CHILEAN NEEDLE GRASS (*NASSELLA NEESIANA*) – WHAT WE KNOW AND WHERE TO NEXT?

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Abstract Efforts to prevent the proliferation of *Nassella neesiana* in Australian pastures have had little success to date. A study of the biology of *N. neesiana* on the Northern Tablelands of New South Wales has shown that it has many characteristics which allow it to persist in these pastures regardless of efforts to remove it.

The successful traits of *N. neesiana* fall into two categories - reproductive fecundity and persistence of various stages in its lifecycle. The most successful reproductive trait of *N. neesiana* is its ability to produce large numbers of seeds. It also produces two types of seeds, those borne in the panicles and morphologically distinct cleistogenes found under the leaf sheathes at each of the nodes on flowering tillers. The persistence of *N. neesiana* is facilitated by a large long-lived seedbank which possesses complex dormancy mechanisms. Even without the input of additional seed, the seedbank declines slowly over many years. Furthermore, seeds only germinate when gaps are created in pastures, and survival of both seedlings and adult tussocks is high.

This paper discusses the implications of these biological characteristics for the management of *N. neesiana*. Since there is overwhelming evidence that *N. neesiana* will continue to persist in pastures, we recommend that it be utilised as a feed source as far as possible. We discuss the desirable features of *N. neesiana* which support its use as a pasture species and a grazing strategy which may decrease its dominance. Possibilities for future research on *N. neesiana* are also indicated.

INTRODUCTION

Nassella neesiana (Trin. & Rupr.) Barkworth (Chilean needle grass) is widespread in pastoral and conservation lands of south eastern Australia and is naturalised in many locations in New South Wales, Victoria and South Australia. A conservative estimate of the potential distribution of *N. neesiana* in Australia based on its current Australian distribution was generated using the climate matching program CLIMATE. Nearly 40 million ha in Australia from south east Queensland to Western Australia had matching climates (Gardener 1998, McLaren *et al.* 1998). *N. neesiana* appears to have the ability to colonise most grasslands and grassy woodlands in temperate areas of Australia with more than 500 mm of rainfall. *N. neesiana* was found to grow in a diverse array of Australian climates from the warm wet summers and cold dry winters on the Northern Tablelands of New South Wales to a Mediterranean type climate with hot dry summers and cool wet winters in Victoria and South Australia.

Based on a four year study of *N. neesiana* in pastures on the Northern Tablelands of New South Wales, this paper describes the underlying biological mechanisms that has allowed *N. neesiana* to invade such a diverse array of habitats in Australia. This paper is meant as an overview, for further details of methods and results, see Gardener (1998). These biological mechanisms have been grouped into four sections; seed production, seed dispersal, seedbank longevity and plant survival. In each section the implications for management have been discussed. Current management has focused on chemical means to control of *N. neesiana* in pastures. The long term success of chemical control has been poor and were dependent on the now banned flupropanate (e.g. Frenock). Hence, the fifth section of this paper, *N. neesiana* as a pasture plant, discusses the potential for *N. neesiana* as a pasture plant and suggests possible grazing systems to maximise its utility.

Seed production *N. neesiana* has the potential to produce large numbers of panicle seeds between spring and early summer. In a dense, ungrazed infestation, panicle seed production of *N. neesiana* ranged from 1,600 to 22,200 seeds m^{-2}. These differences are related to the amount of spring rainfall, the former being in a drought year and the latter being in an above average rainfall year. The fluctuation in seed production can be attributed mainly to the change in number of flowering tillers produced per unit area.

