Can competition from *Themeda triandra* inhibit invasion by the perennial exotic grass *Nassella neesiana* in native grasslands?

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Summary

Change in the distribution of the perennial, exotic Chilean needle grass, *Nassella neesiana* (Trin. & Rupr.) Barkworth, was documented over a 10-year interval in a temperate grassland reserve dominated by kangaroo grass, *Themeda triandra* Forsskal, in western Melbourne, Victoria. *Nassella neesiana* increased from 16% of quadrats in 1986 to 42% in 1996. There was a significant negative association between *T. triandra* cover in 1986 and the number of quadrats in each cover class which were invaded by *N. neesiana* in 1986 (P<0.05) and 1996 (P<0.01). Comparatively few quadrats with more than 50% *T. triandra* cover were invaded by *N. neesiana*. Furthermore, there was a significant negative rank correlation between *N. neesiana* cover in 1996 and *T. triandra* cover in 1986 or 1996 (P<0.05) for those quadrats where *N. neesiana* occurred in 1996. The expansion of *N. neesiana* cover in each quadrat was also significantly negatively correlated with *T. triandra* cover in 1986 (P=0.001). Where *N. neesiana* did invade areas which supported dense *T. triandra* in 1986, only small stands generally developed. The present extent of *T. triandra* and *N. neesiana* in the reserve is a function of past land use; areas most heavily disturbed in the past (by ploughing last century and grazing) were the most prone to *N. neesiana* invasion. It is concluded that competition from dense swards of *T. triandra* may play a valuable role in slowing (but not necessarily preventing) invasion by *N. neesiana* in temperate grassland reserves.

Introduction

The South American perennial tussock grass *Nassella neesiana* (Trin. & Rupr.) Barkworth (syn. *Stipa neesiana* Trin. & Rupr.), Chilean needle grass, is a rapidly expanding weed of pastures and remnant vegetation in eastern Australia (Duncan 1993, Gardener *et al.* 1996, McLaren *et al.* 1998). It is now perhaps the most serious environmental weed in remnant native grasslands in southern Victoria (McDougall and Kirkpatrick 1994, McLaren *et al.* 1998). Due to widespread destruction and modification by agriculture, temperate lowland grasslands are one of Australia's most endangered ecosystems, and only small intact remnants now survive (McDougall and Kirkpatrick 1994). Invasion by *N. neesiana* poses a major threat to the conservation of this endangered ecosystem.

Nassella neesiana can be controlled by herbicides such as Roundup® and Frenock®, but may rapidly re-establish on the bare ground created by herbicide application (Duncan 1993, Gardener *et al.* 1996). Effective post-herbicide control in pasture areas requires the replacement with competitive, perennial pasture grasses (Duncan 1993). Consequently, it might be expected that competition from the dominant native grass of many temperate grasslands, *Themeda triandra* Forsskal, may play an important role in controlling the spread of *N. neesiana* in grassland reserves. However, no information is available on interactions between the two species.

In this paper we report on patterns of invasion of *N. neesiana* in an urban grassland reserve in western Melbourne between 1986 and 1996. We compare the extent of invasion in areas with different levels of *T. triandra* canopy cover, in order to determine whether *N. neesiana* invasion was related to the degree of *T. triandra* dominance at the start of the 10-year period.

Methods

The study was conducted at the Derrimut Grassland Reserve, a 154 ha reserve in western Melbourne, Victoria (37°48'30" S, 144°47'40" E). Mean annual rainfall at Laverton, 7 km SSW of the reserve, is 568 mm, which is evenly distributed throughout the year (Bureau of Meteorology Victoria unpublished data). The geology is Early Pleistocene olivine basalt (Douglas 1982), and most soils are duplex, with gradational soils in poorly drained areas. Topsoils range from silty clay to clay loam, of pH 6.0–7.5, and the topography is flat to gently undulating (Lunt 1990). Three areas were ploughed last century, but no ploughing or cropping is known to have occurred this century (Lunt 1990). The property was grazed by sheep until the 1960s and then by cattle until 1985, when management changed to the state conservation agency (now the Department of Natural Resources and Environment Victoria) for the purposes of grassland conservation. Since 1985, stock have been excluded from the reserve and the vegetation has been managed by intermittent burning (Craigie and Stuwe 1992).

