# CHAPTER FOUR

# ROADSIDE NATIVE GRASS TRIAL

## 4.1 INTRODUCTION

"Revegetation" is a widely used term which can have a variety of meanings, depending on the context in which it is used and the condition of the land to be revegetated. The most extreme situation is that in which the vegetation has been completely removed and where soil stabilisation is of the utmost urgency and importance. "Revegetation" in minesite rehabilitation has been defined as "plants or growth that replaces original ground cover following land disturbance" (Brown 1986), and more generally as "to grow vegetation (any vegetation) on a site which was previously vegetated" (Offor and Watson 1991). Other terms such as "restoration", defined as "upgrading damaged, or re-creating destroyed, land to restore its biological potential" or "rehabilitation", defined as returning the land "to a form and productivity in conformity to a prior land use, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values" (Brown 1986) imply a more complex end product and a more exacting process to achieve it. While the latter two terms imply not only vegetation establishment but also re-landscaping, erosion control and other methods, they also seem applicable to the roadside situation. Unlike mine sites in which revegetation usually begins with bare ground, roadsides present a variety of situations in which revegetation can be undertaken, ranging from bare ground to a dense cover of unwanted vegetation. Also unlike mine sites, where rehabilitation work usually begins soon after the mining operations cease, some roadside sites with revegetation potential have been denuded since the initial roadworks years before.

The use of Australian native plant species for revegetation has gained popularity in the past 15 years (Hampel *et al.* 1990, Langkamp and Plaisted 1987b). While native trees and shrubs are commonly used, however, little attention has been given to native grasses and other native forbs until more recently. Cameron (1961) noted a large number of native grass species with soil conservation value, but Hannan (1984) listed slow establishment, poor erosion protection during establishment, and low productivity as reasons for a lack of research into native grasses for mine rehabilitation. Whalley (1987b) also listed a lack of information on dormancy and germination requirements, and problems of seed harvesting and supply as reasons for the lack of use of native grasses in reclamation work. Traditionally revegetation and stabilisation of old open cut mines have used native trees, shrubs, and exotic grasses such as *Chloris gayana* (Rhodes Grass), and others depending on the desired future land use. More recently, two native grasses, *Dichanthium sericeum* (Queensland bluegrass) and *Bothriochloa macra* (Redgrass) have been found to have establishment success equal to *C. gayana* on cracking black soils (Watt and Whalley 1982b), and *Spinifex sericeus* (Hairy Spinifex), a native grass with exceptional dune-binding abilities, has been used extensively in revegetation after sand mining operations

(Whalley 1987a). A survey in 1982/83 of the native plant seed used in the mining industry revealed 12 native grass species, including five species of *Triodia* (West Australia, South Australia), three species of *Cenchrus* (W.A., N.T.), two species of *Stipa* (NSW, W.A.), *Bothriochloa pertusa*, and *Spinifex sericeus* (NSW) (Langkamp and Plaisted 1987a).

On roadsides "revegetation" generally refers either to planting of trees and shrubs into an existing understorey (e.g., New England Highway Tree Planting Project 1993), or revegetation immediately following roadworks. In the latter case a cover crop of exotic grass such as *Echinochloa esculenta* (Japanese Millet), *Secale cereale* (Ryecorn), or similar species is sown as a cover crop in association with native trees and shrubs, but no native grasses. Hagon *et al.* (1975) suggested that native grasses as well as trees and shrubs should be used in construction of low maitenance parklands and on roadsides. Interest in native grasses for roadside revegetation has increased since then and is desirable for many safety, economic, ecological, and aesthetic reasons. Native grasses can be planted in areas where the road verge is, for safety reasons, too narrow for planting of taller strata of vegetation, and on embankments and cuttings close to the road. Features considered desirable in native grasses for use in roadside revegetation include a low profile (up to 300 mm) to reduce mowing and fire hazard, good germination and re-seeding ability in order to cover ground rapidly and compete with weeds, tolerance of a wide range of soils and variable climatic conditions, and a tussocky, upright growth habit with a good root system (Chang 1987). Many native grasses are tolerant of drought and low fertility soils (Whalley 1987b) and under certain circumstances some, such as *T. australis* are able to successfully compete with weeds (Stafford 1990a, 1990b). Revegetation with native grasses can result in swards with lower maintenance costs of re-seeding, fertiliser application, and spraying of weeds. Some of the best and most diverse examples of remaining native grassland are present in road reserves (Scarlett and Parsons 1982, Specht *et al.* 1974) including endangered species (Breckwoldt 1990). Grassland communities should be preserved (Jeffersen *et al.* 1991), can be used as models for re-creation of grassland habitats, and are as important as, and have equal conservation value to, trees and shrubs. They often provide important habitat and food sources for various fauna (Hampel *et al.* 1990) such as Turquoise Parrots (Quin and Baker-Gabb 1993) and Eastern Barred Bandicoots (Robson 1991). Many of the native grasses have attractive inflorescences and foliage which can add to the aesthetic value of the roadside. On the Northern Tablelands of NSW some examples of attractive species include *Themeda australis* (kangaroo grass) with attractive golden-brown inflorescences, *Dichelachne micrantha* (shorthair plumegrass) with silky white inflorescences, and *Poa sieberiana* (snowgrass) with fine delicate-looking foliage.

Interest in native grasses has encouraged research into the re-creation of grasslands, including the grass species which form the matrix of these communities, and the forbs which grow in the spaces amongst the grass plants. Research on native forbs has included the effect of temperature and light on germination of seven native forbs in the ACT (Willis and Groves 1991), germination of eight NSW native perennial dicotyledons with potential for revegetation (McIntyre 1990), aspects of germination and establishment of eight

Victorian native forbs for use in re-creation of flowering grasslands (Hitchmough *et al.* 1989), and germination, nutrition, and depth of sowing trials of four NSW native dicotyledons (Witchard 1989). Jeffersen *et al.* (1991) studied establishment of *Danthonia richardsonii* on roadsides.

Much of the research into native grasses has been related to their role in agronomic systems, and this information is also useful for revegetation purposes. Cameron (1961) lists a large number of native grasses as having forage value. More recent studies have included the effect of fertility on yield (Lodge 1979), seasonal variations in various growth and nutritive parameters of some native grasses on the north-west slopes of NSW (Lodge and Whalley 1983); and the nutritive value, growth and herbage production of some native grass species on the Northern Tablelands of NSW (Archer and Robinson 1988, Robinson and Archer 1988). The occurrence in, and adaptation to, agricultural systems is also documented for *Microlaena stipoides* (Magcale-Macandog and Whalley 1991), *Chloris truncata* and *Enteropogon acicularis* (Michalk and Herbert 1978), and for *Danthonia* spp. (Scott and Whalley 1982, Scott and Whalley 1984). The effects of general management practices on native grasses on the Northern Tablelands was documented by Whalley *et al.* (1978), and a general survey of native grasses in the southern tablelands (Munnich *et al.* 1991).

Aspects of native grass seed dormancy, germination requirements, and emergence and establishment in the field have also been investigated. Studies of western NSW and Queensland grasses include seed dormancy in *Aristida armata* (Brown 1982), response of four species of *Astrebla* to photoperiod and temperature (Jozwik 1970), and four species of native south-western Queensland grasses were tested for viable seed retention in the soil (Silcock and Smith 1990) and emergence, seedling development and survival (Silcock and Williams 1976). Studies also included germination of *Heteropogon contortus* (Tothill 1977), quality and storage of a number of south-western species (Silcock *et al.* 1990), aspects of germination and seedling establishment on cracking black soils in western NSW (Watt 1974, 1978, 1982, Watt and Whalley 1982a, 1982b), and dormancy and germination in *Aristida contorta* from Western Australia (Mott 1972, 1974a, 1974b) and *Themeda australis* in the Northern Territory (Mott 1978). Research on the tablelands includes dormancy and germination of *Themeda australis* collected Australia-wide (Groves *et al.* 1982), growth and development of *T. australis* (Groves 1975), germination and dormancy (Hagon 1976), effect of moisture stress on germination (Hagon and Chan 1977), and establishment (Hagon and Groves 1977) of *T. australis*, *Danthonia* spp., *Stipa bigeniculata*, and Bothriochloa *macra*. Further work includes reproduction and establishment of *Aristida ramosa* (Harradine and Whalley 1980), establishment of warm and cool season perennial native grasses on the north-west slopes (Lodge 1981, Lodge and Whalley 1981), effects of various environmental conditions on growth (Huxtable 1990), effect of planting depth (Beckers 1993), seed germination and establishment (Johnson 1993), and seed production (Earl 1993) of *Microlaena stipoides*, and germination of six native perennial grasses (Maze *et al.*1993). Research has also been undertaken with salt-tolerant species, and includes germination (Harty and McDonald 1972), and germination,

seedling occurrence and survival (Maze and Whalley 1992) of *Spinifex sericeus*, and germination of *Diplachne fusca* (Morgan and Myers 1989).

In the effort to make native grasses more readily available for agronomic, revegetation and amenity use, a number of domestication programs are underway to develop cultivars of promising native grass species, and these are at various stages of completion. At Tamworth NSW two new native cultivars for forage use, *Danthonia richardsonii* cv. 'Taranna' and *Danthonia linkii* cv. 'Bunderra', (wallaby grasses) were registered in 1992, and the domestication program is outlined in Lodge (1993) and Lodge and Schipp (1993). *Danthonia richardsonii*, cv. 'Hume' has also been domesticated for amenity use by the Division of Plant Industry, CSIRO Canberra but has yet to be registered. Accessions of *Microlaena stipoides* (weeping grass) are being domesticated at the University of New England, Armidale, for amenity, forage, and turf use (Whalley 1987b, C.E. Jones, pers. comm. 1993). Potential has been outlined and initial plant collection made of *Elymus scaber* (wheat grass) (Robinson 1987). Bellotti (1987) outlined plans of a domestication program for *Astrebla lappacea* (curly mitchell grass), and seed production potential and domestication of *Themeda australis* was outlined by Sindel and Groves (1990).

One of the problems of providing native grass seed in commercial quantities is that the ancillary structures, which may include glumes, lemma, palea, and/or awns, are shed with the seed in many grasses, and make seed harvesting and cleaning with conventional equipment impossible. As a result native grass seed is often collected and cleaned by hand, and therefore becomes very expensive. Some native grass seed harvesters have been developed however, including that of Whitney *et al.* (1979) in the USA, which was designed to harvest chaffy seed, and in the 1980s the Woodward Flail - vac seed stripper for the same purpose. In 1989 an Australian brush harvester for native chaffy seed was developed (Loch 1990), as well as a method of threshing the harvested dispersal units from the seeds and to improve handling of seed (Loch *et al.* 1988)

Three species of native grass were selected for a roadside field trial to assess their emergence and survival when planted in different months and in different roadside environments. The species chosen, *Chloris truncata* R. Br. (Windmill Grass), *Danthonia richardsonii* Cashmore cv. 'Taranna' (Wallaby Grass), and *Microlaena stipoides* (Labill.) R. Br. (Weeping Grass) were selected on the basis of their common occurrence on roadsides and their potential for revegetation work. The three species are described as follows:

*Chloris truncata* is a relatively short-lived warm season perennial grass up to 50 cm tall with pale green folded leaves, and windmill-like flower heads (Plate 4.1). It has an erect growth form which may be stoloniferous, and is common on heavily grazed pastures and on roadsides where it may be found growing on the road shoulder. It grows on many soil types and on the tablelands is common on soils of higher fertility around sheep camps but is also a good coloniser of poorer soils. *C. truncata* is generally regarded as unpalatable to domestic stock.

**Plate 4.1.** ***Chloris truncata*** **R.Br. (Windmill Grass) (rear row) at a site on Cluny Road, 5 km north of Armidale, NSW.**

**Plate 4.2** ***Danthonia richardsonii*** **Cashmore (Wallaby Grass) (rear row) at a site on Cluny Road, 5 km north of Armidale, NSW.**

*Danthonia richardsonii* cv. 'Taranna' is a cultivar of a native grass which has been domesticated in northern NSW (Lodge 1993, Lodge and Schipp 1993). *D. richardsonii* is a yearlong green perennial species up to one metre tall with an erect, densely caespitose growth habit, is frost tolerant, and has fluffy white inflorescences. 'Taranna' is an erect plant up to 70 cm tall, but more commonly 50-60 cm tall, with glabrous leaves (Plate 4.2), and like all *Danthonia* species is drought tolerant and has the ability to grow and persist in areas of low soil fertility. *D. richardsonii* occurs naturally on a range of soil types in all tableland, slope, northern and southern western plains, and all coastal NSW environments except the south coast, as well as in Queensland, Victoria, and South Australia. This species is tolerant of saline conditions, and 'Taranna' is moderately tolerant of acid soils.
*Microlaena stipoides* (Weeping Grass) is a species currently undergoing a domestication program on the Northern Tablelands. It is a native yearlong green perennial grass with a slender, tufted growth habit and weeping inflorescences (Plate 4.3). It is commoner at higher elevations in the Northern Tablelands but is often restricted to areas such as the margins of sheep camps, around tree stumps, and under shade trees. It has great potential as a pasture grass because of its high nutritive value, which approaches that of *Phalaris aquatica* and *Festuca elatior* (Archer and Robinson 1988), and because it provides green feed during winter months on the frost-prone tablelands. It also has great potential as a turf grass because of its ability to adopt a prostrate growth habit under grazing or mowing and form a dense, even sward. *M. stipoides* is also suitable for roadside plantings because of its drought tolerance, low growth habit, lack of dormancy, and ease of establishment.

