

Future Northland Pastures: 2. C4 grasses and subtropical legumes for a future Northland

Shirley NICHOLS^{*1}, Warren McG. KING¹ and Jim CRUSH¹

¹BSI - AgResearch Group, Bioeconomy Science Institute, Ruakura Research Centre, Hamilton, New Zealand

*Corresponding author: shirley.nichols@agresearch.co.nz

Abstract

Northland's subtropical climate presents both challenges and opportunities for pasture systems under future climate scenarios. This study aimed to identify C4 grasses and subtropical legumes with potential to improve resilience, productivity, and sustainability of Northland pastures. Candidate species were compiled from historical Northland trials and the Tropical Forages database, resulting in an initial pool of 60 grass and over 90 legume taxa. Each species was assessed for agronomic potential, availability of seed or cultivars, and regulatory status under the MPI Plant Biosecurity Index. Nomenclature was standardised using authoritative taxonomic databases. Species were classified into three categories—Green, Orange, and Red—based on priority for evaluation. Green list species are both agronomically promising and permitted by MPI, while Orange list species have limitations requiring further consideration. Red list species are either restricted, unrecorded, or deemed agronomically unsuitable. Cultivar availability and breeding activity were highly variable, with legume options especially constrained. A staged approach to evaluation is recommended, including initial use of nitrogen fertiliser in legume trials to defer rhizobium-specific work. This review highlights the need for renewed trialling of selected subtropical species and supports a pathway toward diversifying pasture systems in warmer regions of New Zealand.

Keywords: C4 grasses, pasture species evaluation, subtropical forages, subtropical legumes

Introduction and methods

The objective was to identify pasture species with potential for future use in Northland by assessing a broad range of C4 grasses and subtropical legumes. The evaluation drew on historical trial data and contemporary selection tools, with species classified according to agronomic potential, seed availability, biosecurity status, and other traits relevant to developing more resilient farming systems in the face of climate change.

Candidate species identification

The list of candidate species was assembled from two key sources:

1. Previous trials done in Northland. Over the past 50 years, there have been numerous published studies of comparative field trials of an array of C4 grasses and tropical or subtropical (e.g. Davies and Hunt 1983, 1989; Rumball 1991 (legumes); Rumball and Lambert 1981; Taylor et al. 1976a,b; Woods et al. 1996 (grasses); Goold 1978; Goold and McMeikan 1980; Rumball and Lambert 1980 (legumes)). Work on C4 grasses was mostly summarised in a more recent review by Crush and Rowarth (2007). All species from these trials were considered, regardless of previous performance - resulting in 34 grass and 47 legume species after accounting for taxonomic updates. Given the changing climate, historical trial outcomes may no longer be reliable predictors of future agronomic performance in Northland.
2. Tropical Forages (tropicalforages.info) is a website supported by the Australian Government and CIAT - the International Centre for Tropical Agriculture. It contains descriptions of 172 potentially useful species and a selector tool to narrow the pool of species that are relevant using attributes of the area of interest. These include latitude, altitude, soil pH, rainfall and others. Broadly inclusive selection criteria were applied to minimise the risk of prematurely excluding potentially suitable species: 26 grasses and 46 legumes were considered to have potential for Northland.

Taxonomic review and name validation

Substantial effort was directed toward verifying species nomenclature in accordance with current taxonomic standards. Over time, some names have changed, and other species have been combined under one name. The reference used was the International Plant Names Index (ipni.org; a collaboration of The Royal Botanic Gardens, Kew; The Harvard University Herbaria; and The Australian National Herbarium). This site confirmed whether the name of the plant was currently accepted or whether it was considered a synonym under a different name. Further information on geographic distribution and common names in usage was obtained from Plants of the World Online (<http://powo.science.kew.org>).

Biosecurity and regulatory status

Each species was then searched for in the MPI Plant Biosecurity Index (<https://piersearch.mpi.govt.nz/>)

plants-biosecurity-index/). This index identifies each species' import status - for example, whether it was naturalised and importable with phytosanitary clearance, or restricted and unavailable. Species absent from the Biosecurity Index may require further clarification or formal assessment in consultation with MPI. In addition, small volumes of seeds of some species may be stored at the Margot Forde Genebank (<https://www.agresearch.co.nz/products-and-services/margot-forde-genebank/>).

Supplementary Data Sources

Further information for each candidate species was then assembled from an array of other sources: e.g. reference books, on-line searches, seed company on-line catalogues, scientific literature, Feedipedia (feedipedia.org). Information was sought on current use, cultivar development, and feed value among other attributes as well as any critical flaws that might limit its use in New Zealand such as weed risk or seed production difficulty.

Species classification and prioritisation

The candidate species were then classed into three categories: the Green list contains those species that are considered to have most agronomic potential and are more readily available. The Orange list contains species that may have some potential but have limited availability, potential limitations (such as impacts on product quality), or would require a longer introduction process. The Red list are species that are considered less valuable agronomically or have limitations such as MPI restrictions or no seed availability. In some instances, species were not included where they were unlikely to be of value.

Overall, the data available for each species was highly variable. Much of the data was outdated, increasing the risk of misclassification or omission. For example, *Panicum virgatum* (switchgrass) is a species distributed from Canada to Central America and may have relevance for Northland, but it was not identified by the search methods employed. Wide consultation with industry is recommended to ensure the list of species considered for trialling is as comprehensive as possible.

C4 grasses

Species overview

A total of 60 grass species/taxa were identified from the lists of previously trialled species in Crush and Rowarth (2007), Rumball and Lambert (1981) and the search of tropicalforages.info. Thirteen species are currently permitted in some way by MPI. Of these, the Green list identified 6 species, all of which have been tested before (or are currently used) in Northland and appear worth considering for re-evaluation (Appendix 1): *Panicum coloratum*, *Chloris gayana* (Rhodes grass), and *Paspalum dilatatum* are suggested by Acuña (2021)

to be among species with potential to “advance to highest latitudes within the subtropics or even into the temperate regions”. The Orange list contains a further 3 species (Appendix 2) that have more limitations which may make them less attractive (e.g. relatively lower palatability, nutritive value, requirement for soil moisture, vegetative propagation).

Of the remaining 47 species, 35 have been included in the Red lists for a variety of reasons (Appendix 3a-c). Four species are prohibited by MPI - *Digitaria abyssinica*, *Eragrostis curvula*, *Megathyrsus maximum* (formerly *Panicum maximum*) and *Heteropogon contortus*. The first three have previously been evaluated in Northland. Another species which has also been previously trialled, *Digitaria milaniana*, requires assessment by MPI. Excluding previously assessed species, 30 taxa remain that are not recorded by MPI and are therefore not currently importable. Ten of these have been previously evaluated in Northland, with one also identified by Acuña (2021) as having potential for subtropical or temperate use.

Prioritisation for further investigation

Due to the large candidate pool, a tiered prioritisation strategy was adopted to focus efforts on species with higher potential or regulatory feasibility. Further actions required:

1. Discussion and investigation around the 10 species that are not recorded by MPI but have been trialled previously (Appendix 3a) – several of these species may be quickly excluded based on agronomic limitations or lack of available cultivars.
2. Discussion and investigation around the one species which ‘requires assessment’ by MPI but has been trialled previously (Appendix 3b).
3. Comprehensive investigation into the remaining species (Appendix 3c) is left until some decisions have been made on the two above points.

Notes on use of tropicalforages.info

Tropicalforages.info served as a key information source, particularly for cultivar listings, and additional cultivars were also identified from other references. Although tropicalforages.info lists strengths and limitations for each species, this information was not used as a selection tool as it may not be relevant to Northland, or all parts of Northland – e.g. ‘winter hardiness’.

Breeding and cultivars

Information on breeding and cultivar developments was sought by searching several sources such as websites of seed companies; research institutes (e.g. CSIRO cultivar register); industry bodies or government departments; online databases (e.g. tropicalforages.info and Pastures Australia); searches of the scientific literature; and general internet searches by keywords. Some cultivar information is provided in the tables

but, due to the disparate nature of information and relative scarcity of information for some species, this list is likely incomplete. Nevertheless, the results offer a general indication of breeding activity and cultivar availability.

