EFFECT OF GENOTYPE AND MANAGEMENT SYSTEM ON FORAGE PRODUCTION OF CULTIVATED PEANUTS (*Arachis hypogaea* L.)

By

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To my wife, Maria Olanda Bata, and my daughters Silvia, Jessie Kay, and Nicole Freire, with all my love.

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Although peanut is best known for its edible seed, peanut hay is commonly used throughout the world as high-quality animal feed, as was the case in the U.S. until the early 1950s. The present trend of incorporating multiple pest resistance into peanut, thus reducing the need for chemicals, reopened the possibility of again considering the dual use of peanut for edible seed and forage. This could be of particular importance in North Florida's expanding dairy industry and Florida's beef industry. In order to address these issues an experiment was conducted in 1996 and 1997 involving several peanut genotypes under two harvest management levels. Vines of peanut breeding lines, plant introductions, and released cultivars were harvested once (at the end of the crop cycle, 140 days after planting) or twice (at 80 days and the end of the crop cycle).

As expected, significant differences in pod and forage yields existed among peanut genotypes. The most relevant results of this experiment refer to the differences between harvest management levels. By harvesting twice, higher peanut forage yields were obtained while lowering pod yield when compared to one harvest. However, one of the most important consequences of cutting hay twice during the crop cycle is the reduction of insect and disease incidence.

From 1996 to 1998 a second experiment was conducted to test three entries (Southern Runner, Dixie Runner and UF81206) at three crop sequences. The three genotypes used produced identical forage yields. 'Southern Runner' yielded more nuts, although showing high levels of Tomato Spotted Wilt Virus (TSWV) and an intermediate leaf spot score. The winter crop was found to be crucial to the management of weeds and reducing predation, resulting in more favorable peanut reestablishment.

It was concluded that to maintain a peanut forage field a winter crop is required, but without the inclusion of perennial forages. On the other hand, the inclusion of bahiagrass in the winter crop mix seems to be a promising method for the establishment of a bahiagrass pasture field.

CHAPTER 1
INTRODUCTION

In the United States the peanut (*Arachis hypogaea* L.) is primarily cultivated for the consumption of its seed either directly or in the form of peanut cooking oil and peanut meal for animal consumption. However, throughout the world peanut vines are also used as high-quality animal feed, both for grazing and hay. Vine uses vary from a source of energy for draught animals during the winter in developing countries of Africa and Asia to a source of additional income in Australia (Cook and Crosthwaite, 1994). In the early history of the United States, peanut vines were considered a valuable forage for livestock. As early as 1885, Jones mentioned that "peanut vines are a very good provender for all stock," excellent for cattle, sheep, mules and horses. Other authors mentioned grazing, mowing, feeding and hogging (Killinger et al. 1947; Cook and Crosthwaite, 1994; Hawkins and Autrey, 1953) as methods to utilize peanut vines. Referring to the first half of this century Killinger et al. (1947) reported that "in Florida more peanuts are hogged off every year than are harvested," while Mullin (1969) showed that, in the early days, the peanut was cultivated almost in equal proportion for hay, seed, and hogging.

Hawkins and Autrey (1953) stated that peanut hay costs less than alfalfa hay but allows milking cows to produce a similar amount of milk. Tests show that peanut vines have an *in-vitro* organic matter digestibility (IVOMD) ranging from 68 to 72% and crude protein in the range of 16 to 20%, which is comparable to alfalfa and perennial peanut. A wide spread constraint for peanut hay production is the incidence of leaf spots and other diseases, which reduce forage, seed and protein yields, as well as digestibility (Cummins and Smith, 1973).

Beginning in the late 1960s, the use of high seed yielding varieties, requiring high inputs, and, above all, the use of pesticides limited the possibility of using peanut hay as animal feed. A recent trend of incorporating multiple pest resistance into new peanut cultivars has reduced the need for chemicals, and reopened the possibility of again considering the dual use of peanut. This could be of particular importance for North Florida's expanding dairy industry and Florida's beef industry.

The selection of cultivars adapted to the traditional kernel production or for multipurpose forage use is not as different as it may appear. In both cases, the introduction of resistance to leaf diseases {early leaf spot (*Cercospora arachidicola* Hori), late leaf spot [*Cercosporidium personatum* (Berk. And Curt.) Deighton], and rust (*Puccinia arachidis* Speg.)}, viruses [tomato spotted wilt virus (TSWV), and rosette], insects (aphids and thrips) and nematodes [peanut root-knot nematode, *Meloidogyne arenaria* (Neal) Chitwood] are basic goals. The main difference resides in the harvest index, which is much higher in the case of breeding for kernels. When breeding peanut for forage or multi-purpose use, lower pod and kernel yields are acceptable, both in weight and numbers, while larger forage yield is expected, resulting in a lower harvest index.

Past experience as well as an actively changing economy lead to the need for alternatives for peanut use. In order to address these issues, a set of experiments was conducted to study the potential of peanut and related wild species as forage under various management methods.

CHAPTER 2
LITERATURE REVIEW

The Genus *Arachis*

The genus *Arachis* originated in South America east of the Andes and north of latitude 35° S, including countries of Bolivia and Brazil (Simpson, 1984). It includes both annual and perennial species, as well as diploid (2n=2x=20) and tetraploid (2n=4x=40) species (Stalker, 1990). Although over 70 species have been reported within the genus *Arachis*, until recently only 23 species, 1 botanical variety, and 1 hybrid were validly described (Singh and Simpson, 1994; Gregory and Gregory, 1976; Resslar, 1980; Stalker and Moss, 1987; Stalker, 1990; Stalker, 1991). Krapovickas and Gregory (1994) published a detailed work describing 69 species distributed in 8 Sections (Table 1).

Arachis hypogaea is an amphidiploid (2n=4x=40) that includes the genomes A and B. The putative diploid donor of the B genome is almost certainly *Arachis batizocoi* Krap. et Greg. while for the A genome both *Arachis duranensis* Krap. et Greg. and *Arachis villosa* Benth are considered depending on the cultivated peanut subspecies (Singh, 1988):

- *Arachis hypogaea* ssp. *fastigiata* (A'A'BB)

  A. batizocoi (2n=20; BB) x *A. duranensis* (2n=20; A'A')

- *Arachis hypogaea* ssp. *hypogaea* (AABB)

  A. batizocoi (2n=20; BB) x *A. villosa* (2n=20; AA)

In order to give a better idea about the crossability of the wild species into cultivated peanut and their potential use for plant breeding, the genus *Arachis* was divided into 4 main gene pools (Singh and Simpson, 1994):

a) Primary – includes the tetraploid species in the section *Arachis* i.e. peanut and *Arachis monticola* Krap. et Rig.

b) Secondary/Tertiary – includes all the diploid species in the section *Arachis* with genomes A and B all of which are potentially cross-compatible.

c) Tertiary/Fourth – includes Section *Procumbentes*, which probably co-evolved with the perennial species in the section *Arachis* and can share genes with *A. hypogaea*. In this case crossing with cultivated peanuts may be difficult.

d) Fourth/Fifth – includes all the remaining sections and are mostly cross-incompatible or weakly compatible with *A. hypogaea*.

Because of its relationship and crossability with cultivated peanut Section *Arachis* is the most important for breeding programs (Gregory et al., 1973; Resslar, 1980; Smartt and Stalker, 1982).

Table 1 – Brief description of the genus Arachis, including selected species, genome, ploidy levels, and gene pool.

Section/Series	Number of described species/ Distinguishing trait	Genome	Ploidy level (2n=)	Species	Gene pool
Arachis	17 species	D	2x=20	A. glandulifera Stalker	Secondary/ Tertiary
	Annuals and biennals	B	2x=20	A. batizocoi Krap. et Greg.	
		A	2x=20	A. duranensis Krap. et Greg.	
		A	2x=20	A. stenosperma Greg. et Greg.	
		A	2x=20	A. ipaënsis Krap. et Greg.	
		AB	4x=40	A. *hypogaea* L.	Primary
				A. *monticola* Krap. et Rig.	
	10 species	A	2x=20	A. *hellodes* Martius ex. Krap. et Rig.	Secondary/ Tertiary
	Perennials			A. *villosa* Benth	
				A. *correntina* (Burkart) Krap. et Greg.	
				A. *cardenasii* Krap. et Greg.	
				A. *diogoi* Hoehne	

(continues)

Table 1 – continued.

Section/Series	Number of described species/ Distinguishing trait	Genome	Ploidy level (2n=)	Species	Gene pool
Trierectoides	2 species	E_1	2x=20	A. *guaranitica* Chod. et Hassl. A. *tuberosa* Benth	Fourth/Fifth
Erectoides	12 species	E_2	2x=20	A. *benthamii* Handro A. *martii* Handro A. *paraguariensis* Chod. et Hassl.	Fourth/Fifth
Procumbentes	8 species	P	2x=20	A. *rigonii* Krap. et Greg. A. *lignosa* Krap. et Greg. A. *kretschmeri* Krap. et Greg.	Tertiary/Fourth
Caulorrhizae	2 species	C	2x=20	A. *repens* Handro A. *pintoi* Krap. et Greg.	Fourth/Fifth
Rhizomatozae Series Prorhizomatozae	1 species	R	2x=20	A. *burkartii* Handro	Fourth/Fifth

(continues)

Table 1 - continued.

Section/Series	Number of described species/ Distinguishing trait	Genome	Ploidy level (2n=)	Species	Gene pool
Rhizomatozae	2 species	2R	4x=40	A. *glabrata* Benth	Fourth/Fifth
Series Rhizomatozae			4x=40	A. *pseudovillosa* Krap. et Greg.	
			2x=20		
Extranervosae	9 species	Ex	2x=20	A. *pusilla* Benth	Fourth/Fifth
				A. *marginata* Gardner	
				A. *lutescens* Krap. et Rig.	
				A. *prostrata* Benth	
				A. *villosucarpa* Hoehme	
Heterantae	4 species	AM	2x=20	A. *sylvestris* A. Chev.	Fourth/Fifth
				A. *dardani* Krap. et Greg.	
Triseminatae	1 specie	T	2x=20	A. *triseminata* Krap. et Greg.	Fourth/Fifth

The Peanut Crop

The cultivated peanut originated in South America in parts of Argentina, Bolivia, Brazil, Paraguay, and Uruguay (Krapovickas, 1973; Krapovickas and Rigoni, 1957; Ramanatha Rao, 1987) and is cultivated in more than 80 countries in the tropical, sub-tropical and warm temperate regions between the latitudes 40°N and 40°S (Ramanatha Rao and Murty, 1994).

Based on the plant characteristics *A. hypogaea* have been classified into two fully crossable subspecies (subsp.) and four botanical varieties (var.) (Ramanatha Rao and Murty, 1994; Singh and Simpson, 1994):

- Species = Arachis hypogaea L.
  1. subsp. *hypogaea*
     - With seed dormancy.

     i. var. *hypogaea* – type "Virginia"
     - Usually with 2-seeded pods.
     - Medium-late maturing.
     - Prostrate to erect.
     - Region associated: Bolivia and Amazonia.

     ii. var. *hirsuta* Kohler – type "Peruvian"
     - 2 to 4 seeds pod^{-1}.
     - Very late maturing.

- Prostrate.
- Region associated: Peru.

2. subsp. *fastigiata* Waldron
   - Erect.
   - Seed dormancy usually absent.

   i. Var. *fastigiata* – type "Valencia"
      - 2 to 4 seeds pod^{-1}.
      - Region associated: Guarania, Goiás, Minas Gerais, Peru, and northeast Brazil.

   ii. Var. *vulgaris* Harz – type "Spanish"
      - 2 seeds pod^{-1}.
      - Region associated: Guarania, Goiás, Minas Gerais, and northeast Brazil.

In the U.S., four main market types are grown: runner, Virginia, Spanish, and Valencia, each one distinctive in size and flavor. Runner types are the most important, accounting for about 75% of the total U.S. production and grown mainly in Alabama, Florida, Georgia, Oklahoma, and Texas. Virginia types have the largest seeds and are concentrated in Virginia, North Carolina, and west Texas, accounting for 21% of the total US production. Spanish type seeds are usually small to medium sized, account for about 4% of the US production being grown mainly in Oklahoma and Texas. Valencia types have the least importance, accounting for less than 1% of the total production concentrated mainly in New Mexico. Valencias are roasted in shell or boiled (APCI, 1999; APC, 1999; APSA, 1999). The U.S. runner and Virginia market classes are composed mainly of Virginia type ancestry with substantial introgression from early Spanish ancestors (0-50% Spanish, averaging 35%) (Isleib et al., 1994). Around the world, Virginia and Spanish cultivars are the most commonly used, with a relatively smaller use of Valencia cultivars. In Africa, East Asia, and South Asia (including India) both Virginia and Spanish cultivars are used. While Virginia cultivars tend to be used with longer rainy seasons and inputs, the Spanish cultivars seem to be associated with shorter rainy seasons, need for drought tolerance, post-rainy season cultivation, as well as consumer preference. In Japan and Southeast Asia (Indonesia, Vietnam, the Philippines, and Thailand) Spanish cultivars tend to preferred (Isleib et al., 1994).

Peanut as Forage

Livestock production enterprises in the Southern USA depend mostly on forage for livestock feed (Ball et al., 1991). Research over the past 40 years has established that rhizoma perennial peanut (*A. glabrata* Benth) cvs. 'Florigraze' and 'Arbrook' are high yielding and produce forage with quality similar to alfalfa with *in-vitro* organic matter digestibility (IVOMD) greater than 60% (Prine et al., 1981; Gelaye and Amoah, 1991). These cultivars are better adapted to tropical and subtropical environments than alfalfa (Gelaye and Amoah, 1991). A limitation to extensive use of these cultivars is that rhizoma perennial peanut must be sexually propagated requiring at least two years to reach adequate establishment and full production (Prine et al., 1981). Additionally, perennial peanuts are best adapted to peninsular Florida (Prine et al., 1981), leaving North Florida and other areas of the Southeastern Coastal Plains in need of a well adapted summer forage legume crop.

The cultivated peanut might be a solution to this problem. It is well adapted to the Southern USA, has good potential for high forage quality and yield similar to those of perennial peanut and alfalfa (Gorbet et al., 1994). Prior to the implementation of the current commodity price support programs, research in Alabama demonstrated that the cost of peanut forage production was about half that of alfalfa, while maintaining similar milk yields (Hawkins and Autrey, 1957). Cultivated peanut forage yields of 6000-8000 kg ha^{-1} have been reported (Cook and Crosthwaite, 1994; Gorbet et al., 1994).

Late in the 19^{th} century, peanut vines were considered to be a very good provender for all stock and a excellent fodder for cattle, sheep, mules and horses. The peanut was regarded as a multipurpose crop providing multiple benefits to the farmers: supplying a staple shell that commands ready cash; fattens hogs with leftover pods; provides good hay in the vines. However, the peanut had to be harvested before the leaves fell to any great extent and before frost injury (Jones, 1885).

In the first half of the 20^{th} century, cultivated peanut in the U.S. was grown both for the seed as well as forage (Sturkie and Williamson, 1951). In Florida, prior to 1950, more peanuts were hogged-off every year than harvested (Killinger et al, 1947; Figure 1), while the area harvested for seed was roughly similar to that harvested for hay (Figure 1). When the area was to be hogged-off, hay could be mowed or grazed ahead of time (USDA, 1905). At pod harvest peanuts used to be stacked not only for drying the pods but also to allow fencing to protect the nuts from the hogs usually released into the field (Killinger et al, 1947). From the early 1950s onwards, both the area hogged-off and harvested for hay was reduced until these practices almost disappeared after 1970 (Figure 1).

In other parts of the world, peanut hay is often used, particularly in developing countries. Peanut hay uses can quite diverse. It is a source of energy for draught animals during the winter in developing countries of Africa (Francis and Ndlovu, 1995) and Asia, therefore allowing for early planting and better yields. In Australia, peanut hay is a source of additional income, accepted as a secondary peanut product (Cook and Crosthwaite, 1994).

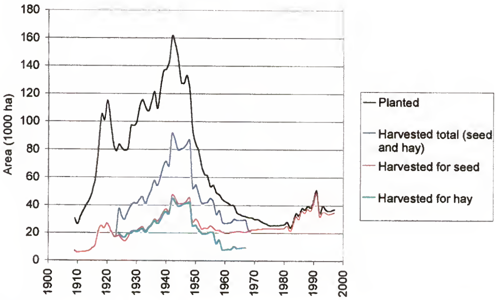


Figure 1 - Evolution of peanut planted and harvested area in Florida (Mullin, 1969; USDA, 1998).

Old cultivars like Dixie Runner produced about twice as much forage as pods (Carver, 1953; Sturkie and Williamson, 1951). More recently cultivars with higher pod yields usually have lower harvest indexes (Carver, 1961; Cummins and Smith, 1973; Knauft and Gorbet, 1990; Norden et al., 1969). The same trends were observed in 50 years of peanut breeding in North Carolina, where research showed increases in seed yield and harvest index while vegetative mass and plant height decreased (Wells et al., 1991).

Presently, very little cultivated peanut hay is harvested (Cummins and Smith, 1973; Knauft and Gorbet, 1990; Norden et al., 1969). One reason for this may be linked to the windrow harvest technique that causes large losses in forage and hay quantity and quality (Young et al., 1982). Switching to a once-over harvest method, whereby the pods are striped from live plants at the time of digging, could increase the possibilities of using peanut vines for forage and hay (Young et al., 1982).

The optimum harvest time for peanut forage is reached well before maximum pod and seed yield is attained (Wright et al., 1991). The peak for forage harvest occurs at about 90 days after planting, while digging is usually done at 130 to 140 days after planting (Cook and Crosthwaite, 1994). The forage peak may be delayed if the crop is irrigated. While forage dry matter yield reaches its maximum at about 20 weeks after planting, the highest nitrogen (N) concentration in the tops is reached at 12-16 weeks after planting (Santos and Sutton, 1982). Therefore, to achieve the best results, a compromise has to be established between forage yield and quality.

Defoliation such as harvesting forage during the crop cycle is expected to reduce pod yield. However, defoliation up to early pod formation may not cause significant pod yield reduction and produces higher quality forage (up to 6-10 weeks after planting). Any delays in defoliation beyond 10 weeks after planting will likely reduce seed yield and lead to lower crude protein content and lower IVOMD of the harvested tops (Santos and Sutton, 1982).

Based on five years of data, Gorbet et al. (1994) reported that the mean forage yield of five breeding lines increased from 5260 kg ha^{-1} with one cut, to 7200 kg ha^{-1} with two cuts, while Southern runner and UF81206 increased from 3750 kg ha^{-1} and 4800 kg ha^{-1} to 5770 kg ha^{-1} and 6450 kg ha^{-1}, respectively. Meanwhile, mean pod yields for the breeding lines were reduced from 2120 kg ha^{-1} with one cut, to 1480 kg ha^{-1} with two cuts, while Southern runner and UF81206 decreased from 2860 kg ha^{-1} and 3530 kg ha^{-1} to 1920 kg ha^{-1} and 2400 kg ha^{-1} respectively. On the other hand, crude protein concentration (CP) and IVOMD of the tops showed a general increase. Crude protein changed from 12.4-15.2% with one cut to 14.2-19.6% for both harvests when two cuts were used, while IVOMD increased from 55.7-62.9% with one cut to 61.1-72.1% for both harvests with two cuts. Cook and Crosthwaite (1994) reported a much wider range of CP concentration ranging from 6% to 20%.

Gorbet et al. (1994) concluded that breeding lines with good potential for forage quality, resistance to leaf spots, and no fungicide requirements are available in the Florida breeding program.

Diseases and Insects of Cultivated Peanut

Leaf spots (early leaf spot *Cercospora arachidicola* Hori, and late leaf spot *Cercosporidium personatum* (Berk. and Curt.) Deighton, also known as *Phaeoisariopsis personata* (Berk. and Curt.) Arx, are among the most damaging diseases affecting the peanut crop (Gorbet et al., 1994; Smith et al., 1994; Ouedraogo et al., 1995). If fungicides are not applied early and late leaf spots as well as rust (*Puccinia arachidis* Speg.) can cause complete defoliation lowering pod and forage yields (Gorbet et al., 1994; Cook and Crosthwaite, 1994; Gorbet et al., 1990) as well as forage quality (Cummins and Smith, 1973). Recent cultivars tend to be highly susceptible to both leaf spot diseases (Gorbet et al., 1994), likely to be related to a increased dependence on fungicides in breeding and selection nurseries.

Leaf spot can be controlled effectively with fungicides leading to increases in pod and forage yields (Cummins and Smith, 1973; Gorbet et al., 1987; Norden et al., 1969) as well as forage protein concentration and IVOMD (Gorbet et al., 1994) mainly because of reduced defoliation (Cummins and Smith, 1973). However, these fungicides generally are not cleared by the EPA (Environmental Protection Agency - USA) for use on forage which will be consumed by livestock (Cummins and Smith, 1973; Young et al., 1982).

