THE FACTORS INFLUENCING WEED SEED LONGEVITY IN BURIED PACKET TRIALS

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ABSTRACT

Since 2008, a series of trials have studied weed seed longevity by burying packets of seeds in a field research enclosure and retrieving them over time. This paper overviews the results of the completed species where the results have been published by past researchers; *Andropogon guyanus*, *Calotropis procera*, *Casabella thevetia*, *Leucaena leucocephala*, *Stevia ovata*, and *Ziziphus mauritiana*. Completed trials of several species (*Azadirachta indica*, *Lantana camara*, *Parthenium hysterophorus*, *Tecoma stans*, *Prosopis pallida* and *Vachellia nilotica*) are unpublished, but are also summarised. Over 1 to 13 years, seeds of each weed species have been subject to different soil, ground cover and depth treatments. This paper summarises the predominant treatment effects on the seed longevity of each species. Results are presented in terms of a percent (%) reduction in viable weed seed to provide decision makers with relative risk-based information on which to base feasible weed management strategies.

Keywords: seedbank, persistence, burial, tropics, viability.

INTRODUCTION

In the absence of seed input, the length of weed control programs is determined by the longevity of the viable seed bank. There are several sources of data to gain indications of weed seed soil seed bank longevity. These include buried packet trials, field records, samples from infestations and controlled ageing laboratory tests. Whilst soil seed banks are inherently variable in field situations, a series of buried packet trials provide insight into the factors that can prolong or expedite their depletion. By understanding the factors that influence seed longevity, then land managers can develop informed and realistic weed management plans and strategies.

A series of buried seed packet trials have been conducted within a research site at Tropical Weeds Research Centre (TWRC) in Charters Towers. The site allows for the replicated study of the effect of a clay and a loam soil, bare and grassed plots, seed packet burial depth and retrieval time. Information on the longevity of six species from this trial have been published and are summarised below.

The results for *Calotropis procera* (calotrope) were reported by Bebawi *et al.* (2015). They noted germination in the buried packets and a relatively quick decline in viability to 0 after 18 months in the first seed lot and >1% after 3 months in the second seed lot tested. Surface seed packets and loam soil plots showed higher viability and no cover effects were evident. The burial trial results for *Ziziphus mauritiana* (chinee apple) were presented by Bebawi *et al.* (2016). They tested two seed lots and recorded germination with-in buried packets, particularly in the first lot. Higher persistence was evident in the surface packets at 3-12 months. No ground cover or consistent soil effects were evident. Chinee apple seed was considered exhausted in under 2 years.

Bebawi *et al.* (2017) reported burial trials of two varieties (yellow and peach) of *Cascabella thevetia* (yellow oleander). In the first trial, the two varieties were exhausted in 18 months, and in the second trial the 'peach' variety was exhausted in 2 years. Due to in-situ germination, no viable seed was recovered from packets buried at 2.5 and 10 cm at any retrieval time. In the second trial, the decline of the surface viability was quicker in clay soil plots, there were no significant cover effects.

The results for *Andropogon gayanus* (gamba grass) were presented by Bebawi *et al.* (2018a). Across all depths, cover, and soil treatments, they retrieved 0 viable seed after 2 years and the soil seed bank only persisted in the short-term. Slightly higher levels of viability were recorded in the deeper (10, 20 cm) buried packets and in loam soil plots. At some retrieval times, there was less viable seed in bare clay soil plots.

Stevia ovata (stevia) seed persistence in the dry tropics was a component of the trials reported by Bebawi *et al.* (2018b). They found that surface seed was exhausted after 2 years, and buried seed exhausted after 2.5 years. Stevia was considered to exhibit short-term longevity. There were also no significant cover or soil effects identified.

Data from a *Leucaena leucocephala* (Leucaena) burial trial was briefly overviewed by Campbell *et al.* (2019). After 8 years they reported viable buried seed at 2.5, 10 and 20 cm, but no viable surface seed was recovered. Leucaena forms a long-term persistent seed bank.

