TROPICAL FORAGE SEED PRODUCTION: PRODUCERS' VIEWS AND RESEARCH OPPORTUNITIES

J.B. Hacker[1] and D.S. Loch[2]

[1] Australian Tropical Forages Genetic Resource Centre, CSIRO, 306 Carmody Rd, St Lucia, Q 4067, AUSTRALIA

[2] Department of Primary Industries, PO Box 395, Gympie, Q 4570, AUSTRALIA

ABSTRACT

Tropical forage species are sown as perennial and annual pastures, as leys and break crops, for turf and amenity purposes (including native species), and for the revegetation of saline and mined land. A wide range of species is grown, but there are comparatively small numbers of cultivars within species. Most of these species have been domesticated for less than 30 years and in many cases, optimal procedures for seed production have not yet been developed. A questionnaire was sent to producers of tropical forage seeds worldwide, requesting information on seed production over the past three years and their perception of problems relating to seed production and marketing. In total, 167 producer x species responses were received from ten countries, with the majority of respondents (35 of 54) from Australia. Seed yields ranged from more than 3,000 kg/ha to less than 40 kg/ha in legumes, and from 1,200 to 30 kg/ha in grasses. Considering problems related to seed production and marketing, the strongest responses for legumes were to questions relating to early growth of seed crops, weed control and the need for advice to improve seed production. Weed control was seen as a less significant problem in grasses, but seed shedding and accurate timing of seed harvest were of more frequent concern. In the Marketing section, the strongest response was in relation to problems associated with variability in demand, and the benefits associated with Plant Breeders Rights. Factors affecting seed yield (soils, climate, pollination failure, harvest date), seed quality (harvesting methodology, hardseededness, dormancy, packaging and storage) and marketing (Plant Breeders Rights, national interests) are briefly reviewed. A survey of recent published research suggests that seed producers are not being provided with the technical information they require, although informal publications and advice (in Australia) provide some assistance. Continuing reductions in funding for research are likely to result in further erosion of tropical forage seed industries to the detriment of the larger primary industries they support.

KEYWORDS

tropical forages, tropical legumes, tropical grasses, seed quality, seed production, seed marketing

INTRODUCTION

Grassland science for the tropics and subtropics has a much shorter history than for temperate regions, and has followed more diverse paths. Sown pastures range from extensive pure-grass or grass-legume pastures in Australia and Brazil to small areas of more intensively managed forage, often less than 0.5 ha, in South-East Asia.

Although vegetative planting (particularly of *Cynodon* and *Pennisetum* spp.) is common in more mesic regions, most pastures are propagated by seed. A few species have been cultivated for 100 years or more, but most tropical cultivars (especially those of legume species) are new to agriculture, having been developed within the last 35 years. Excluding special-purpose annual forages, such as *Sorghum sudanense* hybrids and *Pennisetum glaucum*, almost all are perennials comprising a wide range of growth habits. They also retain many "wild" characteristics that pose problems with commercial seed production. In consequence, seed industries in the tropics are at an earlier stage of development than those in temperate areas. In many cases, seed producers are still learning how to manage these new crops for seed production, with or without the backup of scientific knowledge.

In this paper, we present data obtained through a recent world survey on seed yields achieved commercially from tropical forages and also problems experienced by seed producers. We then consider the consequences of these issues within the framework of **Products**, **Yield and Cost of Production, Quality** and **Marketing** - all of which contribute to the overall commercial success of seed production - and compare these issues with recently published research.

SURVEY OF COMMERCIAL EXPERIENCE

To obtain recent data on seed production and to document current problems from a commercial seed grower's perspective, a questionnaire was sent to as many seed producers and other seed industry contacts as could be accessed. Responses were as follows: Australia (35); Antigua (1); Bolivia (1); Brazil (3): Colombia (1); Costa Rica (1); Guatemala (1); Japan (5); Thailand (4); Zimbabwe (2). Respondents were asked to provide data on annual seed yield for each of the tropical forages they had grown over the past three years and, for each species, to respond to a list of 26 statements relating to problem areas (Table 1). The questionnaire provided a range of five potential answers to each statement, from strongly agree through to strongly disagree.

Completed questionnaires were returned by 28% of Australian recipients and 26% of overseas recipients. Results from the survey are dominated by data from Australia (with 65% of all respondents). In total, 167 species x producer responses were received. All were included in the analysis of yields except for those from Japan where yields were very low and from small areas of land. However, Japanese replies to statements on perceived problems were included.

Seed yields (Tables 2a and 2b) and areas sown to particular species varied widely. Areas ranged from less than 1 ha (mostly from research establishments or from small enterprises in Thailand where seed is hand-picked) to extensive areas. One Brazilian respondent reportedly has 1,000 ha of *Brachiaria* spp. under production, from which 1,000 tonnes of seed are harvested per year. In general, large-seeded legumes such as *Lablab purpureus* and *Mucuna* sp. had the highest yields. However, the yields of comparatively small-seeded species such as *Stylosanthes hamata* and *Aeschynomene americana* sometimes also exceeded 1 tonne/ha. In Australia, there was a strong tendency for seed of some recently released species to be produced by only one seed grower, in part reflecting Plant Breeder's Rights (PBR) agreements.

Considering the "agree" and "disagree" responses to the Management section of the questionnaire, the strongest responses for legumes were to the statements relating to early growth of seed crops, weed control and the need for advice to improve seed production (respectively, Statements 6, 4, 16). Weed control was seen as a less significant problem in grasses, but seed shedding (Statement 8) and accurate timing of seed harvest (Statement 10) were of more frequent concern. In the Marketing section, the strongest response was in relation to problems associated with variability in demand (Statement 23), and the benefits associated with Plant Breeders Rights (Statement 26).

PRODUCTS

Species vs cultivars

In the tropics, there has been a strong tendency to release new species as pasture cultivars, in contrast to forage development in temperate regions where the emphasis has been on developing 'improved' cultivars from established commercial species (e.g. the ryegrasses, fescues, lucerne [= alfalfa], white clover). Table 3 provides data on numbers of cultivars for some of the most widely sown grasses and legumes in the tropics. There are very few cultivars within any of the legume species, in strong contrast to the major temperate legumes each of which has numerous cultivars: for example, in 1990 there were 19 and 26 registered cultivars of lucerne and subterranean clover available in Australia (Oram 1990) and many times these numbers overseas. There are larger numbers of cultivars associated with *Cenchrus ciliaris, Chloris gayana* and *Panicum maximum* among the most widely sown tropical grasses, partly reflecting the fact that these three species have been sown commercially for around 100 years in tropical America, Africa and Australia. Despite the comparatively large number of cultivar names that appear for these species in the literature, however, very few are currently grown commercially to any significant extent. In general, the early cultivars (and often the first cultivar) of a species tend to remain commercially dominant (e.g. Gayndah, American [= American Common] and Biloela are the main *C. ciliaris* cultivars produced in Australia [Table 3], with American Common dominating production in Texas, USA (R.V. Huth, pers. comm.; G.E. Pogue, pers. comm.). Before the recent advent of PBR, with consequent greater opportunities for promoting specific cultivars, the major exception to this outcome occurred when another cultivar with appreciably different attributes was released (e.g. among Australian *Chloris gayana* cultivars, the later flowering and higher palatability of cv. Callide ensured it a significant place in the market alongside the older Pioneer and Katambora cultivars; and in *C. ciliaris,* West Australian - the first cultivar introduced - was later superseded by more productive varieties).

