THE INDIGENOUS SOUTH AFRICAN CLOVERS (*T. AFRICANUM* Ser. AND *T. BURCHELLIANUM* Ser.) AND THEIR POTENTIAL AS PASTURE LEGUMES

R. M. JONES*, B. W. STRIJDOM† and E. P. THERON‡

ABSTRACT

The occurrence of the clovers Trifolium africanum *and* T. burchellianum *in Southern Africa is briefly described, together with available data about* Rhizobium *requirements, physiology and genetics. Agronomic research in both South Africa and Australia is reviewed and it is concluded that although these species have shown some promise, it has yet to be proved that they can be persistent and productive pasture legumes. Their potential appears to be in situations where climate or soil limit white clover,* (T. repens), *and not as alternative species to white clover.*

INTRODUCTION

The role of temperate clovers such as white clover (*Trifolium repens*) in pasture improvement is well known. Indigenous African *Trifolium* species have however received little attention with the exception of Kenya white clover (*T. semipilosum*) which has been recently commercially released in Queensland (Anon 1973).

This review describes the South African clovers, *T. africanum* Ser. and *T. burchellianum* Ser. subsp. *burchellianum*, their distribution in Southern Africa, *Rhizobium* requirements and other characteristics relevant to their potential as pasture legumes.

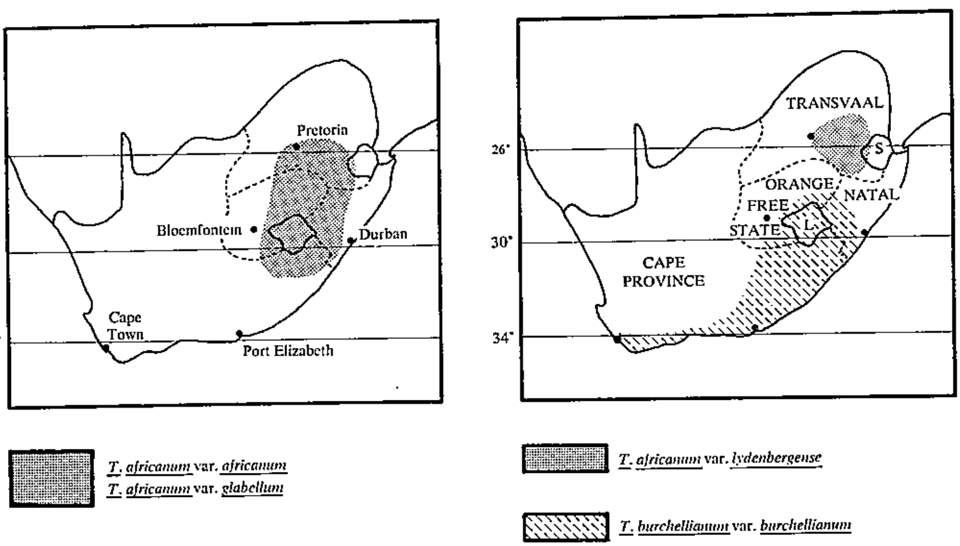

FIGURE 1

The distribution of *T. africanum* and *T. burchellianum* in Southern Africa (L = Lesotho, S = Swaziland).

* C.S.I.R.O., Division of Tropical Agronomy, St. Lucia, Queensland, 4067, Australia.

† Plant Protection Research Institute, Private Bag X134, Pretoria, South Africa.

‡ Department of Agricultural Technical Services, Agricultural Research Station, Private Bag X9059, Pietermaritzburg, South Africa.

NOMENCLATURE AND DESCRIPTION

Trifolium africanum and *T. burchellianum* are both perennials, described in detail by Gillett (1952) and 't Mannetje (1966). The main distinguishing features of the species are listed in Table 1. They are the only *Trifolium* species indigenous to South Africa.

