Dynamics of plant populations in *Heteropogon contortus* (black speargrass) pastures on a granite landscape in southern Queensland. 4. The effects of burning on *H. contortus* and *Aristida* spp. populations

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Abstract

This paper reports an experiment undertaken to examine the impact of burning in spring together with reduced grazing pressure on the dynamics of *H. contortus* and *Aristida* spp. in *H. contortus* pasture in south-eastern Queensland.

The overall results indicate that spring burning in combination with reduced grazing pressure had no marked effect on the density of either grass species. This was attributed to 2 factors. Firstly, extreme drought conditions restricted any increase in *H. contortus* seedling establishment despite the presence of an adequate soil seed bank prior to summer; and secondly, some differences occurred in the response to fire of the diverse taxonomic groupings in the species of *Aristida* spp. present at the study site.

This study concluded that it is necessary to identify appropriate taxonomic units within the *Aristida* genus and that, where appropriate, burning in spring to manage pasture composition should be conducted under favorable rainfall conditions using seasonal forecasting indicators such as the Southern Oscillation Index.

Introduction

Burning in spring increases the proportion of *Heteropogon contortus* (black speargrass) in *H. contortus* pastures in southern Queensland (Tothill 1983; Walker *et al.* 1983; Paton and Rickert 1989). Furthermore, spring burning together with reduced grazing pressure both increases the proportion of *H. contortus* and reduces that of *Aristida ramosa* var. *speciosa* (purple wiregrass) (Orr *et al*. 1997; Orr and Paton 1997). Spring burning directly promotes the germination of *H. contortus* seed, increases seedling establishment and reduces the size of *A. ramosa* plants (Campbell 1996).

Earlier papers in this series reported the population dynamics of *H. contortus* (Orr *et al.* 2004a), seed production and soil seed banks of *H. contortus* (Orr *et al*. 2004b) and the population dynamics of *Aristida* spp. (Orr *et al*. 2004c). However, none of these studies considered the impact of burning. Given the impact of spring burning on pasture dynamics outlined above, it became necessary to understand how burning impacts on plant dynamics at “Glenwood”. Specifically, the recruitment of 4.3 seedlings/m^2 of *Aristida* spp. measured at “Glenwood” in autumn 1991 (Orr *et al*. 2004c) indicated a potential for the overall proportion of *Aristida* spp. in the pasture to increase as a result of this seedling establishment.

This paper reports an experiment designed to measure the impact of spring burning together with reduced grazing pressure on the dynamics of *H. contortus* and *Aristida* spp. at “Glenwood” between 1992 and 1996. For comparative purposes, results from this burning treatment are compared with data from the unburnt 0.3 beasts/ha stocking rates in native pasture in both the narrow-leaved ironbark and silver-leaved ironbark landscape positions.

Materials and methods

Grazing study

A grazing study was conducted between 1989–1996 in a *H. contortus* pasture on a granite-derived soil at “Glenwood” station, 50 km west of Mundubbera (25°41′S, 150°52′E). The overall study consisted of 4 land classes and 3 stocking rates on either native pasture or legume–oversown

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native pasture although the 3 earlier papers reported data from a subset including 2 land classes (narrow-leaved ironbark and silver-leaved ironbark) at 3 nominal stocking rates (0.3, 0.6 and 0.9 beasts/ha) in both native pasture and legume-oversown native pasture. Further details of this grazing study are provided in Orr *et al*. (2004a).

Site and burning treatment

Two additional paddocks, each 6.0 ha in size, were located in a mixed narrow-leaved ironbark/silver-leaved ironbark landscape and were fenced during winter 1992. Prior to the study reported here, the areas contained in these 2 paddocks were parts of additional areas within the original study described in Orr *et al*. (2004a) and, generally, had been grazed intermittently between 1989 and 1992.

One beast grazed each of these 2 additional paddocks (stocking rate of 0.15 beasts/ha) between autumn 1992 and spring 1995 and the pastures were burnt each spring (1992–1995) following the first rainfall event greater than 25 mm between August and November. After burning in spring 1995, the paddocks were stocked with 2 beasts (stocking rate of 0.3 beasts/ha) until the study concluded in autumn 1996.

Measurements

Population changes. In each of the paddocks, 20 permanent quadrats, each 0.5 × 0.5 m, were established in Winter 1992 in 2 nests each of 10 quadrats. Measurements in these quadrats were made initially in Winter 1992 and subsequently each autumn until 1996 using procedures outlined in Orr *et al*. (2004a). Briefly, the position of individual *H. contortus* and *Aristida* spp. plants in each quadrat was charted using a pantograph (Williams 1970) and the diameter measured firstly along the widest diameter and secondly the diameter in the perpendicular direction to this widest diameter.

For the other 2 treatments, population data for both *H. contortus* and *Aristida* spp. were available for each year between 1990 and 1996. However, for the purposes of the comparisons reported here, data for the 1990, 1991 and 1992 populations in each of these 4 paddocks were merged and these merged data were regarded as the original population. By doing this, all populations had a common starting time in 1992.

