FORAGE PEANUT BREEDING PROGRAM IN BRAZIL

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Introduction

Brazilian pastures occupy close to 200 million hectares, with the area of cultivated pastures estimated at 135 million hectares in 2003 (DIAS-FILHO; ANDRADE, 2005). According to IBGE (2009), the country has the greatest commercial cattle herd of the world with around 200 million heads. These expressive numbers place Brazil in a upstanding position in the world market as the greatest meat exporter since 2004, the greatest exporter of tropical forage seeds (VALLE et al., 2000) and the second greatest world meat producer. The world forage seed market alone represents over 250 million dollars per year (ANDRADE, 2001), an amount similar to the seed market for hybrid corn.

Brazilian cattle production systems are based predominantly on pastures as the source of feed for the animals, a fact that make them very competitive due to their low production costs. However, animal production and reproduction indexes are still unsatisfactory. Average stoking rate of pastures in Brazil is around 0.85 heads per hectare, less than half of the stocking rates achieved in countries such as France, New Zealand, Ireland, England and Italy (SILVIA; SBRISSIA, 2000). The low performance are a result of the extensive cattle production systems with low technology levels that are predominant in Brazil (VILLA, 2007), where most pastures are under some degree of degradation. Low productivity of low quality forages, lack of adequate pasture and animal management and the use animals with low genetic potential are other causes for the low observed indexes.

The use of grass-legume pastures is an excellent option for farmers to promote the reclamation of degraded pastures because it increases yield and quality of the forage available to the grazing animals and improves soil quality by adding symbiotically fixed nitrogen, increasing organic matter content and protecting the soil against erosion and nutrient leaching. This results in increased productivity and profitability of cattle production systems. Forage nutritive value has direct effect on animal production. Forage legumes, as components of the animal diet, contribute to increase animal liveweight gains, supply higher amounts of nutrients in the diet and improve ruminal parameters contributing to reduce methanogenesis (MONTENEGRO et al., 2000).

Among several species of forage legumes, wild species of the genus *Arachis*, known as forage peanut, are getting increasing interest of farmers and researchers in several

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regions of the world such as Brazil, Colombia, Costa Rica, Mexico, United States, countries from Southeast Asia, South Africa and Australia, among others (COOK et al., 2005; RADOVICH et al., 2009; ROOTHAERT et al., 2003). In these regions, forage peanut is being used in grass-legume pastures under grazing, for hay production, as a protein bank, as an ornamental plant in gardens, as a cover crop in perennial plantations and for environmental conservation along roads. Shelton et al. (2005) identified success histories in the adoption of forage legumes in livestock production systems in the tropical regions of all the continents of the world where they increase profitability and, frequently, provide multiple benefits for the farmers. The main characteristics of the legumes that were adopted in large scale in the tropics vary widely. However, with a few exceptions, these legumes present high seed production or are easily vegetatively propagated, are easy to establish, have high plant vigor, longevity and are capable to persist under grazing or cutting systems. These legumes increased the profitability of the cattle production systems and provided environmental benefits for the farmers (VALENTIM et al., 2008).

Forage peanut is, unmistakingly, the tropical herbaceous legume with the highest number of favorable attributes relating to persistence under grazing (VALENTIM; ANDRADE, 2004). Some of these attributes are: prostrate and stoloniferous growth habit with many growing buds protected from grazing; long plant lifespan that can reach 25 months; high production of seeds buried in the soil, which germinate vigorously in the beginning of the rainy season; and good shading tolerance (GROF, 1985; JONES, 1993; FISHER; CRUZ, 1995). PEREIRA (2002) reported the existence of mixed pastures of *Brachiaria humidicola* and forage peanut with more than 10 years under grazing.

In the Brazilian State of Acre, there are mixed pastures of massaigrass (a natural hybrid of *Panicum maximum* x *Panicum infestum*) with forage peanut still very productive after more than 15 years under grazing and mixed pastures of African stargrass (*Cynodon nlemfuensis*) and forage peanut established in 2000 that remain very productive with excellent persistence of the legume (Figure 1).