TABLE 1
Main distinguishing features of T. africanum *and* T. burchellianum

Species	Usual Flower Colour	Leaf Characteristics[3]
T. burchellianum subsp. *burchellianum*[1]	purple	hairless, less than 2 x as long as wide; leaflets cuneate-obovate; apex emarginate
T. africanum var. *africanum*	crimson	hairy, less than 4 x as long as wide; leaflets obovate to elliptic; apex acute, rounded or emarginate
T. africanum var. *glabellum*[2]	crimson	hairless, less than 4 x as long as wide; leaflets obovate to elliptic; apex acute, rounded or emarginate
T. africanum var. *lydenbergense*	crimson	hairless, more than 5 x as long as wide; leaflets linear-lanceolate; apex acute, rounded or slightly emarginate

[1] The separation of this subspecies from the East African subsp. *johnstonii* is based on Gillett (1970) and Cufondontis (1958) previously the difference was varietal (Gillett 1952).
[2] This variety may be an interspecific hybrid (Gillett 1952).
[3] Further details and illustrations of botanical terms in 't Mannetje (1966).

The origin of these and other African clovers is not established. Some authors (Gillett 1952, Joffe 1962) have postulated that some of the African clovers have migrated or evolved from the north temperate zones; whereas 't Mannetje and Pritchard (1968) stated there was no clear link between the African and European clovers.

REGIONAL DISTRIBUTION IN SOUTHERN AFRICA

The distribution of *T. africanum* and *T. burchellianum* outlined below and in Figure 1 is based on examination of specimens in the Pretoria Herbarium and on the authors' experience. It is also in agreement with the more general comments of Gillett (1952) and Small (1965).

T. africanum var. *africanum*—mainly confined to the Witwatersrand and Eastern Transvaal highveld; that part of Natal above about 500 metres and 750 mm rainfall; Lesotho; and also areas of the Orange Free State and Cape Province which border Lesotho and Natal.

T. africanum var. *glabellum*—similar to var. *africanum* but more frequent in Natal and less frequent in the Transvaal.

T. africanum var. *lydenbergense*—confined to the Eastern Transvaal highveld, with about 750 mm rainfall.

T. burchellianum subsp. *burchellianum*—In Lesotho up to altitude of about 3,000 m, and fringing areas of Orange Free State, Natal and Cape Province. Also at lower elevations in southern Natal and over a wide range of Cape Province from the fringes of the Karoo, through the Transkei and along the coastal districts such as East London, Knysna (Fourcade 1941) and occasionally in the Western Cape Province (Harvey and Sonder 1894, Adamson 1950). *T. burchellianum* subsp. *burchellianum* has also been recorded in Angola (Gillett 1952).

This distribution pattern suggests that *T. burchellianum* would have the greatest ecological tolerance and/or genetic diversity and *T. africanum* var. *lydenbergense* the least.

All of the areas described have a summer dominant rainfall except for an isolated occurrence of *T. burchellianum* in the winter rainfall region of Cape Province. Most areas are frosted in winter and some receive isolated snow falls.

LOCAL OCCURRENCE

The botanical survey of South Africa describes *T. africanum* and *T. burchellianum* as being found in lightly grazed, moist cool, high altitude sites (West 1949, Killick 1963, Edwards 1967, Roberts 1969). In lower altitudes or lower rainfall (about 650 mm) areas it is specifically noted as occurring in wet sites or riverbanks (West 1949, Louw 1951, Mostert 1958). *T. africanum* is limited to upland swamp areas in Swaziland (Compton 1966).

Observations suggest that these clovers are less common in grazed veld than along disturbed and undisturbed roadsides where they often grow well both in water run-on and run-off sites.

Even though the species can grow vigorously along roadsides they are still usually found only as isolated patches of from less than one square metre to over 10 metres across. Growth along roadsides is not reduced, and sometimes appears to be improved by rotary slashing to a height of 5-10 cm above ground level. *T. africanum* has been noted by the authors as growing well in lawns and playing fields of kikuyu (*Pennisetum clandestinum*) and couch grass (*Cynodon dactylon*) regularly cut to 1-3 cm above ground level.

In Natal, *T. africanum* is more adapted to the acid soils of the Highland sourveld while *T. burchellianum* is widely distributed on the sandy soils derived from the Table Mountain Sandstone series in the coastal hinterland. Both species are frost hardy but not to the same degree as *T. repens* (white clover).

