Evaluation for Pasture Purposes of Some African Clovers in a Plant Introduction Program[1]

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The genus *Trifolium* is one of the most important plant genera for forage crop purposes. While many of the valuable species of the genus have come from the northern part of the temperate zone and from the Mediterranean region, the grasslands of Kenya, in tropical Africa, contain a number of native species of the genus which are locally of great importance. This paper reports on a number of these species which were grown at Melbourne, Australia, a very different environment from that of their original home. The present report is of a preliminary nature, but it is offered in the hope that the more promising species may be investigated more extensively and under more diverse conditions than has been possible in the present instance.

Plant introduction programs sometimes have a tendency to drag on because of the difficulty in evaluating species which differ, not only in yield, but also in the less easily defined morphological and physiological characters. It is to be expected that in parts of the world where forage crop investigations have been under way for some time, most new species introduced during a plant introduction program will not be successful. It is extremely important, however, that an active program be maintained in quest of the exceptional species. When such plants are found, they should be evaluated as thoroughly and as quickly as possible and at the same time they should be brought to the attention of other investigators. Species of no promise should be discarded.

The principal objectives of a plant introduction program are to evaluate the species under consideration and at the same time to procure as great an increase of seed as possible. Usually there is a limited amount of seed available for the first planting of an introduction nursery, so that adequate design of experiments for statistical evaluation of cut forage may be quite impossible. For these reasons, conventional methods of forage crop evaluation, cutting, weighing, and drying, are incompatible with the main objectives of the program, since they are destructive. Therefore, evaluation must be made on characteristics of the plants which can be observed, without recourse to the destructive techniques of harvesting and weighing.

One of the important limiting factors in pasture production is moisture. This is true not only in areas where rainfall is unreliabile and totals marginal, but also in places which may receive abundance of moisture at some times, but which are seasonally deficient of moisture at others. Probably few parts of the world are not subject to one or other of these drought hazards. Apart from irrigation, two solutions to the problem can be made. One, is to grow those perennials which are more efficient of water utilization than other perennials; the other, is to grow annuals which will take advantage of seasonally available moisture to make rapid growth and reproduce before moisture reserves have been exhausted. It is believed that some of the plants mentioned below will be useful in each of these two ways.

Literature Review

Most of the literature dealing with the economic use of the African species of *Trifolium* originates from the Grassland Research Station in Kenya. The writings of Bogdan (1955, 1956), Edwards (1935, 1940b), and Strange (1955, 1958) are most pertinent together with the paper by the Grassland Research Station, Kitale, Kenya, 1956. Horrell (1958) has discussed the trials of some of these clovers in Uganda and concludes that they are of no value under conditions tested, presumably because of the location at too low an elevation near the equator. Hosaka and Matsuura (1958) have given a preliminary account of *T. semipilosum* in Hawaii. Many papers which refer to "*T. johnstonii*" mean, *T. semipilosum*. Gillett (1952) has made a taxonomic revision of the African clovers and has included valuable summaries of notes on economic properties of the species provided by collectors. Bogdan (1956) has provided a summary of the indigenous clover species of Kenya from both the point of view of taxonomy and of agricultural possibilities of this group.

The environmental conditions of the grasslands which are the natural home of the clovers are described by Edwards (1935, 1940a, 1956).

Materials and Methods

Seed for this investigation was obtained from the Grasslands Research Station, Kitale, Kenya; the Plant Introduction Section of the United States Department of Agriculture; and the Cunningham Laboratory, C. S. I. R. O., Brisbane, Australia. Grateful

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acknowledgement is made for this material. Seed was sown in flats in the glasshouse, and seedlings transplanted to the field as spaced plants with 3 by 3 feet and 2 by 3 feet spacing. In addition to the African species, plants of an intermediate type of *T. repens* L. were placed at random in the rows for comparison. Plots were irrigated approximately once a week until the end of January when irrigation was discontinued.

Measurements, two months after transplanting, were made of the height of plant and the horizontal spread at right angles and parallel to the row. Because of some difficulties encountered after transplanting, comparable measurements were not possible for all species.