One method with potential for management of disease pressure is the use of multiple harvests. By increasing the number of forage harvests from one to two, Gorbet et al. (1994) reduced the leaf spot scores (scale 1-10) from 3.2-4.0

to 2.9-3.8 for all entries except 'Southern Runner' (4.7 and 4.5 with one and two harvests, respectively).

The best leaf spot management method is clearly the use of resistant cultivars that have the advantage of permitting a reduction in production cost (Gorbet et al., 1990). Some cultivars, including Southern runner, have moderate levels of rate reducing resistance to late leaf spot (Gorbet et al., 1990), but they require application of fungicides at 14-21-day intervals, requiring a total of 4-8 sprays to achieve good control and yield (Smith et al., 1994; Gorbet et al., 1987).

High levels of leaf spot resistance have been identified especially in wild *Arachis* species (Anderson et al., 1996; Holbrook and Anderson, 1995; Anderson et al., 1993; Sowell et al., 1976). In the case of late leaf spot, resistance mostly due to reduced rates of infestation was found in accessions of *A. duranensis, A. batizocoi, A. monticola, A. paraguayensis* Chod. et Hassl., *A. villosulicarpa* Hoehme, *A. hagenbackii* Harms, and *A. glabrata* Benth (Subrahmanyam et al., 1985a). Germplasm entries of *A. cardenasii* Krap. et Greg., *A. chacoense* Krap. et Greg., and *A. stenosperma* Greg. et Greg. with immunity or high levels of resistance to leaf spots and rust were also identified (Nigam et al., 1991; Singsit et al., 1995). The resistance to late leaf spot and rust was found to be stable over environments, while the resistance to early leaf spot was not as stable even in the wild relatives (Nigam et al., 1991).

The introgression of resistance genes (leaf spots, root-knot nematodes) from species like *A. cardenasii* and *A. chacoense* into cultivated peanut can be successful if *A. batizocoi* is used as a bridge species (Simpson, 1991). However, the transfer of resistance to commercially acceptable cultivars has not been easy because of cross-incompatibility and sterility (Wynne and Gregory, 1981; Singh et al., 1980; Gregory and Gregory, 1979), especially because of problems with recombination and stability of the chromosomes (Singsit et al., 1995). Even though no cultivars have been released with the high levels of resistance from the wild relatives, the genes conditioning early and late leaf spot resistance, high yield and acceptable shelling percentages were combined in at least one interspecific line (Ouedraogo et al., 1995). Hybrids of *A. cardenasii* x *A. hypogaea* have shown high levels of early leaf spot resistance and can be used as source of resistance (Stalker, 1984).

Another hurdle to peanut breeding programs is the negative correlation between leaf spot resistance and early maturity (Higgins, 1956; Kolte, 1984; Miller et al., 1990; Norden et al., 1982; Smith, 1984). Resistance to rust and late leaf spot, moderate levels of resistance to early leaf spot, and multiple disease resistance to the three diseases have been identified within *Arachis hypogaea* (Nigam et al., 1991), but almost always associated with late maturity. Recently, earlier maturing genotypes with high yield and leaf spot tolerance have been identified (Branch and Culbreath, 1995). Studies of inheritance patterns have shown that the genetic control of both early and late leaf spots are controlled by multiple loci (Nevil, 1982; Sharief et al., 1978), with potential involvement of cytoplasmic factors (Chiteka et al., 1997).

Tomato spotted wilt virus (TSWV) has recently become a critical limiting factor for peanut production in Florida and Georgia, with a complex management system that includes several tools like proper cultivar selection, optimal planting date, high plant density, and the use of insecticides (phorate) (Culbreath et al., 1998). The best control method for TSWV is clearly the use of resistant cultivars (Anderson et al., 1996). Partial field resistance to TSWV was found in Southern Runner (Gorbet et al., 1987; Culbreath et al., 1993), 'Georgia Green', 'Virugard', and 'Florida MDR 98' (ex-UF91108) (Culbreath et al., 1998). Other research regarding TSWV has identified 27 plant introductions with greater levels of resistance than Southern runner (Anderson et al., 1996). Recently, through joint research done in Florida and Georgia, several breeding lines with good levels of TSWV resistance were reported, but none seems to be significantly more resistant than Georgia Green (Culbreath et al., 1998).

Resistance to peanut rosette, a virus-caused disease, although present in some peanut germplasm was also found in *A. chacoense* and backcrossed into *A. hypogaea* (Moss et al., 1993). However, the search for virus resistant cultivars should not be restricted to the resistance to the virus *per se*, but also to the resistance to their vectors. The primary vector of rosette is aphids, while the primary vector of TSWV is thrips. Variable levels of resistance to insects like aphids and thrips have been found both in *A. hypogaea* and wild relatives (Nigam et al., 1991).

Root-knot Nematodes

Porter et al. (1982) reported that root-knot nematodes (RKN), *Meloidogyne* spp., are the most important group of plant-parasitic nematodes limiting peanut yield, with potential losses as high as 50% (Riggs and Niblack, 1993). Although *M. arenaria* race 1, *M. hapla*, and *M. javanica* have been reported to parasitize peanut (Riggs and Niblack, 1993; Sakhuja and Sethi, 1985; Ingram and Rodriguez-Kábana, 1980; Franklin, 1978; Taylor and Sasser, 1978), none of the perennial peanuts showed visual symptoms of nematode damage (Rich et al. 1995).

To achieve adequate management of the root-knot disease, the use of crop rotation, host resistance, and adequate chemical control tactics are recommended. Ideally, resistant cultivars should be used alone or in combination with crop rotation and cultural techniques in order to reduce the infestation to economically viable levels (Porter et al., 1982).

Appropriate crop rotations are difficult to develop because of the wide host range of the root-knot nematodes. Franklin (1978) reported species such as *Aphelandra*, *Sanseveria*, *Maranta*, *Gerbera*, *Petunia*, carnation, *Primula*, violet, almond, peach, olive fig, grapevine, forage beet, and lettuce were hosts for *M. arenaria* race 1. More recently, Griffin and Rumbaugh (1996) added 11 legumes to this already extensive list. However, it is important to stress that the continuous cultivation of peanut or the use of short peanut rotations may increase root-knot disease because of the rapid increase in the nematode populations (Norden et al., 1982). Rotation with grasses such as bahiagrass have been shown to reduce RKN population by lowering the population of juveniles (J2) (Rodriguez-Kábana et al., 1994).

Although peanut resistance to *M. arenaria* has been reported (Norden et al., 1982), little information is available about peanut resistance genes (Roberts, 1995). Edwards (1956) reported that 'Natal Common' and 'Kumawu Erect' (both Spanish cultivars) were highly resistant to the peanut RKN. Milton and Hammons (1975), and Holbrook (1981) tested a combined total of over 5000 entries and germplasm lines and found no resistance to RKN (*M. arenaria* race 1). Holbrook and Noe (1992) reported 28 plant introductions with moderate levels of resistance to *M. arenaria* race 1, indicating that full resistance is still far away. More recently, 17 additional resistant lines were identified (Holbrook et al., 1996).

A source of genes for resistance to RKN in peanut is the wild species of *Arachis*. Ruttinger-Lamperti (1989) mentioned that high levels of resistance have been found in most perennial species of *Arachis*. Rhizoma perennial peanut cultivars 'Florigraze' and 'Arbrook' (both *A. glabrata*) were reported to be highly resistant to immune to *M. arenaria* (Baltensberger et al., 1986, Ruttinger-Lamperti, 1989). Evaluation of germplasm belonging to the species *A. glabrata*, *A. repens* (Ruttinger-Lamperti, 1989), *A. stenosperma* (Singsit et al., 1995), *A. cardenasii*, *A. chacoense*, *A. duranensis*, *A. sylvestris*, and *Arachis* spp. (Nelson et al., 1989) were reported as possessing some level of resistance to RKN (*M. arenaria* race 1). However, these species range from very difficult to impossible to hybridize with cultivated peanut. Starr et al. (1990) using a nematode resistant interspecific hybrid (with parents from *A. batizocoi*, *A. cardenasii*, *A. chacoense*, and *A. hypogaea*) concluded that the RKN resistance is not identical to any of the parental lines, suggesting multiple parent origin of the resistance genes. This partial resistance to peanut RKN was successfully transferred into *A. hypogaea* by backcrossing using well known cultivars like 'Florunner', 'Tamnut 74 and 90', and 'NC7' as recurrent parents (Starr et al., 1995). Recently a new runner cultivar ('COAN') with resistance to peanut RKN was released in Texas. Interestingly this cultivar was produced from an interspecific hybrid involving wild species *A. cardenasii*, *A. batizocoi*, and *A. chacoense*, and then backcrossed with Florunner as the recurrent parent (Simpson and Starr, 1999; Simpson, personal communication).

Seed Dormancy

Seed dormancy is a standard characteristic in some subspecies of peanut, and is usually associated with the systematic classification which was summarized by Bailey and Bear (1973):

- Virginia type peanuts – *Arachis hypogaea* L. ssp *hypogaea* var. *hypogaea* – has seed dormancy.
- Spanish type peanuts - *Arachis hypogaea* L. ssp *fastigiata* var. *vulgaris* – has no seed dormancy.
- Valencia type peanuts - *Arachis hypogaea* L. ssp *fastigiata* var. *fastigiata* – has no seed dormancy.

Depending on the existing farming system, both producers and researchers refer to pluses and minuses associated with dormancy. While in USA where Virginia peanuts (runner and Virginia market types) are the most common, very long seed dormancy becomes a problem because it can reduce the stand. Reducing the dormancy period in Virginia peanuts could also allow for the use of seed recently produced elsewhere, with high germination percentage, which is especially advantageous for breeding programs speeding up the cultivar development period. On the other hand incorporating fresh seed dormancy, even for a short period, in Spanish peanuts could avoid seed germination in field (Sanders et al., 1982) especially when there is a risk of rainfall during the harvesting period. This problem can be accentuated in heavier soils because of higher soil water storage. However, it is the seed dormancy of the Virginia peanut cultivars that renders them more suited for permanent forage or hay fields, allowing the peanut seed to survive in the field, only germinating in the spring when the soil temperatures warm to the optimum for germination. Therefore, while some want to remove at least part of the dormancy from runner peanuts, others want to introduce dormancy into Spanish peanuts. This has already been partially achieved. Breeders have already reduced seed dormancy in runner peanuts, and fresh seed dormancy has been added to Spanish cultivars (Upadhyaya et al., 1997; Reddy et al., 1987; Manoharan et al., 1994) transferred from Virginia peanuts (Sarala and Gowda, 1997). The heritability of seed dormancy has been reported to range from 0.49 to 0.57, which is sufficient for a successful pedigree selection program (Khalfaoui, 1991). In a recent study a single gene was found to control fresh seed dormancy, with dormancy dominant over non-dormancy (Upadhyaya and Nigam, 1999) which indicates the existence of different sources of genes controlling seed dormancy.

Breaking of dormancy occurs naturally during the afterripening of the seeds. The period to terminate dormancy depends on storage temperature, being short at high temperatures (45°C) and longer at low temperatures, but always decreasing with time (Sreeramulu, 1974; Sharir, 1978). Besides, as the afterripening progresses germination increases.

After dormancy is broken, peanut germination is controlled by temperature. According to Mohamed et al (1988), the optimum temperature for germination ranges from 29-36.5°C, with base temperatures of 8-11.5°C and maximum temperature of 40-47°C.

Seed dormancy can be broken by high temperatures during storage or by the application of ethylene (Perl, 1982b; Ketring and Morgan, 1971). Seeds of Spanish cultivars (non-dormant) produce ethylene in early stages of development (Whitehead and Nelson, 1992) (mainly from the embryo) while, in Virginia cultivars, dormant seeds have lower ethylene production than non-dormant (after breakage) (Ketring and Morgan, 1969 and 1970). Therefore, these authors correlated ethylene production to germination and treatments to break dormancy. Substances like ethephon and 2-chloroethylphosphoric acid (CEPA) can be used to achieve the same effect as ethylene (Perl, 1982a; Ketring and Morgan, 1971).

The breaking of dormancy is a complex process that involves inhibitors like ABA, promoters like kinetin, ethylene, auxins, and gibberelins (Swamy and Sandhyarani, 1986; Ketring and Morgan, 1971 and 1972). The Pentose Phosphate (PP) pathway seems to have an important role in the dormancy process through the activity of the PP pathway enzymes and their interaction mainly with ABA, kinetin and ethylene (Swamy and Sandhyarani, 1986; Ketring and Morgan, 1971 and 1972).

The intensity of dormancy is affected by cultural practices, mainly harvest timing, with the longer period in the field being related to lower seed dormancy (Sanders et al., 1982).

Perennial Peanut as Forage

Rhizoma perennial peanut is a tropical forage legume native to South America from a region between the latitudes 8°S and 35°S (Brazil, Paraguay, Peru) (Gregory et al., 1973). This species is a rhizomatous summer perennial adapted to deep, well-drained, sandy soils (Skerman, 1988; Prine et al., 1981; French et al., 1993), and well adapted to the Florida climate, with mild winters, and warm and humid summers, which allows the underground rhizomes not to be killed by freezing (Prine and French, 1992).

At present, about 8000 ha of *A. glabrata* are under cultivation in Florida. It grows mostly during the period from late spring to early fall (Prine et al, 1981), with the best results obtained when planted on well prepared fields between early February to late March, when the rhizomes are dormant (Williams, 1993; French and Prine, 1991). Some research supports an expanded planting period from late winter to early summer (Williams et al., 1997). However, there is evidence that *A. glabrata* can be planted whenever there is enough soil moisture for 60-90 frost-free days after planting (Williams et al., 1997). Rhizomes for propagation can be obtained from 3 years old fields (Prine et al., 1986b).

The main advantages of *A. glabrata* are that it is a drought tolerant perennial (French, 1988); tolerant to the mild freezing winter temperatures of Florida; reduced production cost (requires no N); low insect and disease incidence; ability to be intercropped or overseeded (Krouse et al., 1986; Prine et al., 1981); excellent competitiveness against weeds (Atkinson, 1993); good forage quality that is similar to alfalfa in both protein content and digestibility (French and Prine, 1989; French, 1991; Ball et al., 1991); and yields as high as 12000 kg ha-1 (Beltranema et al., 1981; Ocumpaugh, 1990; Dunavin, 1992). Rhizoma perennial peanut is also persistent under a wide range of management systems and adapted to grazing as long as an appropriate combination of grazing cycle and stubble height is used (Ortega-S. et al., 1992).

The main disadvantages of *A. glabrata* are the slow establishment and initial growth during the first year, only reaching full production during the second or third year (Prine, 1985); not producing seed and therefore requiring vegetative propagation (Atkinson, 1993; Williams, 1994a; Williams et al., 1997); not responding to fertilizer applications (Prine et al., 1986a); being less well adapted to wet flatwood soils; and having the potential to be invaded by perennial grasses.

However, in Australia, *A. glabrata* showed good potential as commercial pasture able to compete with aggressive grasses and producing better yields than bahiagrass (*Paspalum notatum* Flugge) (Bowman and Wilson, 1997). Cook (1997), also in Australia, found an introduction of *A. glabrata* from the early 1950s that still persisted and was released as cv. 'Prine'. He also found other perennial peanut species (*A. paraguariensis*) that persisted and expanded almost unattended for 60 years after its introduction.

The forage quality of rhizoma perennial peanut is similar to that of alfalfa with CP ranging 10%-22.3% and IVOMD ranging 45%-78% (Prine et al., 1973; Cook and Crosthwaite, 1994; Dunavin, 1992). Beltranema et al. (1981) reported forage quality increments with the reduction of the time between harvests from 12 weeks to 2 weeks (14.7% to 21.9% CP and 64.8% to 74.0% IVOMD respectively).

Pure perennial peanut stands may have a shorter grazing period than bahiagrass (Sollenberger et al., 1987). When grown in mixtures with Pensacola bahiagrass or Tifton 44 bermudagrass, the perennial peanut component tends to be reduce over time. It maintained a good quality mixture up to 6 years, but after 8 years, the perennial peanut component was reduced to 2% when mixed with bahiagrass and 25% when mixed with bermudagrass (Dunavin, 1992). However, mixed swards of perennial peanut and bahiagrass can be highly productive if grazing and nitrogen are used as tools to manage the botanical composition of the sward (Williams, 1994a).

Some facts must be known while attempting to manage the composition of mixed bahiagrass-perennial peanut swards (Williams, 1994a):

- During spring (April-June) bahiagrass has a lower relative growth ratio (RGR) than perennial peanut and hence is less competitive;

- Bahiagrass grows at lower moisture levels than perennial peanut, becoming more susceptible to grazing during drought periods;
- During summer, bahiagrass has higher RGR than perennial peanut and requires nitrogen (112 kg N ha^{-1}) to reach full yield.

Changes in environmental conditions, crop management, and soil disturbance seem to be related to increased flowering of *Arachis glabrata* that although a prolific flower producer, seeds were never found (Williams, 1994b). Nevertheless, seedlings have been identified and selected from fields of Florigraze but they were always less vigorous than the mother plant (Venuto et al., 1997). This limitations have restricted the breeding activities to screening and evaluation of plant introductions (Gregory et al., 1973).

Summary

Previous research has demonstrated that use of peanut vines for forage is a viable cultural practice. New breeding lines and cultivars with moderate levels of leaf spot, rust, and RKN resistance are being developed. The manipulation of seed dormancy is possible. All the components needed for the establishment of a production system involving cultivated peanut as a forage crop are available, which leads to the establishment of this research project with the objective to study the potential of peanut and related wild species as forage under various management methods.

CHAPTER 3
EFFECTS OF FORAGE HARVEST MANAGEMENT ON SELECTED GERMPLASM OF PEANUT (*Arachis hypogaea* and *Arachis* spp.)

Introduction

The release and expanding use of rhizoma perennial peanut, a forage with high quality similar to alfalfa, have inherent advantages to Florida's dairy and beef industries. The long establishment period of this species and its lack of seed production are the main negative reasons leading to the search of alternatives.

Cultivated peanut produces vines with forage quality similar to perennial peanut and alfalfa, but the susceptibility of most commonly used cultivars to insects and diseases, and their dependence on fungicides to achieve high nut yields, have kept this crop out of the list of potential alternatives for Florida's farmers. New peanut cultivars (Gorbet et al., 1998) and breeding lines with multiple disease resistance, therefore less dependent on the use of chemicals creates a new perspective for this crop.

Florida MDR 98 (also known as UF91108) was released in 1998 and is a good example of the recent breeding advances. In a total of 28 unsprayed tests conducted in Marianna, MDR 98 produced higher pod yields (3046-3708 kg ha^{-1}) than either Southern Runner or Florunner (2635-3189 kg ha^{-1} and 861 kg ha^{-1} respectively). At the same time, late leaf spot incidence was lowest in MDR 98

(4.4-4.6) compared with Southern Runner and Florunner (4.6-5.3 and 9.5 respectively). MDR 98 resulted from the cross between Southern Runner, a multiple disease resistance cultivar released in 1986, and an F_1 plant from the cross Andru93 x UF81206, with UF81206 being the main source of disease resistance. UF81206 has better resistance to late leaf spot, rust, white mold (*Sclerotium rolfsii*), and peanut root-knot nematode than Southern Runner (Gorbet et al., 1998).

Aiming at the multipurpose use of peanut (pods and vines), the management decisions regarding harvesting the vines more than once becomes of vital importance. Harvesting once at the end of the crop cycle allowed a higher pod and kernel yield than the use of two harvests (2120-3530 kg ha^{-1} vs. 1480-2400 kg ha^{-1}), with UF81206 outyielding Southern Runner and eight other entries including five breeding lines. Concurrently, a lower forage yield was obtained with one harvest compared with two harvests (3750-5260 kg ha^{-1} vs. 5770-7210 kg ha^{-1}), with the breeding lines yielding the most, followed by UF81206, while Southern Runner had the lowest yield. However, two harvests reduced late leaf spot intensity, and increased forage quality (Gorbet et al., 1994).

Based on the information presented, an experiment was established with the following objectives:

- Study the potential of cultivated peanut (*Arachis hypogaea*) as forage.
- Test the performance of different entries under two different harvest management methods.

- Evaluate the persistence of different peanut entries across years.
- Identify the best harvest management method.
- Identify the best adapted entries for future use as parents in a breeding program.

Material and Methods

Location and Experimental Design

The experiment was conducted on a loamy sand (Kendrick loamy sand; loamy, siliceous, semiactive, hyperthermic Arenic Paleudults) (USDA-SCS, 1985; NCSS, 1999) located at the Green Acres Research Farm near Gainesville, Florida. The experiment was conducted in two seasons (1996 and 1997) and planted in a strip-plot design with genotypes (entries) as whole-plots (Table 2) and two harvest management methods as sub-plots (Table 3). There were five replications in 1996 and four in 1997. Different sub-plot sizes were used in 1996 and 1997, amounting to two 2 m rows in 1996 and four 2.8 m rows in 1997. Using a planting spacing of 0.6 m between rows and a within row spacing of 0.075 m for *A. hypogaea*, and 0.15 m for the other species the sub-plot size amounted to 2.4 m^2 and 6.72 m^2 in 1996 and 1997, respectively.