NODULATION

Rhizobium *specificity*

Norris (1959) was the first to present evidence that the African *Trifolium* spp. were a separate group having no *Rhizobium* affinities with European clovers. In a more comprehensive study of 26 introductions of 15 African *Trifolium* species or subspecies, Norris and 't Mannetje (1964) confirmed *Rhizobium* specificity between species and between varieties. On the basis of the *Rhizobium* affinities of the clover species studied, they grouped varieties of *T. burchellianum* and *T. africanum* with *T. ruepellianum*, *T. tembense*, *T. usambarense*, *T. bacarinii*, *T. steudneri* and *T. pseudostriatum*; but not with *T. semipilosum*. Results reported by Small and Clarke (1968) agree with those of Norris and 't Mannetje (1964) although Saubert and Scheffler (1967) failed to identify subgroups among African *Trifolium* spp.

An extensive isolation programme to obtain a broad spectrum of *Rhizobium* strains for *T. africanum* and *T. burchellianum* was initiated in South Africa in 1971. Strains were obtained from 25 patches of *T. africanum* and 15 patches of *T. burchellianum* in Natal, and from 16 patches of *T. africanum* in the Transvaal highveld (I. Johnson and B. W. Strijdom, unpublished data). Eight of these *Rhizobium* strains have been tested on three African clover lines and on *T. repens* (Table 2). Whereas strain specificity is evident, the reactions obtained with *Rhizobium* SA3 suggest the possibility of selecting wide spectrum strains for inoculant production. Norris and 't Mannetje (1964) found that both *T. africanum* var. *africanum* and *T. burchellianum* var. *burchellianum* were effectively nodulated by the *Rhizobium* strain CB728. Some field isolates from *T. africanum* have been ineffective on *T. africanum* but effective on white clover (Table 2), suggesting that rhizobia from naturalised white clover can form ineffective nodules on *T. africanum*.

TABLE 2

Response of various Trifolium *spp. to inoculation with* Rhizobium *isolates from* Trifolium africanum *and* Trifolium burchellianum.

Rhizobium strain from	*Trifolium* spp. or introductions inoculated			
	T. africanum B 62/207	*T. africanum* L180	*T. burchellianum*	*T. repens*
T. africanum				
L180	I	E	I	O
L158 C	I		I	I
SA3	E	E	E	O
SA5	E	O	O	O
N 69/276/2A	I		O	E
T. burchellianum				
L 14/1A	E	I	E	O
SE 1		I	E	I
L 83		I	I	I

E = Plants contained pink nodules and yielded significantly better than uninoculated ones.
I = Plants contained white nodules and showed no signs of growth stimulation.
O = No nodules produced.

Nodulation and soil acidity

T. africanum and *T. burchellianum* are reported to be more tolerant of acid conditions than clovers of European origin. However, the effect of low pH on growth and nodulation of these plants has differed from one soil type to another. Accessions of *T. africanum* and *T. burchellianum* grew satisfactorily and were well nodulated after transplanting into one field soil with pH 4.3. In contrast, a pot experiment conducted in a greenhouse using a Farningham topsoil with pH 4.4 and a Clovelly topsoil with pH 4.7 showed that each of four *Rhizobium* isolates from *T. africanum* either failed to nodulate *T. africanum* or formed a few ineffective nodules only (I. Johnson and B. W. Strijdom, unpublished data). When these soils were limed to a pH of 6.0 all strains formed effective nodules.

Small (1968a) showed that soil calcium status might be important for nodulation of *T. africanum* at low pH. In liquid culture the number and size of the nodules on *T. africanum* var. *africanum* and *T. africanum* var. *lydenbergense* increased with an increase in the external Ca concentration from 0–8 ppm. Nodulation and nitrogen fixation commenced at pH 4, provided sufficient calcium was present; *T. pratense* failed to nodulate at this pH in liquid culture.