The vegetation of the Derrimut reserve was initially surveyed in November and December 1986 and 1987, one to two years after grazing stock were removed. Sixty-one quadrats were sampled across a grid which included all vegetation types in the reserve, including grasslands and wetlands (Lunt 1988, 1990). At that time, large infestations of *N. neesiana* had established around the reserve perimeter, along a temporary drainage line in the west of the reserve, around the edges of a large wetland in the south of the reserve (Lake Stanley), and in localized places within native grassland in the centre of the reserve (Figure 9 in Lunt 1988). The range of soils and topographic positions occupied suggested that *N. neesiana* was capable of establishing across the entire grassland area (Lunt 1988). In November 1996, ten years after the original survey, 45 grassland quadrats were accurately re-located and surveyed. In both surveys (1986 and 1996), each quadrat was 5 × 3 m in size, and all vascular plants within or overhanging the quadrat were recorded using the Braun-Blanquet cover/abundance scale (Mueller-Dombois and Ellenberg 1974, Lunt 1990). General changes in vegetation between 1986 and 1996 are reported elsewhere (Lunt and Morgan 1999a).

To assess relationships between *T. triandra* cover and *N. neesiana* invasion, the 45 re-sampled quadrats were grouped into three classes according to *T. triandra* cover in 1986: *T. triandra* absent, *T. triandra* less than 50% cover, and *T. triandra* greater than 50% cover. The proportion of quadrats in each class which were invaded by *N. neesiana* in 1986 and 1996 were calculated and compared statistically using an R × C test of independence with the G-test (Sokal and Rohlf 1981). Spearman's rank correlation coefficient was used to assess two possible relationships:

i. whether the percentage cover of *N. neesiana* in each quadrat in 1996 was correlated with the percentage cover of *T. triandra* in 1986 (using only those quadrats where *N. neesiana* was present in 1996), and
ii. whether the expansion of *N. neesiana* in each quadrat between 1986 and 1996 was related to the original cover of *T. triandra* in 1986.

The mid-points of each Braun-Blanquet

cover class were used in both correlation analyses.

To test whether patterns of *N. neesiana* invasion were simply related to the distance between quadrats and areas of major infestations along reserve boundaries and around the margins of Lake Stanley (rather than being directly related to *T. triandra* cover), the minimum distance of each quadrat from the closest reserve boundary or lake edge was calculated to the nearest 100 m. The mean distance of invaded and uninvaded quadrats from the closest edge was then calculated. Mean distances were then compared using a one-tailed, non-parametric Kruskal-Wallis H test in the SPSS package (Norusis 1993).

Results

The distribution and cover of *N. neesiana* increased dramatically between 1986 and 1996. It was recorded in only seven of the 45 quadrats (16%) in 1986, compared to 19 in 1996 (42%). There was a significant negative association between *T. triandra* cover in 1986, and the number of quadrats in each cover class invaded by *N. neesiana* in 1986 ($P<0.05$) and 1996 ($P<0.01$). Comparatively few quadrats with more than 50% *T. triandra* cover were invaded by *N. neesiana* (Figure 1). In 1996, 83% of quadrats with no *T. triandra* contained *N. neesiana*, compared to just 22% of quadrats where *T. triandra* cover exceeded 50%.

Furthermore, in quadrats where *N. neesiana* occurred in 1996, there was a significant negative rank correlation between *N. neesiana* cover in 1996 and *T. triandra* cover in 1986 (r_s=-0.4366, 1-tailed P=0.031, N=19) and *T. triandra* cover in 1996 (r_s=-0.5144, 1-tailed P=0.012, N=19), indicating that *N. neesiana* cover was significantly less in quadrats with greater *T. triandra* cover (in 1986 and 1996). There was also a significant negative rank correlation between the expansion of *N. neesiana* in each quadrat between 1986 and 1996 and *T. triandra* cover in 1986 (r_s= -0.4585, 1-tailed P=0.001, N=45), indicating a slower rate of invasion in quadrats with greater *T. triandra* cover. Quadrats containing *N. neesiana* in 1996 were not closer to large infestations than those without *N. neesiana*; indeed the mean distance of uninvaded quadrats from reserve edges was less than that of invaded quadrats (180 m c.f. 240 m), although this difference was not significant (P=0.1998).

Discussion

These results demonstrate a significant negative relationship between the extent of invasion by *N. neesiana* in 1986 and 1996 and the cover of the perennial native grass *T. triandra* in both years. Invasion by *N. neesiana* was significantly slower in areas with dense stands of *T. triandra.*

The correlation between *N. neesiana* invasion and *T. triandra* cover is likely to be directly influenced by *T. triandra*, rather than by underlying soil or drainage patterns, for two reasons. Firstly, *N. neesiana* has successfully invaded disturbed areas around the perimeter of the entire reserve, indicating that it can thrive in virtually all areas of the reserve except wetlands. Secondly, *T. triandra* probably dominated all well-drained areas of the reserve before European settlement. The current absence or paucity of *T. triandra* in different parts of the reserve is likely to be due to ploughing last century (in the south of the reserve) and heavy grazing this century, especially near old fencelines and waterpoints (Lunt 1990). Thus, with the exception of wetland areas, the distribution of *T. triandra* and *N. neesiana* is most likely due to past management, not underlying edaphic features. The correspondence between recent *N. neesiana* invasion and the current distribution of *T. triandra* probably represents a long-term impact of past ploughing and grazing. Areas most heavily disturbed in the past were the most prone to *N. neesiana* invasion.