Ladeira et al. (2002) recommended the use of forage peanut hay as feed for ruminants because this forage legume presents high consumption and digestibility, thus providing nutrients in sufficient amounts to meet the requirements in order to achieve the potential production of the animals. Annual liveweight gains of animals grazing forage peanut have ranged from 160 to 200 kg/head and from 250 to 600 kg/ha, depending of the mixed grass species, the environmental conditions and of the pasture management system used (BARCELLOS et al., 1996; LASCANO, 1994; QUAN et al., 1996). In relation to liveweight daily gains there are reports of values ranging from 370g/animal/day up to 650g/animal/day. Research results show that the inclusion of forage peanut in pure grass pastures resulted in increases of 17 to 20% in milk production (GONZALEZ et al., 1996). Research shows, consistently, that grass-legume pastures that include forage peanut result in significant increased in production per animal and per area when compared with pure grass pastures (ARGEL, 1994; LASCANO, 1994).


Figure 1. Mixed pastures of massaigrass with forage peanut (left) and mixed pastures of African stargrass with forage peanut (right) in Acre, Brazil.
Photos: Carlos Maurício Soares de Andrade (left) and Judson Ferreira Valentim (right)

Botanical classification

The genus *Arachis* belongs to the tribe Aeschynomenae, subtribe Stylosanthinae, family Leguminosae (RUDD, 1981) and presents as a differentiating characteristic from the remaining genus of this family the production of underground fruits originating from aboveground flowers. The genus *Arachis* consists of 80 species which are distributed in nine sections, according to the actual taxonomic structure (KRAPOVICKAS; GREGORY, 1994): *Trierectoides*, *Erectoides*, *Extranervosae*, *Triseminatae*, *Heteranthae*, *Caulorrhizae*, *Procumbentes*, *Rhizomatosae* and *Arachis*. The species of this genus are native from South America, with more than 60 wild species occurring naturally in Brazil; 15 in Bolivia; 14 in Paraguay; four in Argentina; and two in Uruguay (VALLS; SIMPSON, 1995).

The most promising accessions for use as forage in the tropics are found in the section *Caulorrhizae* and belong to the species *Arachis pintoi* Krapovickas & Gregory and *Arachis repens* Handro. These species are perennial and have prostrate and stoloniferous growth habit, producing roots at the nodes which are in contact with the soil or in places with high moisture. Both species are exclusive from the Brazilian flora, with natural occurrence in different biomes, such as Mata Atlântica and Cerrado. *A. pintoi* is found between the Brazilian central plains, in the state of Goiás and at the coast of Bahia. *A. repens* has a more restricted area of natural occurrence and is found mainly in the state of Minas Gerais. Original accessions (GK 12787 of *A. pintoi* and GKP 10538 of *A. repens*) showed that the two species of section *Caulorrhizae* had very distinct morphological characteristics. However, with the increasing number of accessions obtained in the germplasm collection trips in the last 30 years, accessions with intermediate characteristics were found (VALLS, 1983). *Arachis glabrata* Benth. (perennial peanut) belongs to *Rhizomatosae* section and is also a perennial species with a dense mat of rhizomes, mostly in the 5-7 cm of soil depth. Cultivars Florigraze and Arbrook are widely used in the Southeastern Unites States as a forage legume for grazing and fed as hay, haylage or greenchop for dairy and beef cattle, for horses, goats and for gestating cows (FRENCH et al., 2006). Because of its quality and uses are so similar to alfalfa is had been coined "Florida´s alfalfa" (BRONSON, 2005).

Around the world, studies regarding the use of the genus *Arachis* for forage production have focused on the species *A. pintoi* and *A. glabrata*. However, there are still other undescribed species (VALLS et al., 1995) which could be used as forages. Species of section *Procumbensae*, for example, present high aboveground biomass production, high plant vigor, seed production potential and are capable to form interspecific hybrids with species of sections *Caulorrhizae and Rhizomatosae* (GREGORY; GREGORY, 1979). Section *Triseminalae* is also promising because it has accessions which are perennial, adapted to dry weather conditions and to structured and compacted soils (VALLS et al., 1995).

