ESTABLISHMENT OF SIRATRO PASTURES

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ABSTRACT

The environmental, plant and management factors affecting the establishment and early growth of Siratro are discussed. Siratro has a vigorous seedling that is well adapted to a range of soil and climatic conditions. It therefore presents few establishment problems on cultivated seedbeds but there is a greater risk of failure when oversowing methods are used. Pasture management factors are of greater importance under such conditions as the successful establishment is dependent on a population build up from seed set.

INTRODUCTION

The success or failure of a pasture species is most critically determined during the phases of germination and seedling establishment (Harper 1965). The seed and seedling behaviour characteristics help to determine successful establishment, spread, and resistance to aggression from competing plants.

Two excellent review papers dealing with establishment principles (Leach *et al.* 1976), and with the ecology of pastures based on *Macroptilium atropurpureum* cv. Siratro (Jones and Jones 1977) have recently been published. However it is apparent that there is a general lack of information on tropical pastures, and of information specifically relating to the establishment of Siratro-based pastures. Much of the research has concentrated on the production phase, and little is known about the fate of the sown seed or of the seedlings which emerge, even though such information is important for understanding the establishment requirements and general ecology of Siratro pastures.

In this paper we will outline some of the principles which we consider to be important for the establishment of Siratro-based pastures. Many of the comments will be more applicable to the areas of southern and central Queensland, where the majority of the research on Siratro has been conducted; however the underlying principles will be relevant to a much wider set of environments. Pasture establishment is defined as the sequence of events that occurs from the time the seed is sown until such time that the species are in a position to contribute substantially and permanently to pasture production. The rate of establishment depends on the number of plants per unit area and on the growth rate per plant. These in turn are dependent on the processes of seed germination and the growth and persistence of the seedlings, the actual time for establishment being determined by various environmental and plant factors that influence these processes. Such factors can be modified to some extent by pasture management, which should aim to favour the establishing seedlings by promoting maximum growth rate and encouraging seed set.

PLANT AND ENVIRONMENTAL FACTORS AFFECTING SIRATRO ESTABLISHMENT

Attributes of Siratro

Few problems have been associated with the establishment of Siratro pastures in cultivated seedbeds (Jones and Rees 1973, Jones 1975) and Siratro has been established successfully by sod seeding direct into native pastures, even under quite dry conditions (Tothill and Jones 1977). Part of this success is no doubt a reflection of

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the adaptability of Siratro to a wide range of soil types and conditions (Jones and Jones 1977) and to the fact that it nodulates freely and quickly from native rhizobia in the soil (Norris 1972, Wilson 1972).

A high seedling growth rate benefits the establishment of legumes (Black 1959), particularly in tropical environments where the growth rate of competing weeds and associate grasses can be quite high (Davies and Hutton 1970, Ludlow and Wilson 1970). Siratro has a relatively large seed that germinates to produce a vigorous seedling. By contrast, Greenleaf desmodium (*Desmodium intortum*) has a smaller seed with a lower seedling vigour (Whiteman 1968) and is therefore more susceptible to competition during the establishment phase (Jones 1975). Combined with its rapid growth rate, Siratro has a twining, vine-like growth habit (Hutton 1962) which allows it to elevate its leaves above those of its competitors and so reduces the effects of shading. On the other hand, low-growing, non-twining legumes such as white clover (*Trifolium repens*) and Townsville stylo (*Stylosanthes humilis*) are quickly shaded by taller-growing grasses and may be strongly suppressed or eliminated from the pasture unless corrective management practices are implemented. Siratro seedlings have the added advantage in that their leaves exhibit diaphotonastic movements (Begg and Torssell 1974) under favourable moisture conditions. This characteristic allows them to orientate their leaflets at right angles to the direction of the incident radiation and trap the maximum amount of radiation and so increase their growth rate, particularly where they are partially shaded by neighbouring species.

