THE POTENTIAL FOR FORAGE LEGUMES IN KENYA

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ABSTRACT

At present legumes are not contributing materially to animal production from pastures in Kenya and means of increasing this are discussed. Possible solutions and areas for legume research in Kenya and other high altitude tropics are the adaptation of temperate species, the use of annuals and the development of indigenous species and shrub legumes. The area in Ethiopia and East Africa for which the use of adapted temperate and Mediterranean legumes may be considered exceeds 70 m ha. Limitations due to low night temperatures, the availability of seed and the necessity for simple management and economy of fertilizer use are also discussed.

INTRODUCTION

Available nitrogen (N) is the key to grassland production: on the majority of soils the productivity of grazing systems is inevitably low unless there is an adequate supply of N. In Kenya, as in most African nations, all N fertilizer is imported and is very expensive in relation to other costs and returns; hence little is used on pastures. For the forseeable future its use will continue to be uneconomic and a decline in productivity of the country's grazing resources seems inevitable unless other sources of N are used. The purpose of this paper is to draw attention to the great potential for forage legumes, particularly adapted temperate species, in Kenya and other high altitude tropical countries.

Kenya is essentially a dry country with 72% of its 58 M ha receiving an annual rainfall in four years out of five of less than 500 mm. This compares with 16% and 12% respectively for Tanzania and Uganda. Conversely only 12% of Kenya receives 750–1250 mm annually compared with 47% and 72% for Tanzania and Uganda (Griffiths 1972). The area of 42 M ha below 500 mm annual rainfall corresponds roughly to ecological zones V and VI of Pratt, Greenway and Gwynne (1966) i.e. the arid or very arid zones which could not be considered for the introduction of herbaceous tropical legumes with the species currently available. Of the remaining 16 M ha, 11 M lie above 1500 m altitude (Brown and Cocheme 1969) where the mean minimum temperatures are below 15°C. This leaves only about 5 M ha, mainly along the coastal strip, and round Lake Victoria, which is suitable for the truly tropical legumes. The area of 11 M ha above 1500 m may be compared with 3 M ha in Uganda, 19 M in Tanzania and 50 M ha in Ethiopia (Brown and Cocheme 1969) and demonstrates the importance of considering the use of temperate legumes in East Africa.

PASTURE LEGUMES ARE SPARSE IN KENYA

Unfortunately, despite research that has continued with varied intensity for about forty years forage legumes are making little contribution to agriculture in Kenya. With rare exceptions pastures in the "highland grassland" region (Edwards and Bogdan 1951) extending from about 2000 m upward and receiving a minimum of 1000 mm rainfall annually, contain few actively growing pasture legumes. In the highest parts of the region with even better rainfall, sown temperate legumes have been shown to yield well, with yields of 10–13000 kg DM ha^{-1} from white and sub-

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terranean clover pastures at Molo (2750 m) (Morrison 1966) but in practice swards based on productive legumes are hard to find. Although at altitudes below 2000 m numerous leguminous species have been recorded, they do not appear to contribute significantly to the forage available for grazing. Herbage legumes are scarce in the extensive *Acacia-Themeda* communities found from about 1200-2000 m (Edwards and Bogdan 1951) but, as the name implies, these communities are dominated by *Acacia* species that contribute substantially in providing browse and probably (Habish 1970, Corby 1974) in fixing nitrogen. In lower and much drier regions leguminous shrubs are also common but their contribution to animal production has not been measured.

Regrettably no survey data are available to confirm these subjective impressions but in 1970 Thairu reported that in the Trans-Nzoia district (the region in which most of improved pasture in the country is found) 17500 ha of grass and legume had been sown. It was estimated, perhaps a little optimistically, that 50000 ha had been sown in the whole country, i.e. only 0.09% of the land area or perhaps 0.3% of the area with an annual rainfall that could sustain grass/legume pastures.

