STABILITY IN SOWN AND OVERSOWN SIRATRO PASTURES

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ABSTRACT

Stability in Siratro (Macroptilium atropurpureum) *based pastures is defined as the maintenance of a long-term balance between grass and legume. Factors governing the behaviour of either of these components will therefore affect stability. The attributes which lead to the success of Siratro as a pasture legume are discussed and related to its persistence and productivity. Where Siratro is adapted its persistence and productivity seem to be assured, provided it is not overgrazed. If a weak or ill-adapted grass is used, or if Siratro is sown into native pastures, then changes in botanical composition are almost inevitable. This may partly be the result of smothering by strong Siratro growth and partly the build-up of soil nitrogen levels encouraging more responsive species to supercede those already there.*

Studies on sown and oversown pastures emphasize the importance of having suitable companion grass species in maintaining the stability of Siratro based pastures.

INTRODUCTION

Siratro can now be accepted as a versatile and successful pasture legume and as such its management and ecology have recently been described by Jones and Jones (1977). Our task is to build up, from this and other experience, a greater understanding of the factors governing the stability of Siratro pastures, particularly in relation to the sub-tropics of south-east Queensland. Siratro is almost always a legume of permanent pastures, therefore Siratro pastures must be botanically stable in the long term, even though fluctuations in botanical composition will still occur and it may be difficult to recognise stability in the short term.

In practical terms a stable pasture implies a continued productive presence of the sown legume and acceptable associated species, almost always grasses, though not necessarily sown grasses, and a minor weed component. In ecological terms pasture stability implies the maintenance of a long term equilibrium state in the vegetation by means of managed inputs such as grazing, fertilizers and plant genetic resources against a background of the natural environment. The grazing animal accelerates the rate of circulation of nutrients, encouraging plants which can take advantage of a better nutrient supply and withstand defoliation. Mostly the equilibrium stage is not natural but maintained by management. Thus the concept of a stable legume-grass pasture being a managed successional stage of vegetation is important in pasture management.

In this paper we outline the key attributes of Siratro and describe factors controlling its persistence and productivity. We then consider factors governing stability in sown and oversown Siratro pastures and show how these have operated in an experimental situation.

KEY ATTRIBUTES OF SIRATRO

First let us briefly consider the main attributes of success with which Siratro, a relatively new pasture legume, is endowed.

1. It has wide adaptation to different soils and climates.
2. It nodulates freely and effectively with wild strains of cow pea *Rhizobium*.
3. It has a large seed, rapid germination and strong seedling development.

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4. Its growth form provides for a rapid spread of occupied space from the established crown, ensuring that seed dispersal occurs over a wide area.
5. The production of hard seed allows for the build-up of viable seed reserves in the soil.
6. Strong perenniality, coupled with potentially high levels of annual seedling recruitment, leads to a dynamic population balance.
7. Rapid extension of trailing stems, which may also behave as stolons, may lead to smothering of weak-stemmed companion species.
8. Its twining habit allows for the maintenance of Siratro in tall grass pastures.
9. Rooting from stolons and rhizomes, primarily in wetter areas, aids persistence and nutrient uptake and provides further sites for nodule development.
10. The relative freedom from diseases and pests in the areas of adaptation is a definite advantage in persistence and productivity.
11. It is palatable, but not to the extent that it is selectively eaten out.

Various attributes are important at different growth stages, in different environments and, relative to one another, at different times. Most of these attributes are strongly conditioned by the management imposed, particularly the effects of grazing and the level of input of fertilizer.

There are two fairly clear phases in the development of a pasture which call for careful management. These are, first of all, an establishment phase and secondly a stable production phase.

MANAGEMENT FOR ESTABLISHMENT

During the establishment phase grazing should be controlled to allow seedlings to develop, grow and propagate, either by seed or vegetatively. It is obviously important to promote the rapid build-up in density of the sown or desired species in the pasture. While grazing may not necessarily be excluded from a pasture during the establishment phase, management must still be directed towards promoting the establishment of the desired species. Under low grazing pressure Mannetje (1967) was able to promote a satisfactory stand of Siratro from an initial seeding rate of 0.6 kg ha^{-1}. In pilot studies at Narayen[1] one of us (J.C.T.) achieved a stand of Siratro in a spear grass pasture when sod seeded in the exceptionally dry 1968/69 summer. With establishment initially very sparse, after 4 years it was equivalent to a stand seeded in the favourable 1967/68 summer.