Further notes:

- Cultivars released since the period in which the previous Northland trials were conducted (1980s onwards) were prioritised.
- For species where there are relatively new cultivars, those that are much older (e.g. pre-1970's) were not listed, particularly if there was little useful information available or they appeared to be very region specific.
- Where older cultivars are predominantly what was available, these have been listed, especially if they still appear to be commonly used.
- For some species very few recent cultivars were identified, suggesting limited breeding activity. For other species, however, older cultivars may still be widely used (e.g. see kikuyu below). Cultivar information for some species was difficult to locate and often required following indirect references. Following a chain of references to one in which a new cultivar was mentioned thus enabled a direct search by that cultivar name. In some cases, more searching unearthed subsequent reference to this cultivar being removed from the market. Nonetheless, some studies indicate ongoing breeding interest in some species (e.g. kikuyu and *P. coloratum*), which may yield new cultivars in the future.
- For some species, many cultivars were mentioned. This is indicated in the tables below by the numbers noted in particular sources along with some cultivar names. This was interpreted as an indication of relatively high material availability; further investigation into cultivars is recommended if these species are selected for trials (e.g. Bermuda grass).
- Most material previously screened in Northland appears to have consisted of germplasm accessions rather than named cultivars – i.e. the material was not selected for agronomic performance. Cultivars of these species are probably worth re-evaluating. In addition, some of the Northland evaluations were 40-50 years ago – climatic conditions now will be quite different to when these species, or cultivars if they are still available, were originally screened.

Some comments on particular species

- *Cenchrus clandestinus* (kikuyu)
Only one relatively recent cultivar of kikuyu was identified, Acacia Plateau from Australia. This was also the newest cultivar mentioned in several recent Australian papers (Fraser et al. 2017; Fulkerson et al. 2021), in which the cultivar Whittet (released in 1970) was often used to compare germplasm. Fraser et al.

(2017) states “Whittet is still the dominant pasture seed cultivar sold in Australia 47 years after registration”. One South African seed company website also notes that Whittet is the most common kikuyu cultivar in South Africa. However, various studies indicate there is interest in, and work on, the potential and breeding (including genetic diversity) of kikuyu in Australia (Fraser et al. 2017; Fulkerson et al. 2021; Lowe et al. 2010; Morris 2009), and a new cultivar “Fulkerson” was released commercially in 2023 (B. Fulkerson *pers. comm.*).

- *Chloris gayana* (Rhodes grass)

Tropicalforages.info lists 35 cultivars – dates of release or granting of Plant Breeders' Rights (PBR) range from 1901-2011, but not all are dated. There have been quite a few cultivars released relatively recently for Australia, and others with PBRs granted but it's not clear if these are commercially available. A number of these newer Australian cultivars have been selected specifically for saline tolerance. The Western Australia Department of Primary Industries and Regional Development separates the Rhodes grass cultivars into diploid and tetraploid types – the former being of subtropical origin and described as more robust (higher frost, salt and drought tolerance) and the latter being ‘giant’ types from tropical regions. These distinctions would need to be considered in any cultivar selection for evaluation in Northland.

- *Cynodon dactylon* (Bermuda grass)

A relatively large number of cultivars, or ‘varieties’, are mentioned in results from online searches which also suggests there has been, and continues to be, ongoing effort in breeding of Bermuda grass. A detailed inventory of cultivars should be developed contingent on the selection of the species for further evaluation in Northland. Some key points to consider when investigating cultivars:

- Bermuda grass cultivars or varieties are seeded or vegetative. Presumably seeded types would be preferred for importation and use in Northland, but any differences in general characteristics between the two types may need to be determined.
- Bermuda grass is commonly used for turf – general sources of information don't always state whether cultivars are for turf or forage, so turf types would need to be filtered out. Some varieties are described as used for both purposes, or were developed for turf but are also used for forage.
- Seeded Bermuda grass is also sold in blends of different cultivars, so this was another factor to consider for Northland. Some sources lack clarity regarding whether seed offerings represent single cultivars or cultivar mixtures.
- *Panicum coloratum* (blue panic grass, klein grass)
In the literature, *P. coloratum* is separated into two

varieties – var. *makarikariense* and var. *coloratum* – although these are no longer separated taxonomically. Very few recent cultivars of either variety were found, although some older cultivars still seem to be in use. However, there are numerous publications in the scientific literature on genetic diversity, characteristics and breeding which suggests there is current effort on improvement of this species, particularly in South America (e.g. Armando et al. 2015; Burgos et al. 2018; Giordano et al. 2013; Lifschitz et al. 2022; Pittaro et al. 2021).

• *Paspalum* spp. (*paspalum*)

A review of the *Paspalum* genus by Acuña et al. (2019) found around 94 cultivars developed from eight species. Fifteen *paspalum* species have been trialled in Northland, though for most of these only a few accessions were tested. Eleven of these species do not have any cultivars noted by Acuña et al. (2019) (and eight are not recorded by MPI), so were not included. The remaining four species, plus two others that were identified from tropicalforages.info, have had some cultivar development and were included in the tables below. However, references were found to indicate that two of these were not commercially available. Three of these species are permitted by MPI and three were not recorded.

Subtropical legumes

Nearly 50 legume species have been previously trialled in Northland – including temperate and subtropical accessions. With the addition of the species identified from tropicalforages.info, over 90 legume taxa were considered. The initial approach has been to focus on those that are permitted by MPI – even with some restrictions.

Of the permitted species, the Green list identified five species, four of which have been tested before in Northland and appear worthy of re-evaluation (Appendix 4). The Orange list contains a further fourteen species (Appendix 5) that may have some potential but have some attributes that may make them less attractive (e.g. relatively lower palatability, nutritive value, requirement for soil moisture, vegetative propagation, weed potential, etc.).

A group of 13 species – most of which have been previously trialled in Northland and are permitted by MPI – were considered to have low (or no) potential for Northland in the future for a range of reasons (Appendix 6a). A further group of 61 species – some of which have been previously trialled in Northland but are either not recorded or restricted by MPI (Appendix 6b). More research into some of the species that are not recorded could be warranted in the future.

Breeding activity, cultivar availability and rhizobium considerations

Searches for cultivars suggested there has been very little current effort in breeding subtropical legumes, even less than for C4 grasses. In addition, seed company websites do not always list cultivars or species under scientific names, so care was required when interpreting these listings. Obtaining trial volumes of seeds for some species may not be easy.

Early cycles of evaluation could be done using repeated low levels of nitrogen fertiliser, with specific rhizobium requirements of any promising species being addressed in later work to reduce initial financial, regulatory and technical costs and delays.

Summary and priority actions

1. The highest priority species for evaluation have mostly been previously trialled in Northland and are currently permitted by MPI, though some import conditions may apply. Initial focus should be on the ten High Priority species (Table 1) and the further six that warrant further consideration (Table 2). Other candidates worthy of consideration may be contained in the Green lists (Appendices 1, 4) and perhaps in the Orange Lists (Appendices 2, 4). Species selection may be constrained by cultivar availability and sourcing options.
2. Consultation with plant breeders and industry stakeholders is recommended to validate the candidate list and ensure comprehensive species coverage.
3. The regulatory situation for species that have been evaluated in Northland before but are currently not recorded by MPI (and therefore do not make the Green or Orange lists) should be investigated. Few species in this category are likely to be of interest.
4. Wider discussion and further investigation may be warranted into a few other species that have been trialled in Northland before but have an MPI status of “requires assessment”.
5. Red list species (Appendices 3a-c, 6a-b) should only be considered once points above are completed. There may be few (or no) species of interest here.
6. Any further investigation into species should include assessment of pest issues, weed potential and companion species (both grasses and legumes). This includes species permitted by MPI but not yet widely adopted in New Zealand agriculture. Some of the species identified by tropicalforages.info, including some which are widely cultivated such as Bermuda grass and buffel grass, are noted for weed potential. Note: some species identified in this section have also been identified as sleeper weeds (e.g. Rhodes grass; Buddenhagen and Ngow 2025).

7. Assess the viability and strategic value of C4 grasses that require vegetative propagation. There is much greater difficulty for establishment compared with seed and this, along with any required changes in equipment and practices, needs to be weighed up against potential (and currently unknown) performance benefits. The latter could include consideration of new cultivar development. Nursery stock of *Cynodon dactylon* and *Hemarthria altissima* is listed by MPI as ‘requires assessment’; clarification of these requirements is needed – for example this would include the development of new import health standards. This is particularly true in the case of *H. altissima*, as there are well established remnant populations in Northland (A. McCahon pers. comm.)

ACKNOWLEDGEMENTS

The authors thank Northland Inc. for funding the literature review that underpinned this paper.

