THE IMPACT OF DEFOLIATION ON YIELD AND GROWTH IN RICE

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Abstract

Fall armyworm, *Spodoptera frugiperda* (J.E. Smith), (FAW) is becoming an increasingly frequent pest of rice grown in the Mid-Southern United States. The current action threshold for fall armyworm in Arkansas is based on the number of larvae per square foot, which is often difficult to determine in rice due to thick stands, large plants, and flooded conditions. A new action threshold based on level of defoliation would help growers and consultants with determining the amount of damage present in the field versus larval counts per square foot. The first objective of this study was to evaluate the impact of damage caused by the FAW at different growth stages of rice using both larval infestation studies and mechanical defoliation. The second objective was to determine if the FAW prefers feeding on the rice head over the foliage. In greenhouse studies, larvae were infested on rice plants grown in the greenhouse at the two-three leaf, second-third tiller, and heading growth stage. Greenhouse research also included rice that was mechanically defoliated to simulate feeding of FAW by defoliating 25, 50, and 100% at the same growth stages. Rice plants in field plots were mechanically defoliated at 0, 33, 66, and 100% with a weed eater at the two-three leaf, early tiller, late tiller, and panicle internode elongation (PIE) growth stages. To determine feeding preference, sleeve cages were infested with one FAW containing different plant parts to determine if the larvae preferred feeding on the head over the foliage. Yield was impacted at the two-three leaf growth stage at 100% defoliation in the larval infestations. When two-three leaf rice was defoliated mechanically at 100%, a yield reduction was observed compared to the untreated control. Yield loss was also observed from mechanical defoliation in the field trial at the late tiller growth stage when defoliation reached 66, and 100%, and again at the PIE stage when defoliation reached 33, 66, and 100% in the field. The preference test determined that the FAW will feed on the rice head and could cause a significant amount of blanked kernels associated with head feeding. These studies will be helpful in developing a defoliation threshold for fall armyworm in rice.

Introduction

Arkansas leads the U.S. in production of rice, a very important grain crop worldwide. In recent years the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (FAW), has become more prevalent in rice, and can be found at high densities throughout the entire growing season. Although much is known about FAW in other crops including corn, grain sorghum, and soybeans, little research has been done to determine the impact of defoliation from this pest in rice. Bowling (1978) observed reductions in rice yields when plants were defoliated at the seedling and tillering growth stages. In the seedling growth stage, a 3% yield loss was observed when defoliated mechanically at 25%, and 8% yield loss at 50% defoliation. In the tillering growth stage, a 5% yield loss was observed at 25% defoliation, and 12% at 50% defoliation. Rice plants recovered rapidly with defoliation at early vegetative growth stages (Bowling 1978). The current economic threshold for FAW in rice is six or more armyworms per square foot prior to heading, and after flag leaf emergence treat when fall armyworms are present and damaging the flag leaf (Lorenz et al., 2019); however, more information is needed to confirm or change this recommendation.

Materials and Methods

Greenhouse Studies

Defoliation studies were conducted using larval infestations and simulated FAW damage through mechanical defoliation. Fall armyworms were reared in the lab at the Lonoke Agriculture Research and Extension Center in Lonoke, Arkansas. A conventional rice cultivar, Diamond, was planted in 6 inch pots at 10 seeds per pot and thinned to 5 plants per pot after germination for greenhouse experiments. The two factors used in this study were percent defoliation and growth stage timing. Plants were defoliated 0, 25, 50, and 100%, at the two-three leaf, tiller, and heading growth stages. Neonates were placed on the rice plant at each timing for the larval infestations and terminated by manually removing the larvae once appropriate defoliation level was achieved. Mechanical defoliation was conducted using scissors to simulate defoliation at the appropriate defoliation level and timing. Defoliation percentage was based on a whole plant basis in the two-three leaf and tiller timings, whereas in the heading growth stage on the flag leaf was defoliated. Plots were defoliated based on a visual estimation of 25, 50, and 100% of the whole plant. To ensure consistency, one individual was responsible for defoliating an entire replication. Pots were maintained using recommended agronomic practices (Hardke, 2019). Once rice plants reached the tiller growth stage, the pots were placed in tubs and flooded, and remained flooded until harvest. Rice heads and all seed were then removed to determine yield. Four replications were completed for both the larval infestations and the mechanical defoliation using a full factorial randomized complete block design. Data was analyzed with an ANOVA using PROC GLIMMIX (SAS version 9.4) and LSD post hoc analysis with an alpha level of 0.05.

