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Napier subterranean clover (*Trifolium subterraneum* L. var. *yanninicum*)

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Abstract. Napier is a late flowering F_6-derived crossbred subterranean clover of var. *yanninicum* [(Katz. *et* Morley) Zohary and Heller] developed by the collaborating organisations of the National Annual Pasture Legume Improvement Program. It is a replacement for both Larisa and Meteora and has been selected for release on the basis of its greater herbage and seed production and disease resistance to both known races of clover scorch and 2 of the common races of Phytophthora root rot. Napier is recommended for sowing in Victoria, Western Australia, New South Wales, and South Australia. It is best suited to moderately acidic soils prone to water-logging and to loamy and clay soils with good water-holding capacity in areas with a minimum growing season length of 7.5 months, which extends into late November. Napier is well adapted to the permanent pasture systems found in the areas in which it will be grown. Its upright, vigorous growth makes it well suited to grazing by cattle or sheep and to fodder conservation. Napier has been granted Plant Breeders Rights in Australia.

Origin

Napier subterranean clover [*Trifolium subterraneum* var. *yanninicum* (Katz. *et* Morley) Zohary and Heller] was bred by P. G. H. Nichols. It is derived from the cross 83Y79 initiated by J. S. Gladstones in 1983. The seed parent was the Greek accession CPI 39326YA and the pollen parent was the crossbred line 76Y51–28 (Meteora/Trikkala), a sister line to cultivar Riverina.

Cross 83Y79 was sown and harvested under the supervision of W. J. Collins as a bulk F_2 population in 1985 in a clover scorch [*Kabatiella caulivora* (Kirchn.) Karak.] disease-screening plot at Denmark, Western Australia (WA). Seed produced from the Denmark plot was screened for hardseededness in a fluctuating 60/15°C temperature cabinet for 16 weeks using the procedure of Quinlivan (1961). Hard seed remaining after the 16-week treatment was retained for sowing in the F_3 generation.

P. G. H. Nichols conducted the remainder of the breeding process at the University of WA Field Station (UFS), Shenton Park. 83Y79.13 was selected as one of 19 F_3 spaced plants at UFS in 1986. Spaced plant selection was also conducted in the F_4 generation in 1987, with 83Y79.13.2 being selected as one of 3 plants from 83Y79.13. In 1989, 83Y79.13.2.3 was selected as one of 8 F_6 plants from 83Y79.13.2 to form Napier. In each of these generations spaced plants were selected on the basis of late maturity, good plant vigour and a formononetin content of less than 0.2% of dry matter (DM), using the procedures of Francis and Millington (1965). Screening for resistance to Race 1 of *Kabatiella caulivora* was also conducted in the F_6 generation in the field at Denmark.

In 1993, Napier was selected by P. G. H. Nichols as one of 96 late maturing breeding lines of var. *yanninicum* for Stage I field evaluation in WA, South Australia (SA), Victoria (Vic.) and Tasmania (Tas.). In 1996, Napier was selected as one of 13 breeding lines to enter Stage II field evaluation trials in WA, Vic., New South Wales (NSW) and SA. Field evaluation was conducted as part of the National Annual Pasture Legume Improvement Program (NAPLIP). Stage I field evaluation was conducted under the codename 83Y79–17, with Stage II evaluation under the codename YL012. The following collaborators of NAPLIP conducted field

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evaluation and final selection of Napier: P. G. H. Nichols and P. Si (Department of Agriculture and Food, WA), P. M. Evans (Department of Primary Industries, Vic.), A. D. Craig (South Australian Research and Development Institute) and G. A. Sandral and B. S. Dear (Department of Primary Industries, NSW). M. J. Barbetti, D. J. Gillespie and M. P. You (Department of Agriculture and Food, WA) conducted screening for disease resistance and D. J. Gillespie conducted further screening for redlegged earth mite resistance. P. G. H. Nichols and P. F. Smith (Centre for Legumes in Mediterranean Agriculture) conducted hard seed screening. The University of WA conducted isoflavone analyses.

