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# A Study of the Fate of Seedlings Growing on Sandy Red Earths in the Charleville District, Queensland

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*Abstract*

A field study was conducted at two sites in south-western Queensland into the fate of over 2100 seedlings which emerged in response to rain falling between October 1969 and April 1972 from sandy red earths that originally supported mulga (*Acacia aneura*) scrubs. The four most numerous taxa were the grasses *Aristida* and *Digitaria*, a group of herbaceous Malvaceae and the shrub *Eremophila gilesii*. Of the emerging seedlings more than 50% died within 14 days and only 7% flowered. Over 60% of those plants which flowered took longer than 4 months to reach this stage. Wilting was common, 31% of plants which flowered having wilted previously, although only 4% of these wilted before 30 days of age.

Of the seedlings which exhibited secondary growth, e.g. tillering in grasses, only 49% eventually flowered. Only 33% of tillered grasses flowered, the perennials in general tillering and flowering later than the annual grasses. Insects, particularly grasshoppers, were a continual problem, over 28% of seedlings which survived 30 days being damaged by them.

## Introduction

In semiarid Western Australia, Mott (1973, 1974) has shown that in annual pasture communities the survival of seedlings is strongly related to the moisture relations of a site while germination is not. In that area there was a pronounced dominance of dicotyledons emerging in winter. In Queensland, Burrows (1971, 1973) has documented changes which have occurred between widely separated points in time in regenerating populations of green turkey bush (*Eremophila gilesii*) and mulga (*Acacia aneura*), and concluded that regeneration was a continuing process in the region. However, he has few data on the numbers of seedlings emerging, the proportion which survived, or how many germination events contributed. There are no data available on the extent of regeneration of the perennial herbaceous species, particularly the grasses, which grow in these mulga communities.

Regeneration involves both seed germination and seedling survival. Both components are vital to the long-term stability of plant communities in western Queensland. Unless seedlings themselves set seed, germination and emergence do not ensure the survival of the species. An earlier report (Silcock 1973) presented results on germination, which usually occurred after effective rains. The present paper gives detailed information on survival of seedlings which emerged in semiarid Queensland over a period of 30 months.

## Methods

The study was conducted at two sites, one on an area from which a mulga scrub had been cleared 1 year prior to the commencement of recordings (site 1), and the other on a grassland disclimax induced by clearing and since maintained for several decades by grazing (site 2). The soil at both sites was an acid, infertile sandy loam similar to that described by Christie (1975). Further details of the two sites and the climatic conditions prevailing during the trial period were given by Silcock (1973) in an account of the pattern of germination which occurred between October 1969 and April 1972 in response to rainfall (see Fig. 1 of this paper) and microhabitat.

At both sites an area, 15 m by 15 m, was fenced to exclude stock and all vegetation removed, a scalpel being used to minimize soil disturbance. Within each exclosure 36 plots each 1 $m^2$ were pegged out and blocked into four groups with nine plots in each. Each new seedling which emerged after rain was permanently marked by a pin with a coloured plastic head and its plot number and date of emergence noted. Where possible seedlings were identified immediately but in some cases identification could not be confirmed before flowering. Many unidentifiable plants died soon after emergence, and could only be classed as monocotyledons or dicotyledons or grouped according to family (see Table 1).

After emergence, regular recordings (averaging one per week) were made of the number of living leaves each seedling possessed and whether it had tillered or flowered. Notes were also taken on the occurrence of defoliation by insects, wilting and any other important symptoms which could influence growth. Detailed records were kept from October 1969 until September 1972, although no new seedlings were included after April 1972.

Data are presented on the frequency with which criteria such as tillering, flowering and seedling death occurred and on the relative magnitude of these events for individual species or species groups.

## Results and Discussion

### *Seedling Development and Survival*

Seedling life histories were assembled for 598 plants at site 1 and 1578 at site 2. A summary of the number of seedlings of every species or species group which emerged is given in Table 1.