One of the reasons for the general belief that *T. africanum* and *T. burchellianum* grow well and fix nitrogen in acid soils is the occurrence in South Africa of well nodulated plants in areas where soils with low pH predominate. However the pH of soils (1 : 2—soil: water suspension) beneath clover patches was 5.5 or higher for all 26 Natal soils sampled and for 18 of 20 Transvaal soils (I. Johnson and B. W. Strijdom, unpublished data). It appears that *T. africanum* and *T. burchellianum* are usually found in soils with a pH of about 5.5 or above, although they can fix nitrogen in some soils with pH well below 5.

Nodulation and Temperature

Results of experiments conducted in quartz sand or in solution culture (Small and Joffe 1968) showed that varieties of *T. africanum* nodulated and fixed nitrogen at higher temperatures than *T. pratense* and *T. repens*. Whereas the numbers of nodules formed on *T. pratense* were reduced markedly by temperatures above 33°C, nodulation of *T. africanum* was only slightly affected by root temperatures up to 40°C. *T. africanum* var. *lydenbergense* and *T. africanum* var. *africanum* fixed appreciable amounts of nitrogen at 33°C; one line fixed nitrogen at a root temperature of 40°C.

In contrast, the critical upper temperature limit for nitrogen fixation by *T. pratense* and *T. repens* was found to be between 26°C and 33°C. Experiments with combined nitrogen failed to show any difference between exotic and indigenous species within the range of 20°–40°C root temperatures. Consequently, the nodulation and nitrogen fixation phase is more temperature sensitive.

NUTRITION AND PHYSIOLOGY

As described in the previous section, the South African clovers can nodulate at pH 4, provided sufficient calcium is present. When grown with combined nitrogen *T. africanum* var. *africanum*, *T. africanum* var. *lydenbergense* and *T. burchellianum* were little affected by varying calcium levels between 5 and 100 ppm whereas yields of *T. repens*, *T. pratense* and *T. incarnatum* increased (Small 1968a). The yield of all species increased with increasing pH, but indigenous species were less affected by low pH than the exotics. Consequently, under optimum growth conditions exotic species outyielded indigenous species, whereas at sub-optimal calcium and pH levels indigenous species could outyield exotics (Small 1968a).

T. africanum and *T. burchellianum* have been observed by the authors to grow well on Natal soils which are phosphorus deficient, but there is no critical evidence showing that phosphorus requirements for these species are different to the requirement of white clover.

Small (1968b) showed that the flowering of the South African clovers was stimulated by low night temperatures but was not affected by seed vernalization. One *T. africanum* var. *africanum*, one *T. africanum* var. *lydenbergense* and two *T. burchellianum* accessions were long day plants whereas one *T. burchellianum* responded like a quantitative short day plant. Joffe (1962) also found *T. africanum* var. *lydenbergense* to be a long day plant. 't Mannetje and Pritchard (1968) found two lines of *T. africanum* var. *africanum* and one of *T. burchellianum* subsp. *burchellianum* were long day plants. Flowering occurs from mid-spring to mid-summer under field conditions in both South Africa and South-east Queensland.

Small and Joffe (1967) found that usually more than 90% of seed from the South African clovers was hard seeded, even with three year old seed, and that soaking in 98% sulphuric acid for 30-90 minutes increased germination. Germination of a seven year old seed lot was greatly improved by scarification (Table 3), with an additional increase in germination of soft seed with use of 0.1% KNO_3 as a germinating medium instead of water (R. M. Jones, unpublished data).

TABLE 3

Percent germination and percent hard seed of seven years old T. burchellianum *(C.P.I. 24132) seed with five levels of scarification and with water or 0.1% KNO_3 as germinating medium.*