Germplasm

According to Valls et al. (1995), the first accession of *A. repens* (GKP 10578) was collected in 1941 by Otero in Jequitaí, Minas Gerais, Brazil. The first accession of *A. pintoi* (GK 12787) was collected in 1954, by Geraldo Pinto in Boca do Córrego, in Bahia, Brazil. *A. pintoi* is native from the valleys of the rivers Jequitinhonha, São Francisco and Paraná (VALLS, 1992). There were intensive field trips to collect germplasm during the 1980s and 1990s, resulting in a collection with more than 130 accessions of *A. pintoi*, more than 40 of *A. repens* and more than 100 of *A. glabrata*.

Germplasm collections of forage peanut can be found in different countries such as Colombia (International Center for Tropical Agriculture) and in the United States (United State Department of Agriculture - Southern Regional PI Station). In Brazil, the Active Germplasm Bank of Forage Peanut is located at the Experimental Station of Embrapa Acre, in Rio Branco, Acre. Most of the accessions of this bank were provided by the Active Germplasm Bank of *Arachis*, located at Embrapa Genetic Resources and Biotecnology, in Brasília, DF, Brazil. The establishment of a specific bank of forage peanut became necessary due to the growing demand of germplasm from researchers interested in the forage potential, specially of *A. pintoi*, and as a result of the reorganization of *National Forage Peanut Breeding Program*, which since 2005 is coordinated by Embrapa Acre. The actual list of species and the number of accessions of this germplasm bank is presented in Table 1.

Table 1. Accessions and hybrids of forage peanut introduced in the last 6 years in the Active Germplasm Bank of Embrapa Acre, Rio Branco-AC, Brazil.

Species / Hybrids	*2004*	*2005*	*2007*	*2008*	*2009*	*Total*
A. pintoi	14	14	22	4	10	64
A. repens	4	5	12	0	3	24
A. glabrata	3	0	0	0	4	7
Hybrids	4	5	8	0	0	17
Total	**25**	**24**	**42**	**4**	**17**	**112**

Forage peanut accessions are maintained in pots in a greenhouse and in field plots of 4 m^2 (Figure 2). Harvested seeds are sent to the Basic Collection located at Embrapa Genetic Resources and Biotechnology for long term conservation. Passport and morphological characterization data are being organized in order to be included in the Brazilian Genetic Resource System (SIBRARGEN) and made available to the scientific community.

Figure 2 – General view of the Active Germplasm Bank of Forage Peanut located at Embrapa Acre, Rio Branco, AC, Brazil: field (left) and greenhouse (right).

Photos: Giselle Mariano Lessa de Assis, Embrapa Acre

Studies of genetic diversity based on morphological and agronomical traits are being conducted since the 1990s (ASSIS et al., 2008a; ASSIS et al., 2009; MONÇATO, 1995; CARVALHO; QUESENBERRY, 2008). Studies of genetic diversity based on molecular markers were conducted for *A. pintoi* and/or *A. repens*, with the use of RAPD markers

(GIMENES et al., 2000; CARVALHO, 2004) and for four species of section *Rhizomatosae*, which includes *A. glabrata* (ANGELICI et al., 2008).

Valls (2004) highlights that although there is a high number of collected accessions of the *Caulorrhizae* section, there is a need for further collections on more sites of natural occurrence of *A. pintoi*, specially in dryer environments. Due to the growing use of these species as forage, ground cover and as ornamental, the search for genetic variability is more intensive. Also genetic studies (BERTOZO; VALLS, 2001; GIMENES et al., 2000; CARVALHO, 2004) do not show redundancy among accessions of this section collected in nature, there being the possibility of expanding variability as a result of more collection expeditions.