Australia provides the best example of the overall species diversity among commercially available herbage cultivars: to date, 38 grass and 36 legume species have been released (either formally or informally) for sowing in the Australian tropics and subtropics, but in both cases almost 60% of these species are single-cultivar releases (Table 4). This compares with 13 grass and 26 legume species listed by Oram (1990) for use in temperate parts of the country. The Australian experience also illustrates how recent much of this development has been, with 45% and 17% respectively of the current grass and legume species available before 1960, but with only 30% and 10% respectively of the present grass and legume cultivars released by that date. In all, 51 species and 117 cultivars of herbage plants have been released in Australia since 1960.

Future development of tropical forage cultivars is likely to proceed at a slower pace than over the past 3-4 decades. In the past, Australia has been a major developer of new species and cultivars, but financial constraints and changing priorities within public organisations are putting research programmes under increasing pressure. Similar pressures are being felt in other countries, and in international institutes such as CIAT. In most countries, the market for perennial tropical forages is small, and the "user pays" principle - axiomatic of the modern era - is likely to work against major programmes of cultivar development in the future.

A direct result of the large number of forage species grown in the tropics is that, for most of these, there are none of the economies associated with large-scale production. The successive release of new species may require the development of new or modified technologies, whereas a single technology is usually appropriate for different cultivars within a species. Similarly, detailed research that may be necessary to develop economically viable seed production technologies for difficult low-volume seed crops cannot be readily justified - hence it is difficult to meet the needs of commercial seed producers most of whom rely on advice from experts (Statement 15 - Table 1). Not surprisingly, almost half the respondents (for legumes) considered that more research should be carried out on seed production of new legume varieties before their release, and more than one-third were of the same opinion with new grasses (Statement 17).

Markets for tropical forage seed

Most tropical grass and legume species are perennial forages, grown primarily for beef production and, to a lesser extent, for dairy cattle. The beef market in particular is intrinsically unstable, with prices and export opportunities fluctuating from year to year. Fluctuation in price tends to be more of a factor in those countries which export a high proportion of their product. The periodic droughts characteristic of most subhumid and semi-arid higher-latitude regions is also a source of instability in beef markets. Seed production primarily aimed at servicing the beef industry is therefore a high risk enterprise; and, not surprisingly, a number of experienced Australian seed growers have recently left the industry, opting to grow more stable alternative crops such as sugarcane. Sown perennial pastures are expected to persist for at least 5-10 years, so it is only when cattle prices are high and the season is favourable that there is a high demand for pasture seed. In contrast, there is a high and recurring demand in Australia for annual tropical forages such as *Sorghum sudanense* hybrids, *Vigna unguiculata* and *Lablab purpureus.*

Many of the tropical forages released for grazing, particularly legumes, are adapted to "niche" environments rather than having a more widespread role. Examples of such species released in Australia in the 1960s are *Desmodium intortum, D. uncinatum, Macrotyloma axillare*, *Lotononis bainesii*, and *Stylosanthes guianensis* var. *intermedia*, each of which is grown for seed by a very few growers in Australia to service markets each of no more than a few tonnes per annum. It is debatable whether the public cost of developing cultivars adapted to such restricted markets can be justified in the future. However, in some cases, a new species released initially for a niche market could turn out to be more broadly adapted and have a larger market than originally envisaged (e.g. *Digitaria milanjiana* cv. Jarra, *Vigna parkeri* cv. Shaw, and on a larger scale, *Arachis pintoi*). Product diversification is needed, both to address future changes in demand and to provide a more stable product mix for seed producers rather than simply servicing the grazing industries if and when they require seed for pasture sowings. In temperate regions, there has been a tendency for producers (e.g. in Oregon USA and in Europe) to diversify into seeds of turf and amenity grasses for which the market is more stable. In the tropics, the turf and amenity industry is not yet highly developed. However, some countries (particularly in South-East Asia) are becoming increasingly affluent and developing a market for amenity grasses for leisure and environmental use. Current grasses for this emerging market include *Cynodon dactylon* and *Paspalum notatum* (both produced mainly in the USA), and *Axonopus affinis, Bothriochloa pertusa* and *Digitaria didactyla* (all from Australia).

A related trend in Australia, albeit still very small in volume, is the use of native grass seeds for revegetation, forage, amenity and ornamental purposes (Loch et al., 1996). For the most part, these are harvested from natural stands to supply what is still a small and fragmented market. Perhaps the judicious use of government policy (e.g. for land rehabilitation, roadside plantings, conservation use) will help to generate the stronger and more consistent demand necessary if this segment of the seed industry is to develop further. Salinisation is an increasing problem worldwide; a wider range of salt-tolerant herbage species and (where possible) improved salt tolerance are needed to address this. For example, *Chloris gayana* is generally regarded as among the most salt-tolerant of our current suite of tropical grasses. It is also an out-breeder with considerable variability both between and within cultivars, and responds quickly to selection pressure for a number of attributes, including salt tolerance, as demonstrated in mass selection studies by Malkin and Waisel (1985). Emerging opportunities also exist for selecting grasses specifically for rehabilitating mine-sites where high concentrations of NaCl or other compounds can make conditions difficult for plant growth (e.g. Naidu et al., 1997).

In many tropical regions, the fertility of cropping lands is deteriorating. In Australia, seed of summer-growing ley legumes such as *Lablab purpureus* and *Vigna unguiculata* is sold in comparatively large volumes for grazing and fertility restoration. Other species such as *Macroptilium bracteatum* are also being developed for this purpose (Brandon and Dalzell, 1996).

Another direction cultivar development is likely to take is in developing "break" crops for the control of pests such as nematodes. This provided the incentive for releasing *Chloris gayana* cv. Nemkat and *Digitaria milanjiana* cv. Jarra, both of which can also be used in longer-term perennial pastures.