Basal area of H. contortus *and* Aristida *spp.* Basal area of *H. contortus* and *Aristida* spp. was calculated on an individual quadrat basis as the sum of the areas occupied by individual plants in the quadrat while mean plant size was determined as the total area divided by the number of plants. (Further details are provided in Orr *et al*. 2004a; 2004c.)

Seed production of H. contortus. Seed production of *H. contortus* was calculated as the product of inflorescence density and seeds per inflorescence. Briefly, inflorescence density was measured annually in the permanent quadrats during late March between 1993 and 1996. The number of seeds per inflorescence was determined annually from 5 inflorescences collected at random from each paddock. (Further details are provided in Orr *et al* 2004b.)

Soil seed bank of H. contortus *and* Aristida *spp.* The soil seed banks of *H. contortus* and *Aristida* spp. were estimated in spring each year between 1992 and 1995 by germinating seed contained in soil cores collected from the areas surrounding the permanent quadrats. Briefly, 4 cores, each 5 cm diameter and 5 cm deep, were bulked to produce each sample and there were 15 samples (*i.e.* 60 cores) from each paddock. In the subsequent summer, each sample was spread as a thin layer on top of sand in a 15 cm diameter drained plastic pot and seed in these samples was germinated by watering with an overhead sprinkler for 30 minutes daily in a glasshouse (Orr *et al*. 1996). Seedlings were identified and counted after 6 weeks. (Further details are provided in Orr *et al.* 2004b).

Data analysis

Data were analysed by standard analysis of variance as a completely randomised design with 3 treatments and 2 replications. Plant survival was analysed using a proportional hazards survival model (Cox 1972).

Results

Seasonal conditions

The overriding climatic condition throughout the study at "Glenwood" was drought with 6 consecutive years of below average rainfall starting in

1990 (Figure 1). Overall, the site experienced moderate drought (395–441 mm received in 12 months) for 39 months and severe drought (less than 395 mm received in 12 months) for 21 months as determined by RAINMAN (Clewett *et al*. 1994). By 1993, the previous 4 consecutive growing seasons had been the driest since district rainfall records commenced in 1887. Furthermore, total rainfall for the 5 years to June 1994 was the lowest for any continuous 5-year period. Thus, the results should be interpreted accordingly.

Changes in plant density

Plant density of *H. contortus* increased after 1993, particularly in the silver-leaved ironbark and burning treatments but overall there were no significant ($P>0.05$) differences between treatments or between years (Figure 2a). Plant density of *Aristida* spp. remained unchanged between 1992 and 1996 (Figure 2b).

Seedling recruitment

Large differences in recruitment of *H. contortus* were apparent between years. Within years, recruitment was higher ($P<0.05$) in the burning than the other 2 treatments only in 1996 (Figure 3a). There were also large differences in recruitment of *Aristida* spp. between years, and recruitment was higher ($P<0.05$) in the narrow-leaved ironbark than the other 2 treatments in 1995 (Figure 3b).

Plant survival

There were no differences between treatments in survival of the original plants of either *H. contortus* or *Aristida* spp. between 1992 and 1996 (Figure 4). Similarly, there were no treatment differences in survival of *H. contortus* for either the 1994 or 1995 seedling cohort (data not presented).

Seed production and soil seed banks

Seed production of *H. contortus* was consistently higher in the burning than in the narrow-leaved ironbark treatment, significantly ($P<0.05$) so in 1993 and 1994 (Figure 5a). There were large differences in the soil seed bank between years and the only significant treatment difference was the larger ($P<0.05$) seed bank for the burning and the silver-leaved ironbark treatments than for the narrow-leaved ironbark in 1995 (Figure 5b). Few *Aristida* spp. seedlings emerged in the soil cores in any year.

Basal area

Basal area of *H. contortus* increased in all treatments between 1992 and 1996, particularly in the burning and silver-leaved ironbark treatments and was higher ($P<0.05$) in these 2 treatments than in the narrow-leaved ironbark treatment in 1994 (Figure 6a). Basal area of *Aristida* spp. in the burning and silver-leaved ironbark treatments increased slightly between 1992 and 1996 and was higher ($P<0.05$) than that in the narrow-leaved ironbark in 1992 and 1994 (Figure 6b). Basal area in narrow-leaved ironbark changed little between 1992 and 1996.

Changes in plant size

The increase in basal area of *H. contortus* (Figure 6) was associated with increasing size of both the original plants and the seedlings recruited in 1994 and 1995 (Figures 7a, 7b and 7c). The original *H. contortus* plants increased in size in all treatments between 1992 and 1996 and plants in the burning treatment in 1995 and 1996 tended ($P>0.05$) to be larger than those in both the silver-leaved and narrow-leaved ironbark treatments. Plants from both the 1994 and 1995 seedling cohorts increased in size in a similar pattern although plants from the 1994 cohort were larger in 1996 ($P<0.05$) in the burning than in both the silver-leaved and narrow-leaved ironbark treatments (Figures 7b and 7c). Similarly, the increase in basal area of *Aristida* spp. was associated with increasing size of the original plants (Figure 7d).

