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# Resistant Palmer Amaranth Seed Production and Retention in Kansas Soybean Production

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# Resistant Palmer Amaranth Seed Production and Retention in Kansas Soybean Production

*Taylor Lambert and K.B. Jeremie Kouame*

## Summary

The effective management of Palmer amaranth (*Amaranthus palmeri*) seedbanks is a critical challenge in Kansas soybean production. This study investigates Palmer amaranth seed production and retention at the time of soybean harvest, providing insights into the weed's seed production in Kansas soybean fields and the potential effectiveness of harvest weed seed control tactics for its control. Data were collected from 12 counties in Kansas, where female Palmer amaranth plants were collected and seed and debris of the plant, fallen on the ground, were vacuumed. Results showed that female Palmer amaranth plants with an aboveground biomass of 0.3 and 0.4 lb produced on average 58,100 and 84,900 seeds, respectively. Moreover, approximately 97% of the seeds remained on the plant at harvest, suggesting that a Harvest Weed Seed Destruction (HWSD) strategy could be highly effective in reducing the number of Palmer amaranth viable seeds that return to the soil seedbank.

## Introduction

Palmer amaranth is a highly invasive weed species that poses a significant threat to soybean production in Kansas. It has been reported to cause nearly 80% yield loss in Northeast Kansas (Bensch, et al., 2003). Also, Palmer amaranth in Kansas has developed resistance to WSSA Group 2 (chlorsulfuron, thifensulfuron, imazethapyr, and imazamox), Group 4 (2,4-D), Group 5 and 6 (atrazine and metribuzin), Group 9 (glyphosate), Group 14 (fomesafen and lactofen), and Group 27 (mesotrione and tembotrione) herbicides (Heap, 2024), leaving growers with very few postemergence options (Peterson and Jugulam, 2019). Its rapid growth and ability to produce large quantities of seed contribute to the development of persistent seedbanks, making it a challenge for farmers (Shaner and Beckie, 2014). In fact, a female Palmer amaranth plant can produce up to 600,000 seeds (Ward, 2013), with the majority of these seeds retained on the plant at the time of harvest and making seeds vulnerable to harvest weed seed control practices. Effective management strategies are necessary to control its spread and reduce its impact on crop yields. Harvest Weed Seed (HWSD) control is an emerging strategy that targets weed seeds during harvest, preventing them from entering the soil seedbank (Walsh and Powles, 2014). Various methods, such as mechanical harvest weed seed destructors, chaff lining, narrow windrow burning, and chaff carts have been explored and have shown promising results for long-term weed management (Schwartz-Lazaro et al., 2017; Walsh & Newman, 2007; Walsh et al., 2017; Walsh et al., 2017; Walsh et al., 2018; Walsh et al., 2018; Walsh et al., 2021). However, a critical step for their use is assessment of seed-retention of the most problematic weeds at crop maturity (Soni et al., 2020; Walsh et al., 2018; Walsh & Powles, 2014). This research aims to investigate the seed production and retention of Palmer amaranth at the time of soybean harvest, with the goal of evaluating the potential effectiveness of HWSD in Kansas soybean fields.

# Procedures

## *Study area*

Twelve thousand farmers plant soybeans on 4.5 million acres of Kansas production ground, averaging harvests of 40.5 bu/a. Some regions of Kansas are better suited for soybeans due to precipitation amounts in Kansas ranging from 6 to 38 inches a year. For the purposes of this study, 22 soybean fields were visited in 12 counties within one week of harvest (Figure 1).

## *Palmer amaranth biomass and seed collection processes*

Two approaches are generally referred to in the scientific literature as ways to assess weed-seed retention: field surveys and periodic monitoring (Walsh et al, 2018). Our study used the field survey approach that involves randomly visiting fields at crop maturity, as it allows an estimation of seed retention as it typically occurs in commercial production environments (Walsh et al., 2018). Palmer amaranth plants were collected from 12 counties in Kansas where herbicide-resistant populations had been previously reported. In each county, one or two soybean fields were selected within one week of harvest. Three mature female Palmer amaranth plants were harvested from each field and bagged separately. For each plant, the surrounding ground, extending 1 ft beyond the plant's diameter, was vacuumed to collect any seed and debris that had fallen from the plant. These materials were also bagged separately. The plants were weighed to determine their biomass, and the seed was manually removed, cleaned, and weighed to determine the total amount of seed retained on the plant. The vacuumed debris samples were sifted and cleaned to collect seeds that had shattered off the plant before harvest. The weight of the collected seeds from both the plant and the vacuumed debris was recorded. On average, 100-seed weights were recorded on 36 subsamples and used to estimate the total number of seeds in each case.

## *Data analysis*

The relationship between Palmer amaranth seed production and its aboveground biomass was evaluated by fitting the linear model to data across counties and fields with the lm function of the stats package in R software (v. 4.3.3; R Core Team 2024). A map of the visited fields and bar graphs of the percentage of Palmer amaranth seeds retained/shattered was also created using R software (v. 4.3.3; R Core Team 2024).