Technology development

Three-quarters of respondents to our questionnaire sought advice from experts in their seed-production enterprises, and a similar number would appreciate more help. Many of the new species released for commercialisation require their own technology package to be developed if they are to be successfully commercialised. The need for such information on many of the newer species was emphasised at a specialist workshop during the Third International Herbage Seed Conference (Schultze-Kraft, 1995). Similarly, in our survey, almost half of the respondents believed that, for legumes particularly, more research should have been carried out before the species was released (Table 1).

The need to develop better technology, however, does not stop at commercial release of the crop; rather, it may be an on-going requirement throughout its commercial life. In responding to our questionnaire, issues which producers considered most important and which are also potentially amenable to improvement through development of technology or advice, are weed control (particularly in legumes), seed shattering (both grasses and legumes, but especially grasses), deciding the best time to harvest (grasses), and disease and insect control (legumes). In Table 5, we examine these issues a little more closely, and provide examples of species responses.

Environmental concerns

There is increasing concern in Australia and other developed countries over the tendency for many introduced pasture plants to become weeds, either on cultivated or grazing land, or in nature reserves and national parks. These concerns are likely to impinge on both the volume and nature of pasture seed traded in the future, particularly as some of the more successful pasture species have been strongly targeted as environmental weeds (Humphries et al., 1991; Lonsdale, 1994). Twining legumes, in particular, can become significant weeds in mesic areas and some tree legumes such as *Leucaena leucocephala* have also become weeds in many tropical countries. In the future, this is likely to result in greater attention being paid to species native to the particular region, and in research efforts being redirected towards a more limited number of commercial species, rather than making further introductions of new species. A further cause for concern is soil acidification under legume-based pastures, a phenomenon which has long been recognised in temperate Australia (Williams, 1980) but has only recently been shown to occur under tropical legume-based pastures (A. Noble, pers. comm.).

In the longer term, concerns over weediness are likely to extend to developing countries. However, in those developing countries with high population densities, opportunities for improved forages to become weeds are minimal, unless they interfere with cropping.

YIELD AND COST OF PRODUCTION

Price is dependent on the cost of producing the product, and also on demand. Clearly, cost of production is intimately and closely linked to yield . More than 40% of respondents considered that the high price of legume seed was a limitation to the seed industry; fewer considered high prices for grass seed to be a problem (Table 1).

Commercial yields of legume seed ranged from 40-1850 kg/ha, with highest yields from the large-seeded species *Arachis pintoi*, *Mucuna* sp. and *Cajanus cajan* (Table 2a). However, some large-seeded species (e.g. *Leucaena leucocephala*) or moderately large-seeded species (e.g. *Vigna parkeri*) had low seed yields, while the small-seeded, relatively "new" species *Desmanthus virgatus* and *Aeschynomene americana* had yields close to or exceeding 800 kg/ha. Commercial yields of grass seed were substantially lower, with 12 species having yields lower than 100 kg/ha (Table 2b). Highest yields were from some *Brachiaria* species, reflecting in part harvesting methods employed to recover mature detached seeds caught by the leaf layer (Australia) or by ground sweeping (Brazil) (Hopkinson et al., 1996). High yields reported for *B. ruziziensis* and *Panicum maximum* are associated with some values for hand-harvested seed, the normal practice in Thailand. Comparison across species is also influenced by the level of cleaning which might have been carried out: although less than 30% of respondents considered cleaning seed to acceptable levels to be a problem (Table 1), graziers are often more concerned with price than with the purity of the product.

Seed production needs to be carried out on appropriate soils and in appropriate climates. The diversity of production sites required can be illustrated by reference to Australia where tropical forage seeds are produced mainly in Queensland with much smaller amounts in northern New South Wales, the Northern Territory and the Ord River irrigation area of Western Australia (Loch 1995). The greatest volume of seed comes from *Cenchrus ciliaris* which is harvested almost entirely on an opportunist basis from pastures in sub-humid and semi-arid parts of central and southern Queensland, much of it either for use on-farm or for direct sale to other landholders. The greatest diversity of production is found on the Atherton Tablelands of north Queensland where specialist seed producers grow a range of tropical grasses and legumes (including *Brachiaria* spp., late-flowering *Bothriochloa* spp., *Lablab purpureus*, *Stylosanthes* spp. and *Aeschynomene americana*) under irrigation. *Chloris gayana* is grown from north Queensland through to northern NSW, with the main areas of production in central Queensland where Silk sorghum, *Setaria incrassata* and the shorter *Panicum maximum* cultivars are also prominent. Large quantities of *Panicum coloratum* are produced in southern Queensland and northern NSW for both on-farm use and for sale, while seed production of *Pennisetum clandestinum* revolves around two specialist growers with purpose-built machinery in northern NSW. *Axonopus affinis* and *Paspalum dilatatum* are produced largely by opportunist harvesting in coastal northern NSW; not infrequently, both species are harvested as a mixture from the same paddock and later separated during cleaning.

In Zimbabwe, forage seed production also tends to be opportunistic, farmers being more concerned with higher-value crops (J. Clatworthy, pers. comm.). In other countries, there has been a tendency to concentrate on species which seed freely, but may not be the best forages for animal production. In Thailand, 1,000 tonnes of *B. ruziziensis* seed were produced in 1993 (Satjipanon, 1995), amounting to 76% of the total forage seed production for the country. Although it is probably not the best species in terms of animal production, it has the merit of being a heavy and reliable seed producer. The more productive *B. brizantha* is a shy seeder in equatorial regions (Hopkinson et al., 1996), but preferable for animal production, as it is more productive in the dry season (Satjipanon et al., 1995).

Nutrition of tropical grass seed crops is generally well understood. Adequate levels of nitrogen are essential if a heavy seed crop is to be obtained (Humphreys and Riveros, 1986). For both grasses and legumes, 80% of respondents considered strong early growth to be essential (Table 1) and this is best achieved in grasses by N and adequate moisture, provided other nutrients are non-limiting. Ideally, there should be a high level of control through irrigation to maximise efficiency of utilisation. By comparison with the grasses, the nutritional requirements of legumes to promote maximum seed production have not been extensively investigated.

Weed control, particularly in legume seed crops, was a major concern to those who responded to our questionnaire (Table 1). This is one of the most important, and often neglected, steps towards successful seed production of new herbage species. In established perennial legume crops, the problem of maintaining a pure sward for seed production becomes progressively more difficult as soil N levels build up and encourage the growth of both grass and broadleaf weeds. In contrast, vigorous well-established perennial grasses usually compete strongly with annual weeds, especially where fertiliser nitrogen is applied. Annual grasses, however, present greater problems during establishment when the slower-growing perennial crop seedlings are more vulnerable to competition; and invasion by other perennial grasses (including sown species) can also occur at this stage.

