TROPICAL PASTURE SEED PRODUCTION: PRACTICE, EXPERIENCES AND PERSPECTIVES

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ABSTRACT
The characteristics of the pasture exploitation systems and of the pasture species allied to economical and social conditions existing in the tropical world have generated a diversity of pasture seed supply systems. Compared to grain seed systems, tropical pasture seed production systems are less regulated by government, and the relationship among participants can be very informal. Research in tropical seed production is a relatively new activity but it has generated enough technology to support seed production of the main tropical pasture species. Adoption of this technology, however, may be restrained by deficient extension and communication services or by low adequacy of the technology to the different seed production systems existing in each country. A successful tropical seed industry only prospers in specific and delimited regions with suitable climatic conditions. Some countries, may not have these regions and selection of pasture germplasm able to produce seed under the prevailing conditions may be a feasible alternative to support pasture development activities. Harvest timing has received great priority from research, mainly in Latin America. The choice of an adequate harvesting method and improving harvesting efficiency to reduce losses, so that a greater share of the total yield can be collected, is the most direct way to improve seed yields in tropical pasture species. Although the tropical pasture seed market is expanding, at least in Latin America, research funding is diminishing and researchers will have to use all their creativity to find alternative ways to finance tropical pasture seed research.

KEYWORDS
Seed production, germplasm adaptation, harvest, *Brachiaria*, *Stylosanthes*

INTRODUCTION

Tropical and subtropical pasture species are highly variable in regard to morphological types, seed positioning, and response to flowering control mechanisms. They vary from tall grasses such as *Andropogon gayanus* and some *Panicum maximum* cultivars to short stoloniferous species such as *Brachiaria humidicola* or *Pennisetum clandestinum*. Considering the pasture legumes, variability in morphological types is even greater. There are prostrate legumes such as *Chamaechrista rotundifolia*, *Desmodium ovalifolium*, shrub or tree species such as *Leucaena leucocephala* and climbing legumes such as *Calopogonium mucunoides*, *Pueraria phaseoloides* or *Neonotonia wightii*. Variation also exists in relation to seed positioning. Seeds can be exposed above the vegetation (e.g. *Desmodium intortum* and *D. uncinatum*), inside a green vegetative mat (e.g. *Stylosanthes guianensis*) or underground, as in *Arachis pintoi*.

Associated to this variability, tropical pasture species present a short history of domestication and most species retain wild characters. These characters, while benefiting their survival under natural conditions or in pastures, are troublesome for the management and harvesting of seed production areas.

Inventiveness was one of the main requirements for the tropical pasture seed industry and research to cope with the above problems and also, to develop adequate seed production systems for the diverse climatic, economical, and social conditions existing in the tropical world.

SEED PRODUCTION SYSTEMS AND MARKET VOLUMES

Initially, cattle production in the tropical world was based on native or naturalized pastures. There was little use of pasture seeds and pasture establishment was made through the use of plant cuttings. Australia was the first country in the world to have an organized tropical pasture seed industry, mainly as a response to seed demand created by the "tropical pasture revolution" that took place during the sixties and beginning of seventies. As a pioneer, Australia had a strong influence on subsequent pasture development programs which took place in other tropical countries around the world. A common feature of these programs was an initial strong dependence on Australian cultivars and on seed importation from that country. After this importation phase, many countries developed a national tropical pasture seed industry to supply their internal market. Nowadays, other countries besides Australia have important participation on the international tropical pasture seed market.

The characteristics of the pasture exploitation systems and of the pasture species allied to economical and social conditions existing in the tropical world have generated a diversity of pasture seed supply systems, which can vary, depending on species and production region, from specialist to non-specialist or opportunistic systems. Within this range, the main use of an area can be used to define the degree of specialization. The system is considered specialist if the main objective of an area is seed production and grazing or cutting is used as a management tool to favor seed production. Systems that rely on opportunistic harvesting in pasture or in cover crop areas are considered non-specialist or opportunistic systems. In these systems, the degree of mechanization is not a function of specialization. There are specialist systems based on manual sweeping e.g. *Brachiaria decumbens* or *Brachiaria brizantha* specialist seed production systems in Brazil. There are also opportunistic systems in which harvesting is fully mechanized (e.g. *Cenchrus ciliaris* seed production in Australia). In these systems, the decision upon mechanized or manual harvesting is dependent on availability and relative costs of labor and machinery. Ferguson (1978) and Turton and Baumann (1996) described forage seed supply systems existing in Latin America and India, respectively, and identified measures to be taken to increase pasture seed availability and quality.

