# Emergence, survival and seed production of curly windmill grass in wheat or pasture systems

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**Summary** *Enteropogon ramosus* is a summer-active ($C_4$) native grass species found throughout Australia. It is a useful pasture species in some regions, but may adversely impact winter annual crop yield. Research was conducted into the emergence, survival and seed production of this species over 2 years, in a pasture-pasture or pasture-wheat rotation, in the Western Australian wheatbelt. Within the continuous pasture system, *Enteropogon ramosus* grew and set seed throughout the year. Minimum tillage cropping did not prevent growth or seed production of this weed, and wheat yield was reduced (21%; from 1.31 to 1.04 t $ha^{-1}$) through weed competition. However, a single cultivation event at the beginning of the 2 year research programme was sufficient to reduce emergence and prevent seed production by *E. ramosus* in both the pasture and wheat crop phase. *Enteropogon ramosus* is clearly a weed favoured by the minimum tillage system, and so in the absence of disturbance, herbicide options are required to control this species in wheat.

**Keywords** *Enteropogon ramosus*, curly windmill grass, cultivation, minimum tillage.

## INTRODUCTION

*Enteropogon ramosus* B.K.Simon (curly windmill grass) is a tufted, native, perennial species found throughout Australia (note: the name *E. acicularis* (Lindl.) Lazarides has been misapplied to this species, Australia's Virtual Herbarium 2009). *Enteropogon ramosus* has previously been identified as a beneficial native pasture species, particularly in areas subject to salinity, low fertility or drought (Rogers *et al.* 2005).

While *E. ramosus* is a summer active $C_4$ grass, it is a perennial, and so can also grow and produce seed during the winter. As a summer weed, *E. ramosus* may reduce the yield of winter crops by utilising moisture and nutrients that would otherwise be available to the crop, or delay sowing due to the time taken removing the weed in autumn (Tennant 2000, Osten *et al.* 2006). However, as a winter weed directly competing with crops, this species may be a more severe problem, as there are no registered herbicide options for in-crop control.

There is anecdotal evidence that *E. ramosus* is becoming increasingly common in the broad scale grain and pasture region (wheat-belt) of Western Australia (WA). The emergence, survivorship and seed production of *E. ramosus* was investigated within a pasture/pasture or pasture/crop rotation in the WA wheatbelt. The research aimed to test the hypothesis that growth of *E. ramosus* would reduce wheat yield within the minimum tillage cropping system in WA.

## MATERIALS AND METHODS

**Site** A site was identified at Merredin, WA (619284 mE, 6515587 mN, Zone 50), on the property of Judith and Roy Butler. The soil (to 10 cm) was light brown sand (texture 2–2.5 mm). The site had previously been utilised as a pasture, where *E. ramosus* was the dominant summer grass species.

**Emergence and survivorship of *E. ramosus* in a pasture-pasture or pasture-wheat rotation** The trial design included a summer weed control and no summer weed control treatment (eight replicates, randomised block design). In December 2007, the site was pegged with plots of 4.5 m by 20 m, and fenced to prevent further grazing. Cultivation (5–10 cm) was used to remove the *E. ramosus* plants in the weed control plots. A permanent quadrat of 1 $m^2$ was established in each of the 16 plots. A further eight permanent quadrats were established in the area adjoining the trial site. From December 2007 to November 2009, establishment and survival of each individual *E. ramosus* plant was recorded in each quadrat, each month. Mature seed heads were counted each month, removed from the plant and returned onto the ground (to ensure that monitoring did not impact the available seed bank). In this trial, each new growth pulse was considered as a new cohort. Vegetative growth of an *E. ramosus* plant can die back, and then resprout. However, many seeds are caught within the tufted mature plant, and it is difficult to tell if new growth on a tuft results from a new seedling or re-sprouting of the old plant (without destructive harvest of the plant).

**Crop growth in the presence of *E. ramosus*** In July 2009, soil cores (to 10 cm) from four randomly selected weed control plots and four no weed control plots were collected and analysed (performed by CSBP Soil and Plant Analysis Laboratory, 2 Altona Street Bibra Lake WA 6163). Further soil cores were taken to assess surface soil moisture. Overall, soil properties did not differ between weed control (cultivated) and no weed control plots (i.e. no difference in nutrient availability or moisture levels). However, the average bulk density of the top soil was 1 g $cm^{-3}$ in the weed control plots and 1.3 g $cm^{-3}$ in the no weed control plots. The wheat crop was sown in July 2009, using a 1.84 m wide plot seeder (each 4.5 m wide plot was sown in two passes). The crop was sown at 74–80 kg $ha^{-1}$ to a depth of 3 cm and fertiliser (86–94 kg $ha^{-1}$ Agras®) placed at 4 cm, using 50 mm wide bolt-on combine dart points (to allow adequate penetration of the soil compacted by grazing). Row spacing was 18 or 36 cm, but impact of row spacing is not discussed in this paper. Glyphosate at 810 g a.i. $ha^{-1}$ with carfentrazone-ethyl at 9.6 g a.i. $ha^{-1}$ (1 week prior to sowing) was sprayed to remove other weeds. Visual assessment indicated that the herbicides had very little impact on *E. ramosus*). The wheat crop was harvested on 30 November 2009. Within the crop, four permanent quadrats per plot were established to measure *E. ramosus* density prior to seeding, wheat and *E. ramosus* density following crop emergence, and *E. ramosus* density, seed head production, wheat head number and wheat biomass at the milk grain fill stage of the crop. Crop yield was assessed at harvest.