REFERENCES

- Acuña CA. 2021. Breeding perennial warm-season grasses for the subtropical belt in South America. In: *Proceedings of the XXIV International Grasslands Congress/XI International Rangeland Congress*. 25-29 October 2021. Kenya Agricultural and Livestock Research Organization.
- Acuña CA, Martínez EJ, Zilli AL, Bruognoli EA, Espinoza F, Marcón F, Urbani MH, Quarín CL. 2019. Reproductive systems in *Paspalum*: relevance for germplasm collection and conservation, breeding techniques, and adoption of released cultivars. *Frontiers in Plant Science* 10: 1286. <https://doi.org/10.3389/fpls.2019.01286>
- Armando LV, Tomás MA, Garayalde AF, Carrera AD. 2015. Assessing the genetic diversity of *Panicum coloratum* var. *makarikariense* using agro-morphological traits and microsatellite-based markers. *Annals of Applied Biology* 167: 373-386. <https://doi.org/10.1111/aab.12235>
- Buddenhagen CE, Ngow Z. 2025. Identifying sleeper weeds of pastoral systems in Northland, New Zealand. *Journal of New Zealand Grasslands* 87: <https://doi.org/10.33584/jnzg.2025.87.3760>
- Burgos E, Thompson C, Giordano M, Tomás MA. 2018. Pre-breeding studies in *Panicum coloratum* var. *coloratum*: characterization using agro-morphological traits and molecular markers. *Tropical Grasslands* 6: 82-92. [https://doi.org/10.17138/TGFT\(6\)82-92](https://doi.org/10.17138/TGFT(6)82-92)
- Crush JR, Rowarth JS. 2007. The role of C4 grasses in New Zealand pastoral systems. *New Zealand Journal of Agricultural Research* 50: 125-137. <https://doi.org/10.1080/0028823070951029>
- Davies LJ, Hunt BJ. 1983. Growth of tropical grass introductions in mixed swards with ryegrass and clover under mowing. *New Zealand Journal of Agricultural Research* 26: 415-422. <https://doi.org/10.1080/00288233.1983.10427034>
- Davies LJ, Hunt BJ. 1989. Evaluation of five introductions of the subtropical grass *Hemarthria altissima* at a frost-prone site in Northland. *New Zealand Journal of Agricultural Research* 32: 469-476. <https://doi.org/10.1080/00288233.1989.10420832>
- Fraser D, Sharp P, Ahmad N, Morris B, Trethowan R. 2017. Abiotic stress tolerance of kikuyu (*Cenchrus clandestinus*) and some related grasses and potential of kikuyu for agricultural and urban environments. *Crop and Pasture Science* 68: 285-296. <https://doi.org/10.1071/CP16358>
- Fulkerson WJ, Jennings NR, Callow M, Harper KJ, Wong PTW, Martin PM. 2021. Selection for resistance to fungal diseases and other desirable traits in kikuyu grass (*Cenchrus clandestinus*). *Tropical Grasslands* 9: 60-69. [https://doi.org/10.17138/TGFT\(9\)60-69](https://doi.org/10.17138/TGFT(9)60-69)
- Giordano MC, Berone GD, Tomás MA. 2013. Selection by seed weight improves traits related to seedling establishment in *Panicum coloratum* L var. *makarikariense*. *Plant Breeding* 132: 620-624. <https://doi.org/10.1111/pbr.12120>
- Goold GJ. 1978. Small-plot studies of *Desmodium intortum* (Mill.) Urb. cv. ‘Greenleaf’, *D uncinatum* (Jacq.) DC. cv. ‘Silverleaf’, and *Lotononis bainesii* Baker cv. ‘Miles’, in Northland, New Zealand. *New Zealand Journal of Experimental Agriculture* 6: 23-28. <https://doi.org/10.1080/03015521.1978.10425965>
- Goold GJ, McMeikan WB. 1980. Preliminary assessment of subtropical legume species at several sites in Northland. *Proceedings of the Agronomy Society of New Zealand* 10: 55-57.
- Grant WF. 2004. List of *Lotus corniculatus* (Birdsfoot trefoil), *L uliginosis*/*L pedunculatus* (Big trefoil), *L glaber* (Narrowleaf trefoil) and *L subbiflorus* cultivars. Part 1. Cultivars with known or tentative country of origin. *Lotus Newsletter* 34: 12-26. <https://www.inia.org.uy/sitios/lnl/vol34/lnvol34num1.pdf>
- Hayot Carbonero C, Mueller-Harvey I, Brown TA, Smith L. 2011. Sainfoin (*Onobrychis viciifolia*): a beneficial forage legume. *Plant Genetic Resources* 9: 70-85. <https://doi.org/10.1017/S147926211000037X>
- Lifschitz M, Tommasino E, Zabala JM, Grunberg K, Ramos JC, Tomás MA. 2022. Combined effect of salinity and hypoxia in seedlings of two varieties of *Panicum coloratum*: morphology, root system architecture, oxidative damage and antioxidant response. *Annals of Applied Biology* 180: 283-293. <https://doi.org/10.1111/aab.12733>

- Lowe KF, Bowdler TM, Sinclair K, Holton TA, Skabo SJ. 2010. Phenotypic and genotypic variation within populations of kikuyu (*Pennisetum clandestinum*) in Australia. *Tropical Grasslands* 44: 84-94.
- Mora-Ortiz M, Smith LMJ. 2018. *Onobrychis vicifolia*: a comprehensive literature review of its history, etymology, taxonomy, genetics, agronomy and botany. *Plant Genetic Resources: Characterisation and Utilization* 16: 403-418. <https://doi.org/10.1017/S1479262118000154>
- McCahon AD, Ussher GR, & McCahon KS. (2021). Diversified pastures at the front line of climate change in Northland: farmers' experiences, new directions and wider implications for other parts of the country. Resilient Pastures – Grassland Research and Practice Series, 17: 213-224. <https://doi.org/10.33584/rps.17.2021.3474>
- Morris B. 2009. Variation and breeding of kikuyu grass (*Pennisetum clandestinum*). PhD thesis. University of Sydney.
- Moser LE, Burson BL, Sollenberger LE (eds). 2004. *Warm-Season (C4) Grasses. Agronomy Monographs* 45. American Society of Agronomy, Madison. 1171 pp. DOI: [10.2134/agronmonogr45](https://doi.org/10.2134/agronmonogr45)
- Pittaro G, Lifschitz M, Sánchez M, Bustos D, Otondo J, Tomás MA. 2021. Prospective genetic gain to improve salinity tolerance in a population of *Panicum coloratum* var. *coloratum* with two different selection methods. *Tropical Grasslands* 9: 171-181. [https://doi.org/10.17138/TGFT\(9\)171-181](https://doi.org/10.17138/TGFT(9)171-181)
- Real D, Altier N. 2005. Breeding for disease resistance, forage, and seed production in *Lotononis bainesii* Baker. *New Zealand Journal of Agricultural Research* 48: 93-100. <https://doi.org/10.1080/00288233.2005.9513669>
- Ribotta AN, López Colomba E, Bollati GP, Striker GG, Carloni EJ, Griffa SM, Quiroga MP, Tommasino EA, Grunberg KA. 2019. Agronomic and molecular characterization of *Chloris gayana* cultivars and salinity response during germination and early vegetative growth. *Tropical Grasslands* 7: 14-24. [https://doi.org/10.17138/TGFT\(7\)14-24](https://doi.org/10.17138/TGFT(7)14-24)
- Rumball W, Claydon RB. 2005. 'G35' sainfoin (*Onobrychis vicifolia* Scop.). *New Zealand Journal of Agricultural Research* 48: 127-128. <https://doi.org/10.1080/00288233.2005.9513672>
- Rumball PJ. 1991. Performance of several subtropical grasses in Northland hill pastures. *New Zealand Journal of Agricultural Research* 34: 375-382. <https://doi.org/10.1080/00288233.1991.10428401>
- Rumball PJ, Lambert JP. 1980. Plant introduction trials: Performance of some forage legumes in Northland. *New Zealand Journal of Experimental Agriculture* 8: 179-183. <https://doi.org/10.1080/03015521.1980.10426346>
- Rumball PJ, Lambert JP. 1981. Plant introduction trials: Performance of some subtropical grasses in Northland. *New Zealand Journal of Experimental Agriculture* 9: 79-83. DOI: [10.1080/03015521.1980.10426255](https://doi.org/10.1080/03015521.1980.10426255)
- Taylor AO, Rowley JA, Hunt BJ. 1976a. Potential of new summer grasses in Northland. I. Warm-season yields under dryland and irrigation. *New Zealand Journal of Agricultural Research* 19: 127-133. <https://doi.org/10.1080/00288233.1976.10426759>
- Taylor AO, Rowley JA, Hunt BJ. 1976b. Potential of new summer grasses in Northland. II. A further range of grasses. *New Zealand Journal of Agricultural Research* 19: 477-481. <https://doi.org/10.1080/00288233.1976.10426791>
- Tomás MA, Lifschitz M, Giordano M, Armando L, Cardamone L. 2021. Progress in breeding of a forage allogamous subtropical grass. pp. 99-101. In: Basigalup D, Odorizzi A (eds). *Proceedings of the First Plant Breeding Symposium. Plant Genetics for Innovation*.
- Woods PW, Couchman JN, Clark DA. 1996. Dairy cow performance on limpgrass (*Hemarthria altissima*). *Proceedings of the New Zealand Society of Animal Production* 56: 245-250. <https://www.nzsap.org/proceedings/1996/dairy-cow-performance-limpgrass-hemarthria-altissima>

Table 1 High priority candidate C4 grasses and legume species.

