Adaptation of Palmer amaranth to cropping systems

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ABSTRACT

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INTRODUCTION

Palmer amaranth (*Amaranthus palmeri* S. Watson) is currently considered one of the most economically damaged weed species to cropping systems in the United States (Ward et al., 2013). The species has showed a remarkable capacity to evolve resistance to herbicides. Thus far, Palmer amaranth has evolved resistance to eight herbicide sites of action, increasing the weed management complexity (Lindsay et al., 2017). Uncontrolled Palmer amaranth in competition for water, light and nutrients can drastically reduce crop yields (Berger et al., 2015). Although currently considered a problematic weed, Palmer amaranth would emerged as a threat to sustainable agriculture only in the 1990s.

Palmer amaranth is a fast growing summer annual forb indigenous to northern Mexico and southern US (Sauer, 1957), Palmer amaranth weediness is likely a result of human intervention in combination with species biology. Use and movement of farm equipment across locations, conservation agriculture, and reliance on herbicides for weed management are the main human driver selection of Palmer amaranth to cropping systems. On the other hand, Palmer amaranth is a prolific seed producer with a C4 photosynthetic apparatus. With a dioecy nature, Palmer amaranth male and female plants are obligate outcrosser species, increasing the chances of exchanging herbicide resistant alleles among plants. Also, Palmer amaranth small seed size tend to thrive in no-tillage systems (Price et al., 2011), and spread across locations through farm equipment (Sauer, 1972), manure(Yu et al., undefined/ed), and animals (Farmer et al., 2017). These combinations make Palmer amaranth one of the most successful cases of weed adaption to cropping systems.

Palmer amaranth is commonly found at crop (Garetson et al., 2019) and non-crop land (Bagavathiannan and Norsworthy, 2016) in the southern United States, and its range is expanding northward. For example, herbicide resistant Palmer amaranth is widespread in Nebraska (Oliveira et al., 2021) and Michigan (Kohrt et al., 2017). Successful cases of Palmer eradication is documented in Minnesota (Yu et al., undefined/ed) and Iowa. Palmer amaranth was also found in Argentina (Larran et al., 2017), Brazil (Küpper et al., 2017), and Italy (Milani et al., 2021). Climate change can increase Palmer amaranth invasion to Australia and Sub-Sahara Africa (Kistner and Hatfield, 2018). Palmer amaranth can survive under continuous water stress and produce a significant amount of seeds Chahal et al. (2018)]. Produced seeds from Palmer amaranth growing under drier conditions are less dormant and prompt for germination (Matzrafi et al., 2021). Therefore, Palmer amaranth has showed a plasticity to adapt and potential to invade new environment.

The increase movement of Palmer amaranth to US Midwest warrants investigation on species adaptation to that environment. Most studies are based on reactive but not in the proactive management.

Understanding Palmer amaranth biology can enhance our knowledge on species adaptation to new environments and aid on design proactive and ecological weed management strategies. Therefore, the objective of this study was to investigate the flowering pattern, biomass, and height of Palmer amaranth growing under different environments and timings across five locations.

MATERIAL AND METHODS

Plant material and growing conditions

The study was performed with a *A. palmeri* accession (Per1) from Perkins County, Nebraska. Per1 accession collection is documented in (Oliveira et al., 2021), with no reported herbicide resistance. Three weeks prior to the field experiment, seeds were planted in plastic trays containing potting-mix. Emerged seedlings (1 cm) were transplanted into 200 cm-3 plastic pots (a plant pot-1). Palmer amaranth seedlings were supplied with adequate water and kept under greenhouse conditions at Arlington, Clay Center, Lincoln, and Macomb; and kept outdoors in Grant. Palmer amaranth seedlings were kept under greenhouse/outdoors until the onset of the experiment (7 to 10 cm height).

Field study

The experiment was conducted in 2018 and 2019 under field conditions at five locations: Arlington (Washington County, Wisconsin), Clay Center (Clay County, Nebraska), Grant (Perkins County, Nebraska), Lincoln (Lancaster County, Nebraska), and Macomb (McDonough County, Illinois).

The experimental unit were adjacent 9.1 m wide (12 rows at 72.2 cm row spacing) by 10.7 m long. Each experimental unit was planted with corn or soybean, or left fallow. Palmer amaranth seedlings were transplanted to the field experiment by making a whole in the soil (6 cm deep and 8 cm wide); and gently transferring in the ground (potting mix + two seedlings). After a week, if both plants were alive, one was eliminated. There were two transplant timing: early (June 1^{st}) and late (July 1^{st}). There were 24 Palmer amaranth plants in each crop/fallow and timing, with a total of 144 plants. The study was repeated twice.