Reproductive structure

Studies of flowering biology in *Arachis* are normally based in *A. hypogaea*, which present papilionoid corolla composed of five petals: the standard, two wings and the keel, this consisting of two petals united through the inferior border. The keel involves the style and the stamens. The style runs internally all the length of the hypanthium (tubular extension of the calyx), curving in the corolla and ending in the stigma, whose morphology at the top varies among species (BANKS, 1990; LU et al., 1990).

Flowers occur on leaf axil, which grow from the reproductive nodes in inflorescences (SIMPSON et al., 1995) which are composed of one to nine potential buds (Figure 3). The flower buds generally appear after 36 to 48 hours before anthesis takes place. Usually only one flower per inflorescence opens each day. In *A. pintoi*, the flowers can present distinct colors which vary from white, cream, yellow to orange (Figure 4), with yellow being the most frequent color observed. In *A. repens* the flowers are yellow or orange.

Usually fertilization occurs 12 hours after pollination. When fertilization takes place the young embryo goes through four or five more divisions, remaining in a latent state. Simultaneously, an intercalar meristem is activated at the basis of the ovary resulting in growth of the peg (peduncle of the ovary) which has positive geotropism. According to Simpson et al. (1995), peg growth has genetic and environmental influence, varying considerably among *Arachis*. This variation was also observed in experimental conditions among accessions of *A. pintoi* by Assis et al. (2008c). These authors verified that there is variability among accessions in relation to depth of occurrence of the fruits in the soil profile, and that is related to peg growth. However, the majority of the accessions evaluated presented more than 90% of the total fruit produced in the first 6 cm of soil depth. Differently from common peanut (*A. hypogaea*), in which the majority of the pods remain connected to the plant, the wild species of *Arachis*, such as *A. pintoi* and *A. repens* have their mature pods disconnected from the plants.

Species of the genus *Arachis* are generally autogamous, although cross-pollination can occur as a result of the action of insects, specially bees (SIMPSON et al., 1995). In *A. glabrata*, for example, there are reports of a 10% cross-pollination rate (OLIVEIRA; VALLS, 2002). Peñaloza (1995) verified that plants of some accessions of *A. pintoi* and *A. repens* when maintained in greenhouse protected from pollinators did not produce seeds. When plants of these same accessions were grown in the field, without the protection from possible pollinators, there was seed production, which suggests the existence of self-incompatibility mechanisms in these accessions.

Species of *Arachis* have the same basic 10 chromosomes. Therefore, the diploid species, such as *A. pintoi* and *A. repens* have 2n=2x=20 and the tetraploid, such as *A. glabrata* and *A. hypogaea* (common peanut) have 2n=4x=40 chromosomes. In *A. pintoi* it was observed one triploid accession (2n=3x=30) by Peñaloza (1995), who counted the chromosome number of 16 accessions of section *Caulorrhizae*.

Figure 3. Detail of the reproductive node in *A. pintoi* (left) and in *A. glabrata* (right), highlighting the occurrence of wilted flowers and floral buds originating from the same leaf axil.
Photos: Hellen Sandra Freires da Silva, Embrapa Acre

Figure 4. Flowers of *Arachis pintoi* which can be found in the colors white, cream, yellow and orange.
Photos: Rui C. Peruqueti, Embrapa Acre

Genetic improvement of *Arachis pintoi*

Research with forage peanut in Acre started in December 1987 when vegetative material (rhizomes and stolons) of *Arachis glabrata* cultivars Florigraze and Arbrook and an accession of *Arachis* spp. named Pantanal were introduced at the Experimental Station of Embrapa Acre from the United States. In 1989 an accession of *Arachis repens* that was used as an ornamental in landscape in Rio Branco-AC was collected. In the same year vegetative material of three accessions of *A. pintoi* (BRA 013251 – cv. Amarillo, BRA 014931, BRA 015121) were introduced from Embrapa Genetic Resources and Biotechnology. These materials were multiplied during 1989 and in 1990 an experiment was established and the adaptation and dry matter yield of these accessions was evaluated between December 1991 and August 1993. The accession of *A. pintoi* BRA 015121 showed excellent adaptation and dry matter productivity (VALENTIM, 1996).

