Cotton Catchment Communities CRC

FINAL REPORT

(due on completion of project)

Part 1 - Summary Details

Cotton CRC Project Number: **1.01.54**

Project Title: The ecology of fleabane (*Conyza* spp.)

Project Commencement Date: 11/07/2007 **Project Completion Date:** 31/10/2010

Cotton CRC Program: The Farm

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Part 3 – Final Report Guide (due within 3 months on completion of project)

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

Weeds are persistent and continue to change and adapt to cotton farming practices, as evidenced by herbicide resistance and in weed species shifts (e.g. with the introduction of conservation farming and reduced tillage practices). In these situations, weeds are often more difficult to control, and weed management needs to be based on an understanding of weed ecology and biology to be successful. One of the dominant emerging weed threats for cotton production systems in Australia is flaxleaf fleabane (*Conyza bonariensis*), found to be difficult to control with herbicides and increasingly important in a range of locations across northern New South Wales and southern Queensland.

It is believed that the relatively recent success of *C. bonariensis* in Australian cropping systems is due to a shift in farming practices from conventional to conservation (zero or minimum) tillage systems and a reduced reliance on soil-applied residual herbicides. The incidence of minimum tillage methods in cropping and pasture lands in Australia has risen to 57% in 2008, from 26% in 2001, and is likely to continue increasing (Australian Bureau of Statistics 2009). *Conyza bonariensis* is thought to be adapted for both germination and growth under reduced-tillage systems. The abundance of this weed may also be due to a tolerance to many of the herbicides commonly used in crops and fallows. Glyphosate resistant *C. bonariensis* was initially reported in South Africa in 2003.

The majority of weed problems are ecological in nature and therefore sustainable long-term control strategies must be based on an understanding of the biotic and abiotic factors which promote or suppress the establishment, growth and spread of weeds.

Objectives

2. List the project objectives and the extent to which these have been achieved.

The project objectives, as per the Scholarship Application, were:

- Assess the ecological reasons for the emerging threat of fleabane (*Conyza* spp.) in the Australian cotton industry;
- Determine the biotic and abiotic factors that influence seed germination, growth, reproduction and spread;
- Assess seed bank dynamics and dormancy factors contributing to seed longevity in different soil types, and
- Identify the principles needed to manage fleabane and other similar emerging weeds more effectively.

These objectives were achieved by a series of experiments which addressed all the key life-stages (germination, emergence, growth and development, seed dispersal and seed longevity) of the weed. In addition, to better understand the ecological niche occupied by flaxleaf fleabane, the results were compared with those of a related species, tall fleabane (*Conyza sumatrensis*), which is present in the regions although not problematic in cropping systems. The experiments conducted were:

- The effect of temperature, moisture levels and shading on flaxleaf and tall fleabane germination;
- The effect of soil types and stubble on flaxleaf and tall fleabane emergence;
- The effect of emergence cohort on the growth, development and reproduction of flaxleaf and tall fleabane;
- The effect of humidity on pappus geometry and seed settling velocities of flaxleaf and tall fleabane, and
- The effect of seed burial depth and time on flaxleaf and tall fleabane seed longevity.

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

Germination

The objectives of this study were to determine and contrast the optimal germination conditions for two species of *Conyza*, namely *C. bonariensis* and *C. sumatrensis*, to better understand why *C. bonariensis* more successfully invades crops in Australia than *C. sumatrensis.*

Investigations into environmental influences on flaxleaf fleabane germination included temperature, shading and moisture. All experiments involved eight replicates for each treatment, each with 100 seeds, and a 21 day treatment period. Temperature experiments included two species (flaxleaf and tall fleabane) and seven temperatures (5, 10, 15, 20, 25, 30 and 30^{o}C) with total germination and rate of germination recorded. Shading experiments included two species (flaxleaf and tall fleabane) and five shading levels (0, 50, 70, 90 and 100%) with total germination and rate of germination recorded. The moisture levels were achieved using a potassium chloride (KCl) and agar mix. Moisture levels tested were -0.2, -0.4, -0.6, -0.8, -1.0, -1.2, -1.4 and -1.6 MPa for both flaxleaf and tall fleabane. Moisture levels were also prepared using polyethylene glycol (PEG 8000), although there was no germination for either species at any osmotic potential.

Emergence

Limited results are available on the effect of soil type and stubble on emergence for *C. bonariensis* and *C. sumatrensis.* This study provides a greater understanding of the microsite conditions required for *Conyza* species seeds to emerge and demonstrate any

differences in responses between the two species which might explain their distribution and occurrence in Australia.

The effect of soil type and stubble level on fleabane emergence was examined. A randomised complete factorial design comprising of four soil types (black/grey/red vertosol, sandy loam), two species (flaxleaf and tall fleabane) and three stubble loads (0, 1.8 t ha^{-1}, 3.6 t ha^{-1}) was used. Each treatment was replicated four times, using 50 seeds per treatment replicate. Soils were analysed for pH (1:5 water), Cation Exchange Capacity (CEC) (sum of the exchangeable magnesium (Mg), calcium (Ca), sodium (Na), potassium (K), hydrogen (H) and aluminium (Al)), total carbon (C) and nitrogen (N), organic matter (calculated as total carbon (C)% x 1.75), phosphorus (Colwell) and soil texture (clay/silt/sand composition). Lucerne (*Medicago sativa* L.) hay was used for the stubble treatment. Pots were setup in a glasshouse with relevant soil type, 50 surface-sown seeds and relevant stubble levels and watered daily for the 21 day treatment period.

At the end of the treatment period, the stubble was carefully removed and emergence was counted. Emerged seeds were defined as those with visible cotyledons. The glasshouse temperature was maintained between 20 and 25°C. A photometer was used to determine the amount of shading created in the microsite below the different stubble levels

Growth and development

The objectives of this study were to (i) determine the effect of emergence cohorts (late-autumn and spring) on the fecundity of *C. bonariensis* and *C. sumatrensis*, (ii) quantify and compare the life stages for the two emergence cohorts, including growing degree days, (iii) quantify the differences in growth of overwintered and non-overwintered individuals, and (iv) compare the results of *C. bonariensis* with *C. sumatrensis*, a less important *Conyza* species in cropping systems.

The two *Conyza* species were grown under controlled conditions simulating both autumn and spring germinations with multiple harvests. The experimental design was a 2 x 6 x 2 mixed-design or split-plot with four replicates.