# Results and Discussions

## *Palmer amaranth biomass and seed production in Kansas*

Palmer amaranth seed production showed a strong relationship with the weed's aboveground biomass (Figure 2), with 78% of the variability in seed production explained by the linear regression ($R^2 = 0.78$). It could be predicted from the results that female Palmer amaranth plants with an aboveground biomass of 0.1, 0.2, 0.3, and 0.4 lb produced on average 4,600, 31,400, 58,100, and 84,900 seeds, respectively, in soybean fields in Kansas in 2023. Also, results revealed that we could expect an increase of 540 seeds for each increase in a female Palmer amaranth aboveground biomass (Figure 2).

Palmer amaranth's prolific seed production results in this study are consistent with previous research (Ward et al., 2013). Palmer amaranth plants that emerged between mid-June and late-July in 38-inch row-spacing soybean fields produced 19,618 seeds/sq. ft., while those in 7.5-inch row-spacing soybean fields produced 1,200.68 seeds/sq. ft. (Jha et al., 2008). The relationship between Palmer amaranth biomass and seed production is not surprising. Previous research documented a strong relationship between the total amount of organic matter produced through photosynthesis (gross primary production) and grain yield of plants, with a well-defined relationship between plant productivity and the photosynthetically active radiation absorbed by the green portion of the vegetation (Gitelson et al., 2015).

### *Palmer amaranth seed retention in Kansas*

Palmer amaranth seed retention varied between 90% and 100%, with an average of 97% of the seeds retained at harvest (Figure 3). The average number of seeds that remained on a single plant was 40,541 seeds, while 1471 seeds (3%) were lost to shattering. These findings suggest that Palmer amaranth seeds are largely retained on the plant and, if not effectively managed, are likely to enter the soybean combine, be mixed with the chaff and redistributed to the field with the potential of contributing to the increase of the soil seedbank.

### *Palmer amaranth biomass and seed production*

The findings from this study demonstrate that Palmer amaranth retains the vast majority of its seed on the plant at harvest. Results are comparable to other data around the US. Previous research reported 98% seed retention at soybean maturity and 95% seed retention one month after soybean maturity (Norsworthy et al., 2014). Also, seed retention of Palmer amaranth in soybean fields was reported to range from 85% to 95% (Schwartz-Lazaro et al., 2017).

The high retention rate observed in this study makes it compelling for Kansas soybean farmers to integrate HWSC technologies into their harvest practices. The use of equipment such as the Seed Destructor or chaff carts can destroy or collect weed seeds during harvest and prevent them from contributing to the weed seedbank. By targeting the 97% of seeds that remain on the plant, HWSD offers an efficient and practical solution for managing multiple herbicide-resistant Palmer amaranth populations. While this study provides valuable insights into seed production and retention, it is limited to fields in Kansas and may not fully represent variability across different regions. Different management practices (herbicide programs, cover crops, etc.) will affect seed production in different ways. Future studies should explore the long-term effects of integrating HWSD strategies on Palmer amaranth seedbank dynamics and soybean yield.

## Acknowledgments

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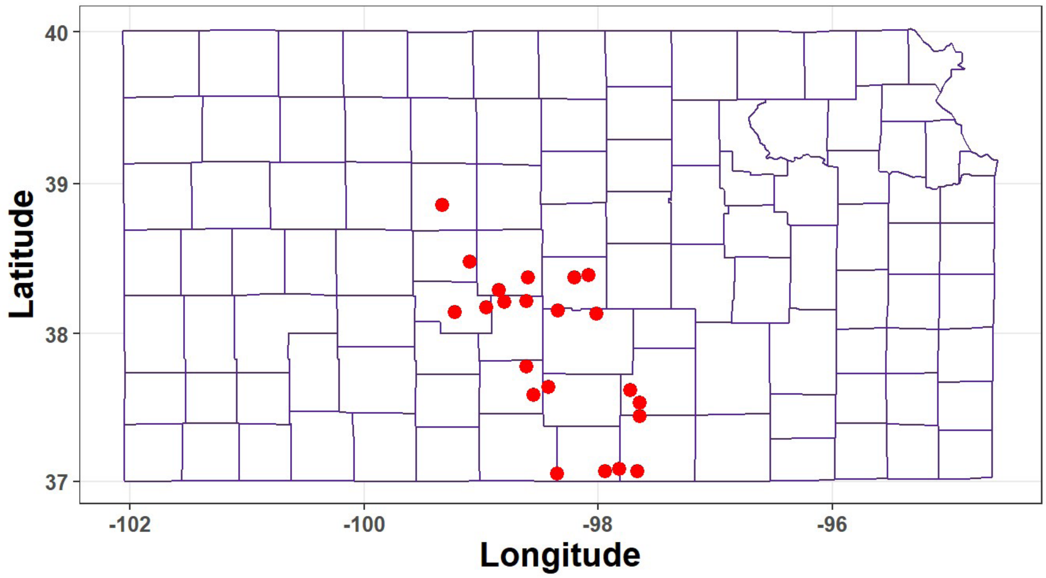


**Figure 1. Distribution of soybean fields visited in 2023 for evaluating Palmer amaranth seed production and retention at harvest.**