Napier was selected for release as a new cultivar in 2000. Selection criteria included late maturity, greater winter and spring herbage production than existing late maturing cultivars Larisa and Meteora, high production and maintenance of seed reserves, strong regeneration density, resistance to Races 1 and 2 of clover scorch and resistance to 2 common races of Phytophthora root rot. Napier is recommended for registration by the collaborating organisations of NAPLIP. It has been granted Plant Breeders Rights in Australia and is described in Nichols (2002). The Department of Agriculture and Food, WA, will maintain breeders' seed.

Napier is named after Mt Napier, an extinct volcano in the Hamilton district of western Vic.

Morphological description

Napier is morphologically similar to Gosse, Riverina and Meteora. It has a leaf mark of $C_4(A_1)$, using the classification of Nichols *et al*. (1996), consisting of a light green crescent positioned in the leaf centre and extending to the margins. Faint white arms beneath the crescent can sometimes be observed, but tend to fade later in the season. A purplish-brown anthocyanin flush along the midrib and extending to the margins proximal to the crescent is often seen under cold and other growth-limiting conditions, along with occasional anthocyanin flecking. These anthocyanin markings also tend to fade later in the season. Indentation of the distal margin is moderate. Stipules under closed canopies have an intermediate to strong reddish-purple pigmentation. Calyx tubes are generally green but may have a pale brown pigmentation when exposed to light. Petioles are weakly pubescent and peduncles are glabrous to weakly pubescent, while stems (runners) and leaflet upper surfaces are glabrous. Seeds are large, cream to amber in colour, with about 88 000 seeds/kg when grown under ideal conditions.

Agronomic characters

Napier is a late flowering variety. In Perth, both Napier and Larisa commence flowering about 140 days after sowing in early May. This is about 2 weeks later than Gosse, 3 weeks later than Riverina, 4 weeks later than Trikkala and 1 week earlier than Meteora. Fresh leaves in spaced plants of Napier have a formononetin content of about 0.1% DM, while levels of genistein and biochanin A are about 0.9 and 0.4% DM, respectively (Nichols 2002). The low level of formononetin indicates a low potential for Napier to cause sheep infertility problems.

Both field and laboratory measurements indicate that Napier is quite hardseeded for its maturity, having a similar level to Meteora and being more hardseeded than other var. *yanninicum* cultivars. Over 6 seasons, Napier seeds derived from 1-m single rows averaged 37% hard seed after 16 weeks in a 15/60°C cabinet, using the standard laboratory procedures of Quinlivan (1961), while Larisa, Trikkala, Riverina, Gosse and Meteora had 7, 11, 22, 23 and 30% hard seed, respectively. Laboratory results from spaced plants (Nichols 2002) also support these relative differences.

Field data indicates that Napier is better able to cope with seed bank losses from false breaks than Larisa and Trikkala. Seed harvested from Manjimup, WA, and softened in the field at Perth over the following 5 months showed that by mid-March, Napier still had 58% hard seed, compared with Meteora with 56%, Trikkala with 50% and Larisa with 34%. A false break at this stage would, therefore, cause a higher proportion of the seed banks of Larisa and Trikkala to be lost than Napier. In the areas for which Napier is likely to be recommended, a high proportion of seedlings germinating after late March are likely to survive (Evans and Smith 1999).

Napier is resistant to both Race 1 and Race 2 of clover scorch disease caused by *Kabatiella caulivora*. Napier had a disease severity rating of 3.0 in a Race 1 field screening trial at Denmark, compared with scores for Riverina, Meteora, Gosse, Larisa, Trikkala and Yarloop of 3.5, 3.7, 4.7, 4.8, 5.7 and 7.5, respectively (increasing disease severity scale of 0–10). In a Race 2 screening trial at Condingup, WA, Napier had a disease severity rating of 2.9, compared to scores for Meteora, Trikkala, Larisa, Gosse, Riverina and Yarloop of 1.1, 1.2, 1.8, 2.8, 3.3, and 4.0, respectively (increasing disease severity scale of 0–10). These levels of resistance should protect Napier from major damage in clover scorch-prone areas.