There were noticeable floristic differences between the seedling population at each site, reflecting the different management histories over the previous few decades. *Aristida* spp. and the woody weed *E. gilesii* were prominent only at site 2. Malvaceae and *Digitaria* spp. were more numerous at site 2 than site 1, despite the lower frequency of established plants in the surrounding vegetation at site 2. The latter two groups of species were prominent under mulga scrubs in the region, but are of minor importance on most cleared sites. Relative seed loads in the soil could have had a big influence on these emergence figures, fewer seeds probably being present at site 1 because of the sparse herbage understorey which originally existed. In all, Malvaceae and *Digitaria* spp. contributed only 7% of the seedlings at site 1 compared with 22% at site 2.

The pattern of seedling death during the study period, compiled from individual life histories, is given in Table 2. At both sites the majority of seedling deaths occurred in the first 14 days after emergence. After 30 days deaths were relatively few (11–17% of the original population), and after 60 days the average rate of seedling death was only 3% of the total per week.

**Table 1. Numbers of seedlings of every recorded species or taxonomic group which emerged at each site, October 1969 to April 1972**

| Taxon | Site 1 | Site 2 | Total |
|---|---|---|---|
| *Aristida* spp.[A] | 2 | 275 | 277 |
| *Eremophila gilesii* | 0 | 248 | 248 |
| Malvaceae[B] | 25 | 177 | 202 |
| *Digitaria* spp.[C] | 18 | 172 | 190 |
| *Tripogon loliiformis* | 26 | 65 | 91 |
| *Euphorbia drummondii* | 23 | 48 | 71 |
| *Acacia aneura* | 27 | 24 | 51 |
| *Portulaca oleracea* | 3 | 40 | 43 |
| *Muelleranthus trifoliolatus* | 12 | 28 | 40 |
| *Eragrostis eriopoda* | 25 | 13 | 38 |
| *Goodenia glabra* | 37 | 0 | 37 |
| *Eragrostis lacunaria* | 37 | 0 | 37 |
| Chenopodiaceae[D] | 0 | 34 | 34 |
| *Brachiaria piligera* | 1 | 25 | 26 |
| *Haloragis odontocarpa* | 21 | 1 | 22 |
| *Velleia glabrata* | 12 | 0 | 12 |
| *Thyridolepis mitchelliana* | 11 | 0 | 11 |
| *Perotis rara* | 2 | 4 | 6 |
| *Dactyloctenium radulans* | 3 | 0 | 3 |
| *Citrullus vulgaris* | 2 | 0 | 2 |
| *Ptilotus leucocoma* | 1 | 0 | 1 |
| *Anthephora pubescens* | 1 | 0 | 1 |
| *Paspalidium rarum* | 0 | 1 | 1 |
| Unidentified dicotyledons | 204 | 104 | 308 |
| Unidentified monocotyledons | 105 | 319 | 424 |
| Total | 598 | 1578 | 2176 |
| Dicotyledons (general) | 367 | 704 | 1071 |
| Monocotyledons (general) | 231 | 874 | 1105 |

[A] Predominantly *A. armata* and *A. jerichoensis*.
[B] Predominantly *Sida brachypoda* and *S. filiformis*.
[C] Predominantly *D. ammophila* and *D. diminuta*.
[D] Predominantly *Maireana villosa*.

The proportion of emergent seedlings which reached the tillering or secondary growth stage varied considerably with the species and appeared to be related to the type of plant. Tillering is easily observed, and in this paper is defined as the emergence of basal shoots in grasses and the expansion of axillary buds in dicotyledons. Of the species occurring at both sites, *Eragrostis eriopoda* was the one most consistently reaching this stage, followed by *Haloragis odontocarpa* and *Muelleranthus trifoliolatus*

(Table 3). However, subsequent flowering data show that some species which occurred only at site 1 tillered very successfully also, particularly the annual grass *Eragrostis lacunaria* (59%) and the short-lived dicotyledons *Vellia glabrata* (50%) and *Goodenia glabra* (35%). Overall, the perennial plants such as *Acacia aneura* and *Digitaria* spp. were less successful in reaching the tillering stage than plants with a shorter life-span such as *Brachiaria piligera* and *M. trifoliolatus*.

