Influence of crop rotation on weed seedbank dynamics in Central NSW

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Abstract

Incorporation of effective crop rotations for supplemental weed control has been shown to reduce the growth and establishment of annual weeds and deplete the weed seed bank in broadacre cropping systems. Long term rotational trials were established in 2014-2018 to quantify the impact of strategic management practices upon weed infestations, with a focus on key winter annual and summer fallow weeds, in the moderate rainfall zones of the Riverina in NSW. Trials were designed with grain, dual-purpose and pasture crops to determine if weed management is facilitated through successful manipulation of crop rotational and cultural practices by evaluating weed seedbank dynamics over five growing seasons. Weed seedbank dynamics were assessed by sampling the soil seedbank, and recording weed emergence in a glasshouse over an 18 month period following collection. Weed suppressive rotations included a series of cereal and break-crops, while the weediest rotation contained dual purpose and pulse crops.

Keywords

Weed seedbank, crop rotation

Introduction

Continuous cropping poses detrimental effects on subsequent crop growth, and is generally associated with the accumulation of plant pests in susceptible hosts (Peters et al., 2003), reduced nutrient use in the root zones (Ghosh et al., 2007), reduced soil microbial diversity (Dias et al., 2015) or increased selection pressure for specific weeds (Skinulienė et al., 2020). In Australia, typical cereal crop rotations incorporate wheat, barley and oats and a high-value broadleaf species, such as canola or lupins (Rathke et al., 2005). More recently, pulses have been recommended to enhance crop diversity and increase soil nitrogen through atmospheric nitrogen fixation (Williams et al., 2014). The strategic use of competitive crops and pasture species can reduce subsequent weed establishment through competition for resources, including photosynthetically active solar radiation, water and nutrients (Bhagirath et al., 2012). In addition, chemical interference mediated by the production and release of phytotoxic secondary plant metabolites in decomposing plant residues or root exudation into the soil rhizosphere can limit weed establishment (Bertin et al., 2003).

The southern cropping zone of Australia often utilises mixed farming practices to support livestock in parallel to cereal crops, with rotational crops providing diverse sources of forage over winter and occasionally summer growing seasons (Robertson et al., 2016; Seymour et al., 2012). Furthermore, annual pasture legumes, more specifically, *Trifolium* spp. such as subterranean, arrowleaf and gland clover have been shown to effectively suppress the emergence and establishment of annual weeds, with recent findings suggesting that competition for resources and release of allelochemicals are involved in weed interference (Gurusinghe et al. 2018; Latif et al., 2019). Thus, incorporating an annual pasture phase in the rotational sequence may effectively reduce the emergence and establishment of common annual weeds in southern Australia.

Long term crop rotations with diverse crop species have been shown to reduce the weed seedbank significantly (Barberi and Lo Cascio, 2001; Butkevičienė et al., 2021). However, the impact of successive crop rotations on other weed species of significance, such as *Conyza bonariensis* (flaxleaf fleabane), *Sonchus oleraceus* (common sowthistle), and *Panicum spp* have not been investigated across southern Australia, under varying climatic conditions, including drought. Therefore, a series of field and accompanying greenhouse studies were conducted to assess the ability of various long term crop rotational strategies to reduce weed seedbank infestations in the southern mixed farming region.

Site characteristics and establishment of field trials

Field experiments were conducted from 2014 to 2018 at Charles Sturt University (CSU) Graham field research site in Wagga Wagga (35°02'00.5"s 147°21'40.6"e), New South Wales, which typically receives on average 570 mm of annual rainfall. Experiments were sown from April 25 to May 20 in 2014-2018. Rotational treatments consisted of cereal crops including grain and dual-purpose wheat, barley andoats, both seed and dual-purpose canola (oilseed rape), field pea, a subterranean clover/phalaris pasture mix and a perennial lucerne pasture, which served as a control to assess weed infestation and subsequent weed seedbank impact in the absence of annual crop management practices (Table 1). With the exception of the perennial lucerne treatment and the annual pasture mixture, all other treatments containing annual species were rotated each year over the trial period and all treatments were seeded at recommended sowing rates. Standard cultural practices were applied in all years, including use of knock-down and pre-emergent herbicide, application of fertilisers, insect-pest management and simulated grazing. Plots (12.6 m long, 1.6 m wide) were established as a randomised complete block design with 4 replications. Standard pasture management practices were followed with simulated grazing on the dual purpose cereal cultivars prior to GS31, prior to bud set on the grazing canola, at 10% flowering stage for lucerne and at 20 cm height for the phalaris/subclover mix. Cereal crops were harvested in late November with the stubble left undisturbed until planting in the subsequent growing season.