REASONS FOR THE LACK OF LEGUMES

Productive legumes may be absent from pastures simply because they have not been introduced or because, having been introduced or occurring naturally, they have not been maintained for various reasons including:

Inadequate supply of nutrients, primarily phosphorus (Suttie 1968) and sulphur (Bumpus and Poultney 1960) and possibly trace elements (Birch 1960, N.C.O. Keya pers. comm., 1975).

Failure to tolerate heavy grazing—tropical legumes of twining or scrambling habit are intolerant of heavy grazing (e.g. Whiteman 1969, Jones 1974). Improper grazing management is undoubtedly one explanation for the scarcity of legumes in many pastures in Kenya. However, as high animal production per unit area cannot be sustained unless stocking rates are high this susceptibility to overgrazing on the part of some tropical legumes is a major drawback to their use, regardless of the farm managers' expertise. All legumes use the C_3 carbon fixation pathway and are in any case at a competitive disadvantage when grown in warm climates in association with tropical grasses that possess the fast growth rates and greater water use efficiency of C_4 plants (Hatch and Boardman 1973).

Inability to grow well at cool temperatures (Whiteman 1968, 't Mannetje and Pritchard 1974, Sweeney and Hopkinson 1975) and in particular with cold nights. Perennial tropical legumes commonly available require > 750 mm rainfall to grow well, yet in Kenya at the altitude at which this rainfall is assured, the nights are cold. At Muguga (alt. 2080 m) monthly mean minima range from 8–13°C throughout the year and at Kitale (1890 m) from 10–12°C.

Drought stress—rainfall distribution in East Africa is characterized by one, or in some cases, two, pronounced dry periods each year (Griffiths 1972) and perennial legumes may fail to survive because of lack of moisture. They are under particular stress at the lower altitudes where total rainfall is lower and evaporation rates are higher. Suttie (1968) states that generally in Kenya, pasture legumes only make a worthwhile contribution to pasture productivity in areas with an expected annual rainfall in excess of 875 mm. This would generally be true for *Glycine wightii*, *Macroptilium atropurpureum*, *Leucaena leucocephala*, *Macrotyloma axillare* and *Stylosanthes guianensis* (cv. Oxley) in Australia. More recently, however, some *Stylosanthes* species introduced to Australia from South America, notably *S. hamata* and *S. scabra*, have shown potential for good production in areas of much lower rainfall (Burt *et al.* 1974) and these could also be of value in the low altitude areas of Kenya.

Ineffective nodulation—if legumes are not effectively nodulated the plants are unlikely to compete successfully with the associated grasses (Bumpus and Poultney 1960). Although many tropical legumes are promiscuous and may not need inoculation there are notable exceptions and if the genera do not occur in Kenya it will be necessary to inoculate (Norris 1966, de Souza 1969, Thomas 1973).

Insufficient seed of annual species—the persistence of annual legumes depends initially on the existence of a sufficient quantity of germinable seed at the start of the growing season and a persistent, effective, *Rhizobium* associate. The former is a function of the seed production, the overcoming of dormancy and the rate of breakdown of hard seed. However, many factors, such as variability in dry season rainfall, can perturb the ecology of annual pastures, particularly those based on non-indigenous legumes, and eliminate the legume.

High seed costs—in many cases in Kenya legumes are not sown due to the unavailability or relatively high cost of the seed. Recent figures for legume seed sales (R. G. Combes, Kenya Seed Co., pers. comm.) indicate that only about one tonne year^{-1} is currently being sown in the country.

POSSIBLE SOLUTIONS AND AREAS FOR RESEARCH

It is unlikely that any one of the reasons discussed earlier is the sole, or even the major, cause of the lack of productive legumes in Kenyan grasslands; rather, these factors have brought about the present situation by combination and interaction. Similarly, the solution is unlikely to lie in overcoming a single specific difficulty but in the development of a number of lines of research and extension, of which some will certainly prove much more fruitful than others.