For purposes of comparison, calculations were made in the following ways. An approximate measure of the spread of the plant was obtained by multiplying the diameter of the plant at right angles with that parallel with the row. This figure represents a "spread index" of the plant, an important indication of production and of potential persistence of a forage plant. The figure does not represent the area of the ground covered by the plant, but figures so obtained can be used for comparison of different species. An approximate figure for comparison of production, is given by multiplying the "spread index," previously obtained, with the height of the plant. The cube roots of the figures, so obtained, were then determined to remove skewness from the distribution. This figure is referred to as "volume index." Means and standard error of means were then obtained (Steel and Torrie, 1960).

Results and Discussion

Melbourne, the southernmost city of the Australian continent, is situated at 37°50′, at the same latitude south of the equator, as San Francisco is north. The climate is a modified Mediterranean type, characterized by wet winters and dry summers. The spring and summer of 1961-62 were particularly dry, forcing severe water restrictions for the city of Melbourne. Monthly rainfall totals and mean maxima and minima temperatures for the months October-April 1961-62 are shown in Table 1. It should be mentioned that temperatures fluctuate greatly from day to day in Melbourne. Temperatures of 100°F in December and January are not uncommon. The averages shown in the table should, therefore, be read with this in mind. Practically none of the rain which fell from January 1 until April 29 was in sufficient quantity to be effective for plant growth. Irrigation was discontinued at the end of January so that the plants underwent severe test of drought tolerance for the rest of the summer.

Some signficant morphological and physiological features, important in evaluating pasture plants, are presented in Table 2 and applied to the species under study. Whether or not the species flowered during the period of observation is also pointed out. Much of significance can be learned from a consideration of these features of the plants. A perennial habit is to be preferred over an annual habit for most conditions, but for certain situations such as a long, dry, hot, season, an annual habit may be advantageous. A plant with prostrate habit, rooting at the nodes, will probably withstand the rigors of grazing more than an upright plant. The character, "leaflet shape," in the table is an indication of productivity of leaf material. Clovers with broad-shaped leaflets are usually more valuable than those with narrow leaflets. The data on flowering merely indicate whether or not the requisite environmental factors for the promotion of flowering were present.

Below are presented some of the more salient points of the different species, together with comments on their possible potential.

Trifolium baccarini Chiov. This species produced plants with upright habit, less than six inches high with sparse leaves. Plants lost thrift at the onset of warm weather and disappeared completely by midsummer. It is difficult to conceive of this plant making an important contribution to pastures unless its behavior is markedly different under quite different environmental conditions. Gillett (1952) states that the prostrate habit is adopted under conditions of overgrazing and that a form has been reported which may be

Table 1. Total Rainfall and Mean Temperatures October-April 1961-62, Melbourne, Austrialia.

Month	Rainfall Inches	Temperatures Mean Maxima °F	Mean Minima °F
October	1.73	73.4	51.8
November	0.89	74.8	53.7
December	1.94	77.4	57.1
January	1.54	80.8	60.0
February	1.60	77.4	57.1
March	0.56	78.4	57.2
April	1.35*	70.8	51.6
Total	9.61		

*Most of this rain came April 29 and 30, the amount for April 1-28, being 0.19 inches.

Table 2. Certain characters of eleven species of African *Trifolium* observed at Melbourne, Australia.

Species	Life span	Habit	Rooting at nodes	Leaflet shape	Flowering
T. baccarini	A*	U*	−*	B	−
T. burchellianum	P	Pr	+	B	−
T. cheranganiense	P	Pr	−*	I	+
T. masaiense	A	Pr	−*	B	+
T. polystachyum	P	Pr	−	I	−
T. pseudostriatum	A	U	−	I	−
T. rueppellianum	A	Pr	+	B, N	+
T. semipilosum	P	Pr	+	B	+
T. steudneri	A	U	−	N	+
T. tembense	A	Pr	−	B	+
T. usumbarense	A	Pr	−	I	−

MEANING OF SYMBOLS:
Life Span—A = annual, P = perennial;
Habit—U = upright, Pr = prostrate;
Rooting at nodes and Flowering—+, plants exhibited this character
−, plants did not exhibit this character
Leaflet shape—B—leaflets tend to be broad as in *T. repens.*
N—leaflets tend to be narrow
I—intermediate
*Some published reports indicate individual exceptions to present observations.

perennial and which may root at the nodes.