The first Brazilian Forage Peanut Evaluation Network started in 1999 and included experiments in the states of Acre, Bahia and Distrito Federal. As a result of this effort a new cultivar of *A. pintoi* with high forage value was developed in the state of Acre using the mass selection method. This selected genotype presents as favorable traits fast establishment rate, high dry matter productivity and excellent nutritive value and, most important, high seed productivity which under experimental conditions reached approximately 3,500 kg/ha, eighteen months after planting in the environmental conditions of Rio Branco – AC (VALENTIM; ASSIS, 2009). High seed yield of this cultivar together with the development of a seed production system, with the use of mechanized harvesting equipment are the key factors which will contribute to reduce the price of the commercial seed for the farmers, thus creating favorable conditions for wide scale adoption of forage peanut in the pasture based beef and dairy cattle production systems in Brazil. Partnership between Embrapa and the private sector, through the Unipasto Consortium (Association for the Support of Tropical Forage Improvement Research) has increased the speed of the process of technology development and adoption, with focus on commercial seed production of new tropical forage cultivars.

Another important result achieved through the process of evaluation of accessions and on farm validation of the technologies was the recommendation of *A. pintoi* cv. Belmonte for use in grass-legume pastures in the state of Acre in 2001 (VALENTIM, 2001). This cultivar was released in 1999 by CEPLAC (*Comissão Executiva do Plano da Lavoura Cacaueira*) in Bahia. In 2007, this technology was already under use in more than 2,500 farms in approximately 105,000 hectares of pastures, providing annual economic benefits of R$ 39 million to the farmers (EMBRAPA, 2008). The establishment of cultivar Belmonte is done exclusively through the use of vegetative propagation (stolons), since seed production is practically non-existent.

Establishment of forage peanut by seeds is easier and makes it technically and economically viable to use forage peanut in pastures, as ground cover or in landscape in gardens or along roadsides. However, the establishment of forage peanut using vegetative material with the purpose of establishing nurseries in the farms for later introduction of this legume in the existing grass pastures or in the establishment of protein banks is of great importance, especially for small dairy farmers who use family labor in their production systems. Vegetative propagation is also very common in large beef cattle farms, in regions where low-cost labor is available and where environmental conditions (topography, soil conditions) are not favorable for mechanization. In the state of Acre, it is possible to find mixed forage peanut-grass pastures in areas above 2,000 hectares in the same farm where the establishment was made using vegetative propagation of cultivar Belmonte.

The Forage Peanut Breeding Program at Embrapa Acre is very recent, and started in 2005. Projects aimed at structuring the program are being developed with focus in actions targeting the expansion and adaptation of the required infrastructure (laboratories and greenhouses); acquisition of equipments; training of research and support personnel; and strengthening of partnerships.

The program has the objective of developing forage peanut cultivars with the following traits: i) capable of being propagated by seed and/or vegetatively; ii) high speed of establishment measured in terms of ground cover; iii) high productivity of dry matter of high nutritive value; iv) show persistence under grazing and in association with grasses. Additionally, it is highly desirable that these cultivars show adaptation to a wide range of environmental and management conditions of the main regions where beef and dairy cattle production systems are developed in Brazil. Regions with cold weather, with more severe Autumn and Winter seasons or regions with long dry seasons must have cultivars specially developed taking into consideration these conditions. The incidence of pests and diseases still not pose any serious treats to cultivation of forage peanut. However, basic studies of the main pests and diseases must be conducted with the objective of future selection of resistant or tolerant genotypes.