Table 1. Cereal, dual purpose and pasture crop species assessed in the study

Crop/ pasture	Description	Identification key	Sowing rate (kg/ha)	Crop/pasture	Description	Identification key	Sowing rate (kg/ha)
Wheat	Grain	W	186	Canola	Seed	C	8
	Dual-purpose	GW	166		Dual- purpose	GC	10
Barley	Grain	B	205	Lucerne	Grazing	L	2
	Dual-purpose	GB	185	Field pea	Seed	P	100
Oats	Dual-purpose	GO	189	Faba bean	Seed	F	175
Triticale	Dual-purpose	GT	210	Phalaris+ Sub. clover	Grazing	PM	11 +11

Soil collection and weed seedbank assessment

Shallow soil cores (5.5 cm in diameter, 5 cm depth, 10 from each plot) were taken along diagonal transects within each plot immediately before planting and after harvest in each growing season. All soil samples were spread evenly over the top of a commercial potting mix in shallow seedling trays (300 × 350 × 60 mm) for optimal weed seed germination and covered to a depth of 1-2 cm, as previously described (Kleemann et al., 2016). The trays were placed in a glasshouse and watered daily between autumn and early summer, with the emergence of various weed seedlings noted at bi-monthly intervals for ~18 months. To stimulate germination at each census, the soil was lightly disturbed. Identification and eventual removal of weed seedlings were continued until no further emergence was recorded for three consecutive measurements. Weed seedlings in each tray were counted and converted to the number of seedlings per unit volume and presented as the number of viable weed seeds/m^3.

Statistical analysis

Prior to performing analysis of variance, all data were tested for normality or homogeneity of error (Bartlett's test). To maintain normality, weed seedling density data required square root-transformation. Treatment means were compared using a protected LSD test at $P < 0.05$.

Results and discussion

Climatic conditions

In Wagga Wagga, the rainfall received from March to November in the years 2017 and 2018 was significantly less than the long term average growing season rainfall of 442 mm during winter crop growth (312 and 278 mm, respectively). However, precipitation in 2015 and 2016 growing seasons exceeded the long term average, with 503 and 651 mm received respectively during the growing season.

Impact of crop rotational sequence on the weed seed density

The density of weed propagules in soil samples collected at sowing from each rotational treatment did not differ in 2014, the first year of establishment experiencing average growing season rainfall (389 mm), suggesting that the weed seedbank was uniform at experimental initiation (Figure 1). In the subsequent growing seasons, the choice of crop rotation impacted weed seedling density at the time of sowing in 2015 ($P<0.01$), 2016 ($P<0.05$) and 2017 ($P<0.01$), but not in 2018. Lack of response in 2018 was associated with the severe drought conditions experienced in 2017, resulting in poor crop stands in 2017 and a spike in weed numbers in 2017-2018 after rains resumed.