## 4.2 MATERIALS AND METHODS

### 4.2.1 Seed Supply for Trials

*Chloris truncata* seed was collected from plants growing on the road shoulder approximately 20 km north of Armidale on the New England Highway in April 1991, *Danthonia richardsonii* cv. 'Taranna' harvested in December 1991 was supplied by West Brothers Seed Company, and *Microlaena stipoides* seed was collected during July 1992 as bulk seed from several accessions being grown at Clark's Farm, University of New England.

### 4.2.2 Selection of Sites for Trials

Two sites were selected for the trials - one a roadside site approximately five kilometres north of Armidale at the intersection of Cluny and Kirby roads (hereafter referred to as "Cluny Road"), and the other at the Traffic Education Centre in Mann Street, east Armidale (hereafter referred to as "T.E.C."). The Cluny Road site was selected because there had recently been major road reconstruction in the area and represented an ideal site that was (initially) free of weeds. Dumaresq Shire Council fenced off the study area to exclude stock. The T.E.C. was selected because the skid pan had been recently constructed, and the surrounding ground was fairly bare and free of weeds and stock. Both sites had yellow podzolic/solodic duplex soils

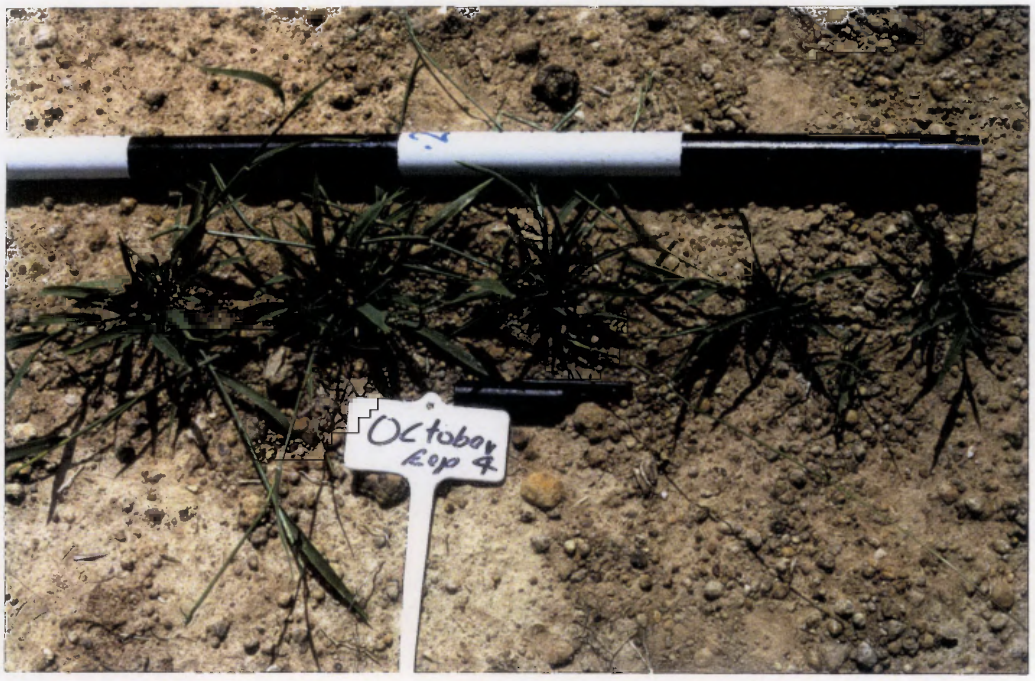


**Plate 4.3.** ***Microlaena stipoides*** **R.Br. (Weeping Grass) at a site on Cluny Road, 5 km north of Armidale, NSW.**

(Northcote primary profile form subdivision Dy, Northcote 1984) derived from Paleozoic sediments. In the undisturbed profile, both sites had 'A' horizons of brown sandy clay loam and 'B' horizons of heavy reddish-brown clay, with slightly acidic pHs in both horizons (5.5 at Cluny Road and 6.0 at the T.E.C.). The 'C' horizon exposed next to the skidpan at the T.E.C. was a yellowish brown sandy clay loam with a pH of 8.5.

### 4.2.3 Positioning of Experimental Plots ("environments") Within the Sites

The plots were set up in specific roadside environments, some of which were linear in shape and some not (hereafter referred to as "environments").

Five environments were selected at the Cluny Road site (Fig. 4.1). The first of these was situated on top of a bank approximately one metre wide which had been pushed up during previous road works (hereafter referred to as the "bank" environment, Plate 4.4.). The second environment was situated on an old dirt road which had been covered with three to six centimetres of topsoil ("old road", Plate 4.5). The third environment was situated in a flat, relatively undisturbed area ("flat unripped", 4.6). The fourth environment was on the other side of the road in a flat area which had been ripped for tree planting ("flat ripped", Plate 4.7). The fifth environment was situated in the table drain on the same side of the road as the "flat ripped" environment ("drain", Plate 4.8).

Two environments were selected at the Traffic Education Centre (Fig. 4.2). The first of these was situated next to the skidpan on its south-eastern side, on subsoil at the bottom of a three metre high cutting ("skidpan", Plate 4.9). The second environment was situated at the top of the cutting on the south-western side of the skidpan and had been previously ripped for tree planting ("topbank", Plate 4.10).

### 4.2.4 Size and Design of Plots

Each plot consisted of four randomly-located replicates - each of which was one metre wide and six metres long. The arrangement of replicates within the environments depended on the location and shape of the environment in which each was placed (Figs 4.1 and 4.2). The replicates in the bank and drain plots were arranged longitudinally, the flat ripped replicates were arranged laterally adjacent to each other with one metre wide walkways between replicates, while all other plots were arranged with two pairs of replicates arranged longitudinally with a one metre wide walkway between them.

Each one metre wide replicate was divided into nine sub-plots of 0.75 m long, each of which was randomly allocated a monthly sowing time from October 1992 through to May 1993 (Fig. 4.3).

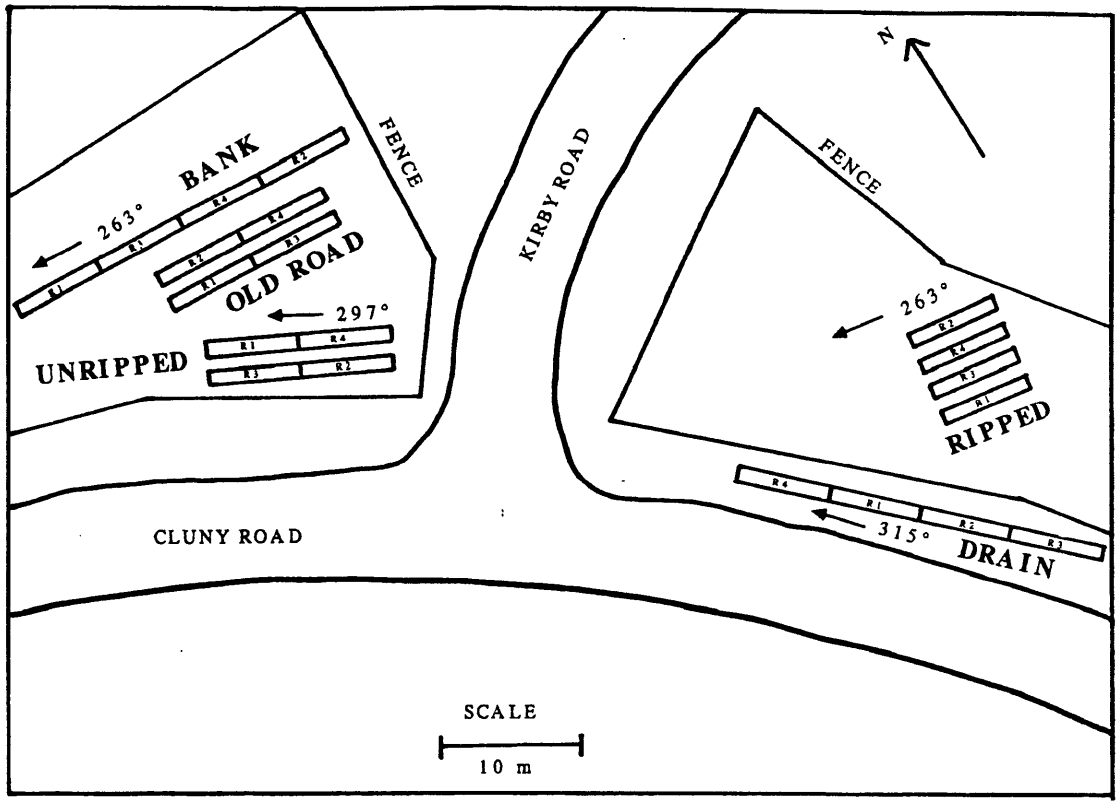


**Figure 4.1. Layout of environments and replicates for an emergence and survival trial of three native grasses at a roadside site at the corner of Cluny and Kirby roads, 5 km north of Armidale, NSW.**

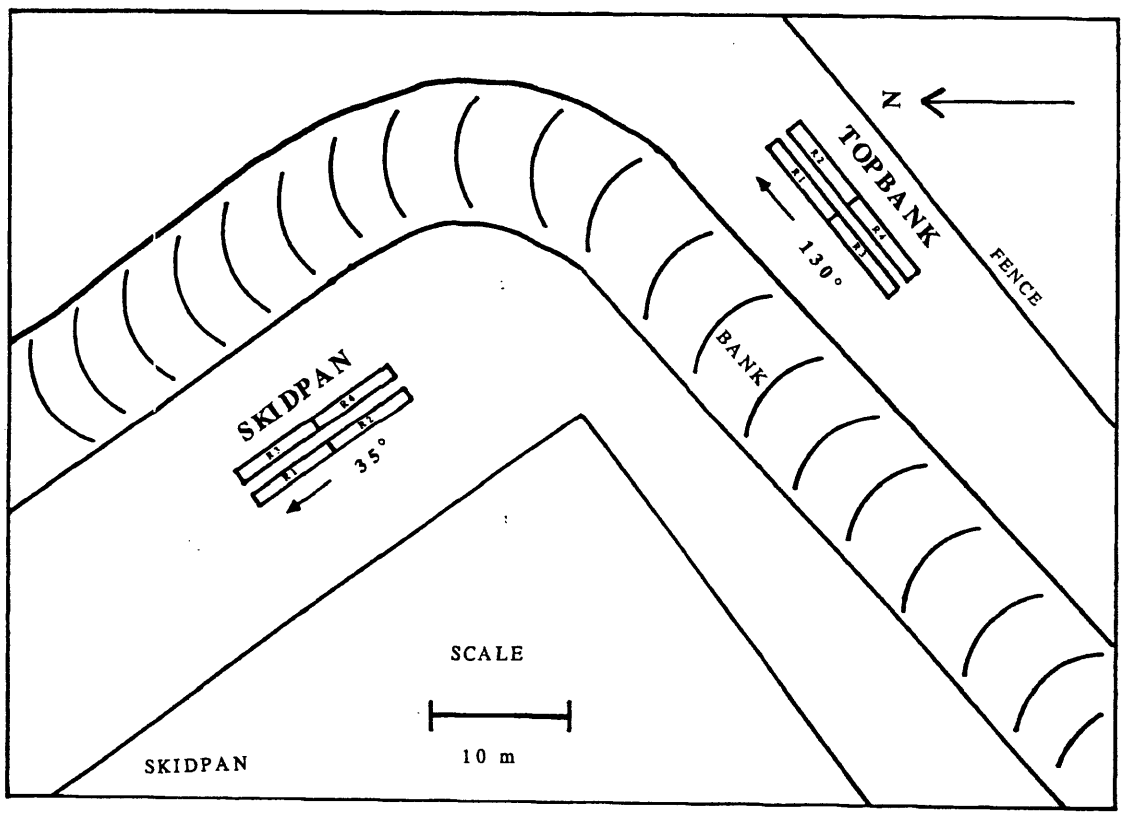


**Figure 4.2. Layout of environments and replicates for an emergence and survival trial of three native grasses at the Traffic Education Centre, Armidale, NSW.**