Napier is highly resistant to leaf rust (*Uromyces trifolii-repentis* Liro). Inoculated field plots of Napier, along with Meteora and Riverina, had no rust incidence or leaf collapse (Barbetti and Nichols 2005*a*). Napier is also highly resistant to cercospora leafspot (*Cercospora zebrina* Pass.). Inoculated field plots of Napier, along with Meteora and Gosse, had negligible cercospora leafspot incidence and no leaf collapse (Barbetti and Nichols 2005*b*). Field observations indicate that Napier has some susceptibility to powdery mildew (*Erysiphe polygonii* DC) under ideal disease epidemic conditions, but it is unlikely that the disease will cause severe losses in grazed swards.

Napier is highly resistant to Race 001 and resistant to Race 173 (formerly known as Race 0 and Race 1, respectively, and recently recoded by You *et al*. 2005*c*), 2 of

Table 1. Mean field performance of Napier, Larisa and Trikkala (as a percentage of Larisa) in 13 field trials across southern Australia

Not all traits were measured at each site in every year

Cultivar	Seed bank	Seedling regeneration density	Herbage production			
			Autumn	Winter	Early spring	Late spring
Napier	161	127	105	107	105	115
Larisa	100	100	100	100	100	100
Trikkala	146	152	110	112	106	79

the most widespread races of root rot caused by *Phytophthora clandestina* Taylor, Pascoe and Greenhalgh. In glasshouse trials Napier was just as resistant to Race 001 as Trikkala, Riverina, Denmark, Goulburn, Leura and Seaton Park, but was more resistant than Meteora and much more resistant than Woogenellup (You *et al*. 2005*a*). Napier was also more resistant to Race 173 than Larisa, Trikkala and Woogenellup, had similar resistance to Meteora, but was less resistant than Riverina and Seaton Park (You *et al*. 2005*a*). The greater resistance of Napier to Race 173 than Larisa and Trikkala should confer an advantage over these cultivars in disease-prone areas.

Napier is susceptible to root rot caused by *Pythium irregulare* Buisman. In glasshouse trials Napier suffered more tap-root damage from *Pythium* infection than Riverina and Larisa with similar damage levels to Gosse and Meteora, but suffered less damage than Trikkala and Woogenellup, while lateral-root damage was equally as great as Trikkala and Woogenellup (You *et al*. 2005*b*). Napier is also susceptible to root rot caused by *Fusarium avenaceum* (Fr.) Sacc. In glasshouse trials Napier suffered more tap-root damage than Riverina, Meteora and Trikkala and had similar levels of damage to Gosse and Larisa, while lateral-root damage was greater than each of these cultivars, apart from Gosse (You *et al*. 2005*b*).

Napier is similar in susceptibility as other cultivars to redlegged earth mite, *Halotydeus destructor* (Tucker), particularly at the cotyledon stage. Growth room tests on 2-week-old seedlings gave mean cotyledon damage ratings of 3.7 for Napier, 3.5 for Larisa, 3.7 for both Gosse and Trikkala, 4.0 for Riverina and 5.7 for Meteora, (on an increasing damage severity rating of 0–10). Field observations on mature plants also indicate similar susceptibility of Napier to other cultivars.

Field performance of Napier was measured in 13 trials across southern Australia. Its mean performance across all sites is compared in Table 1 with that of the var. *yanninicum* cultivars Trikkala and Larisa. The outstanding seed production of Napier is the key to its success. Napier out-yielded Larisa in every seed bank measurement and its mean was 61% greater (Table 1). Seed banks of Napier were also 10% greater than Trikkala, in spite of its much later flowering and the shorter than average growing seasons experienced at several trial sites. Mean seedling regeneration of Napier in the second and third year after sowing was superior to Larisa (Table 1), in spite of its greater hardseededness. This is presumably a result of its greater seed production. The earlier flowering Trikkala tended to have the highest regeneration densities.