ANOVA using weed control as the factor and the in-crop measurements as the response were performed (GENSTAT Version 12.1 2009).

**Seed production** Seed heads of *E. ramosus* were harvested from 124 individual plants from March to October 2008 (from within and outside the trial area), and seeds were counted. A regression analysis (origin constrained to zero) was used to compare the number of seed heads to the number of seeds produced (GENSTAT Version 12.1 2009).

## RESULTS

**Seed production** The 124 sampled plants produced from 1 to 10 seed heads during any single monthly sampling time (note plants with zero seed heads were apparent, but were not sampled). Total seed production ranged from 10 to 1343 per plant, and was closely correlated to number of seed heads ($y = 113x$, $r = 0.92$, $P < 0.001$).

**Emergence, survivorship and seed production in the pasture-pasture and pasture-wheat rotation** Within the pasture-pasture phase, cohorts of *E. ramosus* emerged during all seasons, although generally cohorts were largest in late autumn or winter (Table 1). Emergence of *E. ramosus* was greater in the first year, but total rainfall in the first 12 month span was 352 mm, compared to 285 mm in the second 12 months (i.e. above and below the long term average of 314 mm). Temperatures below 0°C occurred in the winter of both years (Department of Agriculture and Food Western Australia 2009), but did not kill plants.

The minimum tillage cropping system (i.e. June 2009 to November 2009) did not prevent survival and seed production by *E. ramosus*. However, where cultivation was used to control weeds in December 2007, subsequent cohorts of *E. ramosus* were less frequent, during both the pasture year (2008) and in the cropping year (2009). Further, cohorts in the cultivated plots were short lived and did not produce seed over the 2 year period.

**Wheat growth in the presence of *E. ramosus*** Weed control (through cultivation in December 2007) caused *E. ramosus* density to remain at very low levels during the cropping phase, although a small cohort appeared after crop seeding in June 2009 (Table 1, Table 2). Initial density of wheat was not affected by the weed control, but wheat head number, biomass and yield were significantly greater in the weed control plots. Wheat grain yield was reduced by 21% in the absence of weed control (Table 2).

## DISCUSSION

Cultivation was highly effective at removing all *E. ramosus* plants, reducing emergence and preventing seed production for the following 2 years. This species is clearly favoured by the no tillage (minimal soil disturbance) system, which is becoming increasingly common in the WA wheatbelt (D'Emden and Llewellyn 2006). Therefore, the anecdotal evidence that *E. ramosus* is becoming a more common cropping weed is probably accurate.

Growth and seed production of *E. ramosus* was not prevented by the knockdown herbicide (glyphosate) or the minimum tillage crop sowing operation. Therefore this weed was in direct competition with the crop for moisture during the entire cropping phase. This likely resulted in the reduced wheat head production, biomass and yield. Soil bulk density did not affect initial crop emergence, and was unlikely to have affected crop growth, as the difference in bulk density was restricted to the top soil (David Hall, DAFWA Esperance, pers. comm.).

**Table 1.** Month of *E. ramosus* cohort emergence, number of plants in each cohort, number of months the cohort survived, number of seed heads produced by the cohort, and the number of seeds produced by each cohort (estimated from the number of heads), for each rotation type in which *E. ramosus* was observed.