The development of effective herbicide strategies is an on-going process for seed crops, both new and old. Demand for forage species changes, as also does availability of herbicides. Recommendations quickly become out of date if supporting research is neglected for a period, as has happened recently with many of the current species. Research with earlier legume releases up to the 1980s looked at only four of the current broadleaf herbicides and two grass herbicides; by comparison, 23 broadleaf and five grass herbicides (including many from new chemical groups) are being screened in current work (Loch and Harvey, 1997). In the case of tropical grasses, >10 selective grass herbicides are now being screened compared with the major focus on atrazine in earlier work.

Pollination is essential for seed to set. Grasses are wind-pollinated and large quantities of pollen are necessary to ensure a high percentage of seed set. To our knowledge, no studies have been carried out to determine to what extent poor pollen production limits seed set in tropical grasses. Most of the tropical pasture legumes are largely self-pollinated (Hacker and Hanson, in press), but a percentage of outcrossing occurs in many species, including some not yet studied in detail. To what extent is seed set limited by the absence of pollinators to "trip" the flowers? *Desmodium heterocarpon* var. *heterocarpon* sets pods freely, whereas flowers of the related var. *strigosum* need to be tripped (Hacker and Hanson, in press). In temperate regions, pollination management is an important adjunct to legume seed production, but without detailed work on individual tropical legume species, it is impossible to determine whether or not their seed production is being restricted by absence of pollinators.

In legume seed crops, pods may fail to set for a number of reasons; but whilst a failure to set pods is easily recognised, the reason is not always obvious. In Australia, poor seed production resulting from the low proportion of pods set has hampered commercialisation of the promising *Macroptilium psammodes*. In a preliminary tagging experiment, only 24% of buds produced a ripe pod, with losses occurring mainly before or during flowering (Loch and Schultze-Kraft 1995). While the relatively large and colourful flowers suggest a need for a pollinator, the loss of potential pods before and after flowering suggests that other factors are also involved.

Commercial seed yields in Tables 2a and 2b are annual yields. We did not ask respondents how many seed crops had been taken each year. The possibility of multiple seed crops adds a complexity to tropical forage seed production not evident in temperate regions. In the higher-latitude subtropics and monsoonal tropics there is a cooler and drier rest period, but many daylength-insensitive (or apparently daylength-insensitive) grasses such as *Setaria sphacelata* (e.g. Hacker, 1994), *Digitaria eriantha* (Ramirez and Hacker, 1994), *Brachiaria decumbens*, diploid *Chloris gayana*, shorter *Panicum maximum* cultivars and *Setaria incrassata* can produce two seed crops during the following wet season. Experimental studies often indicate the first is the heavier crop. The daylength-insensitive legume *Chamaecrista rotundifolia* cv. Wynn can be cropped twice in a growing season (R.M Jones, pers. comm.), as also can *Macroptilium atropurpureum* (Hopkinson, 1977); but in practice, growers tend to let fallen seed accumulate on the ground and in the litter, and to target it with a single harvest at the end of the growing season. Consequently, mid-season management to maximise a second crop has been little studied, but issues here within the control of the seed producer would be concerned primarily with level of defoliation, fertilisation and irrigation.

Several authors have discussed the concept of "potential seed yield" (e.g. Humphreys and Riveros, 1986; Hill and Loch, 1993). Any seed-harvesting process only recovers a proportion of the seed on the standing crop. As a concept, potential seed yield covers all the seed the stand is capable of producing over the season. This quantity will be reduced, to varying degrees, by abortion of flowers, pollination failure, immature seed and loss of seed through disease, predation, shedding or during the harvesting process.

The relative importance of these limitations varies from species to species. In most situations, seeds which are immature or already shed are responsible for the heaviest loss in production, as recognised by respondents to our questionnaire. Although losses in yield may be minimised through careful selection of harvest date, reduction in yield (in grasses) is still likely to exceed 50%. This figure will not be reduced unless a gene controlling spikelet abscission (in grasses) or preventing pod dehiscence (in legumes) can be incorporated into forage cultivars. No such genes have been identified in perennial tropical forages, although substantial differences between species are evident (e.g. *Lablab purpureus vs. Macroptilium purpureum*).

QUALITY

Seed cleaning and processing

Most of the equipment for harvesting and cleaning tropical herbage seed was developed for cereals or temperate herbage species. Only 25% of the respondents to our questionnaire, however, found cleaning to be a difficult procedure, and less than half believed graziers were prepared to pay for higher quality seed (Table 1). In Australia and throughout the tropics, farmers and other end users tend to buy the cheapest possible seed per kilogram without properly assessing its quality (Loch, 1995). As a result, the demand for high-quality herbage seed is insufficient to set prices at a level that would encourage producers to clean their seed to a higher standard of purity. On the other hand, our respondents generally considered that seed certification of grasses was useful in ensuring quality, though not for legumes. This probably reflects the greater numbers of cultivars for the more widely sown grasses (and hence the greater risk of admixture or substitution) than for the legumes.

Novel seed cleaning and processing methods are needed for some tropical herbage species. Past examples include the Walker cleaner for *Cenchrus ciliaris* and the Enever cleaner for *Stylosanthes humilis* (Linnett, 1977). Currently, the need for innovative equipment applies particularly to chaffy-seeded grasses from the Andropogoneae (e.g. *Andropogon, Bothriochloa, Dichanthium*) which are becoming more widely sown because of their ability to grow on low fertility soils and to stabilise and rehabilitate degraded land. Their inert appendages (awns, sterile spikelets, and surface hairs or bristles), however, can restrict the flow of seed during planting. Better processing methods for these grasses are now developing. With *Bothriochloa insculpta* and *B. pertusa*, for example, the scalped seeds are passed through a fan to dislodge inert appendages before using an air/screen cleaner to remove this material, leaving a more free-flowing product (N. Blanch, pers. comm.). Processing rates vary (generally 30-60 kg/hr), but are still relatively slow by commercial standards for more free-flowing seeds.

Another aspect of seed cleaning relates to weed contamination. In the past, serious weed species such as *Parthenium hysterophorus* and *Sporobolus pyramidalis* have entered Australia with imported seed, and there is a risk that these and other weed species could be dispersed with commercial seed. Cleaning to remove weed seeds, however, can be extremely difficult and expensive (mainly because of the amount of crop seed that must inevitably be sacrificed), particularly where the crop and weed seeds are similar. Moreover, the complete removal of weed seeds at the cleaning stage is virtually impossible - hence the importance of developing and applying effective field control measures beforehand.

Hardseededness and dormancy

Hardseededness (in legumes) and dormancy (in grasses) can be seen as both an advantage and a disadvantage. In pastures, the survival of hard or dormant seeds for several years in the soil contributes to persistence of the pasture through seedling renewal. However, high levels of dormancy or hardseededness in purchased seed can lead to less than optimal establishment unless these can be largely overcome before sowing.

