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Adaptation of Palmer amaranth to cropping systems

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ABSTRACT

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Keywords: Text Text Text Text Text Text Evolution Weed

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. 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). Palmer amaranth is documented with potential to reduce 91%, 68%, and X% of corn (Massinga et al., 2001), soybean (Klingaman and Oliver, 1994), and cotton yields.

Palmer amaranth is a fast growing summer annual forb indigenous to Sonoran Desert (Sauer, 1957). The species would eventually emerge as a threat to US agriculture in the 1990s. Palmer amaranth weediness is likely a result of human-assisted selection in combination with species biology. The increased use and movement of farm equipment across locations, conservation agriculture (e.g., no-till), and reliance on herbicides for weed management are the main human mediated selection of Palmer amaranth to cropping systems. On the other hand, Palmer amaranth is a prolific seed producer with a C4 photosynthetic apparatus (Ward et al., 2013). With a dioecy nature, Palmer amaranth male and female plants are obligate outcrosser species, increasing the chances of exchanging herbicide resistant alleles among plants (Oliveira et al., 2018). Also, Palmer amaranth small seed size (1 mm) tend to thrive in no-tillage systems (Price et al., 2011), and spread across locations through farm equipment (Sauer, 1972), manure (Yu et al., 2021), animals (Farmer et al., 2017), and plant propagules (Hartzler and Anderson, 2016). Therefore, Palmer amaranth dispersal capacity make the species one of the most successful cases of weed adaption to cropping systems.

Light and temperature are likely the main environment requirements for Palmer amaranth successful adaptation. Palmer amaranth is reported with an extended germination period (Jha et al., 2010). Germination of Palmer amaranth is triggered by 18 C soil temperature (Keeley et al., 1987), and optimal germination and biomass production were at 35/30 C day and night temperatures (Guo and Al-Khatib, 2003). Water has not shown to limit Palmer amaranth fitness. Under continuous water stress, Palmer amaranth survived and produced at least 14000 seeds plant-1 (Chahal et al., 2018). Also, seeds from Palmer amaranth growing under water stress conditions were heavier, less dormant, and prompt for germination (Matzrafi et al., 2021). The continuous global temperature warming can impact agriculture and promote niches for Palmer amaranth invasion/adaptation into new environments. Currently, the greatest climatic risk of Palmer amaranth establishment is agronomic crops in Australia and Sub-Sahara Africa (Kistner and Hatfield, 2018). Temperature is a key factor limiting Palmer amaranth northward range expansion (Briscoe Runquist et al., 2019); however, under future climate change Palmer amaranth is likely to expand northward into Canada and Northern Europe (Kistner and Hatfield, 2018).

Palmer amaranth is already found in agronomic crops of South America (Larran et al., 2017; Küpper et al., 2017) and Southern Europe (Milani et al., 2021). In the US, Palmer amaranth is commonly found at crop (Garetson et al., 2019) and non-crop land (Bagavathiannan and Norsworthy, 2016) in the warm southern United States but its range is expanding to cool temperatures northward. For example, herbicide resistant Palmer amaranth is widespread in Nebraska (Oliveira et al., 2021), Michigan (Kohrt et al., 2017), and Connecticut (Aulakh et al., 2021). Successful cases of Palmer amaranth invasion and near to eradication is well documented in Minnesota (Yu et al., 2021) and Iowa. No Palmer amaranth actively growing was found in Canada; however, Palmer amaranth seeds was detected in sweet potato slips (Page et al., 2021). Nonetheless, it seems fated to manage Palmer amaranth in agronomic crops throughout multiple environments in the near future. Therefore, strategies on Palmer amaranth management should encompass the agroecosystem level but not attempts to eradicate the weed. The continuous Palmer amaranth dispersal and potential establishment into northern US/Canada warrant investigation on species growing morphology in such environments.

Most Palmer amaranth studies are based on reactive (e,g, herbicide and tillage) rather than proactive management. Understanding Palmer amaranth biology and growing strategies under different environments can enhance our knowledge on species adaptation. Also, it can aid on designing proactive and ecological tactics to limit Palmer amaranth range expansion and reduce its negative impact while conserving diversity. Therefore, the objective of this study was to investigate the flowering pattern, biomass production, 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

You can use `R` chunks directly to plot graphs.

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.

ACKNOWLEDGMENTS

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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