The experiment was conducted in a growth chamber at the University of New England, Armidale, using 21 cm pots and a potting medium of sand:peat (3:1). Pots were filled with potting mix, watered to field capacity and seeds were sown by scattering them onto the soil surface. Ten grams of slow release Osmocote® fertiliser (18% nitrogen, 5% phosphorus, 10% potassium and 5% sulphur) was added to each pot. Additional pots were sown for each species as backups in case of poor survival rates. All treatments were initially established at 25°C and constant light for a period of 28 days. After establishment, the temperature and lighting was adjusted to simulate the two different emergence cohort treatments (late-autumn and spring).

Destructive and non-destructive measurements were made during the experiment (Table 1). During the destructive harvests, pots were squeezed around the sides to loosen the potting mix and roots. The plant was then removed and any soil adhering to the roots was removed by careful washing with gently running water. The plant biomass was divided into root, shoot, leaf and flower components and wet weights obtained for all using an electronic balance. The plant components were then dried to a constant weight at 80°C for 48 hrs and weighed.

Table 1. A list of the morphological measurements recorded

Measurement type	Measurements recorded
Non-destructive	plant height, number of leaves rosette, number of non-rosette, rosette diameter, number of branches, number of capitula.
Destructive	as for non-destructive harvest, plus taproot length, root dry weight, stem dry weight, flowers dry weight. The final destructive harvest also measured the number of seeds per capitulum.

Seed dispersal

There are no reported measurements of settling velocities for *C. bonariensis* or *C. sumatrensis* using samples from Australian populations. Furthermore, the effect of humidity environments on the pappus geometry and settling velocities of *C. bonariensis* and *C. sumatrensis* has not been reported.

To create microsites of predetermined relative humidities, saturated solutions of hydrated calcium chloride ($CaCl_2.6H_2O$), sodium nitrite ($NaNO_2$) and hydrated zinc sulphate ($ZnSO_4.7H_2O$) were placed in three separate desiccators at 20^{o}C. The respective humidities for each of the saturated solutions were 30, 75 and 90%. The saturated solutions were left in the desiccators for 24 hrs and the relative humidity was confirmed using a hygrometer. Forty seeds of each species were placed into separate glass Petri-dishes, with lids off, within each of the three relevant desiccators.

Pappus geometry response to humidity was tested using a stereoscopic microscope and protractor. The pappus bristle forming the greatest angle from the achene summit was measured to the nearest degree.

Settling velocities were measured by dropping, pappus-up, individual *C. bonariensis* and *C. sumatrensis* diaspores down a vertical glass tube, with its base on the floor, measuring 1.45 m in length and 0.15 m inside diameter. A round plastic container with a small hole in the centre was placed at the top of the glass tube to minimise impact of room air currents. To assist in locating the seed during descent, black cardboard was placed around part of the bottom 40 cm of the glass tube and a 40 W fluorescent light illuminated the lower part of the tube. The glass tube was treated inside with anti-static wipes prior to use to eliminate static interference. The descent of the seed was timed using a digital stop-watch.

Seed longevity

Prior to the field based investigation of seed longevity, a controlled environment experiment was performed, to assess the ability of *C. bonariensis* and *C. sumatrensis* to emerge from different depths. The experiment included the two species of *Conyza*, six burial depths (0, 0.5, 1, 2, 5 and 7 cm) and four replicates (each of 100 seeds). A three part sand and one part peat substrate was mixed and placed into aluminium trays measuring 10 cm wide, 20 cm long and 10 cm deep. Seeds were then distributed onto the soil and more soil was added to cover the seeds to the appropriate treatment depths. Treatments were placed in a growth chamber in a randomised block design at 25^{o}C with constant light. Seeds were watered daily using a mist spray to avoid soil and seed movement and the locations of the aluminium trays were changed every three days during the 30 day treatment period. Germinated seeds were counted at the end of the treatment period. Seeds were defined as germinated when the radicle or shoot extended further than 1 mm beyond the seed coat.

To investigate the effects of depth on seed longevity over time, seeds were buried in mesh bags, in a field site at 'Trevanna' on the grounds of the University of New England, Armidale, Australia. A factorial experiment design of two species (*C. bonariensis* and *C. sumatrensis*), four burial depths (1, 2, 5 and 10 cm) and six exhumation intervals (0, 3, 6, 9, 12 and 15 months), was employed with four replications. Grey vertosol soil was collected for use within the bags, but before use was sieved to 2 mm and autoclaved at 121^{o}C for 2 hrs to kill any seed and pathogens. Mesh bags were each filled with 50 cm^{3} of soil and 300 seeds.

Four 13 m long trenches 1 m apart measuring 45 cm wide and 30 cm deep were dug at 'Trevanna' to house pots of soil containing the buried seeds. The area of the in-ground experiment and immediate surrounding was sprayed with glyphosate (a.i. 360 g L^{-1}) at the rate of 1.6 L ha^{-1} prior to commencement. Polyethylene pots measuring 30 cm diameter and 35 cm deep were filled with grey vertosol soil, placed into the trenches and soil was backfilled around each pot. Two bags, one of each species, was then buried to the appropriate depth and secured by a loop of wire in each pot. The soil above the bag was padded down and smoothed over by hand to minimise movement of soil (e.g. via heavy rain) which could alter the burial depth. The field site was maintained with manual weeding. After exhumation of seeds for each of the six intervals (0, 3, 6, 9, 12 and 15 months), seeds were tested for ability to germinate.

Exponential decay curves ($Y = Ae^{-kx}$) for loss of seed persistence were calculated for both species and each depth treatment using SPSS regression curve fitting to determine k (slope), R^2 (variance accounted for) and A (y intercept).

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

Germination

Species, temperature and the interaction were significant (Table 2). The optimal constant temperature for germination for both species was 25^{o}C (Figure 1). There was no germination in either species at a constant 5^{o}C. Germination of *C. sumatrensis* remained relatively high from 10^{o}C to 30^{o}C, whereas germination of *C. bonariensis* had a distinct peak at 20 to 25^{o}C and dropped away more rapidly above and below these temperatures than *C. sumatrensis* (Figure 1). In *C. sumatrensis*, 13.7% (±3.7%) of seeds also germinated at 35^{o}C, with zero germination of *C. bonariensis* seeds at this temperature. These differences in peak and overall ranges between the species suggest that *C. sumatrensis* may have a greater capacity to emerge in a broader diversity of climatic environments, compared with *C. bonariensis* which may need the milder temperatures of autumn and spring. As well, *C. sumatrensis* germinated more rapidly after imbibition than *C. bonariensis* across the range of temperatures tested, which may help it to compete more vigorously with other species, such as along roadsides, where it is commonly seen, but may also make it more vulnerable to early post emergence herbicide applications in a cropping environment.

Table 2. Analysis of variance results for temperature.