Siratro seedlings are susceptible to moisture stress (Peake *et al.* 1975) but they are better equipped to survive than many other legumes. The vigorous seedling produces a rapidly elongating tap root (P. S. Cornish and S. J. Cook, unpublished data) that enables the plant to reach moisture supplies that are deeper in the soil profile. At the onset of moisture stress young seedlings are able to minimise their radiation load by orientating their leaflets parallel to the suns rays, and follow the course of the sun in this position (parahelionasty), in a way similar to that of Townsville stylo (Begg and Torssell 1974). Under more severe moisture stress Siratro sheds its leaves to avoid complete desiccation (Peake *et al.* 1975).

Once established, Siratro plants produce twining stems two to three metres long and set large quantities of seed. Although the amount of seed set varies according to the environmental conditions and management imposed, it is generally well in excess of the initial sowing rate (Agishi 1974, Jones and Jones 1977). The long twining stems, together with the shattering seed pod, facilitate population build up and spread.

Environmental Factors

Within the subtropical areas of southern and central Queensland, where Siratro is generally the most promising legume available (Jones and Jones 1977), the climatic factors of temperature and rainfall set the geographic limits for Siratro growth (Fitzpatrick and Nix 1970). They also limit the period over which establishment is likely to be successful.

Effect of Temperature

Low night temperatures restrict the growth of Siratro to a four to five month period during summer in southern and central Queensland (Jones and Jones 1977). Frosting usually kills the top growth but the taproots and rhizomes can survive severe and repeated frosting better than many other tropical legumes (Jones 1969). Although it is not known whether plant survival is dependent on the age of the plant, it is generally accepted that larger plants with their more extensive root systems are usually more tolerant of adverse conditions. Frost temperatures at the soil surface are also markedly influenced by the amount of herbage cover (insulation) present, with temperatures being from 3° to 5°C lower (−5°C *vs.* 0°C) in areas with no surface cover compared to those with a standing dry grass cover of about 4000 kg D.M. ha^{-1} (S. J. Cook, unpublished data). The later in the season that the pastures are sown, the less time the plants will have to establish before the first frosts; sub-optimal temperatures will begin to slow seedling growth and the plants may be subjected to lower frost temperatures because of the lack of surface cover.

Plant Competition and Moisture

Two major factors cause the failure of pasture species to establish in Australia, namely: a lack of moisture, and inter-plant competition (Campbell 1972). The native and weed species present are often better adapted to the local environment than the introduced pasture species; the older plants have well developed root systems while annual weed seedlings often have rapid growth rates and are thus able to capitalize on favourable growing conditions. These native and weed species compete strongly with the establishing seedlings for limited resources such as moisture, nutrients and light. Consequently, seedling growth may be restricted to such an extent that the young plants succumb to moisture stress before they have a chance to become properly established.

Rainfall in Australia is variable making pasture establishment a risky process in many areas. Southern and central Queensland have been described as being difficult environments for tropical legumes because of this large seasonal variation in rainfall (Fitzpatrick and Nix 1970). The lack of moisture at critical stages during establishment is responsible for many failures. Rainfall frequency and its seasonal distribution are factors of equal, or even greater, importance than the total amount of rain received.

Two of the main functions of cultivated seedbeds are therefore the destruction of the competing plant cover, and the improvement of moisture infiltration and retention. The fact that cultivated seedbeds also provide an improved environment for seed germination and more favourable conditions for root growth is probably of secondary importance for Siratro, particularly in the drier inland parts of southern and central Queensland. Fallowing before sowing increases the amount of soil moisture that may be drawn upon by young seedlings during dry periods. However, the presence of weeds in the fallow reduces moisture storage because of increased losses from evapotranspiration. The aim in preparing a good seedbed should therefore be to maximise water infiltration by having a rough cloddy surface, and to control weeds which reduce soil moisture storage and compete with the establishing seedlings. Poor establishment of many sowings can be traced to inadequate seedbed preparation and failure to control weeds particularly where the pasture is planted in an area previously used for cropping. Such areas generally contain a higher population of weed seeds as well as having a degraded soil structure. Low cost establishment techniques based on aerial seeding and sod seeding compound this problem even further and will be discussed in a later section. Siratro may establish successfully in "weedy" seedbeds when climatic conditions are favourable (e.g. Jones 1975), but the risk of prolonging the establishment phase, or of a complete failure, is increased considerably.