Discussion

Burning in spring between 1992 and 1995 failed to have any marked effect on either *H. contortus* or *Aristida* spp. This outcome was in direct contrast with the results from *H. contortus* pastures elsewhere in southern Queensland (Tothill 1983; Orr *et al*. 1997; Orr and Paton 1997). The research of Orr *et al*. (1997) and Orr and Paton (1997) was conducted at Brian Pastures Research Station, where the dominant *Aristida* spp. is

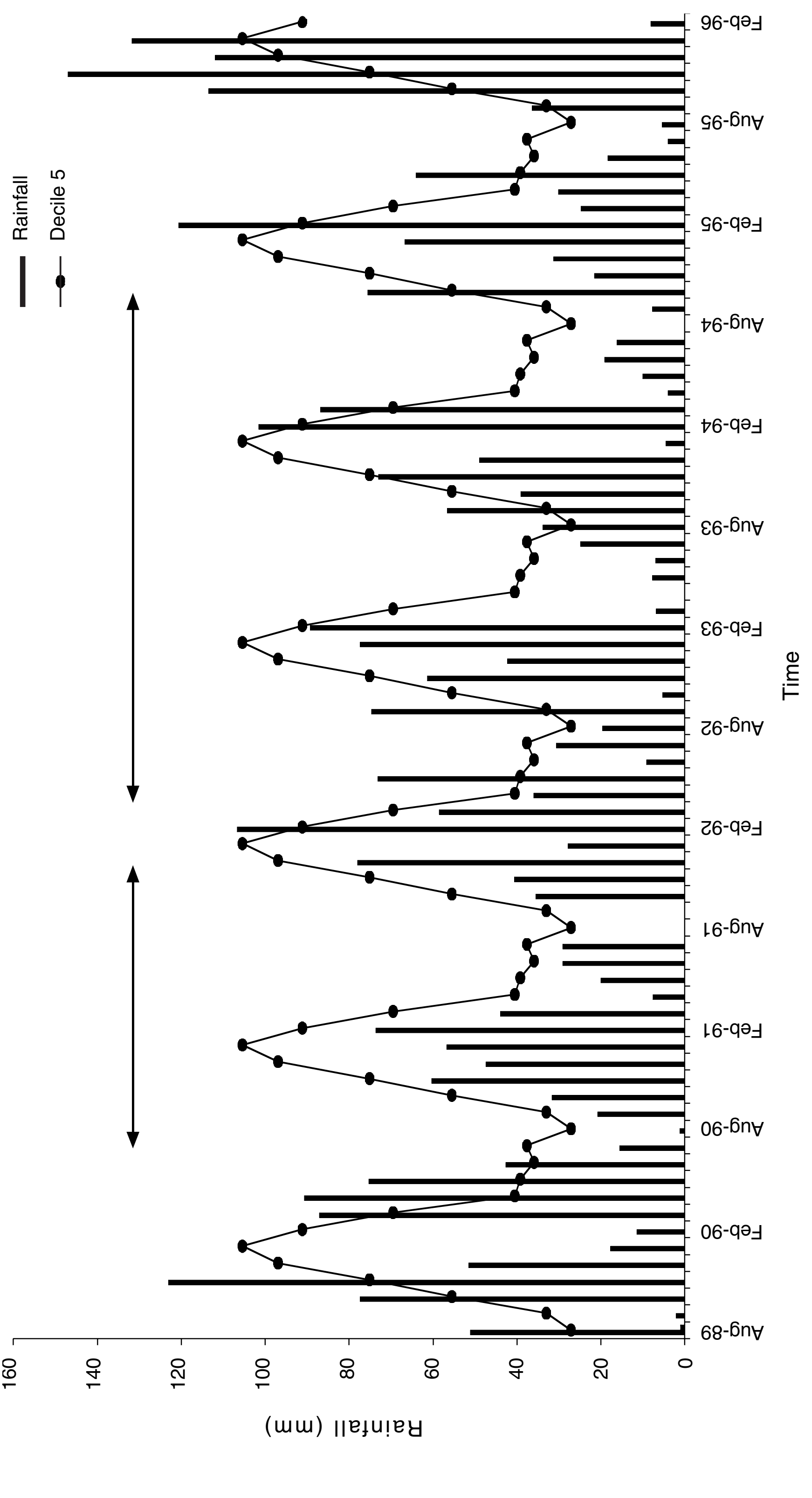

Figure 1. Monthly rainfall recorded at "Glenwood" (bars) between August 1989 and February 1996 compared with Decile 5 rainfall (continuous). Arrows (⟵⟶) indicate times of drought during the experimental period as defined by RAINMAN (Clewett *et al*. 1994).