The negative association between cover of *N. neesiana* and *T. triandra* suggests strongly that *T. triandra* plays an active role in slowing the rate of *N. neesiana* invasion. Where *N. neesiana* had successfully invaded areas of dense *T. triandra*, patches of *N. neesiana* tended to be small, and extensive swards were not formed. The role of competition from the established dominant grass, *T. triandra*, in slowing *N. neesiana* invasion accords with agricultural studies of *N. neesiana* which suggest that relatively little seedling establishment occurs in vigorous pastures (Gardener *et al.* 1996). Duncan (1993, p. 2) concluded that effective control of *N. neesiana* required 'removal of plants followed by replacement with a competitive perennial pasture'.

Competition against *N. neesiana* by *T. triandra* has two important implications for conservation management:

i. the most efficient way of slowing *N. neesiana* invasion across large areas is likely to be by maintaining a healthy, actively growing sward of *T. triandra*, and
ii. re-establishment of a dense sward of *T. triandra* after herbicide treatment of *N. neesiana* may play a valuable role in slowing re-invasion by *N. neesiana* (Gardener and Sindel 1998), as has been found to occur for *N. trichotoma* (Nees) Arech. (Phillips and Hocking 1996, Hocking 1998).

Vigour of *T. triandra* tussocks is strongly affected by fire and grazing management. Heavy grazing can rapidly deplete or eliminate *T. triandra* (Moore 1959, 1964, Lodge and Whalley 1989). In ungrazed, burnt areas in southern Victoria, maintaining a healthy sward of *T. triandra* requires frequent burning (at intervals of less than five years). A recent study at Derrimut and the nearby Laverton North Grassland Reserve documented massive mortality of *T. triandra* in areas which remained unburnt for more than five years (Morgan and Lunt 1999), presumably because of self-shading from dead grass litter. After senescent *T. triandra* swards were finally burnt, tussock and tiller densities were dramatically less than in frequently burnt areas (Morgan and Lunt 1999, Lunt and Morgan 1999b). The large areas of dead *T. triandra* at Derrimut are now likely to be easily invaded by exotic perennial grasses such as *N. neesiana*, *Phalaris* species and *Paspalum dilatatum* Poiret.

In summary, these results demonstrate significantly less invasion by *N. neesiana* in areas which supported a high tussock density of *T. triandra* cover, compared to areas with little *T. triandra*. We conclude that maintenance of a healthy sward of

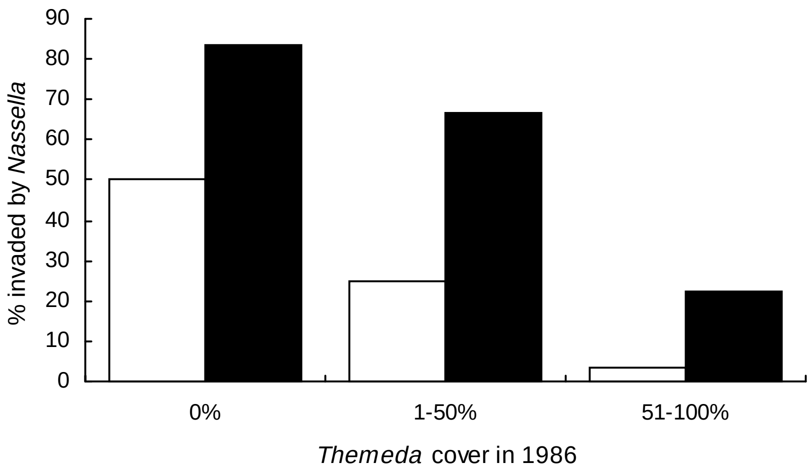

Figure 1. Relationship between proportion of quadrats in each cover class invaded by *Nassella neesiana* in 1986 (☐) and 1996 (■) and original cover of *Themeda triandra* in 1986.

T. triandra may prove an extremely cost-effective method of slowing (although not necessarily preventing) invasion by *N. neesiana* in grassland reserves. In productive, ungrazed sites in southern Victoria, frequent burning (at less than five year intervals) is required to prevent *T. triandra* mortality, and thereby maintain its competitiveness.

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