Soils

Most soils on which Siratro is grown in Queensland are deficient in phosphorus, sulphur, and to a lesser extent potassium and molybdenum. Correction of such deficiencies by fertilizer application improves the growth of Siratro, but the ultimate effects may depend on the associate species and soil nitrogen availability (Jones 1975). Application of superphosphate may tend to stimulate the growth of the faster growing grasses more than that of Siratro (Wendt 1970, R. L. Hall, personal communication), and the enhanced competitive ability of the grass may thus lead to a suppression of Siratro growth.

The nutritional responses of Siratro have been well researched (Andrew and Fergus 1976), but few data are available on the effects of fertilizers on Siratro establishment. However, on low phosphate ($<$ 20 ppm P) duplex soils in sub-coastal southern Queensland, Siratro seedling numbers increased as superphosphate application was increased to 750 kg ha^{-1} (K. F. Lowe, unpublished data).

Pests and Diseases

In southern and central Queensland Siratro has few pests and diseases of any significance. Although the seedlings are susceptible to attack by bean fly (*Melanagromyza phaseoli*) establishment does not appear to be significantly affected over much of the area; if necessary seedlings can be protected by a dieldrin seed dressing (Jones 1965). Removal of sown seed by seed harvesting ants is a problem in some areas where the seed is broadcast onto the soil surface (Campbell 1966, Russell *et al.* 1967, Johns and Greenup 1976). Ants are not likely to be a problem in cultivated seedbeds as the cultivation process destroys their natural habitat and the majority of the seed is placed below the soil surface where it cannot be found. Even where the seed is broadcast into undisturbed grassland, the larger seeds of Siratro are less likely to be removed than the smaller grass seeds. If any doubt exists as to the importance of seed harvester ants, the seed can be treated with dieldrin or chlordane before sowing (Campbell 1966, Russell *et al.* 1967).

Rufous rat-kangaroos (*Aepyprymus rufescens*) have been serious pests in some experimental Siratro pastures. These nocturnal marsupials dig out and eat the tap roots of Siratro, particularly during late autumn and winter. Their effect on pasture establishment in larger areas is unknown but we suggest that they might be a serious pest in situations where the initial Siratro plant numbers are low.

Management Factors

Factors that are under the control of the landholder are termed management factors. They include decisions such as the time and method of sowing, the seeding rate, and the grazing management during the establishment period. Such decisions should be made with a view to combining the species and environmental factors so as to get the best establishment possible.

The build up of seed reserves in the soil should be one of the objectives of establishing a new pasture. The "seed bank" enables the stand to thicken and spread, but more importantly, reduces the need for resowing by acting as a buffer against adverse seasonal conditions.

Time of Sowing

The time of sowing may vary from one area to the other depending on the local climatic factors. Sowing early in the season gives the plants a better chance of becoming firmly established before the first frosts. There is also a greater chance of seed set. However, pastures should be sown when there is the greatest chance of getting follow-up rain within a short time after germination. For example, at the Narayen Research Station near Mundubbera (25°41'S, 150°52'E; average annual rainfall = 713 mm) the 89-year average rainfall for December is 100 mm, while that for January is 105 mm. However, on average there are more wet days in January and the rain is often associated with cyclonic influences. Such weather patterns usually result in rain of light to moderate intensity falling over three or four consecutive days. Furthermore, the associated cloud cover may extend for several more days thereby reducing the incoming radiation and moderating temperatures. Such conditions are more favourable for establishment than those commonly experienced in December, when most of the rain is associated with thunderstorm activity and hence is often of short duration and high intensity with hot and dry periods intervening. One of us (S.J.C.) has measured soil surface temperatures in excess of 50°C during such periods. The young seedlings therefore have to cope with supra-optimal temperatures in addition to the increasing moisture stress. In the near coastal areas rainfall patterns are more favourable than those further inland and Siratro pastures are often sown in October and November.

Method of Sowing

There are three main methods of sowing Siratro pastures. They include the conventional cultivated seedbed, sod seeding, and surface broadcasting or aerial seeding.