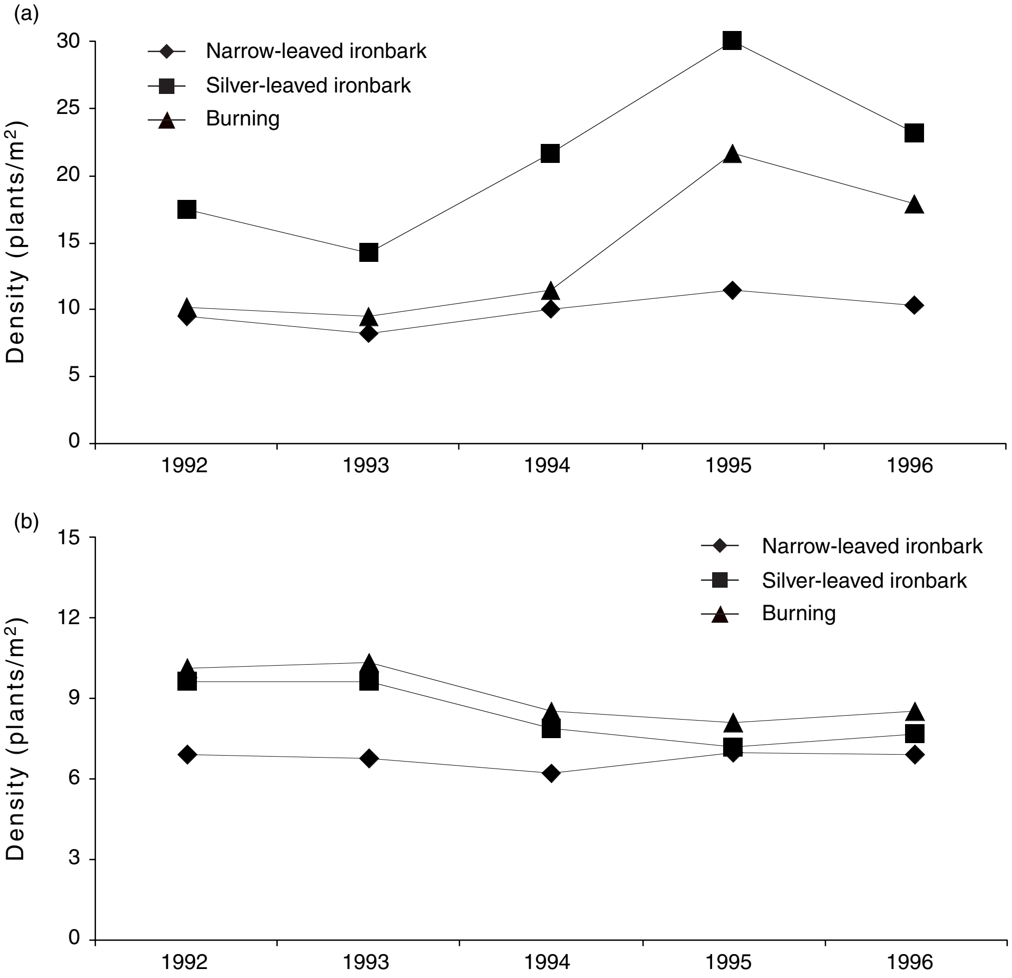

Figure 2. Changes in the density of (a) *H. contortus* and (b) *Aristida* spp. measured in autumn in unburnt narrow-leaved ironbark and silver-leaved ironbark pastures and a mixed pasture burned in spring in *H. contortus* pasture in southern Queensland.

Aristida ramosa. In that research, fire stimulated the germination of *H. contortus* seed (Campbell 1996) and the subsequent seedling recruitment increased both plant density and basal area (Orr *et al*. 1997). Furthermore, fire initially reduced the size of individual plants of *A. ramosa* and then resulted in their death (Orr *et al*. 1997). Neither of these effects was recorded at "Glenwood".

Two explanations can be advanced for the different responses at "Glenwood" and Brian Pastures. Firstly, extreme drought conditions suppressed the expected response by *H. contortus* at "Glenwood"; and, secondly, there are taxonomic differences between the *Aristida* species present at "Glenwood" and the different species groups differ in their responses to fire.

Extreme drought conditions throughout this study (Orr *et al*. 2004a) reduced seedling recruitment, despite the presence of adequate seed (Figure 5), compared with other fire studies in this pasture type. For example, maximum seedling recruitment in autumn in the current study was 10 seedlings/m^2 in 1995 compared with 20 seedlings/m^2 in autumn 1991 (Orr *et al*. 1997) at Brian Pastures and 150 seedlings/m^2 in autumn 2000 in central Queensland (D.M. Orr, unpublished data), both recorded after "average" summer rainfall. However, measuring seedling recruitment in autumn, as occurred in the current study, fails to account for those seedlings which germinate over the summer but die before recordings are made in autumn.