**Table 2. Percentage of emergent seedlings (i) dying before flowering or (ii) flowering at the two sites**

| Age at death | Percentage of seedlings Site 1 | Site 2 | Mean |
|---|---|---|---|
| | (i) Died before Flowering | | |
| < 14 days | 63 (380)[A] | 49 (783) | 53 (1163) |
| 14–29 days | 14 (79) | 29 (461) | 25 (540) |
| 30–59 days | 4 (25) | 5 (72) | 4 (97) |
| 60–119 days | 4 (24) | 5 (78) | 5 (102) |
| > 120 days | 3 (18) | 7 (109) | 6 (127) |
| Total | 88 (526) | 95 (1503) | 93 (2029) |
| | (ii) Flowering (or Remaining Vegetative)[B] | | |
| Survived | 12 (72) | 5 (75) | 7 (147) |

[A] Figures in parenthesis indicate the actual numbers.
[B] 'Or remaining vegetative' is used to denote plants which remained alive in the vegetative state at the end of the study period. This classification applies particularly to *A. aneura* and *E. gilesii*, which have a long juvenile period.

**Table 3. Percentage of seedlings of the taxa which occurred at both sites and which tillered**

Data on specific taxa are given only if taxa occurred at both sites

| Taxon | Percentage of seedlings tillering Site 1 | Site 2 | Mean |
|---|---|---|---|
| Malvaceae | 28 (25)[A] | 11 (177) | 13 (202) |
| *Aristida* | 100 (2) | 17 (275) | 17 (277) |
| *Digitaria* | 44 (18) | 5 (172) | 9 (190) |
| *Muelleranthus* | 33 (12) | 32 (28) | 32 (40) |
| *Acacia* | 22 (27) | 0 (24) | 12 (51) |
| *E. eriopoda* | 32 (25) | 69 (13) | 45 (38) |
| *Brachiaria* | 0 (1) | 32 (25) | 31 (26) |
| *Haloragis* | 29 (21) | 100 (1) | 32 (22) |
| *Euphorbia* | 9 (23) | 10 (48) | 10 (71) |
| *Perotis* | 50 (2) | 0 (4) | 17 (6) |
| *Tripogon* | 0 (26) | 0 (65) | 0 (91) |
| *Portulaca* | 0 (3) | 0 (40) | 0 (43) |
| Monocotyledons (general) | 20 (231) | 9 (874) | 11 (1105) |
| Dicotyledons (general) | 13 (367) | 7 (704) | 9 (1071) |
| Total | 16 (598) | 8 (1578) | 10 (2176) |

[A] Figures in parenthesis are population totals taken from Table 1.

Once a plant had tillered, its chances of flowering were improved, compared with plants which survived for at least 30 days (49% compared to 31%). Some species which tillered had 100% survival to flowering, e.g. *Perotis rara*, *V. glabrata*, *G. glabra* and *H. odontocarpa*, but usually there was a proportion of deaths during this growth phase. In all, at site 1, 16% of the original seedlings tillered and 12% flowered (or remained vegetative), while at site 2, 8% tillered and 5% flowered (or remained vegetative) (Table 4). Plants which remained in the preflowering stage are included in these calculations, because most were well-grown shrubs of *A. aneura* or *E. gilesii*, and very favourable rains in November 1972 ensured that the other herbaceous species flowered eventually.

**Table 4. Percentage of emergent seedlings for all taxa having at least one plant flowering (or remaining vegetative)**

| Taxon | Percentage of seedlings Site 1 | Site 2 | Mean |
|---|---|---|---|
| Malvaceae | 24 (25)[A] | 8 (177) | 10 (202) |
| *Aristida* | 50 (2) | 8 (275) | 8 (277) |
| *Digitaria* | 17 (18) | 0 (172) | 2 (190) |
| *Muelleranthus* | 8 (12) | 18 (28) | 15 (40) |
| *Acacia* | 19 (27) | 0 (24) | 10 (51) |
| *E. eriopoda* | 8 (25) | 8 (13) | 8 (38) |
| *Brachiaria* | 0 (1) | 20 (25) | 19 (26) |
| *Haloragis* | 29 (21) | 100 (1) | 32 (22) |
| *Euphorbia* | 9 (23) | 4 (48) | 6 (71) |
| *Perotis* | 50 (2) | 0 (4) | 17 (6) |
| *Tripogon* | 0 (26) | 0 (65) | 0 (91) |
| *Portulaca* | 0 (3) | 0 (40) | 0 (43) |
| *E. lacunaria* | 57 (37) | 0 (0) | 57 (37) |
| *Goodenia* | 35 (37) | 0 (0) | 35 (37) |
| *Velleia* | 50 (12) | 0 (0) | 50 (12) |
| *Ptilotus* | 100 (1) | 0 (0) | 100 (1) |
| *Citrullus* | 100 (2) | 0 (0) | 100 (2) |
| *Dactyloctenium* | 33 (3) | 0 (0) | 33 (3) |
| *Thyridolepis* | 9 (11) | 0 (0) | 9 (11) |
| *Eremophila* | 0 (0) | 10 (248) | 10 (248) |

[A] Figures in parenthesis are population totals from Table 1.