**Plate 4.4. The 'bank' plot at the Cluny Road site, 5 km north of Armidale, NSW.**

**Plate 4.5. The 'old road' plot at the Cluny Road site, 5 km north of Armidale, NSW.**

**Plate 4.6. The 'flat unripped' plot at the Cluny Road site, 5 km north of Armidale, NSW.**

**Plate 4.7. The 'ripped' plot at the Cluny Road site, 5 km north of Armidale, NSW.**

**Plate 4.8. The 'drain' plot at the Cluny Road site, 5 km north of Armidale, NSW.**

**Plate 4.9. The 'skidpan' plot at the Traffic Education Centre, Armidale, NSW.**

**Plate 4.10. The 'topbank' plot at the Traffic Education Centre, Armidale, NSW.**

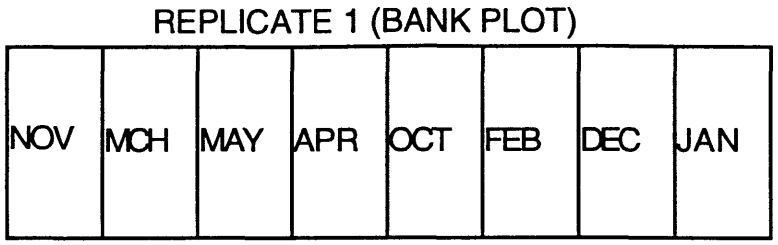


**Figure 4.3. Layout of subplots within one replicate. Each subplot has been randomly allocated a month for sowing. Replicate one in the bank plot is used here as an example.**

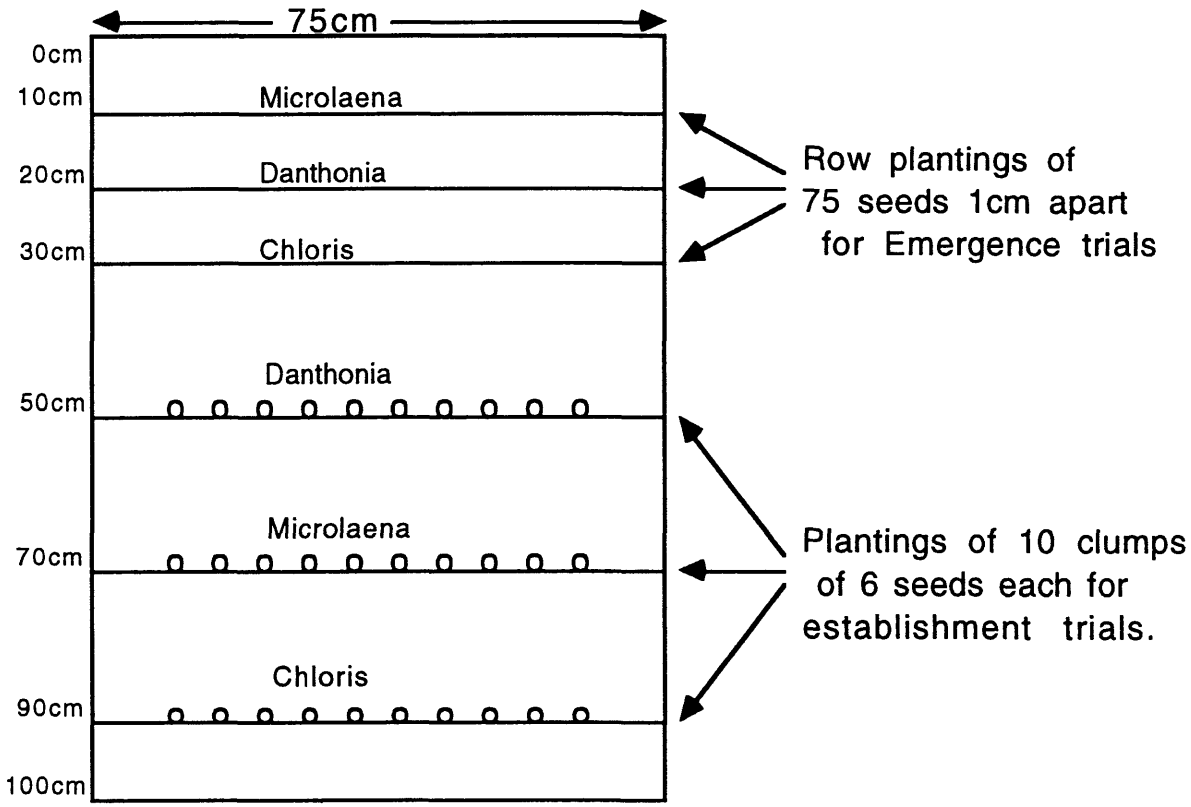


**Figure 4.4. Layout of rows within each subplot. Species were randomly allocated into rows for emergence and establishment trials. Replicate four in the bank plot is used here as an example.**

Because both emergence and establishment trials were being set up, seeds for these were sown in separate rows so that seedlings in the emergence trial could be removed after emergence, and seedlings in the survival trial would remain undisturbed. Within each sub-plot (or monthly sowing time) six rows, each 0.75 m long, were pegged out (Fig. 4.4) .Three rows ten centimetres apart on the most easterly side of the subplot were for the emergence trials of the three species, and three rows 20 cm apart on the most westerly side were for establishment trials of the same three species. Within both the emergence and the establishment trials the three grass species were randomly allocated to their rows.

### 4.2.5 Sowing Technique

Sowings commenced at both sites in October 1992 and concluded in May 1993, that is, a total of eight monthly sowings. Prior to each sowing, the relevant subplots were raked to a depth of approximately five centimetres to provide a soft seedbed.

For the emergence trial seeds were sown every centimetre along 0.75 m rows, that is, 75 seeds per row. This was done by cutting a furrow along the row with a knife, replacing the loose soil, planting the seeds in the loose soil at the required depth, and tamping the soil down. *Chloris truncata* and *Danthonia richardsonii* cv 'Taranna' were sown at 2 mm and *Microlaena stipoides* at 10 mm.

For the establishment trial ten clumps of six seeds each were sown at 7 cm intervals along the 0.75 m rows. This was done by digging a hole with a knife, into which the seeds were placed, the hole filled in, and the soil tamped down. Seeds were sown at the same depths as for the emergence trial. The seedlings which germinated in these clumps were later thinned out so that only one plant remained from each initial clump of seedlings.

### 4.2.6 Collection of Emergence and Survival Data

Seedlings in the emergence trial were counted and either removed with tweezers or killed with glyphosate applied with a paintbrush. The frequency at which these counts occurred varied depending on rainfall events.

The data in the survival trial were collected as the number of plants surviving on each of four occasions - 30th December 1992, 11th February, 15th April and 30th July 1993.

### 4.2.7 Measurement of Climatic Data

Throughout the experiment rainfall at the Cluny Road site and the Traffic Education Centre was measured using standard rain gauges. Ambient temperatures were recorded every three to five days from maximum/minimum thermometers inside Stevenson screens.

Soil temperatures over 24 hour periods were recorded once a month for some plots during the months of January, March, April, May, and July. Thermocouples connected to a data logger measured temperatures hourly at depths of 2 mm and 10 mm. Each depth was duplicated and each pair of readings was averaged. For any month measured, the maximum and minimum temperatures were averaged over all plots measured during that month.

### 4.2.8 Assessment of Soil Physical Features

4.2.8.1. Microtopography and Soil Surface Features

Microtopography was assessed by measuring the slope along a 1.0 m transect running at 90° to the seed rows, through the centre of each subplot (designated as 'slope 1'); and along a 0.75 m transect running parallel to the seed rows through the centre of each subplot ('slope 2'). Thus, within each replicate, 'slope 1' was measured at intervals of 0.75 m, and 'slope 2' was continuous through the long axis of the replicate. Slopes were then placed in classes for analysis (Appendix 2 Table A.3.). Soil surface features of each subplot were classed during September 1993 using a simple 'finger test' to see how soft the soil was and visual assessment of surface aggregate (Appendix 2 Table A.4.).

4.2.8.2. Water Infiltration Rate

A disc permeameter was used to measure the unsaturated conductivity of the soil in representative subplots within each plot during October 1993. The infiltration rates at tensions of 40, 30, 20 and 10 mm were used to calculate the saturated hydraulic conductivity and the number of soil pores within different size ranges. The method is outlined in Appendix 2.

### 4.2.9 Analysis of Results

4.2.9.1. Emergence

The total cumulative % emergence data out of a possible 100%, (as of the end of the experiment, July 30th 1993) were subjected to an analysis of variance using the NEVA program (Burr 1980) and means were separated using Duncan's Multiple Range test for significance. Because the experiment was of a split plot design, a composite error term was used to manually calculate Duncan's Multiple Range values when means from two subplots lying in different mainplots were compared.

The emergence of seedlings following episodic rainfall events during the experimental period was subjected to univariate, standard multivariate, and stepwise multivariate regression using the multivariate general linear model in the SYSTAT program (Wilkinson 1992). Following each rainfall event emergence data were expressed as a percentage of the sown seed that had not previously emerged and was theoretically capable of emerging. These data were regressed against 14 independent variables (See Appendix 2).

4.2.9.2. Survivorship

Final % survival was defined as the % of plants alive out of a possible 100%, at the end of the experiment (30th July 1993) and these data were subjected to an analysis of variance using the NEVA program (Burr 1980). Where relevant, composite error terms were calculated as outlined above for the emergence data. The maximum % survival of each species for each monthly sowing was defined as the highest % of living plants attained during the experiment, as recorded at one or more of the four survival measurement dates, and the % mortality was calculated by subtracting the final % survival from the maximum % survival.

## 4.3 RESULTS

### 4.3.1 Rainfall and Stevenson Screen Temperature

The rainfall and temperatures recorded at the TEC between October 1992 and July 1993 differed on average by only 4 mm and 2° C respectively from those recorded at Cluny Road. The following description of results refer to means of measurements taken at the two sites.

4.3.1.1. Rainfall.

The highest monthly rainfall recorded during the experimental period was in January 1993 with 152.5 mm, and the lowest in April 1993 which had no rain (Fig. 4.5). Rainfall was over 50 mm in October 1992 and was higher in the subsequent three months. During February to May 1993 less than 40 mm per month fell, while in June and July it was over 50 mm per month.

The fluctuations in rainfall recorded between October 1992 and July 1993 followed the same general pattern as the averages recorded at Laureldale Research Station, Armidale between 1967 and 1986, but rainfall during individual months was lower than average, except in January, June and July 1993 (Fig. 4.5). In November and December 1992 rainfall was only slightly lower (3.2 and 4.9 mm respectively) and October was 27.2 mm lower than the average. Falls in February, March and May were less than half the average, and no rain fell in April which had an average of 35.9 mm. January, June and July received 27.7, 18.6, and 25.1 mm more rain respectively than the average (Fig. 4.5).

4.3.1.2. Stevenson Screen Temperatures

The highest mean maximum and minimum temperatures in the Stevenson screen were recorded during January (31.1/12.4° C) and February (30.8/9.7° C) 1993, and the lowest mean minimum temperatures were recorded during May to July (0.8, -0.3, and -0.1° C respectively) (Fig. 4.6).

The fluctuations in average maximum and minimum temperatures recorded between October 1992 and July 1993 followed the same general pattern as those recored at Laureldale Research Station, Armidale between 1967 and 1986, but in general were higher and lower respectively (Fig. 4.6). Average minimum temperatures in October, December, February, March, April and May were 3 - 4° C lower than the Laureldale average, while all other months differed by less than 3° C (Fig. 4.6). Average maximum temperatures in January, February, April, and July were between 5.7 and 6.7° C higher than the Laureldale average, March, May and June were 3.4 - 4.8° C higher, and all other months differed by less than 3° C (Fig. 4.6).