In 1996 20 entries were used for the whole plots while in 1997 only 15 were planted. The entries were selected to account for various desirable qualities and divided into 3 main groups (Table 2):

1. With resistance to leaf spots and rust (resistance to other diseases would be advantageous).

2. With potential resistance to nematodes (Meloidogyne arenaria).

3. Derivatives from crosses with wild relatives and wild relatives.

4. Control - Southern Runner

Table 2 – List of the entries used by characteristic, including species and other identification.

Entry no.	Description	Species; Other names	Year used†
1. Resistance to leaf spots and rust			
1	84x23-1-1-1-2-b2-B	Arachis hypogaea	1,2
2	84x23-1-2-1-2-b3-B	*Arachis hypogaea*	1,2
3	84x28-5-4-1-2-2-1-b2-B	*Arachis hypogaea*	1,2
4	86x43-6-1-2-1-1-b2-B	*Arachis hypogaea*	1,2
5	86x43-1-1-1-1-1-b2-B	*Arachis hypogaea*	1,2
6	UF91108	*Arachis hypogaea*	1,2
2. Resistance to nematodes (Meloidogyne arenaria)			
7	UF81206	*Arachis hypogaea*	1,2
8	PI 268710 (Co.No. 7)	*Arachis hypogaea*; Natal Common	1
9	PI 290594 (Co.No. 230)	*Arachis hypogaea*	1
10	PI 269008 (Co.No. 457)	*Arachis hypogaea*; Kongwa Mixed	1
11	PI 268903 (Co.No. 461)	*Arachis hypogaea*; Early Ripening Bun	1,2
12	PI 399563 (Co.No. 696)	*Arachis hypogaea*; M25.68	1,2
13	TARS 4	*Arachis hypogaea*	1,2
3. Derivatives from crosses with wild relatives and wild relatives.			
14	8701	*Arachis pintoi* (Section Caulorrhizae)	1
15	18x7	*A. major* (S. Erectoides) x *A. repens* (S. Caulorrhizae)	1
16	96x7	*A. pintoi* (S. Caulorrhizae) x *A. repens* (S. Caulorrhizae)	1
17	39x34	*A.* sp. (S. Arachis, perennial) x *A. cardenasii* (S. Arachis, s. perennial)	1
18	Pantanal	*Arachis kretschmerii*; PI 446898	1,2
19	Arbrook	*Arachis glabrata*; PI 262817	1,2
21	Guanajuato-2	*A. hypogaea var. hirsuta*; PI 280688	2
4. Control			
20	Southern Runner	*Arachis hypogaea*; PI 506419	1,2
5. Others			
22	8815B-4-2-2-1-B	*Arachis hypogaea*; UF 1436; UF81206-2 x GPNC 343	2

† - Year the experiment was tested. 1 = 1996; 2 = 1997.

Table 3 - List of the sub-treatments used and their description.

Code	Sub-treatments	Description
H1	1 Harvest	At the end of the crop cycle (140 DAP)
H2	2 Harvests	At the middle and end of the crop cycle (80 and 140 DAP)

In both years, the entries were planted on the 25th of April and harvested close to the prescribed dates. In 1996 peanut forage was harvested at 88 and 133 days after planting (DAP), while in 1997 the harvests were done at 82 and 143 DAP (Table 4).

Table 4 – Important experimental dates, planting, and harvest dates by year.

	1996			1997		
	Planting	Harvest	DAP	Planting	Harvest	DAP
First season						
First harvest	25/Apr/96	22/Jul/96	88	25/Apr/97	16/Jul/97	82
Second harvest		05/Sep/96	133		15/Sep/97	143
Second season						
First harvest		22/Jul/97				

Cultural Practices

In order to generate recommendations adapted to the farmers' conditions, the crop was conducted using cultural practices similar to those used by forage or hay producers. As a result, irrigation, fertilizers, pesticides and other inputs were kept to a minimum.

Adequate weed control was achieved at planting, in order to guarantee at least a 30 days weed-free period (after planting). For this initial weed control, two herbicide applications were used: (1) a pre-planting, incorporated application of pendimethalin (0.85 kg ha^{-1} active ingredient); and (2) a post-emergence (3 weeks after planting) application of a mixture of paraquat + 2,4-DB + bentazon (0.14 + 0.22 + 0.56 kg ha^{-1} active ingredient).

The experiment was conducted as much as possible, without the use of irrigation. However, in cases of extreme drought, irrigation was supplied to allow survival of the plants. To justify the use of life saving irrigation, we must assume that we are not testing for extreme drought conditions with a low probability of occurrence and, therefore, irrigation becomes acceptable when extreme conditions occur.

Nutrients were supplied through an application of 500 kg ha^{-1} of 4-8-12 to all plots at planting, for a total of 20 kg N ha^{-1}, 40 kg P_2O ha^{-1}, and 60 kg K_2O ha^{-1}. No gypsum was applied. It is important to emphasize that the main purpose of the study was forage and not grain, the later requiring a larger amount of calcium for adequate pod filling.

No fungicides or insecticides were used. To control bird damage (primarily crows), the fields were flagged both at planting and at harvest.

<u>Data Collection and Analysis</u>

To determine forage dry matter yield, a strip of 0.9 m width was cut with a Jari mower at 7.5 cm height and the total fresh weight was measured. A random sub-sample of about 0.6 kg was then taken and dried at 80°C for at least 24 hours to constant weight. The percentage dry matter was then computed and applied to the total fresh weight to calculate the forage dry matter yield. Adjustments were also made based on the degree of weed contamination.

To evaluate pod and seed yield a 1 m row in each sub-plot was harvested. All pods were picked, sun-dried (about 8% moisture), and weighted. Pods were shelled and sound mature kernels selected and weighted. Weights were used to calculate pod and seed yields. Although samples were made, pod yields were not taken in 1997 because of the extremely low pod setting, pod filling and seed development, caused by the low rainfall that occurred from the time of first harvest to the second harvest.

The oven-dried forage sub-sample was than finely ground and analyzed for crude protein (CP) and *in-vitro* organic matter digestibility (IVOMD). After the digestion of the samples with a modified aluminum block digestion procedure (Gallaher et al., 1975; Sollenberger and Fethiere, 1998), nitrogen content was determined by semiautomated colorimetry (Hambleton, 1977; Sollenberger and Fethiere, 1998). Crude protein concentration was then computed by multiplying the nitrogen concentration by 6.25. IVOMD was performed by a modification of the two-stage technique (Moore and Mott, 1974; Sollenberger and Fethiere, 1998).

Relative to pest damage, early and late leaf spots scores were combined and followed the 1-9 scale proposed by Subrahmanyam et al. (1985c) (Appendix A). Observations were made prior to final harvest both in 1996 and 1997. Insect damage was scored using an informal 1-3 scale prior to final harvest and only in 1997 when damage from several insect pests including caterpillars, leaf hoppers and leaf minors reached notable proportions.

Weed infestation was only major in 1997 prior to final harvest and was scored as a percentage of the total plot area occupied by weeds.

All the data were submitted to analysis of variance combined over years and with replications nested into years, using the PROC GLM option in SAS 6.02 for windows. Because of a few cases of missing data and the use of unbalanced design, Type III sum of squares was used throughout. The analysis of variance was conducted using a model for randomized complete block design or split-plot design depending on the variable collected and the time of collection

Results and Discussion

Forage Dry Matter Yield

In all cases, forage dry matter yield (kg ha^{-1}) showed significant differences for the main effects (year, entry, and harvest management method) at less than 5% probability (Table 5). Excluding the three-way interaction year*harvest*entry, which was not significant, most of the two-way interactions also showed significant differences for peanut forage dry matter yield (kg ha^{-1}).

Table 5 – Summarized ANOVA table for peanut forage dry matter yield.

Peanut forage dry matter yield (kg ha^{-1})				
		First harvest		
	DF	MS	F value	Pr > F
Year	1	11979913	33.83	0.0001
Entry	17	4386974	12.39	0.0001
Year*Entry	12	918978	2.60	0.0049
Error	97	354121		
		Second harvest		
	DF	MS	F value	Pr > F
Year	1	108755404	249.03	0.0001
Harvest	1	68261435	156.30	0.0001
Year*Harvest	1	2197355	5.03	0.0488
Error (a)	7	436721		
Entry	17	4450117	14.33	0.0001
Year*Entry	12	633756	2.05	0.0220
Harvest*Entry	17	347173	1.11	0.3450
Year*Harvest*Entry	12	247932	0.82	0.6274
Error (b)	194	311403		
		Total harvest		
	DF	MS	F value	Pr > F
Year	1	165792136	195.46	0.0001
Harvest	1	65222222	76.89	0.0001
Year*Harvest	1	931409	1.10	0.3308
Error (a)	7	848212		
Entry	17	10204482	19.79	0.0001
Year*Entry	12	1503503	2.92	0.0010
Harvest*Entry	17	1651462	3.20	0.0001
Year*Harvest*Entry	12	461076	0.89	0.5538
Error (b)	194	515586		
		First harvest - second year (1997)		
1996, first harvest	DF	MS	F value	Pr > F
Entry	19	3860830	5.79	0.0001
Error	51	666996		

First and foremost it is important to emphasize that the yields of the interspecific hybrids were quite low and therefore no dry matter yields will be presented. However, it should be noted that the interspecific hybrids maintained full ground cover with few weeds and may have potential as turf type plants. With one exception, for the first harvest at about 80 days after planting, peanut forage yield was always significantly higher in 1996 than in 1997, averaging 2310 kg ha^{-1} and

1760 kg ha^{-1} respectively (Table 6,

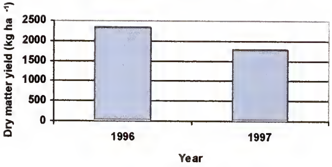


Figure 2, and Figure 3). The lower yields obtained in 1997 probably were related to the higher total rainfall and near waterlogged conditions during the first half of the crop cycle in 1997 (480 mm in 1996 and 610 in 1997). In contrast, three entries TARS, Pantanal, and Arbrook formed a separate group with forage yields that were significantly lower than all the other entries in both years (Table 6).

For the second harvest, the forage yields obtained in 1996 (2500 kg ha^{-1}) were always higher than that for 1997 (1270 kg ha^{-1}) (Table 7 and Figure 4). On average, the higher forage yields were obtained by the breeding lines 86x43-6-1, 86x43-1-1 and 81206, and the entry TARS ranging from 2360 kg ha^{-1} to 2710 kg ha^{-1}. Although in 1996, these entries yielded significantly more than most of the other entries including Southern Runner, their yield was not different from most of the other entries in 1997. Southern Runner, the control entry, had an intermediate yield in 1996 (2230 kg ha^{-1}) and one of the lowest yields in 1997 (750 kg ha^{-1}).

In 1996, PI 268710, also known as Natal Common, an early maturity Spanish cultivar, susceptible to leaf spots and rust suffered extensive defoliation, had limited regrowth after the first harvest which resulted in a low forage yield (1510 kg ha^{-1}) (Table 7). This entry was not repeated in 1997.

As expected, Arbrook, still in the establishment year, produced poorly in both years (1120 kg ha^{-1} in 1996 and 460 kg ha^{-1} in 1997). On the other hand, the cultivar Pantanal which had an intermediate yield in 1996 (2070 kg ha^{-1}) had the lowest yield in 1997 (250 kg ha^{-1}) indicating a preference for wetter conditions. The rainfall for the period between the first and final harvests amounted to 264 mm in 1996 and 188 mm in 1997. However, to emphasize the drought conditions present in 1997 is the fact that 123 mm fell during the first 10 days of August and during the last 30 days of the crop cycle (August 20 through September 20) only 7 mm were registered.

Regardless of the year (weather conditions), for the second harvest, the one-cut harvest system yielded significantly more than the two-cut system (3110 kg ha^{-1} and 1720 kg ha^{-1} compared to 1880 kg ha^{-1} and 820 kg ha^{-1} for 1996 and 1997, respectively) (Table 8, Figure 5, and Figure 6). This was expected because with the one-cut harvest system we harvest fully grown plants, while with the two-cut system we are harvesting plants that have already been harvested once and had to reconstitute the vegetative mass based on the photosynthesis of the diminished plants, and reallocation of the photosyntates normally intended for the pods.

By adding the totals from the first and second harvests the total peanut forage yield was obtained. For total forage yield, the mean yields (averaging 3650 kg ha^{-1}) obtained in 1996 were significantly higher than those (2150 kg ha^{-1})

in 1997 for all the entries (Table 9 and Figure 7). In 1996, seven entries had forage yields greater than 4000 kg ha^{-1}.

The lowest yields were obtained with the cultivars Pantanal (2620 kg ha^{-1} and 310 kg ha^{-1} in 1996 and 1997 respectively) and Arbrook (1320 kg ha^{-1} and 610 kg ha^{-1} in 1996 and 1997 respectively). Although the low yield obtained from Arbrook was expected during the first year after planting, Pantanal appears to have not only a low yield potential but also poor adaptation to the dryer weather of 1997 (Table 9 and Figure 7).

Although the second harvest of TARS in 1996 contributed to an acceptable forage yield (3800 kg ha^{-1}), the 1997 yield was very low (1180 kg ha^{-1}) because of the poorer second harvest because of the low rainfall. TARS seems to have not only a longer cycle but also more susceptibility to drought.

In 1996, Southern Runner had an intermediate total forage yield (3570 kg ha^{-1}) only significantly lower than 86x43-6-1 (4950 kg ha^{-1}), but, in 1997, the yield dropped to 1820 kg ha^{-1} which was significantly lower than that of 84x23-1-2 and 86x43-6-1 (3000 kg ha^{-1} and 2920 kg ha^{-1} respectively).

Although the PIs 268710, 290594, and 269008 had acceptable yields, they were removed from the second year experiment due to general performance factors, mainly susceptibility to diseases. The 1997 replacements, Guanajuato-2 and 8815B, had acceptable yields. The yield of 8815B was relatively high but was replicated only twice. Guanajuato-2, a Peruvian type peanut, besides having a respectable yield, had an impressive appearance. However, due to the prostrate growth habit, much of the vines remained in the field after the first harvest. This is a desirable feature to promote more rapid regrowth after the first cut and increases pod yield. However, it also leads to a lower forage yield.

When both harvests are added, on average the two-cut method resulted in a significantly higher forage yield than the one-cut method (3520 kg ha^{-1} and 2530 kg ha^{-1}, respectively). The same was true for all the entries except for Pantanal and Arbrook which yielded slightly better under a one-cut method (Table 10, Figure 8 and Figure 9). The higher yield obtained from the two-cut method can be attributed to plant rejuvenation after the first cut as well as redistribution of carbohydrates to vegetative growth instead of reproductive growth. The lower yields of Pantanal and Arbrook seem to have different causes. Arbrook was still in the establishment period and the first harvest only resulted in a very small yield which seemed to retard growth, while Pantanal did not seem to be adapted to mid-cycle harvesting.

Forage yields in the second season after planting, can only be taken as an indicator of the potential because only one harvest was made, and because of the small plot size and interference on the normal growth due to the harvest of pods. The highest yields where achieved by the wild relatives 96x7, Arbrook, and 18x7 with yields ranging from 4930 kg ha^{-1} to 5470 kg ha^{-1} (Table 11 and Figure 10). Among *A. hypogaea* entries, 84x23-1-2 and 84x28-5-4, yielded the highest (3720 kg ha^{-1} and 3720 kg ha^{-1} respectively). A group of 11 entries mostly cultivated peanut, including Southern Runner, had intermediate yields (2340-3370 kg ha^{-1}). The lowest yields were obtained with Natal Common (PI 268710) (1910 kg ha^{-1}) and the *A. pintoi* 8701 (1430 kg ha^{-1}). Being a Spanish cultivar with early maturity and no seed dormancy, the low yield of Natal Common was expected. PI 268710 does not have seed dormancy and therefore the seeds tend to germinate at any time the temperature and soil conditions are suitable, only to be killed by the cold temperatures of the winter months. This leads to a low available seed stock at the time of normal germination and therefore reduced plant stand and low yield. On the other hand, the early maturity and disease susceptibility acts as a handicap reducing the forage yield. As far as *A. pintoi* 8701 is concerned it is just a slow growing entry with low forage yield.

Table 6 – Peanut forage dry matter yield for the first harvest presented by year and entry.

Entry	Crop year†		
	1996	1997	Mean
	------------------------ ($kg\ ha^{-1}$) ------------------------		
2. 84x23-1-2	2530 bcde	3610 a	3010 A
22. 8815B		2970 abc	2970
4. 86x43-6-1	3150 ab	2090 cdef	2680 AB
9. PI 290594	2650 bcde		2650
11. PI 268903	2780 abcd	2210 cdef	2560 ABC
3. 84x28-5-4	3110 ab	1880 defg	2560 ABC
12. PI 399563	2720 bcd	2140 cdef	2460 ABC
20. S. runner	2690 bcd	2150 cdef	2450 ABC
8. PI 268710	2440 bcde		2440
6. 91108	2820 abc	1740 efg	2340 ABC
10. PI 269008	2190 cdef		2190
21. Guanajuato-2		2170 cdef	2170
7. 81206	2430 bcde	1510 fg	1970 BC
1. 84x23-1-1	2110 cdef	1750 efg	1950 BC
5. 86x43-1-1	2490 bcde	1070 gh	1860 C
13. TARS 4	1400 fg	460 hi	1130 D
18. Pantanal	1100 gh	120 i	670 ED
19. Arbrook	400 hi	300 hi	350 ED
Mean	2310 A	1760 B	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

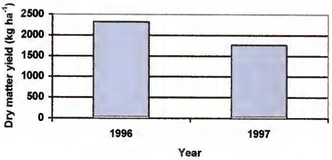


Figure 2 - Peanut forage dry matter yield for the first harvest presented by year.

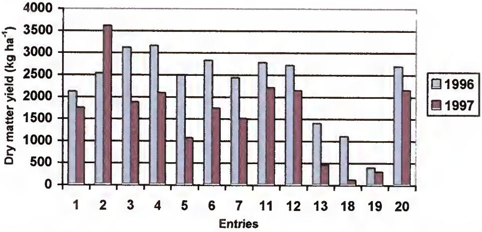


Figure 3 - Peanut forage dry matter yield for the first harvest presented by year and entry.

Table 7 - Peanut forage dry matter yield for the second harvest presented by year and entry.

Entry	Crop year†		
	1996	1997	Mean
	(kg ha^{-1})		
4. 86x43-6-1	3380 a	1870 defgh	2710 A
10. PI 269008	2580 abcde		2580
7. 81206	3360 a	1680 fghij	2520 AB
13. TARS 4	3100 ab	950 ijklm	2490 AB
5. 86x43-1-1	3090 ab	1440 ghijk	2360 ABC
9. PI 290594	2340 bcdef		2340
12. PI 399563	2790 abc	1530 fghijk	2230 ABCD
3. 84x28-5-4	2540 bcde	1770 efghi	2190 BCD
11. PI 268903	2730 abc	1170 hijkl	2150 BCDE
22. 8815B		2130 cdefg	2130
6. 91108	2640 abcd	1160 hijkl	1990 CDEF
21. Guanajuato-2		1840 defgh	1840
2. 84x23-1-2	2330 bcdef	1190 hijkl	1820 DEF
1. 84x23-1-1	2290 bcdef	880 jklm	1670 EFG
20. S. runner	2230 cdefg	750 klm	1570 FG
8. PI 268710	1510 fghijk		1510
18. Pantanal	2070 cdefg	250 m	1260 G
19. Arbrook	1120 hijkl	460 lm	820 H
Mean	2500 A	1270 B	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

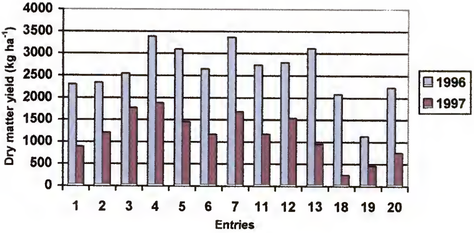


Figure 4 - Peanut forage dry matter yield for the second harvest presented by year and entry.

Table 8 - Peanut forage dry matter yield for the second harvest presented by year, harvest management level and entry.

Peanut forage dry matter yield						
Entry	Crop year / Harvest management method†‡					
	1996		1997		Mean	
	H1	H2	H1	H2	H1	H2
	(kg ha^{-1})					
4. 86x43-6-1	4230	2520	2460	1280	3450	1970
7. 81206	4280	2430	1940	1410	3110	1920
10. PI 269008	3050	2120			3050	2120
5. 86x43-1-1	3840	2340	2000	880	3020	1690
13. TARS 4	3640	25709	1220	680	2950	2030
12. PI 399563	3470	2100	2140	930	2880	1580
11. PI 268903	3420	2040	1920	430	2860	1440
3. 84x28-5-4	3240	1830	2350	1180	2850	1540
9. PI 290594	2760	1920			2760	1920
21. Guanajuato-2			2500	1180	2500	1180
6. 91108	3200	2090	1550	770	2470	1500
2. 84x23-1-2	2980	1680	1760	620	2440	1210
22. 8815B			2310	1950	2310	1950
1. 84x23-1-1	2880	1700	1260	510	2160	1170
20. S. runner	2700	1750	1220	270	2040	1090
8. PI 268710	2010	1010			2010	1010
18. Pantanal	2960	1190	360	130	1800	720
19. Arbrook	1330	910	670	240	1040	610
Mean	3110	1880	1720	820	2530	1440
	a	b	b	c	A	B

† - Means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.
‡ - H1 refers to the only harvest with the one cut harvest management method, while H2 refers to the second harvest with the two cut method.