Cultivated seedbeds result in better germination and establishment and are more reliable than the other methods because they provide a better environment for the seed to germinate as well as destroying competition and allowing for moisture storage.

The first two to three weeks after germination appear to be the most critical in the establishment of aerial seeded Siratro. Very little Siratro seed germinates on falls of rain of less than 10 mm; 30 to 50 mm of rain falling over at least 36 to 48 hours is required for good germination. Follow-up rain is required within a further 8 to 10 days to prevent the soil surface drying out and causing high mortality. Once the first trifoliate leaf emerges (14 to 21 days) the seedlings are better able to tolerate periods of moisture stress.

Initial establishment is generally proportional to the amount of soil disturbance, or in the case of aerial seeded pastures, is proportional to the amount of standing cover present (S. J. Cook, unpublished data). The standing cover leads to an increase in the humidity at the soil surface, which results in increased nett moisture uptake by the seed and an increase in seed germination. It also shades the emerging seedlings from the direct radiation of the sun. However subsequent seedling growth is dependent on the competition from the native vegetation. At Narayen, Siratro sown in January flowered and set seed in the year of sowing when sown in a cultivated seedbed, but did not in pastures that were sod seeded (Tothill and Jones 1977) or surface broadcast (S. J. Cook, unpublished data). Because of the lower initial establishment and reduced growth in the two latter methods the period of establishment may be extended from two to four years (e.g. Tothill and Jones 1977), depending on the environmental conditions, and amount of seed set. Grazing management during establishment is thus more critical when pastures are either sod sown or aerial seeded.

Seeding Rate

Siratro is commonly seeded at rates ranging from 2 to 4 kg ha^{-1}, but experiments conducted over a range of soil and climatic conditions in cultivated seedbeds suggest that no long term benefit is had by seeding at rates in excess of 2 kg ha^{-1} (Middleton 1970, Jones 1975). In each case seedling emergence was proportional to the sowing rate but there was no difference in legume production in the second year, even though seeding rates ranged from 2 to 18 kg ha^{-1}. Seeding rates as low as 0.6 kg ha^{-1} have given rise to satisfactory stands ('t Mannetje 1967), although such low rates are usually reliant on the pasture thickening from seed set and the establishment phase is prolonged by one to two years.

The hard seed content of Siratro seed samples may range from 10 to 70 per cent for commercially harvested seed (J. E. Butler, personal communication) up to 95% for seed picked by hand (Hutton and Beall 1977). The germination and early establishment may be increased by either acid or heat treatment, or by passing the seed through a mechanical scarifier. However we believe that it is advisable to sow seed with a hard seed content of about 20% to 30%, particularly in the drier inland areas where rainfall is more variable. The hard seed allows for a later germination if the first germination fails because of unfavourable weather conditions.

Burning and Grazing

In northern Australia, burning followed by heavy grazing is used to reduce the competition from the tall-growing tropical grasses which shade Townsville stylo during establishment (Norman 1965). However no such advantage can be cited for Siratro pastures; initial establishment may in fact be reduced because of the reduced grass cover present. Competition for light is also likely to be less important than with Townsville stylo because of the growth habit of Siratro. Furthermore, soil surface temperatures are from 5° to 7°C higher under close defoliated pastures than under native grass pastures with 2000 to 3000 kg of standing dry matter ha^{-1} (S. J. Cook, unpublished data).

Light to moderate grazing during the early establishment phase can be quite beneficial to the growth and competitive ability of Siratro. Cattle tend to preferentially graze the competing grasses rather than Siratro early in the growing season, but their diet selection changes to preference for the legume during the early autumn period (Stobbs 1977). If the pasture is being grazed it should be closely observed as the month of February progresses so that the change in diet can be quickly detected. It is advisable to spell the establishing pasture from grazing during this time, as it also coincides with the main period of seed set. Once the peak seeding period is over the pasture can be restocked. If the pasture is continuously stocked during seeding the amount of seed set is dependent on the stocking rate. For example, at Samford, Jones and Jones (1977) report that 15 and 40 kg seed ha^{-1} were set at stocking rates of 1.7 and 1.1 beasts ha^{-1} respectively, while further inland at Narayen, two-year-old Siratro-based pastures contained 12.2 and 19.6 kg seed in the soil at stocking rates of 1.10 and 0.58 beasts ha^{-1} respectively (Agishi 1974).