### 4.3.2 Soil Temperatures

In general, soil temperatures measured over any 24 hour period fluctuated more at 2 mm depth than at 10 mm depth (Table 4.1). Average maximum and minimum soil

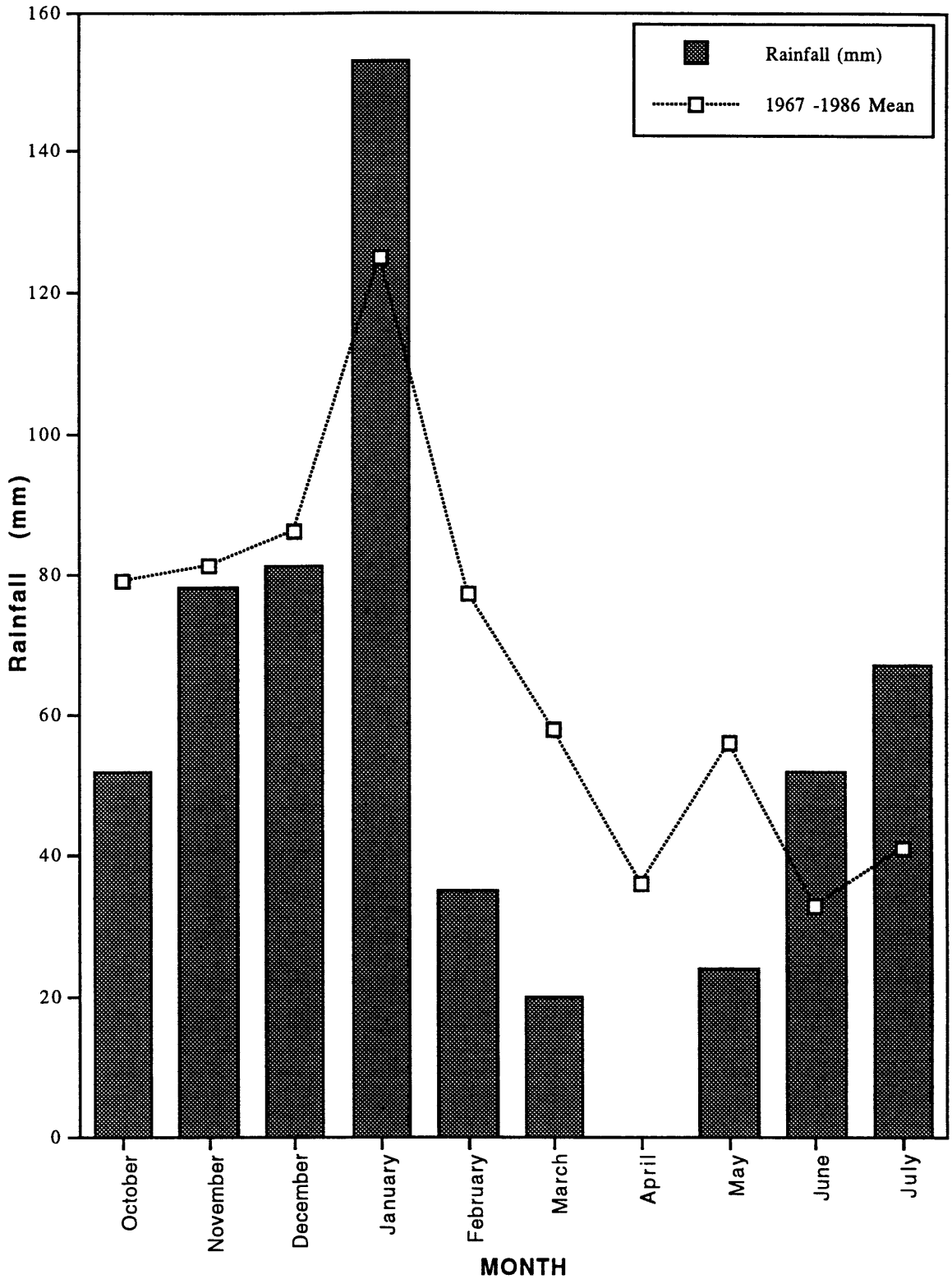


**Figure 4.5. Monthly rainfall between October 1992 and July 1993; means of sites at Cluny Road, 5 km north of Armidale and the Traffic Education Centre, Armidale; and average monthly rainfall between 1967 and 1986 recorded at Laureldale Research Station, Armidale, NSW (from Charles 1988).**

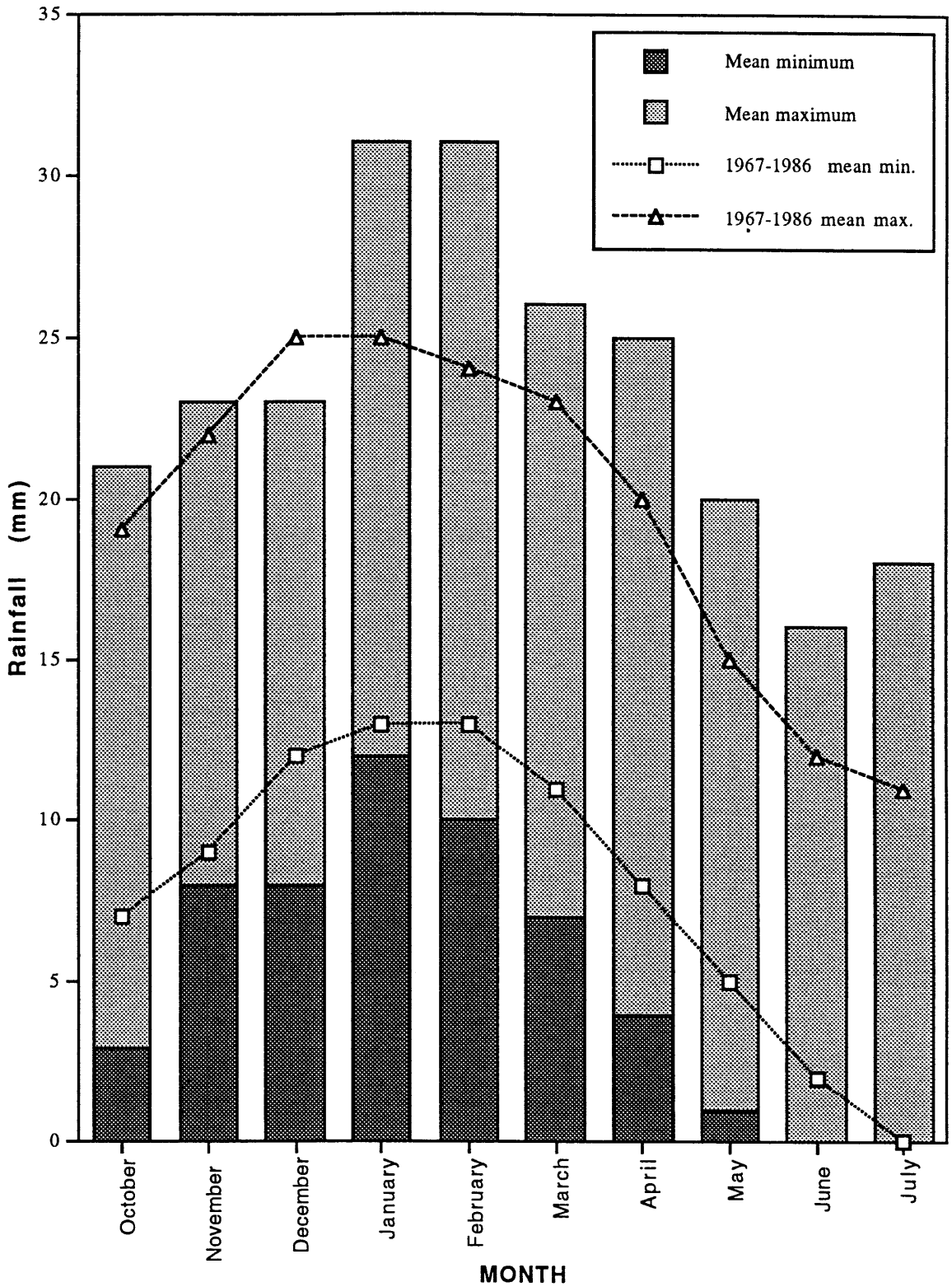


**Figure 4.6. Average monthly diurnal maximum and minimum temperatures between October 1992 and July 1993; means of temperatures taken every three to five days at the Cluny Road site, 5 km north of Armidale, and the Traffic Education Centre, Armidale; and average monthly maximum and minimum temperatures between 1967 and 1986 recorded at Laureldale Research Station, Armidale (from Charles 1988).**

temperatures were highest when measured in January, and declined through to July when they were the lowest (Table 4.1). The highest average maximum soil temperature was 49.9° C measured at 2 mm depth during January and maximum soil temperatures of over 40° C occurred at 2 mm up until March 1993 (Table.4.1). During May mean soil temperatures measured never exceeded 24.4° C. The lowest mean maximum temperature of 19.6° C was recorded in February 1993 at 10 mm depth. The highest mean minimum soil temperature was 20.0° C recorded at 10 mm during January and the lowest was 3.7° C at 2 mm during July.

### 4.3.3 Emergence Trial Results

#### 4.3.3.1. % Emergence Over Time

Rainfall events of 40 mm or more were associated with substantial emergence events of at least some of the species sown (Table 4.2, Fig. 4.7). Seedlings of the three species which emerged from September through to January sowings generally did so within a month of sowing following rainfall events and generally reached their maximum emergence percentage within two to ten weeks (Table 4.2, Fig. 4.7).

**Table 4.1. Average maximum, minimum and standard deviations of soil temperatures measured at 2 mm and 10 mm depth at a roadside native grass establishment trial site three km north of Armidale, NSW at the intersection of Cluny and Kirby roads, in January, March, April, May and July 1993. Means of hourly readings over 24 hour periods in 4, 6, 6, 5, and 6 plots respectively.**

| MONTH | 2mm | 2mm | 2mm | 10mm | 10mm | 10mm |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Stand. Dev. | Maximum | Minimum | Stand. Dev. |
| | | | | | | |
| January | 49.9 | 18.8 | 10.1 | 45.7 | 20.0 | 8.4 |
| March | 43.7 | 14.2 | 9.6 | 39.2 | 15.5 | 7.7 |
| April | 38.2 | 11.6 | 8.1 | 34.5 | 12.9 | 6.8 |
| May | 24.4 | 7.4 | 4.9 | 22.1 | 8.5 | 4.1 |
| July | 20.2 | 3.7 | 4.8 | 19.6 | 4.3 | 4.3 |

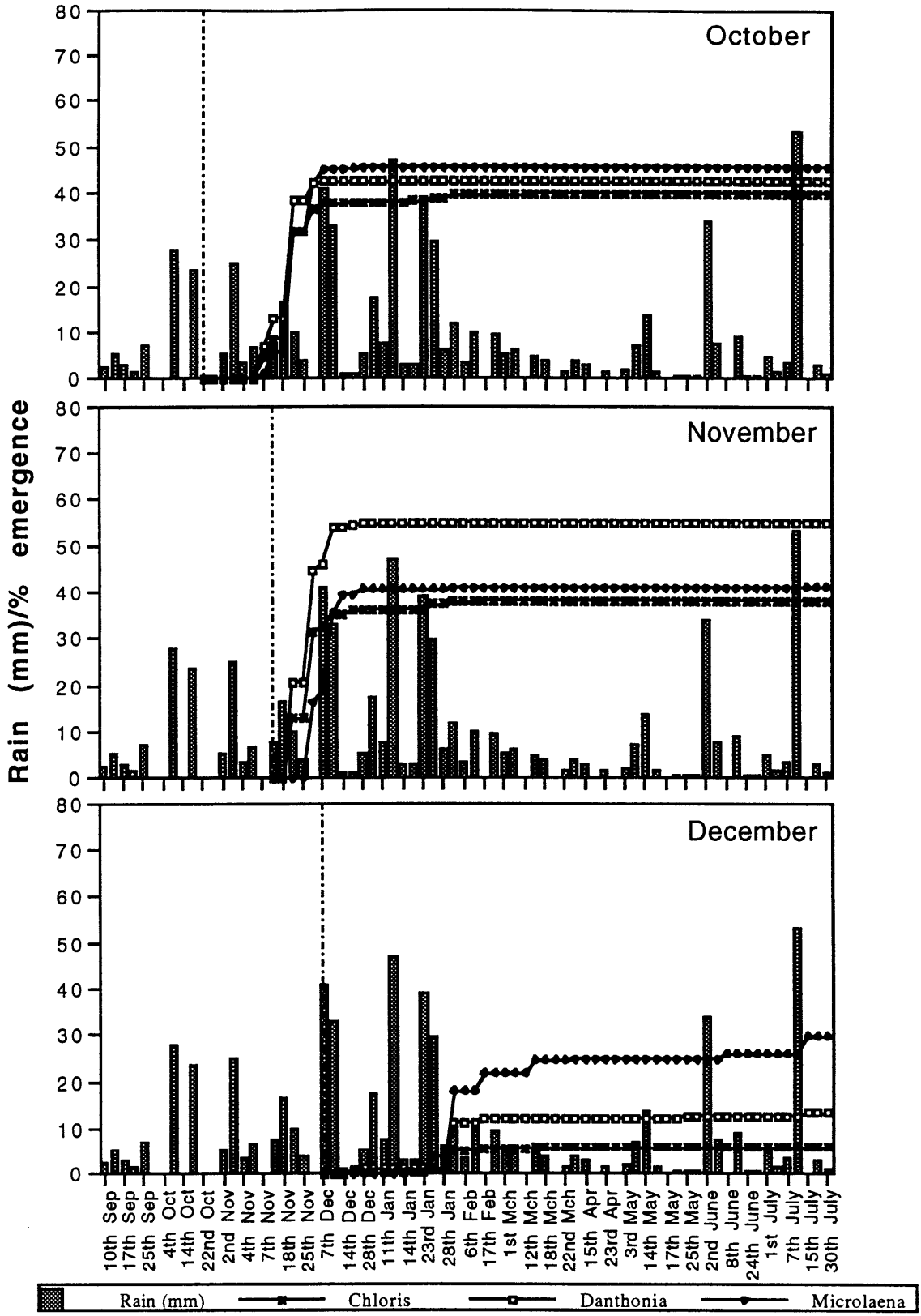


**Figure 4.7. Cumulative emergence of *Chloris truncata*, *Danthonia richardsonii* cv. 'Taranna', and *Microlaena stipoides* sown in October, November and December 1992, and January, February, March, April and May 1993; means of 7 roadside environments; and daily rainfall at the Cluny Road site. (Perforated lines indicates sowing dates.)**