Adaptation of temperate legumes

At altitudes of 2250 m and above, temperate legumes such as *T. repens*, *T. subterraneum* and *Medicago sativa* are used successfully (Birch 1960, Morrison 1969) and suitably adapted temperate legumes may offer more immediate promise than tropical species at medium altitudes also. The users of the existing commercial varieties of tropical legumes are faced with a dilemma: Kenya and virtually all tropical countries require high animal production per unit area rather than per animal, but high production per unit area is impossible without high stocking rates, and these in turn are inimical to the production and persistence of many tropical legumes especially those of twining or scrambling habit. In contrast, *Trifolium* and other temperate genera will generally persist and thrive under continuous and often high stocking pressure if moisture is adequate. Moreover, temperate legumes, notably white clover are known to grow well in the sub-tropics and high-altitude tropics (Morrison 1969, Crowder 1967). In Kenya, the *T. repens* cultivar Louisiana seeds freely and is productive and persistent at high altitudes although at medium altitudes it grows well but is not persistent in pastures (Bogdan and Mwakha 1970, Suttie 1970). In an experiment at Samford, Australia (27°S) Whiteman (1969) found that plots of four common tropical legumes were taken over by volunteer white clover when subjected to close regular defoliation. This legume in fact contributes extensively to pastures in subtropical Australia although limited to areas of good rainfall (for reviews see O'Brien (1970) and Ostrowski (1972)).

In Kenya, isolated productive stands of lucerne are grown from 1500 to 3000 m for hay or green feed although lucerne is reputedly very susceptible to leaf diseases in most areas of good rainfall (Suttie 1968). There has been considerable success in breeding for disease resistance elsewhere and because of the well recognized capacity of this plant to promote rapid liveweight gain (Reed 1972) the development of suitable lucernes would appear to be a worthwhile project. However, the plant must be grazed intermittently rather than continuously if it is to persist so it may be unlikely to survive on the average smallholding. Creeping lucernes may be more suitable under such conditions (Davies and Hutton 1970). Most lucerne in Kenya is grown with irrigation and there is substantial but unexplored potential for the species sown for grazing as a dryland crop at seeding rates of 0.5–1.0 kg ha^{-1}.

Use of annual legumes

The occurrence of prolonged dry periods suggests that annual legumes might be better adapted to the environment than perennials (Strange 1955).

Numerous potentially suitable species and cultivars of annual legumes exist, notably in the genera *Trifolium, Vicia, Medicago, Lotus, Lotononis, Ornithopus, Aeschynomene, Astragalus* and *Lupinus*. The introduction of *Stylosanthes humilis* has been highly successful in parts of Northern Australia but the temperature requirements of this species are too high for it to be successful above say 1000 m altitude in Kenya and daylength would also limit growth of existing cultivars. Davidson (1958) suggested that sub clover (*T. subterraneum*) could have extensive application in Kenya and defined areas potentially suited to certain cultivars but as far as we know his predictions have not been tested as it has only been used commercially above 2300 m (Morrison 1969). Annual medics grow well in many parts of the world and a suite of cultivars adapted to various specific environments is now available in Australia (e.g., Barnard 1972, Clarkson and Russell 1975). In the U.S.A., *Vicia dasycarpa* is used in Western rangelands (MacLauchlan *et al.* 1974) and *Trifolium vesiculosum* in the humid S.E. (Hoveland 1974). It seems highly probable that well adapted annuals could be found for intermediate altitudes in Kenya.

Development of indigenous legumes

East Africa has a rich leguminous flora and many annuals and perennials are to be found scattered in its diverse habitats although collectively, apart from the browse species, they do not appear to contribute much to animal production or N accretion. Their potential has been discussed (e.g., Strange 1955) and is illustrated by the fact that several (*Lablab, Glycine, Macrotyloma* and *Trifolium semipilosum*) have been collected and taken to Australia where cultivars have been developed and put into commercial use (Barnard 1972).