| Month of cohort emergence | No. plants $m^{-2}$ | No. months the cohort survived | No. seed heads $m^{-2}$ | Estimated seed number $m^{-2}$ |
|---|---|---|---|---|
| Pasture 2008; Crop 2009; No cultivation in Dec 2007 | | | | |
| Jan-08 | 3.4 | 15 | 10.8 | 1215 |
| Mar-08 | 0.5 | 13 | 0.4 | 42 |
| Apr-08 | 9.4 | 12 | 22.9 | 2585 |
| May-08 | 0.4 | 11 | 0.9 | 99 |
| Jul-08 | 0.1 | 8 | 0.6 | 71 |
| Aug-08 | 6.9 | 8 | 4.6 | 523 |
| Oct-08 | 0.4 | 6 | 0.5 | 57 |
| Nov-08 | 2.1 | 5 | 2.8 | 311 |
| Dec-08 | 1.5 | 4 | 0.6 | 71 |
| Jan-09 | 0.4 | 2 | 0.0 | 0 |
| Jun-09 | 5.9 | 6* | 1.3 | 141 |
| Jul-09 | 0.4 | 5* | 0.3 | 28 |
| Aug-09 | 0.1 | 4* | 0.0 | 0 |
| Sep-09 | 1.5 | 3* | 1.9 | 212 |
| Oct-09 | 1.9 | 2* | 1.1 | 127 |
| Nov-09 | 0.3 | 1* | 0.0 | 0 |
| Total | 35 | | 49 | 5481 |
| Pasture 2008; Crop 2009; Cultivation in Dec 2007 | | | | |
| Aug-08 | 14.3 | 9 | 0.0 | 0 |
| Feb-09 | 0.1 | 2 | 0.0 | 0 |
| Jun-09 | 7.4 | 4 | 0.0 | 0 |
| Sep-09 | 0.3 | 3 | 0.0 | 0 |
| Total | 22 | | 0 | 0 |
| Pasture 2008; Pasture 2009 | | | | |
| Dec-07 | 0.9 | 16 | 3.6 | 410 |
| Jan-08 | 1.9 | 16 | 9.3 | 1045 |
| Mar-08 | 0.9 | 13 | 4.6 | 523 |
| Apr-08 | 7.9 | 12 | 23.6 | 2670 |
| May-08 | 3.6 | 10 | 1.3 | 141 |
| Jul-08 | 0.3 | 8 | 0.0 | 0 |
| Aug-08 | 2.4 | 8 | 3.3 | 367 |
| Sep-08 | 0.8 | 7 | 0.3 | 28 |
| Nov-08 | 2.3 | 5 | 0.1 | 14 |
| Dec-08 | 0.4 | 3 | 0.0 | 0 |
| Jun-09 | 9.6 | 6* | 14.9 | 1681 |
| Jul-09 | 1.0 | 5 | 1.5 | 170 |
| Aug-09 | 0.3 | 4* | 0.4 | 42 |
| Sep-09 | 1.0 | 3* | 0.9 | 99 |
| Oct-09 | 2.6 | 2* | 2.5 | 283 |
| Nov-09 | 0.1 | 1* | 0.0 | 0 |
| Total | 36 | | 66 | 7472 |

Note: * indicates that a cohort survived the designated number of months, but was still alive when the trial finished in November 2009.

**Table 2.** The impact of summer weed control by cultivation on the density of *E. ramosus* at the pre-seeding and post-seeding stage of wheat crop development, density and seed head production of *E. ramosus* at the milk grain fill stage of the wheat, density of wheat pre-seeding, wheat seed head production and biomass at the milk grain fill stage, and wheat yield. P and LSD values indicate where means are significantly different.

| Crop stage | Measurement | No weed control | Weed control | LSD | P |
|---|---|---|---|---|---|
| Pre-seeding | *E. ramosus* density ($m^{-2}$) | 12.3 | 0 | 1.61 | <0.001 |
| Post-seeding | *E. ramosus* density ($m^{-2}$) | 4.0 | 1.3 | 1.17 | <0.001 |
| | Wheat density ($m^{-2}$) | 100.5 | 106.0 | 6.32 | 0.082 |
| Milk grain fill | *E. ramosus* density ($m^{-2}$) | 7.4 | 0.1 | 1.23 | <0.001 |
| | *E. ramosus* heads ($m^{-2}$) | 5.3 | 0.04 | 1.54 | <0.001 |
| | Wheat heads ($m^{-2}$) | 174.2 | 194.6 | 9.09 | <0.001 |
| | Wheat biomass (g $m^{-2}$) | 276.3 | 332.6 | 17.33 | <0.001 |
| Harvest | Yield (t $ha^{-1}$) | 1.04 | 1.31 | 0.05 | <0.001 |

While it is necessary to remove *E. ramosus* to maximise crop yield, in a minimum tillage system this needs to be achieved with herbicides. Unfortunately, as *E. ramosus* is a native species without global distribution, there are no registered herbicides available for use. There is some indication that paraquat + diquat controls *E. ramosus* (to a greater extent than glyphosate) (Borger 2008), but further research is required to identify chemical control options.

Alternatively, *E. ramosus* may be an excellent choice for use in a 'pasture cropping' system. In these systems, summer dominant native pastures are maintained throughout the year and grain crops are direct drilled into the pasture. These systems do not maximise crop yield, but provide other benefits, i.e. reduced erosion, summer grazing potential, ground water control and salinity reduction (Millar and Badgery 2009).

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