From the mid seventies the tropical pasture seed industry expanded and nowadays large seed volumes are traded yearly (Table 1).

In Brazil, where the largest seed volumes are commercialized, grasses dominate the market, with *B. brizantha* cv. Marandu and *B. decumbens* accounting for approximately 80 % of the total market (Cardoso, 1994). Large amounts of *Brachiaria ruziziensis* are in the market in Asia. *Stylosanthes scabra* and *Stylosanthes hamata* are the main pasture legumes in the market, mainly in Australia and Thailand.

Participants of the Tropical Seed Production Systems. Compared to grain seed systems, tropical pasture seed production systems are less regulated by government, and the relationship among participants can be very informal. The knowledge about the various participants and their relationship is a prerequisite to interfere and improve the prevailing seed production systems. Figure 1 shows the various participants in the tropical pasture seed industry and their interrelationships. The participation and relative importance of each participant depend on the degree of development of the particular seed production system. In more developed systems, seed firms and specialist seed growers are the main participants. For less developed pasture seed production systems, the middleman, the opportunistic harvester and the government play the most important roles.

Tropical pastures seed firms are highly variable in size. They can be large companies, selling seeds to national and international markets, or be small, supplying seeds to a restricted regional market. Seed procurement of these seed firms is diversified. They can produce their own seed, have contracted growers, buy seeds from opportunistic harvesters or from other seed firms.

Specialist seed growers can produce seed on owned land or on rented land. Generally, specialist seed growers are located in regions where the climate is suitable for seed production. They normally produce seed under contract with a seed firm or sell seeds directly to the farmers. Also, in view of scarcity of specialized machinery, tropical seed growers are highly inventive in adapting or developing seed harvesting and cleaning machinery.

The middleman is very common during initial stages of a pasture development program. Basically, a middleman buys small amounts of seed from a number of opportunistic harvesters or seed producers in a village. When he is able to gather a seed lot of reasonable size he sells it to another middleman, normally located in larger towns. This middleman, in turn buy seeds from a number of other smaller middleman and can sell seeds to farmers, to other middleman or to a seed firm. The succession of middlemen in the chain is variable. Everyone in the chain earns money in the process and, generally, the seed grower receives the smallest share of the final seed price. Dishonesty is common in the chain and it is not unusual for seed lots to increase in weight just with the addition of soil, sand, or straw. The middlemen chain, however, is an effective marketing channel during the initial phases of a pasture development program and for some species.

The participation of the opportunistic harvester depends mainly on the perspective of good seed prices. They can be a road-side seed harvesters or a crop grower, who use their spare combine harvesters to harvest seed in pasture areas. Harvesting is characteristically opportunistic in some species such as: buffel grass (*Cenchrus ciliaris*), some Rhodes grass (*Chloris gayana*) cultivars, in Australia, and andropogon grass (*Andropogon gayanus*), in Brazil. In some developing countries, government is the main customer in the market; it buys seeds to provide for pastures or reclamation activities as described by Turton and Baumann (1996). Experiences in Africa, however, has showed that the public sector is not an efficient pasture seed provider for smallholders (Griffiths, 1993). The government, or official sector, also has the duties of establishing and enforcing seed standards in the market, producing basic seed, defining release procedures and supporting research.

The farmer, or seed user, wants a cheap and good quality seed. However, he is not fully aware of the pasture seed quality parameters, and normally, buys the cheapest seed in the market making his decision on a price per kilo basis. This behavior opens opportunities for dishonesty from firms and middlemen, which makes the enforcement of minimum seed quality standards in the market a difficult task.

RESEARCH IN TROPICAL PASTURE SEED PRODUCTION

Research in tropical seed production is a relatively new activity (Loch, 1991). The first efforts on tropical pastures seed production research happened in Africa, in a research program carried out in Kenya from the 1950's to the 1970's. This program was discontinued until the beginning of the 1990's when interest in pasture seed production was renewed, mainly to supply small holders needs.