On average only 49% of all tillered plants (i.e. those showing secondary growth) flowered eventually, though individual species success ranged from 18 to 100%, with little consistent difference evident between the two sites. Within the grasses only 33% of tillered seedlings survived to flower, which indicates that either the nodal root system did not always fully establish or that other factors caused the seedlings' death. In either case, after tillering, grasses appeared to be less reliably established than the tap-rooted dicotyledons.

Tillering is usually accompanied by the initiation of nodal roots in grasses, but unless they elongate into the soil their value is negligible. Plants possessing an adequate nodal root system should have their chances of survival enhanced under moisture stress conditions (Van der Sluijs and Hyder 1974). During 1970–71 when the bulk of this study was done, surface soil moisture would rarely have been present long enough for grasses to successfully establish their nodal roots.

Table 5 shows the percentage of plants which flowered within the detailed study period (66 at site 1 and 51 at site 2), within various age classes. Those species which flowered in less than 60 days after emergence were usually annual grasses. Most seedlings were more than 4 months old before they flowered. These figures compare favourably with Mott's (1973) findings that annual summer grasses could flower within 45 days of emergence if given good growing conditions. The greater proportion of seedlings flowering within 60 days of emergence at site 2 was due to the larger numbers of the annual summer grass *B. piligera* germinating at this site (Table 1).

**Table 5. Percentage of seedlings reaching the flowering stage within certain age groupings**

| Age at flowering | Percentage of seedlings: Site 1 | Site 2 | Mean |
|---|---|---|---|
| < 60 days | 8 (5)[A] | 22 (11) | 14 (16) |
| 60–120 days | 32 (21) | 16 (8) | 25 (29) |
| > 120 days | 61 (40) | 63 (32) | 62 (72) |

[A]Figures in parenthesis indicate the actual numbers of seedlings flowering.

Before flowering most plants exhibit secondary growth, but in this study some of the annual species (*Dactyloctenium radulans* and *Citrullus vulgaris*) flowered without tillering.

It should be noted here that the shortest time to flowering of an *E. gilesii* seedling was 477 days, but most took more than 2 years to reach this stage under the prevailing climatic conditions. Some *A. aneura* seedlings eventually produced their first flowers as they passed into their fourth year, but no seed was set. Flowering takes on a greater importance in semiarid areas because of the need for seedling regeneration, and in this paper is regarded as the best guide to successful establishment of any species.

**Table 6. Mean age (and range) at which grasses tillered and flowered during this trial, plus leaf number at tillering**

| | Time to tiller (days) | Time to flower (days) | Leaf number at tillering |
|---|---|---|---|
| | *Perennials* | | |
| Mean | 57 | 193 | 5·8 |
| Range | (17–229) | (36–715) | (3–10) |
| | *Annuals* | | |
| Mean | 29 | 66 | 7·5 |
| Range | (12–50) | (29–103) | (5–11) |

The grasses were of particular interest in this study, and two stages in their ontogeny which can be determined objectively are tillering and flowering. The average age at which the grasses tillered and flowered varied between very wide limits. However, as a group, the annual grasses tillered and flowered earlier than the perennials, which is probably causally correlated with the higher percentages mentioned previously for the plants of shorter life-span (Tables 3, 4). The number of leaves at tillering was also significantly ($P < 0 \cdot 05$) greater in the annuals (Table 6). Most grasses flowered within 240 days, but the age distribution was very clumped and reflected the strong influence of follow-up rain in determining how rapidly a seedling developed.

The *Aristida* spp., all perennials in this study, though not tillering earlier than other perennial grasses, usually did flower much earlier. Their average time to tillering was 54 days (SE 8·3) and to flowering 125 days (SE 16·8). At tillering they had an average of 5·4 leaves (SE 0·24), which is not significantly fewer than the perennials as a group.