Mechanical Defoliation

Field plots were located at the University of Arkansas Pine Tree Research station in Colt, Arkansas and the RiceTec research station in Harrisburg, Arkansas. At the Colt location, rice was drill seeded with a conventional cultivar, Diamond, and a hybrid cultivar, RT 7311, in Harrisburg. The Harrisburg location was planted April 20th, 2018, and the Colt location was planted May 2nd, 2018. Plot sizes were 8 rows on 7.5 inch spacing by 15 foot long. After emergence, rice was removed for a final plot size of 5 foot by 10 foot in Harrisburg and 5 foot by 8 foot in Colt. The two factors that were used in this study were percent defoliation and defoliation timing. Defoliation levels were 0, 33, 66, and 100%, with the defoliation timings being two-three leaf, early tiller, late tiller, and panicle internode elongation. A randomized complete block design with a full factorial arrangement of treatments with eight replications were used at both locations. A battery powered weed eater was used to defoliate each plot at the appropriate defoliation level and timing. Plots were defoliated based on a visual estimation of 33, 66, and 100% of the whole plant. To ensure consistency, one individual was responsible for defoliating an entire replication. For 100% defoliation treatments rice was defoliated to the soil line preflood and defoliated to the water line post flood. Plots were maintained using recommended agronomic practices until harvest (Hardke, 2019). The entire plot was then harvested using a plot combine, and yield was calculated based on the weight and grain moisture for each plot. Data was analyzed with an ANOVA using PROC GLIMMIX (SAS version 9.4, Cary NC) and LSD post hoc analysis with an alpha level of 0.05.

Fall Armyworm Feeding Choice Assay

Sleeve cages were used to determine the ability of FAW to feed on and damage developing rice heads, and to determine if larvae have a preference for feeding on the rice head or flag leaf. Sleeve cages were infested with FAW at the Rice Research and Extension Center in Stuttgart, Arkansas in 2018. Sleeve cages were placed around the flag leaf alone, the head alone, and both the flag leaf and the head together. Cages were placed on plants just after the anthesis stage.

Sleeve cages were either infested with one FAW, or left uninfested as a control. Larvae were allowed to feed for 6 days with mortality checked every 24 hours. If a larvae were found dead or had escaped they were replaced. Infestations were terminated after 6 days. Ten replications were performed for infested cages and five replications for uninfested cages. To ensure sleeve cages remained closed after infestation, a zip tie was used to close both the top and bottom of the cage with a wooden dowel rod holding the plant in the upright position. Plots were maintained using recommended agronomic practices (Hardke, 2019). For cages that contained both a flag leaf and head, the location of the larva was recorded every 24 hours to determine where the larva was feeding. Cages were left on the plant until harvest. The seed head was then removed and kernels were counted. The number of unfilled seed (blanked kernels) from each head was then used as a metric to determine the level at which the larvae were able to successfully feed on and damage the rice head. Data was analyzed with an ANOVA using PROC GLIMMIX (JMP version 14.2.0) and LSD post hoc analysis with an alpha level of 0.05.

Results and Discussion

Greenhouse Studies

Larval Infestations

At 100% defoliation by FAW at the two-three leaf growth stage we observed a 40% yield loss compared to the untreated check. The highest level of defoliation by larvae in the tiller growth stage was 25% and no differences were observed. At the heading growth stage, only 3% defoliation was achieved because most larvae were found feeding on the rice head. Although blanked kernels were observed from feeding there was no yield reduction when compared to the untreated check (Table 1).