Cook and Lowe (1977) in this Symposium have discussed the factors governing the behaviour of Siratro during this phase so we shall not consider it further other than to say that, while the phase may be reasonably well defined for sown pastures, it is necessarily not so for oversown pastures. In the latter the establishment phase may extend well into the production phase, as is demonstrated later in this paper in a case study.

MANAGEMENT FOR PRODUCTIVITY

Once a pasture is established the main objectives of management are to achieve satisfactory animal production while maintaining or even improving the desired species composition of the pasture. Thus we are concerned with the maintenance of a satisfactory level of the desired plants in the pasture, i.e. density or occurrence, as well as their continued productivity, i.e. yield. Density or occurrence may be used as a measure of the continuing level of adaptation of the species in the pasture in relation to other species, the environment and management, and this is closely conditioned by the mechanisms for persistence that the species possess. Productivity is affected by changes in density of the main species and also by changes in vigour of individual plants in relation to defoliation and fertilizer responses.

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1. C.S.I.R.O. Narayen Research Station (25° 42'S, 150° 52'E).

Density

Different sowing rates result in widely different densities in the first year but the differences decrease with time (Jones 1971, Jones 1975a, Walker and Potere 1974). Siratro plant densities of 3-7 m^{-2} have been measured in several grazed pastures, in some cases densities have been unaltered by stocking rate (Agishi 1974, Bisset and Marlowe 1974—Lowmead site) or decreased by increasing stocking rate (Jones 1971, Bisset and Marlowe 1974—Brooweena site, Rees, Jones and Roe 1976, I. J. Partridge and B. Walker—personal communications). In a stable environment and with moderate stocking rates there is likely to be a nearly stable Siratro density: in a pasture at Samford[2], stocked at 1.7 beasts per hectare (b ha^{-1}) for five consecutive years, the density has been 6.3, 4.2, 4.9 and 5.5 plants m^{-2} (R. M. Jones, unpublished data). However, densities may fluctuate markedly when rainfall between seasons varies widely. For example, during a drought Siratro numbers dropped from 13 to 4 plants m^{-2} in a buffel grass/Siratro pasture at Narayen (L. 't Mannetje, personal communication), whereas in another pasture at Nanango after two years of favourable rainfall there was a short-term increase of from 4 to 14 plants m^{-2} (Jones 1973a).

Mechanisms of persistence

Siratro has persisted in coastal pastures at Samford by different mechanisms, stocking rate being the controlling factor (Jones 1973a, 1975b). At the lowest rate of 1.1 b ha^{-1} individual plants were large and long-lived with secondary rooting from stolons and rhizomes. New seedlings which emerged in this dense pasture almost always died, probably due to competition for light. At the highest stocking rate the more rapid death of plants was initially offset by better survival of seedlings resulting from seed set in the establishment and early years. Survival of these seedlings was satisfactory, competition for light being negligible, but the life span of such plants was subsequently reduced by heavy grazing.

Stolon rooting and growth of rhizomes are associated with moist, light-textured soils, low grazing pressure and high Siratro and pasture yield (Jones 1973b, Bisset and Marlowe 1974—Lowmead site, I. J. Partridge, B. Walker and A. E. Kretschmer—personal communications). Under these conditions the need for seedling regeneration is less than when Siratro is heavily grazed or grown in a drier environment. However, in heavily grazed situations where the need for seedling regeneration is greatest, seed production is least.

