Chapter 3

Soil Management for the Establishment of the Forage Legume Arachis pintoi as a Mean to Improve Soil Fertility of Native Pastures of Mexico

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Additional information is available at the end of the chapter

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1. Introduction

Pasture (rangelands) degradation in the humid tropics of Latin America is a fact that dates back several decades, and to date not only has not been resolved, but tends to worsen according to the unfavorable economic situation of livestock in the region [1].

In Mexico, according to a report [2], 75% of the degradation is caused by deforestation (25.8%), overgrazing (24.6%) and changing land use (agricultural and urban-industrial, 25.5%). The report adds that, in the north as well as in the southern of Mexico, livestock have overgrazed pastures and supports excesives stocking rates, causing a radical change in the floristic composition of rangelands and reduced permeability of the soil, increasing runoff and causes accelerated erosion thereof.

In this paper we addressed several land management practices for the establishment of the forage legume *Arachis pintoi* (CIAT accesions 17434, 18744 and 18748) as a means to improve soil fertility on native pastures of Mexico. *Arachis pintoi* was selected because it is a forage species that has enormous potential to improve the vegetation cover of the grazing areas in the Mexican tropics, and its contribution of nutrients to the soil, improving the fertility of this. All experiments were conducted in the northern of Veracruz state, Mexico, in a hot and humid climate, where soils are classified mainly as Ultisols or Oxisols. Some of the experiences were developed in native pastures and or in citrus plantations because this is a very important crop in this region.

In the most recent experience, three land preparation management experiments were conducted, in order to evaluate the establishment of *Arachis pintoi* CIAT 17434. The results offer a range of practices to cattle producers from which they could select the best practice according their specific conditions.

Previously, in 2006, two experiments were carried out in order to assess the establishment of *Arachis pintoi* as a cover crop in citrus plantations.

Also, were evaluated two treaments to establish *Arachis pintoi* and *Pueraria phaseoloides*. The two treatments consisted of (1) weeding by slashing (S) and application of herbicides (H), and (2) burning (+B) or not (-B), as main plots. Phosphorus (simple superphosphate) application (-P, +P) was included as subplots.

In other experiment, two methods of soil preparation were evaluated in a native pasture. The two methods, conventional tillage and minimum tillage were evaluated under the establishment of *A. pintoi* CIAT 17434 with fertilization (T1 and T2) and without fertilization (T3 and T4). In terms of number of *A. pintoi* plants established and soil cover, with complete soil preaparation, gave the best results. The legume did not respond to fertilization because of its slow initial growth.

2. Establishment of *Arachis pintoi* Krapov & W.C. Greg. as a cover crop in citrus plantations of Veracruz, México

The citrus crop in Mexico is one of the most important agricultural activities, both in area established as the value of marketing. At the end of 1999, 322.000 ha of orange (*Citrus sinensis* L.) and 32,000 ha of Persian lime (*Citrus latifolia* Tan), which depend altogether more than 15,000 families involved in the processes of production, harvesting, packing and marketing. In the case of the orange, the estimated production in 1997 was 3.9 million tonnes, while for the Persian lime was 244 thousand tons [3].

Arachis pintoi has shown a high potential as a cover crop in perennial crops such as citrus [4], peach [5], banana [6] and papaya [7]; thus, its incorporation in orange and lemon plantations in Mexico could be a viable alternative. Considering this, we evaluated the ecotypes *A. pintoi* CIAT 17434, 18744 and 18748 as options in citrus vegetation of Veracruz, Mexico.

2.1. Materials and methods

In April 1996 we established two experiments on commercial farms located in the municipalities of Martinez de la Torre and Misantla, Veracruz, Mexico (20 º 03 'north latitude and 97 ° 03'longitud west), with hot and humid climate (24 º C average and 1980 mm annual rainfall), and no definite dry season, at 112-151 meters above sea level. Figure 1 presents the data of temperature and rainfall recorded during the course of the experiments, which is typical of the region, whereas data of 20 years, except for rain April, where the normal is half of that shown in graph mentioned.

2.2. First experiment

This was done in a lemon orchard Persian 3-year-old plantation trees with 7 x 7 m. We evaluated the establishment as cover crop of the ecotypes: CIAT 17434, 18744 and 18748. The field was prepared with cross harrowing, 20 cm deep. AP 17434 was used for vegetative material (stolons 20 cm in length) while the remaining were planted with seeds (two seeds per planting point). All ecotypes were inoculated with *Bradyrhizobium* strain CIAT 3101. Sowing was done in furrows separated by one meter and 50 cm between plants. For the availability of plant material or seed ecotypes had different number of test sites, with three repetitions of a square meter per site, so the 17434 had five sites, while the 18744, two, and the 18748, a site. The treatments were fertilized at planting date with superphosphate single at 50 kg/ha of P_2O_5, and 30, 90 and 180 days after planting date with KCl (83 kg/ha). Number of plants (plants/m2) and plant height (cm) was evaluated at 4, 8 and 12 weeks; and coverage (%) at 4, 8, 12, 16, 20 and 24 weeks. The data of number of plants were subjected to a logarithmic transformation to meet assumptions of analysis of variance. Analysis of variance were performed, and means were compared using the Tukey test. For plant height only averages were estimated. We used a completely randomized design, with *Ap* ecotypes as treatments, and a level of probability (P) for comparison of means of 0.05 was used.