Australia has the most effective research program in tropical pasture seed technology. This program, which started at the end of the 1960's, is accomplished by the Queensland Department of Primary Industries (QDPI) and University of Queensland. QDPI has two research groups working with applied seed production research. These groups are strategically located inside the main seed production regions so that appraisal of research demands and transfer of technology are very efficient processes. The University of Queensland works with basic aspects of seed production and has made important contributions to the understanding of flowering control mechanisms in tropical pasture species. Another important contribution from this University is the pos-graduate training of overseas students. During the !970s, University of Queensland, in a cooperative program with the Khon Kaen University, had important influence for the establishment of tropical pasture seed production research and development in South-East Asia. In this region, research has been oriented to the development of production systems for smallholder farmers.

In Latin America there has been concern about problems related to the pasture seed production activity since the early 1970s. This concern, however, has not been translated in a expressive volume of research. Research concentrates in agronomic adaptive aspects of seed production and on seed quality. During the 1980s, the Tropical Pasture Program of the Centro International de Agricultura Tropical (CIAT) gave a great impulse to tropical pasture seed production in Latin America. This program, which is now discontinued, assisted, complemented and trained researchers from the national research organizations in all aspects of tropical pasture seed production.

In a broad way, research in tropical pasture seed production has attempted to solve the basic questions: Where and how to grow a seed crop and when and how to harvest it ?

Where to grow a seed crop? A successful tropical seed industry only prospers in specific and delimited regions where climatic conditions are consistently conducive to high seed yields. Ison and Hopkinson (1985) reviewed the flowering control mechanisms of tropical grasses and legumes. These are, in general, the photoperiod, temperature, and, mainly for legumes, a component of stress (normally moisture stress).

Climate in a suitable region is conducive to a strong vegetative growth, profuse flowering, successful seed setting, and efficient harvesting. Many times, a region with these characteristics is located away from the region where a genotype shows good performance as a pasture. The characteristics and the identification of regions suitable for seed production of tropical pasture species were discussed by Hopkinson and Reid (1978), Loch (1980), Andrade et al. (1981), Ferguson et al. (1981), Humphreys and Riveros (1985).

Whether or not a country has suitable regions for seed production is an important point in defining how to supply the internal pasture seed demand. In countries with suitable regions, further fine tuning is required regarding selecting adequate microregions for seed production of specific pasture species or cultivar involve watching ongoing seed grower's experiences or, as postulated by Andrade et al. (1981), running of regional trials. These authors have shown that, within suitable regions, agronomical factors, such as presence of endemic diseases, may define the final adequacy of a region for seed production.

For countries that do not have regions with adequate climate for seed production, a situation commonly found in countries located in the Equatorial zone, four strategies can be used: 1. Import seeds; 2. Select pasture genotypes with ability to produce seed under the prevailing climate conditions; 3. Identify microregions where specific interactions among flowering mechanisms favor seed production (Hopkinson, 1986) and; 4. Use of agronomic management tools to favor seed production.

Most of the time the first option is not applicable because it creates a situation of dependency and government generally impose restrictions on importation due to sanitary or financial problems.

Many countries have adopted the second option and experiences have shown that it is a viable option. Selection or release of *A. pintoi* BRA 013151 or CIAT 17434 in many low latitude countries exemplifies the success of this approach (Argel, 1994). This genotype presents good forage attributes, and because of a neutral response to photoperiod, is able to produce high seed yields in a range of latitudes and altitudes as shown in table 2.

The third strategy, identifying microregions where interactions among flowering control mechanisms favor seed production, may be the only option when the demand for a outstanding pasture cultivar can only be supplied by way of internal seed production. Seed production of short day *S. guianensis* cultivars at high altitude sites in a Equatorial zone (Ison and Humphreys, 1983) is a successful example of this approach. Flowering control mechanisms, and their interactions, were not deeply studied by research in tropical pasture species, and lack of knowledge may be the main reason for the little use of this approach.

The fourth alternative involves application of agricultural or management strategies to substitute for favorable climatic conditions or to mitigate those unfavorable conditions. Use of irrigation in drier regions or the use of trellises to supply a need for moisture stress or to avoid light ground frosts are among these strategies (Ison and Hopkinson, 1985).

How to Grow a Seed Crop? This topic was covered by a comprehensive array of adaptive agronomic research and there is technology to support seed production of the main tropical pasture species as shown in Humphreys and Riveros (1986). World wide adoption of this technology, however, may be hindered by deficient extension and communication services or by low adequacy of the technology to the different seed production systems existing in each country.