Herbage production of Napier averaged 5% more in autumn and 7% more in winter than Larisa, while both cultivars produced less than Trikkala (Table 1). These differences in early season herbage production largely reflect differences in seedling density. Early spring production of Napier was 5% more than that of Larisa and similar to that of Trikkala (Table 1). However, late-spring/early summer production of Napier was on average 15% greater than Larisa and 46% greater than Trikkala (Table 1). This clearly demonstrates the ability of the late maturity of Napier to exploit long growing season environments and provide more late season green feed for grazing animals.

Napier is recommended as a replacement for Larisa and Meteora in Vic., WA, NSW and SA. For reliable persistence, its late maturity requires a minimum growing season length of 7.5 months that extends into late November. Napier is best suited to moderately acidic (pH_{Ca} 4.5–6.5) soils prone to water-logging and to loamy and clay soils with good water-holding capacity. Napier is well adapted to the permanent pasture systems found in the areas in which it will be grown. Its upright, vigorous growth makes it well suited to grazing by cattle or sheep and to fodder conservation.

Seed licenced to: Seedmark (Seed Technology and Marketing Pty Ltd), 78 Sir Donald Bradman Drive, Hilton, SA 5033, Australia.

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References

Barbetti MJ, Nichols PGH (2005*a*) New sources of resistance in *Trifolium subterraneum* to rust (*Uromyces trifolii-repentis*). *Australian Journal of Experimental Agriculture* **45**, 1163–1166. doi:10.1071/EA04150

Barbetti MJ, Nichols PGH (2005*b*) New sources of resistance to *Cercospora zebrina* in subterranean clover. *Australasian Plant Pathology* **34**, 197–201. doi:10.1071/AP05017

Evans PM, Smith FA (1999) Patterns of seed softening in subterranean clover in a cool, temperate environment. *Agronomy Journal* **91**, 122–127.

Francis CM, Millington AJ (1965) Varietal variation in the isoflavone content of subterranean clover: its estimation by a microtechnique. *Australian Journal of Agricultural Research* **16**, 557–564. doi:10.1071/AR9650557

Nichols PGH (2002) *Trifolium subterraneum* var. *yanninicum* subterranean clover 'Napier'. *Plant Varieties Journal* **15**, 50–51.

Nichols PGH, Collins WJ, Barbetti MJ (1996) Registered cultivars of subterranean clover — their characteristics, origin and identification. Agriculture Western Australia Bulletin No. 4327.

Quinlivan BJ (1961) The effect of constant and fluctuating temperatures on the permeability of the hard seeds of some legume species. *Australian Journal of Agricultural Research* **12**, 1009–1022. doi:10.1071/AR9611009

You MP, Barbetti MJ, Nichols PGH (2005*a*) New sources of resistance in *Trifolium subterraneum* L. to root rot caused by two races of *Phytophthora clandestina* Taylor, Pascoe and Greenhalgh. *Australian Journal of Agricultural Research* **56**, 271–277. doi:10.1071/ R04293

You MP, Barbetti MJ, Nichols PGH (2005*b*) New sources of resistance identified in *Trifolium subterraneum* breeding lines and cultivars to root rot caused by *Fusarium avenaceum* and *Pythium irregulare* and their relationship to seedling survival. *Australasian Plant Pathology* **34**, 237–244. doi:10.1071/AP04092

You MP, Barbetti MJ, Sivasithamparam K (2005*c*) Characterization of *Phytophthora clandestina* races on *Trifolium subterraneum* in Western Australia. *European Journal of Plant Pathology* **113**, 267–274.

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