Trifolium burchellianum Ser. This species was slow in growth although appearing robust at all times. It produced a dense mat and was still actively growing when observations ceased. It had not flowered. This species is worthy of consideration from two points of view. The first is that the plants remained green and continued to grow throughout the year, during which time, leaves of *T. repens* had died. The other point of interest is that this species produces underground rhizomes which enable it to spread most effectively. This feature would undoubtedly be an important factor for survival under close grazing. The species deserves thorough investigation, in spite of its rather poor productivity in the present circumstances. Bogdan (1956) states that this species is slow to start and has poor seeding qualities but when well established is actually more vigorous than *T. semipilosum.* Some fundamental investigations would seem well justified for this species considering its possible potential.

Trifolium cheranganiense Gillett. Growth was slow in this species relative to *T. repens.* A rather loose mat was produced, with no roots emerging at the nodes. The species has some attributes of a good pasture legume, but unless it can produce a much greater amount of forage than in the present case, it cannot be considered as a species to replace other clovers currently commercially available. It does, however, appear to merit further investigation. Gillett (1952) states that the species is the most important clover in the open grassland at 2100-3000 m. in the Cherangani Hills of Kenya. Bogdan (1956), however, states that it develops slowly and dries at the beginning of the dry season.

Trifolium masaiense Gillett. This species did not establish well and growth was slow. Gillett (1952) describes the species as an annual which would explain the lack of persistence of the species under the present conditions. The plant did not offer sufficient potential to warrant further research. Gillett (1952) states that although one collector has attributed economic importance to the species, he has not been able to confirm this. Bogdan (1956) does not mention this species.

Trifolium polystachyum Fres. A sparse cover, extending less than five inches from the center was produced by this species. The plants were robust. The performance of the plant did not recommend it for further investigation.

Trifolium pseudostriatum E.G. Baker. This species grew poorly. Its poor growth and lack of favorable features do not recommend it for further study. Bogdan (1956) does not mention this species. Gillett (1952) reports on its altitudinal distribution, but it is not clear how important the species is to native pastures.

Trifolium rueppellianum Fres. This annual species grew rather rapidly. It's prostrate habit renders it a potentially valuable species. The plants under observation were stemmy with the leaves rather sparse. It is considered to be one of the best annual species in Kenya (Bogdan, 1955). Two distinct botanical varieties were examined. *T. rueppellianum* var, *lancelolatum* has much narrower leaves than *T. rueppellianum* var. *rueppellianum,* making it a less favorable variety. This species may have value for special conditions, as Bogdan states that it grows well in wet places. Further study of the var. *rueppellianum* seems justified.

Trifolium semipilosum Fres. This species resembles *T. repens* by the appearance of the leaves and the flowers, which in most plants have a reddish-brown pigment at the base. The plants produced an abundance of leaves which remained green for most of the hot, dry season. At the peak of the hot weather many leaves did dry up. The plants recovered their fresh green appearance with the

onset of cooler weather even before rain had fallen. Seedlings develop a pronounced tap root. On the basis of its outstanding performance, this species is considered to be the most valuable of the African species under test. It may prove to be more valuable than *T. repens* when grown under conditions of limiting moisture. Gillett (1952) states that this species is the "most important leguminous fodder in the Kikuyu grass *(Pennisetum clandestinum)* pasture of the Kenya uplands." The workers of Kitale confirm this report (Edwards 1940, Bogdan 1953).

Trifolium steudneri Schwf. Rapid growth at the seedling stage made this species appear promising early after emergence. The mature plant did not fulfill this early promise. The erect bush-like plants bore small leaves, sparsely arranged, which, coupled with the species' annual habit of growth, render it an unlikely plant for commercial use.