Scarification	% germination—21 days			% hard seed—21 days		
	H_2O	KNO_3	Mean	H_2O	KNO_3	Mean
Nil	13 (21.1)†	33 (35.0)	23 (28.1)	43 (41.2)	41 (40.1)	42 (40.7)
Heavy Mechanical	54 (47.3)	85 (67.3)	69 (57.3)	0 (0)	1 (2.8)	1 (1.4)
Moderate Mechanical	40 (39.5)	73 (58.4)	57 (48.9)	6 (14.1)	5 (12.9)	6 (13.5)
98% H_2SO_4—30 min.	37 (37.7)	55 (47.6)	46 (42.7)	24 (29.3)	21 (27.1)	23 (28.2)
98% H_2SO_4—10 min.	25 (29.9)	32 (34.1)	28 (32.0)	32 (34.5)	37 (37.5)	34 (35.9)
Mean:	34 (35.1)	55 (48.5)	45 (41.8)	21 (23.8)	21 (24.1)	21 (23.9)
L.S.D. ($P < .05$) for:						
scarification means		(4.5)			(4 7)	
solution means		(6.3)			(ns)	

(† Statistical analysis on arcsine transformation, n.s. = not significant)

Small and Joffe (1967) recorded no clear cut light-temperature reaction on seed germination of the South African clovers and established that the optimum germination temperature of 21°C was similar to that of the European clovers.

There are approximately 700 seeds per gram of the South African clovers, with a range of from 450 to 1,100 (authors' unpublished data), whereas there are usually 1,500–2,000 white clover seeds per gram.

CYTOLOGY AND BREEDING

Pritchard and 't Mannetje (1967) found that *T. africanum* var. *africanum* and *T. burchellianum* were both cross pollinating and Pritchard (1962) reported 2n = 32 chromosomes for *T. africanum* var. *africanum* and 2n = 48 for *T. burchellianum* subsp. *burchellianum* introduced into Queensland. Grobler (1966) also found that these species were cross pollinating and that purple flowered plants usually had 2n = 48 chromosomes, though ranging from 2n = 40 to 2n = 64, and red flowered plants 2n = 32. Pritchard (1962) and Britten (1963) recorded 2n = 96 for *T. burchellianum* subsp. *johnstonii* from Kenya. Some inter and intra species crosses made in a breeding programme at Pretoria are now being evaluated in agronomic studies in Natal. Experience during this program also suggested that the present classification was unsatisfactory, as some *T. africanum* plants did not cross with *T. africanum* but some *T. africanum* plants crossed with *T. burchellianum.*

PESTS AND DISEASES

Red spider (*Tetranychus* spp.) and root knot nematode (*Meloidogyne* spp.) have been the two main pests in trials with *T. africanum* and *T. burchellianum* at Cedara, Natal. *T. africanum* var. *glabellum,* which is the common local variety, appears most resistant to both pests. Root-knot nematode has been noted at Pretoria and in *T. africanum* var. *africanum* and *T. burchellianum* subsp. *burchellianum* in Queensland, although sward growth of the latter species was not noticeably reduced ('t Mannetje 1964). *T. burchellianum* subsp. *burchellianum* was infected by root-knot nematode at Grafton, N.S.W., but to a lesser extent than Ladino white clover (Garden 1968). Rugose leaf curl virus has been noted on *T. burchellianum* subsp. *burchellianum* in Queensland ('t Mannetje 1964) where Grylls, Galletly and Campbell (1972) showed that the susceptibility of *T. burchellianum* subsp. *burchellianum* (CPI 24132) was similar to that of the two white clover cultivars in which the virus was usually only serious in recently established pastures and not in older pastures.

POTENTIAL AS PASTURE LEGUMES

Growth habit

Both species readily root from lateral runners and, unlike white clover, growing points are not restricted to the soil surface and so these species may be able to tolerate shading better than white clover. Swards of these clovers develop small taproots connected by both surface and sub-surface stolons, the latter being noted on both clovers by the authors and on *T. burchellianum* by Britten (1962). Slow growth in the first year has been reported for *T. burchellianum* subsp. *johnstonii* (Bogdan 1956), for an unnamed *T. burchellianum* variety by Britten (1962) and for *T. burchellianum* subsp. *burchellianum* (R. J. Jones—personal communication).

Field occurrence under grazing

The insignificant contribution of these clovers to the South African grazing industry is reflected by their omission from Acocks' (1953) long list of important veld species. Both clovers are only found in occasional patches in grazed veld. Such patches are selectively grazed when growing with grasses such as N'gongoni (*Aristida* *junciformis*), but to a lesser extent among grasses such as *Paspalum dilatatum*. Selective grazing, low soil fertility and to a lesser extent nematode infestation may account for the patchy occurrence of these species in natural pasture.