Kenya white clover (*T. semipilosum* var. *glabrescens*) is capable of good dry matter yields and seed yields of up to 400 kg ha^{-1} in Queensland (CSIRO 1973, Jones 1973). Liveweight gains of cattle over three years at 2.4 beasts ha^{-1} were 466 kg ha^{-1} on *T. semipilosum* pastures compared to 370 with *T. repens*. It merits considerable research on factors such as virus infection, ineffective nodulation (Jones and Evans 1961), inappropriate cutting height, nutrient deficiency especially phosphate, or management that could account for its mediocre performance (Keya 1974) and lack of acceptance in its native environment. Jones and Date (1975) present evidence that in S.E. Queensland at least, *T. semipilosum* is readily nodulated by its specific *Rhizobium* strain and suggest that the symptoms of most reported "nodulation failures" are those of rugose leaf curl virus from which a large proportion of infected plants recover and grow normally. *T. rueppellianum, T. tembense, T. burchellianum* (Bogdan 1956) are further examples of indigenous clovers (Gillett 1952) with prospects for commercial use at 1500 m and upwards which have not been exploited. *Dolichos formosus, Rhynchosia sennaarensis* and *Glycine wightii* are other legumes with potential at the lower altitudes (Anderson and Naveh 1968). However, a determined and multi-faceted program would be necessary to bring any of these plants into common acceptance and use.

Perhaps the most obvious indigenous genus which awaits development is *Glycine*, found in various forms from the coast to altitudes of 2700 m (Bogdan 1966). Over nine years an ungrazed cover crop of the twining perennial species *Glycine wightii* (syn. *G. javanica* L.) added 145 kg N ha^{-1} $year^{-1}$ to the soil (Gethin Jones 1942). The species is productive and drought resistant but seed yields in Kenya were erratic (Suttie 1968). It is regarded as being more sensitive than most other tropical legumes to low pH, low exchangeable calcium and high manganese (Andrew and Hegarty 1969, Philpotts 1975). Large interactions have also been shown between *Rhizobium* strain and cultivars for this species (Nicholas and Haydock 1971).

Low night temperatures

What is required at intermediate altitudes in Kenya is not frost-resistance but rather the capacity to withstand cool nights. The ability to withstand or preferably thrive at low night temperatures would be a useful primary criterion in screening introductions for these environments. As has been mentioned, low night temperatures are probably the cause of the failure of several tropical legumes to yield well and persist in what would otherwise appear to be appropriate areas (Suttie 1968, Keya 1974). One native of the permanently cool tropical highlands, *T. semipilosum*, has been found to reproduce and grow best at temperatures below 22°C (Mwakha 1968). *Lotononis bainesii* is outstanding among tropical legumes in Australia for its frost resistance and capacity to grow at both high and low temperatures. It remains green in winter although production is low in cold conditions (Bryan 1972, 't Mannetje and Pritchard 1974). It is also efficient at phosphate sorbtion (Andrew and Vanden Berg 1973) and withstands, indeed requires, heavy grazing (Bryan *et al.* 1971) and warrants further consideration in Kenya. Other tropical legumes with ability to withstand cool conditions and moderate stocking rates are *Glycine tomentella, Aeschynomene falcata* and *Lespedeza striata* (Colman and Mears 1975), and are recommended for trial.

Shrub legumes

Another method of obtaining the benefits of legumes in grazed plant communities is to introduce shrub or tree legume species, although not all non herbaceous legume genera have the capacity to establish an effective symbiosis with N-fixing bacteria. In the drier areas of Kenya indigenous woody legumes occupy a dominant position in the plant communities covering perhaps two-thirds of the country. The advantages of shrub legumes in comparison to shorter, non-woody legumes have been listed by Humphreys (1974):

1. Legume dominance is readily achieved and, once established, shrub legumes are not readily susceptible to damage from heavy grazing.
2. Many shrub legumes have deep rooting systems conferring a degree of drought resistance; green leaf persists longer.
3. In cold regions green leaf may be borne above the height at which light frosts occur.
4. A deeper light profile theoretically provides for more efficient dry matter production.
5. Shrubs can be used as a hedge or windbreak.