Usually sufficient seed is set to allow for build-up of soil seed levels, primarily through dehiscence on to the pasture, bearing in mind also that Siratro stolons may be more than 2 m long and can therefore set seed some distance from the parent plant. A little seed is passed in cattle faeces but although this is a way of colonising new sites it comprises less than 5% of seed reaching the soil surface (Jones and Jones 1977), and may therefore only slowly colonize new areas where there is no Siratro in the immediate vicinity. Appreciable seed reserves can build up in the topsoil of grazed pastures (Table 1) and these can persist for many years (Jones and Jones 1977, B. Walker—personal communication).

Defoliation

Increasing the frequency of cutting of Siratro has consistently reduced Siratro yields (Jones and Jones 1977). For example, in an experiment at Samford, cumulative yields of Siratro cut every 16, 12, 8 and 4 weeks over summer, were 6200, 5800, 3000 and 1500 kg ha^{-1} (Jones 1971). The rate of regrowth after cutting reflects the amount of effective residual photosynthetic material and the number of buds left behind on the indeterminate trailing stems. Repeated severe defoliation reduces the opportunity to build up a framework of stems and so yield is severely depressed. But

2. C.S.I.R.O. Samford Research Station (27° 25'S, 152° 55'E).

TABLE 1

Siratro seed levels in the 0–5 cm topsoil of grazed pastures.

Site	Associated Grasses	Year Sown	Year Sampled	Siratro seeds m^{-2}* Mean	Range	Comments	References to site details
Samford	Nandi setaria	1968	1975	254	154–512	Numbers increased with decreasing stocking rate	Jones (1974)
Narayen	Native pasture	1972	1974	93	59–127	Numbers increased with decreasing stocking rate	Tothill (1974b)
Narayen	Buffel grass	1972	1974	104	76–146	Numbers highest in lightest stocking rate	Tothill (1974b)
Narayen	Buffel grass	1967	1974	268	125–464	Numbers lowest in heaviest stocking rate	Mannetje (1973)
Kogan	Pioneer Rhodes	1974	1976	21	5–62	Most seed with highest Siratro yields	Russell (1975)
Westwood	Green panic	1969	1976	86	0–172	One stocking rate, high values with KCl maintenance fertilizer	Hall (1972)
Nanango	Nandi setaria/green panic	1966	1975	290	—	One stocking rate	Rees, Jones and Roe (1976)
Mackay	Kazungula setaria	1970	1975	520	198–1014	Numbers increased with decreasing stocking rate	Walker and Potere (1974)

*Narayen soil seed data from Agishi (1974), Mackay data from B. Walker (personal communication), all other unpublished data of R. M. Jones.

since these stems are generally prostrate, the height of defoliation has less effect on regrowth than does frequency of defoliation. Jones and Jones (1977) further point out that continued overgrazing of Siratro can lead to elimination of the legume, as overgrazing reduces legume yield which reduces nitrogen fixation and subsequently grass growth. Reduced grass growth then leads to additional grazing pressure on the legume and the decline continues.

Defoliation effects are confounded by the relative response of the companion species in the pasture. Jones and Jones (1977) discuss the situation in which vigorous tall-growing grasses delay Siratro regrowth after defoliation and depress the growth rate of the legume.

A further complication is that of climate. In situations such as Narayen where rainfall during the growing season is often erratic, stocking rate is determined by the periods of low pasture productivity. Consequently during periods of active growth defoliation is never severe. Such may also be the case when the companion grasses are very palatable (Stobbs 1969), or when the relative palatability of Siratro changes throughout the year (Stobbs 1977).

In areas of reliable rainfall near the coast, where the dry season is relatively short, it is possible to maintain a higher stocking rate, either year long or during the grazing season only, than it is in areas of less reliable rainfall and a longer dry season. It is therefore easier with set-stocking to overgraze Siratro pastures in more favourable coastal environments than it is in less favourable inland ones. The effects of consistent heavy grazing pressure on Siratro growth and persistence may be partially alleviated by spelling periods of at least eight weeks (Jones and Jones 1977). However any such system of spelling requires that more than the usual number of animals is carried elsewhere.