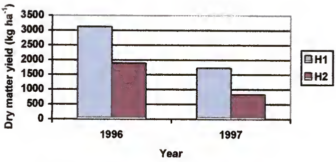


Figure 5 - Peanut forage dry matter yield for the second harvest presented by harvest management method and year.

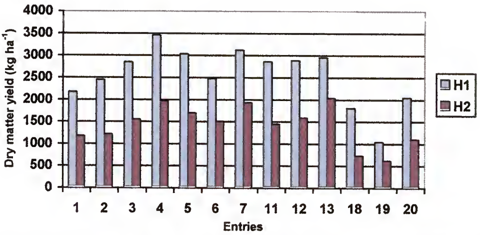


Figure 6 - Peanut forage dry matter yield for the second harvest presented by harvest management method and entry.

Table 9 – Mean total annual peanut forage dry matter yield from the two harvest management methods presented by year and entry.

Entry	Crop year†		
	1996	1997	Mean
	(kg ha^{-1})		
4. 86x43-6-1	4950 a	2920 efgh	4050 A
10. PI 269008	3670 bcdef		3670
9. PI 290594	3660 bcdef		3660
22. 8815B		3620 bcdef	3620
7. 81206	4570 ab	2430 ghi	3500 AB
3. 84x28-5-4	4090 abc	2700 fghi	3480 AB
12. PI 399563	4140 abc	2600 fghi	3460 AB
11. PI 268903	4120 abc	2280 hij	3430 AB
2. 84x23-1-2	3590 bcdef	3000 defgh	3330 BC
5. 86x43-1-1	4330 abc	1980 hijk	3290 BC
6. 91108	4050 abcd	2030 hijk	3160 BCD
13. TARS 4	3800 bcde	1180 klm	3050 BCD
21. Guanajuato-2		2930 efgh	2930
20. S. runner	3570 bcdef	1820 ijk	2790 CD
8. PI 268710	2730 efghi		2730
1. 84x23-1-1	3350 bcdefg	1760 ijk	2640 D
18. Pantanal	2620 fghi	310 m	1590 E
19. Arbrook	1320 jkl	610 lm	1000 F
Mean	3650 A	2150 B	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

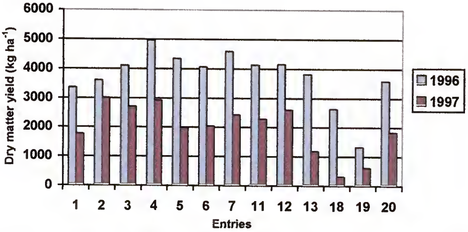


Figure 7 – Total peanut forage dry matter yield presented by year and entry.

Table 10 – Total annual peanut forage dry matter yield presented by year, harvest management method and entry.

Entry	Crop year / Harvest management method†‡					
	1996		1997		Mean	
	H1	H2	H1	H2	H1	H2
	(kg ha^{-1})					
4. 86x43-6-1	4230	5670	2460	3370	3450	4650
7. 81206	4280	4860	1940	2920	3110	3890
10. PI 269008	3050	4300			3050	4300
5. 86x43-1-1	3840	4830	2000	1950	3020	3550
13. TARS 4	3640	3970	1220	1140	2950	3160
12. PI 399563	3470	4810	2140	3070	2880	4040
11. PI 268903	3420	4820	1920	2640	2860	4000
3. 84x28-5-4	3240	4940	2350	3060	2850	4100
9. PI 290594	2760	4570			2760	4570
21. Guanajuato-2			2500	3350	2500	3350
6. 91108	3200	4910	1550	2520	2470	3850
2. 84x23-1-2	2980	4210	1760	4230	2440	4220
22. 8815B			2310	4920	2310	4920
1. 84x23-1-1	2880	3810	1260	2260	2160	3120
20. S. runner	2700	4440	1220	2420	2040	3540
8. PI 268710	2010	3450			2010	3450
18. Pantanal	2960	2290	360	250	1800	1390
19. Arbrook	1330	1310	670	540	1040	970
Mean	3110	4190	1720	2580	2530 b	3520 a

† - Means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.
‡ - H1 refers to the only harvest with the one cut harvest management method, while H2 refers to the two harvests with the two cut method.

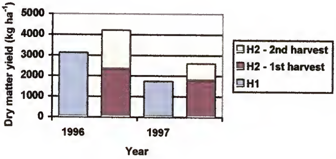


Figure 8 – Total peanut forage dry matter yield presented by year and harvest management method.

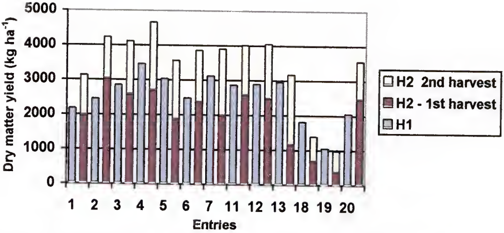


Figure 9 – Total peanut forage dry matter yield presented by harvest management method and entry.

Table 11 - Peanut forage dry matter yield for the harvest of the second cropping year (1996 planting).

Entry	Peanut forage dry matter yield†
	------- (kg ha^{-1}) -------
16. 96x7	5470 a
19. Arbrook	5220 a
15. 18x7	4930 ab
3. 84x28-5-4	3720 bc
2. 84x23-1-2	3720 bc
20. S. Runner	3370 cd
17. 39x34	3150 cde
10. PI 269008	3000 cde
18. Pantanal	3000 cde
7. 81206	2870 cde
6. 91108	2740 cdef
13. TARS 4	2560 cdef
5. 86x43-1-1	2550 cdef
1. 84x23-1-1	2520 cdef
9. PI 290594	2470 cdef
11. PI 268903	2340 cdef
4. 86x43-6-1	2160 def
8. PI 268710	1910 ef
12. PI 399563	1770 ef
14. 8701	1430 f

† - Means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

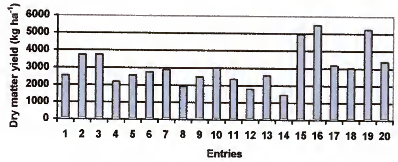


Figure 10 - Peanut forage dry matter yield for the second cropping year (1996 planting).

Pod Yield

Pod yield (kg ha^{-1}) was only observed in 1996, and significant differences where found for all effects (entry, harvest management method, and their interaction) (Table 12).

Table 12 – Summarized ANOVA table for pod yield.

Pod yield (kg ha^{-1})				
1996	DF	MS	F value	Pr > F
Harvest	1	11781465	13.54	0.0212
Error (a)	4	870294		
Entry	13	4434661	20.25	0.0001
Harvest*Entry	13	949682	4.34	0.0001
Error (b)	100	219012		

Pod yields are only reported for 1996. Although observations were made In 1997, the low rainfall that occurred during the pod filling period led to low pod set and poor pod filling. As a result, pod yield was very low in 1997 and seed quality was low.

Although the two cut harvest management appreciably reduced pod yield in 1996, significant differences between the 1-cut and 2-cuts methods only occurred for 4 entries 84x23-1-1, 84x23-1-2, 84x28-5-4, and Southern Runner. These entries, together with UF91108, were the highest yielding entries (1830-2450 kg ha^{-1}) both overall and when the 1-cut method was used. It is important to mention that, with two forage harvests, entries 84x23-1-1, 84x28-5-4, 91108, and

Southern Runner still produced the higher pod yields (Table 13, Figure 11, and Figure 12).

The reduction in pod yield with the two harvests method was expected and results from the removal of photosynthetically active tissues at a time when translocation to the reproductive organs occur. When the tops are removed at the middle of the crop cycle, newly produced carbohydrates have to be reallocated to growing vegetative tissue instead of to the pods.

Table 13 - Peanut pod yield for 1996 presented by harvest management method and entry.

Entry	Harvest management method†‡		
	H1	H2	Mean
	(kg ha^{-1})		
3. 84x28-5-4	3150 a	1750 bcde	2450 A
2. 84x23-1-2	3100 a	1010 efghi	2050 AB
6. 91108	2190 b	1780 bcd	1980 BC
1. 84x23-1-1	2480 a	1220 cdefg	1920 BC
20. S. runner	2240 b	1420 cdef	1830 BC
5. 86x43-1-1	1850 bc	1160 cdefgh	1540 C
8. PI 268710	1000 efghi	1040 defghi	1020 D
4. 86x43-6-1	1180 cdefgh	830 fghi	1000 DE
10. PI 269008	760 fghi	820 fghi	790 DE
12. PI 399563	970 fghi	530 ghi	750 DE
7. 81206	870 fghi	480 ghi	670 DE
9. PI 290594	630 fghi	600 ghi	620 E
11. PI 268903	610 ghi	410 hi	510 E
13. TARS 4	540 ghi	310 i	430 E
Mean	1550 A	950 B	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.
‡ - H1 refers to the one cut harvest management method, while H2 refers to the two cut method.

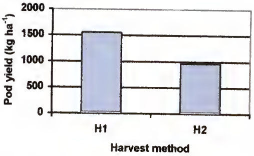


Figure 11 - Peanut pod yield in 1996 presented by harvest management method.

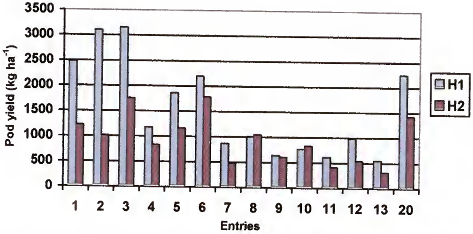


Figure 12 - Peanut pod yield in 1996 presented by harvest management method and entry.

Pest Evaluation

Leaf spot incidence

In terms of incidence of leaf spots on peanut, significant differences were observed between years, harvest management methods and entries, as well as all their 2- and 3-way interactions (Table 14).

Table 14 – Summarized ANOVA table for leaf spot incidence.

Leaf spot score (scale 1-9)	DF	MS	F value	Pr > F
Year	1	30.42	30.12	0.0069
Harvest	1	196.09	193.19	0.0001
Year*Harvest	1	16.52	16.36	0.0033
Error (a)	7	1.01		
Entry	21	46.68	75.41	0.0001
Year*Entry	12	1.82	2.91	0.0008
Harvest*Entry	21	3.92	6.34	0.0001
Year*Harvest*Entry	12	1.22	1.98	0.0276
Error (b)	220	0.62		

In general, the dryer summer weather experienced in 1997 led to a significantly lower leaf spot incidence than in 1996 (4.1 and 3.6 respectively). Overall the wild *Arachis* species showed near immunity (1.0), while entries PI 268710, PI 290594 and PI 269008 had high scores in 1996 and were not included in the 1997 experiment. Among the cultivated peanuts, 86x43-6-1, 86x43-1-1, 81206, TARS 4, and 8815B had the lowest leaf spot scores, but 8815B still needs further testing since it was only included in the 1997 experiment (Table 15 and Figure 13).

At the time of final harvest, significantly lower leaf spot ratings were observed with the two harvest management treatments compared with the two harvest treatment (3.5 and 2.4 vs. 4.7 and 4.8 in 1996 and 1997, respectively). This reduction was observed mainly in the cultivated peanut entries (3.3-7.2 vs. 4.2-9.0 to in 1996, and 2.0-4.5 vs. 4.0-7.0 in 1997), while all the wild relatives showed near immunity. Although the leaf spot incidence for the 1-cut method was similar in both years, with the 2-cut methods there was a tendency to have lower disease scores in 1997, probably because of the lower total rainfall that occurred between the two harvests. The cultivated peanut entry PI 268710 (Natal Common) had a disease score that was significantly higher than all the others (9.0 and 7.2 with one and two harvests respectively). With the 1-cut method, the lowest disease incidence among the cultivated peanut entries was observed with entries 86x43-1-1 and TARS (4.4), which was significantly lower than 84x23-1-1, 84x28-5-4, PI 399563, and Southern Runner (ranging 6.0-6.8). Nevertheless, for most of the cultivated peanut entries, no differences were observed with the 2-cut method (Table 16, Table 17, Figure 14, and Figure 15).

Table 15 - Leaf spot incidence on peanut presented by year and entry.

Entry	Crop year†		
	1996	1997	Mean
	---------------------------- (rating‡)	----------------------------	
8. PI 268710	8.1 a		8.1 A
10. PI 269008	5.9 b		5.9 B
9. PI 290594	5.7 bc		5.7 BC
20. S. Runner	5.6 bcd	4.9 cdefg	5.3 BCD
1. 84x23-1-1	5.6 bcd	4.4 fghi	5.1 CDE
2. 84x23-1-2	5.3 bcde	4.6 efghi	5.0 DE
21. Guanajuato-2		4.8 defgh	4.8
12. PI 399563	5.0 cdef	4.6 efghi	4.8 DE
3. 84x28-5-4	5.3 bcde	4.0 hijk	4.7 DE
11. PI 268903	4.8 defgh	4.2 fghij	4.6 DEF
6. 91108	5.6 bcd	3.4 jkl	4.6 DEF
4. 86x43-6-1	4.7 efghi	3.9 ijk	4.3 EFG
7. 81206	3.9 ijk	4.0 hijk	3.9 FG
13. TARS 4	4.1 ghijk	3.3 kl	3.9 G
5. 86x43-1-1	4.2 fghij	3.0 l	3.7 G
22. 8815B		3.0 l	3.0
18. Pantanal	1.0 m	1.0 m	1.0 H
19. Arbrook	1.0 m	1.0 m	1.0 H
14. 8701	1.0 m		1.0
15. 18x7	1.0 m		1.0
16. 96x7	1.0 m		1.0
17. 39x34	1.0 m		1.0
Mean	4.1 A	3.6 B	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

‡ - leaf score rating followed a 1 to 9 scale where 1 indicates no disease and 9 complete defoliation.

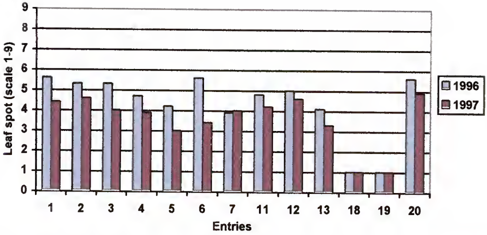


Figure 13 - Leaf spot incidence on peanut presented by harvest management method and entry.

Table 16 – Leaf spot incidence on peanut presented by year, harvest management method and entry.

Entry	Crop year / Harvest management method†‡			
	1996		1997	
	H1	H2	H1	H2
	(rating§)			
8. PI 268710	9.0 a	7.2 b		
6. 91108	6.8 bcd	4.4 ijklm	4.3 ijklm	2.5 opq
10. PI 269008	6.6 bcd	5.2 efghij		
9. PI 290594	6.6 bcd	4.8 ghijkl		
20. S. Runner	6.6 bcd	4.6 hijklm	7.0 bc	2.8 nopq
1. 84x23-1-1	6.4 bcde	4.8 ghijkl	6.0 bcdefg	2.8 nopq
12. PI 399563	6.4 bcde	3.6 lmnop	6.5 bcde	2.8 nopq
3. 84x28-5-4	6.2 bcdef	4.4 ijklm	5.8 cdefgh	2.3 pq
2. 84x23-1-2	6.0 bcdefg	4.6 hijklm	6.8 bcd	2.5 opq
11. PI 268903	5.6 defghi	4.0 jklmn	6.0 bcdefg	2.3 pq
4. 86x43-6-1	5.6 defghi	3.8 klmno	5.0 fghijk	2.8 nopq
5. 86x43-1-1	4.8 ghijkl	3.6 lmnop	4.0 jklmn	2.0 qr
13. TARS 4	4.6 hijklm	3.6 lmnop	4.0 jklmn	2.5 opq
7. 81206	4.5 hijklm	3.3 mnopq	5.8 cdefgh	2.3 pq
14. 8701	1.0 r	1.0 r		
15. 18x7	1.0 r	1.0 r		
16. 96x7	1.0 r	1.0 r		
17. 39x34	1.0 r	1.0 r		
18. Pantanal	1.0 r	1.0 r	1.0 r	1.0 r
19. Arbrook	1.0 r	1.0 r	1.0 r	1.0 r
21. Guanajuato-2			5.0 fghijk	4.5 hijklm
22. 8815B			4.0 jklmn	2.0 qr
Mean	4.7 A	3.5 B	4.8 A	2.4 B

† - Means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

‡ - H1 refers to the one cut harvest management method, while H2 refers to the two cut method.

§ - leaf score rating followed a 1 to 9 scale where 1 indicates no disease and 9 complete defoliation.

Table 17 – Mean over years of leaf spot incidence on peanut presented by harvest management method and entry.

Entry	Harvest management method†‡	
	H1	H2
	---------------- (rating§) ----------------	
8. PI 268710	9.0 a	7.2 b
20. S. Runner	6.8 bc	3.8 klm
10. PI 269008	6.6 bcd	5.2 ghij
9. PI 290594	6.6 bcd	4.8 ij
12. PI 399563	6.4 cde	3.2 mn
2. 84x23-1-2	6.3 cde	3.7 klm
1. 84x23-1-1	6.2 cde	3.9 klm
3. 84x28-5-4	6.0 cdef	3.4 mn
11. PI 268903	5.8 defg	3.8 klm
6. 91108	5.7 efgh	3.6 lm
4. 86x43-6-1	5.3 fghi	3.3 mn
7. 81206	5.1 ghij	3.8 klm
21. Guanajuato-2	5.0 hij	4.5 jk
13. TARS 4	4.4 jkl	3.3 mn
5. 86x43-1-1	4.4 jkl	2.8 n
22. 8815B	4.0 klm	2.0 o
14. 8701	1.0 p	1.0 p
15. 18x7	1.0 p	1.0 p
16. 96x7	1.0 p	1.0 p
17. 39x34	1.0 p	1.0 p
18. Pantanal	1.0 p	1.0 p
19. Arbrook	1.0 p	1.0 p
Mean	4.7 A	3.1 B

† - Means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

‡ - H1 refers to the one cut harvest management method, while H2 refers to the two cut method.

§ - leaf score rating followed a 1 to 9 scale where 1 indicates no disease and 9 complete defoliation.

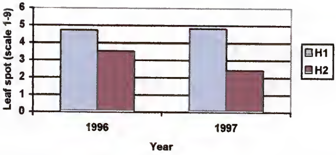


Figure 14 - Leaf spot incidence on peanut presented by harvest management method and year.

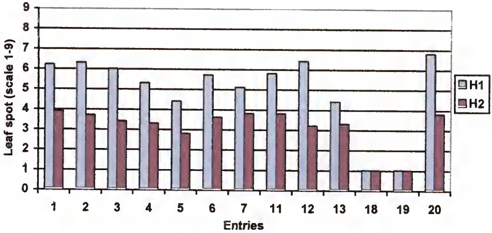


Figure 15 - Leaf spot incidence on peanut presented by harvest management method and entry averaged over years.

Insect damage

Damages caused by insects prior to the final peanut harvest showed highly significant differences between harvesting methods, entries, and the interaction harvest*entry (Table 18).

Table 18 – Summarized ANOVA table for insect damage.

Insect damage (scale 1-3)				
1997	DF	MS	F value	Pr > F
Harvest	1	39.75	69.19	0.0036
Error (a)	3	0.57		
Entry	14	0.70	4.60	0.0001
Harvest*Entry	14	0.70	4.60	0.0001
Error (b)	76	0.15		

In 1996 there was little insect damage but, in 1997, insect damage mainly by caterpillars and leaf miners started very early in the season, well before the first harvest. After the first harvest, the weather become very dry creating poor conditions for insect reproduction and activity. As a result, with the 2-cut method very little additional insect damage was observed after the first harvest. Thus, insect damage scores were significantly lower with the 2-cut treatment compared with the 1-cut method (1.0 compared to 1.5-3.0 when wild relatives are excluded). Among the cultivated peanut entries TARS 4 had the lowest insect damage (1.5). Once again, the wild relatives, Pantanal and Arbrook, showed near immunity against insect damage (Table 19 and Figure 16).

Trying to explain the reduction in insect damage with the 2-cut method, two possibilities arise: (i) during the first harvest there is active removal of the insects reducing the population; and (ii) the most common insects observed are sedentary, tending to continue feeding on the same plants and do not move to the younger tissues growing after the first harvest.

Table 19 – Insect damage on peanut presented by harvest management and entry for the 1997 cropping season.