Other important advantages, we consider, are:

6. Economy of fertilizer usage by growing shrub legumes either scattered or in rows where the soils have a high capacity to fix phosphate.
7. Wood for charcoal, fuel or building can be obtained from some arboreal forms e.g. *Leucaena leucocephala* (Brewbaker 1975).
8. Suitability for utilization by cutting or topping, either routinely by smallholders or on a larger scale, as a dry season feed reserve.

The place of trees and shrubs as sources of forage in tropical and subtropical pastures has been reviewed (Whyte 1947, Gray 1970) and Gray (1968) and Hill (1971) have discussed the literature available on *Leucaena leucocephala*, the shrub legume most extensively used for fodder. Disadvantages of *Leucaena* are its content of mimosine which is liable to cause coat shedding, unthriftiness and even death in stock, and its environmental limitation; Hutton and Gray (1959) observe that in Australia the plant requires a rainfall of 750 mm and a minimum temperature above

10°C in the coldest month. However, the results obtained with *Leucaena* should encourage further study of the use of woody legumes (e.g. Rose-Innes 1965) to overcome several of the problems of growing and using herbaceous legumes in close association with pasture grasses. Many African leguminous shrubs are too spiny to be used extensively by cattle but some could provide large quantities of edible pods and seeds (e.g. Wickens 1969).

Seed availability

Regardless of the types of legumes that are to be used in the improvement of Kenyan pastures—and the wide diversity of environments present suggests that many different species and cultivars will ultimately be required—the availability of inexpensive seed will be critical. Limitations in the supply of tropical legume seed are severe (Thairu 1973) and a well planned research program similar to that successfully implemented by Boonman (1973) for grasses must be a primary objective. The existing information on seed production by tropical legumes has been thoroughly reviewed by Humphreys (1975).

CONCLUSION

With rapidly increasing human population pressure and the move to smallholder rather than broad-acre farming there is an urgent need for legumes that will be sufficiently aggressive to compete, where necessary, with tropical grasses yet be robust enough to withstand hard grazing and protracted dry spells with little or no fertilizer. Solution of these admittedly difficult problems could make a major contribution to the rural economy of East Africa and other lands at moderate to high altitudes in tropical South America and Asia.

Achieving this solution will demand high inputs of research, as it is doubtful if the technology developed in tropical Australia can be directly applied because of differences in day length and low night temperatures. Most emphasis must be placed on the potential of temperate and Mediterranean legumes.

The *Desmodium* species now being widely used at research centres represent a group of tropical legumes with greater low temperature tolerance but unfortunately they are susceptible to over-grazing and are of low digestibility. Although accessions from several temperate and Mediterranean genera have been examined (Morrison 1969) it is essential to study a much wider gene pool in each climatic zone to obtain cultivars with adequate seed production and hard seeded characteristics. The genera *Trifolium, Lotus, Medicago, Vicia, Lupinus* and *Ornithopus* offer possibilities for legumes capable of adaptation. Similarly, in the tropical genera, *Lotononis, Glycine, Aeschynomene, Lespedeza* and *Vigna* would be worth exploring further for adapted legumes capable of withstanding cool temperatures and heavy grazing.

In the drier, warmer areas daylength now precludes the use of Townsville stylo (*S. humilis*) cultivars but a proper search for photoperiod adapted ecotypes may prove rewarding. Also, the more vigorous, drought tolerant *S. hamata* and *S. scabra* accessions from Central and South America, capable of flowering in a 12 hour day could provide persistent legumes for these zones (Edye *et al.* 1976). The contribution of existing leguminous shrub species to the nitrogen economy of grazing lands has not been adequately studied and the input of N and the direct contribution to animal production could be considerable. Furthermore, the planned use of deep rooting leguminous shrubs could overcome some of the problems encountered with the use of herbaceous legume species.

Socio-economic conditions in many tropical areas present major obstacles to the acceptance and implementation of pasture improvement. It is essential to consider and assess the importance of these factors at *all* stages of a pasture research program if the work is to be of lasting benefit to an area.

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