The same trial area and experimental factors have been used to study the longevity of another six species, and this data is summarised below.

MATERIALS AND METHODS

Trial design and analysis

A full description of the trial area and experimental factors is presented by Bebawi *et al*. (2015). Seed of each weed species tested was subjected to two whole plot factors: alluvial river loam and clay (soil types). The trial also contained two subplot factors (present and excluded pasture cover), up to 10 retrieval times, and three or four burial depths in a single pipe. Each seed lot was secured in a permeable packet and buried, (in pipes) at the same time. Packets contained 50 seeds, except for *chinee apple* and *yellow oleander,* where 25 intact endocarps were buried. Four replicates of each soil, cover and depth treatment were removed at each retrieval time.

At the time of burial an unburied sample was germinated to record the initial seed viability. At each retrieval time seeds were removed from the packet, and any endocarp and counted prior to viability testing. Retrieved intact seeds were placed in a 90mm petri dishes on top of a filter paper. All petri dishes were kept moist with distilled water and placed in a Thermoline® incubator set at a 30/20°C diurnal cycle. The outer coat on the Fabaceae species were nicked with secateurs to promote germination. Germinated seeds were recorded and removed.

The data for the unpublished weeds is presented as the viability of the recovered seed relative to the viable seed recorded in the unburied seed, so that time 0 is 100%.

RESULTS

Below is a summary of the main treatment factor means. Further analysis on the interactions between treatments, the soil temperature and moisture conditions, and information from related seed trials may be presented in subsequent species-specific publications. Retrieval time was the most important factor, and it is shown (in years) on the top row of Tables 1-4.

Relative % viable data in each table (1-4) is presented with the following colour coding.

Code % viable	over 50%	50 to 10%	10 to 5%	5 to 1%	under 1%	0%

Acacia nilotica (prickly acacia)

Prickly acacia was the first seed lot to be buried in September 2008. At the final retrieval in 2021, viable seed was obtained from all treatments (Table 1).

Table 1. Relative % viability of prickly acacia seed at various retrievals up to 13 years. Average viability of the unburied seed was 22.6%, this was scaled to 100% at time 0.

Main treatments	0	1	2	4	6	8	10	13
Clay soil	100	84.1	69.7	45.4	21.4	22.9	5.9	2.6
Loam soil	100	88.5	49.0	41.3	38.0	21.8	7.0	5.2
Grass cover	100	92.9	76.0	60.8	42.0	31.3	9.2	5.9
Bare ground	100	79.6	42.8	25.8	17.3	13.3	3.7	1.8
Surface 0 cm	100	58.6	44.8	37.1	14.9	16.0	2.8	2.8
Burial 2.5cm	100	104	59.7	55.3	33.2	20.5	4.4	2.8
Burial 10 cm	100	95.7	73.6	37.6	40.9	30.4	12.2	6.1

Prickly acacia viability was higher across the buried seed packets, more-so at 10 cm, and in grassed plots. At retrievals in years 6, 10 and 13 relative seed viability was higher in the loam soil plots. A repeat trial of prickly acacia seed longevity commenced in the clay soil plots in March 2014 and is expected to run for 15 or more years.

Parthenium hysterophorus (parthenium weed)

Parthenium weed was buried in July 2009. The mean viability of the unburied seed sample was 98.6% and the relative seed viability for the main treatments are shown in Table 2. Seed viability from clay soil plots and 2.5, 10 cm burial packets was usually higher from the 4th year retrieval and onwards. Less than 1% of surface seed was viable after 1 year. Small amounts of viable seed were recovered from buried, grassed, clay soil plots after 7 years and there may not be a sufficient seedbank to establish seedlings.

Lantana camara (lantana orange and pink varieties)

Seed from a pink variety of lantana was buried in March 2009 (initial viability 45.3% - Table 3). Seed from an orange variety of lantana was buried in April 2009 (initial viability 48.3% - Table 4).