Maintenance fertilizer and soil fertility

Jones and Jones (1977) have discussed the maintenance fertilizer requirements of Siratro particularly in relation to P and K. They point out that in most grazing experiments fertilizer is applied after some assessment of its need at levels that would adequately ensure its sufficiency. Few grazing experiments have been carried out to ascertain precise response levels. From his work at Narayen C. Johansen (personal communication) considers economies could be made in fertilizer use on Siratro where the build up of an organic matter layer at the soil surface acts as a store for nutrients awaiting recirculation.

Perhaps the most important element in terms of overall pasture growth is that of nitrogen resulting from the legume's symbiosis with *Rhizobium*. This has a profound effect on the vigour and nature of the companion grasses and of the potential invasion of weeds. It is perhaps the most important factor in determining the level of pasture stability. If, however, a Siratro pasture is grown at sub-optimal levels of superphosphate, Siratro yield may stabilize at a lower level because the legume is short of P and S. The reduced legume growth would lessen the smothering effect of Siratro but also the level of grass growth through lower N, P and S levels and eventually the grass/legume interaction.

STABILITY OF SIRATRO PASTURES

The general agricultural principle that heterogeneity has to be exploited in low yielding and uniformity in high yielding situations has recently been enunciated by de Wit (1977). When applied to pastures, for example, simple sown grass/legume mixtures are more likely to be maintained successfully in uniform high yielding environments. With existing native or natural pastures, increasing the potential productivity of an environment as with legume oversowing and application of fertilizer, may increase the simplicity of the species composition of the pasture and also will initiate a change in species composition towards those found only in higher fertility situations (see review of Tothill 1977). Pasture mixtures with many species are likely to be more suitable for areas of considerable natural variability (e.g.

topographic and soil) or where the growing season is ill-defined or exceeds the climatic limits of some of the species being used (e.g. the use of white clover and medics in pastures which are otherwise composed of summer-growing tropical species).

It should be made clear at this point that de Wit's principle, as applied to perennial, legume based pastures, concerns primary or herbage production of pastures and not necessarily secondary or animal production. The relation between herbage and animal production is usually not direct but modified by the effects of grazing. Animal management, particularly grazing pressure, can have a marked effect on legume productivity, botanical composition, and therefore an over-riding effect on pasture stability.

Sown grass/Siratro pastures

The oldest sown Siratro pasture known to us is at Rodd's Bay (24°05'S, 151°24'E) where, over a period of 14 years, a dynamic equilibrium appears to have been established (N. H. Shaw, personal communication). Initially sown to Rhodes grass (*Chloris gayana*) and Siratro, the Rhodes grass disappeared during a run of very dry years in the mid 1960's and was replaced by native grasses. However, during recent more favourable years the Rhodes grass has re-established itself, even though continuously grazed at a stocking rate high for that environment. Siratro, though persisting at a reduced density, returned to full strength in one season after the drought and undoubtedly aided the recovery of the Rhodes grass.

Several studies have reported and numerous commercial examples show that if Siratro and a suitable grass are reasonably grazed then the pastures are stable in the sense that sown species remain dominant and weed invasion is minimal (Jones 1974, B. Walker and I. J. Partridge, personal communications). There will of course be fluctuations between different seasons and years. Good legume growth in one year could lead to more vigorous grass growth and reduced legume growth in the following year, especially as nutrients in Siratro litter are readily released in spring from Siratro leaf fall in autumn/winter (Vallis and Jones 1973). Drought periods and unavoidably heavy stocking due to property managerial requirements will also cause fluctuations in the yield of sown species but will not necessarily lead to weed invasion.

However, if the sown grass is unsuited and dies out due to climatic stress then weed species invade. One example comes from the Nanango site of Rees, Jones and Roe (1976) where presentation yields in five year old pastures with two adapted grasses, viz. Rhodes grass, and green panic (*Panicum maximum* var. *trichoglume*) and a climatically unadapted grass (*Setaria anceps* cv. Nandi) were as follows:

	Yield (kg ha^{-1})		
Grass	Siratro	Sown grass	Native Weeds
Nandi Setaria	980	40	1180
Green panic	530	770	460
Rhodes grass	360	710	150

The main invading species with the weak sown grass were *Eragrostis parviflora* and *Verbena* spp. The competitive Rhodes grass excluded weeds more effectively than did green panic but also reduced Siratro yield.