Species	Cultivars	Notes
Grasses:		
<i>Cenchrus clandestinus</i> (kikuyu)	2-3 cultivars Fulkerson Acacia Plateau Whittet	Commercially available from 2023. Older cultivar for control.
<i>Chloris gayana</i> (Rhodes grass) – diploid cultivars (subtropical origin)	4-5 cultivars Finecut Endura and/or Tolgar Santana INTA Peman Katambora	Bred from Katambora (1998). Barenbrug Australia website. May need to source from Argentina (2012). Older cultivar for control.
<i>Panicum coloratum</i>	2 cultivars Bambatsi Kapivera INTA	Older, only commercial cultivar until recently. More recent cultivar (2018) from Argentina, if it can be sourced.
<i>Hemarthria altissima</i>	2 cultivars Kenhy Gibtuck	More recent (2014) tetraploid cultivars, which are crosses of older cultivars. Vegetative establishment – as nursery stock it “requires assessment” by MPI.
<i>Paspalum dilatatum</i>	2-3 cultivars listed in Acuña et al 2019	If these can be sourced.
Legumes:		
<i>Clitoria ternatea</i> (Butterfly pea)	Milgarra	1991
<i>Lablab purpureus</i> (Lablab)	2-3 cultivars Rongai and Highworth Sustain LS?	Older cultivars. Listed on Barenbrug Australia website as Dolichos lablab.
<i>Desmodium intortum</i> (Greenleaf desmodium)	Greenleaf	The only cultivar available (1964).
<i>Coronilla varia</i> (Crown vetch)	Penngift	Still seems to be the only cultivar.
<i>Lotus pedunculatus</i>	E-Tanin	Recent cultivar. If commercially available.

Table 2 Candidate C4 grass and legume species (or cultivars) that warrant further consideration.

Species	Cultivars	Notes
Grasses:		
<i>Cenchrus ciliaris</i> (buffel grass)	2-3 cultivars	Permitted by MPI but noted in some sources as potentially invasive – weed assessment should be conducted. There are a number of relatively recent cultivars from which several could be selected, depending on availability.
<i>Cynodon dactylon</i> (Bermuda grass)	Numerous seeded cultivars and blends – research these further to ID and select several. Tifton 85	Sources also have notes on weed potential so it would be wise to assess and understand this prior to evaluation. Vegetative type – need to check with MPI for import requirements.
<i>Chloris gayana</i> (Rhodes grass) – tetraploid cultivars (tropical origin)	Select 2-3 cultivars – at least 2 recent and 1 older were found.	
<i>Panicum coloratum</i>	var. <i>coloratum</i> cultivars	If can be sourced.
Legumes:		
<i>Pueraria montana</i> var. <i>montana</i> (syn. <i>Neonotonia wightii</i>) (perennial soybean)	1 or 2 cultivars depending on availability.	Allowed by MPI, but sources note weedy potential – this should be assessed first. tropicalforages.info also comments it can initially cause meat taint.
<i>Listia bainesii</i> (formerly <i>Lotononis bainesii</i>)	Miles INIA Glencoe	Older cultivar. Recent cultivar. Some sources note this species can cause milk taint – more research is required into this before deciding to evaluate, or plots should only be mown.

APPENDICES:

Appendix 1 C4 grass species considered to have future potential for Northland and permitted by MPI ("Green list").

Cultivar										
Species	Name (common name)	Synonym	MPI status	Material previously tested in Northland (cultivar/ accession)	Number listed in tropicalforages.info	Names	Date of release or PBR	Country of origin	Website for supplier or references	Notes
<i>Cenchrus ciliaris</i> (buffel grass)			Basic	American Biloela In 1025 In 1029	37 (1870's-2017)	American, Biloela, Boorara, Gayndah, Lawes, Molopo, Nunbank, Tarewinabar, West Australian	All pre-1971		https://research.csiro.au/cultivars/grasses/ https://www.agricol.co.za/agricol-products/blue-buffalograss/ https://perman.com.ar/es/productos/buffel-grass	
						Viva	1994	Australia	tropicalforages.info	
						Lakota		USA (Texas)?	https://barenbrug.com.au/forage-pasture/tropical-2/tropical-grasses/lakota.htm	
						Kalahari	1999	South Africa	tropicalforages.info	
						Pecos	2000	USA	https://pogueagri.com/buffel-grass-pecos-brand/	
									https://perman.com.ar/es/productos/pecos	
						Laredo	2000	USA	tropicalforages.info https://pogueagri.com/buffel-grass-laredo-brand/	
						Bergbuffel	2000	South Africa	tropicalforages.info	
						Titan	2017	Mexico	tropicalforages.info	
						Regio	2017	Mexico	tropicalforages.info	

<i>Cenchrus clandestinus</i> (kikuyu)	<i>Pennisetum clandestinum</i>	see 155.02.05 under <i>Echinochloa</i>	KS233 Un-named Whittet	10 (1938-2015)	Whittet	1970	Australia	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/whittet.pdf	Still seems to be the most common cultivar used in Australia. AGT Foods website fact sheet also states Whittet is the most common kikuyu cultivar in South Africa
					Breakwell	1971	Australia	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/breakwell.pdf	
					Crofts	1983	Australia	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/crofts.pdf	
					Noonan	1983	Australia	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/noonan.pdf	
					Hosaka Acacia Plateau	1982/83 c2015	USA (Hawaii) Australia	https://www.seedforce.com.au/product/sf-acacia-plateau	Fast establishing, more cold tolerance, rapid lateral spread
					Fulkerson	2022	Australia		Will be commercially available in October 2022.
<i>Chloris gayana</i> (Rhodes grass)		see 155.02.05 under <i>Agrostis</i>	Samford In 1030 BZ 608, 610, 613	35 (1901-2011)	Pioneer	Pre-1971	Australia	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/pioneer.pdf	Diploid. Also known as commercial Rhodes grass, superseded by Katambora
					Katambora	1967	Australia	https://www.pggwrightson-seeds.com.au/seeds/tropical/common-grasses/katambora-rhodes-grass	Diploid. Later flowering than Pioneer, more leafy and productive into autumn.
								https://barebrug.com.au/international/products/tropical-grasses/katambora.htm	Still appears on South African seed company websites (Limagrain Seeds)
								https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/katambora.pdf	South Africa, AGT Foods, Agrico, Barenbrug). AGT Foods factsheet says Katambora is the most common cultivar in South Africa.
								https://www.daf.qld.gov.au/business-priorities/agriculture/plants/crops-pastures/pastures/rhodes-grass#Varieties	

Callide	1967	Australia	https://irwinhunter.com.au/product/callide-rhodes-grass/ https://irp.cdn-website.com/6e9dac5e/files/uploaded/Callide%20Rhodes%20grass%20Fact%20sheet.pdf https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/callide.pdf https://www.daf.qld.gov.au/business-priorities/agriculture/plants/crops-pastures/pastures/rhodes-grass#Varieties	<p>Tetraploid.</p> <p>Less cold tolerant – better north of Perth. Later flowering than Katambora, less cold tolerant, need higher rainfall than Pioneer or Katambora, more palatable and can be more productive than them under high fertility.</p>
Samford	1967	Australia	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/samford.pdf	Tetraploid?
Nemkat	1992	Australia		Diploid. Selected from Katambora, root knot nematode resistance, tobacco growing area
Asatsuyu Finecut	1995 1998 (PBR granted)	Japan Australia?	https://irwinhunter.com.au/product/finecut-rhodes-grass/	Diploid. Diploid.
Topcut	1998 (PBR granted)	Australia?	https://www.daf.qld.gov.au/business-priorities/agriculture/plants/crops-pastures/pastures/rhodes-grass#Varieties	Bred from Katambora. Selected for improved grazing qualities. Fine leaves and stems, early flowering, uniform maturity, high yielding.
Reclaimer	2010 (PBR granted)		https://irwinhunter.com.au/product/reclaimer-rhodes-grass/ https://irp.cdn-website.com/6e9dac5e/files/uploaded/RECLAIMER%20Rhodes%20grass%20Fact%20sheet.pdf	<p>Developed from Pioneer. Selected for improved haymaking. Fine leaves and stems, early flowering, uniform maturity, high yielding.</p> <p>Diploid.</p> <p>Selection from Finecut from salt tolerance programme.</p>