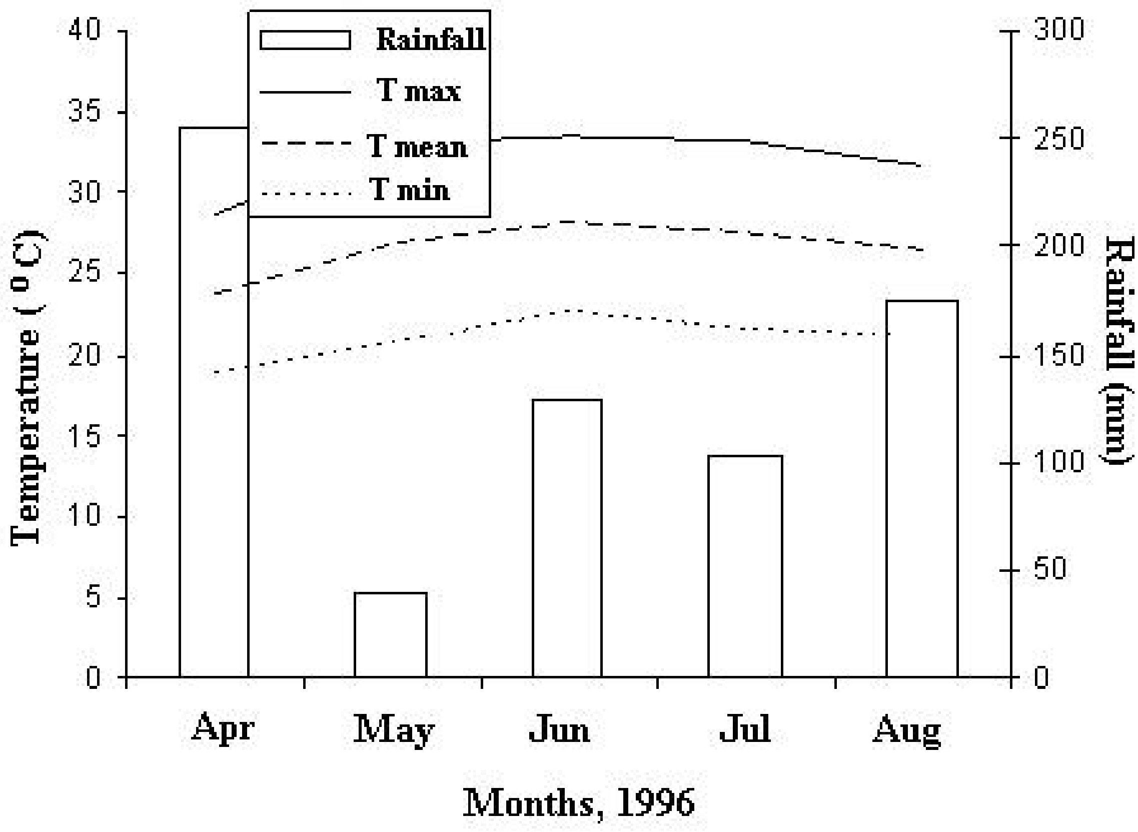

Figure 1. Climatic conditions during the establishment period.

In the case of coverage, the trend of the data indicated the existence of an asymptotic response, so exponential models were fitted to a maximum, logistic and sigmoid, using the routine "Regression Wizard" program SigmaPlot [8]. The model that final showed the best fit to the data coverage with rational values, was the three-parameter sigmoid, which is described below:

$$Y = a/\left(1 + e^{-((X - X0)/b)}\right) \quad (1)$$

where “Y” is the coverage in percentage, at a “X” time, given in weeks; “a” is the maximum coverage value predicted by the model; “e” is the base of natural logarithms; “X0” is the time to “Y” reaches 50% of the value of “a”; and “b” is a constant of proportionality indicating the slope of the "S" on the right side (the higher the value, the greater slope), ie how fast it reaches the value of “a”.

2.3. Second experiment

In this case, the orchard was located in the municipality of Misantla, Veracruz, and consisted of an orange plantation with coffee plants from 14 and 8 years old, respectively. The arrangement of citrus planting was 6 x 6 m, with four coffee plants around each orange tree. A week before the start of the experiment, the native vegetation was controlled with mechanical slashing and application of glyphosate (2 L/ha). The establishment of *Arachis pintoi* CIAT 17434 was evaluated for three methods of site preparation: disking, chiseling and hoeing, with two *A. pintoi* plant arrangements: plants at 35 and 50 cm within furrows separated by 75 cm; and two fertilizer levels: with and without P+K+Mg. P was used as triple superphosphate (50 kg/ha P_2O_5), for K, potassium chloride (50 kg/ha of K_2O), and Mg, magnesium sulfate (20 kg/ha) applied every 30 days post -planting. Plant material consisting of stolons of 20-25 cm was used, placing of 3-4 stolons per plant site.

A randomized blocks design was used, in an split-split plot arrangement, being fertilization treatment the main plot and subplot planting method, sub-divided into two planting densities. This resulted in 12 treatments with four replicates each. The total area was 2268 m^2, and the experimental unit was 144 m^2.

We measured the percentage of coverage, number of plants/m^2 and plant height (cm, five plants per replication), at 4, 8, 12, 16 and 20 weeks post planting. Coverage data, number of plants and plant height were subjected to analysis of variance, and means were compared using the Tukey test from the SAS statistical package [9]. The soil was analyzed at the beginning of the experiment and 16 months later to determine changes in organic matter, soil acidity, as well as levels of nitrogen, phosphorus and potassium. Economic estimates were made to determine costs of establishment, maintenance and return on investment, compared to traditional management of weed control in citrus plantations. Were considered: the cost of slashing of the land, legume plant material and its planting labor, fertilization (P, K, Mg), land preparation, with disking, hoeing; and herbicide application.

2.4. Results

2.4.1. First experiment

*Number of plants.*Table 1 shows the average number of plants (and its standard error) for each accession. For the first and the second accesion an increase from week 4 to 12 was registered, while for the third accesion, the average remained constant during the period evaluated; achieving at 12 weeks an overall average of 5.1 plants/m^2. The analysis of variance did not detect any statistically significant difference within each accession, considering the weeks of sampling.

CIAT accesion	Weeks			
	4	8	12	P**
17434	2.5 ± 0.24*	3.1 ± 0.28	3.2 ± 0.33	0.0875
18744	3.8 ± 0.76	3.8 ± 0.51	4.2 ± 0.48	0.5833
18748	8.3 ± 0.33	7.7 ± 1.45	8 ± 1.0	0.8153

* Standard error of the mean.

** Probability level.

Table 1. Number of plants/m^2 from *Arachis pintoi* ecotypes established as cover crop in a citrus orchard soil of Veracruz, Mexico.

Plant height. Except for the evaluation at 4 weeks, the range was kept between 10 and 20 cm, and the latter value was more frequent in ecotypes 18744 and 18748.

Coverage. In the three ecotypes the model was highly significant (P <0.0001), and in all cases the model parameters were different from zero at the same level of probability. R^2 values were greater than 0.8 (Table 2).

CIAT accesion	n	Model parameters ¥			
		a	X0	b	R^2
17434	90	95.0234	15.9488	3.9614	0.8332
18744	36	96.3046	12.3222	3.0102	0.9481
18748	18	94.1993	12.7762	3.4453	0.9105

¥ "Y" is the percentage of ground covered by the plant, "a" is the maximum coverage, "X0" is the time in weeks to reach half of "a", 'X' is the time in weeks, since planting date; and "b" is a constant of proportionality.

Table 2. Sigmoid model parameters: $Y = a/(1 + e^{-((X - X0)/b)})$, applied to the increase in coverage of three *Arachis pintoi* ecotypes, after planting.

In round numbers, weeks to reach 50% and 100% coverage were 16 and 32; 12 and 24; and 13 and 26, for ecotypes 17434, 18744 and 18748, respectively;

Showing the accesion 17434 the slowest establishment, considering that at 24 weeks, plants covered an average of 84%, compared to 18744 (94%) and 18748 (91%); these latter two, very close to the corresponding value of “a” (Table 2, Figure 2).

2.4.2. Second experiment

Number of plants and plant height. The information related to the number of plants and height of plants/m^2 are shown in Table 3. The disking treatment showed, on average, higher values for number of plants and plant height. This last parameter represented a range of 3.5 to 12.2 cm.