So far we have discussed stability where Siratro has remained productive, but if Siratro is so heavily grazed that it becomes unproductive there is more opportunity for the ingress of weeds as the sown grass becomes nitrogen deficient and may itself be overgrazed. This is illustrated by the following data from Samford for pastures grazed rotationally on the basis of four days grazing after 17 days rest, and sampled just before grazing (R. M. Jones, unpublished data).

	Yield (kg ha^{-1})			
Stocking Rate	Siratro	Setaria	Blue couch	Other Weeds
1.3 b ha^{-1}	1060	3700	50	30
2.8 b ha^{-1}	70	1070	80	80

Naturalized species that frequently invade overgrazed Siratro pastures include blue couch (*Digitaria didactyla*) and carpet grass (*Axonopus affinis*) in coastal south-east Queensland and green couch (*Cynodon dactylon*) and summer grass (*Digitaria ciliaris*) in the drier sub-coastal areas.

Oversown pastures

While sod-seeding or oversowing legumes into existing native or natural pastures has long been carried out successfully in temperate regions with white clover, subterranean clover and medics, and now for some time in the tropics with Townsville stylo, it has not yet been widely performed with Siratro. However, the behaviour of Siratro in sown pastures, and the capacity it shows of regenerating or building up from fairly low population numbers, supports its suitability for oversowing (Lowe 1974, Tothill 1974a).

In oversowing or sod-seeding a legume into an existing pasture the legume has two roles. The first is to stimulate the growth of the grasses, as in a sown pasture, but the other is to provide a medium for the selection of grasses better adapted to the higher fertility, more intensively utilized environment. That is, the management system ensures there is an increased rate of circulation of nutrients due to the higher grazing pressure and there is a natural selection for the species most readily able to use them. These species are the plants with rapid growth rates and low threshold levels for initiating growth. The result, of course, is that whenever a legume in introduced into such pastures a substantial change in botanical composition takes place. However, the change is limited to the genetic material that is naturally available in the region, unless some efforts are made to bring in material from elsewhere. The types of grasses naturally volunteering and building up in these pastures can give a clue as to the potential genetic resources that may be sought.

COMPARISON OF SOWN AND OVERSOWN SIRATRO PASTURES

In order to examine some of these theoretic considerations and to compare the behaviour of Siratro in both sown and oversown pastures at the same time and site, we will now look at contemporary information from studies on a range of land use systems at Narayen. Here for the past five years fully sown pastures of buffel grass (*Cenchrus ciliaris* cv. Biloela) and Siratro, native pasture dominated by spear grass (*Heteropogon contortus*) sod-seeded with Siratro, and native pasture without Siratro have been compared (Tothill 1974b). Superphosphate was supplied to all Siratro treatments at an overall optimal level for the legumes.

The establishment phase

The first and immediately obvious difference between the sown and sod-seeded pastures was the rate of establishment of Siratro (Figure 1). Twelve months after sowing the amount of Siratro in these two treatments was 500 and 100 kg ha^{-1} respectively, the frequency of occurrence being 97% and 60% (0.5 m^2 quadrat). Comparable stands of Siratro were not achieved in these two pastures for a further 12 months i.e. January 1974. In addition the Siratro of the sown pasture had achieved a reproductive stage within its establishment year, and hence contributed to stand build-up, whereas the Siratro of the sod-seeded pasture did not. Siratro appeared to exert little, if any, influence on the other components of the pasture at this stage.