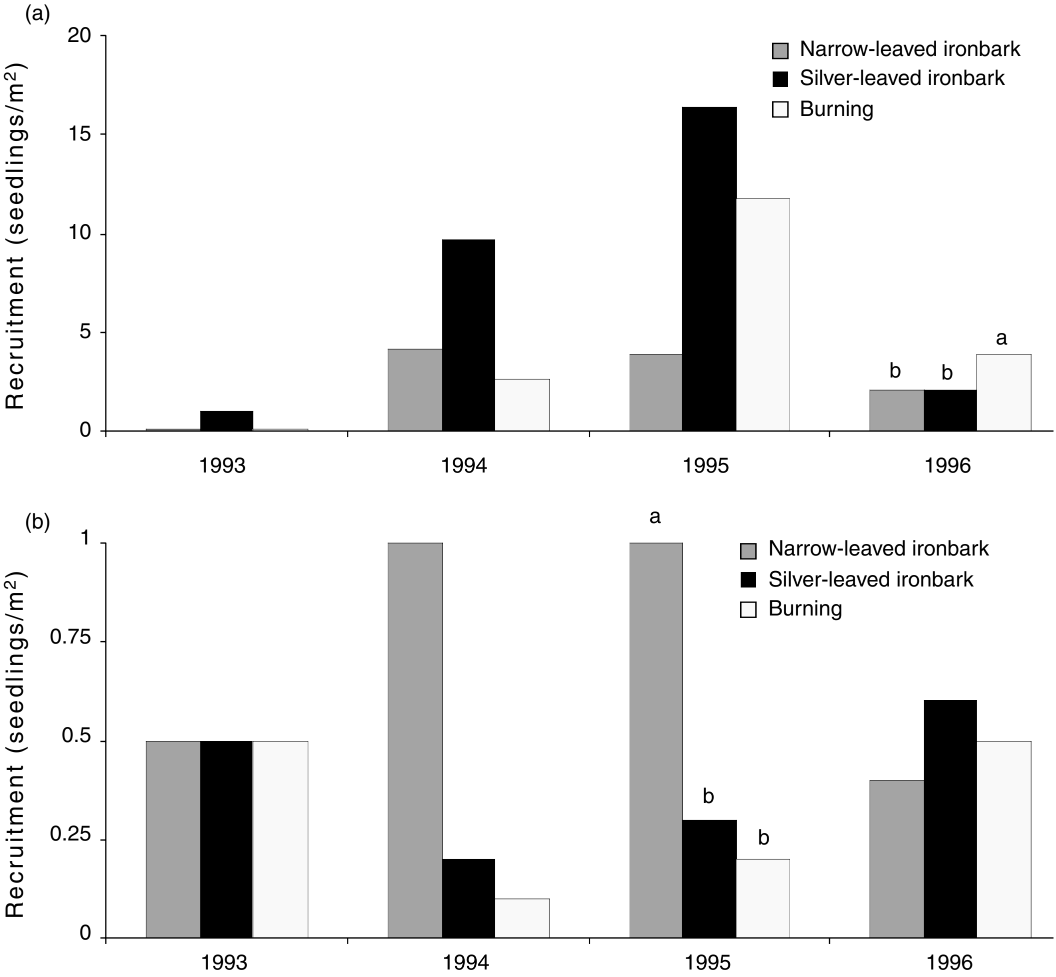

Figure 3. Changes in seedling recruitment of (a) *H. contortus* and (b) *Aristida* spp. measured in autumn in unburnt narrow-leaved ironbark and silver-leaved ironbark pastures and mixed pasture burned in spring in *H. contortus* pasture in southern Queensland. Within years, columns with different letters are significantly (P<0.05) different. (Note differences in scales of recruitment).

For example, the "Glenwood" site received above average rainfall in October 1994 (Figure 1) and a preliminary count of *H. contortus* seedlings in November 1994 revealed substantially more seedlings in the burnt than in the 2 unburnt treatments (R.W. McLean, personal communication). However, severe drought conditions between November 1994 and February 1995 caused most of these seedlings to die. Such seedling death is a direct result of the intermittent summer rainfall throughout the southern speargrass region (Tothill 1966). Similarly, Orr and Paton (1997) indicated that seedling survival is strongly influenced by the occurrence of summer rainfall.

The current study indicates that lack of rainfall is a major limitation to recruitment and this finding suggests that pasture management options such as spring burning should be conducted during periods of favourable rainfall. This supports the recommendation (McKeon *et al.* 1990) that spring burning should not be undertaken when the Southern Oscillation Index (SOI) value is <–5. In the current study, spring SOI values when we burned in 1992–1995 were –5, –11.7, –16.2 and 0.9, respectively. Menke *et al.* (1999) demonstrated that substantial differences in the chance of establishment success of pasture legumes in south-east Queensland can be forecast based on the SOI-phase system.