In legumes, methods of reducing hardseededness and allowing water penetration can be broadly grouped into those causing the lens (or strophiole) to rupture and others simply causing physical damage to the testa (Hopkinson, 1993). Different techniques, however, suit different legume seeds (Loch and Harvey, 1992), requiring a separate evaluation of available methods for each new species.

Despite the fact that it can interfere with seed sales and establishment, there have been few detailed studies of post-harvest dormancy in tropical herbage grasses (e.g. Hacker and Ratcliff, 1989; Simpson, 1990). When marketed within a country, at least 4-5 months normally elapse between harvest and sowing, so that there is generally time for dormancy in most grasses to be largely overcome by natural aging. However, where seed is exported from the southern to the northern hemisphere, purchasers may wish to sow it immediately, in which case there is a need for better techniques of breaking dormancy. There is also a need for further work on post-harvest dormancy in a wider range of grasses, especially those showing strong and/or prolonged dormancy in freshly harvested seed, and to look at the effects of environment on dormancy levels which can vary from place to place and from year to year (Hacker and Ratcliff, 1989; Loch and Schultze-Kraft, 1995).

Packaging and storage

Packaging and storage are critical if seeds are to be maintained in good condition, particularly in tropical countries where hot humid conditions present a challenging environment. Storage requirements are more critical for grasses than for legumes, as indicated through our questionnaire where 35% of respondents considered loss of seed quality to be an issue with grasses compared with only 15% for legumes (which generally do not lose viability as rapidly).

Although the basic principles of seed storage are well established, they are still not widely appreciated or applied at the commercial level (Loch and Schultze-Kraft, 1995; Schultze-Kraft, 1995). Reducing mortality depends on keeping seed drier and/or cooler. In practice, the gains from keeping seed drier are greater than those from refrigeration, and keeping seed dry (and in a low-humidity environment) is normally sufficient for short- to medium-term storage. For producers, however, the storage problem is exacerbated by fluctuating demand because a good season for seed production may not be followed by high demand for the product. Many seed producers also are relatively small companies, and the provision for facilities to seal seed in air-tight packages after dry conditioning represents a considerable expense for them, though small by comparison with the actual loss of a crop in storage.

MARKETING

With tropical forages, market intelligence regarding the particular species and quantities of seed likely to be required is frequently poor (Schultze-Kraft, 1995). Most of these grasses and legumes are perennials and do not require regular sowing - hence markets may tend to become saturated as demand declines, sometimes drastically and without warning for producers. This, however, is not necessarily a universal problem: for example, tropical grass seed production in Australia continues to be dominated by the strongly perennial *Cenchrus ciliaris,* though now at perhaps less than 25% of its annual production during the 1960s and early 1970s when the main development of brigalow scrubs took place.

In Australia and other UPOV (International Union for the Protection of New Varieties of Plants) countries, Plant Breeders Rights have been introduced to promote development of plant cultivars, including forages (Rothwell, 1996). The number of responses to our statement on PBR (Statement 26 - Table 1) was limited; but two-thirds of these considered it to be beneficial, providing an incentive to market and promote registered cultivars. This outcome, however, is by no means certain (Loch, 1995). On the positive side, PBR has raised industry awareness of cultivars and the concurrent need to protect their genetic integrity. It has also encouraged the private sector to invest in the introduction of new cultivars from overseas, in the breeding of new cultivars in Australia (though this is generally done indirectly through supporting public breeding programmes), and in the promotion of their proprietary cultivars. The result is that 18 tropical forage cultivars and five tropical turf cultivars have now been registered under PBR in Australia during the first ten years of operation. From the growers' point of view, they at last have contracts guaranteeing payment for seed on delivery, instead of having to wait for some months or possibly a year or more after harvest to sell their seed. On the negative side, prices paid to seed growers might be depressed if licensees of proprietary cultivars (usually seed merchants) use their economic position to drive hard bargains. PBR could also lead to a proliferation of new cultivars with "marketable" rather than agronomic differences. In turn, cultivars could become superseded more rapidly, leaving growers of perennial species faced with ground contaminated with seed of outmoded cultivars. Proprietary marketing will not necessarily be directed towards ensuring use of the best cultivar in each situation, and may also lead to lower sales of public cultivars with good agronomic characteristics.

At present, tropical forage seeds are largely marketed within their country of origin; only limited quantities are exported . The biggest producer is Brazil with around 100,000 tonnes per annum of predominantly grass seed (mainly *Brachiaria* spp. and *Panicum maximum*). Almost all of this is utilised internally, much of it for rotational use - hence the magnitude of the Brazilian market.

Australia exported considerable quantities of tropical forage seed in the 1970s, especially to Brazil, but this trade declined as customers developed their own local seed industries. The development of a more sophisticated international trade in tropical seeds would be beneficial to all, as it would help to stabilise markets and could source seed of some species more economically than growing it in-country. The latter would be particularly beneficial in equatorial regions where the climate is inherently unsuited to seed production of many forage species and past attempts to grow seed of species such as *Desmodium intortum* in such environments frequently owe more to national politics than to reason. Similarly, in Thailand, the preference for producing their own seed rather than importing it has led to the widespread use of *Brachiaria ruziziensis* in pastures rather than the preferred *B. decumbens* which is a superior forage but has proven much more difficult to grow for seed (A. Topark-Ngarm, pers. com.).

RESEARCH

A specialist workshop during the Third International Herbage Seed Conference drew attention to the small number of researchers working on the seed production of tropical herbage species and to the fact that research in this area is declining as existing programmes are cut or reduced by various institutions around the world (Schultze-Kraft, 1995). So is research currently being carried out appropriate to answer the problems faced by seed producers? To answer this question, we surveyed papers on seed production in *Herbage Abstracts* and its sequel, *Grassland and Forage Abstracts*, for the period 1988 to March 1996 inclusive (Table 6). A total of 106 papers was identified, although some were too general to allow allocation to species. Where a paper considered several species, these were classed as equal fractions in considering research effort devoted to a species. Some species were omitted from the analysis as they were not included in Table 2. The more significant of these (with number of publications) were, for the legumes, *Centrosema brasilianum* (1.3), *C. pascuorum* (0.7), *C. pubescens* (3.8), *Indigofera hirsuta* (1), *Macroptilium lathyroides* (1); and for the grasses, *Cynodon dactylon* (1), *Dichanthium annulatum* (1), *Eragrostis curvula* (1), *Eremochloa ophiuroides* (1), *Hyparrhenia rufa* (1) and *Panicum virgatum* (1).

