Seed longevity of some cropping weeds in several New Zealand soils

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Abstract

Annual C_4 grasses are an increasing problem in summer grown crops in New Zealand. Although some effective herbicides are available for their control, long term sustainable management can only be attained by managing the seed bank in the soil. To determine seed bank persistence, seed of seven grasses and two broadleaf weeds were buried at 50 mm and 200 mm depths at eight sites throughout New Zealand. For the past three years, seed have been retrieved annually and germinated in the glasshouse. Many of the grass species have shown greater than expected longevity. At 50 mm, persistence was inversely related to seed size whereby up to 95% of the larger seeded species disappeared within the first year. Smaller seeds persisted longer at both depths and all seed showed greater persistence at 200 mm. Soil type influenced seed bank persistence as species longevity was less in heavier soil types at both depths.

Additional keywords: C_4 grass weeds, weed seedbank, buried seed persistence, grass weed management

Introduction

Annual grass weeds are of major concern to maize growers (Rahman and James, 2010). They are more competitive for resources than broadleaf weeds and are prolific seeders (James *et al*., 2000). Good control of these weeds is often difficult to achieve due to their close relationship to maize (all Poaceae). For this reason, effective pre-emergence control of grass weeds is mostly dependent on a single family of herbicides, viz. chloroacetamides (James *et al*., 2010a).

With increasing use of maize silage for feed and inclusion of a maize crop in the "Programmed Approach™" to pasture renewal, these same weeds are also causing problems in pasture (Lane *et al*., 2009). Both C_4 grasses and large seeded annual broadleaf weeds are managing to establish in healthy pastures resulting in poor feed quality (Crush and Rowarth, 2007), stock avoidance during seed head stage and also reduced pasture persistence (James *et al*., 2009). These weeds are difficult to control selectively in new pasture and seed that persists after the maize crop can lead to severe competition in newly sown pasture and poor establishment of both ryegrass and clover (James and Rahman, 2009).

For many years the main annual summer grass weeds of concern were summer grass (*Digitaria sanguinalis* (L.) Scop.), smooth witchgrass (*Panicum dichotomiflorum* Michx.), and barnyard grass (*Echinochloa crus-galli* (L.) Beauv). The seed of these weeds are either small, or have soft seed coats (or both). Masin *et al*. (2006) found fewer than 10% persisted into the second growing season. Seeds either germinated the following year or decayed in the soil. Recently, new grass weeds have become established and have spread widely. The worst of these is broomcorn millet (*Panicum miliaceum* L.) which is the foremost grass weed in maize cropping in the USA (Wilson and Westra, 1991). This plant has a large seed with a hard, shiny palea and lemma enclosing the seed which limits imbibition of water and slows germination (Khan *et al*., 1996). There is anecdotal evidence from growers in New Zealand that the seed of this grass weed is able to persist in the soil for more than 5 years. There are also similar reports of long persistence for some of the *Setaria* spp. Although *Setaria* spp. seed are generally smaller, they also have a hard, shiny palea and lemma which may protect the seed from predators and decay (Dekker, 2003).

Good knowledge of the length of viability of seed in soil and silage would enable us to formulate effective management strategies. Benefits for both the maize and pastoral industries would be effective management of these weeds resulting in increased maize yields for grain or silage and reduced spread of these weeds into both new and established pastures.

This study has been designed to determine the seed longevity of seven annual grass weeds: broom corn millet, witchgrass (*Panicum capillare* L.), smooth witchgrass, summer grass, barnyard grass, rough bristle grass (*Setaria verticillata* (L.) P. Beauv.), yellow bristle grass (*Setaria pumila* (Poir.) Roem. & Schult.) and two annual broad leaf weeds, thorn apple (*Datura stramonium* L.) and apple of Peru (*Nicandra physalodes* (L.) Gaertn.) *in situ* at two depths in eight soils.