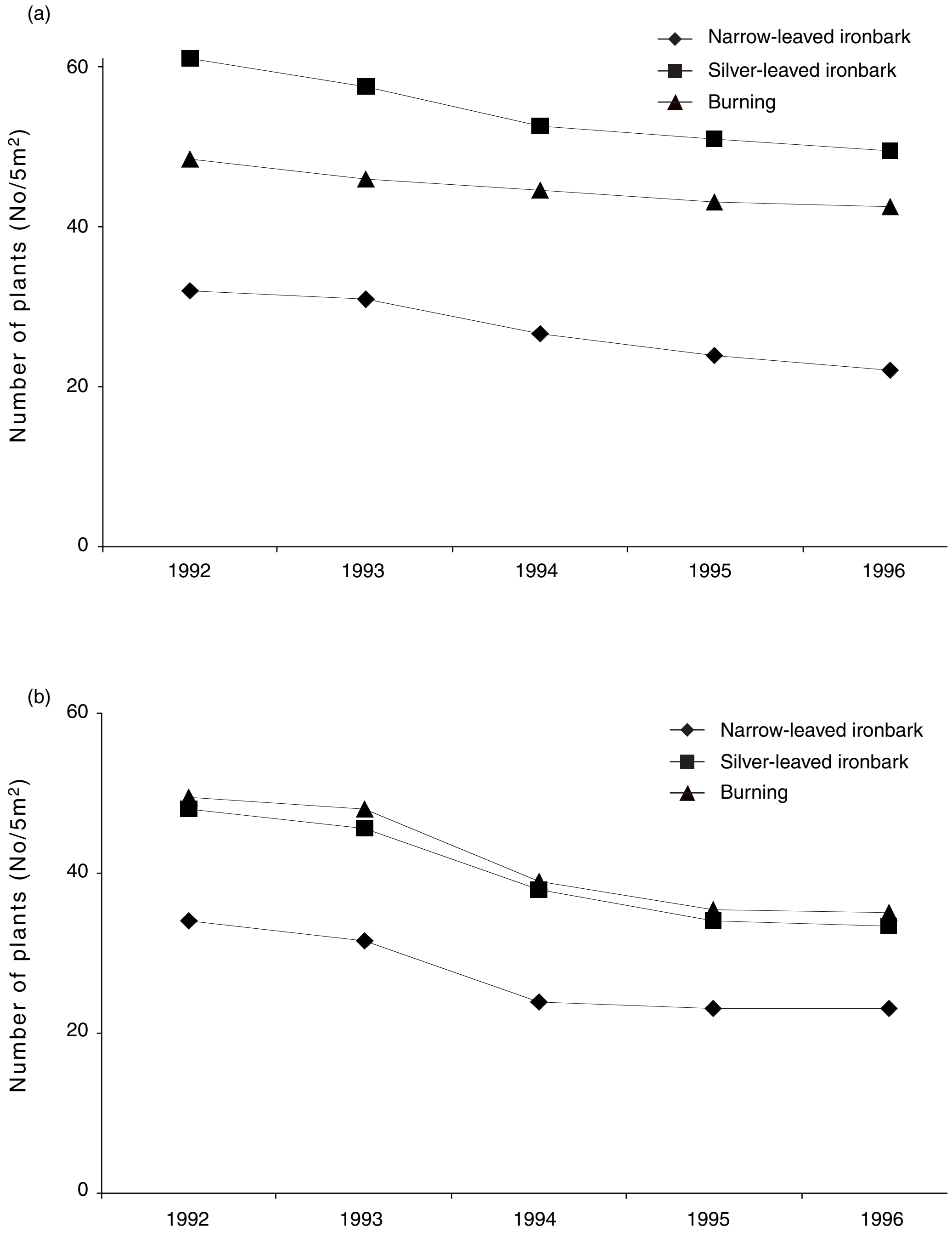

Figure 4. Changes in the survival over time of (a) *H. contortus* and (b) *Aristida* spp. plants in unburnt narrow-leaved ironbark and silver-leaved ironbark pastures and mixed pasture burned in spring in *H. contortus* pasture in southern Queensland.