The research effort was distributed across 30 of the species which our respondents had grown over the three-year period covered by our questionnaire (Table 7). The largest number of papers was from Central America, including the Caribbean - these were largely by Cuban authors. At the other extreme, there was little published work on seed production from Africa. Only three legume and five grass species had three or more publications abstracted. With the exception of *Arachis pintoi*, all of these are species which have been on the market for many years. Very few publications covered seed production aspects of more recently released species, such as *Aeschynomene americana* and *Chamaecrista rotundifolia* (released in 1984 and 1983 respectively). Even for the important species *Stylosanthes scabra* - the most widely sown forage legume in the Australian tropics - there were very few recent publications. From this, it would appear that growers of new species have little in the way of technical back-up support, as evidenced by published papers. Considering the topics of published research, studies on grasses outnumber those on legumes by 2:1 (Table 7). Most of the work on grasses has been in the areas of nutrition, management (burning/cutting/grazing) and timing of harvest. We pointed out earlier in this paper that nutritional effects to maximise seed yields of grasses are well understood, so emphasis on this area is perhaps unwarranted. By comparison, the small amount of research directed towards weed control is a concern, particularly as producers in our questionnaire had considered more effective weed control to be a priority. However, the 13 papers on harvest timing indicate a common area of concern between producers and researchers.

There is, however, another source of information not covered by way of formal publications. In Australia, crop summaries have been produced on many new crops at the time of release as a guide to commercial seed producers; these can then be updated progressively in the light of subsequent commercial experience and research (Loch, 1993). A published example of this approach for *Chamaecrista rotundifolia* was given by Loch (1985), and seed production recipes in the form of brief notes (based on a number of these crop summaries) have recently been published by Partridge (1996). Much of this information is derived by experienced specialists from having grown each new crop rather than from formal experimentation, and as such is not readily amenable to formal research publication - hence the direct reliance on expert advice by many of the commercial seed producers who replied to our questionnaire (Table 1).

CONCLUSIONS

The strongest responses to our questionnaire related to variable seed production between years, weed control, timing of harvest and necessity to get strong early growth. In many ways, this parallels experience by Rowarth and Rolston (1995) with seed production of new species in temperate regions: again, deciding when to harvest and how to control weeds were major difficulties encountered by farmers. For some major species which have been cultivated for many years, experienced seed producers have developed expertise to address many of these early problems. However, with so many species and few economies of scale, the opportunities for developing such expertise are greatly reduced. Moreover, the high proportion of seed growers who sought help from experts - and would appreciate more advice - indicates a need for more information, and a continuing role for research to service this need.

REFERENCES

Alderson, J. and W.C. Sharp. (Eds.) 1995. Grass varieties of the United States. CRC Press, Boca Raton, USA. 296 pp.

Bogdan, A.V. 1977. Tropical pasture and fodder plants. Tropical Agriculture Series, Longman, London, U.K. 475 pp.

Brandon, N.J. and S.A. Dalzell. 1996. *Macroptilium bracteatum*: a promising legume for leys. *Proc. 8th Aust. Agron. Conf.,* p. 625.

Hacker, J.B. 1994. Seed production and its components in bred populations and cultivars of winter-green *Setaria sphacelata* at two levels of applied nitrogen fertiliser. *Aust. J. Exp. Agric.* **34:** 153-160.

Hacker, J.B. and J. Hanson. In press. Crop growth and development: reproduction. *In:* Loch, D.S. and Ferguson, J.E., eds. Forage seed production. Vol. 2. Tropical and subtropical species. CAB International, Wallingford, U.K.

Hacker, J.B. and D. Ratcliff. 1989. Seed dormancy and factors controlling dormancy breakdown in buffel grass accessions from contrasting provenances. *J. Appl. Ecol.* **26**: 201-212.

Hill, M.J. and D.S. Loch. 1993. Achieving potential herbage seed yields in tropical regions. *Proc. XVII Int.Grassl. Congr.,* pp. 1627-1635.

Hopkinson, J.M. 1977. Siratro seed production. *Trop. Grassl.* **11**: 33-39.

Hopkinson, J.M. 1993. The strophiole of leguminous seeds. *Int. Herb. Seed Prod. Res. Group Newsl.* **18**: 7-8.

Hopkinson, J.M., F.H.D. de Souza, S. Diulgheroff, A. Ortiz and M. Sanchez. 1996. Reproductive physiology, seed production and seed quality of *Brachiaria. In:* J.W. Miles, B.L. Maass, C.B. do Valle, eds. *Brachiaria*: biology, agronomy and improvement. CIAT and EMBRAPA/CNPGC, Cali, Colombia, pp. 124-140.

Humphreys, L.R. and F. Riveros. 1986. Tropical pasture seed production, 3rd edition. *FAO Plant Prod. Prot. Pap. 8,* 203 pp.

Humphries, S.E., R.H. Groves and D.S. Mitchell. 1991. Plant invasions of Australian ecosystems: a status review and management directions. *Kowari* **2**: 1-127.

Linnett, B. 1977. Processing seeds of tropical pasture plants. *Seed Sci. Technol.* **5**: 199-224.

Loch, D.S. 1985. Commercial seed increase of new pasture cultivars: organization and practice. Pp. 392-424. *In:* Pasture improvement research in Eastern and Southern Africa, Proceedings of a workshop held in Harare, Zimbabwe, 17-21 September 1984, IDRC, Ottawa, Canada.

Loch, D.S. 1993. Seed production of new herbage species - needs and solutions. *Suppl. J. Appl. Seed Prod.* **11**: 13-23.

Loch, D.S. 1995. Australia: a comprehensive survey of the seed sector. *Asia Pac. Seed Assoc. Spec. Country Rep.* No. 6.

Loch, D.S. and G.L. Harvey. 1992. Comparison of methods for reducing hard seed levels in three subtropical legumes. *4th Aust. Seeds Res. Conf., Rev. & Contrib. Pap.,* pp. 243-246.

Loch, D.S. and G.L. Harvey. 1997. Developing herbicide strategies for herbage seed crops. *Proc. 1st Aust. New Crops Conf.*, University of Queensland Gatton College, 8-11 July 1996. Rural Industries Research & Development Corporation, Canberra, Australia, pp. 273-282.

Loch, D.S., P.J. Johnston, T.A. Jensen and G.L. Harvey. 1996. Harvesting, processing, and marketing Australian native grass seeds. *N.Z. J. Agric. Res.* **39**: 591-599.

Loch, D.S. and R. Schultze-Kraft. 1995. Problems of seed production and germplasm preservation in tropical forage plants. *Proc. 3rd Int. Herb. Seed Conf.,* Halle (Saale), Germany, pp. 96-105.

Lonsdale, W.M. 1994. Inviting trouble: introduced pasture species in northern Australia. *Aust. J. Ecol*. **19**: 345-354.