3 REFERENCES

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FIGURES

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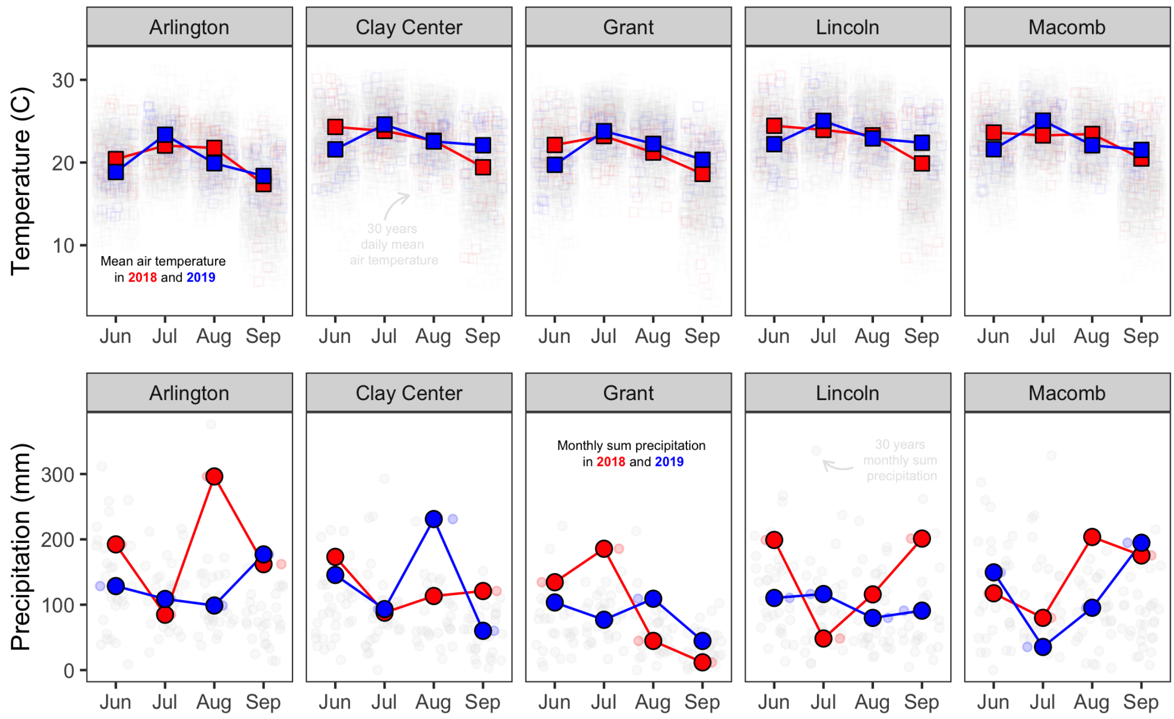

Figure 1. Mean average temperature (C) and montly sum precipitation (mm) at Arlington, WI, Clay Center, NE, Grant, NE, Lincoln, NE and Macomb, IL

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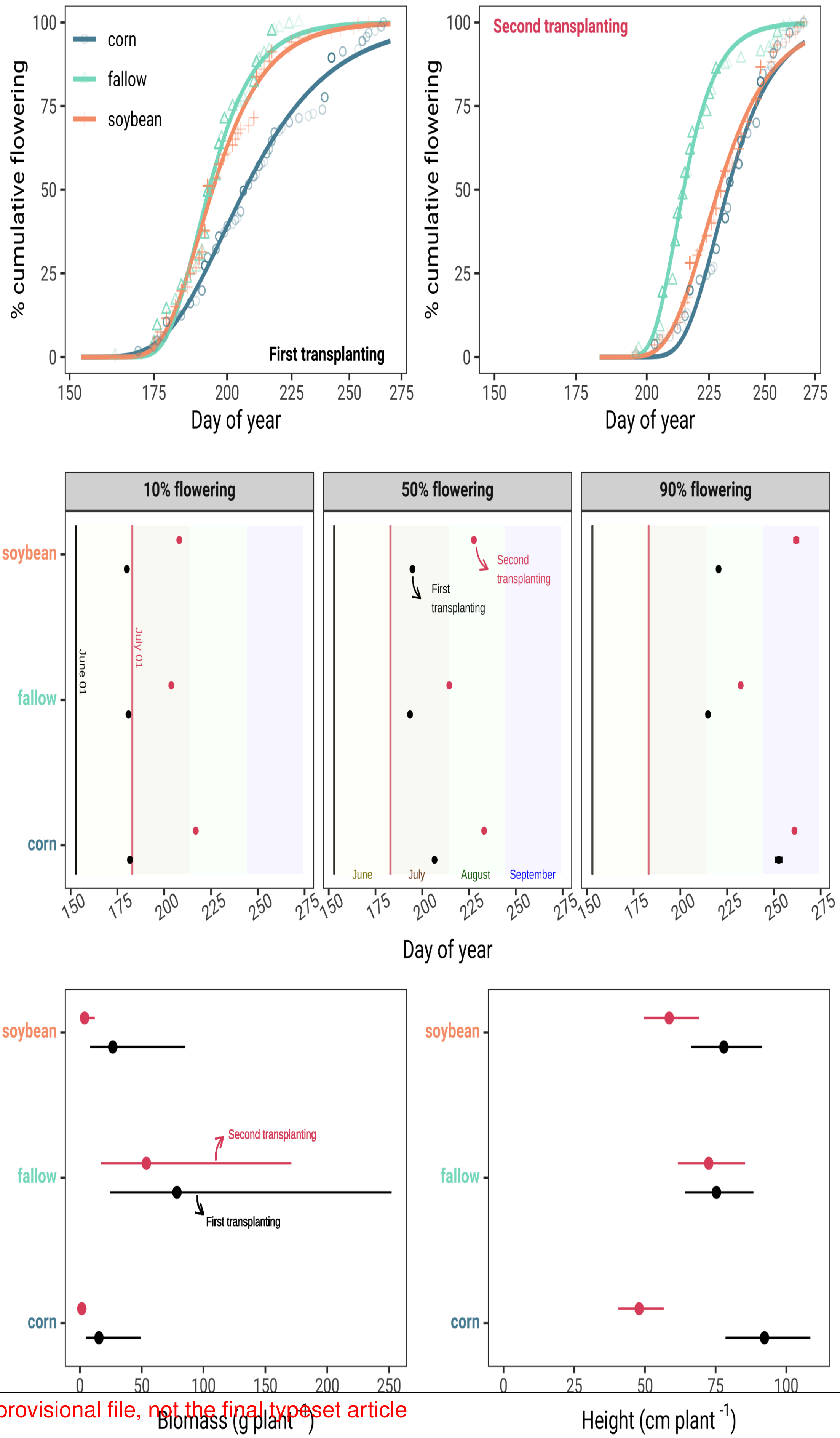

Figure 2. Figure caption

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