Table 2. Relative % viability of parthenium weed seed at various retrievals up to 10 years. Average viability of the unburied seed was 98.6% (100% at time 0 – not shown).

Main treatments	0.25	0.5	1	2	4	5	7	8	10
Clay soil	98.8	56.6	26.1	19.0	13.5	6.8	0.3	0.3	0.3
Loam soil	94.3	61.2	16.5	21.8	4.5	1.8	0.0	0.0	0.0
Grass cover	95.0	60.3	22.9	20.1	11.2	5.4	0.2	0.3	0.3
Bare ground	98.1	57.5	19.7	20.6	6.8	3.2	0.1	0.0	0.0
Surface 0 cm	95.1	32.5	0.3	0.5	0.4	0.1	0.3	0.0	0.0
Burial 2.5cm	97.1	76.5	36.8	35.0	17.9	11.8	0.1	0.5	0.6

Burial 10 cm	95.9	72.9	35.4	32.0	9.0	5.1	0.1	0.0	0.0
Burial 20 cm	98.0	53.8	12.7	14.0	8.8	0.1	0.0	0.0	0.0

Table 3. Relative % viability of lantana (pink) seed at retrievals up to 10 years.

Main treatments	0.25	0.5	1	2	4	5.5	6	8	10
Clay soil	65.1	50.5	5.2	5.2	0.8	0.0	0.0	0.0	0.0
Loam soil	71.2	45.5	5.7	7.3	1.1	0.1	0.0	0.3	0.0
Grass cover	58.6	45.0	11.0	7.4	0.8	0.4	0.3	0.4	0.0
Bare ground	48.4	47.3	9.9	3.4	0.4	0.0	0.1	0.0	0.0
Surface 0 cm	69.1	75.6	9.4	1.7	0.0	0.0	0.0	0.4	0.0
Burial 2.5cm	43.2	34.8	9.1	5.5	0.6	0.6	0.0	0.0	0.0
Burial 10 cm	53.9	39.7	10.5	10.8	0.6	0.3	0.6	0.0	0.0
Burial 20 cm	47.8	34.5	13.0	3.9	1.4	0.0	0.8	0.0	0.0

Table 4. Relative % viability of lantana (orange) seed at retrievals up to 10 years.

Main treatments	0.25	0.5	1	2	4	5.5	6	8	10
Clay soil	68.1	72.0	27.3	9.2	0.1	2.2	2.3	0.0	0.0
Loam soil	109	88.3	23.0	13.6	1.0	2.5	1.6	0.0	0.0
Grass cover	87.1	77.2	18.0	14.9	0.8	4.1	3.6	0.0	0.0
Bare ground	68.1	72.0	27.3	9.2	0.1	2.2	2.3	0.0	0.0
Surface 0 cm	93.4	92.4	16.6	13.2	0.0	2.6	1.8	0.0	0.0
Burial 2.5cm	86.8	69.1	23.0	7.8	0.5	3.9	2.6	0.0	0.0
Burial 10 cm	81.7	78.4	32.1	15.8	0.5	2.1	2.3	0.0	0.0
Burial 20 cm	92.8	80.5	29.0	8.8	1.3	0.8	1.0	0.0	0.0

No viable lantana seed of either variety was retrieved after 10 years, and no viable seed of the orange variety was retrieved after 8 years. There were some differences in the soil factors, but these were inconsistent between the types and the first four retrievals to year 2. Similarly, there was lower and variable %'s of viable seed over the next 4 retrievals to year 8. Given the low proportions of viable seed it seems unlikely the pink variety of lantana would establish after year 5.5.