Age at tillering seemed to have no consistent influence on the success of grasses in reaching the flowering stage (Table 7). There appears to be a site difference influencing the distribution of age at tillering, a much greater proportion of seedlings tillering early at site 2. However, 59% of tillered plants at site 2 were *Aristida* spp., which rarely occurred at site 1.

**Table 7. Distribution of age at tillering for the grass species plus the proportion of these which eventually flowered**

Figures in parenthesis are the percentage F is of total

| Age at tillering (days) | Site 1 F[A] | Site 1 D[B] | Site 1 Total | Site 2 F | Site 2 D | Site 2 Total | Combined sites F | Combined sites D | Combined sites Total |
|---|---|---|---|---|---|---|---|---|---|
| < 30 | 0 (0) | 6 | 6 | 11 (32) | 23 | 34 | 11 (28) | 29 | 40 |
| 30–50 | 9 (60) | 6 | 15 | 7 (30) | 16 | 23 | 16 (42) | 22 | 38 |
| 51–80 | 2 (40) | 3 | 5 | 3 (33) | 6 | 9 | 5 (36) | 9 | 14 |
| > 80 | 4 (67) | 2 | 6 | 0 (0) | 10 | 10 | 4 (25) | 12 | 16 |

[A] Plants which tillered and later flowered.
[B] Plants which tillered and later died.

### *Influence of Previous Vegetation*

At site 2, no *Digitaria* seedlings reached the flowering stage during this trial even though large numbers emerged (Table 4). Very few plants of these species were found in the established vegetation adjacent to the site. By contrast, some *Digitaria* seedlings flowered at site 1 where these species were common components of the existing vegetation. Malvaceae also survived better at site 1 (Table 4), and again established plants of these species were more common at site 1 than site 2.

Mulga (*A. aneura*) survived much better at site 1 (19%) than at site 2 (0%), but in view of the fact that mulga trees existed adjacent to both sites, no simple explanation for this difference can be offered, except that site 2 was generally a less favourable area for survival (Table 4).

### *Climatic Factors*

Rainfall during the study period is shown in Fig. 1. Annual totals were well below average except in 1971 (Aust. Bur. Meteorology 1965), and showed the variability which is characteristic of the region.

Of those plants which flowered or remained alive in the vegetative state at the conclusion of the study, 14% at site 1 and 53% at site 2 were recorded as having been noticeably wilted at some stage prior to flowering. Wright (1971) and Mott (1973) have also observed that wilting of seedlings is not necessarily an indication of imminent death. The greater incidence of wilting at site 2 correlates with a lower percentage of seedlings flowering and indicates a more xeric environment at this site. Of the seedlings which flowered, only 6% at site 1 and 2% at site 2 wilted prior to reaching an age of 30 days. These findings, together with the observation that most seedling deaths occurred within 30 days of emergence (Table 2), emphasize the importance of adequate soil moisture for at least 30 days after emergence if a seedling is to successfully establish.

Overall there did not appear to be a regular pattern in the time of year at which the seedlings flowered (Fig. 1). Rainfall again possibly played a major part in determining the distribution of flowering, but time of year and the age distribution of plants at the time the rain fell would also be important.

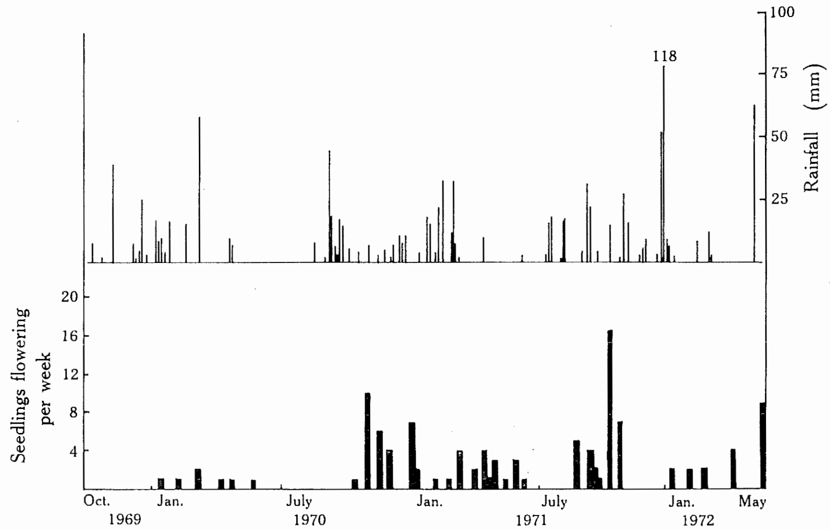


**Fig. 1.** Daily rainfall data over the study period and distribution of flowering dates for the seedling population studied.