Malkin, E. and Y. Waisel. 1985. Mass selection for salt resistance in Rhodes grass (*Chloris gayana*). *Physiol. Plant.* **66**: 443-446.

Naidu, B.P., M.R. Harwood, J.B. Hacker and B.R. Thumma. 1997. Pasture species selection for revegetation of open-cut coal mine areas in Central Queensland, Australia. *Int. J. Surf. Mining Environ.* **11:** 21-25.

Oram, R.N. (ed.) 1990. Register of Australian herbage plant cultivars, 3rd Edition. CSIRO, East Melbourne, Australia. 304 pp.

Partridge, I.J. (ed.) 1996. Tropical pasture seed production - a training manual. Queensland Department of Primary Industries QE96004, Brisbane, Australia.

Ramirez, L. and J.B. Hacker. 1994. Effect of nitrogen supply and time of harvest on seed yield components of *Digitaria eriantha* cv. Premier. *J. Appl. Seed Prod.* **12**: 66-76.

Rothwell, P. 1996. Pastures for prosperity - seeds forum. 1. Proprietary lines and Plant Breeders' Rights. *Trop. Grassl.* **30**: 74-76.

Rowarth, J.S. and M.P. Rolston. 1995. A philosophy for new species. *Int. Herb. Seed Prod. Res. Group Newsl.* **22**: 4-6.

Satjipanon, C. 1995. Pasture seed production in Thailand. *In:* Enhancing susrtainable livestock-crop production in smallholder farming systems. *Proc. 4th Meet. Forage Regional Working Group on Grazing and Feed Resources of Southeast Asia,* pp.73-81.

Satjipanon, C., W. Chinosang, W. Susaena, N. Gobius and S. Sivichai. 1995. Forage seed production in Thailand: activities, results and conclusions. *Proc. 3rd Meet. Southeast Asian Regional Forage Seeds Project,* Samarinda, Indonesia, pp.45-58.

Schultze-Kraft, R. 1995. Report on Workshop III: problems of seed production and germplasm preservation of tropical forage plants. *Proc. 3rd Int. Herb. Seed Conf.,* Halle (Saale), Germany, pp. 469-470.

Simpson, G.M. 1990. Seed dormancy in grasses. Cambridge University Press, U.K. 297 pp.

Skerman, P.J. and F. Riveros. 1990. Tropical grasses. *FAO Plant Prod. Prot. Ser. 23,* 832 pp.

Williams, C.H. 1980. Soil acidification under clover pasture. *Aust. J. Exp. Agric. Anim. Husb.* **20**: 561-567.

Table 1
Perceived problems in seed production of tropical herbage grasses and legumes, expressed as the % of respondents providing data.

		Legumes		Grasses	
		Agree	Disagree	Agree	Disagree
Management					
1.	Seed production much higher in year of sowing	47	45	56	34
2.	Seed production varies greatly between years	72	18	82	14
3.	Burning essential to obtain a good crop	8	57	19	59
4.	Weed control is a significant cost	77	18	41	58
5.	More effective weed control methods are necessary	70	23	30	58
6.	Strong early growth essential to get a good seed crop	83	10	79	9
7.	Seed production improved by a dry period late in growth	46	35	36	29
8.	Shattering or shedding dramatically reduces seed yield	68	17	85	10
9.	Deciding the best time to harvest is difficult	40	42	78	16
10.	A few days error in deciding when to harvest can be critical	48	32	83	13
11.	Large quantities of non-seed material make harvesting difficult	58	20	43	32
12.	Seed is easily damaged by threshing	26	49	23	58
13.	Plant diseases sometimes cause serious losses in seed yield	55	28	15	62
14.	Insects sometimes cause serious losses in seed yield	57	25	38	44
15.	Advice from experts is obtained to maximise yield	71	12	73	10
16.	More advice from experts would be appreciated	76	12	75	12
17.	More research on seed production should have been carried out before release of this variety	46	26	36	37
Marketing					
18.	High cost of seed to grazier a limitation to seed industry	44	40	26	57
19.	Seed quality may be lost rapidly	15	65	35	50
20.	Graziers prepared to pay more for quality seed	40	37	41	35
21.	Difficult to clean seed to acceptable levels	23	66	27	63
22.	Market is limited as the variety is adapted to a small geographic area	42	40	26	58
23.	Variability in demand makes it difficult to operate efficiently	70	19	63	18
24.	Seed certification ensures the user purchases a quality product	38	12	64	20
25.	Seed certification would benefit seeds producer and purchaser	57	23	60	24
26.	Plant Breeders Rights is of benefit for this variety (PBR varieties only)	69	0	67	14

Table 2a
Commercial seed production of herbage grasses over the past three seasons (excluding Japanese data).

Species	Sites x years (nos.)	Seed yield (kg/ha) mean	Seed yield (kg/ha) maximum
Brachiaria spp. (unspecified)	3	1100	1200
B. ruziziensis	9	588	630[a]
Paspalum atratum	3	515	720
Brachiaria decumbens	12	477	1320
Andropogon gayanus	8	356	1000
Bothriochloa pertusa	10	235	890
Panicum maximum	38	192	550[a]
Brachiaria dictyoneura	6	166	240
Chloris gayana	42	119	240
Urochloa mosambicensis	5	101	200
Bothriochloa insculpta	6	98	170
Setaria sphacelata	17	91	220
Panicum coloratum	13	76	220
Hymenachne amplexicaulis	2	75	80
Brachiaria brizantha	3	73	100
B. humidicola	8	60	100
Melinis minutiflora	3	50	50
Paspalum spp.	3	48	110
Digitaria milanjiana	3	47	60
Setaria incrassata	5	45	70
Cenchrus ciliaris	2	42	44
Digitaria eriantha	2	30	30

[a] Thailand - presumably hand-harvested

Table 2b
Commercial seed production of herbage legumes over the past three seasons.