The production phase

From Figure 1 it can be seen that the components of the two Siratro pastures followed a cyclic pattern of behaviour both in the short term, i.e. seasonally, and in the long term over a sequence of years. Although the seasonal pattern was very obvious in its amplitude it represents a normal pattern of behaviour. Grass growth exceeded Siratro growth in early spring and there was a more rapid decline in legume

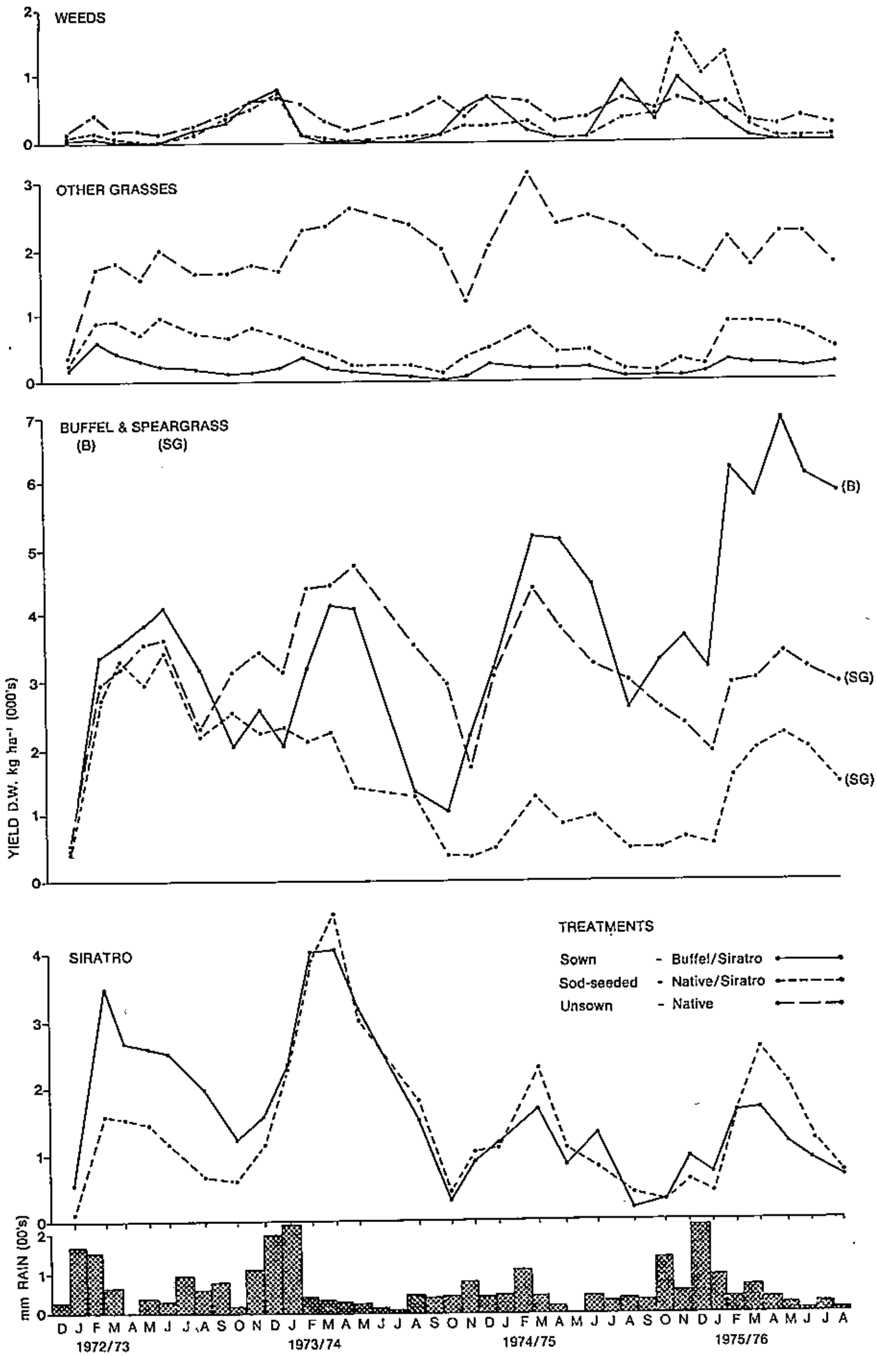

FIGURE 1

Available dry matter for the main components of three pastures at Narayen, i.e. buffel grass/Siratro, native pasture/Siratro and native pasture alone. Actual monthly rainfalls are also given.

herbage in autumn. Spring weeds were also evident in seasons with early rain and these were more pronounced in the Siratro/native pasture than the sown pasture (e.g. 1975/76).