Prosopis pallida (mesquite)

Mesquite was buried in September 2008 with an average unburied seed viability of 92.8%. Across all treatments, the relative seed viability was less than 5% after 1 year and declined further after 1.5, 2 and 3 years to be exhausted after 4 years. The relative viability averages were similar across 0, 2.5 and 10 cm burial depths. The relative viability was slightly higher in the grassed plots than the bare plots at 1.5, 2 and 3 years. The low viability of the retrieved mesquite seed is inconsistent with the other Fabaceae species in this trial and other data sources such as a Controlled Ageing Test (S. Brooks and D. Brazier unpublished data).

Azadirachta indica (neem tree)

Neem seed was buried in March 2009 and exhausted in all treatments 18 months later. Pre-burial viability was 39.7%, but relative viability fell below 5% in packets buried at 2.5, 10 and 20 cm after 3 and 6 months. In the surface packets, the relative viability averaged 56.5% and 24.6% at 3 and 6 months respectively. The last, single viable surface seed was from a loam/grass plot at 12 months. The data indicated a transient seed bank, with short-term and inconsistent differences in soil and cover treated plots.

Tecoma stans (yellow bells)

Yellow bells seed was buried in October 2009 with an initial viability of 97.1%. Viability fell rapidly to an average of 30.6% after 3 months when surface seed and seed in clay plots showed a higher relative viability than the buried treatments (2.5, 10, 20 cm). After 6 months three viable seeds were recorded. No viable seed was recovered after 9 and 12 months, and the trial concluded, indicating a transient seed soil seed bank.

IMPLICATIONS AND LIMITATIONS

In all weeds studies retrieval time was the most important factor, with viability declining over successive retrievals. Neem tree and yellow bells had relatively transient seed banks that were exhausted in under a year. If seed input is prevented, these two weeds should be the easiest to remove with short programs of effective control measures.

Seed of chinee apple, yellow oleander, calotrope, gamba grass and stevia were exhausted in buried packets in 1 to 3 years and thought to form short-term persistent seedbanks. For these weeds, several seasons of effective survey and control would be required to prevent plants producing fresh seed and exhaust the establishment of seedlings from the soil seed bank. Germination of calotrope seed within buried packets was high (Bebawi *et al.* 2015) and may explain the different indication of persistence recorded by Brooks *et al.* (2022) in controlled ageing tests. The germination observed in the seed packets is a mechanism of seed bank depletion. Successful seedling establishment from seeds buried in the soil can be assessed in a 'depth of emergence' trial. A glasshouse trial is planned to assess the soil depths from which seeds of chinee apple, yellow bells, yellow oleander and calotrope can establish as seedlings.

The remaining species trialled (mesquite, leucaena, parthenium, lantana and prickly acacia) all showed longer-term persistence over 3 years, with the majority 8+ years. The persistence of mesquite was inconsistent with other data sources. Many seasons of effective survey and control would be required to prevent seed input and exhaust the seedlings emerging from the soil seed bank of these weeds. This is particularly difficult with the short life cycle of parthenium. The trials provide an indication of weed seed longevity. Under local conditions the duration of emergence and plant absence from weed control records, may also provide land managers with interim guidance as to the length and progress of control programs.

Depth of burial was also a notable factor in the weed seeds trialled. In some short-lived and transient weeds, the decline was greater in the buried packets than the surface packets, partly through germination as was noted above. A more rapid decline was observed in the early retrievals for the longer-lived species, though usually the times to zero converged for surface and buried packets. As trials progress, the accumulation of dust and leaf litter can afford the surface packets some cover and may influence the viability.

The influence of soil type on longevity varied between species, but most cases were either neutral or persistence was greater in loam than clay soil plots. Except for the later retrievals of parthenium weed, which occurs widely on clay soils in central Queensland. None of the trials summarised have noted a positive effect of bare ground on longevity. Though maintaining bare areas is neither desirable nor practical, and grassed plot results are more applicable grazing and environmental land uses. Notwithstanding more detailed analysis of surface x cover packet data, ground cover was the least influential factor on longevity of all the weeds. The data is presented to enable local practitioners to assess the risk of different weeds establishing when the viability is >1% or reaches 0.

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