Endura	Australia		https://barenbrug.com.au/forage-pasture/tropical-2/tropical-grasses/endura-rhodes-grass.htm	Diploid.
Mariner	Australia	2011 (PBR granted)	https://barenbrug.com.au/forage-pasture/tropical-2/tropical-grasses/mariner-rhodes-grass.htm	Tetraploid. Selected from Samford.
Tolgar	Australia		https://barenbrug.com.au/forage-pasture/tropical-2/tropical-grasses/tolgar-rhodes-grass.htm	Diploid.
Epica INTA Peman	Argentina	2007	https://intagob.ar/variedades/epica-inta%E2%80%93peman https://peman.com.ar/en/products/%C3%A9pica-inta-pem%C3%A1n%C2%AE https://irp.cdn-website.com/6e9dac5e/files/uploaded/EPICA%20Rhodes%20grass%20Fact%20sheet.pdf	Tetraploid.
Epica	Australia	2018 (PBR granted)	https://peman.com.ar/en/products/%C3%A9pica-inta-pem%C3%A1n%C2%AE	Might be the same as the above cultivar? Diploid.
Santana INTA Peman	Argentina?	2012 (registered in Argentina)	https://intagob.ar/variedades/santana-inta-peman	
Salcut, Gulfcut	Australia?		Ribotta et al. 2019	Diploid. 2010 PBR granted in Australia to Selected Seeds, but not clear if these have been released
KP8, KG2, Sabre, Toro	Australia?			2011 PBRs granted in Australia to Barenbrug but are not on their website. Not clear if these have not been released or were released but are no longer available. Sabre and Toro, tetraploid (selected from Callide); KP8 and KG2, diploid.

*Cynodon
dactylon*

(Bermuda grass
(USA))

see
155.02.05
under
Agrostis

Alicia
Selection
Cy6 135
Coastal
Coastcross
1

22
(1943-1994)

Brazos

1982

USA (Texas)

tropicalforages.info

These are more recent vegetative types listed on tropicalforages.info. There are varying comments about their winter hardiness but these are likely based on performance in the USA.

Florakirk

1994

USA (Florida)

Grazer

1985

USA (Louisiana)

Jiggs

1989

USA (Texas)

Russell

1994

USA (Alabama)

Tifton 68

1984

USA (Georgia)

Tifton 78

1984

USA (Georgia)

Tifton 85

1991

USA (Georgia)

Other vegetative types found in searches: Ozark, Midland 99 (1999)

Cheyenne and Cheyenne II, CD90160, KF-194, Giant, Wrangler, Jackpot, Mirage, Mohawk, Pyramid

These are some of the seeded types mentioned in a University of Georgia extension circular from 2013 (see link) - only one of these is mentioned on tropicalforages.info. The general number suggests there has been development of cultivars suitable for sowing, but these (and any others) would need investigation into date of release and suitability of characteristics (some may be turf cultivars).

<https://www.pennington.com/all-products/agriculture/cheyenne-ii>

extension circular from 2013 (see link) - only one of these is mentioned on tropicalforages.info. The general number suggests there has been development of cultivars suitable for sowing, but these (and any others) would need investigation into date of release and suitability of characteristics (some may be turf cultivars).

Guymon

1982

USA (Oklahoma)

tropicalforages.info

Seeded type. For lawns, playgrounds, roadsides etc. but also suitable for forage though lower yielding than some other cultivars.

Comanche

USA?

<https://pogueagri.com/grasses/bermudagrass-comanche/>

Seeded type

Sahara II, Arizona
Common

USA?

Seeded types

<i>Paspalum dilatatum</i> (<i>Paspalum dallisgrass</i>)	see 155.02.05 under <i>Panicum</i>	"Australian commercial" KS 107 Commercial Bo113 G15	5 (1951-1980)s	La Estanzuela Chiru Magnifi 217 Pampeano INTA Relincho	Mid-1980's Uruguay 1988 Argentina 2003 Argentina	Acuña et al. 2019 lists 9 cultivars (6 from 1980s-2013)	Noted as having poor seed production and being susceptible to ergot. Noted as having poor seed production and being susceptible to ergot.
<i>Panicum coloratum</i> (Bambatsi panic – Australia; Klein-grass - USA)	see 155.02.05 under <i>Panicum</i>	Bambatsi CPI 13372, 16325, 59874, 59876, 59877 Solai	5 var. <i>makarikariense</i>	Bambatsi	1958 (but see notes)	https://progressiveseeds.com.au/bambatsi-panic/ Tropicalforages.info	Noted as ergot resistant and cold tolerant. There were previously three cultivars in Australia (Bambatsi, Burnett and Pollock), but these merged into one cultivar known as Bambatsi due to outcrossing. This is now the only commercial cultivar available in Australia. https://keys.lucidcentral.org/keys/v3/pastures/Html/Bambatsi_panic.htm
				Kapivera INTA	2018	Lifschitz et al, 2021	Armando et al 2015 also states Bambatsi is the only cultivar of <i>P. coloratum</i> var. <i>makarikariense</i> (however see Kapivera INTA below) https://onlinelibrary.wiley.com/doi/abs/10.1111/aab.12234
	7 var. <i>coloratum</i> (most recent dated 1990)	Verde/Klein Verde Tamidori Tayutaka		USA (Texas) Japan Japan	1981 1986 1990	tropicalforages.info https://pogueagri.com/klein-grass-verde/ tropicalforages.info tropicalforages.info	Tomás et al 2021 also mention registration being underway for "material" with salinity tolerance, and ongoing work for combined tolerance of salinity and waterlogging.

Appendix 2

C4 grass species that may have future potential for Northland and are permitted by MPI with restrictions ("Orange list").

Cultivar									
Species Name	Synonym	MPI status	Material previously tested in Northland (cultivar/ accession)	Number listed in tropicalforages.info	Names	Date of release or PBR	Country of origin	Website for supplier or reference	Notes
<i>Bothriochloa bladhii</i> <i>subsp glabra</i>		Basic		2 (1994)	Swann	1994	Australia	tropicalforages.info https://keys.lucidcentral.org/keys/v3/pastures/Html/Forest_bluegrass.htm	
(Forest bluegrass – Australia)								https://progressiveseeds.com.au/swann-forest-bluegrass/tropicalforages.info	
<i>Hemarthria altissima</i> (Limpograss)		see 155.02.05 under <i>Agrostis</i>	Bigalta Floralta PI 349753 PI 364891 tetraploid PI 364884 diploid "tetraploid" KS 469	6 (1978-2014)	WW-B.Dahl Bigalta Greenalta	1994 1978 1978	USA (Texas) USA (Florida)	tropicalforages.info https://edis.ifas.ufl.edu/publication/AG330	Is tetraploid – which have better in vitro digestibility according to Woods et al 1996. Is diploid – which have better frost tolerance according to Woods et al. 1996. University of Florida stated low digestibility and no longer recommends (see link). Diploid. University of Florida stated most cold tolerant but low digestibility, no longer recommends (see link). Tetraploid. University of Florida states more persistent under grazing than Bigalta (see link). Kenhy and Gibtuck are crosses of Floralta x Bigalta. Selected for better growth, persistence under grazing, and nutritive value than Floralta. University of Georgia (see link) states these have better productivity and persistence than Floralta.
					Redalta	1978			
					Floralta	1987			
					Kenhy Gibtuck	2014 2014?			

Paspalum atratum

see 155.02.05
under
Panicum

7
(1995-2004)
According to com-
ments in Tropical
forages.info and
Acuña et al. 2019,
cultivars Suerte/Hi-
Gane, Camba-FCA,
Ubon and Pojuca
have all been
developed from the
same
accession

Suerte/Hi-
Gane

1995

USA
(Florida)

tropicalforages.info
Acuña et al. 2019.

Marketed as Hi-Gane in Australia.
From Brazilian germplasm.

Camba-FCA

1997

Argentina

tropicalforages.info
Acuña et al. 2019.

From Brazilian germplasm.

Ubon

1998

Thailand

tropicalforages.info
Acuña et al. 2019
<https://www.tropseeds.com/ubon-paspalum/>

From Brazilian germplasm.