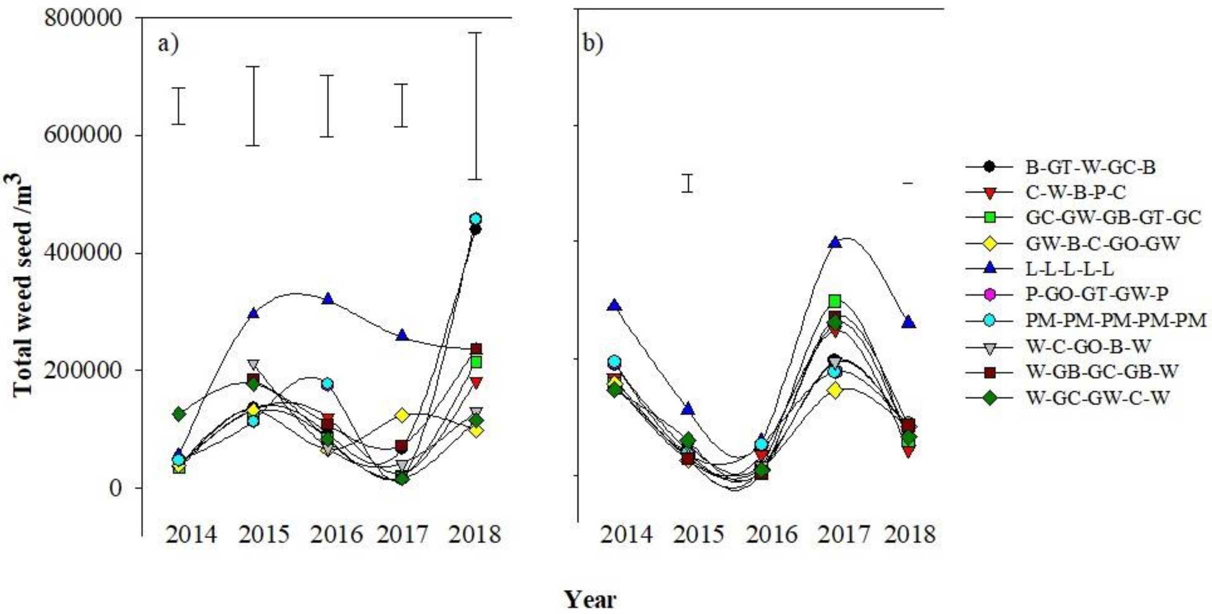

Figure 1. Density of total weed seedlings emerging from collected soil in each crop rotation sequence at sowing (a) and at harvest (b) in Wagga Wagga. See Table 1 for the key used in this figure. Error bars represent $LSD_{0.05}$.

The weed seedbank at the time of sowing gradually depleted in three of the ten rotational treatments following three years of crop rotation. Weed seed depleting rotational sequences included a canola-wheat-barley (cereal varieties), canola-wheat-barley (dual-purpose cultivars), and a dual-purpose wheat-barley-canola rotation, with reductions of 34, 41 and 68%, respectively when compared to the seedling numbers at the initiation of the crop rotation sequence. In the drought-impacted years of 2017 and 2018, the weed suppressive potential of all annual crop rotations reduced significantly ($P<0.05$), with exponential increase in the accumulation of weed seeds. The results suggest that the inclusion of high biomass accumulating cereal or dual-purpose crops competitive against annual weeds may reduce the weed burden under optimal growing conditions, as reported previously (Butkevičienė et al. 2021). The inclusion of diverse broadleaf species including legumes in the crop rotation can add valuable contributions of nitrogen to the system but also reduce the impact of annual weeds such as ryegrass, barley grass, sowthistle and *Panicum spp* (Weston et al., 2014; Haque et al., 2016). The results demonstrated that cereal crop rotations that included a single pulse species or canola in the rotational sequence performed similarly to rotations containing only graminaceous species. The annual pasture mixture suppressed weed seedbank numbers at time of sowing, similarly to other cereal rotational crops. Fewer weed seeds observed at the time of sowing may be influenced by several factors, including closed-canopies, and competition for nutrients and soil moisture associated with competitive crops established during the previous growing season, and the weed suppression provided by crop residues post-harvest (Mwendwa et al., 2018).

Over the five year assessment period, all rotational crops reduced the weed seedbank ($P<0.05$) in soils collected at harvest time when compared to the lucerne monoculture. The weed seed propagules from harvest time over 2014-2016 followed a similar trend to that of the sowing time collection, with dramatic reductions in weed seeds in several of the rotations. The selection of covers with closed-canopy structures was associated with a reduction in weed seedbank numbers at the time of harvest. In contrast to previous years, soils collected at harvest in the drought-affected year of 2017 showed a marked increase in weed seed propagules, likely due to the reduced competitive ability of the rotational crops and lack of activity of pre-emergence herbicide products.

Conclusion

In conclusion, the choice of crop rotational sequence frequently impacted the viable weed seedbank, particularly under non-moisture limiting conditions. Rotations that contained a diverse sequence of cereals followed by pulse crops were generally more successful in reducing weed seedbank numbers than the lucerne monoculture or pasture rotation. Rotations containing dual-purpose and cereal crops along with pulses successfully reduced the weed seedbank in those regimes experiencing average to above-average soil moisture and were superior to a perennial lucerne or mixed pasture rotation. Depletion of the weed seedbank was previously facilitated by the selection of more competitive wheat, oat, barley and canola cultivars (Mwendwa et al., 2018). The use of multiple tools for IWM, including competitive cereal crops, when considering long-term rotations is suggested.

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