CONCLUSIONS

The adaptability of Siratro to a wide range of soil and climatic conditions, together with its inherent seedling characters, have contributed to the generally successful establishment of this legume in cultivated seedbeds. However many of the pastures have been sown in relatively small areas on dairy farms in sub-coastal areas. Siratro also grows well further inland where native pastures are now grazed extensively for beef production. The increased size of individual holdings will require the sowing of larger areas of pasture. However the preparation of cultivated seedbeds over such large areas will be both expensive and time consuming, particularly where the areas to be sown are either wooded or only partially cleared. Furthermore, many of the landholders in these areas are unaccustomed to farming principles and do not possess the necessary machinery to prepare such large areas.

Aerial or surface seeding, when successful, provides an effective means of rapidly developing a large area at relatively low cost. However, in practice the method has the reputation of being unreliable but failures have rarely been investigated to determine the underlying causes. Many of the so-called failures might have been turned into successes if more had been known about the factors affecting Siratro establishment. For example, whereas pastures sown in a cultivated seedbed may initially have large numbers of seedlings which then decline, sod sown and aerial seeded pastures generally rely on a build-up in plant numbers from seed set. To the inexperienced observer, a satisfactory plant population from oversowing may look like an establishment failure in a cultivated seedbed. Only in recent years has more research been concentrated in this area, and already the results are indicating that aerial seeding is a feasible, albeit risky, alternative to sowing in a cultivated seedbed.

REFERENCES

AGISHI, E. C. (1974)—Regeneration of Siratro (*Macroptilium atropurpureum*) in grazed pastures. M.Agric.Sci. Thesis. Univ. of Queensland.

ANDREW, C. S., and FERGUS, I. F. (1976)—Plant nutrition and soil fertility. *In* "Tropical Pasture Research. Principles and Methods." (Eds. N. H. Shaw and W. W. Bryan). Bulletin 51 Commonwealth Bureau of Pastures and Field Crops, Hurley, pp. 101-33.

BEGG, J. E., and TORSSELL, B. W. R. (1974)—Diaphotonastic and parahelionastic leaf movements in *Stylosanthes humilis* H.B.K. (Townsville stylo). *In* "Mechanisms of Regulation of Plant Growth". (Eds. R. L. Bieleski, A. R. Ferguson and M. M. Cresswell). Bulletin 12 The Royal Society of New Zealand, pp. 277-283.

BLACK, J. N. (1959)—Seed size in herbage legumes. *Herbage Abstracts* **29**: 235-41.

CAMPBELL, M. H. (1966)—Theft by harvesting ants of pasture seed broadcast on unploughed land. *Australian Journal of Experimental Agriculture and Animal Husbandry* **6**: 334-38.

CAMPBELL, M. H. (1972)—Pasture establishment. *In* "Intensive Pasture Production" (Eds. A. Lazenby and F. G. Swain, Angus and Robertson, Sydney), pp. 97-113.

DAVIES, J. G., and HUTTON, E. M. (1970)—Tropical and sub-tropical pasture species. *In* "Australian Grasslands". (Ed. R. M. Moore, Aust. Natn. Univ. Press, Canberra), pp. 273-302.

FITZPATRICK, E. A., and NIX, H. A. (1970)—The climatic factor in Australian grassland ecology. *In* "Australian Grasslands", (Ed. R. M. Moore, Aust. Natn. Univ. Press, Canberra), pp. 3-26.

HARPER, J. L. (1965)—Establishment, aggression and cohabitation in weedy species. *In* "The Genetics of Colonising Species". (Eds. H. G. Baker and G. L. Stebbins, Academic Press, New York), pp. 243-68.

HUTTON, E. M. (1962)—Siratro—a tropical pasture legume bred from *Phaseolus atropurpureus. Australian Journal of Experimental Agriculture and Animal Husbandry* **2:** 117-25.