Pojuca

2000

Brazil

tropicalforages.info
Acuña et al. 2019.

From Brazilian germplasm.

Terenos

~1995

SE Asia

tropicalforages.info

Reyan No.

2003

China

tropicalforages.info

Appendix 3a

C4 grass species that are considered unlikely to have future potential for Northland but have been trialled in Northland. However, they are not recorded by MPI and would require a formal assessment process ("Red list").

Species Name (common name)	Synonym	Material previously tested in Northland (cultivar/ accession)	Cultivar Names	Date of release or PBR	Country of origin	Website for supplier or references	Notes
<i>Acroceras macrum</i>		Cedera, BZ 1116					Seems to suit wet or seasonally flooded areas. Three cultivars in tropicalforages.info
<i>Cenchrus purpureus</i> and hybrids	Formerly <i>Pennisetum purpureum</i>	CPI 20362					"It is not feasible or relevant to list the huge range of national and purpose-specific cultivars with claimed strengths". Limitations include frost susceptibility, and vegetative planting, and notes "good management required". Also note that the MPI biosecurity index notes that <i>Pennisetum</i> species other than those recorded are prohibited – it's not clear how this applies here with the previous genus name. Only one cultivar listed on Pastures Australia - noted as "Digit grass", formerly <i>D. smutzii</i> . Note also has entry for <i>D. eriantha</i> "Pangola grass", noted as formerly <i>D. decumbens</i> - only one type of pangola grass in Oz, not been given a cultivar name.
<i>Digitaria eriantha</i>	Has 16 synonyms, none of which are recorded by MPI	As <i>D. decumbens</i> : <i>pargola</i> CPI 118578 KS 386 As <i>D. peritzi</i> Slenderstem CQ911 CPI 17761B As <i>D. smutzii</i> CPI 38869 In 1050	Premier	1987	Australia	https://progressive-seeds.com.au/premier-digit-grass/ https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/premier.pdf	15 cultivars listed on tropicalforages.info – at least six of these from 1980's onwards. AGT Foods website says Irene is the most common cultivar in South Africa.
			Irene	1940's	South Africa	https://www.agricol.co.za/agricol-products/smutsfinger/ https://agffoods.co.za/wp-content/uploads/2018/07/9.-Smuts-finger-grass.pdf	Tiptop is a selection from Irene for improved seed yield, uniformity of growth, leaf:stem ratio and rust resistance.
			Tiptop	1995	South Africa	https://www.barenbrug.co.za/misc-specific/productPdf.aspx?productID=29507&siteID=47 https://agffoods.co.za/wp-content/uploads/2018/07/9.-Smuts-finger-grass.pdf https://www.barenbrug.co.za/misc-specific/productPdf.aspx?productID=29507&siteID=47	
<i>Digitaria natalensis</i>		As <i>D. macroglossa</i> CPI 116267					Is not on tropicalforages.info.

<i>Eragrostis superba</i> (Wilman lovegrass)	CPI 36443 Bz 1029		Is not on Tropicalforages.info.
<i>Paspalum leptum</i>	Formerly <i>P. nicorae</i>	As <i>P. nicorae</i> : CPI 21382	Tropicalforages.info lists five cultivars – only two seem to be for forage use – and one promising accession unofficially released in Australia. Limitations include “difficult to control with cultivation or herbicide” and “competes strongly with legumes”. Note, Acuña et al. 2019 lists three of the cultivars from Tropicalforages.info as <i>P. nicorae</i> – but notes there are no commercially available cultivars of this species. Has had the third highest number of cultivars released in the genus (16) according to Acuña et al. 2019. Nine of these were released from 1983-2012. Twenty-three listed in Tropicalforages.info, going back to 1913 – some no longer available or not recommended.
<i>Paspalum notatum</i> (bahiagrass)		CPI 11858, 11818, and 11863	Noted in Tropicalforages.info as being very competitive and tending to form monocultures, sometimes perceived as a weed in pasture. Three cultivars on Tropicalforages.info from Australia (Bryan, Hartley, Rodds Bay). According to Acuña et al. 2019 these have been reclassified as <i>P. lenticulare</i> , and no commercial seed is available. Tropicalforages.info lists 10 cultivars (not all released) - four of which were in the 2000's and two in the 2010's. Several appear to have been released under different names in different countries (South and Central America, and Cuba). Limitations include “may cause photosensitisation particularly in sheep and goats” and “tends to monospecific sward”. Tropicalforages.info includes <i>U. decumbens</i> and <i>U. ruziziensis</i> – but IPNI classes these as <i>U. eminii</i> , which is not in Tropicalforages.info. Tropicalforages.info lists nine cultivars of <i>U. decumbens</i> (eight of these may be the same cultivar in different countries) – predominantly from the 1960's-1991. Limitations “include photosensitisation in sheep, goats and young cattle” and “poor compatibility with many legumes”. Tropicalforages.info lists only one cultivar of <i>U. ruziziensis</i> (Australia, 1966).
<i>Paspalum plicatulum</i>		CPI 2741 and 11826 Hartley	
<i>Urochloa brizantha</i>	Formerly <i>Brachiaria brizantha</i>	BZ 1081	
<i>Urochloa eminii</i>	Formerly <i>Urochloa decumbens</i> , <i>Urochloa ruziziensis</i> – in turn formerly <i>Brachiaria decumbens</i> and <i>Brachiaria ruziziensis</i>		
		Acuña et al. 2019.	
		Acuña et al. 2019.	

Appendix 3b C4 grass species that are considered unlikely to have future potential for Northland but have been trialled in Northland. They are prohibited or restricted by MPI ("Red list").

Name	Synonym	MPI Status	Material previously tested in Northland (cultivar/ accession)	Notes				
<i>Digitaria abyssinica</i>		Prohibited	As <i>D. scalarum</i> : CPI 59808, 50810, and 50813	Not listed on Tropicalforages.info.				
<i>Eragrostis curvula</i>		Prohibited	Ermelo	Tropicalforages.info lists 18 cultivars but states that there are others which have been released, mostly in USA, Argentina and South Africa. A lot of these are noted as no longer available/redundant. Also notes that the species matures rapidly and has environmental weed potential.				
<i>Heteropogon contortus</i>		Prohibited		AGT Foods and Barenbrug websites say Ermelo is the most common cultivar of the species in South Africa. Tropicalforages.info says no cultivars are released.				
<i>Megathyrsus maximus</i>	<i>Panicum maximum</i>	Prohibited	As <i>P. maximum</i> : Petrie; CPI 16792 and 27630; Makueni	Tropicalforages.info lists >25 tall/medium type cultivars and seven short type cultivars that have been released around the world (Brazil, Australia, Thailand, Kenya, Uganda, South Africa, Malawi, Zambia, Zimbabwe, Japan, China). Dates of release are not given for all but 17 are listed since the 1980's including two Barenbrug cultivars from Australia in 2017 (MegaMax 049 and MegaMax 059).				
Name	Synonym	MPI Status	Material previously tested in Northland (cultivar/ accession)	Cultivar names	Date of release or PBR	Country of origin	Website for supplier or references	Notes
<i>Digitaria milanjiana</i>	Formerly <i>D. polevansii</i> , <i>D. setivalva</i>	Requires assessment	<i>D. polevansii</i> : CPI 40667; <i>D. setivalva</i> : CPI 8383	Jarra	1993	Australia	https://www.pgg-wrightsonseeds.com.au/seeds/tropical/common-grasses/jarra-grass	These are the only three cultivars listed on Tropicalforages.info, which also lists a number of promising accessions. Note that some of these accessions, and the cultivar Strickland, are noted as being collected, or held by certain institutions, as other species of <i>Digitaria</i> .
	Arnhem			1995	Australia			https://industry.nt.gov.au/_data/assets/pdf_file/0020/23321/9740.pdf
				1997	Australia			https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/arnhem.pdf

Appendix 3c C4 grass species that are considered unlikely to have future potential for Northland and have not been trialled in Northland. They are not recorded by MPI and would require a formal assessment process (“Red list”).

