Yield Response of Soybean to Partial and Total Defoliation during the Seed Filling Period

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ABSTRACT

Understanding how defoliation affects soybean [Glycine max, (L.) Merr.] yield during the seed filling period will aid in making management recommendations for control of stresses that reduce yield through defoliation and/or impaired photosynthetic activity of intact leaves (reduced effective leaf area index). Because previous research has studied defoliation effects at only a few specific stages of seed filling, our objective was to gain a greater understanding of the mechanisms for yield reduction with defoliation at various stages across the seed filling period. Defoliations were conducted from the bottom of the canopy up to mimic the progress of soybean rust. Two experiments, one in Kentucky (38º N Lat) and the other in Louisiana (30º N Lat), were conducted in randomized complete block designs in split-split plot arrangements with four replications. Main plots were two cultivars, split plots were defoliation timings at weekly intervals during seed filling, and split-split plots were defoliation levels of 0%, 33%, 66%, and 100% leaf removal. Data were obtained on yield and several growth dynamic and yield component factors. Defoliation-induced yield losses corresponded more closely with % light interception reductions that % leaf area reductions. During the R5-R6 period, defoliation had to be great enough to reduce light interception by 20% before significant yield loss occurred. Greater yield losses resulted as light interception was further depressed. At late seed filling (R6.7 or later), significant yield losses only occurred with total defoliation.

INTRODUCTION

Several biotic and abiotic stresses of soybean affect yield through defoliation occurring during the seed filling period. Examples are defoliating insects, soybean rust, and hail. Previous studies have focused on discrete stages of seed filling and have not provided a comprehensive picture of how partial and total defoliations affect yield throughout the entire period. Potential plant physiological responses to defoliation include effects on canopy photosynthesis, dry matter accumulation, altered partitioning of dry matter to plant parts, leaf abscission, delayed leaf senescence, delayed crop maturity, changes in leaf specific weight, and reduced nitrogen fixation, as well as several others (Welter, 1993). Among these factors, decreased canopy photosynthesis, caused by reduced light interception has been shown to be an important contributor to yield loss from defoliation injury (Browde et al., 1994; Hinson et al., 1978; Ingram et al., 1981; Higley, 1992). Previous studies showed that either leaf area index or light interception have potential use as criteria for significant yield loss at certain stages of seed filling (Board et al., 1997).

OBJECTIVE

The first objective of this study was to determine yield losses from defoliation during the seed filling period that simulated the defoliation pattern of soybean rust; that is, defoliation from the bottom of the canopy up. The research is warranted because no previous study has examined lower-canopy defoliation throughout the seed filling period. A second objective was to determine defoliation effects on seed number per area, seed size, total dry matter at R7, and harvest index. A third objective was to determine the relative accuracies of leaf area index and light interception as criteria for defoliation-induced yield loss.

RESULT AND DISCUSSION

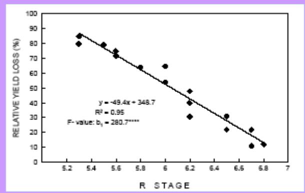

Fig. 1. Percentage yield loss by 100% defoliation during the seed filling period for soybean grown at Lexington, KY and Baton Rouge, LA, 2006-2007.
**** F-value is significant at the 0.0001 probability level.

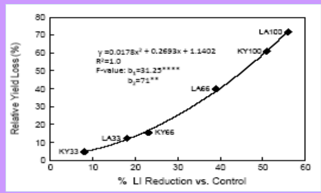

Fig. 2. Response of relative yield loss (% yield loss vs. control) to % light interception (LI) reduction vs. control for partial and total defoliation treatments conducted at Lexington, KY and Baton Rouge, LA, averaged over the R5-R6 period and across 2006 and 2007. Data points are designated by site (LA or KY) and % defoliation (33, 66, or 100%).
,** F-value is significant at the 0.01 and 0.0001 probability levels, respectively.

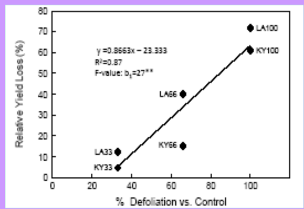

Fig. 3. Response of relative yield loss (% yield loss vs. control) to % defoliation vs. control for partial and total defoliation treatments conducted at Lexington, KY and Baton Rouge, LA, averaged over the R5-R6 period and across 2006 and 2007. Data points are designated by site (LA or KY) and % defoliation (33, 66, or 100%).
**F-value is significant at the 0.01 probability level.