After transplanting, Palmer amaranth flowering was monitored until the end of the study. When a plant started flowering, the day was recorded, plant sex was identified as male or female, and plant height was measured from soil surface to the plant top. Then, aboveground plant biomass was harvest near soil surface and oven dried at 65 C until reaching constant weight before the weight of biomass (g $plant^{-1}$) was recorded.

Statistical analyses

The statistical analyses were performed using R statistical software version 4.0.1.

The cumulative Palmer amaranth flowering estimation was determined using a asymmetrical three parameter log logistic Weibull model of the drc package (Ritz et al., 2015).

$$Y(x) = 0 + (d - 0)exp(-exp(b(log(x) - e)))$$

In this model, *Y* is the Palmer amaranth cumulative flowering, *d* is the upper limit (set to 100), and *e* is the XXX, and *x* day of year (doy).

The doy for 10, 50, and 90% Palmer amaranth cumulative flowering were determined using the *ED* function of drc package. Also, the 10, 50, and 90% Palmer amaranth cumulative flowering were compared among crop/fallow and timings using the *EDcomp* function of drc package. The EDcomp function compares the ratio of cumulative flowering using t-statistics, where P-value < 0.05 indicates that we fail to reject the null hypothesis.

RESULTS

Subsection 1

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Subsection 2

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1 DISCUSSION

DISCLOSURE/CONFLICT-OF-INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

MCO design, wrote,

The statement about the authors and contributors can be up to several sentences long, describing the tasks of individual authors referred to by their initials and should be included at the end of the manuscript before the References section.

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2 SUPPLEMENTAL DATA

Supplementary Material should be uploaded separately on submission, if there are Supplementary Figures, please include the caption in the same file as the figure. LaTeX Supplementary Material templates can be found in the Frontiers LaTeX folder

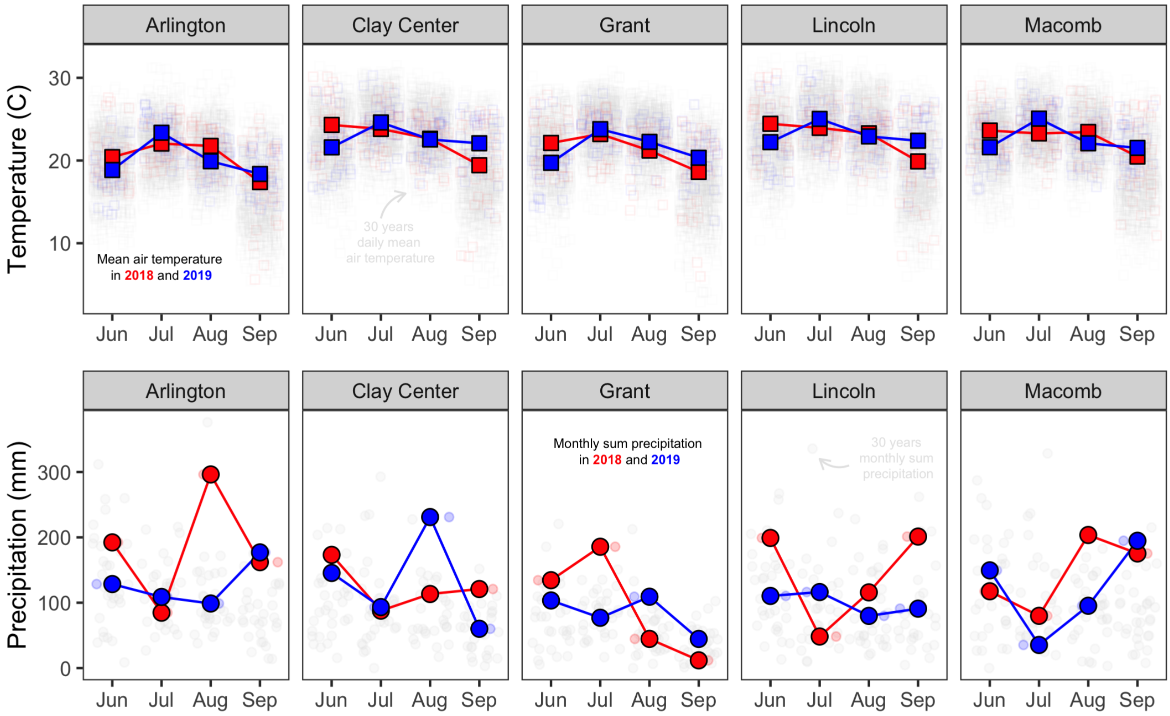

Figure 1. Mean average temperature (C) and montly sum precipitation (mm) at Arlington, WI, Clay Center, NE, Grant, NE, Lincoln, NE and Macomb, IL