Trifolium tembense Fres. This annual clover was characterized by rapid emergence of vigorous seedlings which grew rapidly into sturdy plants with prostrate stems. Because of its extreme vigor and rapidity of growth from seedling stage to maturity, this species may have a place as an early season pasture legume. Further investigations seem warranted.

Trifolium usumbarense Taub. This species grew poorly. Its annual habit, and lack of demonstrated favorable characters, did not recommend it for further study. Gillett (1952) states that several collectors consider it important in its native habitat. Bogdan (1956) states that it lasted longer than *T. rueppellianum* or *T. tembense* at Kitale.

Data on the spread and the volume of the three largest African species and *T. repens* are given in Table 3. The spread index indicate *T. tembense* to cover the greatest ground area. *T. repens* and *T. semipilosum* are very similar and the erect *T. steudneri* is last.

An index of volume occupied by the plant was computed by determining cube root of the spread index multiplied by the height. This is a non-destructive way of comparing size and productivity of plant but not as accurate as cutting and weighing. Data presented in Table 3 shows the two annuals *T. steudneri* and *T. tembense* to have the highest indices. *T. semipilosum* has a smaller index than *T. repens* indicating a probable lower productivity. As already mentioned, *T. semipilosum* does appear to have characteristics which would recommend it even in spite of adverse data on productivity.

The present investigation, indicates the need for further study of four or five African species of *Trifolium* as potentially valuable economic species. Several points should be considered in this connection. Many of the species are native to high altitude regions of Africa near the equator. Since increase in elevation brings about decrease in temperature, just as does increase in latitude (but on a different scale), the species from the high elevations may be found to be adapted to lower elevations and higher latitudes than in their original home. The reverse of this is true for the temperate zone species, *T. repens,* which is adapted to high elevations in the tropics (Britten 1955, 1960). It is important to consider the relation of elevation and latitude when reviewing the comments of collectors concerning the conjectured optimum elevation of the individual species. (Gillett (1952) quotes a number of collectors on this point.)

Another point of great importance must be considered when comparing evaluation of plants from a plant introduction program and reports of the value of these same species in their native habitat. Plants which are to be used as sown pasture must be as good or better for the particular situation than any other plant commercially available, but plants which are native and which volunteer are of value so long as they contribute herbage and are not harmful by way of toxicity or of displacing more valuable species. This means that a statement that a certain native species is of value does not mean that plant will be necessarily of commercial value. It does, however, call for an investigation of the species to determine whether or not it possesses the genes for the morphological and physiological characteristics requisite to a commercially valuable pasture plant.

Two notes of caution should be added. The first is that low temperatures may turn out to be the limiting factor in determining the range of adaptation for these species. The second is that *Rhizobium* cultures for the commonly known species of clover are not effective on the African species, which have very specific requirements (Norris, 1959).

On the basis of the present investigation, it is concluded that

Table 3. Indices of productivity of three African species of *Trifolium* compared with *T. repens*.

Species	Spread Index[1] Inches	Volume Index[1] Inches
Trifolium repens	15.79 ± 1.90	9.13 ± 1.05
T. semipilosum	15.43 ± 0.45	8.75 ± 0.76
T. steudneri	14.87 ± 2.55	10.10 ± 1.80
T. tembense	17.00 ± 0.53	9.74 ± 0.97

[1]Spread index obtained by multiplying two measurements of diameter of plant, parallel and right angles to plant row. Index of volume obtained by multiplying height of plant by spread and then obtaining the cube root.

the perennial species of *Trifolium semipilosum* has the potential of a valuable pasture legume and deserves extensive investigation to determine how widely it is adapted. The species, *T. burchellianum,* has unique characteristics and also deserves further study. The species, *T. cheranganiense,* also has attributes which may make it a useful species but not as likely as the other two.

Two annual species may also find a place for special situations. *T. tembense* may be found useful where rapid early growth is desired. *T. rueppellianum* var. *rueppellianum* may also be of value for poorly drained areas. Its related botanical variety *T. rueppellianum* var. *lanceolatum* does not appear to be nearly as productive.

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