Source	df	MS	F	p
Corrected Model	11	0.573	36.134	<0.05
Intercept	1	12.064	761.174	<0.05
Species	1	3.564	224.899	<0.05
Temperature	5	0.265	16.742	<0.05
Species*Temperature	5	0.054	3.387	<0.05
Error	74	0.016		
Total	86			
Corrected Total	85			
R^2 = 0.843 (adjusted R^2 = 0.820)				

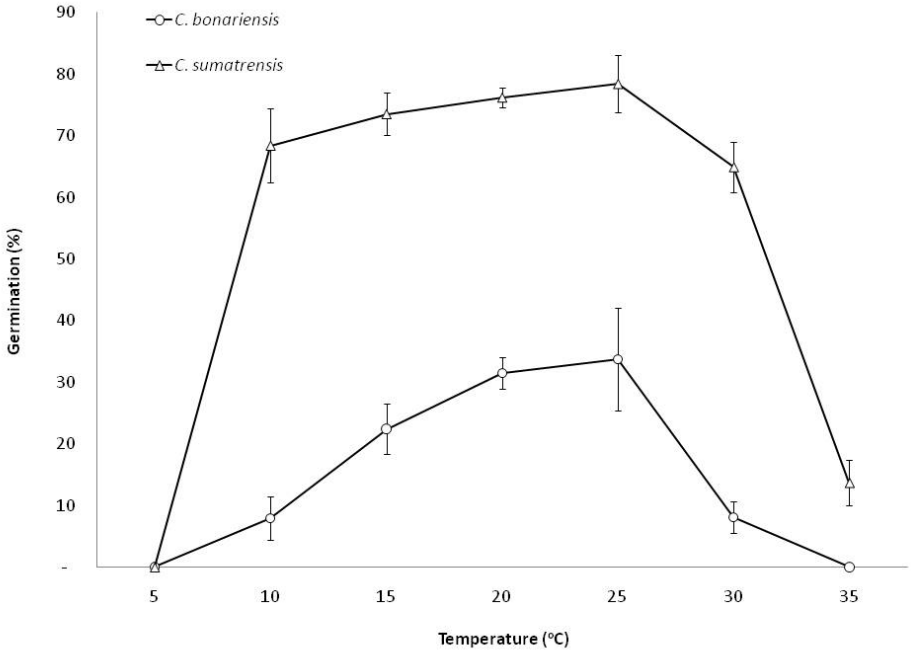

Figure 1. Total germination for *C. bonariensis* (○) and *C. sumatrensis* (Δ) with standard error bars (⌶) after 21 days treatment period under different temperatures.

Analysis of variance returned significant species and shading main effects (Table 3). Dunnett multiple comparison, using 0% shade as the control, showed that shading up to 70% had little or no impact on germination of either species, whereas at 90% shade germination means for both species were significantly reduced compared with the control (Figure 2). There was no germination under full shading (dark) for either species. Overall, shade levels up to 90% reduced the germination of *C. bonariensis* more than *C. sumatrensis*.

These findings may help explain field observations of *C. bonariensis* in uncultivated cropping fallows and *C. sumatrensis* on roadsides competing with grasses and other plants. However, these results do not fully explain the relative lack of *C. sumatrensis* in fallow situations given that its germination was high also in full light. Other ecological factors, such as its longer time to flowering, may disadvantage it in an annual cropping system. This feature may be a disadvantage for *C. sumatrensis* because of failure to complete its life cycle before a crop is sown. It is possible that the cooling effect of shading may also suppress germination of *C. bonariensis* more than *C. sumatrensis*. While low temperatures (10 to 15°C) delayed the

germination of seeds of both *Conyza* species as well as reducing the total germination percentage, shading had little impact on the speed with which germination occurred, just the overall germination rate.

These results on shading support its use as a control method to assist with the integrated management of *C. bonariensis*. Agronomic practices to utilise shade could include tillage to bury seed, as well as stubble retention, covering and competing crops. Compared with full light, under a 90% shade coverage, the germination rate of *C. bonariensis* seeds was reduced from 57.3% (±7.4%) to 10.5% (±3.6%) and to zero germination under full shade

Table 3. Analysis of variance results for shading.

Source	df	MS	F	p
Corrected Model	9	0.550	12.791	<0.05
Intercept	1	12.272	285.414	<0.05
Species	1	0.399	9.288	<0.05
Shading	4	1.090	25.340	<0.05
Species*Shading	4	0.048	1.118	0.355
Error	70	0.043		
Total	80			
Corrected Total	79			
R^2 = 0.622 (adjusted R^2 = 0.573)				

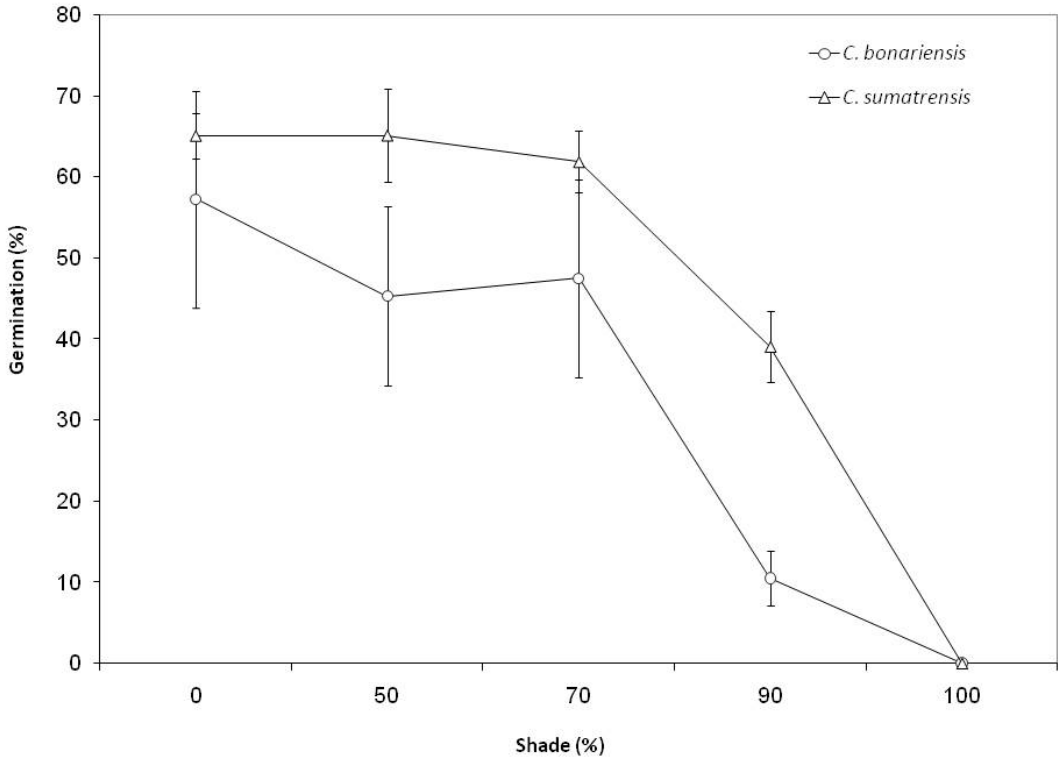

Figure 2. Effect of shade on germination after a 21 day treatment period for *C. bonariensis* (○) and *C. sumatrensis* (Δ) with standard error bars (⌶) at a constant 25°C.