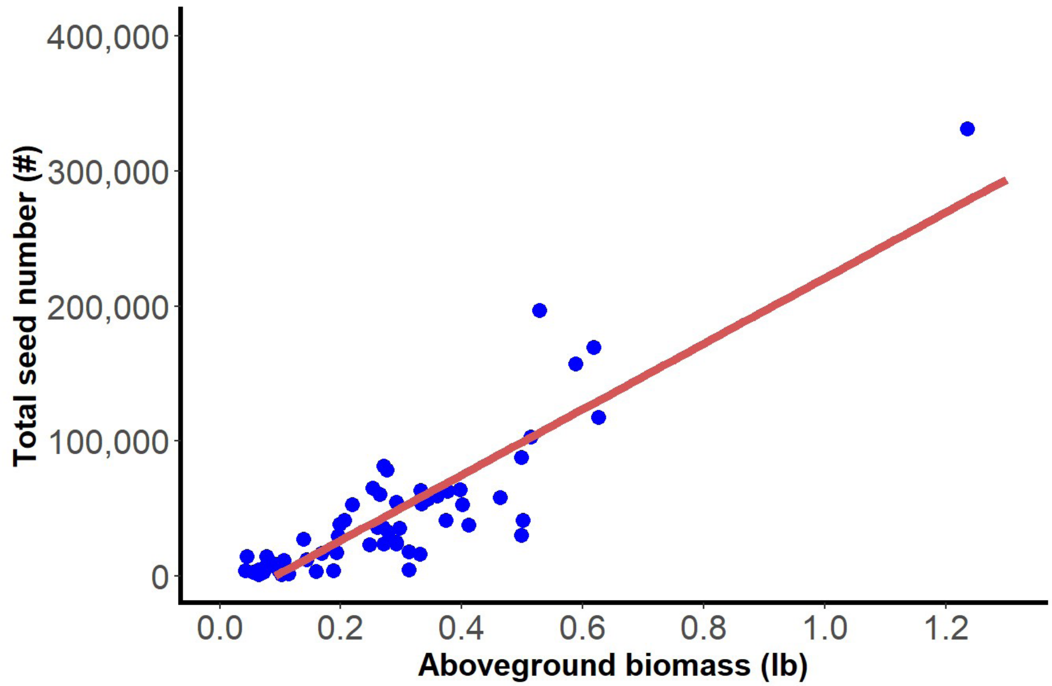


**Figure 2. Relationship between Palmer amaranth seed production and aboveground biomass in Kansas in 2023.**

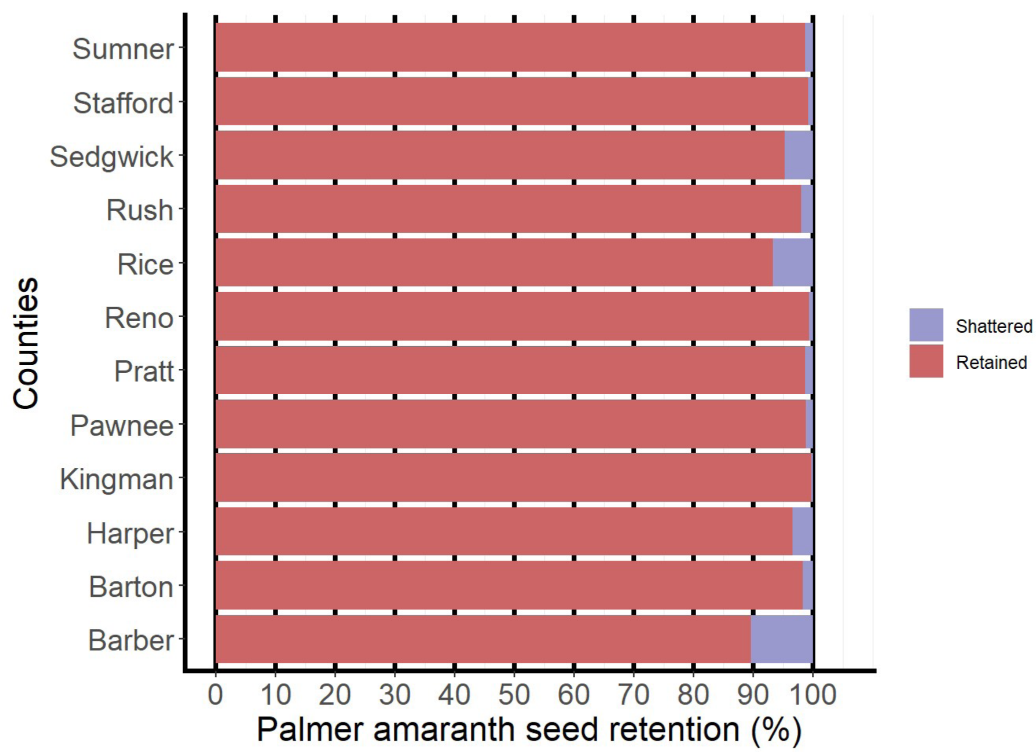


**Figure 3. Palmer amaranth seed retention at harvest in 12 Kansas counties in 2023.**