Studies aimed at evaluating agronomic adaptation and forage quality of accessions of *A. pintoi* and *A. repens* conducted in Rio Branco, AC (ASSIS et al., 2008a; ASSIS et al., 2008b), Campo Grande, MS (SIMEÃO et al., 2009) and Planaltina, DF (FERNANDES et al., 2009), between 2005 and 2008, allowed the identification of genetic variability for several traits such as: speed of ground cover during the establishment, dry matter yield, plant height, leaf/stem ratio, crude protein (CP) content, neutral detergent fiber (NDF) and acid detergent fiber (ADF). According to Lascano (1994), nutritive value of *A. pintoi* is higher than the majority of the tropical legumes of commercial importance, with values for the leaf component between 13 to 22% CP, 60 to 67% *in vitro* organic matter digestibility (IVOMD) and 60 to 70% gross energy digestibility. Another important trait of *A. pintoi* is the small difference between leaf and stem CP digestibility (LASCANO, 1994). Although forage peanut is considered a high nutritive value legume, the existence of variability among genotypes enables the selection for these traits. In Rio Branco, for example, the observed mean CP content ranged from 16 to 24%, NDF varied from 39 to 49% and ADF ranged from 30 to 36% among the 21 accessions evaluated (Figure 5). Dry matter intake is the main factor affecting animal productivity and high quality forages are needed to increase consumption (BELYEA et al., 1999). The lower the fiber contents of a forage, the higher its animal consumption, because of the lower physical filling of the rumen. Besides, forage digestibility will also be higher, since the majority of its components that are not digested are found in this fraction.

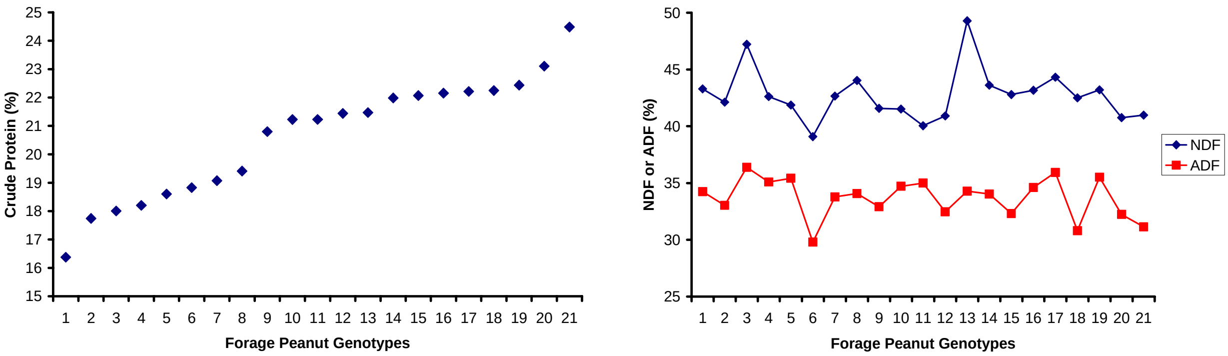

Figure 5. Crude protein content, neutral detergent fiber (NDF) and acid detergent fiber (ADF) observed in agronomic evaluation experiments with accessions of *A. pintoi* and *A. repens* in Rio Branco, AC.

The strategy established for development of the Forage Peanut Breeding Program is presented in Figure 6. The development of cultivars adapted to the different regions requires local evaluations, which are capable of identifying superior and divergent progenitors. Through a hybridization program conducted at Embrapa Acre, these parents are crossed and after advancement of generations, the hybrids are evaluated according to the region of interest. In common peanut genetic improvement programs (*A. hypogaea*), artificial hybridization is the most used method to create genetic variability (SANTOS; GODOY, 1999), allowing the development of superior cultivars. The percentage of seed produced in relation to the number of flowers pollinated ranges from 30 to 70%, and can reach up to 90%. Factors such as environmental conditions, efficiency of the operator, embryo abortion, deformed fruits and floral biology aspects affect fecundity rates.

In the process of hybridization of forage peanut, fecundity rates achieved are generally very low, with values of 7.1% (CARVALHO, 2000), 1.1 to 12.9% (OLIVEIRA; VALLS, 2002) and 3.2% (CASTRO et al., 2005). Therefore, besides the adequate training of the team to do the crossings, it is necessary to carry a high number of pollinations in order to obtain hybrid seeds. The confirmation of the hybrid nature of the descendents must be done using molecular markers, since the choice of genitors is based in traits of agronomic and bromatologic interest, and it is not possible to identify the hybrid plants though the use of morphologic markers.