Analysis of variance returned significance for species, moisture level and the interaction of the two (Table 4). Tukey multiple comparison showed that germination means of all treatment combinations comparing the two species were significantly different except *C. bonariensis* at -0.6 MPa with *C. sumatrensis* at -0.2, -0.4 and -0.6 MPa, and *C. bonariensis* at -

0.8 MPa with *C. sumatrensis* at -0.8 MPa. Germination decreased from 77.6% (±3.0%) to 11.0% (±2.3%) and 51.1% (±4.0%) to 16.0% (±1.9%) for *C. bonariensis* and *C. sumatrensis* respectively, as osmotic potential decreased from -0.2 to -0.8 MPa. The most rapid decline in germination for *C. sumatrensis* occurred at moisture potentials below -0.6 MPa while for *C. bonariensis* the decline occurred below -0.4 MPa suggesting that germination of *C. bonariensis* is more sensitive to declining moisture levels than *C. sumatrensis,* again indicating that *C. bonariensis* may be more seasonally restricted to wetter periods than *C. sumatrensis*. Germination was completely stopped at osmotic potentials of -1.0 MPa or less for both species

Table 4. Analysis of variance results for moisture

Source	df	MS	F	p
Corrected Model	15	0.635	152.137	<0.05
Intercept	1	6.370	1525.329	<0.05
Species	1	0.132	31.684	<0.05
Moisture	7	1.277	305.660	<0.05
Species*Moisture	7	0.066	15.822	<0.05
Error	112	0.004		
Total	128			
Corrected Total	127			
R^2 = 0.953 (adjusted R^2 = 0.947)				

Emergence

Generally, for both species, emergence was lowest under heavy stubble (3.6 t ha^{-1}), although there was either no significant difference in emergence between zero and light stubble (1.8 t ha^{-1}), or light stubble (1.8 t ha^{-1}) was more favourable for emergence (Figure 3). *Conyza* seedlings emerged in all treatments. The highest emergence recorded for *C. bonariensis* was 64.0% (±1.0%) with zero stubble on a grey vertosol substrate, and the lowest, 7.0% (±3.9%), under stubble (3.6 t ha^{-1}) with grey vertosol substrate (Figure 3). *Conyza sumatrensis* reached the highest emergence levels of 37.5% (±7.1%) with stubble (1.8 t ha^{-1}) on a grey vertosol and the lowest of 9.5% (±3.4%) with stubble (3.6 t ha^{-1}) on a grey vertosol (Figure 3). The three-way ANOVA returned significant differences in stubble and species main effects, and the interactions soil*stubble and soil*stubble*species (Table 5).

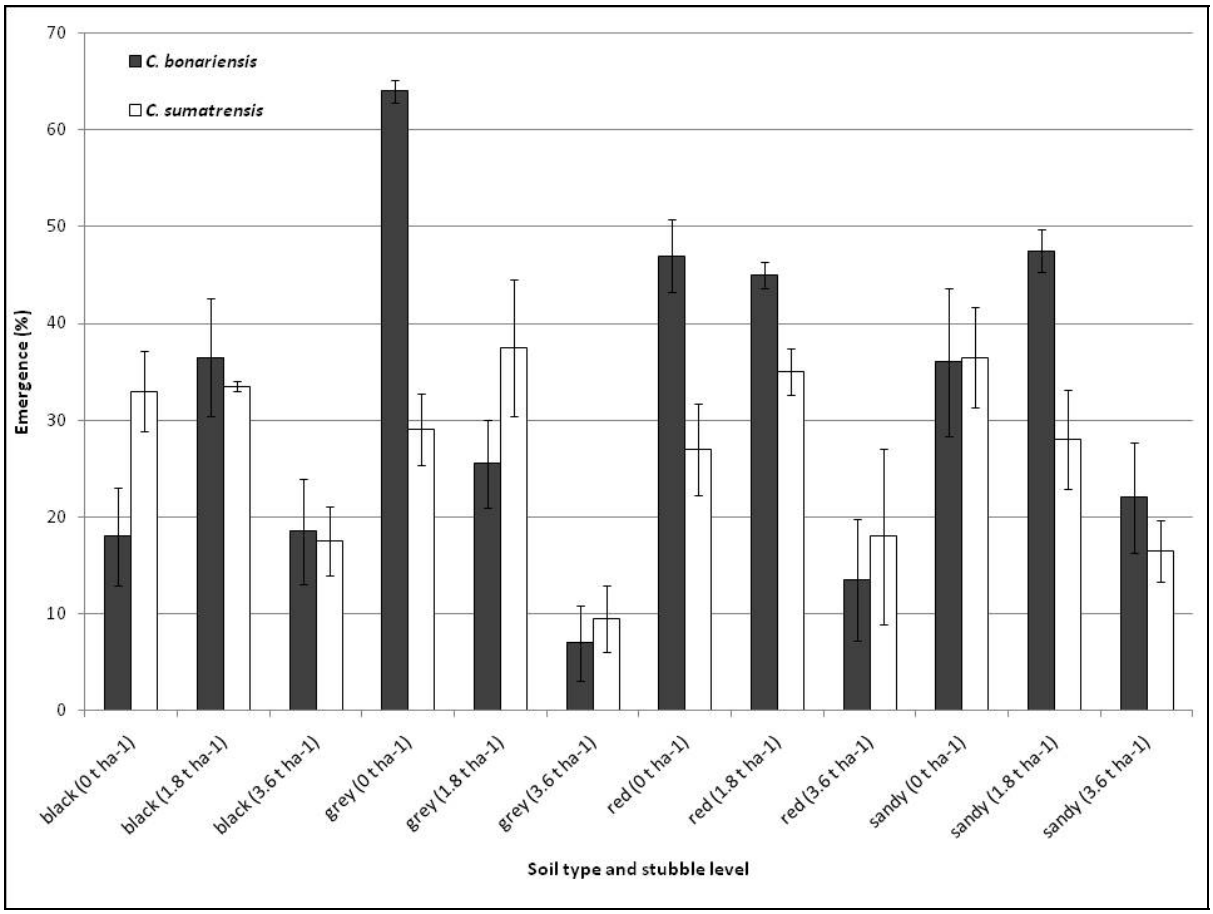

Figure 3. Emergence levels for *C. bonariensis* (■) and *C. sumatrensis* (□) in four soil types and three stubble levels at the end of 21 day treatment period. Values are means (n=4) with standard error (⌶).