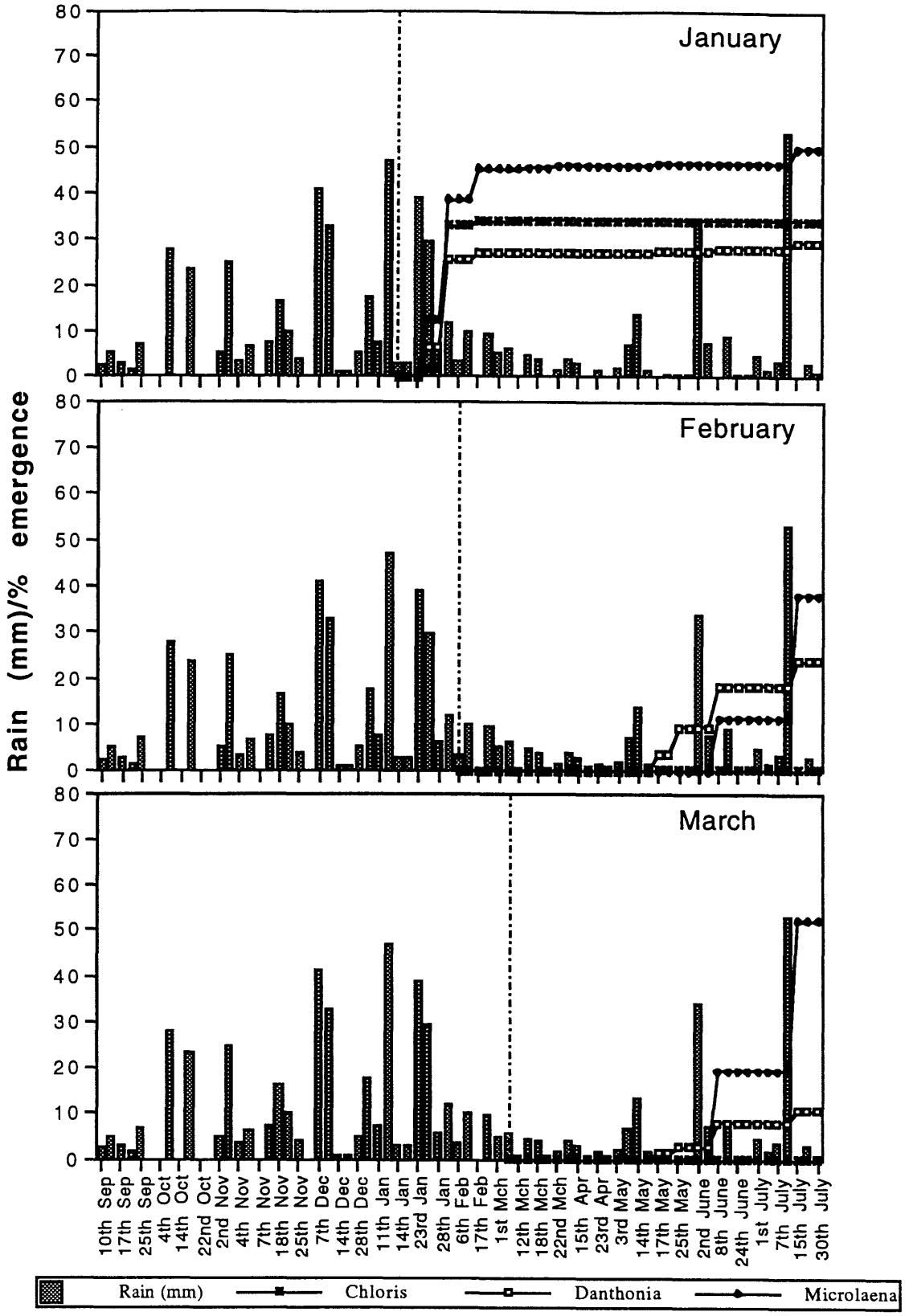


**Figure 4.7 (continued)**

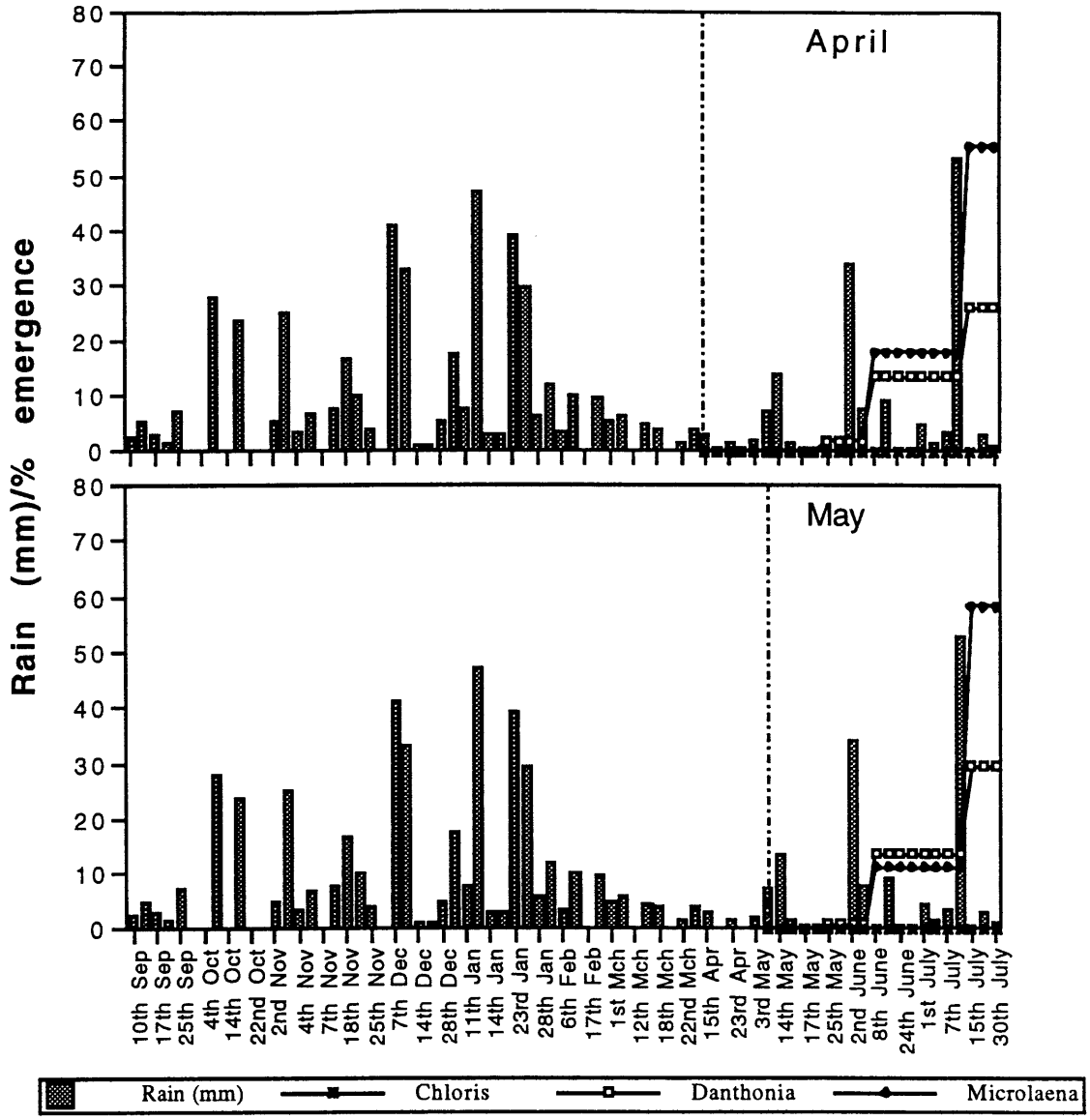


**Figure 4.7 (continued).**

**Table 4.2. Number, date(s), and amount, of rainfall events between October 1992 and July 1993; and monthly sowings between October 1992 and May 1993 from which substantial emergence events occurred following these rainfall events.**

| Rain Event No. | Date(s) on which rain fell | Amnt. (mm) | Sowings from which noticeable.emergence occurred |
|---|---|---|---|
| 1 | 2,3,4 & 6/11/92 | 40.0 | October |
| 2 | 12,18,20 & 25/11/92 | 38.0 | October & November |
| 3 | 7 & 9/12/92 | 74.0 | November |
| 4 | 23, 26 & 28/1/93 | 74.5 | December & January: |
| 5 | 3, 11, 14 & 15/5/93 | 24.0 | February |
| 6 | 2 & 7/6/93 | 41.5 | February, March, April & May |
| 7 | 13/7/93 | 56.0 | December, January, February, March, April & May |

No *Chloris truncata* seeds emerged from the February through to May sowings, while *Danthonia richardsonii* cv 'Taranna' and *Microlaena stipoides* seed sown in these months did not emerge until May or June (Fig. 4.7.).

4.3.3.2. Final Cumulative % Emergence

The three species varied significantly ($P < 0.05$) in their final cumulative % emergence from different monthly sowing times. *C. truncata* had less than 1 % emergence in February and failed to emerge from the March to May sowings. and *M. stipoides* exhibited over 40 % emergence from all sowings except December and February (Fig. 4.8). Emergence of *M. stipoides* from the January through to May sowings was significantly greater than the other two species. The highest % emergence of *C. truncata* was from the October, November and January sowings while the highest % emergence of *Danthonia* occurred from November sowings, when it was significantly ($P < 0.05$) greater than the other two species, and from the October sowings (Fig. 4.8).

There were significant differences in emergence of seedlings among the seven environments sown from October to May, averaged over all species (Fig. 4.9). The topbank environment had significantly ($P < 0.05$) higher emergence than all the others except the bank and the old road, and the skidpan environment was significantly lower than all the rest.

Total % emergence in the seven environments varied significantly ($P < 0.05$) with month of sowing averaged over all species (Fig. 4.10). October, November and January sowings had the highest emergence with five or six environments having over 30 %

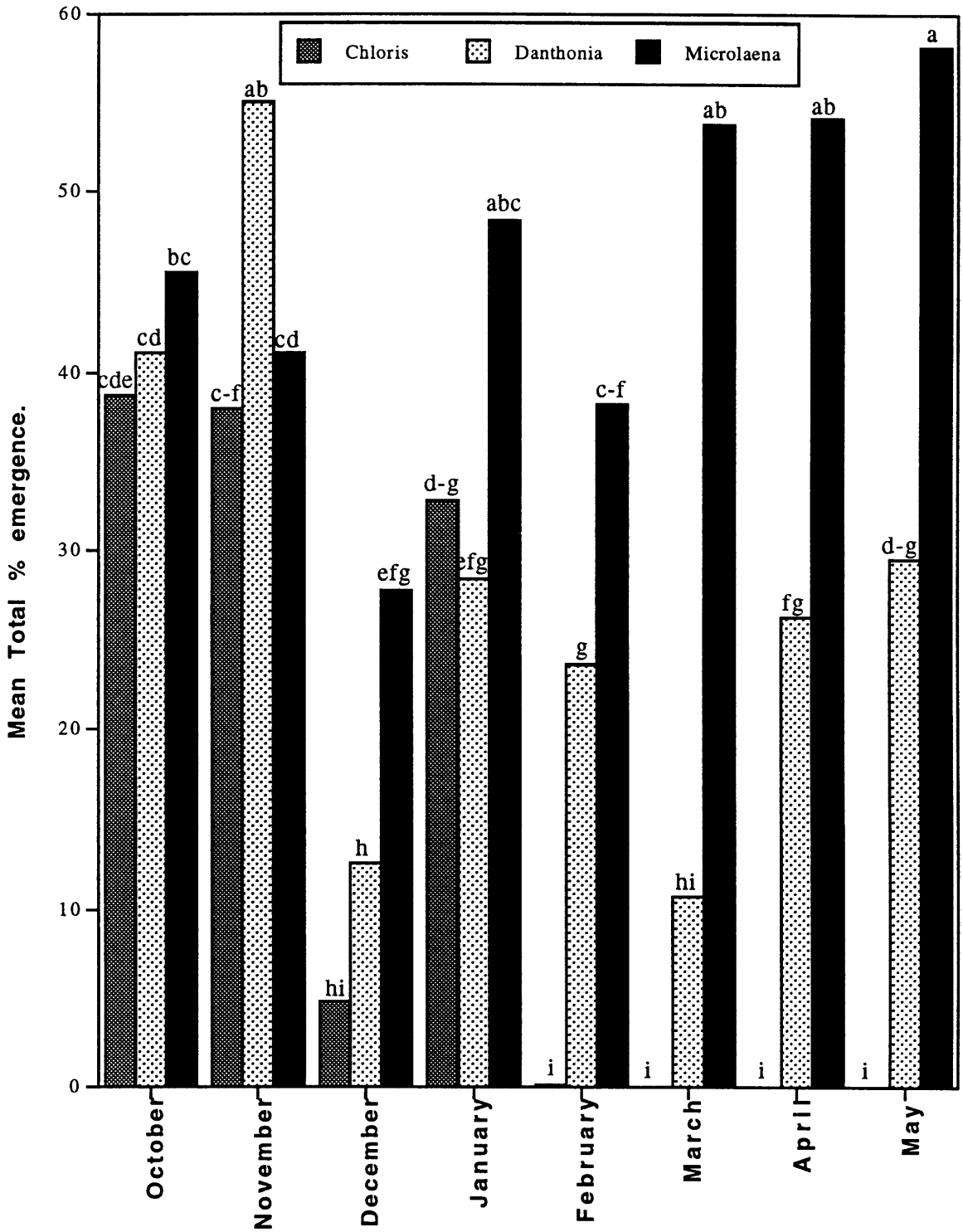


**Figure 4.8. Total % emergence of *Chloris truncata*, *Danthonia richardsonii* cv. 'Taranna' and *Microlaena stipoides* sown monthly from October 1992 to May 1993 at a roadside site; means of data from 7 roadside environments. Means differing significantly ($P < 0.05$) are indicated by different letters.**