Entry	Harvest management method†‡		
	H1	H2	Mean
	(rating§)		
11. PI 268903	3.0 a	1.0 f	2.0 A
20. S. Runner	3.0 a	1.0 f	2.0 A
2. 84x23-1-2	2.8 ab	1.0 f	1.9 AB
4. 86x43-6-1	2.5 bc	1.0 f	1.8 AB
6. 91108	2.5 bc	1.0 f	1.8 AB
12. PI 399563	2.5 bc	1.0 f	1.8 AB
22. 8815B	2.7 ab	1.0 f	1.8 AB
1. 84x23-1-1	2.3 cd	1.0 f	1.6 ABC
3. 84x28-5-4	2.3 cd	1.0 f	1.6 ABC
21. Guanajuato-2	2.3 cd	1.0 f	1.6 ABC
5. 86x43-1-1	2.0 d	1.0 f	1.5 BC
7. 81206	2.0 d	1.0 f	1.5 BC
13. TARS 4	1.5 e	1.0 f	1.3 CD
18. Pantanal	1.0 f	1.0 f	1.0 D
19. Arbrook	1.0 f	1.0 f	1.0 D
Mean	2.2 A	1.0 B	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

‡ - H1 refers to the one cut harvest management method, while H2 refers to the two cut method.

§ - leaf score rating followed a 1 to 3 scale where 1 indicates no or little insect damage and 3 heavy damage.

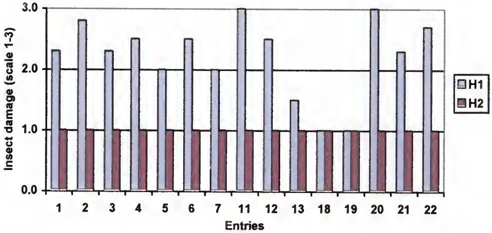


Figure 16 - Insect damage on peanut presented by harvest management and entry for the 1997 cropping season.

Weed infestation

In the case of weed infestation, smaller but significant differences were observed between the main effects while the differences were not significant for the interaction (Table 20).

Table 20 – Summarized ANOVA table for weed cover.

Weed infestation (%)				
1997	DF	MS	F value	Pr > F
Harvest	1	20896.08	18.82	0.0226
Error (a)	3	1110.20		
Entry	14	695.41	1.68	0.0760
Harvest*Entry	14	499.63	1.21	0.2859
Error (b)	76	412.85		

First and foremost, the 2-cut method led to a significantly higher level of weed infestation than the 1-cut method (35% and 6% respectively) because of the presence of bare soil in mid summer after the first harvest at 80 days after planting. The slow growing entries, TARS 4 and Arbrook, allowed weeds to establish at significantly higher rates even in the 1-cut treatment (30%), while the remaining entries tended to outcompete the weeds in the 1-cut treatment (0-15%) (Table 21 and Figure 17).

Table 21 – Weed infestation on peanut presented by harvest management and entry for the 1997 cropping season.

Entry	Harvest management method†‡		
	H1	H2	Mean
	(% weeds)		
19. Arbrook	30 cdefg	48 abcd	39 A
13. TARS 4	30 cdefg	35 bcdef	33 AB
21. Guanajuato-2	0 h	60 a	30 ABC
2. 84x23-1-2	0 h	55 ab	28 ABC
11. PI 268903	0 h	50 abc	25 ABC
1. 84x23-1-1	10 gh	40 abcde	25 ABC
5. 86x43-1-1	15 fgh	35 bcdef	25 ABC
20. S. Runner	0 h	43 abcd	21 ABC
12. PI 399563	15 fgh	28 defg	21 ABC
6. 91108	0 h	35 bcdef	18 ABC
4. 86x43-6-1	0 h	20 efgh	10 BC
7. 81206	0 h	20 efgh	10 BC
18. Pantanal	0 h	20 efgh	10 BC
3. 84x28-5-4	0 h	18 fgh	9 BC
22. 8815B	0 h	10 gh	5 C
Mean	6 B	35 A	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.
‡ - H1 refers to the one cut harvest management method, while H2 refers to the two cut method.

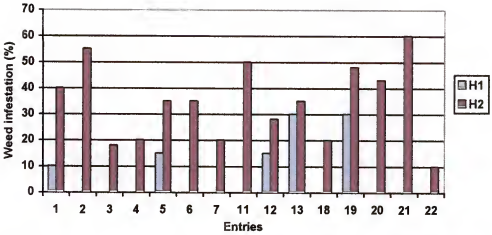


Figure 17 - Weed infestation on peanut presented by harvest management and entry for the 1997 cropping season.

Forage Quality

Significant differences were also found between entries, harvesting methods and their interaction for the harvested forage crude protein concentration (%) of both first and second harvests (Table 22). However, IVOMD only presented significant differences for the main effects on the second harvest (Table 22).

Table 22 – Summarized ANOVA table for crude protein and in-vitro organic matter digestibility for both first and second harvests.

Crude protein (%)				
First harvest				
1996	DF	MS	F value	Pr > F
Entry	15	9.46	3.12	0.0009
Error	59	3.03		
Second harvest				
1996	DF	MS	F value	Pr > F
Harvest	1	128.23	44.27	0.0026
Error (a)	4	2.90		
Entry	15	17.79	11.42	0.0001
Harvest*Entry	15	3.66	2.35	0.0055
Error (b)	118	1.56		
In-vitro Organic Matter Digestibility (%)				
First harvest				
1996	DF	MS	F value	Pr > F
Entry	15	5.87	1.26	0.2568
Error	59	4.66		
Second harvest				
1996	DF	MS	F value	Pr > F
Harvest	1	345.77	39.34	0.0033
Error (a)	4	8.79		
Entry	15	98.80	13.26	0.0001
Harvest*Entry	15	9.80	1.32	0.2035
Error (b)	118	7.45		

During the first harvest, cultivar Natal Common (PI 268710) had the lowest crude protein content (158 g kg^{-1}) only similar to that of PI 268903, Arbrook and PI 269008 (170-174 g kg^{-1}). No differences were observed for the remaining entries (181-208 g kg^{-1}) (Table 23). It is important to mention that these crude protein concentrations are high, similar to those of alfalfa, indicating a good quality forage.

For the second harvest date, the 2-cut treatment method resulted in a significantly higher crude protein concentration than the 1-cut treatment (180 and 162 g kg^{-1} respectively). This was expected because the tissues from the 2-cut method are younger and have higher levels of nitrogen. Again, the lowest crude protein concentrations were observed with Natal Common (PI 268710) both with the 1-cut or 2-cut treatment (114 g kg^{-1} and 152 g kg^{-1}, respectively). With the single harvest method, Pantanal (148 g kg^{-1}) had the second lowest crude protein concentration while the remaining entries formed a larger group ranging from 157 g kg^{-1} to 178 g kg^{-1}. With the two harvest management method, Arbrook had an inexplicably low crude protein concentration (145 g kg^{-1}) being significantly lower than all the cultivated peanut entries (170-200 g kg^{-1}). Overall, Natal Common and Arbrook had the lowest crude protein concentration (133 g kg^{-1} and 154 g kg^{-1} respectively), followed by PI 268710, PI 268903 and Pantanal (163-167 g kg^{-1}), and topped by the remaining entries (171-189 g kg^{-1}) (Table 24 and Figure 18). Similar to the first harvest, the crude protein concentrations indicate a good quality forage, similar to alfalfa, even in the case of the lower values obtained with the 1-cut treatment.

In general, no significant differences were observed for the forage digestibility (IVOMD) of the first harvest, with only Pantanal (719 g kg^{-1}) being significantly higher than 84x28-5-4 (680 g kg^{-1}) and the remaining entries showing intermediate values ranging from 687 g kg^{-1} to 714 g kg^{-1} (Table 25). As it relates to the second harvest, the 2-cut treatment had a significantly higher IVOMD than the 1-cut method (654 g kg^{-1} and 624 g kg^{-1}, respectively). In terms of entries, Pantanal (700 g kg^{-1}) had a IVOMD significantly higher than all the other entries. Entries PI 268710, 84x28-5-4, and PI 269008 formed the group of the low digestibility entries (546 g kg^{-1}, 616 g kg^{-1}, and 624 g kg^{-1}, respectively) while the remaining entries formed an intermediate group (629-658 g kg^{-1}) headed by Pantanal (700 g kg^{-1}) (Table 26 and Figure 19). In general, the IVOMD values obtained for the first harvest are high, confirming the good quality of the cultivated peanut forage.

Table 23 - Crude protein of the first peanut harvest presented by entry for the 1996 cropping season.

Entry	Crude protein†
	--------- (g kg^{-1}) ---------
84x28-5-4	208 a
84x23-1-2	204 ab
TARS 4	202 ab
86x43-1-1	198 abc
84x23-1-1	197 abc
91108	195 abcd
Pantanal	194 abcd
81206	191 abcd
S. runner	189 abcd
PI 290594	185 abcd
PI 399563	183 abcd
86x43-6-1	181 bcd
PI 269008	175 cde
Arbrook	174 cde
PI 268903	170 de
PI 268710	158 e

† - Means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

Table 24 - Crude protein of the second peanut harvest presented by harvest management and entry for the 1996 cropping season.

Entry	Harvest management method†‡		
	H1	H2	Mean
	---------- ($g\ kg^{-1}$) ----------		
5. 86x43-1-1	178 bcdef	200 a	189 A
1. 84x23-1-1	172 cdefgh	194 ab	183 AB
10. PI 269008	173 cdefgh	190 abc	182 AB
6. 91108	173 cdefgh	189 abc	181 AB
2. 84x23-1-2	169 defghi	187 abcd	178 ABC
3. 84x28-5-4	163 fghijk	190 ab	177 ABCD
20. S. runner	171 cdefgh	180 bcdef	176 BCDE
7. 81206	166 efghij	185 abcd	175 BCDE
4. 86x43-6-1	166 efghij	183 abcde	174 BCDE
13. TARS 4	170 defghi	179 bcdef	174 BCDE
12. PI 399563	158 ghijk	184 abcde	171 BCDE
9. PI 290594	158 ghijk	176 bcdefg	167 CDE
18. Pantanal	148 jk	180 bcdef	164 DEF
11. PI 268903	157 hijk	170 defghi	163 EF
19. Arbrook	162 fghijk	145 k	154 F
8. PI 268710	114 l	152 ijk	133 G
Mean	162 B	180 A	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.
‡ - H1 refers to the one cut harvest management method, while H2 refers to the two cut method.

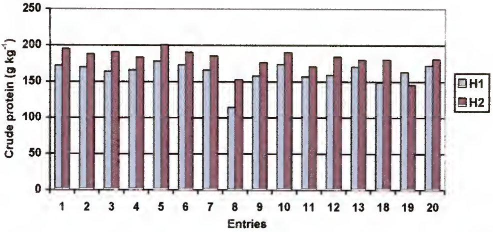


Figure 18 - Crude protein of the second peanut harvest presented by harvest management and entry for the 1996 cropping season.

Table 25 - IVOMD of the first peanut harvest presented by entry for the 1996 cropping season.

Entry	IVOMD†
	-------- (g kg^{-1}) --------
18. Pantanal	719 a
1. 84x23-1-1	714 ab
6. 91108	713 ab
20. S. runner	711 ab
9. PI 290594	709 ab
13. TARS 4	709 ab
2. 84x23-1-2	702 ab
5. 86x43-1-1	700 ab
10. PI 269008	700 ab
19. Arbrook	700 ab
11. PI 268903	698 ab
7. 81206	693 ab
12. PI 399563	691 ab
8. PI 268710	689 ab
4. 86x43-6-1	687 ab
3. 84x28-5-4	680 b

† - Means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

Table 26 - IVOMD of the second peanut harvest presented by harvest management and entry for the 1996 cropping season.

IVOMD			
Entry	Harvest management method†‡		
	H1	H2	Mean
	---------------- (g kg^{-1}) ----------------		
18. Pantanal	695	704	700 a
13. TARS 4	659	667	663 b
7. 81206	650	667	658 bc
5. 86x43-1-1	639	670	655 bcd
1. 84x23-1-1	642	665	654 bcd
2. 84x23-1-2	648	652	650 bcde
12. PI 399563	618	670	644 bcdef
4. 86x43-6-1	626	659	642 bcdef
19. Arbrook	637	647	642 bcdef
20. S. runner	633	652	642 bcdef
11. PI 268903	618	643	630 cdef
6. 91108	607	652	629 def
9. PI 290594	612	647	629 def
10. PI 269008	605	642	624 ef
3. 84x28-5-4	591	641	616 f
8. PI 268710	507	585	546 g
Mean	624 B	654 A	

† - Means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.
‡ - H1 refers to the one cut harvest management method, while H2 refers to the two cut method.

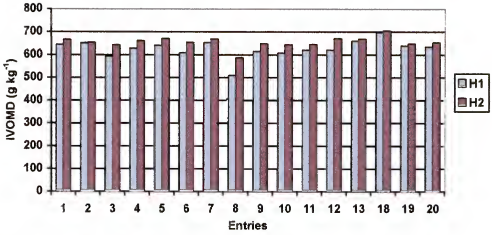


Figure 19 - IVOMD of the second peanut harvest presented by harvest management and entry for the 1996 cropping season.

Conclusions

In general, we can conclude based on these data that: (i) The use of cultivated peanut as a forage crop is a promising practice, if high forage yielding entries with multiple pest resistance are selected. (ii) There is large variability within the material tested, which can be used as a base to begin a specific hybridization program. (iii) Significant differences were found for forage yields, disease susceptibility (leaf spots), and insect damage both among genotypes and harvest management methods.

The successful use of this practice requires an adequate harvest management method and the selection of the proper entries. Based on the present work it is known that: (i) The highest forage yields were obtained with the 2-cut treatment. (ii) The use of two harvests also results in reduction of leaf spot intensity and insect damage. (iii) The use of two harvests resulted in the production of higher quality forage.

To obtain the best results, the timing of the first harvest is crucial. Not only because it increases the overall forage yield and quality, but also because a late harvest can reduce pod yield excessively threatening the re-establishment of the crop year after year. On the other hand, the final harvest, in a two harvest regime should be done later than in a one harvest regime, because plants are still growing and healthier.

To make this practice successful, the proper genotypes have to be selected. The genotypes must have high forage yields, acceptable pod and seed setting, and multiple disease resistance. In the present study, it was found that although the wild peanut relatives are more resistant to both insect and diseases (leaf spots and rust), some of the breeding lines deserve special attention due to their good performance.

CHAPTER 4
EFFECTS OF CULTIVAR AND CROP SEQUENCE ON LONG TERM STAND MAINTENANCE

Introduction

For an efficient use of cultivated peanut as a forage crop, long term maintenance and self-reseeding is essential. Besides selecting peanut cultivars with good dry matter yield and acceptable pod yield, crop sequences and other practices leading to long term stand maintenance are required. One of the possible cropping practices is the use of appropriate winter crops to keep the field covered year round, protected against erosion and keeping the growth and establishment of weeds in check.

The correct selection of the crop mixtures to use in the crop sequence with peanut is critical. A mixture of ryegrass and white clover yielded 15% less than a mixture of ryegrass, white clover and crimson clover (7000 kg ha^{-1} vs. 8180 kg ha^{-1}, respectively) (Mooso et al., 1990). While the forge yield of alfalfa mixed with ryegrass was lower than in sole alfalfa (1300-4750 kg ha^{-1} vs. 2410-6510 kg ha^{-1}), the contribution of the grass (2300-10040 kg ha^{-1}) was enough to compensate for the legume yield losses (Sulc and Albrecht, 1996).

To address these issues, a crop sequence experiment involving various cultivated peanut genotypes planted in the summer followed by winter planted grass-legume mixtures was conducted between 1996 and 1998 with the following objectives:

- To identify the best method for long-time peanut reestablishment.
- To study the effect of crop sequence and crop rotation on peanut reestablishment.

Material and Methods

Location and Experimental Design

The experiment was conducted on a loamy sand (Kendrick loamy sand; loamy, siliceous, semiactive, hyperthermic Arenic Paleudults) (USDA-SCS, 1985; NCSS, 1999) located at the Green Acres Research Farm near Gainesville, Florida. The experiment followed a split-plot design with 3 crop sequences as main plots (Table 27), 3 entries as sub-plots (Table 28), and 4 replications.

For the 1996 and 1997 seasons the crop sequences were selected in order to give a gradual change from no winter competition to high winter competition as follows:

5. No winter competition. This is the control treatment. The plots are left fallow after peanut harvest hence no crop sequence is followed (fallow).
6. Low level of winter competition. After peanut forage is harvested, a mixture of bahiagrass (*Paspalum notatum* Flügge) and rye (*Secale cereale* L.) was sown. Rye was planted in order to have a crop in the field

during the winter and to allow proper bahiagrass establishment in the early spring (R+BG).

7. High level of winter competition. After the final peanut forage harvest, crop mix of rye, ryegrass (*Lolium multiflorum* Lam.), red clover (*Trifolium pratense* L.) and crimson clover (*Trifolium incarnatum* L.) (R+RG+RC+CC), was seeded.

With the objective of reducing weed growth during the winter, it was decided to eliminate the fallow period. Therefore in the 1998 season, a new winter competition series was used:

1. Low level of winter competition. A mixture of rye and ryegrass was planted after the final harvest of peanut forage (R+RG).
2. High level of winter competition. After the harvest of peanut forage a mixture of rye, ryegrass, red clover and crimson clover was planted (R+RG+CC+RC).
3. High level of winter competition with bahiagrass. A mixture of rye, ryegrass, red clover, crimson clover and bahiagrass was planted after the harvest of peanut forage. Bahiagrass is supposed to add a period of extended competition after the harvest of the other crops in the mix (R+RG+RC+CC+BG).

Three peanut entries were used (Table 28). Dixie Runner, released in 1943, is a late maturity cultivar with relatively low pod yield, high forage yield, resulting from the cross between a Spanish cultivar and Dixie Giant (Carver and Hull, 1950; USDA, 1999a). Southern Runner, released in 1986, is a medium to late maturity cultivar with high pod yield with a spreading bunch growth habit, has Florunner as one of its parents, and was the first Florida release with multiple disease resistance, having moderate levels of resistance to late leaf spot, rust, white mold, and TSWV (Gorbet et al., 1998; Whitty et al., 1998; USDA, 1999b). UF81206 is a semi-prostrate breeding line used extensively in the University of Florida peanut breeding program as a source of resistance to late leaf spot, rust and white mold (superior to Southern Runner). UF 81206 also demonstrates a level of resistance to the peanut root-knot nematode (Gorbet et al., 1998), which results in higher pod yields when unsprayed (Gorbet et al., 1990).

Table 27 – List of whole treatments (crop sequences) used in the experiment from 1996 to 1998.

Crop Sequence	1996-1997
Fallow	1
Rye + bahiagrass	2
Rye + ryegrass + red clover + crimson clover	3
	1998
Rye + ryegrass	1
Rye + ryegrass + red clover + crimson clover	2
Rye + ryegrass + red clover + crimson clover + bahiagrass	3

Table 28 – List of sub-treatments (entries) used in the experiment from 1996 to 1998.

Peanut entry	1996-1998
Dixie Runner	1
UF 81206	2
Southern Runner	3

The winter crop cultivars used were as follows:

- Ryegrass - Florida 80 in 1996 and 1997, and Surrey in 1998 at a seeding rate of 23 kg ha^{-1}.
- Rye - Florida 401 in 1996 and 1997, and Wrens 96 in 1998 with a seeding rate of 90 kg ha^{-1}.
- Red clover – Cherokee at a rate of 17 kg ha^{-1} was used from 1996 to 1998.
- Crimson clover - Flame was used in 1996-1998 at a seeding rate of 17 kg ha^{-1}.
- Bahiagrass - Tifton 9 was planted in all three years at a rate of 23 kg ha^{-1}.

The size of the sub-plots varied from 5 rows of 4 m length totaling 12 m^2 in 1996, 5 rows of 3 m length totaling 9 m^2 in 1997, and 6 rows of 4 m length adding up to 14.4 m^2 in 1998. Plant spacing was always 0.6 m between rows and 7.5 cm within the row.

Peanut was planted between the 20 and 25 April in all the years (1996 to 1998). Although the first harvest was maintained at about 80 DAP (days after planting) the second harvest was delayed from 143 DAP, in 1996, to 165 and 170 DAP in 1997 and 1998, respectively. The time for the first harvest of the winter crops depended on the crop growth and ultimately on the weather. After that, harvests were made at 6-8 weeks intervals (Table 29 and Table 30).

Table 29 – Critical dates (planting and harvesting) for the 1996 and 1997 experiments.

Crop		1996/97			1997/98		
		Planting	Harvest	Days	Planting	Harvest	Days
Peanut Y1	Harvest 1	04/25/96	07/17/96	83	04/25/97	07/16/97	82
	Harvest 2		09/15/96	143		10/07/97	165
Winter crop Y1	Harvest 1	10/18/96	01/07/97	81	11/13/97	03/10/98	117
	Harvest 2		03/11/97	144		05/01/98	169
	Harvest 3		05/06/97	200			
Peanut Y2	Harvest 1		07/15/97				
	Harvest 2		10/07/97				
Winter crop Y2	Harvest 1		03/05/98				
	Harvest 2		05/01/98				
	Harvest 3		07/20/98				
	Harvest 4		10/21/98				

Table 30 – Critical dates (planting and harvesting) for the 1998 experiment.