HUTTON, E. M., and BEALL, L. B. (1977)—Breeding of *Macroptilium atropurpureum. Tropical Grasslands* **11:** 15-31.

JOHNS, G. G., and GREENUP, L. R. (1976)—Pasture seed theft by ants in northern New South Wales. *Australian Journal of Experimental Agriculture and Animal Husbandry* **16:** 249-56.

JONES, R. J. (1965)—The use of cyclodiene insecticides as liquid seed dressings to control bean fly (*Melanagromyza phaseoli*) in species of Phaseolus and. Vigna marina in south-eastern Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **5:** 458-65.

JONES, R. J., and JONES, R. M. (1977)—The ecology of Siratro-based pastures. *In* "Plant Relations in Pastures". (Ed. J. R. Wilson, C.S.I.R.O. Melbourne), (in press).

JONES, R. M. (1969)—Mortality of some tropical grasses and legumes following frosting in the first winter after sowing. *Tropical Grasslands* **3:** 57-63.

JONES, R. M., and REES, M. C. (1973)—Farmer assessment of pasture establishment reliability in the Gympie district, South-East Queensland. *Tropical Grasslands* **7:** 219-22.

JONES, R. M. (1975)—Effect of soil fertility, weed competition, defoliation and legume seeding rate on establishment of tropical pasture species in south-east Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **15:** 54-63.

LEACH, G. J., JONES, R. M., and JONES, R. J. (1976)—The agronomy and ecology of improved pastures. *In* "Tropical Pasture Research. Principles and Methods." (Eds. N. H. Shaw and W. W. Bryan). Bulletin 51 Commonwealth Bureau of Pastures and Field Crops, Hurley, pp. 277-307.

LUDLOW, M. M., and WILSON, G. L. (1970)—Studies on the productivity of tropical pasture plants. II. Growth analysis, photosynthesis, and respiration of 20 species of grasses and legumes in a controlled environment. *Australian Journal of Agricultural Research* **21:** 183-94.

MANNETJE, L. 'T (1967)—Pasture improvement in the Eskdale district of south eastern Queensland. *Tropical Grasslands* **1:** 9-19.

MIDDLETON, C. H. (1970)—Some effects of grass-legume sowing rates on tropical species establishment and production. Proceedings 11th International Grasslands Congress, Surfers Paradise. pp. 119-23.

NORMAN, M. J. T. (1965)—Post establishment grazing management of Townsville lucerne on uncleared land at Katherine, N.T. *Journal of the Australian Institute of Agricultural Science* **31:** 311-13.

NORRIS, D. O. (1972)—Leguminous plants in tropical pastures. *Tropical Grasslands* **6:** 159-70.

PEAKE, D. C. I., STIRK, G. B., and HENZELL, E. F. (1975)—Leaf water potentials of pasture plants in a semi-arid subtropical environment. *Australian Journal of Experimental Agriculture and Animal Husbandry* **15**: 645-54.

RUSSELL, M. J., COALDRAKE, J. E., and SANDERS, A. M. (1967)—Comparative effectiveness of some insecticides, repellants and seed-pelleting in the prevention of ant removal of pasture seeds. *Tropical Grasslands* **1**: 153-66.

STOBBS, T. H. (1977)—Seasonal changes in the preference by cattle for *Macroptilium atropurpureum* cv. Siratro. *Tropical Grasslands* **11**: 87-91.

TOTHILL, J. C., and JONES, R. M. (1977)—Stability in sown and oversown Siratro pastures. *Tropical Grasslands* **11**: 55-65.

WENDT, W. B. (1970)—Responses of pasture species in eastern Uganda to phosphorus, sulphur and potassium. *East African Agricultural and Forestry Journal* **36**: 211-19.

WHITEMAN, P. C. (1968)—The effects of temperature on the vegetative growth of six tropical legume pastures. *Australian Journal of Experimental Agriculture and Animal Husbandry* **8**: 528-32.

WILSON, J. R. (1972)—Comparative nodulation, nitrogen fixation, and growth of *Glycine wightii* cv. Cooper and *Phaseolus atropurpureus* cv. Siratro seedlings. *Australian Journal of Agricultural Research* **23**: 1-8.

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