Coverage. Table 4 shows the percentages of coverage, achieved five months after establishment. In all treatments the highest values were achieved with the higher plant densities and fertilization treatment, except for planting treatments with hoeing. Treatments involving the disking had values far above the other ones, regardless of the plant density and/or fertilization applied. Analyses of variance performed within each site preparation, indicated statistically significant differences ($P \leq 0.05$) considering the variables plant density and fe application or not of fertilizer.

Changes in the soil. In relation to changes in soil properties, increases were recorded for the content of nitrogen, phosphorus and potassium, although there was a decrease in organic matter content (Table 5).

Economic considerations. Economic estimates indicated that establishment costs per hectare (in U.S. dollars) for the year in which the experiment was performed, varied according to the evaluated treatments, being lower for those without fertilization (US $ 294, 410 and 396) in compared with those receiving fertilizer (US $ 356, 472 and 473) for treatments with disking, weeding and hoeing, respectively. Moreover, the expenses incurred to control weeds in one hectare included the purchase of a commercial herbicide (glyphosate), an adherent and implementation of both. It imported US $ 222.

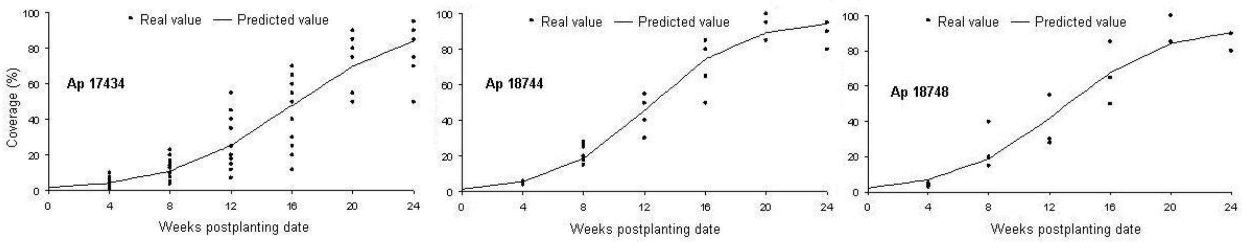

Figure 2. Dispersion data coverage and lines fixed to three-parameter sigmoid model, shown in Table 2.

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2.5. Discussion

2.5.1. First experiment

The number of plants for the three ecotypes at 12 weeks, was on average lower compared with those found by [10] in one of three experiments with *Arachis pintoi* in native pastures of that region. He observed that Ap 17434 presented at that time more than 10 plants/m^2, using plant material grown in field where vegetation was controlled with a machete and herbicide, with or without burning the dead material and fertilized or not with P. The smaller number of plants found here could be due in part to the month after planting (May) was relatively dry (<50 mm), consequently affecting plant emergence. In the mentioned experiment [10] the growth period immediately to planting date had higher humidity (> 150 mm).

	Plants/m^2					Plant height (cm)				
Trat.	**PD1+F**	**PD1-F**	**PD2+F**	**PD2-F**	****P**	**PD1+F**	**PD1-F**	**PD2+F**	**PD2-F**	**P**
D*	32.0 (0.81)	31.0 (1.11)	34.5 (3.42)	34.5 (2.89)	0.2641	11.6 (0.96)	8.2 (0.49)	12.0 (1.05)	8.0 (0.50)	0.5255
Ch	14.0 (1.65)	11.5 (1.93)	13.5 (1.93)	9.5 (0.50)	0.8672	4.6 (0.35)	5.0 (0.53)	5.6 (0.75)	3.5 (0.59)	0.0193
H	21.0 (2.28)	20.5 (1.71)	18.2 (4.11)	20.5 (4.42)	0.6755	9.5 (0.71)	10.2 (0.65)	8.3 (0.78)	10.9 (0.91)	0.2048

PD1 and PD2= Plants sown at 35 and 50 cm within the furrow respectively.

+F: With fertilization (kg/ha: 50 P_2O_5, 50 K_2O, 20 Mg_2SO_4); and, -F: without fertilization.

*D=Disking, Ch=Chiseling, and H=Hoeing.

**P: Probability level.

Table 3. Number of plants of *Arachis pintoi* and its height (Averages; standard error in parentheses), reached five months after planting date according to soil preparation, plant density (PD) and fertilizer application or not (F).

Moreover, it appears that the ecotypes evaluated here shown in the early stages of establishment a tendency of erect growth. It has been indicated [10] a range from 14.4 to 21.0 cm at 12 weeks post planting date, regardless of the treatments.

With respect to coverage, the R^2 values showed good predictive power for the environmental conditions during the study. No one model predicted a maximum coverage of 100%, because the measurement time was only 24 weeks.

In Colombia [4] evaluated in citrus plantations the same ecotypes, and found 8 months after that Ap 17434 was much lower coverage (32%) compared with the other ones (73% on average). On native pastures [10], found in another experiment with Ap 17434 that its establishment was even slower, since the accession planted with no-tillage or reduced tillage, with or without fertilization (P, K, Mg, Ca, Zn, Cu and B), needed 20 to 21 weeks to achieve 50% coverage.

The lower rate of coverage by the accession 17434 was also confirmed [11], on the experiment developed in this same region comparing four species of forage legumes (*Desmodium ovalifolium*, *Neonotonia wightii*, *Pueraria phaseoloides* and *Stizolobium deerigianum*) associated to a citrus plantation. This slowness in the establishment was also reported in Costa Rica [12] to associate in banana plantations.

Treatments	Weeks after planting					
Disking	**4**	**8**	**12**	**16**	**20**	**P***
PD1+F	19.8±2.04	23.2±2.69	33.0±4.40	76.2±6.25	87.5±3.23	0.9641
PD1-F	10.5±1.04	17.7±3.17	23.7±10.5	52.5±10.5	70.0±7.90	
PD2+F	9.0±0.57	13.2±2.98	20.2±3.75	40.0±12.4	63.7±15.46	
PD2-F	8.0±0.71	10.5±1.26	10.5±3.23	26.2±3.14	52.5±9.11	
Chiseling						
PD1+F	6.0±0.91	4.2±1.31	7.0±1.29	10.2±1.11	11.7±1.08	0.0232
PD1-F	6.7±1.25	4.5±1.19	3.7±0.48	6.5±0.64	8.2±0.48	
PD2+F	6.2±0.47	6.5±0.29	5.7±1.31	7.2±1.43	9.0±1.78	
PD2-F	4.2±0.85	4.2±0.94	3.5±0.29	5.7±0.63	6.2±0.85	
Hoeing						
PD1+F	7.5±0.64	12.0±2.00	7.75±1.25	9.5±0.87	23.7±3.75	0.3202
PD1-F	8.7±1.10	8.7±1.89	8.7±0.47	20.0±4.56	33.7±5.54	
PD2+F	9.0±2.16	4.2±0.48	5.2±0.63	12.2±2.25	26.2±5.54	
PD2-F	8.5±0.50	5.0±0.71	10.0±2.38	14.0±3.81	27.5±7.22	

PD1 and PD2= Plants sown at 35 and 50 cm within the furrow respectively.