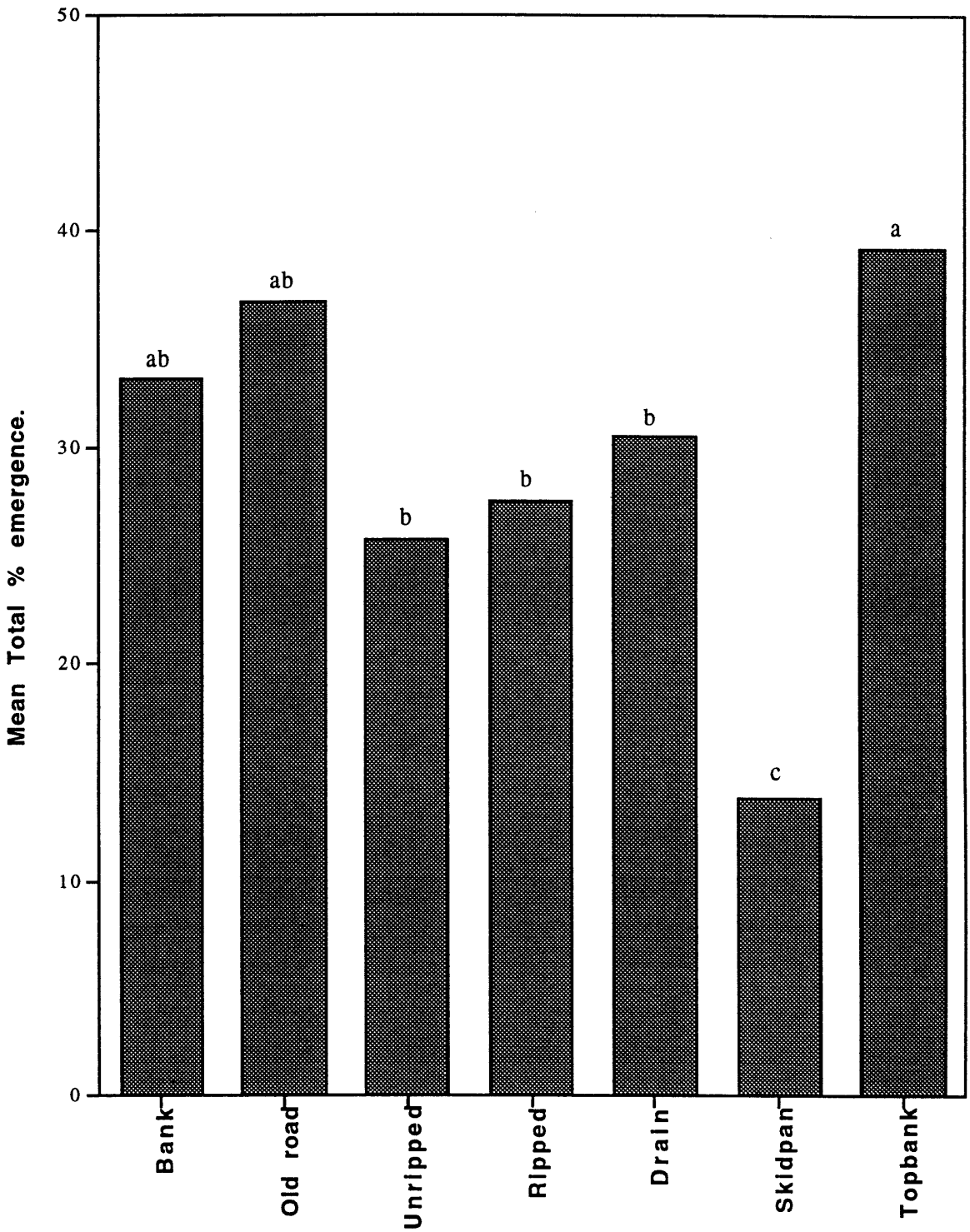


**Figure 4.9. Total % emergence in 7 roadside environments; means of emergence data of *Chloris truncata*, *Danthonia richardsonii* cv. 'Taranna' and *Microlaena stipoides*, sown monthly from October 1992 to May 1993. Means differing significantly ($P < 0.05$) are indicated by different letters.**

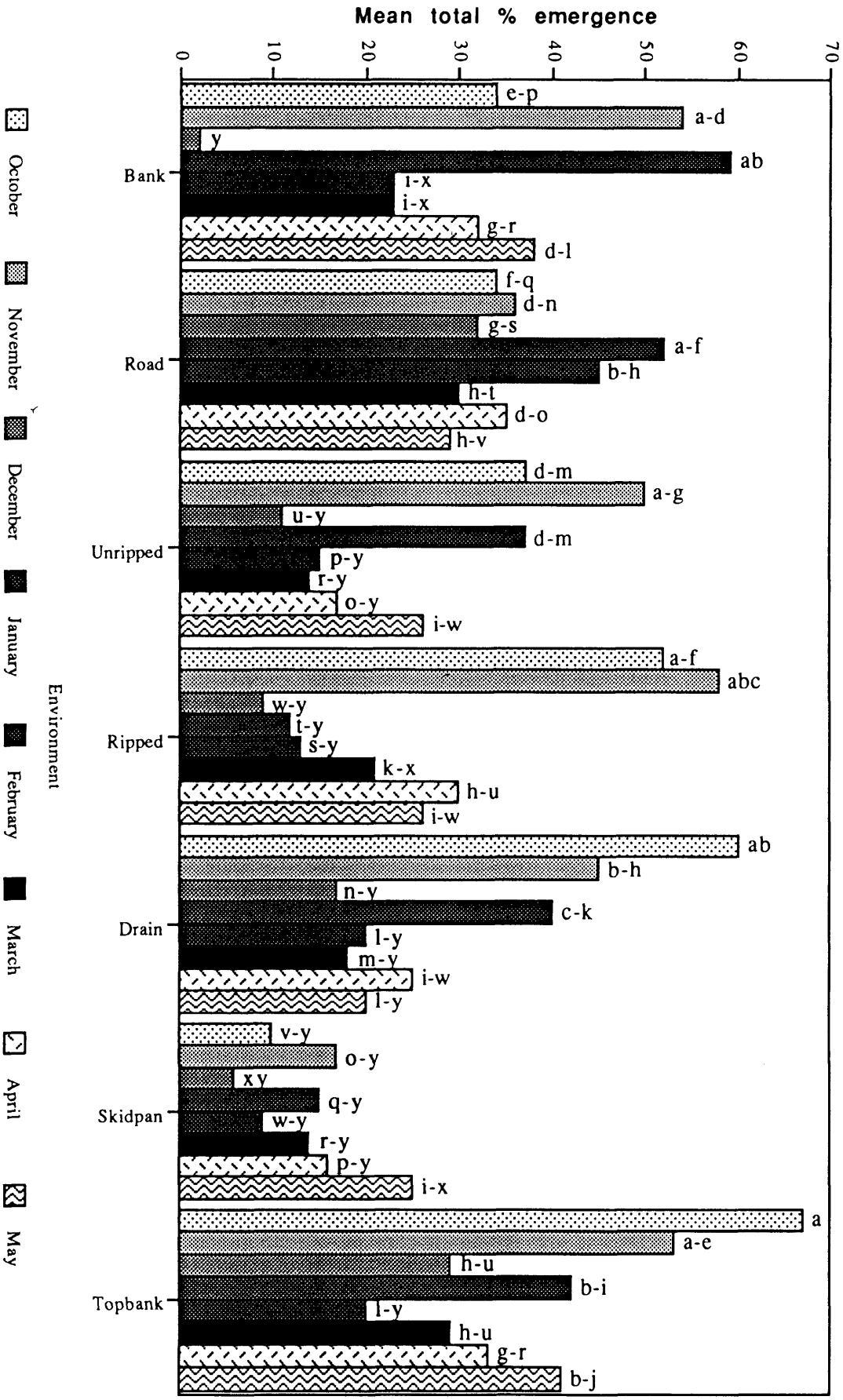


**Figure 4.10. Total % emergence in 7 roadside environments sown monthly from October 1992 to May 1993; means of emergence data of *Chloris truncata*, *Danthonia richardsonii* cv. 'Taranna', and *Microlaena stipoides*. Means differing significantly ($P < 0.05$) are indicated by different letters.**

emergence, while the other months had most environments with under 30 %. The old road environment had around 30 % or more for all months of sowing and the ripped environment had 50 % or greater emergence in October and November, but was always lower than 30 % and often 20 % or lower in later months. Overall the December sowings had the lowest emergence with all plots except the old road having under 30 % emergence. Of all the plots the skidpan had the lowest % emergence over all the sowing times (Fig. 4.10).

There was no significant interaction between species and environments, indicating that the relative emergence of the different species was the same for each environment.

Univariate, standard multivariate, and stepwise regressions of seedling emergence against 14 independent variables only explained less than 38% of the variance and so the results are not included.

### 4.3.4 Survival Trial Results

#### 4.3.4.1. Collection of Survival Data

The collection of plant survival data was affected by the rainfall and temperature pattern which occurred during the experimental period (Fig. 4.5, Fig. 4.7). For October through to December sowings, plant survival data were collected at all four occasions, and for the January sowing, at the last three occasions. Because seeds sown in February through to May did not emerge until after the April measurement, sufficient survival data could not be collected for these months. As a result only data from the October through to January sowings can be considered as true survival data and were used in the analysis of variance. In addition, the precise ages of the plants at the times of the four measurements was not known, so an estimation of age was derived by extrapolating from the emergence data.

#### 4.3.4.2. Comparison of Survival and Emergence

For October to February sowings the mean maximum percentage survival of each species obtained between sowing time and the 30th of July 1993 as recorded at one or more of the four measurement dates, generally closely matched the percentage emergence for the corresponding month of sowing (Table 4.3). The difference between maximum percentage survival and percentage emergence was 10 % or less except for *C. truncata* sown in October and November, where the differences were 10.1 % and 13.4 % respectively, and *M. stipoides* sown in October and February, where the differences were 14.2 % and 22.7 % respectively. For the March to May sowings the difference ranged between 14.2 % and 37.9 %, except for *C. truncata* which failed to emerge at all (Table 4.3).

#### 4.3.4.3.Survival Over Time and Final % Survival

The mortality of *C.truncata* and *D. richardsonii* seedlings sown in the October to January sowings was generally lower than 10 % except *C. truncata* from the January sowing which was 18.6 % (Table 4.3). The mortality of *M. stipoides* was between 13.3 % and 22.5 % except for the December sowing, where there was no mortality.