Name	Synonym	Notes
<i>Bothriochloa insculpta</i>		Tropicalforages.info lists 3 cultivars – all from Australia (1978, 1989, 2004).
<i>Bothriochloa ischaemum</i>		Tropicalforages.info lists 6 cultivars – all from USA (1937-1987). Limitations include “adverse effect on biodiversity”.
<i>Bothriochloa pertusa</i>		Tropicalforages.info lists 7 cultivars – one from India, six from Australia (most of latter of unknown origin). Limitations include “invasive with weed potential”.
<i>Cynodon plectostachyus</i>		Tropicalforages.info notes giant types of <i>Cynodon</i> look very similar and so there has been a lot of taxonomic confusion – therefore treats 3 species of <i>Cynodon</i> in one factsheet. States no cultivars released of <i>C. plectostachyus</i> .
<i>Dichanthium annulatum</i>		Tropicalforages.info lists 4 cultivars (1944, 1954, 1961, 1981) from USA and India, and lists a number of promising accessions mostly selected, or collected, in India.
<i>Dichanthium aristatum</i>		Tropicalforages.info lists 5 cultivars – only four are dated, with the most recent being 1981 and 1995 (Australia – “suppresses <i>Chloris gayana</i> under heavy grazing”).
<i>Dichanthium caricosum</i>		Tropicalforages.info only lists one cultivar of unknown origin, but commercially available in Paraguay and northern Argentina. Two promising accessions mentioned.
<i>Dichanthium sericeum</i>		Tropicalforages.info only lists one cultivar. Released in Australia in 2006 (Scatta). Limitations include “declines under heavy grazing”.
<i>Digitaria didactyla</i>		Tropicalforages.info states <i>D. swazilandensis</i> is very similar to <i>D. didactyla</i> so is considered as a synonym by some.
<i>Digitaria swazilandensis</i>		See comments above for <i>D. didactyla</i> .
<i>Megathyrsus maximus</i> <i>x M. infestus</i>		Assume this would be “Prohibited” by MPI as it contains <i>M. maximus</i> . Group with characteristics intermediate to the two species, but some class them as a type within <i>M. maximus</i> . Tropicalforages.info lists three cultivars – several seem to be used selected, or used, in very specific types of environments or geographic locations.
<i>Panicum trichocladum</i>		Tropicalforages.info lists two cultivars – however states one of these is “considered to be <i>M. maximus</i> in Brazil”
<i>Paspalum guenoarum</i>		Tropicalforages.info lists 11 cultivars, mostly released in South America. Most of these have no date given or are from pre-1980’s. A number of promising accessions are listed. The review by Acuña et al. 2019 lists four cultivars, three of which are not in Tropicalforages.info.
<i>Setaria incrassate</i>		Tropicalforages.info only lists one cultivar (Australia, 1977), with no promising accessions.
<i>Tripsacum dactyloides</i>		Tropicalforages.info lists 11 cultivars (8 released in the 2000’s), all from the USA. Limitations include “difficult to establish”.
<i>Urochloa arrecta</i>		Semi aquatic. Tropicalforages.info – no cultivars released. Limitations include photosensitisation and nitrate toxicity.
<i>Urochloa mutica</i>		Semi aquatic. Tropicalforages.info lists four cultivars (Brazil, DRC, Cuba). Limitations include “possible oxalate problems with horses”.
<i>Urochloa dictyoneura</i>	<i>Urochloa humidicola</i>	Tropicalforages.info does not contain <i>U. dictyoneura</i> , but it does contain <i>U. humidicola</i> (with the synonym of <i>Brachiaria dictyoneura</i>) which lists <i>U. dictyoneura</i> as a similar species. Tropicalforages.info lists one cultivar of <i>U. humidicola</i> from Brazil (2013) and two groups of cultivars which each seem to be for plant introductions under different names. Several Australian seed company websites list a few cultivars under <i>U. humidicola</i> or just as “Humidicola” (not clear if the latter is actually <i>U. humidicola</i>). https://progressiveseeds.com.au/humidicola/ https://www.pggwrightsonseeds.com.au/seeds/tropical/common-grasses/humidicola Lots of limitations listed.
<i>Urochloa trichopus</i>	<i>Urochloa mosambicensis</i>	Tropicalforages.info lists a few cultivars released in Australia under <i>U. mosambicensis</i> (including one in 2010), and numerous promising accessions. https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/nixon.pdf https://progressiveseeds.com.au/saraji-sabigrass/
<i>Urochloa oligotricha</i>		Tropicalforages.info lists no cultivars released, but some promising accessions in Queensland.

Appendix 4

Legume species considered to have future potential for Northland and permitted by MPI ("Green list").

Cultivar										
Species	Name (common name)	Synonym	MPI Status	Material previously tested in Northland (cultivar/accesion)	Number of cultivars listed in Tropicalforages.info	Names (preferred/available CVs)	Date of release or PBR	Country of origin	Website for supplier	Notes/references
	<i>Coronilla varia</i> (Crownvetch)		Basic	No. (see "G34")	0	G34	2005	New Zealand	https://www.tandfonline.com/doi/pdf/10.1080/00288233.2005.9513640	Pre-cultivar developed in Palmerston North. Bred for soil conservation and high country pastures.
	<i>Desmodium intortum</i> (Greenleaf desmodium)		see 155.02.05 under <i>Desmodium</i>	Goold and McMeikan 1980; Goold 1978; Rumball and Lambert 1980, Table 1; Rumball and Lambert 1980, Table 2	1?	Greenleaf	1964	Australia	https://progressive-seeds.com.au/greenleaf-desmodium/	https://keys.lucidcentral.org/keys/v3/pastures/Html/Greenleaf_desmodium.htm
	<i>Pueraria montana</i> var. <i>montana</i> (Perennial soybean)	<i>Glycine javanica</i> // (Neonotonia wightii)	see 155.02.05 under <i>Glycine</i>	Goold and McMeikan 1980; Rumball and Lambert 1980, Table 1	8+	Cooper Tinaroo	1962 1962	Australia Australia	https://progressive-seeds.com.au/glycine/	https://keys.lucidcentral.org/keys/v3/pastures/Html/Glycine.htm https://tropicalforages.info/text/entities/neonotonia_wightii.htm?zoom_highlight=neonotonia
	<i>Lotus pedunculatus</i> (Lotus major, 'pedunc')	<i>L. uliginosus</i>	See 155.02.05 under <i>Lotus</i>	McCahon et al. 2021	8+				https://tropicalforages.info/text/entities/lotus_uliginosus.htm https://keys.lucidcentral.org/keys/v3/pastures/Html/Greater_lotus.htm http://www.inia.org.uy/sitios/InI/vol34/grant.pdf	
						Grasslands Trojan	2003	New Zealand		

LUX97	2007	Australia	<p>https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/LUX97_Lo-tus_uliginosus.pdf</p> <p>Bred from Portuguese and NZ accessions, including Grasslands Sunrise. This is a breeding line that despite comments doesn't seem to have been further developed so far.</p>
Barsilvi		New Zealand?	<p>Agriseeds. On IPONZ site with status as "surrendered".</p>
E-Tanin		Uruguay	<p>https://www.specseed.co.nz/portfolio-item/lover/ ?</p>
Beaver, Columbia, Kaiser, Marshfield		USA	<p>On IPONZ site with status as "filed" in 2018, PGGW as agent and INIA as applicant.</p> <p>Notes in Grant (2004) seem to be for specific locations for conditions</p>
Sharnaee	1991		<p>Withdrawn due to seed production issues</p> <p>https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/sharnaee.pdf</p>
<i>Trifolium alexandrinum</i> (Berseem clover)	Basic	Rumball and Lambert 1980, Table 1; McCahon et al. 2021.	<p>?</p> <p>https://wesco.co.nz/products/clovers/other-clovers/berseem-clover-gold-strike/</p>

Appendix 5

Legume species that may have future potential for Northland and are permitted by MPI (with restrictions; "Orange list").