+F: With fertilization (kg/ha: 50 P_2O_5, 50 K_2O, 20 Mg_2SO_4); and, -F: without fertilization.

**P: Probability level.

Table 4. Coverage (%) of plants of *Arachis pintoi* (mean ± standard error) reached five months after planting date according to soil preparation, planting density (D) and the application or no fertilizer (F).

Soil factors	Start	End	Difference
Organic matter (%)	2.2	2.0	- 0.20
Nitrogen (Kg/ha)	8.9	28	+ 19.1
Phosphorus (Kg/ha)	6.0	40	+ 34
Potasium (Kg/ha)	86	301	+ 215
pH	5.0	5.8	+ 0.8

Table 5. Changes in the soil with the use of *Arachis pintoi* 16 months after planting.

Moreover, the ecotypes established by seed showed a higher rate of coverage, however, however, these differences in the velocity of establishing tend to disappear as time passes.

2.5.2. Second experiment

The coverage obtained with the disking treatment with plants every 35 cm along the furrow, and with or without fertilization are considered acceptable and are superior to those reported for *Ap* 18748 in coffee plantations of Nicaragua for high plant densities using vegetative material (strips of 3.3 m wide, with furrows 50 cm) and three weedings in the first 90 days [13]. This author reported that at 158 days post seeding, the legume exceeded 60% of ground cover. In Brazil [14], assessed *A. pintoi* at plant densities of 8 to 16 plants/linear m, reaching a 50% coverage to 84 and 68 days post seeding, respectively; whether the separation between furrows was 25 or 50 cm. The above percentages indicate superior performance under these conditions that found here, which is explained by the higher plant density used.

Respect to changes detected in the soil properties, the increase in the concentration of N could be attributed to a transfer to the soil of the element present in the leaves of *Arachis pintoi* by the effect of decomposition thereof. In this regard, [15] estimated litter decomposition of grasses and legumes, among whom was *A. pintoi*. They found that the decomposition of organic matter and nitrogen in leaves of this legume, along with that of *Stylosanthes capitata*, decomposed faster than the other species studied, although the amounts released of P, K, Ca and Mg were similar among grasses and legumes. Other researchers [13], working with *Ap* 18748 or *Desmodium ovalifolium* CIAT 350 associated with coffee plants, found no differences for any legume in N, P and K soil, three years after establishment; unlike [6], who in Australia, in banana plantation with or without *Arachis pintoi* after 5.5 years found significant increases in the association, in terms of organic matter (3.94 vs. 3.71%), N (0.42 vs. 0.39%); the K, Ca, Mg and Na increased to at 52, 26, 43 and 23%, respectively.

By comparing these costs with the traditional management of weed control in citrus orchards, we found that the costs for these plantations were around US $ 222 per year. Economic estimates in coffee plantations in Nicaragua [13], mentioned that the relative costs (%) in the establishment and maintenance of the associations were higher in the first two years, compared with the traditional control of weeds, but at that time the use of herbicides was lower between 30-50%. Establishment costs in the three experiments [see 10] fell in the range of US $ 282 to 623 (the exchange rate in 2001) in terms of inputs applied. Although costs for the establishment of *Arachis pintoi* is higher, this is recovered in about a year and a half or two, with the advantage of having a highly competitive species for weed control and its long persistence in the land, plus inputs of nutrients to the soil as an additional benefit.

2.6. Conclusions

Arachis pintoi is a promising legume to associate as a cover crop with citrus plantations and other crops of high commercial value, such as bananas, pineapple, coffee and papaya. In the case of the first experiment, *Ap* ecotypes CIAT 18744 and 18748 represent for citrus plantations area of Veracruz, a better option compared to *Ap* CIAT 17434, due to the slowness of this accesion to cover the ground. Regarding the second experiment, the disking treatment, proved to be the best treatment for the establishment of the legume, but the costs of establishment will vary depending on the inputs applied, but a long-term coverage will absorb these costs converting this costs in an effective alternative.

3. Establishment of *Arachis pintoi* in native pastures of Mexico

Research results from the hot humid areas of México and from other parts of Latin America showed that the forage legume *Arachis pintoi* CIAT 17434 has the ability to be associated with grasses, because it has shows better persistence than other legumes and also has high nutritive value and palatability [16, 17-20]. *A. pintoi* establishment techniques range from a complete soil tillage and planting with seed to zero tillage and planting with vegetative material (stolons) into an existing pasture [17]. The objective of this study was to evaluate the agronomic performance of different techniques of establishing *A. pintoi* CIAT 17434, as well as the accessions CIAT 18744 and 18748, into existing native pastures in the humid tropics of the coastal plains of the Gulf of México.

3.1. Materials and methods

3.1.1. Site characteristics

Three experiments were conducted during 1991 and 1996 at the Centre for Teaching, Research and Extension in Tropical Animal Husbandry (CEIEGT, its acronym in Spanish) of the Faculty of Veterinary Medicine, of the National University of Mexico (UNAM). The Centre (CEIEGT) is located in the eastern coastal plain of México about 40 km West of the Gulf of México coast line at 20° 02′ N and 97° 06′ W, at 112 m a. s. l.

The climate is hot and humid, with rains all year round. Mean yearly rainfall was 1,917±356 mm from 1980 to 1997. Monthly rainfall is highly variable being September (322 mm) and October (248 mm) the rainiest months while March (85 mm) is the driest. The coldest and hottest months are January (18.9 °C) and June (27.8 °C). Minimum daily temperatures from November to February (winter) are around the critical range of 8-10 °C, below which the growth of C_4 tropical grasses is severely reduced [21-23]. These combinations of rainfall and temperature lead to a seasonal DM production pattern, a common situation in the tropics of Latin America: A high growth rate on the rainy season followed by poor growth during the winter and dry seasons.

The experiments were conducted in different years. Temperatures were typical of each season, but the current maxima were below, and the current minima above the long term (1980-1997) mean (Figure 3a). Total rainfall during experiment 1, December 1991 to September 1992, was 39% above average (Figure 3b). Rainfall in the experimental planting seasons was 339 mm in winter (November 29, 1991 to February 14, 1992), 637 mm in the dry season (March 2 to May 18 of 1992) and 1,352 mm in the rainy season (July 2 to September 17 of

1992). Rainfall was 19% above average during experiment 2 in 1993, but rains in 1996 were 43% below average for experiment 3 (Figure 3b).