Grasses. There is a consensus that further increases in the efficiency of grass seed production will come from a better understanding of the dynamics of the tiller population (Loch, 1991; Hopkinson, 1986; Nabinger and Medeiros, 1996). Most of the existing studies are restricted to a census of the tillers bearing inflorescences by the time of harvesting. Little is known about how factors like nitrogen, cutting, competition for water, light and nutrients affect the dynamics and formation of the final population of tillers producing seeds

Another area deserving more studies refers to nitrogen fertilization. It is known that this nutrient has a strong influence on seed production. Most studies on nitrogen fertilization levels for grass seed production were carried out using small plots and normally using manual harvesting of the standing seed yield. It is not known, however, whether the optimum nitrogen fertilization levels determined with this methodology still apply for more efficient harvesting methods, such as those targeting shattered seeds.

Legumes. In Latin America, the low availability of seeds of adapted legume cultivars in the market is generally used to explain the low adoption of legume based pasture technology. The development of alternative production systems, in which the legume seed production activity is associated with other agricultural activities can be a valid strategy to attract seed growers into seed production of legume species. One of these alternatives is the use of companion cropping. Cardozo and Ferguson (1995) showed that use of corn and beans as companion crops to provide a rapid cash income is a viable alternative to bring Colombian smallholders involved in *A. pintoi* seed production (Table 3). In this case, *A. pintoi* seed yield was partially reduced with the use of corn and beans. While corn yield was not affected, beans yield was reduced by the competition from *A. pintoi*. With both crops, however, crop yield was enough to provide seed growers with an alternative income source. Seed production can be associated with a range of farming activities, and those traditionally existing in a given region should be given priority in developing alternative legume seed production systems.

Weed competition is a main problem in seed production areas, mainly after the establishment year in perennial legume seed crops. For larger areas, only chemical control is feasible and more research is needed to select effective herbicides for weed control in different legume species. There is a regular flow of new herbicides reaching the market, all of them developed for weed control in major crops, and the testing of these herbicides with pasture legumes should be continuous research process (Hawton et al., 1990)

When and How To Harvest the Seed Crop? Harvest timing has received great priority from research, mainly in Latin America. Days after inflorescence emergence was the chosen parameter to define optimum harvest timing and a great deal of this research was carried out with grasses. This parameter, however, is not dependable because it is affected by local, regional and yearly climatic conditions. It indicates when harvesting is likely to occur after inflorescence emergence and this information can help growers to prepare, in advance, the infrastructure necessary for harvesting. Growers base their final decision on their local experience and on a series of morphological indicators such as shattering, color change, and seed or caryopses hardness. Normally, seed growers adjust the harvest timing considering the time necessary to harvest a given area with the available harvesting infrastructure.

The choice of an adequate harvesting method involves considerations about species to be harvested, size of the area, and availability and relative costs of labor and machinery. Based on information such as that produced by Cardozo et al. (1993), who compared different manual and mechanized harvesting methods for *B. dictyoneura*, seed growers can decide which harvesting method is more appropriated for their condition.

Reducing losses and improving harvesting efficiency, in such a way that a greater share of the total yield can be collected, is the most direct way to improve seed yields in tropical pasture species. For harvesting methods aiming at collecting the standing seed yield, greater efficiency can be achieved simply by the use of more powerful combine harvesters, which suffer less clogging problems and present more efficient treshing and separation systems (Hopkinson and Clifford, 1993).

For species showing non-uniform long flowering periods and with shattering problems, efficiency may only be achieved through harvesting methods aiming the shattered seeds. In Australia, shattered seeds retained in the leaf mat of *B. decumbens* can be collected with the use of powerful combine harvesters. In Brazil, seed growers recognized the advantages of harvesting shattered seeds from the soil a long time before researchers. Manual sweeping of seeds from the ground is the main harvesting method for *B. decumbens* and *B. brizantha* (Andrade, 1994). For these two species, compared to traditional combining harvesting of the standing seed yield, sweeping harvesting allowed eight times increase in yields and much higher seed quality (Table 4).

The recent successful development of sweeping harvesting machinery in Brazil will certainly extend this harvesting method to a number of other species such as *A. gayanus, P. maximum, C. mucunoides* and *S. guianensis* cv. Mineirão, in which manual sweep harvesting is already occasionally practiced.