Mechanical Defoliation

A yield reduction of 46% was observed in plots with 100% defoliation at the two-three leaf growth stage. This yield reduction is 6% greater than the larval infestations at this timing. At the tiller growth stage we observed yield reductions of 26% at 50% defoliation, and 58% at 100% defoliation. The heading growth stage had no differences across all defoliation levels compared to the untreated check (Table 1).

Bowling (1978) observed a yield reduction for the seedling growth stage at 25 and 50% defoliation. We observed no differences in yield until 100% defoliation at the two-three leaf growth stage. He also concluded that when defoliation at the tiller growth stage reached 25% there was a reduction of 5%, and 12% at 50% defoliation. We observed no differences at 25% defoliation, but saw greater reductions in yield at 50% defoliation compared to Bowling's study.

Table 1. Comparison of yield in greenhouse studies with larval infestations of FAW and mechanical defoliation at three different growth stages of rice.

		Larval Infestations	Mechanical Defoliation
Growth Stage	**Defoliation Level**	**Grams (SEM*)**	**Grams (SEM*)**
2-3 Leaf	**0%**	**43 (1.37) a**	**41 (4.2) a**
	25%	**39 (2.1) a**	**38 (2.6) ab**
	50%	**42 (1.1) a**	**39 (7.2) ab**
	100%	**26 (3.6) b**	**22 (3.0) b**
Tiller	**0%**	**44 (3.2) a**	**38 (1.6) a**
	25%	**37 (1.8) a**	**36 (2.7) a**
	50%	**.**	**28 (2.4) b**
	100%	**.**	**16 (1.0) c**
Heading	**0%**	**40 (5.5) a**	**42 (2.5) a**
	25%	**36 (1.0) a**	**40 (2.0) a**
	50%	**36 (2.7) a**	**33 (1.8) a**
	100%	**36 (1.0) a**	**38 (3.1) a**

Yields followed by a different letter are significantly different according to Fisher's LSD post hoc analysis at $\alpha=0.05$.
*Standard error of the mean

Mechanical Defoliation

Harrisburg
No differences in yield were observed at the two-three leaf growth stage compared to the untreated check. At 100% defoliation a 13% yield reduction occurred at the early tiller growth stage and 22% reduction in the late tiller growth stage. We also observed a 14% yield reduction at 66% defoliation and a 37% reduction at 100% defoliation in the PIE growth stage when compared to the untreated check (Table 2).

Rice et al. (1982) concluded that there were differences in yield when comparing larval and mechanical defoliation methods at 3-4 weeks before heading, which is similar to the late tiller and PIE timings in our study. In that study no differences were found at 25% defoliation compared to the untreated check. A yield reduction of 44 and 65% was observed at 50 and 100% defoliation, respectively. Comparing this to the Harrisburg location, a 22% yield reduction at the late tiller growth stage was observed at 100% defoliation. A yield reduction of 14 and 37% was observed at the PIE growth stage at 66 and 100% defoliation, respectively. Lower yield reductions were observed compared to Rice et al. (1982).

Colt
No differences were observed between defoliation levels at the two-three leaf or the early tiller growth stages (Table 2). At the late tiller and PIE growth stages, all defoliation percentages decreased yield compared to the untreated control, with 100% defoliation yielding less than all other defoliation levels. At the late tiller growth stage a yield reduction of 16%, 20%, and 60% was observed at the 33%, 66%, and 100% defoliation levels, respectively. At the PIE growth stage, yield reductions of 22%, 28% and 69% were observed at the 33%, 66%, and 100% levels of defoliation, respectively (Table 2).