During the program, trials under grazing aiming at evaluating legume persistence and animal performance are also carried out (Figure 6). In the final phase, tests of distinctness,

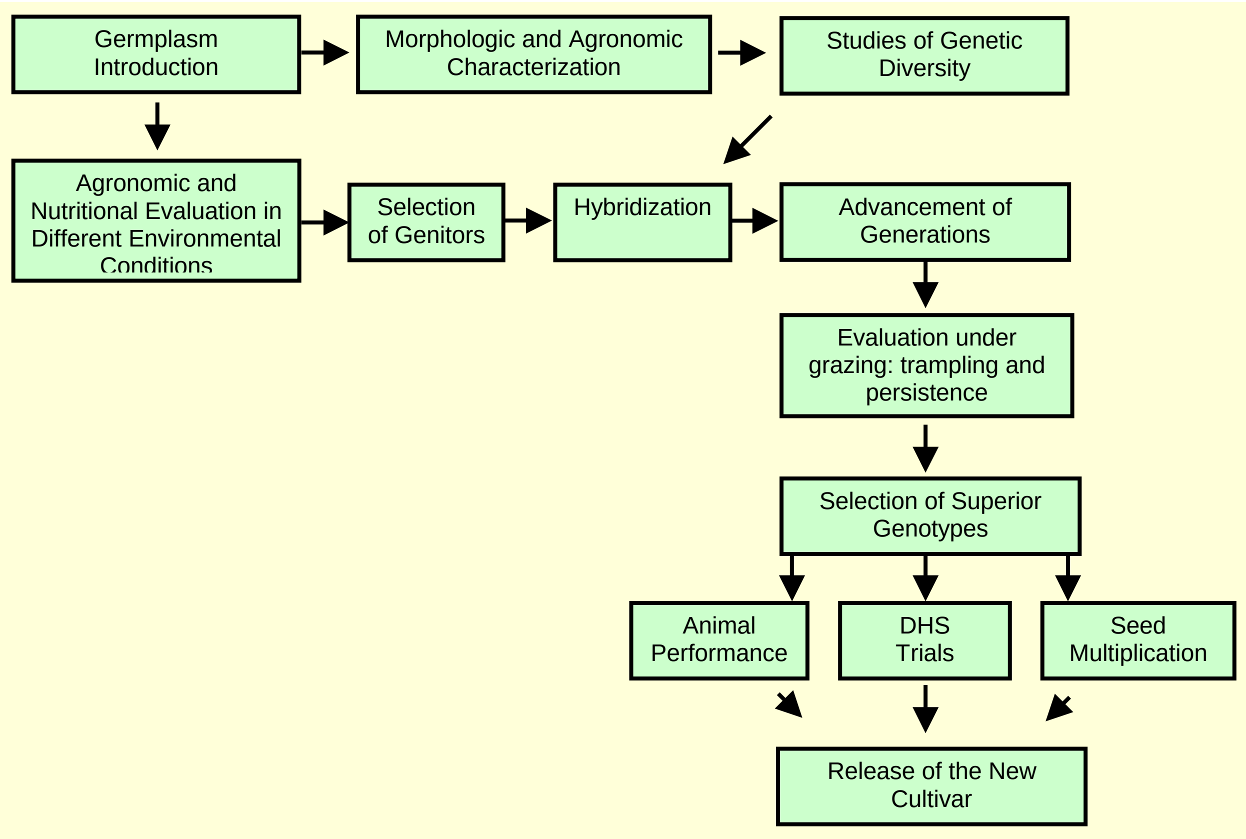

Figure 6. Graphic representation of the different phases of the Forage Peanut Breeding Program, since germplasm introduction to the release of the new cultivar.

homogeneity and stability (DHS) are also carried out since they are required by the Ministry of Agriculture, Livestock and Supplies and are necessary for the protection of the new cultivar. Support trials in the areas of seed technology, phytopathology, entomology, plant physiology, biotechnology, among others, also compose the research and development actions of this program.