**Table 4.3. Percent emergence, maximum % survival between December 30th 1992 and July 1993, final % emergence as of 30th July 1993, and % mortality between December 1992 and July 1993 of *Chloris truncata*, *Danthonia richardsonii* cv. 'Taranna' and *Microlaena stipoides* sown monthly between October 1992 and May 1993; Means of seven roadside environments.**

| Species | CHLORIS | | | | DANTHONIA | | | | MICROLAENA | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Emerg | Max % Surv. | Final % Surv. | % Mort. | % Emerg | Max. % Surv. | Final % Surv. | % Mort. | % Emerg | Max. % Surv. | Final % Surv. | % Mort. |
| Month Sown | | | | | | | | | | | | |
| OCTOBER | 39.9 | 50.0 | 43.2 | 6.8 | 42.5 | 52.5 | 48.2 | 4.3 | 45.5 | 59.6 | 43.9 | 15.7 |
| NOVEMBER | 38.1 | 51.5 | 46.4 | 5.1 | 55.1 | 49.6 | 42.1 | 7.5 | 41.1 | 50.4 | 37.1 | 13.3 |
| DECEMBER | 5.7 | 11.1 | 7.5 | 3.6 | 13.3 | 10.7 | 5.0 | 5.7 | 29.7 | 28.2 | 28.2 | 0.0 |
| JANUARY | 34.3 | 55.0 | 36.4 | 18.6 | 31.0 | 32.5 | 26.1 | 6.4 | 51.5 | 50.0 | 30.4 | 19.6 |

For individual months of sowing, there was no significant difference ($P < 0.05$) among percentage survival of the three species except for the December sowing where *M. stipoides* was significantly higher than *C. truncata* and *D. richardsonii* (Fig. 4.11). The October sowing of all 3 species and the November sowing of *C. truncata* were significantly higher ($P < 0.05$) than December and January sowings, and *C. truncata* and *D. richardsonii* sown in December were significantly lower than all other sowings. Survival of *C. truncata* and *D. richardsonii* was significantly higher ($P < 0.05$) in October and November than in January, which was significantly higher than in December (Fig. 4.11). Survival of *M. stipoides* from December and January sowings did not differ significantly ($P < 0.05$), but was significantly lower than the October sowing, with the November sowing intermediate.

When averaged over the October, November, December and January sowings, the final percent survival on the Unripped, Ripped and Topbank environments did not differ significantly ($P < 0.05$) from one another, and were significantly higher than the rest (Fig. 4.12). The Bank, and Drain did not differ significantly from one another, and were significantly higher than the Skidpan, which was significantly higher than the Old Road (Fig. 4.12).

There were significant differences ($P < 0.05$) in survival among sowing times in each environment, except the Old Road and Skidpan plots (Figure 4.13). Survival from October and November sowings was significantly higher than both December and January sowings in the Ripped environment and higher than December in the Bank, Unripped and Topbank (Fig. 4.13). In the Drain, survival from the October sowing was significantly higher than the rest, which did not differ significantly from one another, and in the Bank, Unripped and Topbank environments, survival from January sowings was significantly ($P < 0.05$) higher than December (Fig. 4.13).

## 4.4 DISCUSSION

### 4.4.1 Emergence

The emergence results were strongly affected by the rainfall pattern recorded during the experimental period. Rainfall events of 40 mm or more during October through to January were frequent enough to allow emergence within a few weeks of sowing. These emergence responses can therefore be related directly to rainfall and temperature conditions experienced during the month of sowing. The months of February, March, April and May each had less than 40 mm of rain, and seedlings from sowings during these months did not emerge until over 40 mm of rain fell in June. These results are therefore related to rainfall and temperature conditions in June, and to the survival of seed in the soil during the dry period. Watt (1982) found that cracking black soils to a depth of 6 mm could dry to below plant wilting point within a day or so after rain, and Michalk and Herbert (1978) found that rainfall was less effective (calculated from Prescott's ratio, cited in Hounam 1961) in summer when temperature and evaporation were higher than in winter. The

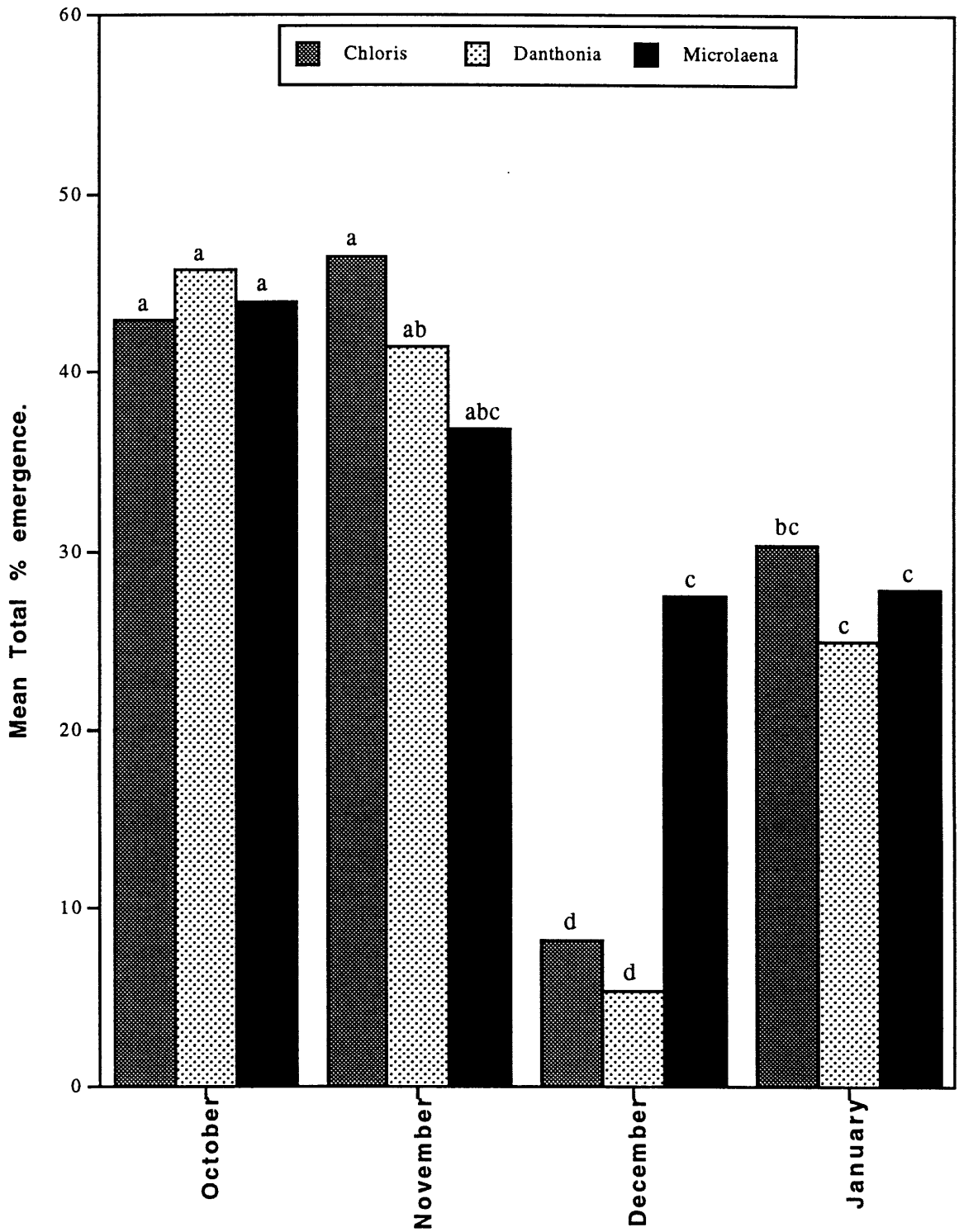


**Figure 4.11. Final mean % survival as of 30/7/93 of *Chloris truncata*, *Danthonia richardsonii* cv. 'Taranna' and *Microlaena stipoides*, sown monthly from October 1992 to May 1993; means of data from 7 roadside environments. Means differing significantly ($P < 0.05$) are indicated by different letters.**

nature of the soil at the two field sites suggests rapid drying, especially under the denuded conditions, and it would appear that 'effective rain', although not calculated, had a threshold of 40 mm or more at these sites.

*Chloris truncata* and *D. richardsonii* had their highest emergence from October and November sowings when maximum/minimum ambient temperatures were 20.9/3.2 and 22.6/7.7° C respectively, and predicted mean soil temperatures at 2 mm and 10 mm depths were 29.9/10.2 and 31.6/14.7° C respectively. Maze *et al.* (1993) reported that *C. truncata* had over 50% germination over a range of temperatures, and that water potential was most likely the limiting factor in germination rather than temperature. Lodge (1981) reported that the most favourable period for emergence and establishment of *C. truncata* on the north-west slopes of NSW was from mid-summer to early autumn, and for *Danthonia linkii* from mid-autumn to late winter. Lodge and Whalley (1981) reported that the highest % germination on a thermogradient plate of *C. truncata* of 43 - 57% was achieved within the range of 15 - 35° C, and Watt and Whalley (1982) report maximum emergence of *C. truncata* from a seedbed temperature of 25° C, and over 80% emergence within the range 15-30° C, with approximately 65% at 35°. The mean percentage emergence of 38 % for *C. truncata* from October and November sowings in this experiment was a bit lower than Watt and Whalley's (1982) and this is perhaps because the data in this study were averaged over all environments, including the skidpan, which had an extremely low percentage emergence. The emergence data of *D. richardsonii* from these months of sowing were comparable to those of Lodge and Schipp (1993) who found that percentage emergence of cv. 'Taranna' appeared to be related to mean maximum soil temperatures, decreasing in winter as temperatures declined below 20° C and increasing in spring when it was greater than 23° C, and in summer when temperatures were 30 - 35° C.

The low percentage emergence of all three species from the December sowing was significantly ($P < 0.05$) lower than for November, even though rainfall and maximum and minimum temperatures for these months were very similar. A possible explanation for this is that the heavy rain which fell on the day of the December sowing and soon after, caused crusting of the soil surface, which physically impeded seedling emergence. January had both the highest rainfall (153 mm) and maximum (49.9° C) and minimum (18.8° C) temperatures at 2 mm depth of any month, and while emergence of *C. truncata* and *D. richardsonii* was lower than from the November sowing, they still achieved 32.7% and 28.4% emergence respectively. It seems likely that in January the high rainfall counteracted to some extent the effects of the high temperatures.

The conditions in June, when the February to May sowings emerged, appeared to be unsuitable for *C. truncata*, if we assume that seed was still viable in the soil. No emergence of *C. truncata* occurred from the March, April, and May sowings, and very little from the February sowing. That this lack of emergence was associated with a mean maximum ambient temperature during June of only 15.8° C and a mean minimum of -0.3° C concurs with the findings of Lodge and Whalley (1981) and Watt and Whalley (1982). That *D. richardsonii* showed a general (though non-significant) increase in percentage emergence from the February through to May sowings may indicate that some

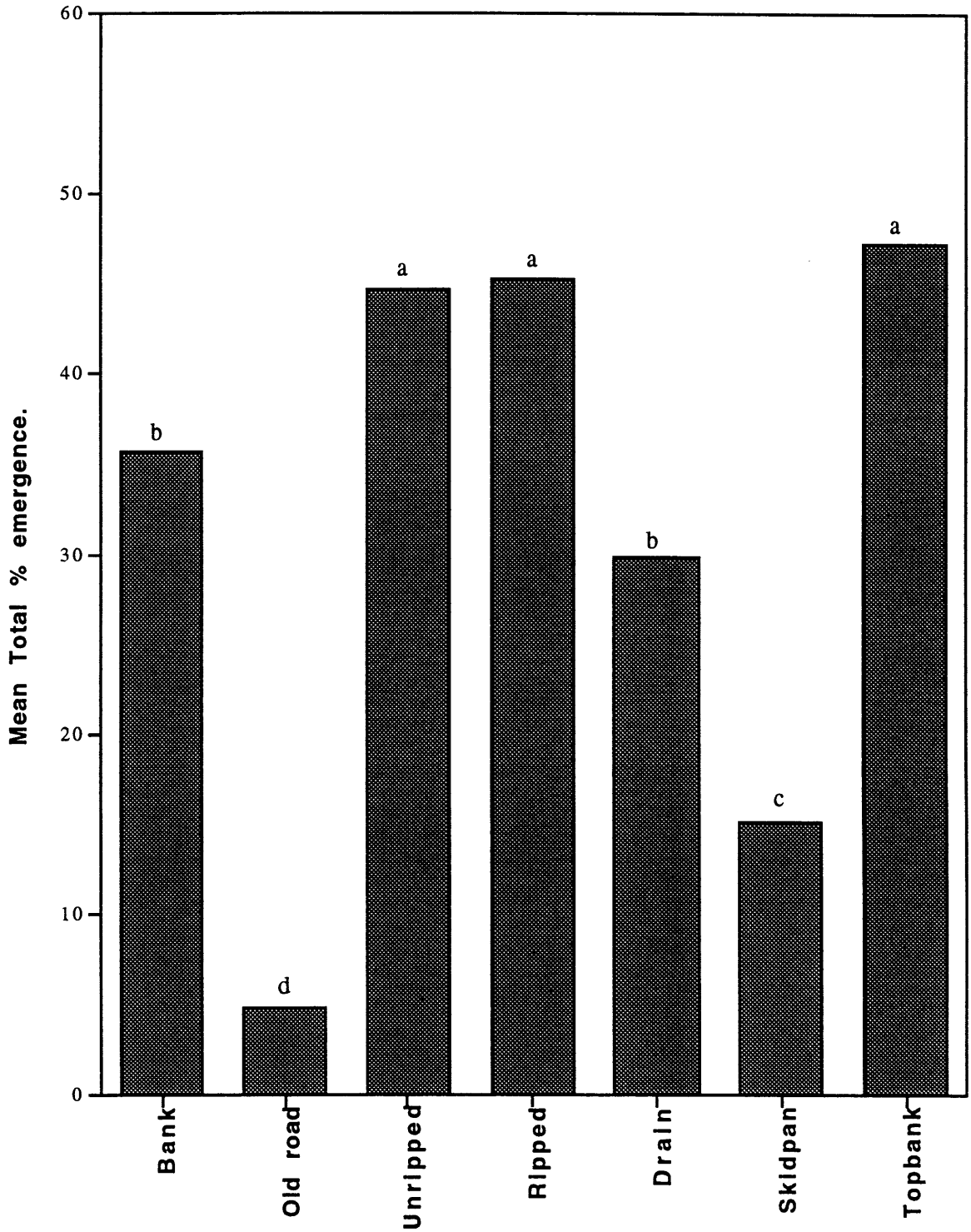


**Figure 4.12. Final mean % survival as of 30/7/93 in 7 roadside environments; means of data of *Chloris truncata*, *Danthonia richardsonii* cv. 'Taranna' and *Microlaena stipoides*, sown monthly from October 1992 to January 1993. Means differing significantly ($P < 0.05$) are indicated by different letters.**