Feeding value

There are no published data on the digestibility of these clovers. Preliminary comparisons from three sites in south-east Queensland, where *T. burchellianum* has been growing alongside white clover (*T. repens*) and Kenya white clover (*T. semipilosum*), suggests that it has the lowest, although still satisfactory, *in-vitro* digestibility (Table 4). The nitrogen percentage of the three clovers was similar, as also recorded by Garden (1971). *T. burchellianum* subsp. *johnstonii* has been shown to have a higher fibre content than temperate clovers (Dougall 1962). The South African clovers contain no prussic acid (Grobler 1966).

TABLE 4

In-vitro *dry matter digestibility of three clover species grown in south-east Queensland—sampled October/November 1972.*

Site	Plant Part	*T. repens* (naturalized)	*T. semipilosum* (CPI 27218)	*T. burchellianum* (CPI 24132)
Samford—grazed paddock	leaves	80.5	77.8	73.7
Samford—grazed paddock	stolon (5cm tip)	82.2	79.8	73.9
Samford—mown laneway	leaves	78.2	77.6	71.9
Grafton—grazed plots	leaves	84.0	81.5	77.0
Mean % N from three sites	leaves	3.9	3.8	3.6

T. burchellianum subsp. *burchellianum* (CPI 24132) has very low levels of fraction 1 protein, although this was not associated with condensed tannin (W. T. Jones, personal communication). This would suggest that this species has a low bloat potential (McArthur and Miltimore 1969).

South African agronomic evaluation

Farmers and scientists have shown occasional interest in the agronomic value of the South African clovers (Anon 1955, Fisher 1955). However, there are little quantitative data available. At Pretoria white clover consistently outyielded the South African clovers in the first year, but was poorer in subsequent years (L. J. Grobler, personal communication).

Detailed small plot evaluation of *T. africanum* and *T. burchellianum* has now commenced under nursery conditions in Natal and selected lines are now being grown for seed increase.

Australian agronomic evaluation

Trials in the northern New South Wales wheat belt suggested that *T. africanum* was hardier than white clover (Cameron 1958, 1961). *T. burchellianum* has shown some promise in south-east Queensland ('t Mannetje 1964, authors unpublished results) and has persisted and at times produced well on the New South Wales north coast (Garden 1970, 1971). At the latter site *T. burchellianum* yielded over 3000 kg legume/ha during a six months period four years after sowing (D. Garden, personal communication). However, at the three sites (Samford, Gatton and Grafton) where *T. semipilosum* and *T. burchellianum* have been compared, *T. semipilosum* had consistently higher plant density and yield. The introduction of *T. burchellianum* var. *burchellianum* commonly used in these trials, CPI 24132, is currently outyielding a recent range of introductions in nursery rows in S.E. Queensland (R. J. Williams, personal communication).

Three lines of *T. burchellianum* never nodulated or established properly on the Atherton Tableland in tropical North Queensland (Gartner 1968). The first year growth of *T. burchellianum* (unspecified variety) was slow but satisfactory at Melbourne, southern Australia, but no second year observations were reported (Britten 1962).

CONCLUSIONS

Available evidence suggests that *T. africanum* and *T. burchellianum* should not be considered as alternative species to white clover, but rather as possible species for situations where white clover is not a persistent and productive legume. Their greater tolerance to low soil pH and low calcium status, stronger taproot development and ability of stolons to grow away from the ground are particularly valuable attributes. Effective rhizobia are available, but further understanding of *Rhizobium* specificity is required. It has not yet been determined if these clovers can be persistent and productive under grazing. Therefore field fertilizer and defoliation trials on both naturally occurring and sown swards of these clovers, including some studies under controlled grazing, are required. The limited experience with these species in sub-tropical eastern Australia suggests that these species could have potential as pasture legumes in countries other than South Africa.