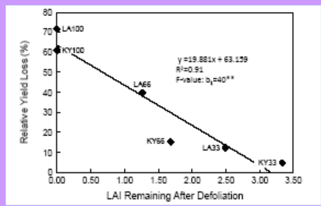

Fig. 4. Response of relative yield loss (% yield loss vs. control) to leaf area index (LAI) remaining after defoliation for partial and total defoliation treatments conducted at Lexington, KY and Baton Rouge, LA, averaged over the R5-R6 period and across 2006 and 2007. Data points are designated by site (LA or KY) and % defoliation (33, 66, or 100%).
** F-value is significant at the 0.01 probability level.

Total Defoliations

Relative yield loss for 100% defoliation vs. control was regressed against developmental stage within the Kentucky and Louisiana locations; resulting in highly correlated negative linear relationships (R^2=0.95-0.99). These regression relationships were homogenous across locations and therefore the data were pooled into a single negative linear relationship (Fig. 1). From early seed filling (R5.3, 85% yield loss) to late seed filling (R6.8, 10% yield loss), each 0.1 delay in developmental stage resulted in a 5% decline in yield loss.
These results provide general guidelines for management of defoliating pests at different stages of seed filling. Because pest agents potentially can eliminate leaf area index and/or effective leaf area index (leaf area index corrected for disease effect on photosynthetic rate, Jesus Junior et al., 2003) across a short time period (Baldwin et al., 1994; Dorrance et al., 2007), data in Fig. 1 identifies relative yield losses expected in worst-case scenarios. For example, a defoliating pest that entered a soybean field at R5.8 and completed total defoliation within a 1-wk period (to R6.2) would be expected to create a yield loss of approximately 60%. Determination of economic feasibility for insecticide application would be based on the farmer's potential yield, expected soybean price, and the cost of pesticide application.

Partial and Total Defoliations

Partial defoliations did not give consistent results across sites. Results were therefore analyzed through effects on light interception, leaf area reductions, and leaf area remaining after defoliation. Within each site, relative yield loss (% yield loss vs. control), relative light interception reduction, percent defoliation, and leaf area index remaining after defoliation were averaged across the R5-R6 period (the period during which most significant yield losses from partial defoliation occurred). Across sites, relative yield loss was very closely linked to relative light interception reduction (R^2=1.0) in a quadratic response (Fig. 2). Relative yield loss was also significantly related to percent defoliation (R^2=0.87) in a positive linear relationship (Fig. 3) and to leaf area index remaining after defoliation in a negative linear relationship (Fig. 4) (R^2=0.91). Comparison of these three quadratic relationships indicated that % light interception reduction is a better criterion of yield loss from defoliation than either % leaf area index reduction or leaf area index remaining after defoliation. Throughout early and mid seed filling (R5-R6.2), comparison of yield responses at both sites indicated that for significant yield loss to occur (14% yield loss), defoliation must be great enough to reduce light interception by about 20%.

MATERIAL AND METHODS

Field studies were conducted at Baton Rouge, Louisiana and Lexington, Kentucky in 2006 and 2007. Experimental designs at both locations were randomized complete blocks in split-split plot arrangements with four replications. Main plots were cultivars: DP4331 (MG IV) and P95M80 (MG V) for Louisiana and AG3906 (MG III) and DP4331 (MG IV) for Kentucky. Split plots were six weekly defoliation timings in Louisiana starting at 1 wk>R5 and five weekly defoliation timings in Kentucky starting at 2 wk>R5. Split-split plots were the following defoliation levels: 0% defoliation (control), 33% defoliation, 66% defoliation, and 100% defoliation. Throughout the seed filling periods, data were taken on leaf area index and light interception. At maturity, data were taken on yield, harvest index, dry matter, seed number per area, and seed size. Data were analyzed by SAS PROC MIXED with mean separation by SAS LSMEANS using Tukey's test. Regression analyses for determination of linear, quadratic, and cubic relationships were also analyzed with PROC MIXED.

CONCLUSIONS

Data from the current study provide the following guidelines for defoliation-induced yield loss during seed filling:

1. Defoliation-induced yield losses corresponded more closely with % light interception reductions vs. control than % leaf area index reductions vs. control.
2. Significant yield losses during the R5-R6 period occurred when defoliation was great enough to reduce light interception by 20%. Greater light interception reductions resulted in greater yield losses.
3. At late seed filling (R6.7 or later), significant yield losses only occur with total defoliation.
4. Defoliation during seed filling affects yield mainly through reduced seed size, although seed number per area is also affected if defoliation occurs prior to R6.
5. Narrow rows have greater tolerance to leaf defoliation due to greater light interception per unit leaf area.
6. Yield losses from total defoliation were greatest in early seed filling (78%) but gradually diminished as the period progressed.

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