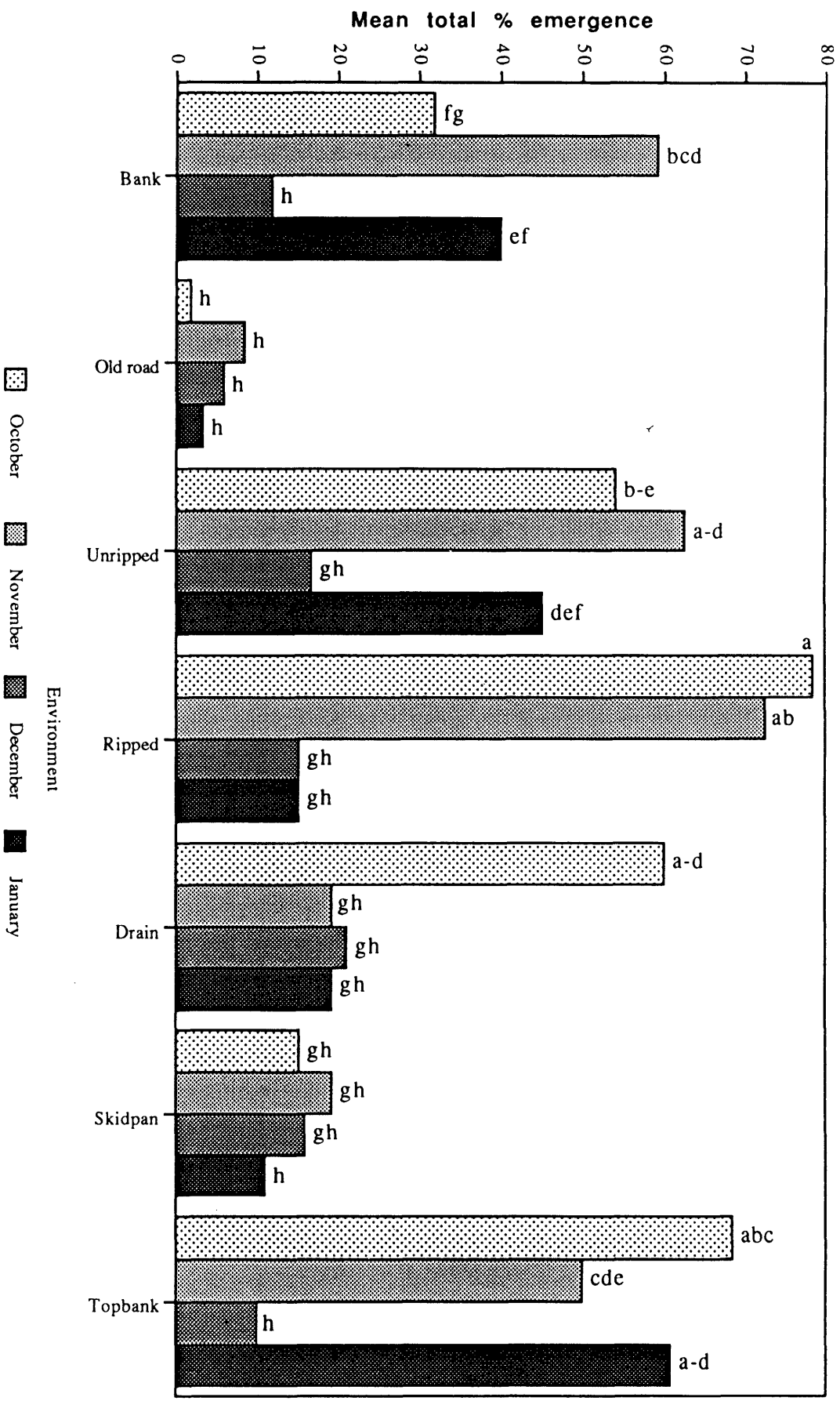


**Figure 4.13.** Final mean % survival as of 30/7/93 in 7 roadside environments sown monthly from October 1992 to January 1993; means of data of *Chloris truncata*, *Danthonia richardsonii* cv. 'Taranna', and *Microlaena stipoides*. Means differing significantly ($P < 0.05$) are indicated by different letters.

seed may have lost viability or become dormant in the soil during the dry period. The lower temperatures experienced in June may have further depressed the general emergence percentage. Silcock and Smith (1990) found that seeds of four western Queensland pasture species varied considerably in their viability and dormancy after being stored in the soil for two years under dry conditions. It is possible that some secondary dormancy or loss of viability ocurred during the dry months of this experiment. Watt (1974, 1978) documented the occurrence on cracking black soils of an 'intermediate stationary phase' termed 'hydropedesis' in the germination of some grass species whereby seeds germinate but further development is arrested by reduced soil water potentials. It has been found that survival of desiccated hydropedetic seed of *Dichanthium sericeum* was high (Watt 1974, 1978, 1982), that of *Danthonia linkii* was low, and very little *Chloris truncata* seed became hydopedetic, and of that which did, few survived desiccation (Watt 1982).

*M. stipoides* appeared to be the least affected by temperature conditions, and it seems likely that given adequate rainfall, emergence from sowing in most months is possible. In addition, the maximum percentage emergence for this species was highest from the March, April, and May sowings, after the seeds had been in the soil for four, three, and two months respectively. Either this time delay appeared to have a positive effect on percentage emergence, or the climatic conditions in June were highly favourable for *M. stipoides* emergence. The higher percentage emergence of *M. stipoides* than *D. richardsonii* from the February through to May sowings may also have been related to the greater seed size and depth of planting of the former species. Mean maximum soil temperatures during March and April were about 4° C lower at 10 mm depth, where *M. stipoides* seeds were sown than at 2 mm depth, where the other two species were sown.

The particularly low percentage emergence obtained from the skidpan is possibly because this environment, unlike all the others, was on subsoil. Soil in this environment tended to form a crust approximately 1mm thick, probably as a result of its high clay content - a feature of this type of duplex sedimentary soil. (Jessop 1965). Exploratory penetrometer measurements indicated that this environment had soil with the lowest bulk density of any of the environments, and a saturated hydraulic conductivity midway in the range for all environments (Appendix 2). The environment with the highest percentage emergence was the Topbank which also had the least disturbed soil, the highest saturated conductivity (Appendix 2), and there were also adjoining patches of native grassland. It is possible that the soil here had beneficial features which were absent in the other environments. The old road environment had a 2 - 5 cm layer of topsoil overlying the extremely compressed surface of the old dirt road surface, and had the second lowest unsaturated hydraulic conductivity of any of the environments. The high percentage emergence achieved there can probably be attributed to confinement of soil moisture to this topsoil layer, enabling the seeds to imbibe water more effectively. The fact that the ripped environment - one which might be expected to have a high percentage emergence - was intermediate, was probably because the beneficial effects of the ripping seemed to wear off as the experiment progressed. A high percentage emergence from this environment occurred from the October and November sowings, but was low from all other sowings.

In the bank, unripped, ripped, skidpan and topbank environments percentage emergence from February - May sowings generally increased with each month, being lowest from February and highest from May sowings. This indicates that, on average, the longer the seeds remained in the soil without water, the lower the percentage emergence.

### 4.4.2 Survival

The highest percentage survival was from the October and November sowings for all three species, indicating that plants sown in these months were able to establish prior to the dry months of February to May. Survival from December sowings was low, except for *M. stipoides*, concurring with the emergence data for this month. The same effect of heavy rain on the day of sowing, causing crusting, and also a shorter period before the dry months, influenced these results. Survival from the January sowing was significantly lower ($P < 0.05$) than from October and November sowings, which also concurred with the emergence data, however there appeared to be a higher mortality rate over time which caused a lower percentage survival.

Survival of seedlings on the old road environment was the poorest, and considering that this environment had the second highest percentage emergence, a high mortality rate must have occurred over time. The poor survival can be attributed to the almost impermeable layer of the compressed dirt road, and the rapid drying out of the topsoil layer. Percentage survival on the bank, drain, and skidpan closely matched the emergence for those environments, indicating a low mortality rate of seedlings over time. In the unripped, ripped, and topbank environments percentage survival was higher than percentage emergence, but this was probably due to emergence being averaged over eight monthly sowings, and survival over only four.

The depth of sowing possibly influenced the results of this trial, in that soil temperatures and moisture probably varied considerably at different depths. Greater seed burial has been suggested as a way to increase the time of water availability to seeds and seedlings in revegetation of semi arid rangelands in the USA (Roundy *et al.* 1993). *D. richardsonii* cv. 'Taranna' should be surface sown (Lodge 1993), but given that this cultivar is being domesticated for its pasture value, cultivation would ensure that seeds were covered by some soil after sowing. This would also help prevent predation by ants. Seed of a number of native grasses including two *Danthonia* spp. (*D. carphoides* and *D. caespitosa*) failed to germinate when surface sown on soils with various controlled moisture contents and with and without straw mulch (Hagon and Chan 1977). Harper *et al.* (1965) and Winkel *et al.* (1991) outline the role of the heterogeneity of the soil surface in determining plant establishment. *C. truncata* has successfully emerged from 10 mm (99%) and 20 mm (59%) (Watt and Whalley 1982a), and some accessions of *M. stipoides* have emerged from up to 50mm depth (Beckers 1993).

4.4.3 Implications

These results indicate that all three species, if sown at the right time of year, given adequate rainfall and suitable temperatures are able to emerge and to survive at least in the short term. *D. richardsonii* appears to be the best of the three species used because of its good colonising ability and perennial life form. In this experiment it formed tussocks of up to 20 cm diameter one year after sowing in October and November. *C. truncata* is also a good colonising species, as recognised by Cameron (1961), who also noted that it readily colonised natural waterways. In this experiment *C. truncata* was often rhizomatous and formed a continous cover between plants one year after sowing in October and November. The possible disadvantage of *C. truncata* being only a short-lived perennial is somewhat offset by its prolific seeding ability. *M. stipoides* seems able to emerge when sown at any time of the year on the tablelands, provided there is adequate rainfall (C.E Jones 1993, pers. comm.), usually 40 mm or more as was shown in this experiment. Although survival of *M. stipoides* was relatively good (35-45%) when sown in October and November in this experiment, the plants were not as big and robust as *D. richardsonii* cv. 'Taranna'. This percentage could probably be improved by other types of seed bed preparation, denser planting, or because of its shade tolerance (Rose 1986; Taylor and Hedges 1984), planting in association with trees.

These results have shown that on the tablelands, both *D. richardsonii* cv. 'Taranna' and *M. stipoides* can be sown during dry summer periods and that seed can remain viable in the soil for several months until adequate rain in autumn or early winter enables emergence, albeit at a reduced rate. This means that artificial watering of these species is not necessary, and that once established, seed from these species can build up in the seedbank during dry periods without loss of viability. *C. truncata* seed appears to be less tolerant of prolonged dry periods, and have more specific climatic condition requirements than the other two species. *C. truncata* should be sown in October or November on the tablelands, or during summer when there is adequate soil moisture.

It is to be hoped that the use of native grasses in roadside revegetation will become possible in the next few years as species are domesticated and seed becomes available in commercial quantities. If some native herbs and groundcovers are combined with the grasses, the re-creation of native grasslands on roadsides can then become possible, not only providing a low-maitenance ground cover, but one that is aesthetically pleasing and environmentally sound.