Species	Sites x years (nos.)	Seed yield (kg/ha) Mean	Seed yield (kg/ha) Maximum
Arachis pintoi	7	1850	3170
Mucuna sp.	3	1833	2000
Cajanus cajan	6	1085	2400
Lablab purpureus	8	1009	2500
Vigna unguiculata	1	1000	1000
Desmanthus virgatus	7	893	1530
Calapogonium mucunoides	6	810	1200
Aeschynomene americana	3	797	1170
Macroptilium atropurpureum	3	747	930
Stylosanthes hamata	10	689	940
Neonotonia wightii	6	633	1000
Macrotyloma axillare	3	370	400
Stylosanthes macrocephala	1	350	350
Pueraria phaseoloides	3	317	400
Stylosanthes guianensis	7	249	600
Desmodium ovalifolium	3	240	260
Leucaena leucocephala	8	203	300
Stylosanthes scabra	21	189	500
Stylosanthes capitata	1	150	150
Lotononis bainesii	3	77	90
Chamaecrista rotundifolia	7	64	130
Vigna parkeri	3	40	100

Table 3
Cultivars of some of the more widely sown tropical forage species, with dates of formal or informal release for commercial use in Australia. These are grouped into cultivars that are widely sown, cultivars not widely sown (including those no longer available commercially), and cultivars recently released.[a]

Species	Widely sown	Not widely sown	Recently released
Legumes			
Chamaecrista rotundifolia 1983	Wynn		
Leucaena leucocephala 1962	Cunningham, Peru	El Salvador	Tarramba
Stylosanthes. guianensis 1930s	Pucalpa (=CIAT184)	Cook, Endeavour, Graham, Oxley, Schofield	Bandeirante, Mineirao
S. hamata 1973	Amiga, Verano		
S. scabra 1976	Seca	Fitzroy	Siran
Grasses			
Brachiaria brizantha	Marandú		La Libertad
Brachiaria decumbens 1973	Basilisk		
Cenchrus ciliaris 1870-80s	American, Biloela, Gayndah	B-1S, Blue (Blao), Boorara, Chipinga, Edwards Tall, Lawes, Higgins, Kongwa 531, Llano, Manzimnyarna, Mbalambala, Molopo, Nueces, Nunbank, Pusa Giant, Sebungwe, Tarewinnabar, West Australian, Zeerust	Bella, Viva.
Chloris gayana 1901?	Boma, Callide, Elmba, Katambora, Pioneer	Bell, Giant, Hatsunatsu, Karpedo, Kongwa, Masaba, Mbarara, Mpwapwa, Nzoia, Pokot, Rongai, Samford	Finecut, Nemkat, Topcut
Panicum maximum 1900s	Colonião, Common (Comun) Guinea, Gatton, Likoni, Makueni, Petrie, Riversdale, Tanzânia-1	Aruana, Boringuen, Broadleaf, Centauro, Centanário, Coarse Guinea, Embu, Gramalote, Guiné, Guinezinho, Hamil, King Ranch, Nchisi, Sabi, Sempre-verde, Silky guinea, St Mary's Cowgrass, Sigor, TD-58, Tobiatã, Vencedor	Mombaça, Natsukaze, Natsuyutaka

[a] Data from Bogdan (1977); Oram (1990); Skerman and Riveros (1990); Alderson and Sharp (1995); J.E. Ferguson, A Kruger, F.H.D. de Souza and J.C. Tothill (pers. comm., 1996).

Table 4
Numbers of herbage species and cultivars commercially released in Australia.

	Grasses		Legumes		Total	
	Pre-1960	Current[a] (1996)	Pre-1960	Current[a] (1996)	Pre-1960	Current[a] (1996)
No. of species	17	38	6	36	23	74
No. of cultivars	26	87	6	62	32	149
No. of single-cultivar species	13	22	6	21	19	43
Maximum no. of cultivars from a single species	6	11	1	5	6	11

[a] including those no longer available

Table 5
Some key seed production issues for tropical forages (for statement numbers and producer responses, see Table 1).

Statement	Problem	Issue	Solutions or requirements
6	Establishment	Germination	Develop commercial-scale dormancy breaking methodology (*e.g. Brachiaria* spp. ., *Dichanthium aristatum*)
		Weed control	Develop species-based herbicide recommendations (*e.g. Stylosanthes* sp. aff. *S. scabra* differs from *S. scabra* in herbicide sensitivity)
8	Shattering/ shedding	Pod shattering in legumes	Vacuum harvester developed for retrieving seed from ground
9	Deciding best time to harvest	Inducing flowering/ seed set	Some legumes (*e.g. Macroptilium atropurpureum*) require a dry spell to promote flowering
		Deciding when to harvest	Indicators of optimum harvest time necessary, particularly with the grasses
11	Non-seed material harvested	Presentation of seed/pods	Overcome difficulties in crop synchronisation and seed harvesting that have severely limited commercialisation of *Aeschynomene falcata* and *Desmodium heterophyllum*
		Seed burial (*Arachis pintoi*)	Technology for harvesting buried seeds developed
		Chaffy-seeded grasses	New seed processing technology developed

Table 6
Number of abstracted publications on tropical forage seed production, 1988-March 1996. Where a single publication covers two or more species, each species is allocated a decimal, total for all species equalling 1.0 (Source: *Herbage Abstracts; Grassland and Forage Abstracts*).

Species	Total	Aust.	Asia	Africa	America		
					Cent.	South	North
Legumes							
Aeschynomene americana	1						1
Arachis pintoi	3	1				1	1
Cajanus cajan	0.5				0.2	0.3	
Chamaecrista rotundifolia	0.7			0.7			
Desmodium ovalifolium	0.3					0.3	
Lablab purpureus	3.5				3.2	0.3	
Leucaena leucocephala	0.8	0.2			0.6		
Macroptilium atropurpureum	2.9	1		1.5	0.4		
Neonotonia wightii	0.4				0.4		
Pueraria phaseoloides	0.2				0.2		
Stylosanthes capitata	1.3			0.3		1	
S. guianensis	2.3		1.3		1		
S. hamata	3.6	1	1.6	1			
S. macrocephala	1					1	
S. scabra	0.3		0.3				
Grasses							
Andropogon gayanus	3.1	0.3		1	0.2	1.6	
Bothriochloa insculpta	0.3	0.3					
B. pertusa	0.3	0.3					
Brachiaria brizantha	1				1		
B. decumbens	8.8	1.3			3.2	4.3	
B. dictyoneura	1					1	
B. ruziziensis	1.3		1.3				
Cenchrus ciliaris	9		6		1.7	1.3	
Chloris gayana	1.5	1.3			0.2		
Digitaria eriantha	1	1					
Melinis minutiflora	2					2	
Panicum coloratum	1						1
P. maximum	14	1.3	4		8.7		
Paspalum spp.	2					1	1
Setaria sphacelata	5.3	2.3	2			1	
Total	73.4	11.3	16.5	4.5	21.0	16.1	4.0

Table 7
Published research on tropical forage seed production, 1988-March 1996, listed according to topic. Total of 106 publications; 8 with multiple topics allocated whole unit value to each topic.

Topic	Legumes	Grasses and legumes	Grasses
Nutrition	4		15
Consistency year to year			
Climate/daylength	1	1	4
Weed control	2		
Burning/cutting/grazing	4		13
Seed yield components/pollination/seed set	2		3
Shattering/shedding			1
Timing of harvest	1		13
Diseases/pests			
Harvesting	2		2
Cultivar/species differences in seed yield	2		4
Cleaning/processing/drying/storage	1		4
General; Reviews etc.	6	13	2
Other	9		7