Materials and Methods

Seed collection and seed bag preparation

During the summer of 2007-08, plants of the test species were grown in a glasshouse using seed obtained from the field. Seed collected from these glasshouse grown plants were used in the present study. Approximately 200 seeds of each of three large seeded grass weed species (broom corn millet (0.855 g), yellow bristle grass (0.505 g) and barnyard grass (0.422 g)) were weighed into a coarse mesh bag. Similarly, 200 seeds of each of four small seeded grass weed species (witchgrass (0.084 g), smooth witchgrass (0.168 g), summer grass (0.130 g) and rough bristle grass (0.250 g)) were weighed into a separate, fine mesh bag. Two broadleaf weed species were also weighed into a fine mesh bag, approximately 200 apple of Peru seeds (0.226 g) and 50 thorn apple seeds (0.361 g). Four hundred and eighty bundles, each comprising one each of the above three bags, were prepared.

Trial location

Eight seed burial sites were selected in various locations across New Zealand. These locations and their respective longitude and latitude co-ordinates and soil types were: Jordan Valley, Northland (35° 36’ 49” S, 174° 15’ 47” E), Wairua clay; Tamahere, Waikato (37° 50’ 24” E, 175° 22’ 19” S), Horotiu silt loam; Matata, Bay of Plenty (37° 50’ 38” S, 176° 36’ 27” E), Ohinepanea loamy sand soil; Manutuke, Poverty Bay (38° 40’ 40” S, 177° 53’ 05” E), Matawhero clay loam; Havelock North, Hawke’s Bay (39° 36’ 25” S, 176° 54’ 41” E), Te Mata Mangateretere silt loam on clay; Palmerston North, Manawatu (40° 19’ 21” S, 175° 27’ 18” E), Kairanga fine sandy loam; Motueka, Nelson (41° 03’ 43” S, 172° 59’ 16” E), Sherry sand/sandy loam; and Lincoln, Canterbury (43° 40’ 35” S, 172° 32’ 46” E), Taitapu silt loam.

Seed burial

In July 2008, 240 seed burial tubes (250 mm lengths of perforated, 60 mm diameter plastic drainpipe) were prepared. At each of the eight sites, 30 tubes were filled with soil and a bundle of seed bags was placed 50 mm from each end of every tube. The pipes were buried vertically with their tops flush with the soil surface resulting in one bundle of bags buried at 50 mm and the other at 200 mm from the soil surface.

Seed germination tests

In early summer each year for 3 years, five replicate tubes were removed from each site, the top end marked, and brought to the Plant Protection glasshouses at Ruakura Research Centre, Hamilton (37°46’35”S, 175°18’33”E). For each seed bag, a polystyrene seed tray was half filled with potting mix and topped with a layer of weed mat. The contents of each bag were mixed evenly through one kilogram of seed-raising mix (Daltons, Matamata, New Zealand) and spread out on top of the weed mat to a depth of 10 mm. The seed trays were placed on benches in the glasshouse for germination testing and maintained at ambient temperature and watered as required. Seedlings were allowed to germinate for a minimum of 4 weeks before being counted. Initial seed viability was determined as the percentage of seed that germinated, using the method above, after being stored in a cool dry environment for 5 months.

Data analysis

All data were normalised to percent of initial viability for each species. Each year’s data were then subjected to an analysis of variance (ANOVA) to identify differences due to soil types. Least significant differences (LSD) were determined for each species at each burial site (P=0.05).

Results and Discussion

Initial viability

Initial viability of the seed was: broomcorn millet 74%, yellow bristle grass 85%, barnyard grass 90%, witchgrass 68%, smooth witchgrass 88%, summer grass 87%, rough bristle grass 87%, apple of Peru 75% and thorn apple 69%.