Statistical analysis of data in genetic improvement of forage peanut generally involve use of mixed models in which the variance components are estimated by the Restricted Maximum Likelihood Method (REML) and the genotypic values are predicted by the Best Linear Unbiased Prediction (BLUP). Among other advantages (ASSIS et al., 2009), this methodology can be adequately employed when working with unbalanced experiments and is appropriated to analyze data from repeated measures in the same experimental unit in a period of time (several harvests during the years). Multivariate analyses techniques (CRUZ; REGAZZI, 1997; KHATTREE; NAIK, 2000) also are being used routinely in forage peanut breeding, contributing significantly to the studies of genetic divergence, in the establishment of heterotic groups and in genotype discrimination, mainly when there is a high number of accessions in the initial phases of evaluation.

Some cultivars of *A. pintoi* were released in different countries in the last 22 years (Table 2); however, of 11 cultivars released, six are proceeding from the original accession GK 12787 (BRA 013251), first released with the name Amarillo in Australia (PAGANELLA; VALLS, 2002). During a period of approximately 10 years, this accession was transferred and released in other countries with distinct denominations. Since 1996, cultivars originating from other accessions started to be released (ARGEL; VILLARREAL, 1998). However, the release of new cultivars has taken place based on selection of ecotypes found in nature. In relation to *A. glabrata*, several cultivars (Arb, Arblick, Florigraze, Arbrook, Ecoturf, Brocksville 67, Brocksville 68) were released in the United States, where this species has more importance (COOK et al., 2005; PRINE et al., 1981; PRINE et al., 1986).

Table 2. Cultivars of *A. pintoi* released in different countries in the last 22 years.

Cultivar	*Country of Release*	*Year*	*Accession of Origen*
Amarillo	Australia	1987	BRA 013251
Maní Forrajero Perenne	Colombia	1992	BRA 013251
Maní Forrajero	Panama	1992	BRA 013251/BRA 012122
Pico Bonito	Honduras	1993	BRA 013251
Maní Mejorador	Costa Rica	1995	BRA 013251
Amarillo MG-100	Brazil	1995	BRA 013251
Golden Glory	United States	1996	Unknown
Porvenir	Costa Rica	1998	BRA 012122
Alqueire-1	Brazil	1998	BRA 037036
Belmonte	Brazil	1999	BRA 031828
Itacambira	Southeast Asia	2002	BRA 031143

Final considerations

In the actual scenario, genetic improvement of forage plants, particularly of legumes deserves special attention. Pressed by the environmental impacts which include emission from slash and burn of native ecosystems (particularly tropical forests) and methane emission by ruminants, cattle production systems need solutions that reconcile increased productivity per animal and per area and reduced environmental impacts.

Cattle production systems that have pastures as the basis for animal feed will be pressured to gradually migrate towards more sustainability, particularly those located in the Amazon biome. The urgent need to reduce deforestation, associated with the increasing prices of agricultural inputs, such as nitrogen fertilizers and herbicides, open excellent perspectives to improve economic, social benefits and reduce negative environmental impacts of cattle production systems in the Amazon biome. Production systems should be intensified while maintaining its pasture-based production characteristic. Grass-legume pastures established with forage species adapted to the specific environmental conditions and adequately managed will have increase carrying capacity. This will allow for adequate supply of feed for the still growing cattle herd thus resulting in increased productivity per animal and per area.

The actual pasture area in Brazil should stabilize and gradually decrease, as a proportion of these areas will be converted for food, bioenergy production (sugarcane, oil palm and forest plantations) or will be destined for environmental reclamation (permanent preservation areas). The technological innovations to achieve this goal have as their basis the use of well adapted and highly productive grasses and legumes which are capable of providing the animals with the nutrients needed for an economic and sustainable meat and milk production in the different biomes and systems.

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