Species Name (common name)	Synonym	MPI Status	Material previously tested in Northland (cultivar/ accession)	Cultivar			Date of release or PBR	Country of origin	Website for supplier	Notes/references
				Number listed in Tropical-forages.info	Names (pre-ferred/ available CVs)					
<i>Anthyllis vulneraria</i> (Kidney vetch)		Basic	In 1005	0					Most search results seem to refer to material from natural grasslands.	
<i>Cajanus cajan</i> (Pigeon pea)		Basic	Unknown AI 638	1?					Mostly bred for grain.	
<i>Clitoria ternatea</i> (Butterfly pea)		Basic		3+	Milgarra	1991	Australia	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/milgarra.pdf	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/milgarra.pdf	
<i>Desmodium uncinatum</i> (Silverleaf desmodium)		see 155.02.05 under <i>Desmodium</i>	Silverleaf 10 CPI lines AI 451	1	Techuana Conchita Clara Silverleaf	1988 1990 1962	Mexico Honduras Australia	?	https://keys.lucidcentral.org/keys/v3/pastures/Html/Butterfly_pea.htm https://futurebeef.com.au/wp-content/uploads/2011/09/Butterfly_pea_book.pdf https://keys.lucidcentral.org/keys/v3/pastures/Html/Silverleaf_desmodium.htm	
<i>Lablab purpureus</i> (Lablab)		see 155.02.05 under <i>Lablab</i>	Rongai	8+	Highworth	1973	Australia	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/highworth.pdf	'Velcro' plant – some weed potential Annual cultivars. A perennial cultivar was released in 1998 but was less productive and is no longer available.	
<i>Listia bainesii</i> (Lotononis)	Formerly <i>Lotononis bainesii</i>	Basic (as <i>Lotononis</i>)	Miles AI 518 (CPI16833)	3	Sustain LS? INIA Glenceoe	c2003	Uruguay	Real et al., 2005	On Barenbrug website as <i>dolichos</i> lablab – assume this is the same species.	
<i>Medicago truncatula</i> (Barrel medick)	Formerly <i>Medicago tribuloides</i>	see 155.02.05 under <i>Medicago</i>	In 1007, 1008	0	Paraggio	1982	Australia		https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/paraggio.pdf	

<i>Omithopus sativus</i> (Serradella)	Basic	CPI 13101 In 1011	0	Cadiz Erica	1996 (PBR)	Australia Australia	https://irwinhunter.com.au/product/cadiz-french-serradella/	Soft seeded. Hard seeded. Developed from Cadiz. More prostrate growth so better for heavy grazing. Hard seeded. Developed from Cadiz.
Winter annual				Margurita	2002 (PBR)	Australia	https://www.ausweststephenseeds.com.au/products/pastures/serradellas/margurita	
				Eliza	2010 (PBR)	Australia	https://irwinhunter.com.au/product/margurita-french-serradella/	Soft seeded
				Grasslands Koha	1988	New Zealand		PVR surrendered.
<i>Stylosanthes hamata</i> (Stylo)	Basic	Verano	2+	Verano	1973	Australia	https://www.amazon.in/RIK-Seeds-Stylo-Hamata-Grass/dp/B07L8L6W4K	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/verano.pdf
				Amiga	1988	Australia	http://www.blueribbongroup.com.au/seed-products.html	https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/amiga.pdf
<i>Trifolium burchellianum</i> (Burchell's clover)	Basic	13 accessions	0?				https://www.sunshine-seeds.de/product_info.php?products_id=47096&language=en	
<i>Trifolium semipilosum</i> (Kenya white clover)	Basic	Az 466 (CPI 24132)	2+	Safari	1973	Australia		https://research.csiro.au/cultivars/wp-content/uploads/sites/162/2017/03/safari.pdf
				Kabete 4	Pre 1965	Kenya		https://www.grassland.org.nz/publications/nzgrassland_publication_689.pdf
<i>Trifolium vesiculosum</i> (Arrowleaf clover)	Basic	Az 44 Apache Arrotas	0				https://www.pennington.com/all-products/wildlife/resources/arrowleaf-clover-trifolium-vesiculosum	

Appendix 6a Legume species that are permitted by MPI but considered unlikely to have future potential for Northland. Most have been trialled in Northland before. ("Red list").

Name	Synonym	Trialled in Northland before?
<i>Desmodium varians</i>		Rumball and Lambert 1980, Table 1
<i>Glycine max</i>		
<i>Glycine ussuriensis</i>	Now <i>Glycine max</i> subsp. <i>soja</i>	Rumball and Lambert 1980, Table 1
<i>Indigofera pseudo-tinctoria</i>	Now <i>I. bungeana</i>	Rumball and Lambert 1980, Table 1
<i>Sesbania sesban</i>		
<i>Trifolium neglectum</i>	Now <i>Trifolium repens</i> subsp. <i>repens</i>	Rumball and Lambert 1980, Table 1
<i>Trifolium procumbens</i>	Now <i>T. micranthum</i>	Rumball and Lambert 1980, Table 1
<i>Trifolium rueppellianum</i>		Rumball and Lambert 1980, Table 1
<i>Trifolium squamosum</i>		Rumball and Lambert 1980, Table 1
<i>Trifolium tembense</i>		Rumball and Lambert 1980, Table 1
<i>Trifolium usambarense</i>		Rumball and Lambert 1980, Table 1
<i>Vicia villosa</i>		Rumball and Lambert 1980, Table 2
<i>Vigna sinensis</i>	Now <i>V. unguiculata</i> subsp. <i>unguiculata</i>	Goold and McMeikan 1980

Accession numbers/identifiers listed where available see Rumball & Lambert 1980

Appendix 6b Legume species that either not recorded or prohibited by MPI and would require a formal assessment process ("Red list"). Some have been trialled in Northland before.

Name	Synonym	Trialled in Northland before?
<i>Aeschynomene americana</i>		
<i>Aeschynomene villosa</i>		
<i>Alysicarpus monilifer</i>		
<i>Alysicarpus rugosus</i>		
<i>Alysicarpus vaginalis</i>		
<i>Arachis glabrata</i>		
<i>Arachis paraguariensis</i>		
<i>Arachis pintoi</i>		
<i>Centrosema mole</i>		
<i>Chamaecrista Pilosa</i>		
<i>Chamaecrista rotundifolia</i> (entry prohibited)		
<i>Desmanthus bicornutus</i>		
<i>Desmanthus glandulosus</i>		
<i>Desmanthus leptophyllus</i>		
<i>Desmanthus pernambucanus</i>		
<i>Desmanthus pubescens</i>		
<i>Desmanthus tathuyensis</i>		
<i>Desmanthus virgatus</i>		
<i>Desmodium batocaulon</i>		CPI 12346
<i>Desmodium canadense</i>		In 1010
<i>Desmodium canum</i>	Now <i>D. incanum</i>	CPI 18006
<i>Desmodium dillenii</i>		In 1009, 976
<i>Desmodium gyroides</i>	Now <i>D. perplexum</i>	CPI 13379
<i>Desmodium incanum</i>	Now <i>D. canum</i>	
<i>Dolichos axillaris</i>	Now <i>Macrotyloma axillare</i>	unknown
<i>Grona heterocarpus</i> subsp. <i>heterocarpa</i>	Now <i>Grona heterocarpus</i>	
<i>Grona trifloral</i>		
<i>Lespedeza cuneata</i>		In 1038, 1040

Name	Synonym	Trialed in Northland before?
<i>Lespedeza stipulacea</i>	Now <i>Kummerowia stipulacea</i>	In 1039
<i>Lespedeza striata</i>	Now <i>Kummerowia striata</i>	In 1037
<i>Macroptilium atropurpureum</i>		Siratro
<i>Macroptilium bracteatum</i>		
<i>Macroptilium lathyroides</i>		
<i>Macrotyloma axillare</i>		
<i>Phaseolus lathyroides</i>	Now <i>Macroptilium lathyroides</i>	Murray
<i>Pueraria montana</i> var. <i>lobata</i>		
<i>Pueraria phaseoloides</i>	Now <i>Neustanthus phaseoloides</i>	unknown
<i>Pueraria triloba</i>	Now <i>Pueraria montana</i> var. <i>lobata</i>	In 1046
<i>Stylosanthes fruticosa</i>		
<i>Stylosanthes gracilis</i>	Now <i>S. guianensis</i> var. <i>gracilis</i>	CPI 11490-1, 11493
<i>Stylosanthes guianensis</i> var. <i>gracilis</i>	Now <i>S. gracilis</i>	
<i>Stylosanthes guianensis</i> var. <i>guianensis</i>		
<i>Stylosanthes guianensis</i> var. <i>intermedia</i>	Now <i>Stylosanthes montevidensis</i>	
<i>Stylosanthes guianensis</i>		In 975
<i>Stylosanthes humilis</i>		unknown
<i>Stylosanthes scabra</i>		
<i>Stylosanthes seabrana</i>		
<i>Teramnus labialis</i>		
<i>Teramnus uncinatus</i>		In 1035
<i>Vicia amoena</i>		In 1042
<i>Vicia nipponica</i>		In 1041
<i>Vicia unijuga</i>		In 1043
<i>Vigna hosei</i>		
<i>Vigna luteola</i>		unknown
<i>Vigna marina</i>		CPI 21347
<i>Vigna oblongifolia</i>		unknown
<i>Vigna parkeri</i>		
<i>Vigna parviflora</i>	Now <i>V. oblongifolia</i> var. <i>parviflora</i>	In 1034
<i>Vigna schimperii</i>		unknown
<i>Vigna trilobata</i>		
<i>Vigna vexillata</i>		unknown