Seed buried at 50 mm depth

Seed germinated quickly in the seed trays in the glasshouse but there was some variability between years and replicates. Few significant trends of decreasing viability were observed over the 3 years of this study as viability often was similar or even increased (Table 1). The reasons for the high variation and reverse trends are not immediately obvious as the seeds from each site were all treated the same. At the first sampling, approximately 5 months after burial, it was obvious that some of the large seeded species (broom corn millet, yellow bristle grass and barnyard grass), had germinated *in situ* before the seed tubes were excavated. These same species generally had the lowest germination of 5-30%, except at the Bay of Plenty and Nelson sites, indicating the greatest loss of seed (Table 1). The smallest seeded species (witchgrass and smooth witchgrass) had the highest germination of 30-100% indicating greater persistence of seed. These trends were consistent over all sites and all years of the study. At this depth the larger grass seeds would have readily germinated (James *et al*., 2002) and were lost from the seed bank while the smaller grass seeds did not and therefore continued to persist in the seed bank. It has previously been shown that smaller seeds are more persistent than larger ones (Thompson *et al*., 1993), although Leishman and Westoby (1998) have proven that this pattern is not consistent within the Australian flora.

Apple of Peru and thorn apple, although large seeds, did not germinate *in situ* before sampling as the large grass seeds did. These species showed a similar persistence over the 3 years, although, apple of Peru had unexpectedly low germination in the second year (Table 1). Broadleaf weeds, in general, have a much harder seed coat than grasses and it is evident that many do not germinate as readily as grass seeds (Burnside *et al*., 1996).

Along with the consistent trends due to seed size observed between species, there were also consistent trends between locations and soils. Germination of the seed buried in Poverty Bay was always very low, with many species having no germination in the third year (Table 1). Conversely, seed buried in Bay of Plenty had the highest germination, particularly in Years 1 and 2, but by Year 3, germination was similar to most of the other locations. The Poverty Bay soil is a heavy clay loam while that from Bay of Plenty is a light sandy soil. Seeds buried in the other heavy soils (Northland, Manawatu and Canterbury) tended to have lower seed bank persistence while the lighter soils of Waikato and Hawke's Bay had greater persistence. This is supported by the results of a 28 year buried seed study where the seed of five broadleaf weed species persisted for longer in the lighter Horotiu silt loam soil compared with the heavier Hamilton clay loam soil (James *et al*., 2010b).

Seed buried at 200 mm depth

Overall, more seed germinated in the glasshouse from samples buried at 200 mm compared with those at 50 mm depth, particularly for the larger seeded grasses: broom corn millet, barnyard grass and yellow bristle grass (Table 2). This supports the suggestion that the seeds of these species were lost from the 50 mm depth due to germination *in situ* before excavation of the seed burial tubes. When buried at a depth from which they could/would not germinate, seed bank persistence was greater. Conversely the germination of the small seeded grass species, witchgrass and smooth witchgrass, was similar at both burial depths.

Persistence of the two broadleaf species was generally greater at 200 mm, compared with those buried at 50 mm, although again, germination of apple of Peru was very low in the second year of the study (Table 2).

Differences due to soil type were clearly present but less consistent at this depth (Table 2). For several species however, persistence in the Northland and Poverty Bay soils was reduced, particularly by Year 3. This is supported by Burnside *et al*. (1996) who found in a 17 year long burial study in Nebraska, that the seed buried at this same depth from several *Setaria* spp. (yellow bristle grass and rough bristle grass), large crabgrass (summer grass), and jimsonweed (thorn apple), had greater seed bank persistence in a fine sandy loam versus a silty clay loam soil.

From a management perspective these results confirm that the dynamics of any weed seed bank is complicated. This study will continue for another 3 years, by which time patterns of seed bank persistence should be better defined and weed management strategies developed accordingly.

Table 1: Persistence of seed over 3 years buried at a depth of 50 mm in eight different soils.