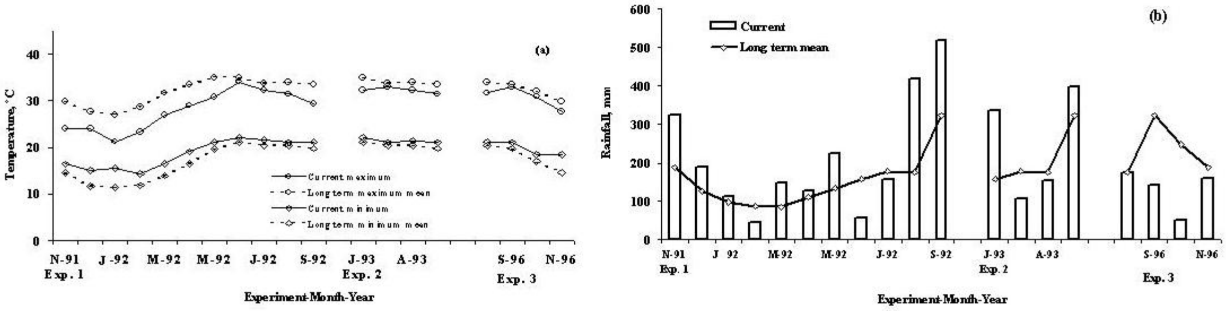

Figure 3. Current and long term monthly temperatures (a) and rainfall (b) for the 3 experiments.

The soils are acid Ultisols (Durustults), with a range in pH from 4.1 to 5.2, and an impermeable hardpan between 0 and 25 cm in depth, that result in a inadequate drainage during the rainy and winter seasons. The soil texture is clay-loam with low levels of P (< 3 ppm), S (< 30 ppm), Ca (< 3 meq/100 g) y K (< 0.2 meq/100 g). Both cation exchange capacity and aluminum saturation increase with depth, but the latter do not reach toxic levels for pasture plants [24].

3.1.2. Experiment 1. Reduced and zero tillage, with or without fertilisation

The study was conducted to test the combined effects of tillage type: reduced and zero, and fertilisation with (kg/ha): P 22; S 25; K 18, Mg 20; Ca 100; Zn 3; Cu 2 and B 1, or no fertilisation, in a four treatment combination: T1, reduced tillage and fertilisation; T2, reduced tillage without fertilisation; T3, zero tillage and fertilisation; and T4, zero tillage without fertilisation. Reduced tillage consisted of four passes of a disk harrow, while zero tillage only required the elimination of pasture vegetation by machete to ground level.

The experimental area was 2,000 m^2 (50 m x 40 m split in two plots of 1,000 m^2 - 25 m x 40 m). These plots were divided in two sub plots of 500 m^2 (25 m x 20 m), of which one sub plot was fertilised. Three 2,000 m^2-experimental areas were used: one per each climatic season (winter, dry and rainy season).

Arachis pintoi was planted on sub-plots of 500 m^2 on 29 November, 1991 (winter season), 2 March, 1992 (dry season) and 2 July, 1992 (rainy season). Three to four stolons, approximately 15 cm in length and with five nodes per stolon, were planted per planting position. On the reduced tillage treatments the distance between rows and planting positions were 1.0 m and 0.5 m, respectively. Planting was done on 3 m wide strips, which alternated with 3 m intact native pasture strips. Three rows of the legume were planted per strip and 3 strips were contained in a subplot, being the sampling quadrat size 3.0 m x 1.5 m. On the zero tillage treatment, distance between rows and positions was 2 m and 0.5 m, respectively, with the subplot containing nine sampling rows also and a sampling quadrat dimensions of 6 m x 3 m. Even though this planting arrangement was confounded with tillage treatments, it gave a similar number of planting positions per sub-plot and two sampling hills/m^2 in each sampling quadrat, regardless of type of tillage. Fertiliser was broadcast 30 days after planting.

3.1.3. Experiment 2. Type of control of native pasture growth, with or without P fertiliser

This experiment tested the combined effect of the type of pasture vegetation control: herbicide (glyphosate) or slashing (by machete) with or without burning of dead vegetation, and with or without localised P-fertilisation which resulted in eight treatment combinations. The choice of treatments attempted to reduce competition to *A. pintoi* from existing native pasture vegetation, enhance legume establishment and early growth, following the approach described by [25] for the establishment of legumes into existing Speargrass (*Heteropogon contortus*) native pastures, in Australia.

Slashing was done by machete and burning was carried out between 1-5 days after slashing. A 2% aqueous solution of glyphosate (480 g of isopropyl amine salt of glyphosate/l) was applied on a 0.25 m wide strip 15 days before planting; burning was done 15 days after herbicide application.

The planting legume was done between June 28 and July 3. Application of herbicide and herbicide plus burning, and slashing or slashing plus burning, were applied 15-16 days and 3-5 days earlier, respectively. Vegetative material, 0.25 m length stolons with eight nodes, was used for planting. This material was inoculated just prior to planting with a specific *Bradyrhizobium* culture obtained by suspension of 1 kg of profusely nodulated *A. pintoi* ground roots in a solution 7.5 litres of water and 1.5 litres of sugarcane molasses. Three stolons per planting position were put in a hole and covered with soil, allowing about 1/3 of the stolon to remain above ground. Distances among rows and planting position were 1.0 m and 0.5 m, respectively. The sub plot (10.0 m x 6.5 m) had 10 rows with 14 planting positions/row. Two sampling quadrats (2 m x 1 m) each with 4 planting positions were randomly allocated per sub plot. Single super phosphate (30 kg of P/ha) was applied at planting in a 0.07 m depth hole adjacent to the planting position.

3.1.4. Experiment 3. Establisment of Arachis pintoi accessions using seed pods

This experiment compared the establishment of three *A. pintoi* accessions using seed pods: CIAT 17434 (cv. Pinto peanut or Amarillo), 18744 and 18748. Seed germination was assessed in the laboratory at room temperature; using 125 seeds per accession. Petri dishes, bottom-lined with filter paper, were used and were watered twice daily. The seeding rate was equivalent to 10 kg of germinable seed pods per hectare, based on quadruplicate germination tests. The experimental plots (10 m x 5 m; ten 5 m length rows/plot) were established within a grazing experiment where milk production from native pastures and native pastures associated with *A. pintoi* was to be compared. Three replicates were established in one paddock and three in another. Each replicate had three plots, with an accession each. Plots were excluded from grazing for the 12 weeks of the establishment period. A 2% aqueous solution of glyphosate was applied on a 0.30 m wide strip 15 days before planting to eliminate competition from existing vegetation. Distance between rows and planting positions was 1.0

m and 0.5 m, respectively. Seed pods were placed in a 5 cm deep hole made with pointed wooden stick, and lightly covered with soil by the planter's foot. Three replicates were planted on August 2 and three on September 3, 1996. Fertiliser was not applied.

3.2. Measurements and statistical analyses

The response variables were: 1) plant number (PN, plants/m^2) by counting; 2) plant height (PH, cm), on each plant within the sampling quadrat, measured with a ruler from the soil surface to the uppermost part of the plant; and 3) soil covered by the legume or cover (COV, % of quadrat area covered by the legume) measured with the aid of a 1 m^2 quadrat, divided into 25 squares, which was placed over the row. These measurements were done on weeks 4, 8 and 12 after planting [26]. In experiment 1, PH was not measured, but COV was measured again at 24 weeks after planting.