Yield reductions of 16-60% and 22-69% were observed in the late tiller and PIE growth stages, respectively. Rice et al. (1982) observed greater yield losses at 50% defoliation compared to 66% in our study looking at the late tiller and PIE growth stages. Greater yield losses were observed at the PIE growth stage defoliated 100% compared to Rice et al.'s study.

Table 2. Comparison of rice yields mechanically defoliated with a weed eater at multiple percentages and growth stages for two location in Arkansas.

		Location	
		Harrisburg	Colt
Growth Stage	Defoliation Level	Bushels/acre (SEM*)	Bushels/acre (SEM*)
2-3 Leaf	0%	197 (9.8) ab	149 (4.5) a
	33%	228 (6.0) a	146 (6.0) a
	66%	220 (3.4) ab	145 (5.6) a
	100%	197 (6.6) b	129 (12.8) a
Early Tiller	0%	225 (6.5) a	150 (5.9) a
	33%	224 (4.7) a	151 (9.4) a
	66%	222 (3.3) a	143 (3.3) a
	100%	196 (5.1) b	137 (5.0) a
Late Tiller	0%	221 (4.0) a	158 (4.0) a
	33%	220 (4.8) a	132 (6.5) b
	66%	221 (3.8) a	126 (4.5) b
	100%	172 (4.7) b	68 (4.0) c
Panicle Internode Elongation	0%	228 (5.6) a	148 (4.6) a
	33%	227 (4.2) a	115 (4.8) b
	66%	197 (6.9) b	106 (5.0) b
	100%	144 (3.3) c	46 (5.7) c

Yields followed by a different letter are significantly different according to Fisher's Protected LSD post hoc analysis at α=0.05.
*Standard error of the mean

Fall Armyworm Feeding Choice Assay

No differences were observed in the proportion of blanked seed when FAW only had the flag leaf to feed on. Differences were observed when the FAW fed on the head and the head+flag leaf (Table 3). There were no differences in yield when the FAW fed on the flag leaf and the head+flag leaf, but yield reductions were observed when the FAW only had the head to feed on (Table 4). In the sleeve cage when FAW had the option to feed on the flag leaf or head, the FAW was found to be feeding on the flag leaf 29% of the time and 33% on the rice head (Table 5).

Table 3. Comparisons of Proportion of Blanked Seed Associated with FAW Feeding on Rice Heads

Plant Part		Proportion of Blanks (SEM*)
Flag Leaf	Treated	16 (0.01) a
	Untreated	16 (0.02) a
Head	Treated	47 (0.06) b
	Untreated	19 (0.01) a
Head+Flag Leaf	Treated	25 (0.03) b
	Untreated	16 (0.01) a

* Yields followed by a different letter are significantly different according to Fisher's Protected LSD post hoc analysis at α=0.05.
* Standard error of the mean

Table 4. Comparisons of Yield Associated with FAW Feeding on Rice Heads

Plant Part		Grams (SEM*)
Flag Leaf	Treated	4.7 (0.2) a
	Untreated	4.9 (0.3) a
Head	Treated	3.2 (0.4) a
	Untreated	4.6 (0.5) b
Head+Flag Leaf	Treated	4.8 (0.3) a
	Untreated	5.1 (0.4) a

*Yields followed by a different letter are significantly different according to Fisher's Protected LSD post hoc analysis at α=0.05.
* Standard error of the mean

Table 5. Percent of time the FAW was found feeding on either the head or flag leaf in the sleeve cage with both plant parts.

Plant Part	Percent of Time
Head	33%
Flag Leaf	29%
Mesh Cage	38%

Summary

Fall armyworm has become more prevalent in Arkansas rice fields over the last few years and it is currently unclear when economic damage is occurring from defoliation. This study suggests defoliation from FAW has the potential to impact yield throughout multiple growth stages. More work needs to be conducted to determine if planting date or cultivar are a factor in the effect of defoliation in rice. Further studies will lead to a defoliation based threshold to determine when foliar applications are necessary to maintain yield potential for the rice growers of Arkansas.

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