The long term pattern is of considerable interest. In spite of the large difference in rate of establishment of Siratro in the sown pasture compared with the sod-seeded native pasture, Siratro nevertheless achieved a comparable and high level of dominance in both pastures two years after sowing (1973/74). As a result of this dominance the sown buffel grass continued to build up substantially in the sown pastures, while spear grass collapsed in the sod-seeded native pastures. This collapse was observed to be substantially related to mechanical smothering by the Siratro with spear grass insufficiently strong-stemmed to stand up to the weight, or responsive enough late in the season to grow through and away from the Siratro. Following this dominant phase there was a decline in the level of Siratro in both pastures, with a continued and increased predominance of buffel grass in the sown pastures. The resurgence of spear grass and "other grasses" in 1975/76 may be a seasonal effect or a new cycle of grass growth associated with fertility accumulation. There was a comparable seasonal increase of spear grass in the native pasture without Siratro, but in the case of "other grasses" the increase was associated with a complete change in species composition. While almost none of the original "other grasses" remained, there was a build up of summer grass (*Digitaria ciliaris*), green couch (*Cynodon dactylon*) and green summer grass (*Brachiaria miliiformis*), generally considered grasses of high fertility situations.

There was also a seasonal cycle of herbs or broadleaved weeds which remained fairly constant until the last season when they showed a substantial increase in the native pasture-Siratro treatment. While this was associated with a favourable season for the growth of weeds it was more pronounced where the grass component had been severely weakened.

These two responses, i.e. the build up of the so-called high fertility weedy grasses and of the broad-leaved weeds, are indicative of the vegetation changing towards an early stage of succession where the species most adapted are those which can best take advantage of the enhanced soil fertility conditions following good Siratro growth. Our job as husbandmen is to manipulate existing species or introduce new species to ensure that those that grow in this new situation are palatable to grazing animals, capable of withstanding repeated defoliation, and able to exclude undesirable weeds.

PROBLEM AREAS AND FUTURE WORK

The practical objective in seeking to understand the ecology of Siratro is to enable accurate conceptual or even quantitative modelling of how persistence and productivity of Siratro pastures will be affected by management. This approach would be particularly useful in predicting how to integrate sown and native pastures (Winks 1975). Our current knowledge allows for some measure of prediction (Jones and Jones 1977) but the main deficiency is that we know very little about the effects of seasonal changes in grazing pressure on Siratro or its associated species. Most grazing experiments have been done under a variety of fixed stocking rates, in either year-long continuous or rotational grazing systems. This may be quite different from management on commercial properties where pastures may be grazed for certain periods and then rested, primarily to satisfy animal management requirements. Variable grazing pressures in different seasons could well affect Siratro productivity but have an even greater effect, favourable or otherwise, on botanical composition of a complex oversown pasture. This has been well illustrated for temperate pastures by Jones (1933).

The other major deficiency in our knowledge of Siratro pastures concerns the use of sub-optimal levels of fertilizer on both the increase in the level of soil fertility from establishment and the decline in fertility on pastures previously well-fertilized. Since soil phosphorus below critical levels will undoubtedly affect the vigour of the legume and its associated species, there is likely to be a strong interaction with grazing pressure. Studies on both these aspects are currently being undertaken but mostly they are likely to be fairly long-term, particularly where they concern changes in botanical composition.

Finally, there is a need to consider whether we are searching as effectively as we might for appropriate genetic material, particularly grasses, for oversown pastures. Not only are such pastures likely to be developed in environments of greater heterogeneity than fully sown pastures, therefore requiring a wider spectrum of genetic resources, but it must also be necessary for the adapted genotypes to regenerate and spread under the appropriate management conditions. For this, the types of native grasses volunteering can give us a clue. Furthermore, the presence of unpalatable weeds indicates there are resources within the system not being effectively used for productive purposes.

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