Table 5. Results of three-way analysis of variance for emergence levels (r^2=0.764).

Source	df	MS	F	p
Corrected Model	23	0.068	7.293	<0.05
Intercept	1	7.980	851.918	<0.05
Soil	3	0.012	1.313	0.277
Stubble	2	0.459	48.951	<0.05
Species	1	0.057	6.129	<0.05
Soil*Stubble	6	0.035	3.708	<0.05
Soil*Species	3	0.019	2.063	0.113
Stubble*Species	2	0.019	2.055	0.136
Soil*Stubble*Species	6	0.054	5.775	<0.05
Error	70	0.009		
Total	92			
Corrected Total	93			

Growth and Development

Fecundity for both species was significantly higher in the late-autumn cohort than in the spring cohort, with seed production of 85 074 (±2 086) and 21 488 (±1 138) for *C. bonariensis* and *C. sumatrensis* respectively (Table 6). Seed production in the spring cohort was 70.3% and 63.8% of that for the autumn cohort in *C. bonariensis* and *C. sumatrensis* respectively. Both the total number of capitula and seed per capitulum were reduced for both species in the spring cohort when compared with the late-autumn cohort. Compared with *C. sumatrensis, C. bonariensis* produced more seeds from both emergence dates and had a greater number of capitula and seed per capitulum. The ANOVA for seed production showed significance in the main effect of species and cohort and the interaction between the two (Table 7).

Table 6. Total fecundity in *C. bonariensis* and *C. sumatrensis* for different emergence cohorts. Values are means with standard errors in parentheses.

Cohort	No. of capitula	Seed/capitulum	Total seed
C. bonariensis			
Late-autumn	232.0 (±11.9)	366.5 (±4.4)	85 074.8 (±2 086.4)
Spring	190.0 (±10.9)	315.0 (±4.5)	59 847.5 (±1 598.7)
C. sumatrensis			
Late-autumn	166.0 (±7.7)	128.8 (±5.5)	21 488.0 (±1 138.9)
Spring	126.2 (±7.8)	109.0 (±3.4)	13 712.5 (±475.1)

Table 7. Results of two-way analysis of variance for seed production.

Source	df	MS	F	p
Corrected Model	3	134416.2	650.2	<0.05
Intercept	1	3183494.7	15398.2	<0.05
Species	1	372763.4	1803.0	<0.05
Cohort	1	28843.4	139.5	<0.05
Species*Cohort	1	1641.8	7.9	<0.05
Error	76	206.7		
Total	80			
Corrected Total	79			
$R^2 = 0.962$ (adjusted $R^2 = 0.961$)				

In addition to fecundity levels, the proportion of plant biomass attributed to seeds out of the total plant biomass (reproductive effort) was determined. Reproductive effort is defined as the total amount of resources allocated to reproduction and therefore diverted from vegetative activity. The highest reproductive effort was observed in overwintered *C. bonariensis* plants, with 11.8% (±0.92) of the final biomass represented by seeds. In both species, the spring cohort had significantly lower energy inputs diverted into seed production when compared with the late-autumn cohort. In addition to differences in fecundity between cohorts and species, there were also differences in growth characteristics between the two species over the different emergence times. The late-autumn emerged

C. bonariensis plants were taller, had a larger rosette diameter, a deeper taproot, a higher root:shoot ratio and a higher number of branches per plant compared with the spring emerged cohort. This was the case for *C. sumatrensis* as well, except that the taproot length was not significantly different at the seed maturity stage. Root to shoot ratios were calculated to determine the effect in allocation to above ground and below ground biomass for overwintered plants and those emerging in spring. Late-autumn emerging *C. bonariensis* plants had a root:shoot ratio which was more than double that of the spring cohort at the flowering and seeding stages.

The time to bolting was fastest in *C. bonariensis,* taking 8.08 (±0.06) weeks in the spring cohort (Table 8). *Conyza bonariensis* plants also had a shorter time between bolting and flowering, 3.92 and 3.09 weeks for the late-autumn and spring cohorts respectively. This time contrasts with 5.92 and 4.65 weeks for late-autumn and spring cohort respectively for *C. sumatrensis* (Table 8). The time between flowering and seed set was similar for both species and cohorts; however, *C. bonariensis* set seed earlier overall than *C. sumatrensis*. The late-autumn cohort of *C. bonariensis* set seed 3.85 weeks ahead of *C. sumatrensis* and 3.29 weeks ahead in the spring cohort. The growing degree days (GDD) required to reach seed maturity between the two species was significantly different. *Conyza bonariensis* required 1 636.0 (±17.7) and 1 781.7 (±16.2) GDDs for late-autumn and spring cohort respectively compared with 2 134.3 (±11.9) and 2 208.3 (±20.7) in *C. sumatrensis* (Table 8).

Table 8. Life stage development in weeks and growing degree days for *C. bonariensis* and *C. sumatrensis* for different emergence cohorts.

Cohort	Life stage	Time (weeks)	Growing degree days
C. bonariensis			
Late-autumn	bolting	11.39 (±0.12)	916.9 (±9.4)
	flowering	15.31 (±0.18)	1 345.5 (±23.3)
	seed maturity	17.55 (±0.14)	1 636.0 (±17.7)
Spring	bolting	8.08 (±0.06)	1 046.8 (±7.9)
	flowering	11.17 (±0.07)	1 446.3 (±8.8)
	seed maturity	13.76 (±0.12)	1 781.7 (±16.2)
C. sumatrensis			
Late-autumn	bolting	13.13 (±0.20)	1 074.3 (±22.0)
	flowering	19.05 (±0.16)	1 830.1 (±21.0)
	seed maturity	21.40 (±0.09)	2 134.3 (±11.9)
Spring	bolting	9.84 (±0.10)	1 274.1 (±13.3)
	flowering	14.49 (±0.11)	1 875.9 (±14.7)
	seed maturity	17.05 (±0.16)	2 208.3 (±20.7)

Furthering the success of *C. bonariensis* is the short time between bolting and seed production. The total time from bolting to producing seed was 6 weeks or 719 GDDs from the simulated late-autumn cohort. To illustrate this time period, a cumulative GDD graph based on the temperatures at Narrabri, NSW is provided for *C. bonariensis* (Figure 4). In addition to the short time between bolting and seeding, *C. bonariensis* reaches the bolting stage in 8 weeks for spring emerged plants (917 GDDs) and there is a 3 to 4 week period between bolting and flowering.