As well as these panicle seeds, each node on the flowering tiller is capable of bearing cleistogenes underneath the leaf sheath furthering the plant's reproductive potential. Cleistogenes account for a considerable amount of the total seed production in *N. neesiana*. For example, in 1996, a dense, ungrazed infestation produced 22,200 panicle seeds m^{-2} and 6,100 cleistogenes m^{-2} resulting in a total seed production on 28,300 seeds m^{-2}. On average, *N. neesiana* produced 7.2 cleistogenes per flowering tiller. It was found that damage to the flowering tiller, such as severing below the flag leaf, did not affect the production of cleistogenes at the remaining nodes. Basal cleistogenes in particular, which are often below the surface of the soil, were produced even if the tiller was cut just above the soil surface.

These findings have important implications for the management of *N. neesiana*. Several management strategies have been used to reduce seed production of undesirable grasses including spray topping (Dowling and Nicol 1993), spray grazing (Leys *et al.* 1991) and strategic grazing (Jones *et al.* 1992). However, even under the most adverse conditions *N. neesiana* is likely to produce enough seeds to perpetuate itself from season to season. The panicles may be prevented from setting seed by herbicide or heavy grazing but it may be impossible to prevent the production of cleistogenes.

Seed dispersal Of further concern of is the dispersal of seeds away from the parent plant. Most seeds produced by *N. neesiana* fall near to the adult plant. The heavy seeds (approximately 6 mg) are not adapted to wind dispersal and were found a maximum of 2.8 m away from the parent plant. Hence, without a suitable extrinsic dispersal agent *N. neesiana* will spread slowly. If the movement of seeds across fence lines is a concern, a 5 m *N. neesiana*-free buffer would probably be sufficient to prevent dispersal by wind.

The primary dispersal mechanism of *N. neesiana* over long distances is by adhering to the coats of animals, clothing or machinery. In two different experiments, unshorn sheep still carried some *N. neesiana* seed (at least 10% of the original seed) in their wool after more than 5 months. In that time there would be ample opportunity for dispersal over large distances by movement of stock. Furthermore, although shearing sheep before seed set reduced the number of seeds attached to the animal, it did not prevent it altogether.

The possibility of seed dispersal through ingestion by animals was also investigated. Very few seeds of *N. neesiana* survived passage through the gut of Angus steers, that is, 0.5% of panicle seeds and 2.7% of cleistogenes recovered from the faeces were viable. All viable seeds had passed through the digestive tract within 4 days. Even though there is a small chance of seed passing through cattle in a viable state and an even smaller chance that they will germinate once they have been excreted, a withholding period of seven days in a seed-free paddock before moving them to a clean area will ensure that no seed remains in their digestive tract.

How can seed dispersal of *N. neesiana* be minimised? People working in areas where *N. neesiana* is seeding must be sure to remove seed from clothing and machinery when they leave. It must be assumed that sheep which have grazed paddocks where *N. neesiana* is dropping seed are carrying such seed in their wool and will do so until they are shorn. Landowners with *N. neesiana* have three options to reduce seed dispersal when moving sheep from their property. They can keep animals in a paddock without *N. neesiana* over the flowering period, sell sheep directly to the abattoir, or shear the sheep between seed fall and sale. It must be remembered that the dry flowering tillers of *N. neesiana* can remain standing for up to six months and still contain viable cleistogenes. These seeds may be dispersed if tillers are harvested and used for fodder.

Seedbank longevity The key reason for the persistence of *N. neesiana* despite various management attempts is its large and long-lived seedbank. The seedbank of *N. neesiana* in this study persisted for more than 3 years without seed input. After this time, the numbers of viable seeds of *N. neesiana* in vegetated plots (seed production was prevented) declined from 4,600 to 1,500 m^{-2} (these numbers are underestimates as only the panicle seeds and cleistogenes loose in the soil were counted - cleistogene containing tiller bases were discarded). These data were fitted with an exponential decay curve and it was estimated that an initial seedbank of 7,100 seeds m^{-2} would take 12.4 years to reach 10 seeds m^{-2}.

The large, long-lived seedbank of *N. neesiana* makes management very difficult because preventing re-infestation from the seedbank is almost impossible.