SEED MULTIPLICATION TO SUPPLY RESEARCH NEEDS

A pasture evaluation program focused on native or introduced genotypes will not succeed in the objective of releasing new cultivars if not complemented by a strong effort in seed multiplication of selected genotypes to suply the internal seed needs. In a pasture evaluation scheme, plot size increases from small plots, for initial cutting evaluations, to very large plots, necessary for the final under-grazing evaluations. Consequently, as a promising genotype moves up in the evaluation scheme, progressively greater seed amounts are required. Seeds of promising genotypes (experimental seeds) are also necessary to supply parallel trials in fertilization, forage quality evaluation, regional trials and on-farming trials. In a eventual release, the existing experimental seeds are the genetic seed to start basic and commercial seed production (Andrade, 1983).

The experience accumulated during the process of experimental seed multiplication allows the identification of bottle necks which will be solved through specific seed production research, so that, by the time of release of a new cultivar, a first hand seed production technology is available for the seed growers. Refinements of this production technology can be performed later.

PERSPECTIVES

Market prospects. The tropical pasture seed market is expanding. It is estimated that by the year 2000, Latin America will have a market demand of 179,000 ton of pasture seed per year. The money value of this market is close to US $1.8 billion, of which Brazil will have a share of about 60 (Rivas and Cadavidad, 1994). Some facts and conditions supporting this market expansion are:.

1) There is an area of over 30 million hectares of pasture in some stage of degradation which will require reclamation and this involve reseeding or seeding of new species (Macedo, 1995).

2) There is a better understanding about the important role of pastures to the biological and economical sustainability of cropping systems and the ley farming approach is becoming a common feature in farms in Brazil and South America. This creates recurrent seed buyers and may become a main market in the future.

3) The market globalization and formation of market blocks will facilitate the commerce of seeds among countries, and this will open new opportunities and markets for the pasture seed industry.

Research funding. Following a worldwide tendency, there have been budget cuttings in pasture research programs. Within these programs, normally, the seed specialist is the first to be cut. The reason for this is that pasture seed is a sub system of the pasture system which in turn is a sub system of the beef or dairy industry and, consequently, the weakest participant in the overall system. The possibility of seed firms supporting research is not clear and the future prospects of plant variety protection as a fund source is still a mere speculation. Research funding is a main bottle neck in the near future and researchers will have to use all their creativity to find alternative ways to finance tropical pasture seed research.

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Table 1
Estimates of annual seed production of some commercial tropical grasses and legumes

Species	Australia[2]	Brazil	Latin America	Asia[3]
Brachiaria[1]				
B. brizantha	0	40000	5 - 60	
B. decumbens	150	40000	45 - 150	
B. dictyoneura	0		15 - 30	
B. humidicola	50	>500	50 - 100	
B. ruziziensis	0	100 - 400		490 - 630
Stylosanthes				
S. scabra	200			
S. hamata	70			100

1. Figures for Brachiaria spp are from Hopkinson et al., 1996.
2. Figures for *Stylosanthes* spp., in Australia, are from Smith, 1996.
3. Figures for *Stylosanthes hamata* in Asia, refers specifically to Thailand, and are from Hare, 1993.

Table 2
Seed yield of *Arachis pintoi* cv. Amarillo (CIAT 17434) in different countries

Country	Latitude	Altitude m	Rainfall mm	Yield ton/ha[1]
Australia	22 ^{0}S	50	1000	1.0
Bolivia	17 ^{0}S	250	1825	0.5
Brazil	15 ^{0}S	1000	1500	1.2
Colombia	4 ^{0}N	182	2281	0.8-2.5
Costa Rica	10 ^{0}N	250	4670	2.0
	9 ^{0}N	703	2954	0.5

Adapted from Ferguson, 1994.
1 - Several harvesting methods and crop ages

Table 3
Seed and grain yield (kg/ha) for *Arachis pintoi* cv. Amarillo using corn and beans as companion crops

		Companion crop	
Crop	*A. pintoi*	Corn	Beans
A. pintoi	6371 a	4688 a	638 b
Corn	5220 b	4833 a	-
Beans	5411 b	-	976 a

Adapted from Cardozo and Ferguson, 1995.
In the columns, yields followed by distinct letters are different at P>0.05

Table 4
Seed yields and quality for combine and sweeping harvesting of *B. decumbens* and *B. brizantha* in Brazil

	B. brizantha		*B. decumbens*	
	Combining	Sweeping	Combining	Sweeping
Yield (kg/ha)	150	1000	130	800
Germination (%)	20 -30	70 -80	30 -50	75 -85

Data for germination from Santos Filho, 1996.

Figure 1
Participants and main seed flows in the Tropical Pasture Seed Industry