In experiment 1, there were no field replications, since it was perceived that treatments applied in larger areas would have a closer resemblance to that of farmers' fields. Also, if several sampling quadrats were used within each treatment plot, this would yield information as useful as that obtained from randomised complete block designs. In experiments 2 and 3, the design was a randomised complete block design with 3 blocks as replicates. The treatment arrangement was a split-plot in experiment 2, where the main plot was the combination of type of pasture vegetation control (slashing and herbicide), while the combinations of burning (with and without) and P application (with and without) were the sub-plots; additionally the effect of time after planting was considered a sub-sub-plot. The treatment arrangement of the third experiment was a split plot, in which the main factor was the combination of month of planting by accession and time after planting the sub-plot. Here, number of plants was expressed as "plants/50 m^2", in order to be clearer and avoid fractions of plant/m^2. Analyses of variance were done with linear additive models in accordance to the experimental design [27]. The natural log transformation of the response variable was used if its response to time was exponential. If necessary, linear or exponential relationships provided rates of increase with time in the measured variables. Also, means comparisons using Tukey's test were done when was necessary.

3.3. Results

3.3.1. Experiment 1. Reduced and zero tillage, with or without fertilisation

The main effect of treatment on plant number (PN) was highly significant ($P<0.01$) in all seasons. The linear effect of week after planting was highly significant ($P<0.01$) on PN in the winter season of 1991-92 and the rainy season of 1992, but it was not significant ($P>0.05$) in the dry season of 1992 (Table 6). There was no significant treatment x week interaction on PN in any season. The main effects of treatment and week after planting and its interaction were highly significant ($P<0.01$) on COV, except for the interaction in the rainy season. Weeks to reach 50% cover were 21, for T2 (winter season) and T4 (dry season); and 20, for T1 and T4 in the rainy season (Table 7).

Treatments			Season		
	Tillage	Fertilisation	Winter	Dry	Rainy
T1:	Reduced	With	$1.36^{b} \pm 0.06$	$0.78^{a} \pm 0.06$	$2.56^{a} \pm 0.17$
T2	Reduced	Without	$1.70^{a} \pm 0.09$	$0.73^{ab} \pm 0.07$	$2.56^{a} \pm 0.22$
T3	Zero	With	$0.81^{c} \pm 0.03$	$0.60^{b} \pm 0.02$	$0.96^{b} \pm 0.09$
T4	Zero	Without	$0.82^{c} \pm 0.04$	$0.59^{b} \pm 0.03$	$0.80^{b} \pm 0.07$
Effect of week after planting:			$1.16^{**} \pm 0.04$	$0.68^{NS} \pm 0.02$	$1.72^{**} \pm 0.10$
P≤0.0001.					

Table 6. Effect of treatments on the number of plants of *Arachis pintoi* CIAT 17434 (pl/m^2) by season (Mean ± standard error), according to the tillage by fertilisation combination in experiment 1.

Treatments			Season		
	Tillage	Fertilisation	Winter	Dry	Rainy
T1	Reduced	With	22 ± 0.4	25 ± 0.8	20 ± 0.3
T2	Reduced	Without	21 ± 0.3	24 ± 0.7	21 ± 0.5
T3	Zero	With	23 ± 0.4	23 ± 0.5	21 ± 0.4
T4	Zero	Without	24 ± 0.3	21 ± 0.6	20 ± 0.2
P≤0.01.					

Table 7. Mean ± standard error for weeks to reach 50% cover by *A. pintoi* CIAT 17434 according to the tillage by fertilisation combination in experiment 1.

3.3.2. Experiment 2. Control of native pasture growth, with or without P fertiliser

The effect of time after planting was highly significant ($P<0.01$) upon all response variables. Height values increased with time, but to a different degree on each main plot combination. The increase in plant height (PH) with time was much larger than the increases with time shown by the other two response variables. The standard deviations were high in all cases and increased with time also (Figure 4). The coefficients of variation remained relatively uniform through time: 28% to 31% for plant number (PN), 29% to 35% for plant height, and 75% to 83% for cover (COV).

When herbicide was applied, the burned plots produced taller plants than the non-burned ones ($P= 0.01$), but the contrary happened on slashed plots ($P<0.05$) (Table 8).

P fertilisation did not increase ($P>0.05$) legume cover in any vegetation control by burning combination. Slashing without burning and without fertiliser, the treatment with the least external inputs, had significantly ($P<0.05$) less legume cover than the herbicide plus burning plus fertilisation treatment, the treatment requiring the most external inputs (Table 9).

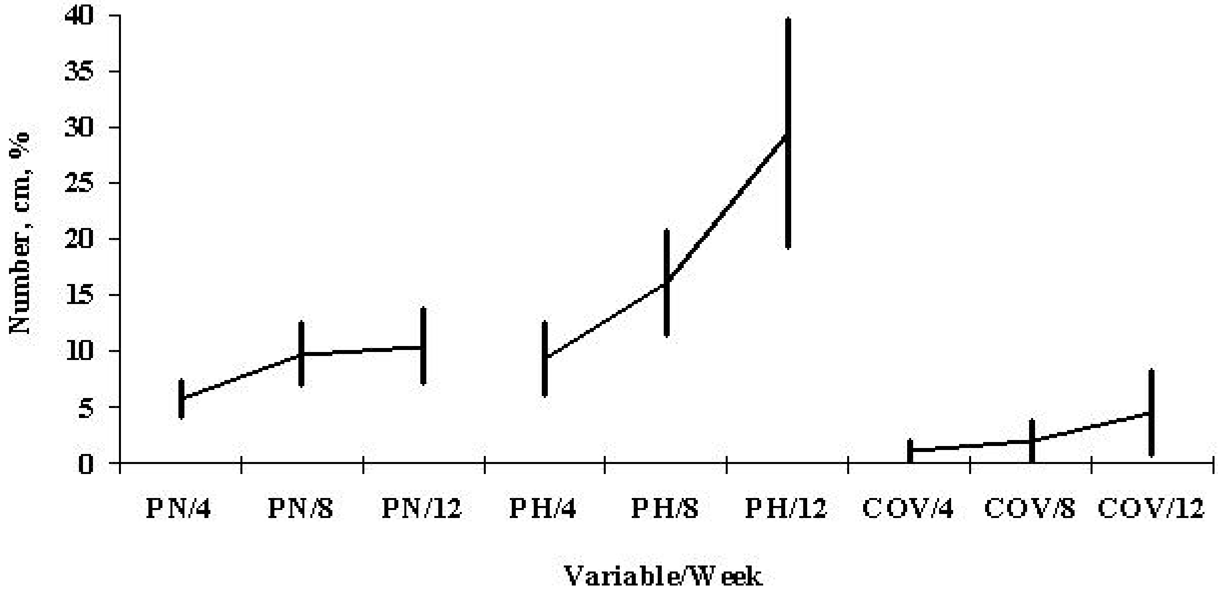

Figure 4. Effect of time after planting (4, 8 and 12 weeks) on *A. pintoi* CIAT 17434 plant number (PN, number/m^2), plant height (PH, cm) and legume cover (COV, %). The vertical lines are the standard deviations.