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to Dr. L. 't Mannetje and Dr. R. J. Jones of the C.S.I.R.O. Division of Tropical Agronomy for their helpful criticisms of this paper and to officers of the South African Department of Agricultural Technical Services for their interest and co-operation.

REFERENCES

ACOCKS, J. P. H. (1953)—Veld types of South Africa. Botanical Survey of South Africa, Memoir No. 28.

ADAMSON, R. S., and SALTER, T. M. (1950)—Flora of the Cape Peninsula. Juta & Co. Ltd., Capetown p. 493.

ANON. (1955)—Veldtrust. **16**: 17.

ANON. (1973)—A new clover from Africa. Rural Research in C.S.I.R.O. No. 80, 8-10.

BOGDAN, A. V. (1956)—Indigenous clovers of Kenya. *East African Agricultural Journal.* **22**: 40-5.

BRITTEN, E. J. (1962)—Evaluation for pasture purposes of some African clovers in plant introduction program. *Journal of Range Management.* **15**: 329-33.

BRITTEN, E. J. (1963)—Chromosome numbers in the Genus Trifolium. *Cytologia.* **28**: 428-49.

CAMERON, D. G. (1958)—Legumes tested for soil conservation—results to April 1957. *Journal of Soil Conservation Service of New South Wales.* **14**: 245-59.

CAMERON, D. G. (1961)—Legumes tested for soil conservation—results to April 1960. *Journal of Soil Conservation Service of New South Wales.* **17**: 109-22.

COMPTON, R. H. (1966)—An annotated check list of the Flora of Swaziland. *Journal of South African Botany*: Supplementary Volume. **10** (p. 47, 121).

CUFONDONTIS, G. (1958)—*Trifolium* in Systematische bearboitung der in Sud Athiopien gesammelten Pflanzen. *Senckenbergiana Biologica.* **39**: 296.

DOUGALL, H. W. (1962)—The chemical composition of some species and varieties of *Trifolium. East African Agricultural and Forestry Journal.* **27**: 142-4.

EDWARDS, D. (1967)—A plant ecology survey of the Tugela River Basin, Natal. Botanical Survey of South Africa, Memoir No. 36, (p. 192-267).

FISHER, A. (1955)—The grass ley in South Africa—In 'The Grasses and Pastures of South Africa'. (Ed. D. Meredith). C.N.A. p. 688.

FOURCADE, H. G. (1941)—Check-list of the flowering plants of the division of George, Knusna, Humansdorp and Uniondale. Botanical Survey of South Africa. Memoir No. 20 (p. 54).

GARDEN, D. L. (1968)—Grafton Agricultural Research Station 1967-68 Annual Research Report: 20-1.

GARDEN, D. L. (1970)—Grafton Agricultural Research Station 1969-70 Annual Research Report: 30-1.

GARDEN, D. L. (1971)—Grafton Agricultural Research Station 1970-71 Annual Research Report: 24-8.

GARTNER, J. A. (1968)—*Trifolium* species at Millaa Millaa, North Queensland. *CSIRO Plant Introduction Review*. **5**: 49-55.

GILLETT, J. B. (1952)—The genus *Trifolium* in southern Arabia and in Africa, south of the Sahara. *Kew Bulletin*. **3**: 367-404.

GILLETT, J. B. (1970)—Further notes on *Trifolium L.* in tropical Africa. *Kew Bulletin*. **24**: 217-220.

GROBLER, L. J. (1966)—Breeding and improvement of fodder crops in the humid and subhumid area of South Africa, requirements, problems and methods. *Grassland Society of South Africa Proceedings*. **1**: 87-94.

GRYLLS, N. E., GALLETLY, J. C. and CAMPBELL, R. C. (1972)—A field study of rugose leaf and virus infection in stoloniferous *Trifolium* species. *Australian Journal of Experimental Agriculture and Animal Husbandry*. **12**: 293-8.

HARVEY, W. H., and SONDER, O. W. (1894)—Flora capensis. Vol. II. L. Reeve & Co. (p. 159).

JOFFE, A. (1962)—Photoperiodism in relation to the origin of African *Trifolium* species. *Nature*. **195**: 1117-18.