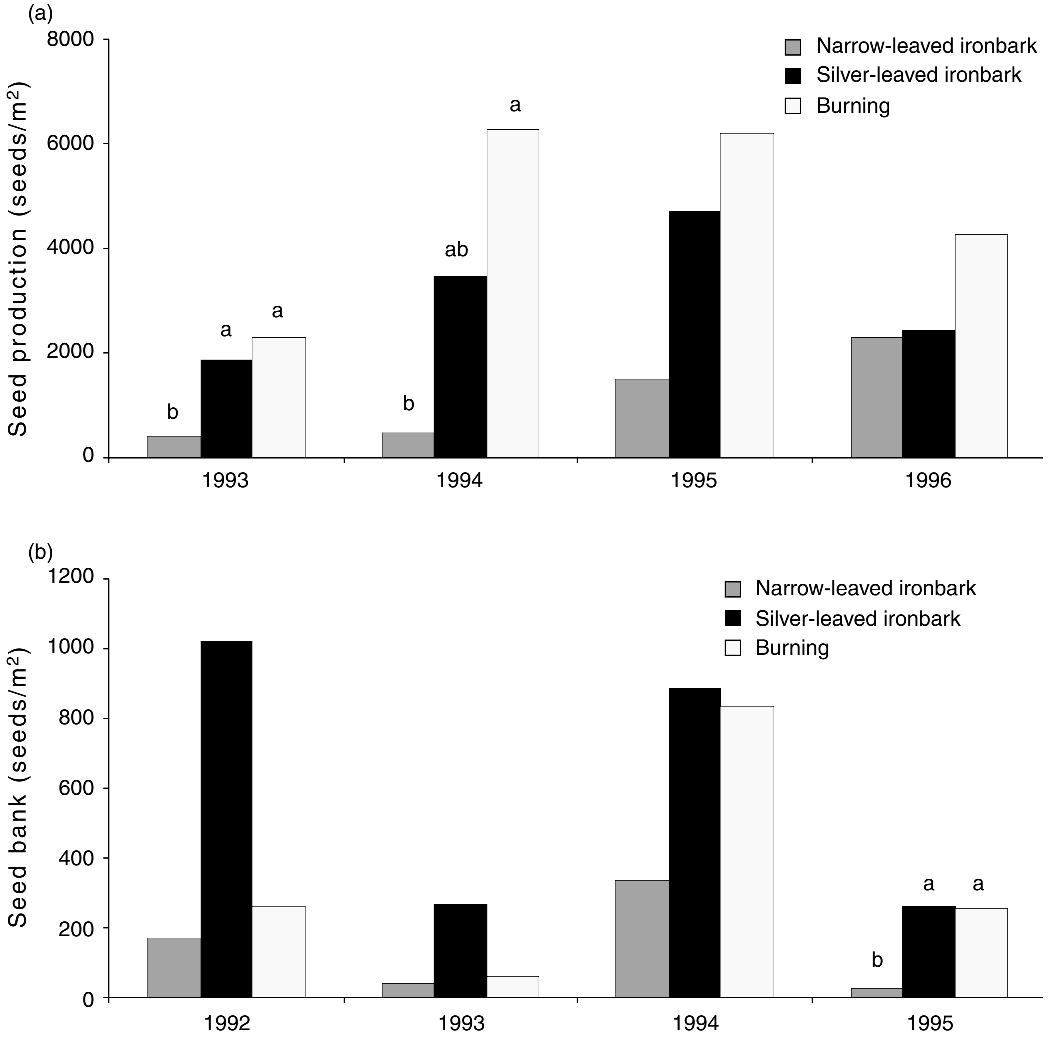

Figure 5. Changes in (a) seed production measured in autumn and (b) soil seed bank measured in spring of *H. contortus* in unburnt narrow-leaved ironbark and silver-leaved ironbark pastures and mixed pasture burned in spring in *H. contortus* pasture in southern Queensland. Within years, columns with different letters are significantly (P<0.05) different.

Aristida species at "Glenwood" and Brian Pastures are quite different. At "Glenwood", more than 90% of *Aristida* spp. plants are "fine" taxa (Sections *Arthratherum* and *Streptachne*) whereas at Brian Pastures the most common taxa are "coarse" taxa (Sections *Calycinae* and *Aristida*) (McIntyre 1996), in particular, the "coarse" *A. ramosa.* Different results at the two locations may be a reflection of different fire responses of the different taxa of *Aristida* spp. These differences support the call (McIntyre and Filet 1997) for the use of the appropriate taxonomic units when quantifying the effects of grazing and other management practices on plant species diversity in managed pastures.

The levels of seed production and soil seed banks in the current study are higher than those reported earlier (Orr *et al*. 2004b). This fact probably results from the lighter stocking rates used both on the burning treatment between 1992 and 1995 and on the lightest stocking rate (0.3 beasts/ha) in the native pasture in both the narrow-leaved and silver-leaved ironbark treatments. Despite this, and as indicated above,