Baring the ground with herbicide (glyphosate) did not increase the rate of decline compared with vegetated plots. If herbicides or other forms of disturbance are to be used to kill the adult plants, the resultant bare ground only encourages further recruitment. Cultivation treatments have been shown to decrease the seedbank of *N. neesiana* substantially (see Bourdôt and Hurrell 1992, Lowien *et al*. 1998) but cannot eradicate it completely.

Another means of reducing the seedbank is to prevent the production of seeds but the seedbank can be maintained with relatively low seed inputs. In 1996, when panicle seed production was high, 41.6% of seed produced were incorporated into the seedbank whereas in 1995 and 1997 lower seed production was sufficient to maintain seedbank numbers. Replacing the adult plants with competitive and more desirable pasture species is likely to reduce the probability of recruitment but it is unlikely that the seedbank of *N. neesiana* will be sufficiently exhausted to prevent regeneration. Seeds of *N. neesiana* have dormancy mechanisms that allow them to persist for many years.

Plant survival On bare ground only a small proportion of the viable seeds of *N. neesiana* in the seedbank emerged as seedlings whereas no emergence was observed in undisturbed vegetated areas. Seedlings emerged predominantly in autumn and spring but emergence was also observed at other times of the year when sufficient soil moisture was available. Although seedling density was low, seedling survival over a 20 month period was high (77%).

The dormancy mechanisms common in stipoid grasses (Gardener and Sindel 1998) probably account for the small proportion of seedlings emerging in the field with each suitable rainfall event. Seeds which have fallen from the plant have an after-ripening requirement of between 3 months and 1 year before most of them are capable of germinating. Also, the lemma surrounding the caryopsis may provide a barrier to gas and water exchange or mechanically restrain the embryo. It must be removed or damaged before most seeds will germinate. Increasing time buried in the soil resulted in higher germinability of exhumed seeds which suggested that the lemma somehow decomposed in the soil.

From a management perspective, these findings have important implications. Creating bare ground or large gaps in the pasture canopy may encourage recruitment from the long-lived seedbank of *N. neesiana* resulting in a possible increase in plant density. Since the most important management goal in pastures is to maintain canopy cover, it is not recommended to blanket spray large areas as competing pasture species will also be killed and may not possess inexhaustible reserves of seeds in the soil like *N. neesiana*. If individuals or small patches of plants must be treated this should be done in a way that minimises disturbance. Hand grubbing the tussocks or careful spot spray is preferential. Conversely, if the management objective is to increase seedling emergence as a way of reducing the seedbank, baring the ground with herbicide will not significantly expedite the process as not all seeds will germinate and some will remain dormant in a viable state from many years. Hence, repeated herbicide applications over prolonged periods, resulting in loss of production and damage to the soil, will probably not prevent re-infestation of *N. neesiana*.

***Nassella neesiana* as a pasture plant** The overwhelming evidence presented above is that *N. neesiana* will persist in pastures despite all attempts at eradication has led to the recommendation of utilising it as a pasture plant on grazing lands (see Figure 1 for decision making). Attempts to resow infestations with more competitive pasture species have been unsuccessful (e.g. Bourdôt and Hurrell 1989) and can lock land managers in a cycle of repeated expenditure of resources and time. *N. neesiana* will probably always remain a component of previously infested pastures and therefore, must be managed to maximise its productivity and reduce its dominance.