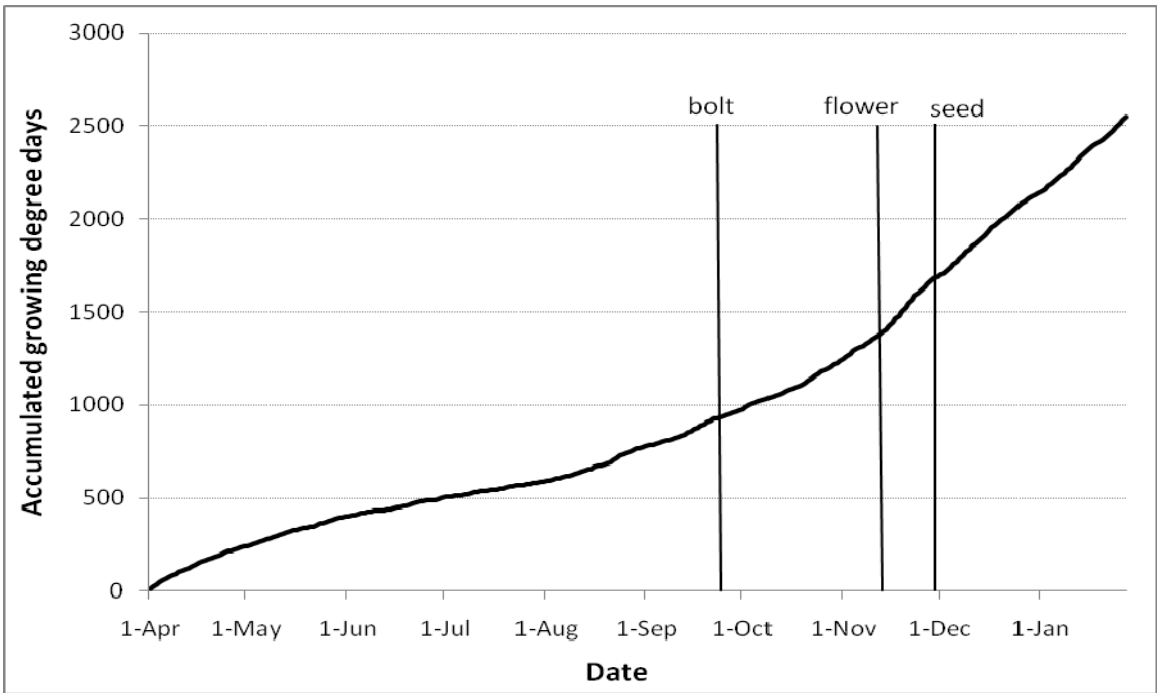

Figure 4. Accumulated growing degree days for Narrabri, New South Wales, from 1/04/2009 to 27/01/2010 with *C. bonariensis* bolting, flowering and seeding time based on seedlings established in late-autumn.

Ecological differences between the two *Conyza* species which support why *C. bonariensis* is more prevalent than *C. sumatrensis* in crops are the production of more seeds, a higher relative reproductive effort and more rapid development in *C. bonariensis*. *Conyza sumatrensis* grows much taller than *C. bonariensis,* which is likely to be an advantage in more competitive ruderal environments, e.g. roadsides.

Seed Dispersal

Conyza bonariensis diaspores had a faster settling velocity than *C. sumatrensis* in all humidity treatments. When comparing the 30 and 90% humidity results and the 30 and 75%, both species experienced an increase in settling velocities with an increase in humidity (Figure 5). The settling velocities in 30% humidity for *C. bonariensis* and *C. sumatrensis* were 0.281 m s^{-1} (±0.008) and 0.242 m s^{-1} (±0.010) respectively and in 90% humidity 0.329 m s^{-1} (±0.010) and 0.282 m s^{-1} (±0.011) respectively. When contrasted with *C. sumatrensis*, *C. bonariensis* had a greater range in mean settling velocities between the low 30% humidity and the high 90% humidity (Figure 5).

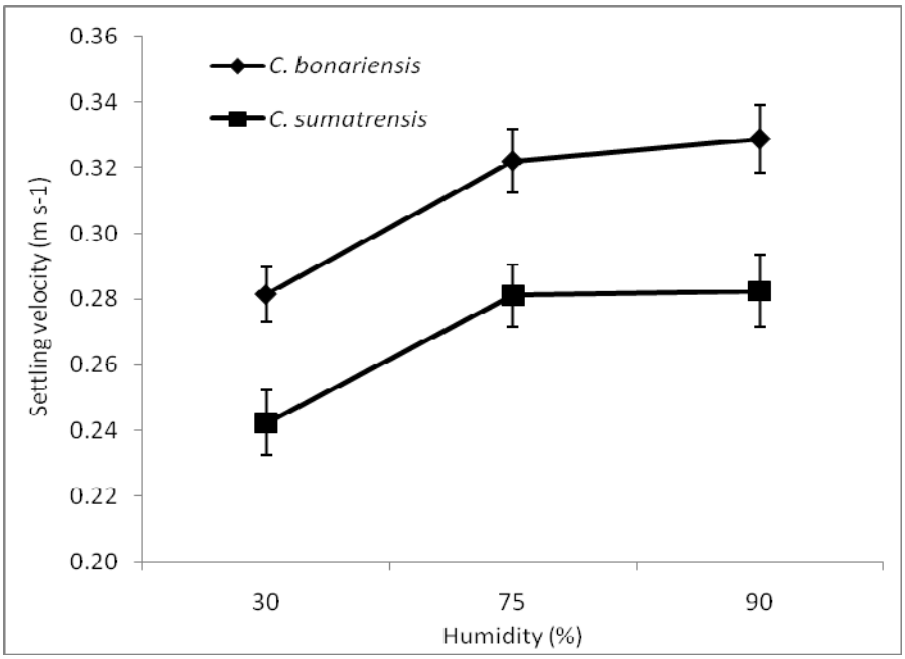

Figure 5. Mean settling velocities for *C. bonariensis* (◆) and *C. sumatrensis* (■) under three different humidity levels with standard errors ( ).

Conyza sumatrensis seed has the potential to disperse greater distances than *C. bonariensis* due to a slower settling velocity. The dispersal capacity is further enhanced in *C. sumatrensis* with this species growing, on average, taller than *C. bonariensis*, with maximum heights of 2 m and 1 m respectively, and therefore having a higher seed release height. Dispersal distance calculations are given in Table 9.