Crop		1998/99		
		Planting	Harvest	Days
Peanut Y1	Harvest 1	04/20/98	07/16/98	87
	Harvest 2		10/07/98	170
Winter crop Y1	Harvest 1	11/21/98	03/22/99	121
	Harvest 2			
	Harvest 3			
Peanut Y2	Harvest 1		06/28/99	
	Harvest 2			

Cultural Practices

As it relates to weed control, irrigation, peanut fertilization, and chemical sprays, the cultural practices used in these experiments were similar to the ones mentioned in Chapter 3.

Nutrients were supplied through the application of 504 kg ha^{-1} of 4-8-12 to all plots at planting, totaling 20 kg N ha^{-1}, 40 kg P ha^{-1}, and 60 kg K ha^{-1}. For the winter crop a one time application of 100 kg ha^{-1} urea (45%) equivalent to 45 kg N ha^{-1} was applied after the first harvest.

Data Collection and Analysis

The collection of data for the calculation of peanut and winter crop forage dry matter yield, peanut pod and seed yield, as well as crude protein and IVOMD of peanut forage followed the procedures described in Chapter 3.

The evaluation of early and late leaf spots scores were combined and followed the 1-9 scale proposed by Subrahmanyam et al. (1985c) (Appendix A). Observations were made prior to final harvest only in 1996 and 1998, because in 1997 the year was so dry that diseases were not a significant problem. Tomato spotted wilt virus (TSWV) was recorded also recorded prior to the final harvest in 1996 as a percentage of the plot affected and based on the known symptoms of the disease. Insect damage was scored only in 1998 as a percentage of damaged foliage prior to final harvest.

Weed infestation was only observed in 1997 on reseeded peanut (planted in 1996) and in 1998, in both cases prior to final harvest and scored as a percentage of the total plot area occupied by weeds.

All the data were submitted to analysis of variance combined over years and with replications nested into years using PROC GLM option in SAS 6.02 for windows. Type III sum of squares was always used. Although this experiment was carried out for a period of three years (1996, 1997, and 1998), combined analysis over years was only conducted for 1996 and 1997 while 1998 was analyzed separately. Because, although the same cultivars were used for the whole period, in 1998 the crop sequences imposed as a winter crop were different from the ones used in 1996 and 1997.

Results and Discussion

Dry Matter Yield

The results from the ANOVA of peanut forage dry matter yield indicate a significant difference between the years 1996 and 1997 for the first and second harvests as well as the overall yield. Differences between entries were only found for the second harvest both for 1996-97 as well as 1998 (Table 31).

Significant differences between years (1996 and 1997) were also found for the first and second harvests, and overall forage yield of the winter crops. Statistically significant effects of peanut entries on winter crops were observed only for the first harvest and overall winter crop forage yield in 1996 and 1997. Also related to the experiments conducted in 1996 and 1997, the only other factors that showed significance were crop sequences (first harvest) and the interaction year*crop sequence (total harvest) (Table 32).

Table 31 – Summarized ANOVA table for peanut forage dry matter yield.

Peanut – Dry matter yield (kg ha^{-1})				
First harvest – 1996 and 1997				
	DF	MS	F value	Pr > F
Year	1	108158832	238.72	0.0001
Entry	2	225711	1.52	0.6101
Year*Entry	2	67986	0.50	0.8610
Error	60	453080		
Second harvest – 1996 and 1997				
	DF	MS	F value	Pr > F
Year	1	22325030	220.63	0.0001
Entry	2	1363629	13.48	0.0001
Year*Entry	2	39837	0.39	0.6763
Error	60	101189		
Total harvest – 1996 and 1997				
	DF	MS	F value	Pr > F
Year	1	228762521	393.32	0.0001
Entry	2	836269	1.44	0.2455
Year*Entry	2	125214	0.22	0.8069
Error	60	581619		
First harvest – 1998				
	DF	MS	F value	Pr > F
Entry	2	407963	0.84	0.4434
Error	30	488181		
Second harvest – 1998				
	DF	MS	F value	Pr > F
Entry	2	545997	6.56	0.0043
Error	30	83183		
Total harvest – 1998				
	DF	MS	F value	Pr > F
Entry	2	10327	0.01	0.9861
Error	30	737225		

Table 32 – Summarized ANOVA table for winter crop dry matter yield.

Winter crop – Dry matter yield (kg ha^{-1})				
First harvest – 1996 and 1997				
	DF	MS	F value	Pr > F
Year	1	4445068	58.10	0.0001
Error (a)	6	76503		
Sequence	1	286820	18.48	0.0051
Year*Sequence	1	10042	0.06	0.7783
Error (b)	6	155181		
Entry	2	255662	4.19	0.0276
Year*Entry	2	52552	0.86	0.4356
Sequence*Entry	2	73541	1.20	0.3175
Year*Sequence*Entry	2	82672	1.35	0.2774
Error (c)	36	61080		
Second harvest – 1996 and 1997				
	DF	MS	F value	Pr > F
Year	1	12427593	110.61	0.0001
Error (a)		112354		
Sequence	1	12410	0.06	0.8099
Year*Sequence	1	11750	0.06	0.7919
Error (b)	6	196468		
Entry	2	20735	0.65	0.5305
Year*Entry	2	34724	1.09	0.3522
Sequence*Entry	2	5140	0.16	0.8519
Year*Sequence*Entry	2	40953	1.29	0.2948
Error (c)	36	31850		
Third harvest – 1996				
	DF	MS	F value	Pr > F
Entry	2	24697	0.41	0.6832
Error	6	60791		
Total harvest – 1996 and 1997				
	DF	MS	F value	Pr > F
Year	1	8980880	69.45	0.0001
Error (a)		129319		
Sequence	1	6	0.00	0.9969
Year*Sequence	1	2521539	7.39	0.0169
Error (b)	6	341073		
Entry	2	321112	4.26	0.0261
Year*Entry	2	6677	0.09	0.9155
Sequence*Entry	2	156505	2.08	0.1473
Year*Sequence*Entry	2	476	0.01	0.9937
Error (c)	24	75358		

(continues)

Table 32 (continued)

First harvest – 1998				
	DF	MS	F value	Pr > F
Sequence	2	240709	1.38	0.3210
Error (a)	6	174263		
Entry	2	81214	0.21	0.8102
Sequence*Entry	4	129987	0.34	0.8468
Error (b)	18	381267		

Mean peanut forage yield obtained from the first harvest was significantly higher in 1996 (5000 kg ha^{-1}) than in 1997 (2550 kg ha^{-1}). The 1998 first harvest forage yield (2560 kg ha^{-1}) was very similar to the one obtained in 1997 (Table 33, Table 34 and Figure 20). No differences among entries were observed.

Table 33 - Peanut forage dry matter yield for the first harvest presented by year, and entry (1996-1997).

Entry	Crop year†		
	1996	1997	Mean
	---------------------------- (kg ha^{-1}) ----------------------------		
Southern Runner	5100 a	2670 b	3890 A
81206	5010 a	2450 b	3730 A
Dixie Runner	4890 a	2530 b	3710 A
Mean	5000 A	2550 B	

† - Means in the table, overall column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

Table 34 - Peanut forage dry matter yield presented by harvest, and entry (1998).

Entry	Harvest† First	Second	Total
	----------	(kg ha^{-1})	----------
Dixie Runner	2360 a	830 b	3190 A
81206	2610 a	530 c	3140 A
Southern Runner	2720 a	420 c	3140 A
Mean	2560	590	3160

† - Means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

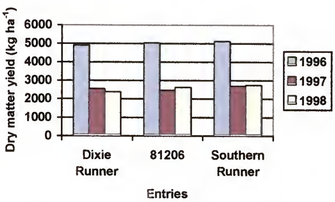


Figure 20 - Peanut forage dry matter yield for the first harvest presented by year, and entry (1996-1997).

The yields from the second harvest tended to be lower than the forage yields from the first harvest. Similarly to what happened with the first harvest, 1996 yield (1670 kg ha^{-1}) was higher than the 1997 yield (560 kg ha^{-1}), which was similar to the peanut forage yield obtained in 1998 (590 kg ha^{-1}). However, at the second harvest, significant differences between entries surfaced, with Dixie Runner yielding more than 81206 and Southern Runner that had similar yields (Table 34, Table 35 and Figure 21). The higher yields of Dixie Runner might be related to a greater tendency to replace the top growth. Of the three entries, Dixie

Runner has the more spreading growth habit, while Southern Runner and 81206 have a more bunch to spreading-bunch growth habit. This seems to lead to a greater production of vegetative organs.

Table 35 - Peanut forage dry matter yield for the second harvest presented by year, and entry (1996-1997).

Entry	Crop year†		
	1996	1997	Mean
	----------	(kg ha^{-1})	----------
Dixie Runner	1910 a	870 c	1390 A
81206	1550 b	450 d	1000 B
Southern Runner	1550 b	350 d	950 B
Mean	1670 A	560 B	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

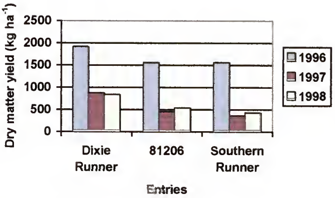


Figure 21 - Peanut forage dry matter yield for the second harvest presented by year, and entry (1996-1998).

As mentioned previously, the dry matter yield from the first harvest was always larger than the second harvest, amounting to the bulk of the peanut forage yield. For the total yield only differences between years were observed with 1996 yielding the most (6670 kg ha^{-1}) when compared to 1997 (3110 kg ha^{-1}) and 1998 (3160 kg ha^{-1}) (Table 36 and Figure 22). These differences are closely related to the rainfall. Although in 1996 the rainfall was lower than in 1997 and 1998 (Table 37), it was much better distributed allowing no extended dry periods. In 1997 an end of cycle drought began in mid-August and lasted till the final harvest severely reducing the vegetative growth during this period. In 1998, the situation was different because the drought occurred in the beginning of the crop cycle and lasted until the end of June (Appendix B). In 1998 the peanut plants were kept alive by the use of a minimal use of life saving irrigation.

Table 36 - Peanut forage dry matter yield for the total harvest presented by year, and entry (1996-1998).

Entry	Crop year†			
	1996	1997	1998‡	Mean
	---------- (kg ha^{-1}) ----------			
Dixie Runner	6790 a	3390 b	3190	5090 A
Southern Runner	6650 a	3020 b	3140	4840 A
81206	6560 a	2900 b	3140	4730 A
Mean	6670 A	3110 B	3160	

† - Means in the table, overall column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

‡ - Not included in the combined ANOVA and the overall mean.

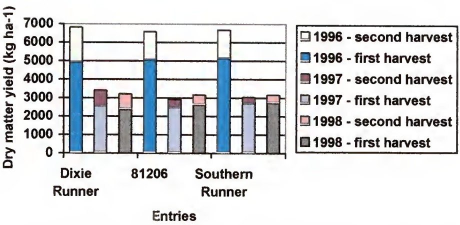


Figure 22 – Total peanut forage dry matter yield presented by year and entry (1996-1998).

Table 37 – Rainfall (mm) quantity and distribution during the peanut crop cycle.

Period		Year 1996	1997	1998
		-----	(mm)	-----
First harvest	(20-25/Apr - 11-16/Jul)	476	514	152
Second harvest	(11-16/Jul - 15/Sep-7/Oct)	264	330	672
Total	(20-25/Apr - 15/Sep-7/Oct)	740	844	824

The winter crops were harvested 3 times in 1996, twice in 1997 and only once in 1998. Forage yield of the winter crop for the first harvest was larger in 1997 (1750 kg ha^{-1}) than in 1996 (1140 kg ha^{-1}) (Table 38 and Table 39). However, it is important to mention that in 1996 the first harvest was made in January, while in 1997 and 1998 it was made in March. The earlier harvest in 1996 indicates that a substantial crop was already present, while in 1997 and 1998 very little had already grown in January. A moist fall 1996 and a warm winter 1996 allowed the 1996 winter crop a head start compared to the other two years.

The 1998 overall yield was more similar to that of 1997 (1600 kg ha^{-1}). As far as the first harvest is concerned, the previous peanut entry had no significant effect on the yield of the winter crop in 1996 (ranging 1060-1260 kg ha^{-1}) and 1998 (average of 1520-1690 kg ha^{-1}). In 1997, the winter crop following Dixie Runner significantly outyielded the winter crops following Southern Runner (1920 kg ha^{-1} and 1590 kg ha^{-1}, respectively) while crops following 81206 had an intermediate yield (1750 kg ha^{-1}). Both in 1996 and 1997 the crop sequence rye + bahiagrass yielded significantly more than the mix of rye + ryegrass + red clover + crimson clover (1690 kg ha^{-1} and 1200 kg ha^{-1} respectively). In 1998, no differences were observed among winter crop mixtures. (Table 38, Table 39, Figure 24 and Figure 25). During the whole duration of the experiment (1996-1998) red clover and crimson clover had very little impact of the forage yields, due to the poor establishment and, therefore, low plant density. This indicates that red clover and crimson clover are more difficult to establish and less competitive than the grasses in the mixtures.

Table 38 - Forage dry matter yield of the winter crop for the first harvest presented by year, entry, and cropping sequence (1996-1997).

	Cropping sequence†			
1996	Fallow	R+BG	R+RG+RC+CC	Mean
	---------- (kg ha^{-1}) ----------			
Dixie Runner		1480	1040	1260 c
81206		1310	810	1060 c
Southern Runner		1420	810	1110 c
Mean		1400	890	1140 **B**
		B	C	
1997				
Dixie Runner		2060	1780	1920 a
81206		2130	1360	1750 ab
Southern Runner		1760	1430	1590 b
Mean		1980	1520	1750 **A**
		A	B	

	Cropping sequence†			
Overall	Fallow	R+BG	R+RG+RC+CC	Mean
	---------- (kg ha^{-1}) ----------			
Dixie Runner		1770	1410	1590 A
81206		1720	1090	1400 B
Southern Runner		1590	1120	1350 B
Mean		1690	1200	
		A	B	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

Table 39 - Forage dry matter yield of the winter crop for the first harvest presented by entry and cropping sequence (1998).

1998	Cropping sequence† R+RG	R+RG+ RC+CC	R+RG+RC +CC+BG	Mean
	(kg ha^{-1})			
81206	2030	1450	1590	1690 a
Southern Runner	1530	1550	1730	1600 a
Dixie Runner	1630	1360	1570	1520 a
Mean	1730 a	1450 a	1630 a	1600

† - Means in the column and row of means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

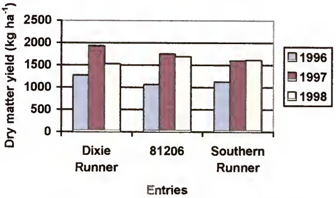


Figure 23 - Forage dry matter yield of the winter crop for the first harvest presented by year and entry (1996-1997).

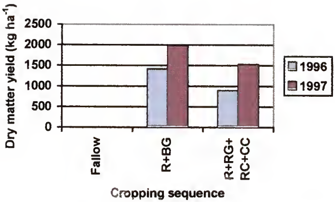


Figure 24 - Forage dry matter yield of the winter crop for the first harvest presented by year and cropping sequence (1996-1997).

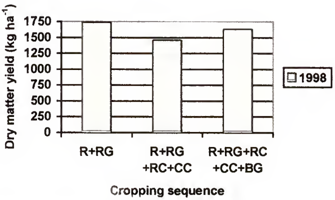


Figure 25 - Forage dry matter yield of the winter crop for the first harvest presented by cropping sequence (1998).

For the second harvest, no differences were observed either between the effect of the preceding peanut entry or the winter crop mixture. However, a higher yield was found in 1996 (1330 kg ha^{-1}) than in 1997 (310 kg ha^{-1}) (Table 40, Figure 26 and Figure 27). If, instead of looking at yields by harvest, we decide to take a time based approach the picture gets clearer. Using the end of March as reference point, 1996 outyields both 1997 and 1998 (Figure 28), that can be attributed to the larger availability of soil moisture and warmer winter temperatures.

Table 40 - Forage dry matter yield of the winter crop for the second harvest presented by year, entry, and cropping sequence (1996-1997).

		Cropping sequence†		
1996	Fallow	R+BG	R+RG+RC+CC	Mean
		(kg ha^{-1})		
81206		1440	1380	1410 a
Dixie Runner		1270	1380	1330 a
Southern Runner		1180	1310	1250 a
Mean		1300 A	1360 A	1330 **A**
1997				
81206		250	350	300 b
Dixie Runner		290	320	300 b
Southern Runner		390	260	330 b
Mean		310 B	310 B	310 **B**
		Cropping sequence†		
Overall	Fallow	R+BG	R+RG+RC+CC	Mean
		(kg ha^{-1})		
81206		850	870	860 A
Dixie Runner		780	850	810 A
Southern Runner		780	790	790 A
Mean		800 A	830 A	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

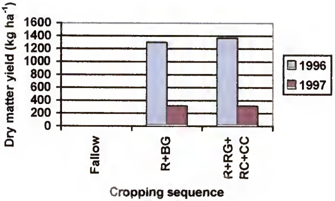


Figure 26 - Forage dry matter yield of the winter crop for the second harvest presented by year and cropping sequence (1996-1997).

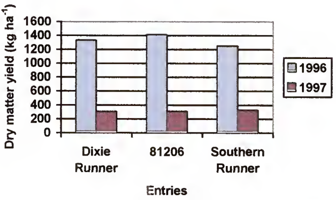


Figure 27 - Forage dry matter yield of the winter crop for the second harvest presented by year and entry (1996-1997).

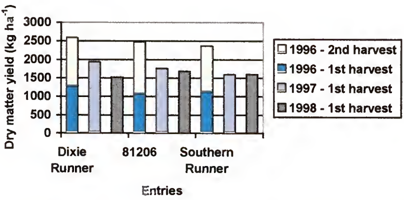


Figure 28 – Cumulative forage dry matter yield of the winter crop through the month of March presented by year, harvest and entry (1996-1997).

A third harvest of the winter crop was only possible in 1996 (at about the same time as the second harvest in 1996) with an average yield of 920 kg ha^{-1} and no significant effect of the preceding peanut entry was observed (Table 41 and Figure 29).

Table 41 - Forage dry matter yield of the winter crop for the third harvest presented by year, entry, and cropping sequence (1996).

	Forage dry matter yield†
	----- (kg ha^{-1}) -----
Dixie Runner	980 A
Southern Runner	930 A
81206	830 A
Mean	920

† - Means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

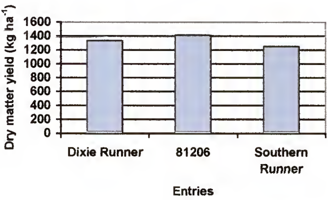


Figure 29 - Forage dry matter yield of the winter crop for the third harvest presented by year, entry, and cropping sequence (1996).

The total yield of the winter crop was larger in 1996 (2930 kg ha^{-1}) than in 1997 (2060 kg ha^{-1}) and 1998 (1600 kg ha^{-1}). The winter crop mixture had no overall significant effect on the forage yield, while in the preceding peanut entry had a significant effect on the winter crop yield, with Dixie Runner having the most influence and Southern Runner the least (Table 42, Figure 30 and Figure 31). The higher soil moisture availability in 1996, the warmer winter 1996-97 that allowed a headstart for bahiagrass, and the general conditions leading to the failure of bahiagrass to grow in 1997 and 1998 and only one harvest in 1998 are the main reasons for the observed differences. In summary the winter crop yield was directly influenced by the performance of the individual crops composing the mix. For instance, red clover and crimson clover never had a significant influence on yield due to the poor establishment and inherent lower competitiveness. Secondly, bahiagrass did not establish both in 1997 and 1998, while it already contributed to the winter crop yield in 1996.

Table 42 – Total forage dry matter yield of the winter crop presented by year, entry, and cropping sequence (1996-1997).

	Cropping sequence†			
1996	Fallow	R+BG	R+RG+RC+CC	Mean
	------------------- (kg ha^{-1}) -------------------			
Dixie Runner		2750	3400	3080 a
81206		2740	3840	2880 a
Southern Runner		2600	3050	2830 a
Mean		2700 A	3160 A	2930 **A**
1997				
Dixie Runner		2350	2100	2220 b
81206		2380	1710	2050 bc
Southern Runner		2140	1690	1920 c
Mean		2290 B	1830 B	2060 **B**

	Cropping sequence†			
Overall	Fallow	R+BG	R+RG+RC+CC	Mean
	------------------- (kg ha^{-1}) -------------------			
Dixie Runner		2550	2750	2650 A
81206		2560	2370	2460 AB
Southern Runner		2370	2370	2370 B
Mean		2500 A	2490 A	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

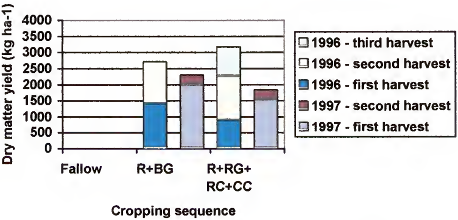


Figure 30 – Total forage dry matter yield of the winter crop presented by year, harvest and cropping sequence (1996-1997).