Treatments		Plant height (cm)	Statistical significance of the non-burning vs burning comparison within vegetation control
Vegetation control	Burning		
Herbicide	Without	14.54 ± 1.14	0.01
Herbicide	With	21.01 ± 1.57	
Slashing	Without	20.89 ± 1.23	0.05
Slashing	With	17.09 ± 1.25	

Table 8. Combined effect of vegetation control x burning treatments upon *A. pintoi* CIAT 17434 mean plant height (PHT, cm).

3.3.3. Experiment 3. Establishment of three A. pintoi accessions using seed pods

The averages of percentage of seed germination at 7 days on the laboratory were of 44.8±4.08, 44.8±4.45 and 32.8±1.50, for CIAT 17434, CIAT 18744 and CIAT 18748, respectively; and values (percentages) of emergence at 7 days after planting were 91.3±1.5, 82.0±2.4 and 73.8±1.4, respectively, which were statistically different among them ($P<0.05$). The main effects of month of planting and accession were significant ($P<0.05$) on COV. Legume cover increased linearly with time (4, 8 and 12 weeks), but without differences in slope among accessions (Figure 5). Using the regression equations of cover *vs.* time, it was calculated that for the August planting it took 45, 46 and 56 days for accessions CIAT 17434, CIAT 18744 and CIAT 18748, to cover 5% of the soil, respectively. Values for September were 55, 50 and 55 days. Plant height was affected by month of planting (P<0.01), the plants being taller in August. The interaction month x accession was significant (P<0.05), but the accession CIAT 17434 was about 2 cm shorter than the others in both planting months (Table 10). Maximum height at the end of the establishment period was greater for August (27.4 cm) than for September (18.2 cm).

Treatment combination			Cover, %
Vegetation control	Burning	P-fertilisation	
Herbicide	Without	Without	2.39 ± 0.45
		With	2.18 ± 0.54
	With	Without	2.48 ± 0.42
		With	4.21 ± 0.91
Slashing	Without	Without	1.74 ± 0.31
		With	2.59 ± 0.84
	With	Without	3.17 ± 0.69
		With	2.01 ± 0.52

P≤0.01.

Table 9. Combined effect of vegetation control x burning x P-fertilization treatments upon *A. pintoi* CIAT 17434 mean cover (COV, %, ± standard error).

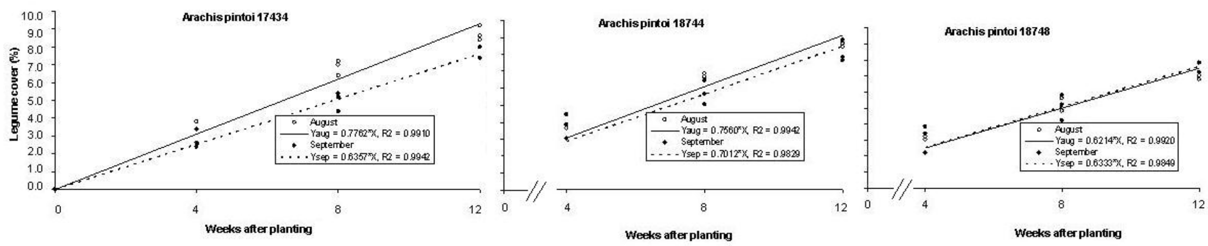

Figure 5. Effect of time after planting (4, 8 and 12 weeks) upon soil covering (%) of three *A. pintoi* accessions in experiment 3.

3.4. Discussion

In experiment 1, reduced tillage gave better results than zero tillage during the winter season, but the opposite occurred in the dry season. As soil moisture and temperature conditions increased in the rainy season, the difference between reduced and zero tillage not disappeared and was significant. Other trials conducted in the same region have indicated the advantage of reduced tillage over zero tillage to establish vegetatively *A. pintoi* [28]. The literature shows a general agreement among researchers in that some sort of soil disturbance is necessary to assure establishment [29, 30].

Month	CIAT accession	Cover, %	Plant Number	Plant height, cm
	17434	6.4 ± 0.8 [a*]	109 ± 5 [a]	11.9 ± 1.4 [b]
August	18744	6.2 ± 0.8 [a]	106 ± 6 [a]	13.8 ± 1.6 [ab]
	18748	5.1 ± 0.7 [b]	97 ± 6 [b]	14.3 ± 1.6 [a]
		5.9±0.42	103.8±3.29	13.3±0.87
	17434	5.1 ± 0.7 [NS]	124 ± 2 [a]	9.6 ± 0.9 [b]
September	18744	5.8 ± 0.7 [NS]	113 ± 3 [ab]	12.1 ± 1.0 [a]
	18748	5.2 ± 0.6 [NS]	99 ± 4 [b]	10.0 ± 0.9 [b]
		5.4±0.38	112.0±2.61	10.6±0.55

Means followed by the same letter are not statistically different at P≤0.01.

NS= Non-significant.

Table 10. Mean ± standard error of cover (COV, %), plant number (PN, plants/50 m^2) and plant height (PH, cm) per month of planting by accession combination in experiment 3.

It has been suggested [25] that seedlings facing more root competition from existing vegetation responded to fertilisation, whereas those without competition had a lesser or nil response.

In the winter season planting of experiment 1, fertilisation failed to stimulate COV of slashed plots, those supposedly with a larger competition from existing pasture. In the dry season planting, fertilisation was detrimental to COV in the slashed plots, in contrast to [25]; finally, in the rainy season the effect of fertilisation was negligible. The second experiment showed a positive effect of fertilisation on COV only when herbicide was applied and the dried vegetation was burned. When plots were slashed, but not burned, the effect of fertilisation on COV was positive. Nevertheless, when the slashed plots were burned, the fertilisation effect on COV was negative.

Fertilisation with 23 kg P/ha, 25 kg K/ha, 20 kg S/ha and 20 kg Mg/ha had a positive effect on COV (83.4% *vs.* 61.3%) and PH (12.0 cm vs. 8.6 cm) when the soil was prepared with 4 passes of disc harrow, but with zero tillage, fertilisation reduced both COV (25.0% vs. 30.6%) and PH (8.4 cm vs. 10.1 cm) [28].

As suggested by the inconsistent results of our trials and those of the literature, fertilisation appears not to be of great importance for the establishment of *A. pintoi*, when vegetative material is used. The lack of P response on *Arachis* species has been reported by other researchers. In experiment 2, single superphosphate was used, and perhaps the use of this source could explain, partially, the lack of response. Also, the very low P levels on soils at CEIEGT

(0.6 to 1.2 μg g^{-1} soil on 0-30 cm depth), could limit N mineralization [31], resulting in a poor legume performance.