KILLICK, D. J. B. (1963)—An account of the plant ecology of the Cathedral Peak Area of the Natal Drakensburg. Botanical survey of South Africa Memoir No. 34 (p. 69, 88, 128).

LOUW, W. J. (1951)—An ecological account of the vegetation of the Potchefstroom area. Botanical Survey of South Africa. Memoir No. 24 (p. 22, 78).

MANNETJE, L. 't (1964)—The use of some African clovers as pasture legumes in Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry*. **4**: 22-5.

MANNETJE, L. 't (1966)—A punched card Key to species of *Trifolium L.* in Africa south of the Sahara excluding Ethiopia. *East African Agricultural and Forestry Journal*. **31**: 261-270.

MANNETJE, L. 't, and PRITCHARD, A. J. (1968)—The effects of photoperiod and night temperature on flowering and growth of some south African *Trifolium* species. *New Phytologist* **67**: 257-63.

MCARTHUR, J. M., and MILTIMORE, J. E. (1969)—Studies on soluble proteins and nucleic acids in bloating and non bloating legumes. *Canadian Journal of Animal Science*. **49**: 69-75.

MOSTERT, J. W. C. (1958)—Studies of the vegetation of parts of the Bloemfontein and Brandfort Districts. Botanical Survey of South Africa. Memoir No. 31 (p. 40, 183).

NORRIS, D. O. (1959)—*Rhizobium* affinities of African species of *Trifolium*. *Empire Journal of Experimental Agriculture*. **27**: 89-97.

NORRIS, D. O., and MANNETJE, L. 't (1964)—The symbiotic specialization of African *Trifolium* spp. in relation to their taxonomy and their agronomic use. *East African Agricultural and Forestry Journal*. **24**: 214-36.

PRITCHARD, A. J. (1962)—Number and morphology of chromosomes in African species in the genus *Trifolium L. Australian Journal of Agricultural Research*. **13**: 1023-9.

PRITCHARD, A. J., and MANNETJE, L. 't (1967)—The interbreeding systems and some interspecific relations of a number of African *Trifolium* spp. *Euphytica.* **16**: 324-9.

ROBERTS, B. R. (1969)—The vegetation of the Golden Gate Highlands N.P. *Koedeo.* **12**: 15-28.

SAUBERT, SYNNOVE, and SCHEFFLER, J. G. (1967)—Strain variation and host specificity of *Rhizobium.* III. Host specificity of *Rhizobium trifolii* on African clovers. *South African Journal of Agricultural Science.* **10**: 357-64.

SMALL, J. G. C. (1965)—Ph.D. Thesis, University of Pretoria.

SMALL, J. G. C. (1968a)—Physiological studies on the genus *Trifolium* with special reference to the South African species. IV. Effect of calcium and pH on growth and nodulation. *South African Journal of Agricultural Science.* **11**: 441-58.

SMALL, J. G. C. (1968b)—Physiological studies on the genus *Trifolium* with special reference to the South African species. V. Effect of seed vernalization, photoperiod and night temperature of flowering. *South African Journal of Agricultural Science.* **11**: 649-54.

SMALL, J. G. C., and CLARKE, Brenda (1968)—Physiological studies on the genus *Trifolium* with special reference to the South African species. III. Rhizobium affinities. *South African Journal of Agricultural Science.* **11**: 227-236.

SMALL, J. G. C., and JOFFE, A. (1967)—Physiological studies on the genus *Trifolium* with special reference to the South African species. I. Germination. *South African Journal of Agricultural Science.* **10**: 123-34.

SMALL, J. G. C., and JOFFE, A. (1968)—Physiological studies on the genus *Trifolium* with special reference to the South African species. II. Influence of root temperature on growth, nodulation, and symbiotic nitrogen fixation. *South African Journal of Agricultural Science.* **11**: 41-56.

WEST, O. (1949)—The vegetation of Western Country, Natal. Botanical survey of South Africa, Memoir No. 23. (p. 136).

(Accepted for publication October 20, 1973)