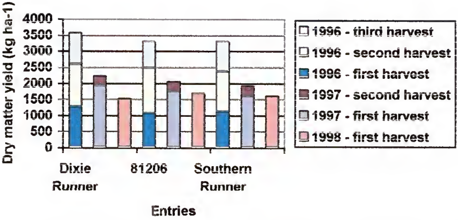


Figure 31 – Total forage dry matter yield of the winter crop presented by year, harvest and entry (1996-1998).

Pod Yield

Pod yield (kg ha^{-1}) observed in 1996 showed highly significant differences among entries (Table 43).

Table 43 - Summarized ANOVA table for pod yield for 1996.

Peanut – Pod yield (kg ha^{-1})				
1996	DF	MS	F value	Pr > F
Entry	2	3626453	29.50	0.0001
Error	30	122934		

In 1996, the University of Florida breeding line 81206 had a significantly higher pod yield (2040 kg ha^{-1}) than the remaining entries, while Southern Runner registered the lowest pod yield (940 kg ha^{-1}) (Table 44).

The combination of pod and forage yields is useful to examine for future consideration of use of cultivated peanut as a forage crop. With pod yields ranging from 940 kg ha^{-1} to 2040 kg ha^{-1} enough seed was produced to guarantee the continuity of the crop without having to replant every year (Figure 32).

Table 44 – Peanut pod yield presented by entry and cropping sequence (1996).

1996	Peanut pod yield†
	------ (kg ha^{-1}) ------
81206	2040 a
Dixie Runner	1470 b
Southern Runner	940 c
Mean	

† - Means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

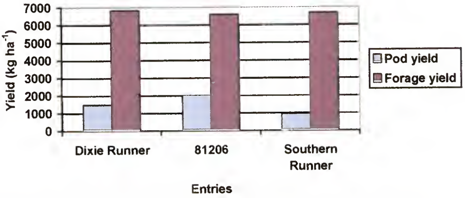


Figure 32 - Peanut pod and forage yields presented by entry (1996).

Pest Evaluation

Highly significant differences among entries was observed for the leaf spot score (1996 and 1998), TSWV incidence, insect damage, and winter crop weed infestation and peanut weed infestation [1999 (1998 planting)] (Table 45). As it relates to the occurrence of pests, only the variable weed infestation of peanut (1998) did not show significant differences among entries.

Table 45 - Summarized ANOVA table for pest related variables observed both on peanut and the winter crop.

Peanut – Leaf spot score (scale 1-9)				
1996	DF	MS	F value	Pr > F
Entry	2	28.58	30.69	0.0001
Error	30	0.93		
1998	DF	MS	F value	Pr > F
Entry	2	35.08	78.61	0.0001
Error	30	0.45		
Peanut – TSWV (%)				
1996	DF	MS	F value	Pr > F
Entry	2	7358.33	67.69	0.0001
Error	30	108.70		
Peanut – Insect damage (scale 1-3)				
1998	DF	MS	F value	Pr > F
Entry	2	3158.33	30.95	0.0001
Error	30	102.04		
Peanut – Weed infestation (%)				
1998	DF	MS	F value	Pr > F
Entry	2	786.11	2.53	0.0969
Error	30	311.30		

In 1996 TSWV had with a higher level of incidence than during the other two years. The breeding line was the most affected with 58% of the area affected by the disease, while Southern Runner and Dixie Runner performed similarly with only 18% and 12% of the area affected. A lower level of TSWV on Southern Runner was expected as the cultivar is know to have field resistance to the virus disease. However, no information was found about resistance of Dixie Runner to TSWV. In 1996 and 1998 when leaf spots (mostly late leaf spot) were a problem the highest disease incidence was observed in Southern Runner (6.0 and 6.8 in 1996 and 1998 respectively), followed by 81206 (4.3 and 5.0 respectively) while the lowest scores were observed with Dixie Runner (2.9 and 3.4 respectively. In relation to the performance of Southern Runner and 81206, the same trend was observed elsewhere (Gorbet et al., 1990; Gorbet et al., 1994). Insect damage near the end of the 1998 crop cycle was heavy, with Southern Runner being the most damaged entry (70%), followed by 81206 and Dixie Runner with similar damage levels (46% and 39% respectively). No differences among entrys were observed for weed infestation in 1998 (Table 46, Figure 33 and Figure 34). Dixie Runner, a cultivar released in the early 1940's appears to have potential for dual purpose forage use with its low levels of TSWV, leaf spot and insect damage.

Table 46 - Peanut TSWV, leaf spot score, both for 1996 and 1998, insect damage, and weed infestation, for 1998, presented by entry.

	TSWV†‡	Leaf spot score†		Insect damage†¶	Weed infestation†‡
	1996	1996	1998	1998	1998
	(%)	------ (rating§) ------		(%)	(%)
Southern Runner	18 b	6.0 a	6.8 a	70 a	35 a
81206	58 a	4.3 b	5.0 b	46 b	46 a
Dixie Runner	12 b	2.9 c	3.4 c	39 b	51 a
Mean	29	4.4	5.1	52	44

† - Means in the column followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.
‡ - TSWV (tomato spotted wilt virus) and weed infestation – rated based on percentage area affected.
§ - leaf score rating followed a 1 to 9 scale were 1 indicates no disease and 9 complete defoliation.
¶ - Insect damage – rated based on percentage of damaged plant.

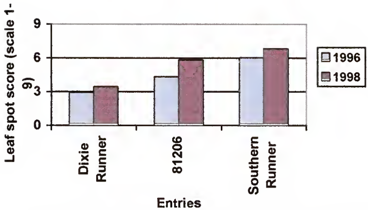


Figure 33 - Peanut leaf spot score both for 1996 and 1998, presented by entry.

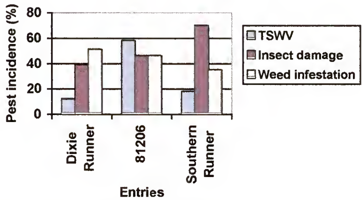


Figure 34 - Peanut TSWV, for 1996, insect damage and weed infestation, for 1998, presented by entry.

Peanut Forage Quality

The three entries showed no significant differences for crude protein or IVOMD concentration (1996) for both first and second harvests (Table 47).

Table 47 - Summarized ANOVA table for peanut crude protein and IVOMD for 1996.

Crude protein (%)				
	First harvest			
	DF	MS	F value	Pr > F
Entry	2	1.11	0.80	0.4910
Error	6	1.38		
	Second harvest			
	DF	MS	F value	Pr > F
Entry	2	2.15	1.49	0.2419
Error	6	1.44		
IVOMD (In-vitro organic matter digestibility) (%)				
	First harvest			
	DF	MS	F value	Pr > F
Entry	2	1.88	2.29	0.1823
Error	6	0.82		
	Second harvest			
	DF	MS	F value	Pr > F
Entry	2	13.15	2.49	0.1001
Error	6	5.28		

No differences were observed between entries in terms of either crude protein and IVOMD for both harvests. For the first harvest, the crude protein (168-179 g kg^{-1}) and IVOMD (691-704 g kg^{-1}) levels were similar to those obtained by Gorbet et al. (1994) (169 g kg^{-1} and 704 g kg^{-1} respectively) and in Chapter 3. However, for the second harvest, the crude protein (182-191 g kg^{-1}) and IVOMD (650-668 g kg^{-1}) were slightly higher than those reported by Gorbet et al. (1994) (165 g kg^{-1} and 639 g kg^{-1} respectively) (Table 48).

Table 48 – Crude protein and IVOMD of peanut forage for 1996, presented by entry.

Entry	Crude protein Harvest† First	Second
	---------------- ($g\ kg^{-1}$) ----------------	
Dixie Runner	179 a	191 a
81206	175 a	185 a
Southern Runner	168 a	182 a
Entry	**IVOMD Harvest† First**	**Second**
	---------------- ($g\ kg^{-1}$) ----------------	
Dixie Runner	702 a	668 a
81206	691 a	668 a
Southern Runner	704 a	650 a

† - Means in the column followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

Second Season Peanut Forage Dry Matter Yield

For the second growing season (reestablishment of peanut from previous year seed) only the results from 1997, planted in 1996, and 1999, planted in 1998, are presented. The dry weather experienced by the peanut planted in 1997 was responsible for a poor pod set and pod filling, resulting in very low seed yield and low quality seed. The consequence was an extremely low peanut plant population in 1998.

For the first harvest of 1997 the only significant differences in peanut forage yield was observed among crop sequences but, for the second harvest significant differences were found among entries. When the first and second harvests were combined (total peanut forage yield) only the differences between crop sequences were maintained. In 1999, significant differences in peanut forage yield were observed only among entries (Table 49).

During the second cropping season, bahiagrass had already established and was mixed with peanut. A few other grassy weeds appeared in the field and were not separated from bahiagrass. Significant differences were observed only among sequences for the yield of the second harvest and total yield (Table 50). For the total yield (peanut + bahiagrass and weedy grasses) significant differences were observed among entries, for the first harvest, and among crop sequences, for the second harvest (Table 51).

Table 49 - Summarized ANOVA table for peanut forage dry matter yield for the second cropping season.

Peanut – Dry matter yield (kg ha^{-1})				
	First harvest - 1997 (1996 planting)			
	DF	MS	F value	Pr > F
Sequence	2	7271597	9.63	0.0134
Error (a)	6	755076		
Entry	2	332937	2.78	0.0903
Sequence*Entry	4	39089	0.33	0.8565
Error (b)	17	119804		
	Second harvest - 1997 (1996 planting)			
	DF	MS	F value	Pr > F
Sequence	2	85908	1.43	0.3097
Error (a)	6	59899		
Entry	2	110607	10.34	0.0010
Sequence*Entry	4	34960	3.27	0.0352
Error (b)	18	10701		
	Total harvest - 1997 (1996 planting)			
	DF	MS	F value	Pr > F
Sequence	2	6096566	7.84	0.0212
Error (a)	6	778006		
Entry	2	85283	0.66	0.5302
Sequence*Entry	4	117866	0.91	0.4802
Error (b)	17	129474		
	First harvest - 1999 (1998 planting)			
	DF	MS	F value	Pr > F
Sequence	2	222442	1.38	0.3207
Error (a)	6	160870		
Entry	2	492522	3.68	0.0459
Sequence*Entry	4	218424	1.63	0.2101
Error (b)	18	134006		

Table 50 - Summarized ANOVA table for bahiagrass forage dry matter for the second cropping season.

Bahiagrass – Dry matter yield (kg ha^{-1})				
First harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Entry	2	307486	1.64	0.2706
Error	11	187725		
Second harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Sequence	2	1456467	9.03	0.0155
Error (a)	6	161365		
Entry	2	27777	0.94	0.4104
Sequence*Entry	4	26520	0.89	0.4879
Error (b)	18	29672		
Total harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Sequence	2	17113667	23.71	0.0014
Error (a)	6	721928		
Entry	2	94744	1.21	0.3204
Sequence*Entry	4	173667	2.22	0.1071
Error (b)	18	78080		

Table 51 - Summarized ANOVA table for peanut+bahiagrass forage dry matter yield for the second cropping season.

Total peanut + bahiagrass – Dry matter yield (kg ha^{-1})				
First harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Sequence	2	54240	0.06	0.9447
Error (a)	6	944427		
Entry	2	722477	4.91	0.0208
Sequence*Entry	4	209589	1.42	0.2688
Error (b)	17	147226		
Second harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Sequence	2	2137530	17.75	0.0030
Error (a)	6	120435		
Entry	2	92464	3.09	0.0702
Sequence*Entry	4	54550	1.82	0.1684
Error (b)	18	29925		
Total harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Sequence	2	2680159	2.02	0.2138
Error (a)	6	1328849		
Entry	2	361293	1.78	0.1984
Sequence*Entry	4	416995	2.06	0.1318
Error (b)	17	202814		

When peanut was able to set good seed and the winter was cold enough to keep the seed from germinating too early, the stock of seed in the ground was able to germinate and generate a new second season crop. In 1997 (1996 planting) Dixie Runner yielded significantly less forage (1280 kg ha^{-1}) than 81206 and Southern Runner (1620 kg ha^{-1} and 1750 kg ha^{-1}, respectively). The peanut germinating following the winter crop of rye and bahiagrass (R+BG) was strongly suppressed by the existing bahiagrass resulting in the lowest yield of the 3 cropping sequences (680 kg ha^{-1}). Peanut yielded about 2010 kg ha^{-1} when following fallow or the mixture R+RG+RC+CC. In 1999 (1998 planting) the situation was somewhat different with no significant differences between cropping sequences and Dixie Runner yielding significantly more than Southern Runner. The yields from the second harvest of 1997 were very low. These yields coincide with the low yields reported for the second harvest of the 1997 initial planting (Table 35, Figure 21). Dixie Runner yielded more than the other two entries, while the cropping sequences had no effect on the peanut forage yield (Table 52, Table 53, Figure 35 and Figure 36). It is important to stress that peanut yield was suppressed by bahiagrass and that except for bahiagrass, the winter crops had no effect with yield similar to the fallow system. For 1999, the lack of differences between cropping sequences is directly related to the fact that the established population of red clover and crimson clover was very low, and that bahiagrass never germinated and established, rendering the same mix R+RG in all plots.

During 1997 peanut growing period (1996 planting) bahiagrass was already established on the R+BG plots. At the first harvest of 1997 bahiagrass yield averaged 1470 kg ha^{-1} with no significant effect of the competing peanut entry. At the second harvest the peanut entry still had no effect on the yield of bahiagrass that amounted to 1120-1190 kg ha^{-1}. On the fallow and R+RG+RC+CC plots 500 to 650 kg ha^{-1} of weeds (mainly grasses) were harvested with the peanuts. Very few weeds were found on the plots containing bahiagrass. As a result the total bahiagrass harvest averaged 2630 kg ha^{-1} with no effect from the companion crop (peanut) (Table 54 and Figure 37).

Looking at the combined yield of peanut and bahiagrass, one aspect seems to gain special emphasis. Although the peanut yield is suppressed by the more competitive bahiagrass, bahiagrass is able to produce enough dry matter to compensate for the loss rendering all cropping sequences similar at the time of first harvest. For the second harvest the sequence R+BG significantly outyields the others. The final result is a R+BG system yielding significantly more than the fallow and the R+RG+RC+CC sequence. Looking to the effect of the peanut entry planted into the system, the most important message comes from the Southern Runner mix that yielded significantly more than the other entries (3240 kg ha^{-1} compared with 2820-3070 kg ha^{-1} (Table 55, Figure 38 and Figure 39). The competitiveness of bahiagrass makes the combination peanut-bahiagrass more efficient and higher yielding than peanut alone, whether or not other winter crops are used.

Table 52 – Second season peanut forage dry matter yield for 1997 (1996 planting) presented by entry, and cropping sequence.

First harvest	Cropping sequence†			
	Fallow	R+BG	R+RG+RC+CC	Mean
	---------- ($kg\ ha^{-1}$) ----------			
Southern Runner	2260	910	2090	1750 a
81206	2170	590	2080	1620 a
Dixie Runner	1460	540	1870	1280 b
Mean	2010	680	2010	
	A	B	A	

Second harvest	Cropping sequence†			
	Fallow	R+BG	R+RG+RC+CC	Mean
	---------- ($kg\ ha^{-1}$) ----------			
Southern Runner	70	300	80	150 b
81206	140	280	190	200 b
Dixie Runner	200	330	470	340 a
Mean	140	300	250	
	B	A	A	

Total harvest	Cropping sequence†			
	Fallow	R+BG	R+RG+RC+CC	Mean
	---------- ($kg\ ha^{-1}$) ----------			
Southern Runner	2330	1210	2170	1900 B
81206	2310	870	2270	1820 B
Dixie Runner	1590	870	2340	1600 A
Mean	2120	980	2260	
	A	B	A	

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

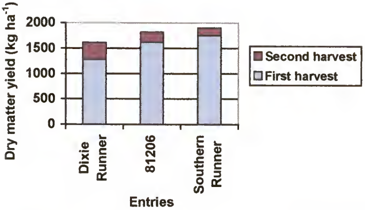


Figure 35 - Second season peanut forage dry matter yield for 1997 (1996 planting) presented by entry and harvest.

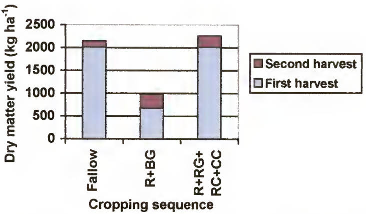


Figure 36 - Second season peanut forage dry matter yield for 1997 (1996 planting) presented by cropping sequence and harvest.

Table 53 – Second season peanut forage dry matter yield for 1999 (1998 planting) presented by entry, and cropping sequence.

First harvest	Cropping sequence†			
	R+RG	R+RG+RC+CC	R+RG+RC+CC+BG	Mean
	------------------------ ($kg\ ha^{-1}$) ------------------------			
Dixie Runner	1110	1590	830	1170 a
81206	1120	950	1090	1020 ab
Southern Runner	850	840	630	770 b
Mean	990 a	1120 a	850 a	

† - Means in the column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

Table 54 – Second season bahiagrass forage dry matter yield for 1997 (1996 planting) presented by entry, and cropping sequence.

First harvest	Cropping sequence†				
	Fallow	R+BG	R+RG+RC+CC	Mean	
	(kg ha^{-1})				
Dixie Runner		1310		1310	a
81206		1310		1310	a
Southern Runner		1790		1790	a
Mean		1470			

Second harvest‡	Cropping sequence				
	Fallow	R+BG	R+RG+RC+CC	Mean	
	(kg ha^{-1})				
Dixie Runner	520	1120	550	730	a
81206	640	1180	630	820	a
Southern Runner	390	1190	650	750	a
Mean	520	1160	610		
	B	A	B		

Total harvest‡	Cropping sequence†				
	Fallow	R+BG	R+RG+RC+CC	Mean	
	(kg ha^{-1})				
Dixie Runner	520	2430	550	1170	A
81206	640	2490	630	1260	A
Southern Runner	390	2980	650	1340	A
Mean	520	2630	610		
	B	A	B		

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

‡ - Includes a certain amount of contaminating weeds (mainly grasses).

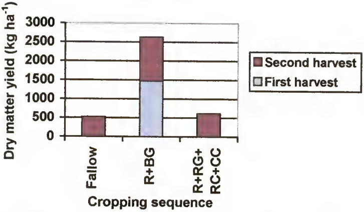


Figure 37 - Second season bahiagrass forage dry matter yield for 1997 (1996 planting) presented by cropping sequence and harvest.

Table 55 – Second season peanut + bahiagrass forage dry matter yield for 1997 (1996 planting) presented by entry, and cropping sequence.

First harvest	Cropping sequence†				
	Fallow	R+BG	R+RG+RC+CC	Mean	
	(kg ha^{-1})				
Southern Runner	2260	2700	2090	2350	a
81206	2170	1900	2080	2050	ab
Dixie Runner	1460	1850	1870	1750	b
Mean	2010	2150	2010		
	A	A	A		

Second harvest‡	Cropping sequence				
	Fallow	R+BG	R+RG+RC+CC	Mean	
	(kg ha^{-1})				
Southern Runner	460	1490	740	900	b
81206	780	1460	820	1020	ab
Dixie Runner	730	1450	1010	1060	a
Mean	660	1470	860		
	C	A	B		

Total harvest‡	Cropping sequence†				
	Fallow	R+BG	R+RG+RC+CC	Mean	
	(kg ha^{-1})				
Southern Runner	2720	4190	2820	3240	A
81206	2950	3360	2910	3070	AB
Dixie Runner	2100	3300	2890	2820	B
Mean	2640	3610	2870		
	B	A	B		

† - Means in the table, and column and row of means followed by the same case letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

‡ - Includes a certain amount of contaminating weeds (mainly grasses).

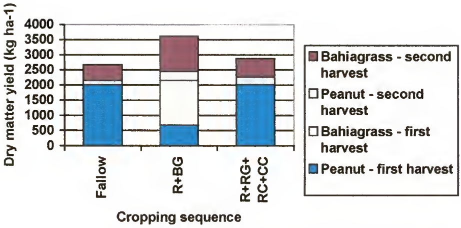


Figure 38 - Second season peanut + bahiagrass forage dry matter yield for 1997 (1996 planting) presented by cropping sequence.

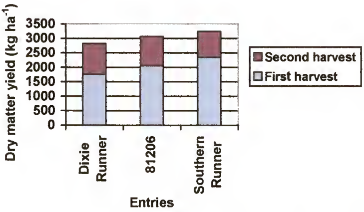


Figure 39 - Second season peanut + bahiagrass forage dry matter yield for 1997 (1996 planting) presented by entry and harvest.

<u>Second Season Winter Crop Forage Dry Matter Yield</u>

In terms of the forage yield of the winter crop during the second growing season, significant differences among entries were observed at the third harvest and for the total yield (Table 56).