In South America, *N. neesiana* is considered one of the most important winter growing native species producing good quality feed (Rosengurtt *et al*. 1970, Fernandez *et al*. 1986). Furthermore, *N. neesiana* has several desirable features which supports its use as a pasture plant. It is perennial persisting during heavy grazing and drought, it grows in winter, it is self perpetuating and the tussocks are long-lived with a high survival rate (73% survived over 3 years). In order to quantify feed production of *N. neesiana* a comparative study was done with *Festuca elatior* L. as it was the co-dominant species in pastures at the study site. *N. neesiana* produced lower herbage mass than *F. elatior* (0.1986 compared with 0.252 g cm^{-2} basal area $year^{-1}$), the crude protein of *N. neesiana* green leaf samples ranged from 12.7 to 16.6% (compared with 13.0 to 18.8% for *F. elatior*). Digestible dry matter was between 58 to 66% in *N. neesiana* and 62 and 69% in *F. elatior*. These figures combined with the fact that *N. neesiana* has an comparatively high basal cover (20%), resulted in the production of a large amount of reasonable quality feed. On a whole paddock basis, average green leaf production of *N. neesiana* was calculated to be 2400 kg ha^{-1} year^{-1}. Hence, if *N. neesiana* infested paddocks are managed correctly so that the stalks left from summer flowering are removed, good production throughout the cooler months is possible.

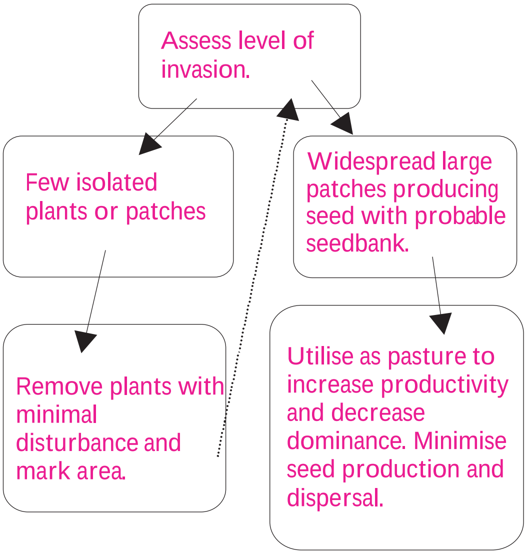

Figure 1. Decision making for management of *N. neesiana* in pastures

A management strategy that can remove flower stalks and bulk of *N. neesiana* and give other more desirable pasture species a competitive advantage is necessary. For example, the high stock densities used in cell grazing reduce selective herbivory, forcing animals to eat bulk material and trample flower stalks. Since the most desirable pasture species (in this case *F. elatior*) have a faster growth rate than *N. neesiana*, the long rest period between intensive grazing events used in cell grazing may allow them to outcompete *N. neesiana* by growing a larger canopy and more roots.

FUTURE RESEARCH

Several areas for future research have arisen from this work. *N. neesiana* was shown to have gone beyond its native climatic boundaries in Australia (Gardener 1998). In South America, its distribution may be constrained more by biotic factors such as pathogens and predators rather than by climatic. This supports the search for biological control agents of *N. neesiana* in South America currently being carried out by CSIRO Entomology.

A key goal in successfully managing *N. neesiana* in a pasture is the reduction in the number of flowering tillers. This has two benefits, increasing its feed value during summer months and reducing seed production. Quantitative experiments are needed to determine the stock density, species of grazer and timing of grazing needed to achieve this goal. Studies on competitive interactions between *N. neesiana* and other pasture species are under different grazing regimes are also necessary.

Seed production may also be reduced by the application of non-lethal doses of herbicide (spray topping) and may be used in conjunction with grazing (spray grazing). Research on the most effective concentration, timing of application and the type of herbicide required is needed. Knowledge on the effect of herbicides on the production and viability of cleistogenes would also be useful. However, care must be taken to ensure that any control program using herbicide does not adversely affect desirable species or created gaps in the pasture.

The most weedy characteristic of *N. neesiana* is its persistent seedbank. Any management strategy that does not take this into consideration will surely fail. *N. neesiana* was shown to have a large long-lived seedbank in this study and in work by Bourdôt and Hurrell (1992) in New Zealand. However, it was found that *N. neesiana* had a negligible seedbank in Argentina (Gardener *et al*. 1997). An explanation for this is required. Furthermore, information is required on establishment of seedbanks in recent infestation to determine at what point removal become impractical.

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