Table 9. Dispersal distances (m) calculated for *C. bonariensis* and *C. sumatrensis* at different humidity, wind speed and release heights.

	Humidity level (%)					
	30			90		
	Wind speed (km hr^{-1})					
	15	25	35	15	25	35
Release height (m)						
C. bonariensis						
0.2	3.0	4.9	6.9	2.5	4.2	5.9
0.4	5.9	9.9	13.8	5.1	8.5	11.8
0.6	8.9	14.8	20.7	7.6	12.7	17.7
0.8	11.8	19.7	27.6	10.1	16.9	23.7
1.0	14.8	24.7	34.5	12.7	21.1	29.6
C. sumatrensis						
0.2	3.4	5.7	8.0	3.0	4.9	6.9
0.4	6.9	11.5	16.0	5.9	9.8	13.8
0.6	10.3	17.2	24.1	8.9	14.7	20.6
0.8	13.8	22.9	32.1	11.8	19.7	27.5
1.0	17.2	28.6	40.1	14.8	24.6	34.4
1.2	20.7	34.5	48.2	17.7	29.5	41.3
1.5	25.8	43.1	60.3	22.1	36.9	51.6
2.0	34.4	57.3	80.2	29.5	49.2	68.8

Seed Longevity

Neither *C. bonariensis* nor *C. sumatrensis* were able to germinate below the soil surface. Depth was the only significant main effect – there was no significant difference in species response. The 0 cm burial depth had germination levels of 54.2% (±3.9%) and 58.5% (±3.1%) for *C. bonariensis* and *C. sumatrensis* respectively.

Viability of buried seeds in both species decreased with time and the depth of burial influenced this process (Figure 6). Seeds buried closer to the surface lost viability more rapidly than those buried deeper. Modelled viability loss in seed over time, using exponential decay curves, are presented (Table 10).

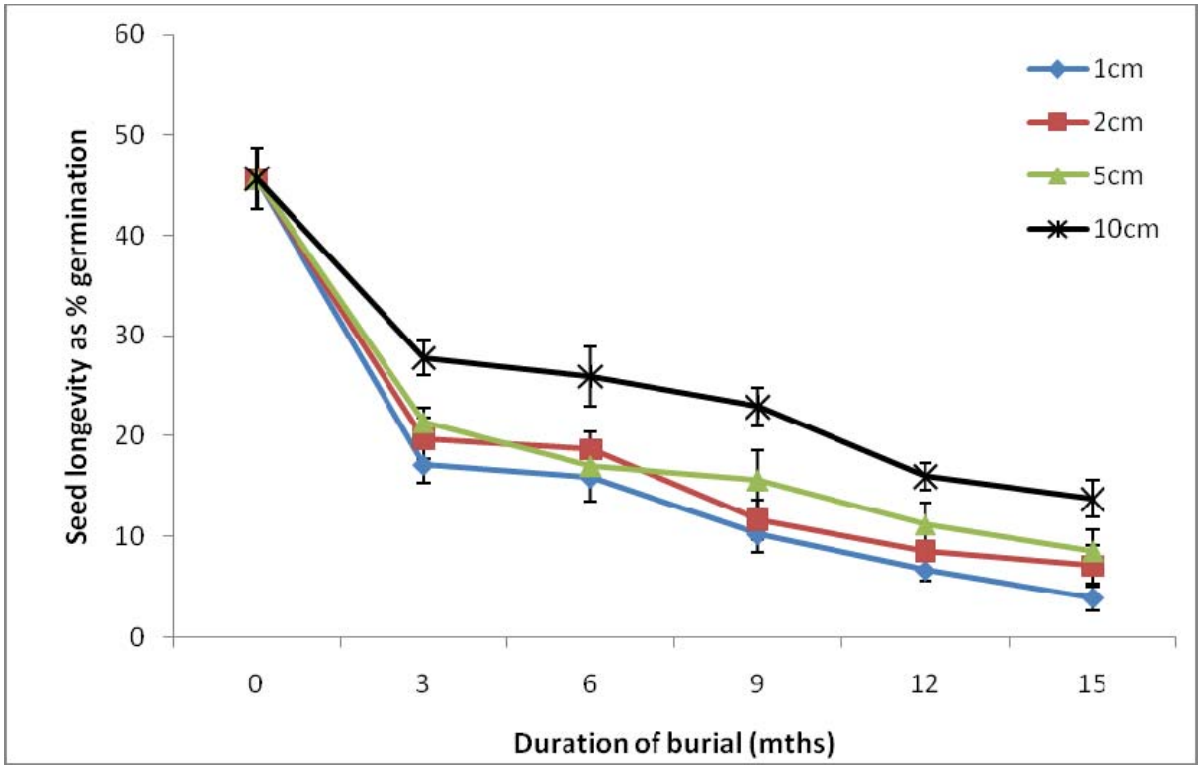

Figure 6. Effect of burial depths over time on the seed longevity of *C. bonariensis* expressed as percentage germination from the original 300 buried seeds. Data points are mean values and include standard errors (I).

Table 10. Time (months) for 95, 99 and 99.9% of the original seed bank of *C. bonariensis* to lose viability when buried at depths of 1, 2, 5 and 10 cm. Time was calculated using the respective exponential decay curve equations.

Depth (cm)	Viability loss in seeds (%)		
	95	99	99.9
C. bonariensis			
1	12.7	22.7	37.1
2	15.9	28.8	47.2
5	18.7	34.0	55.7
10	27.8	49.3	79.9

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

Outcomes, as stated in the Scholarship application:

- A better understanding of the ecological reasons for the emergence of fleabane as a problem weed in the northern cropping region,
- Information on the ecology of fleabane that can be used for better management of this predominantly summer weed, and
- A PhD thesis and student trained in weeds research.

6. Please describe any:-
   a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);
   b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and
   c) required changes to the Intellectual Property register.

There are no changes to the Intellectual Property register to report, or any commercially significant developments from this project.

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

Conyza bonariensis is an annual weed and therefore, effective long-term management needs to target the weed seed bank. This involves promoting a reduction in the seed bank and minimising future seed bank inputs. Reducing the seed bank is promoted in a minimum tillage system where seeds remain on or near the soil surface, thereby promoting seedling emergence and increasing decay rates. Reducing the seed bank through seedling emergence is reliant on the effective control of seedlings to avoid high plant numbers, competition and further seed bank replenishment. With the ability of *C. bonariensis* to emerge all-year-round given light and soil moisture greater than or equal to -0.8 MPa, there is a requirement for all-year-round monitoring and control of this weed. Seed input is not just provided by plants within the cropping system. Seeds from outside the cropping area can be blown in and therefore the control of such plants is also important.

