begum and Eden, 1965; Turnipseed, 1972) have reported that yield reductions from defoliation were more significant when pods are forming than from earlier (vegetative growth stages) or later (when beans have filled pods) growth stages. Researchers have also reported that the significance of defoliation on soybean yield after pod filling is not significant, even at very high levels (Kalton et al., 1945; Turnipseed, 1972). Therefore, soybean defoliation can have different impacts on yield depending upon when the foliage is removed. In addition to a reduction in yields, significant losses in soybean seed quality have been observed due to extreme levels of defoliation (Weber, 1955).

The problem with using these thresholds in Mississippi and other southern states is that most of the soybean production area is planted to indeterminate maturity group IV varieties, but current thresholds are based on research using determinate maturity group VI and VII varieties. Conventional soybean production systems in the southern U.S. frequently faced yield limiting conditions for determinate V, VI, and VII varieties due to drought and high temperatures during the reproductive stages of these late-maturing soybeans (Heatherly, 1999). To avoid this situation, early season soybean production systems have been adopted where indeterminate cultivars (MG III and IV) are planted earlier in the growing season so that critical periods of reproduction more frequently coincide with adequate rainfall and lower temperatures (Heatherly, 1999). Indeterminate cultivars generally begin flowering before maximum plant height is reached, whereas determinate cultivars are at full height before flowering is initiated (Pickle and Caviness, 1984). Previous research by Fehr et al. (1977) showed that indeterminate and determinate varieties responded differently to 100% defoliation with determinate varieties losing more yield than indeterminate varieties.

Because obtaining precise defoliation levels caused by insect pests in field tests is difficult, simulated insect defoliation levels have been used in previous studies to estimate yield effects on soybeans. Simulated insect defoliation methods provide a reliable and feasible technique for determining damage–loss relationships. With simulation, levels of damage, placement within a plant canopy, and distribution through time can be precisely measured (Ostlie and Pedigo, 1984). Begum and Eden (1965) conducted a simulated defoliation study to determine its influence on yield and seed quality using maturity group VI and VII varieties. They evaluated four levels of hand defoliation (0, 33, 67, and 100%) at three growth stages (at bloom, seeds half grown in pods, and when beans were fully grown in the pod).

Most of the work on which current thresholds in the mid-southern U.S. are based was conducted 20 or more years ago using determinate and later maturing varieties that likely did not possess the yield potential of current ones. Also, most of the research was conducted prior to the development of a system where growth stages of soybean were clearly defined (Hanway and Thompson, 1967). The description of soybean maturity in these studies are often vague and confusing, making it difficult to interpret the physiological growth stages (Dunphy et al., 1979).

Previous studies that have evaluated the impacts of defoliation on soybeans have only quantified yield loss based on a whole-plant basis. However, in practice, defoliation estimates are often determined by examining the upper portion of the soybean plants during full canopy. Defoliation within the bottom portion of the plants is often overlooked. Research is needed to compare levels of defoliation in different areas of the canopy.

The objective of this study was to evaluate the impacts of various levels of defoliation within different canopy regions during various reproductive growth stages on yields of indeterminate maturity group IV soybeans using simulated defoliation. Results from this research can be used to adjust thresholds where needed and to improve our understanding of the role of defoliation in determining soybean yield.

2. Materials and methods

2.1. Plot establishment

Experiments were conducted in 2009 and 2010 at the R.R. Foil Plant Research Center in Starkville, MS, and the Delta Research and Extension Center in Stoneville, MS. Asgrow® 4605 (Monsanto) soybeans were planted in 2009 on 28 April at Starkville and on 30 April at Stoneville into raised conventionally-tilled beds at a seeding rate of ~275,000 seeds per hectare with 97 cm row spacing. In each year and location, plots were furrow irrigated and managed for high yield potential, and irrigation timings varied by year and location. In 2010, soybeans were planted on 15 April at Starkville and on 1 May at Stoneville at the same rate and with the same agronomic practices as in 2009. Previous crop at each location was cotton in 2009 and soybean in 2010. Fertilizer regimens were determined by soil samples and followed Mississippi State recommendations. Prior to planting at all locations, seed was treated with thiamethoxam (Cruiser®, Syngenta Crop Protection, Greensboro, NC) at 35.49 ml/45.36 kg of seed and fludioxonil + mefenoxam (Apron Max®, Syngenta Crop Protection, Greensboro, NC) at 147.87 ml/45.36 kg of seed. Planting depth was set to 2.54 cm below the soil surface. The plot area was scouted and over-sprayed weekly to reduce the effects of any insect or disease. Applications of pyrethroid, carbamate, and neonicotinoid insecticides were applied weekly to target most insect species. Fungicide applications of azoxystrobin (Quadris®, Syngenta Crop Protection) at 444 ml/ha were made during the R3 and R5 growth stages for both years of the experiment. Treatments were planted in a randomized complete block (RCB) design with four replications at both locations during each year of the experiment. Plots were two rows wide and 3.05 m long.

2.2. Defoliation treatments

Treatments were evaluated as a 3 × 5 × 3 factorial with factors including soybean growth stage (R3, R5, and R6), defoliation levels (0, 17, 33, 67, and 100%), and portion of the soybean plant (upper canopy, lower canopy, and whole plant). To achieve simulated levels of defoliation, removing one leaflet from each trifoliate was equivalent to 33% defoliation. The 17% defoliation level was achieved by removing one leaflet from every other trifoliate on the plant. Plant canopies within the plot were divided by estimating the top 50% or the bottom 50% of the plant. Within top and bottom defoliated plots, the desired defoliation levels were removed from that plant portion only. Therefore, on a whole-plant basis, defoliation levels were approximately half of the stated defoliation level. Treatments were initiated when 75% of the plants within the plot area were at the desired growth stage. Defoliation was completed progressively to better simulate insect defoliation over time. On the first day of defoliation during 2009, all plots receiving defoliation during the R3 growth stage were defoliated to the 17% level. Two to three days later, the 33, 67 and 100% plots were defoliated to 33%. After an additional 2–3 days, the 67 and 100% plots were defoliated to the 67% level, and after another 2–3 days, the 100% defoliated plots were defoliated to 100%. The progression of defoliations was