Table 56 - Summarized ANOVA table for winter crop dry matter yield for the second cropping season.

Winter crop – Dry matter yield (kg ha^{-1})				
First harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Entry	2	5515	0.79	0.4948
Error	6	6956		
Second harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Entry	2	5746	0.24	0.7923
Error	6	23733		
Third harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Entry	2	808075	8.24	0.0190
Error	6	98084		
Fourth harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Rep	3	92880		
Total harvest - 1997 (1996 planting)				
	DF	MS	F value	Pr > F
Entry	2	2191029	15.44	0.0043
Error	6	141880		

In 1998, after the harvest of the second season peanut [1997 (1996 planting)], the yield of bahiagrass was quite high (6530-7350 kg ha^{-1}), with the preceding peanut entry influencing significantly the yields of the third harvest and total yield. Breeding line 81206 had a positive effect on the bahiagrass yield that was significantly higher than that influenced by Dixie Runner. Out of all the harvests, third and fourth are the highest yielding and most important (July through October) (Table 57 and Figure 40).

Table 57 – Bahiagrass forage dry matter yield for the second season crop presented by entry and harvest for the R+BG cropping sequence (1997, 1996 planting).

	Winter crop forage dry matter yield Harvest (cropping system R+BG)*				
	First 3/5/98	Second 5/1/98	Third 7/20/98	Fourth 10/21/98	Total
	(kg ha^{-1})				
81206	510 a	690 a	4310 a	1870 a	7350 A
Southern Runner	480 a	760 a	3830 ab	1870 a	6970 AB
Dixie Runner	560 a	700 a	3410 b	1870 a	6530 B
Mean	520	720	3850	1870	6950

- \- Means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

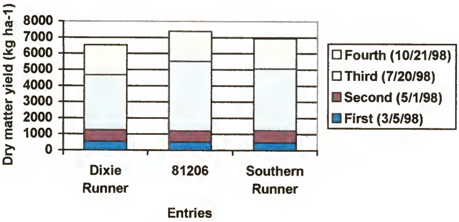


Figure 40 - Bahiagrass forage dry matter yield for the second season crop presented by entry and harvest for the R+BG cropping sequence (1997, 1996 planting).

Weed Infestation During The Winter Crop Of The Second Season

Highly significant differences among entries was observed for the winter crop weed infestation and peanut weed infestation [1999 (1998 planting)] (Table 58). As it relates to the occurrence of pests, only the variable weed infestation of peanut (1998) did not show significant differences among entries.

Table 58 - Summarized ANOVA table for pest related variables observed both on peanut and the winter crop.

Winter crop – Weed infestation (%)				
1997 (1996 planting)	DF	MS	F value	Pr > F
Sequence	2	26043.75	99999	0.0001
Error	30	52.08		
Peanut – Weed infestation (%)				
1999 (1998 planting)	DF	MS	F value	Pr > F
Sequence	2	1011.11	2.18	0.1938
Error (a)	6	462.96		
Entry	2	4636.11	10.72	0.0009
Sequence*Entry	4	486.11	1.12	0.3762
Error (b)	18	432.41		

No significant differences between entries were found in terms of weed infestation at the time of the final peanut harvest of 1997. The winter crop reduces significantly (from 84% weeds with fallow to 0-5% weeds with winter crops. In 1999 more weeds appeared in the field. With the red clover and crimson clover having such a small plant density and the non-germination of bahiagrass, all plots were left with rye and ryegrass that was harvested in March leaving the field almost completely open for the growth of peanut (Table 59).

Table 59 - Weed infestation for the second season peanut crop presented by entry, and cropping sequence (1997, 1996 planting and 1999, 1998 planting).

	Cropping sequence†				
1997	Fallow	R+BG	R+RG+RC+CC	Mean	
	(%)				
Dixie Runner	84	5	1	30	a
81206	84	5	1	30	a
Southern Runner	84	5	1	30	a
Mean	84	5	1		
	a	b	c		

	Cropping sequence†				
1999	R+RG	R+RG+RC+CC	R+RG+RC+CC +BG	Mean	
	(%)				
Dixie Runner	33	13	55	33	b
81206	55	45	50	50	b
Southern Runner	70	70	78	73	a
Mean	53	43	61	52	
	a	a	a		

† - Means in the column and row of means followed by the same letter are not significantly different according to the Duncan Multiple Range Test at 5% probability.

Conclusions

There is potential for the use of cultivated peanut as forage. However, it is important to accumulate more information about its persistence and reestablishment, particularly the extreme effects of the weather, especially rainfall.

Forage yields were similar for the three tested entries, but the pod yields were different (Southern Runner highest). Southern Runner had a high pod yield despite being the entry most affected by TSWV and late leaf spot.

At the time of initial planting, weeds were controlled by an application of herbicide. After the first season, the required expenditure and the uncertainty of when peanut will germinate make spraying with a herbicide is not the best option. Therefore the winter crop becomes fundamental for weed control, by keeping the weed population in check. On the other hand, the presence of a winter crop in the field and later the residues and stubble seem to be a good tool to keep small animals like raccoons out of the field.

The winter crops are a important source of additional feed. The mix of Rye + Ryegrass + Red clover + Crimson clover besides having the best weed and pest control (for the 1996 planting), allowed a third harvest resulting in a good forage yield. It is important to mention that red clover and crimson clover had virtually no influence on the performance of the cropping mixes.

Planting bahiagrass as a winter crop after peanut harvest seems to be a promising method for the early establishment of bahiagrass pastures. Bahiagrass has a higher competitive ability than the peanut, suppressing peanut forage yield. At the same time bahiagrass is able to compensate for the yield losses, returning good forage yields. When bahiagrass seed is planted mixed with winter grasses in the fall, the seed tends to germinate earlier than the normal planting date (February) being able to achieve full cover of the field in no more than two years.

In order to have permanent forage fields of peanut, winter crops must be planted, but only to annuals like rye and ryegrass. Red clover and crimson clover proved to be unable to compete with the winter crops becoming more of an expense rather than an advantage.

APPENDIX A
RUST AND EARLY LEAF SPOT SCORING SCALES

Modified 9-point scale used for field-screening groundnut genotypes for resistance to rust.

Disease score	Description	Disease severity (%)[1]
1	No disease	0
2	Pustules sparsely distributed, largely on lower leaves	1-5
3	Many pustules on lower leaves, necrosis evident; very few pustules on middle leaves	6-10
4	Numerous pustules on lower and middle leaves; severe necrosis on lower leaves	11-20
5	Severe necrosis of lower and middle leaves; pustules may be present on top leaves but less severe	21-30
6	Extensive damage to lower leaves; middle leaves necrotic, with dense distribution of pustules; pustules on top leaves	31-40
7	Severe damage to lower and middle leaves; pustules densely distributed on top leaves 41-60	41-60
8	100% damage to lower and middle leaves; pustules on top leaves, which are severely necrotic	61-80
9	Almost all leaves withered; bare stems seen	81-100

1. Percentage leaf area damaged by the disease.

Source: Subrahmanyam et al. (1985c)

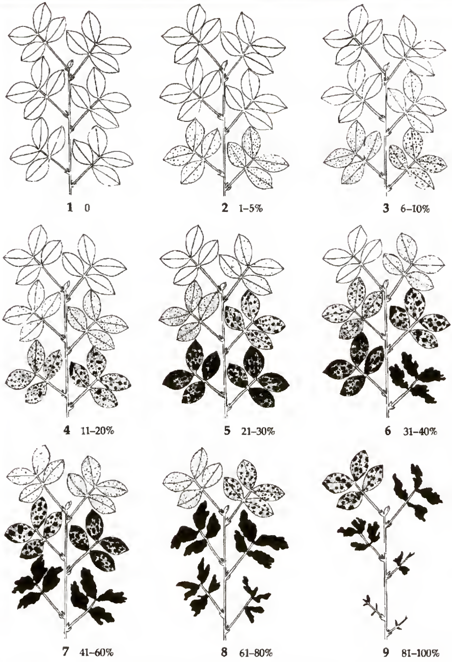


Figure 8. The modified 9-point scale for field evaluation of rust.

Source: Scanned page from Subrahmanyam et al. (1985c)

Modified 9-point scale used for field-screening groundnut genotypes for resistance to late leaf spot.

Disease score	Description	Disease severity (%)[1]
1	No disease	0
2	Lesions present largely on lower leaves; no defoliation	1-5
3	Lesions present largely on lower leaves, very few on middle leaves; defoliation of some leaflets evident on lower leaves	6-10
4	Lesions on lower and middle leaves but severe on lower leaves; defoliation of some leaflets evident on lower leaves	11-20
5	Lesions present on all lower and middle leaves; over 50% defoliation of lower leaves	21-30
6	Severe lesions on lower and middle leaves; lesions present but less severe on top leaves; extensive defoliation of lower leaves; defoliation of some leaflets evident on middle leaves	31-40
7	Lesions on all leaves but less severe on top leaves; defoliation of all lower and some middle leaves	41-60
8	Defoliation of all lower and middle leaves; severe lesions on top leaves; some defoliation of top leaves evident	61-80
9	Almost all leaves defoliated, leaving bare stems; some leaflets may remain, but show severe leaf spots	81-100

1. Percentage leaf area damaged by the disease.

Source: Subrahmanyam et al. (1985c)

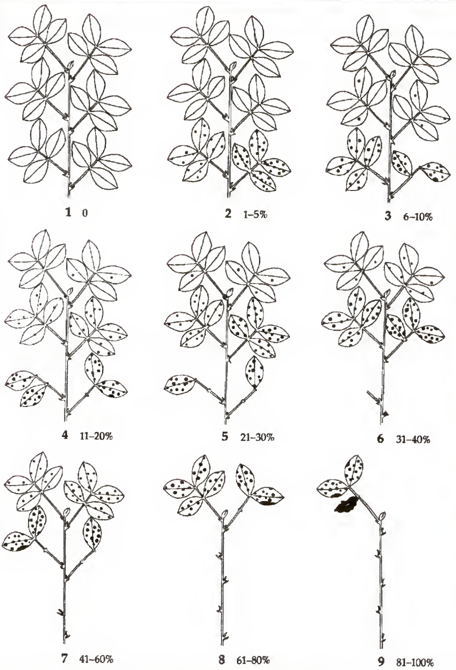


Figure 9. The modified 9-point scale for field evaluation of late leaf spot.

Source: Scanned page from Subrahmanyam et al. (1985c)

APPENDIX B
GREEN ACRES WEATHER DATA: RAINFALL, MINIMUM AND MAXIMUM TEMPERATURES

Weather data [rainfall (mm), and minimum and maximum temperatures (^{o}C)] for the period from January 1903 to October 1999 was used. For the rainfall totals for 10 days periods (1-10, 11-20 and 21 to the end of the month) was computed. Probabilities of occurrence were also computed independently for the rainfall of each 10 days period. The data is presented in Table B1, Figure B1, Figure B2, and Figure B3.

Table B1 – Rainfall (mm) and respective probability of occurrence (%) by 10 day periods and based on data from 1903-1999†.

	Jan1 (mm)	prob (%)	Jan2 (mm)	prob (%)	Jan3 (mm)	prob (%)	Feb1 (mm)	prob (%)	Feb2 (mm)	prob (%)	Feb3 (mm)	prob (%)	Mar1 (mm)	prob (%)	Mar2 (mm)	prob (%)	Mar3 (mm)	prob (%)
1996	34	69	4	24	7	28	24	46	2	14	3	27	85	93	72	92	78	92
1997	24	57	11	44	36	73	0	4	18	46	18	53	0	9	38	71	48	77
1998	26	58	20	58	55	82	44	73	165	100	144	100	40	67	57	84	0	12
1999	42	75	7	34	77	92	31	64	12	35	10	38	3	21	51	77	0	13
Minimum (1%)	0		0		0		0		0		0		0		0		0	
Median (50%)	21		16		17		25		21		15		25		14		22	
Maximum (100%)	139		110		154		162		113		112		155		215		176	

	Apr1 (mm)	prob (%)	Apr2 (mm)	prob (%)	Apr3 (mm)	prob (%)	May1 (mm)	prob (%)	May2 (mm)	prob (%)	May3 (mm)	prob (%)	Jun1 (mm)	prob (%)	Jun2 (mm)	prob (%)	Jun3 (mm)	prob (%)
1996	5	31	9	43	53	89	6	35	8	39	25	42	73	77	44	53	53	41
1997	0	15	24	66	156	100	0	15	52	79	29	51	110	93	52	62	30	22
1998	3	26	3	27	0	26	1	21	6	34	64	75	6	15	3	6	36	25
1999	0	16	16	54	11	56	12	49	61	85	27	47	47	58	48	59	87	72
Minimum (1%)	0		0		0		0		0		0		0		0		3	
Median (50%)	15		15		6		12		18		29		39		40		60	
Maximum (100%)	203		123		99		173		117		167		181		208		175	

† - prob (%) – probability of occurrence.

Table B1, continued.

	Jul1 (mm)	prob (%)	Jul2 (mm)	prob (%)	Jul3 (mm)	prob (%)	Aug1 (mm)	prob (%)	Aug2 (mm)	prob (%)	Aug3 (mm)	prob (%)	Sep1 (mm)	prob (%)	Sep2 (mm)	prob (%)	Sep3 (mm)	prob (%)
1996	179	97	35	34	0	3	60	51	75	79	93	84	13	19	23	44	11	29
1997	85	82	93	78	35	24	123	93	23	23	6	7	0	1	1	9	45	63
1998	36	38	115	92	58	57	97	79	65	71	16	20	106	89	38	60	90	91
1999	71	75	20	16	44	35	97	80	75	80	10	13	18	24	56	72	132	95
Minimum (1%)	0		2		0		3		0		0		1		0		0	
Median (50%)	45		50		50		57		43		54		40		28		24	
Maximum (100%)	292		216		168		268		194		277		288		197		185	

	Oct1 (mm)	prob (%)	Oct2 (mm)	prob (%)	Oct3 (mm)	prob (%)	Nov1 (mm)	prob (%)	Nov2 (mm)	prob (%)	Nov3 (mm)	prob (%)	Dec1 (mm)	prob (%)	Dec2 (mm)	prob (%)	Dec3 (mm)	prob (%)
1996	130	97	2	30	0	19	16	65	0	23	11	65	76	96	62	94	0	5
1997	4	20	6	46	124	99	41	86	45	89	31	84	26	69	138	100	91	94
1998	87	92	0	20	0	20	3	37	5	53	2	32	0	18	5	24	9	37
1999	5	25																
Minimum (1%)	0		0		0		0		0		0		0		0		0	
Median (50%)	19		7		8		6		4		5		13		15		16	
Maximum (100%)	163		231		191		98		104		82		133		110		172	

† - prob (%) – probability of occurrence.

Figure B1 – Rainfall (mm) presented by 10 days periods for 1996 through 1999.

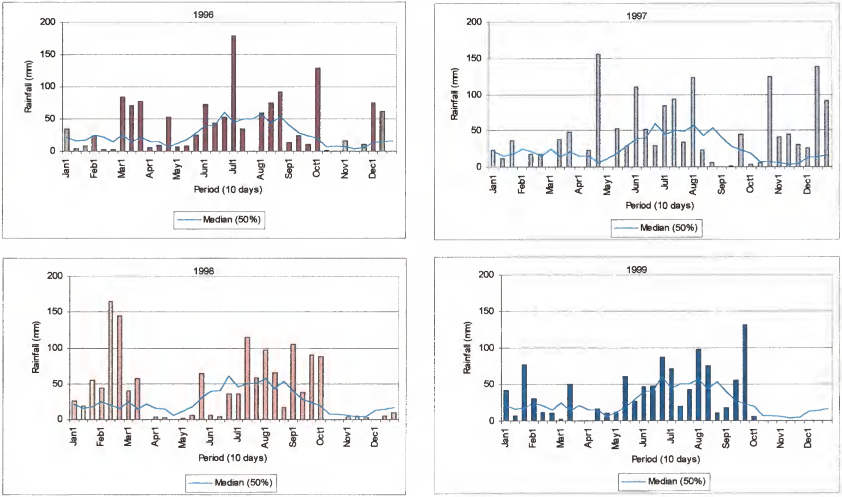


Figure B2 – Probability of rainfall occurrence (%) presented by 10 days periods for 1996 through 1999 and based on the period from 1903 to 1999.

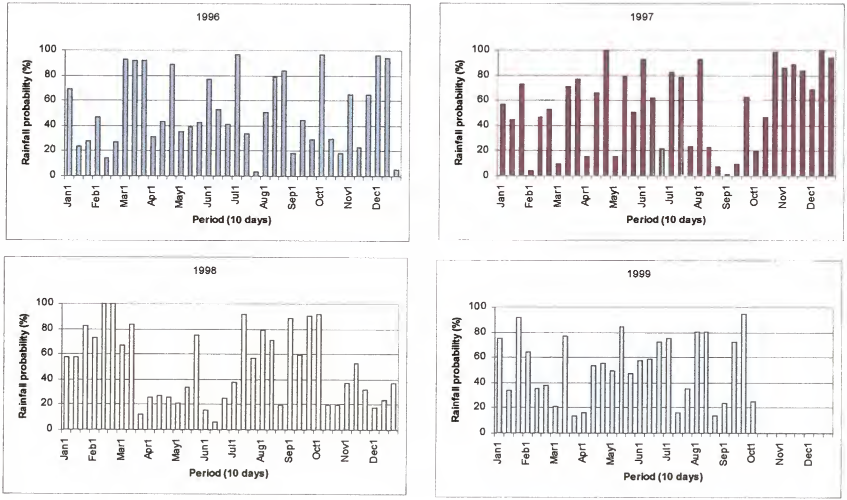
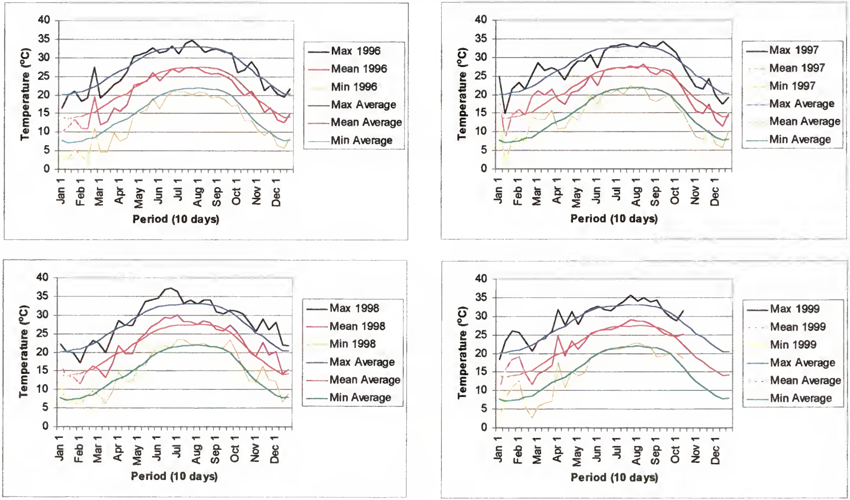


Figure B3 – Maximum, minimum and mean temperatures (°C) presented by 10 days periods for 1996-1999. Average temperatures (°C) are based on the period from 1903 to 1999.



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BIOGRAPHICAL SKETCH

I was born Marcos João Vitória Corona de Albuquerque Freire, the son of Eduardo Domingos Ribeiro de Albuquerque Freire and Francisca Corona da Silva Ribeiro Albuquerque Freire (a.k.a. Hortense) on January 8, 1960, in Maputo (then Lourenço Marques), Mozambique. I am married to Maria Olanda Bata and we have three daughters (Silvia, fifteen years old; Jessie Kay, thirteen years old; and Nicole Freire, four years old).

I did all my primary and high schooling in Maputo. In 1981, I received a college degree–Licenciatura in Agronomy–from the Universidade Eduardo Mondlane, Faculdade de Agronomia e Engenharia Florestal (Faculty of Agronomy and Forestry Engineering - FAFE) in Maputo, Mozambique. In 1982, I was hired by the university (FAFE) in Mozambique, and until 1985 was involved in practical training, teaching, research, and peanut seed production. From August 1985 to November 1987 I earned a M.Sc. (Ag) degree from the Andhra Pradesh Agricultural University, India, while doing research at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) on the effects of staggered sowing dates on intercropping groundnut-maize. From the end of 1987 until 1995 I worked at FAFE. My responsibilities included: teaching mainly legume crops, vegetables, and general agriculture; research and extension focused on peanut agronomy, breeding and farming systems; administration, from 1988 to 1994, including service as head of the Department of Crop Production and Protection and director (coordinator) of the Agronomy degree (specializing in crop production and protection).

In the future, after my return to Mozambique and to FAFE, I shall resume my activities with expected enhanced performance. I also expect to start research projects related to the collection of germplasm of fruit species native to Mozambique, and sustainable peanut production through a farming systems approach. Meanwhile I hope to be able to continue to be the best father and husband I can be.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

K.H Quesenberry, Chair
Professor of Agronomy

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P.L. Pfahler
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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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