Cultivation can appear to be counter-productive to the ideals of a conservation tillage system; however, in the case of large infestations or difficult to control populations, cultivation could be useful. Rotating tillage practices reduces selection pressures on *C. bonariensis* and other weeds which are favoured by minimum tillage systems. The burial of *C. bonariensis* seed, however, extends the period the seed remains viable, therefore, if seed burial was used as the primary means of control, there would need to be no additional deep cultivation which could return those buried seeds to the surface for 3 to 4 years, or further active control of seedlings would be required.

The effective long-term management of *C. bonariensis* requires an integrated approach to weed management, in which herbicide use is complemented with non-chemical control tactics. These tactics may include strategic cultivation, crop competition, grazing, burning and manual removal. The use of herbicides, even when used in conjunction with non-chemical options, needs to be practised in a way to minimise selection pressures for resistance to a single herbicide. This can be achieved by rotating the mode of action groups of the herbicides used.

Farm hygiene is another important element in effectively managing this weed. With a very high fecundity and ability for long-distance seed dispersal, control measures need to be extended to non-cropping areas of the property.

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken:
   (a) to further develop or to exploit the project technology.
   (b) for the future presentation and dissemination of the project outcomes.
   (c) for future research.

A one-page brochure on the identification, ecology and management principles of flaxleaf fleabane has been produced.

Ecological influences on all key life stages of *C. bonariensis* were investigated in this study. To assist with population modelling of *C. bonariensis,* however, research is required to obtain information on the survival of *C. bonariensis* during each of the life stages. With the establishment of population models, different management scenarios could be investigated.

Publications

9. A. List the publications arising from the research project and/or a publication plan.
   (NB: Where possible, please provide a copy of any publication/s)

Peer-reviewed conference proceedings

Green, T. D., B. M. Sindel, G. Charles and J. Werth. 2008. A review of the ecology of fleabane (*Conyza* spp.). Pages 171-173 in Klinken, R. D., V. A. Osten, F. D. Panetta, and J.C. Scanlan (eds), Proceedings of the 16th Australian Weeds Conference, Queensland Weeds Society, Brisbane, Australia

Other

An article in NSW I&I publication, 'AgToday'.
An article in NSW Weed Society magazine 'A Good Weed', 2010.
Oral presentation Big Day Out – 'Keytah', 2009.
Oral presentation, 16th Australian Weeds Conference, Cairns, 2008.
Oral presentation UNE Post-graduate Faculty Conference (2008/2009/2010).
Oral presentations Cotton CRC Science Forum (2007/2008)

Publication Plan

When thesis is returned, plan to write a comparative ecology article on flaxleaf and tall fleabane in Australia.

B. Have you developed any online resources and what is the website address?

Not applicable.

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

Conyza bonariensis (L.) Cronquist, flaxleaf fleabane, originating from South America, is a major emerging weed threat for dry-land cropping systems in Australia. *Conyza bonariensis* is particularly increasing in importance within the northern cropping region of Australia, is one of the most difficult-to-control weeds in minimum tillage systems, and is tolerant to important herbicides. *Conyza bonariensis* is common in fallows, thereby depleting the soil stored moisture, and has caused a doubling of control costs in certain areas of the northern cropping region. Control costs are likely to further increase due to the weed's rapid development of herbicide resistance. Control of *C. bonariensis* is greatly dependant on herbicides, thereby increasing the risk of herbicide resistance.

In this study, ecological aspects of the key life stages of *C. bonariensis* were investigated. All findings were compared with a congeneric species, *C. sumatrensis* (Retz.) E. Walker (tall fleabane), which is currently not problematic in cropping systems in Australia, despite being present in the region within other ruderal sites (e.g. roadsides), as a way of determining what ecological characteristics in *C. bonariensis* may be responsible for its increase in the northern region cropping system.

Germination was limited by temperature, moisture and light. Seeds of *C. bonariensis* germinated between 10 and 30^{o}C, with optimal germination at 25^{o}C. *Conyza bonariensis* seeds were able to germinate under moisture stress down to -0.8 MPa. Light was essential for germination of *C. bonariensis*. In a 90% shade environment, *C. bonariensis* germination was reduced by 80% compared with a full light environment. With adequate temperature, light and moisture, *C. bonariensis* seeds can germinate within 2 to 3 days. Soil type and stubble levels affected *C. bonariensis* emergence. Emergence was reduced in heavy black vertosol soil compared with lighter soils. There was no significant difference in emergence with 1.8 t ha^{-1} of stubble compared with no stubble.

There are differences in development and fecundity between *C. bonariensis* emergence cohorts. More than 85 000 seeds were produced per plant in the overwintering cohort, which was 40% higher than the spring emerged plants. The root:shoot ratio at the time of stem elongation in overwintered *C. bonariensis* plants was 60% higher than spring emerged plants. This ecological feature makes the late-autumn cohort more difficult to control. There was a short period of six weeks between stem elongation and seed production in *C. bonariensis*, and with a slow response to herbicide, this adds to the success of this weed.

Conyza bonariensis seed settling velocity and pappus geometry was affected by humidity. Settling velocity was 0.28 m s^{-1} at 30% humidity and increased to 0.33 m s^{-1} at 90% humidity. *Conyza bonariensis* seeds were not able to emerge from burial depths of 0.5 cm or greater, although the length of time that the seed remained viable increased with burial depth. Seed longevity at 1 cm burial depth was 37 months and at 10 cm depth, this increased to 80 months. Seeds which enter a minimum tillage system typically remain on or near the soil surface, the preferred germination site for *C. bonariensis*, therefore adding to the weed's success in these systems.

In comparison with *C.* sumatrensis, *C. bonariensis* produced more seed, had a higher relative reproductive effort, developed more rapidly, could germinate in milder temperatures only and had a longer lived seed bank. These ecological findings are likely to account for the greater success of *C. bonariensis* in minimum tillage cropping systems. The effective long-term management of *C. bonariensis* requires an integrated approach to weed management, in which herbicide use is complemented with non-chemical control measures. Through limiting soil disturbance, there will be a reduction in the burial of seed and thereby a more rapid depletion of the seed bank, assuming there is no further addition of seed to the soil seed bank from elsewhere. Where appropriate, cultivation could be used to bury the seeds of *C. bonariensis* and prevent germination or to perhaps kill overwintering plants with large taproots. Agricultural practices should also aim to maximise competition, including shade, against *C. bonariensis*. Diligent control is required to prevent seed set, especially for the overwintered plants which are more difficult to control and have a higher seed production.