3 REFERENCES

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FIGURES

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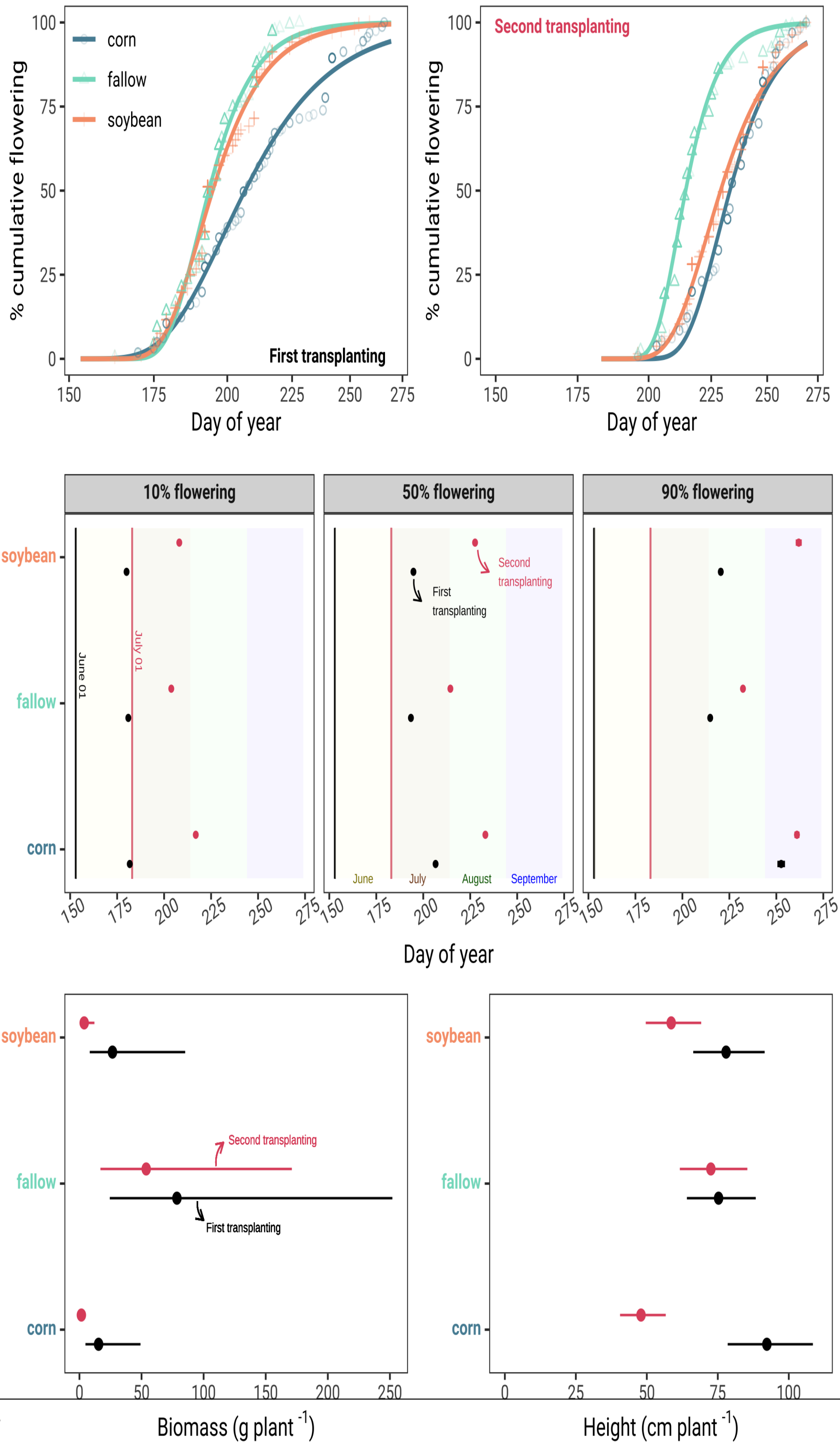

Figure 2. Figure caption

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