*Insect Damage*

Seedlings at both sites were subjected to similar levels of insect damage, mainly by grasshoppers, caterpillars and mites. Of the plants which survived for over 30 days after emergence, 23% at site 1 and 31% at site 2 were damaged to some degree. Insect attacks consisted mainly of partial defoliation by grasshoppers, but *M. trifoliolatus* was eaten by lepidopterous larvae as well. Mites appeared to infest *Sida* spp. at times, causing leaf roll which was difficult to distinguish from normal wilting; these observations have been omitted from the data on insect attack.

Altogether, of the plants which flowered or remained vegetative, 22% at site 1 and 44% at site 2 were at least partially defoliated at some time. Many mulga seedlings were attacked on several occasions, yet survived. Severe defoliation of tillered plants by insects did not always kill them: thus agents other than insects must be responsible for some losses of tillered plants. The influence of termites was difficult to assess, although there were a few instances where *E. gilesii* and *Sida brachypoda* plants had their tap-roots destroyed by them.

Defoliation of seedlings by insects was not as lethal as may have been expected, although interpretation of the defoliation data requires caution. However, since

28% of all older seedlings were defoliated to some extent, this factor needs to be clearly recognized. The resistance of *A. aneura* and *E. gilesii* seedlings to repeated insect attack merits special mention.

*Morphology*

The importance of various morphological features of a seedling in shaping its establishment success is not easily judged from other data collected. Though 2176 seedlings were studied, only four genera contributed a significant number to this total, namely *Sida*, *Eremophila*, *Aristida* and *Digitaria*. The dicotyledons both exhibited tremendous drought resistance once they possessed six leaves, though in the cotyledon stage *Sida* was particularly tolerant of moisture stress while *E. gilesii* was not. The germination of two and sometimes three seeds from one *E. gilesii* fruit at the one time did not improve establishment potential, as few such seedling groups ever survived longer than a few months.

The two grass genera mentioned above are very different, both in appearance and natural habitat. The *Aristida* spp. encountered in this experiment are a low-crowned, invading group, while the *Digitaria* spp. have high crowns and are not usually invaders. The figures on survival to flowering (Table 4) demonstrate the potential of *Aristida* to establish more easily on cleared mulga land, as 8% of *Aristida* plants flowered compared with only 2% of *Digitaria* plants. Though both tillered comparatively early, *Digitaria* was particularly sensitive to moisture stress and quickly ceased to grow once the soil began to dry. On the other hand, *Aristida* seedlings kept growing slowly even in very hot weather, provided some moisture existed in the soil, and also flowered far more readily under stress than *Digitaria*: these factors would enhance the ability of *Aristida* to dominate cleared sites.

## Conclusion

Provided a seedling survives for 30 days it will probably have a 30% chance of flowering and reproducing. Without subsequent seed replenishment, germination of seed merely reduces the future regeneration capacity of the species. Yet despite the importance of flowering, very few native species normally flower before reaching 2 months of age, while most take longer than 4 months.

Whether the dominant regenerating species in this study are desirable is debatable, but some probably are not, e.g. *E. gilesii*. On the other hand, continued regeneration of *A. aneura* is advantageous, as this plant still acts as an important drought reserve in management strategies in south-western Queensland. Obvious differences exist between the pattern of species regeneration at the two sites studied. This is to be expected in view of the differences in botanical composition of the surrounding vegetation. However, sufficient numbers of seedlings continued to survive the establishment phase and set seed to at least ensure soil surface stability in the absence of grazing animals. Management may alter this situation radically, but the opportunity exists to manipulate botanical composition when more information is available about the reaction of the major species to grazing, spelling and rainfall.

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