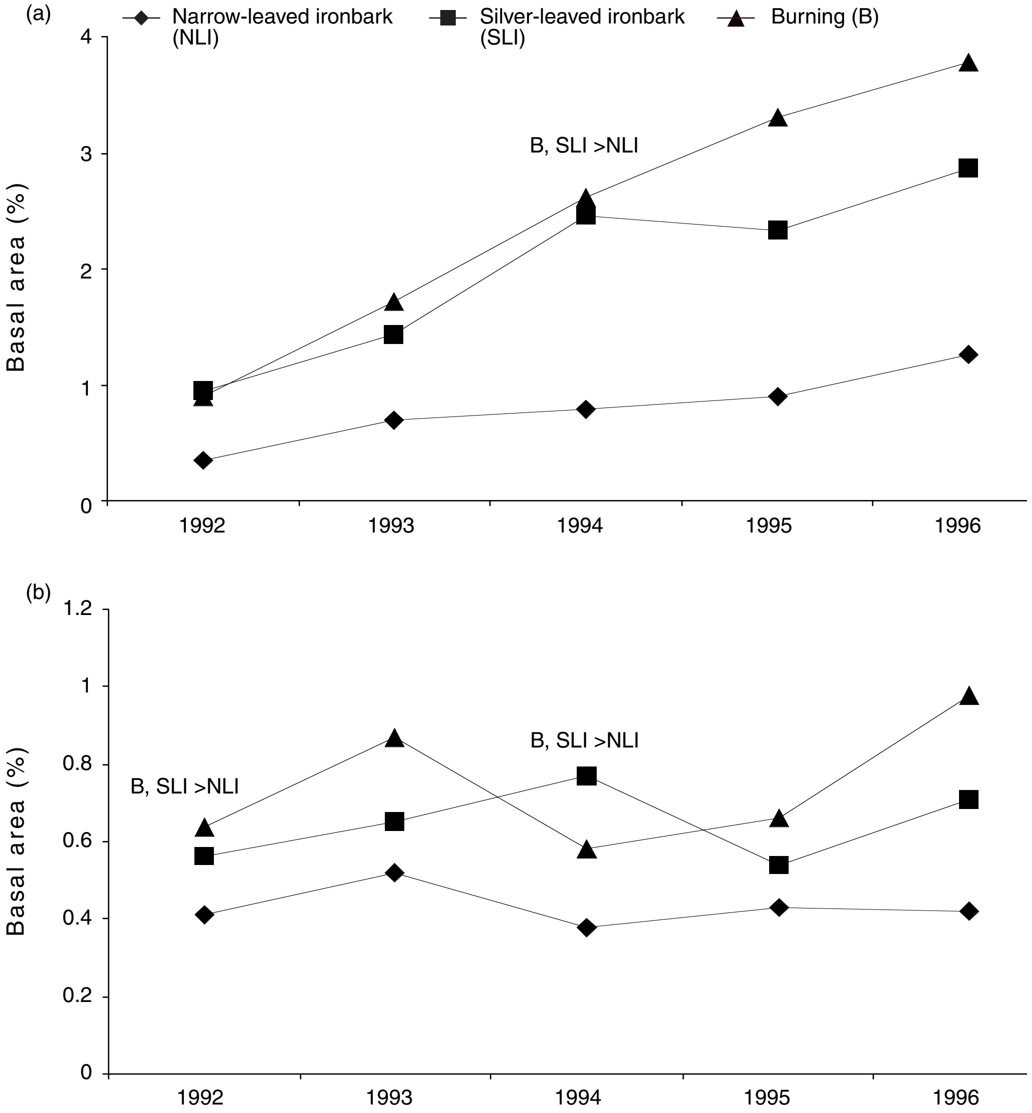

Figure 6. Changes in the basal area of (a) *H. contortus* and (b) *Aristida* spp. measured in autumn in unburnt narrow-leaved ironbark and silver-leaved ironbark pastures and mixed pasture burned in spring in *H. contortus* pasture in southern Queensland.

severe drought precluded the increased level of seedling recruitment that could be expected. This finding that low rainfall was the major limitation to seedling recruitment contrasted, for example, with seedling recruitment studies of *Themeda triandra* (kangaroo grass) in southern Africa (O'Connor 1996), which indicated that seed supply was the major limitation to recruitment.

Implications for grazing management

Results presented here indicate that burning *H. contortus* pastures in spring in combination with reduced grazing pressure does not always increase the proportion of *H. contortus*. Some of this failure was probably due to the lower than average rainfall received throughout most of the study. Another factor may be that different taxa

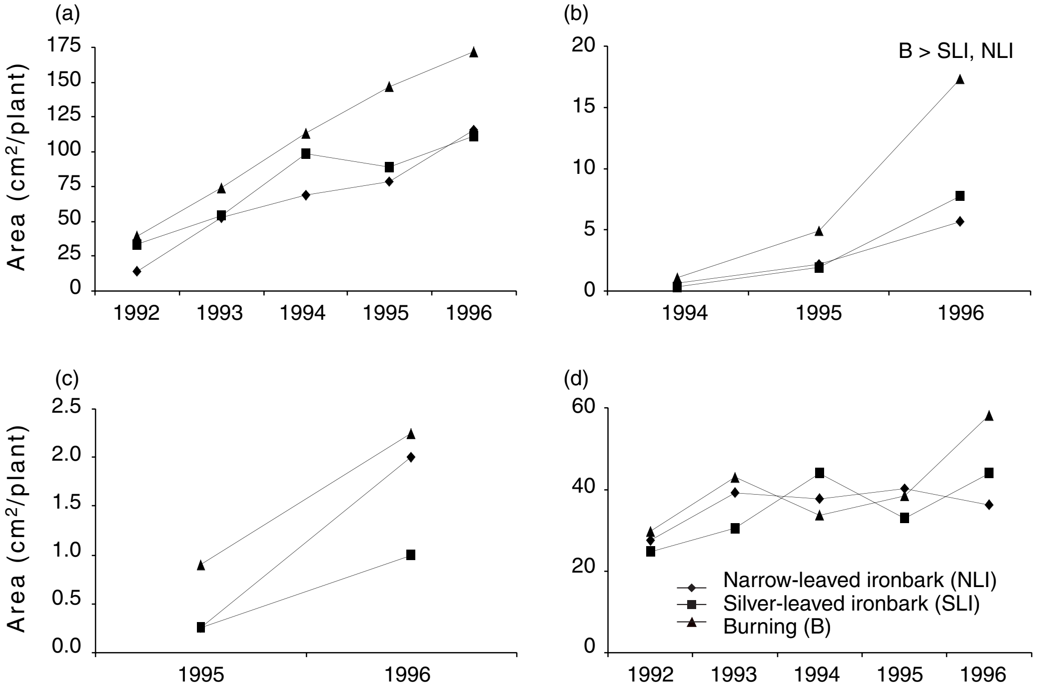

Figure 7. Changes in plant size of (a) original plants, (b) 1994 seedling cohort, and (c) 1995 seedling cohort of *H. contortus* and (d) original *Aristida* spp. plants in unburnt narrow-leaved ironbark and silver-leaved ironbark pastures and mixed pasture burned in spring in *H. contortus* pasture in southern Queensland.

within the genus *Aristida* respond differently to burning.

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