Emerged seedlings (percentage of original viable buried seed)

	Thorn apple			Apple of Peru			Broomcorn millet			Yellow Bristle grass			Barnyard grass		
Location	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3
Northland	66	36	68	68	8	59	6	4	1	11	12	1	8	32	4
Waikato	46	52	76	61	5	77	1	10	21	25	21	16	21	20	12
Bay of Plenty	86	72	66	67	7	42	34	40	12	56	34	13	81	52	26
Gisborne	18	6	6	1	1	1	3	1	0	11	2	0	18	8	0
Hawkes Bay	60	74	70	5	0	40	10	10	28	11	12	20	17	61	43
Manawatu	38	52	20	50	0	7	3	7	6	0	5	2	3	25	19
Nelson	80	66	66	44	25	13	20	3	5	22	3	5	47	16	19
Lincoln	46	74	46	61	2	27	1	8	0	25	11	1	21	53	10
$LSD_{(0.05)}$	41.6	19.0	16.8	11.4	6.7	7.8	7.9	7.4	10.4	9.5	10.8	8.3	16.3	17.6	18.0

	Rough bristle grass			Smooth witchgrass			Summer grass			Witchgrass		
Location	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3
Northland	24	29	5	28	46	57	27	13	5	19	31	49
Waikato	46	27	29	44	67	79	22	4	9	20	26	49
Bay of Plenty	78	55	27	87	43	67	71	27	40	49	24	43
Gisborne	13	3	0	46	36	35	15	23	1	18	8	0
Hawkes Bay	34	43	80	40	62	70	58	29	48	66	52	61
Manawatu	2	12	3	36	38	38	31	26	28	31	75	39
Nelson	37	21	6	63	12	33	47	9	12	45	23	23
Lincoln	46	35	4	44	57	89	22	33	7	20	38	61
$LSD_{(0.05)}$	14.1	18.5	9.3	26.3	25.1	18.9	17.1	13.8	20.6	13.1	17.6	17.6

Table 2: Persistence of seed over 3 years buried at a depth of 200 mm in eight different soils.

	Emerged seedlings (percentage of original viable buried seed)														
	Thorn apple			Apple of Peru			Broomcorn millet			Yellow Bristle grass			Barnyard grass		
Location	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3
Northland	70	60	78	81	23	60	16	19	11	9	3	1	9	4	2
Waikato	74	50	80	76	11	74	10	18	45	39	18	21	38	13	41
Bay of Plenty	62	80	70	51	9	34	45	37	32	64	29	21	87	19	43
Gisborne	22	78	66	6	6	33	32	46	34	26	21	6	42	42	7
Hawkes Bay	70	72	86	9	1	69	21	50	62	11	57	42	18	78	41
Manawatu	96	78	60	86	7	28	23	24	16	5	8	5	65	89	52
Nelson	78	98	72	74	59	28	46	51	19	49	46	28	94	70	45
Lincoln	82	66	88	54	6	84	46	37	61	40	23	21	82	51	83
$LSD_{(0.05)}$	29.0	13.2	12.0	8.0	9.9	8.8	9.7	11.7	11.6	8.5	17.5	12.2	17.2	17.2	24.5

	Rough bristle grass			Smooth witchgrass			Summer grass			Witchgrass		
Location	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3
Northland	34	36	2	62	61	72	32	25	4	33	14	55
Waikato	49	52	45	74	56	55	17	2	26	18	8	54
Bay of Plenty	87	30	36	87	39	71	79	27	28	59	21	50
Gisborne	34	34	18	36	46	57	36	39	16	21	54	34
Hawkes Bay	20	80	84	49	66	66	67	74	65	58	67	56
Manawatu	37	46	36	50	58	60	60	48	61	28	76	57
Nelson	81	63	25	72	44	31	81	64	45	25	27	24
Lincoln	72	45	55	45	61	70	66	57	70	72	34	82
$LSD_{(0.05)}$	15.8	18.7	18.6	19.6	21.5	20.2	17.3	17.8	23.5	14.9	10.3	11.8

Conclusions

Large seeded grass species showed shorter seed bank persistence than the smaller seeded grass species when buried at 50 mm. All seed persisted for longer when buried at the greater depth of 200 mm. After 3 years burial, the viability of apple of Peru and thorn apple seed was largely unchanged. When buried at 50 mm, in most cases, seed buried in light soil persisted longer than those buried in heavy soil.

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