In experiment 2, burning was directed to reduce competition from existing grasses, since the way *A. pintoi* vegetative material was planted assured a close contact with the soil. However, burning, as well as fertilisation, did not show a clear positive trend either on COV or on PHT.

When only herbicide was applied in bands in experiment 2, pasture canopy height was not reduced, leading to reduced PH of *A. pintoi*. On the other hand, when the herbicide treated vegetation was burned, PH of *A. pintoi* was not impeded. Non-burned plots gave slightly taller *A. pintoi* plants than those burned. *A. pintoi* CIAT 18744 flowers less and produces a denser stolon mat than the other two accessions and it also has a vigorous initial growth, covering the soil more rapidly than the CIAT 17434 accession [32-33]. For this reason, a better behaviour during establishment, particularly with respect to COV and PN was expected from this cultivar. Nevertheless, in experiment 3, COV performance at the end of establishment was similar to that of CIAT 17434 (8.5% *vs.* 8.7%) and only slightly better than CIAT 18748 (7.5%). Then, the 3 accessions behaved similarly during establishment. Rates of plant emergence are considered to be good, as *A. pintoi* is a legume that can have a strong dormancy [34]. However, emergence (from 125 seeds originally planted/plot) of new branched plants/plot was not so bad, considering that these values ranged from 70% to 90% for three accessions. Therefore, there was low coverage but high number of new branched plants. This situation is common for *A. pintoi*, which is characterized by its slow establishment, as has been reported [6, 35-36]. Zero tillage failed to stimulate a rapid establishment of *A. pintoi* in these trials, the reproductive mechanisms of this species ensure that eventually it will establish and encroach within the pasture. Our experience with this legume is that eventually it ends up to be the dominant species when associated with native pasture, Stargrass, or to both. A good strategy would be to establish *A. pintoi* in strips with reduced tillage at high density. This will result in a rapid establishment of a mixed sward in a minimum of time.

3.5. Conclusions

Neither fertilisation nor burning were successful in enhancing *A. pintoi* establishment; slashing did not improve establishment either. On the contrary, herbicides were effective and improved establishment over slashing. The best alternative to introduce *A. pintoi* into a native pasture is by reduced soil tillage in strips using, within the strips, 8 kg of pure live seed pods/ha; or 0.70 m between rows and 0.35 m between planting positions for vegetative material.

4. Establishment of *Arachis pintoi* CIAT 17434 and *Pueraria phaseoloides* CIAT 9900 using minimum tillage in Veracruz, Mexico

In the watershed Gulf of Mexico region, there is a highly seasonal pasture production due to climate variability. The main genera are components of *Paspalum*, *Panicum* and *Cynodon*

(Gramineae), and in smaller proportions *Centrosema* and *Desmodium* [37]. Among the legumes evaluated in that area, *A. pintoi* CIAT 1434 and *Pueraria phaseoloides* CIAT 9900 outstanding for their performance and good adaptation [38].

The cost of establishing pastures in native savanna vegetation is high when following traditional methods. Given this, it is justified to evaluate planting systems cheaper, to promote the adoption of new forages and their use to recover degraded pasture [39]. Therefore, this trial is performed to supporting evidence to assess the effect of various types of tillage and application of phosphorus on the establishment of *A. pintoi* CIAT 17434 and *Pueraria phaseoloides* CIAT 9900 in native pastures.

4.1. Materials and methods

4.1.1. Characteristics of the experimental site

The research was conducted at the Centre for Teaching, Research and Extension in Tropical Animal Husbandry of the Faculty of Veterinary Medicine, of the National University of Mexico (UNAM), located in north-central region State of Veracruz, 20 ° 4 'north longitude 97 ° 3' W and a height of 105 meters above sea level. The climate is hot and humid with rain all year, type Af (m) with average daily temperature of 23.4 ° C and average annual total precipitation of 1840 mm (1980-1989). The soil texture ranges from sandy loam to sandy clay. The area has a hard horizon with low permeability that occurs between 5 and 25 cm deep. The soils are acidic (pH 4.1 to 5.2), and are classified as Ultisols.

We used an area of 6.000 m^2 of degraded native pasture grazed by cattle. The treatments were the type of weeding (slashing, S; and herbicide, H) and the burning (B) application or not (with + B and without -B), to temporarily control the growth of existing vegetation (larger plots), and thus prove its effectiveness to allow the establishment of the legumes *Arachis pintoi* CIA 17434 (Ap) and *Pueraria phaseoloides* CIAT 9900 (Pp). Additionally we evaluated the application of phosphate fertilizer or not (+P addition; no-P as single superphosphate). The factorial combination between legumes and fertilizer was the subplot.

Treatments were applied between 28 May and 3 June 1993. The slashing (S) was a machete to the whole plot. In S + B, the burning was applied between one and five days after slashing. The application of herbicide (H) was done using a backpack sprayer, applied in bands 50 cm wide, spaced 1 m apart from the center of each. The dose was 0.96 kg (2 l) of a nonselective systemic herbicide (Glyphosate). The product was dissolved in 200 l of water and applied 15 days before seeding. In H + B, herbicide application was the same way as above, burning 15 days after application, only the bands where the herbicide is applied.

Ap vegetative material, was inoculated with the specific *Rhizobium*, by means of a suspension prepared with nodulated roots, washed and crushed to release *Rhizobium* bacteria, then adding cold water and molasses, placing the suspension in a refrigerator, performing all procedure in the shade. Each kg of root was added 1.5 kg of molasses (as adherent) and 7.5 l of cold water.

Legumes were planted between 3 and 5 days after applying treatments S or S + B, and between 15 and 16 days after applying treatments H or H + B. *Ap* was planted with stolons of 20 cm long, inoculated with the suspension of *Rhizobium* already described. By planting, we used a metal digging stick, to make a biased hole of 15 cm lenght and 5 cm depth. Three stolons were placed by hole and soil was compacted with foot to ensure contact with the ground. The distance between plants and rows was 0.5 and 1 m, respectively.

For planting of kudzu (*Pp*) botanical seed was used, previously scarified with sulfuric acid to 98% for 10 minutes. This ensured the seed germination in three days post seeding. The effectiveness of this treatment has been verified by other researchers [40].

Planting density was 2 kg/ha of pure and viable seed. After scarified, the seed was inoculated and seeded similarly as *Ap* placing about 8 seeds per site, but was not covered preventing soil compaction. The distance between plants and rows was 0.5 and 1 m, respectively. Single superphosphate (333 kg/ha = 30 kg P/ha) was applied at planting time in 5 cm band from the seed or plant material.

We used two sampling sites per plot at random. Firstly, two rows of each plot were chosen, and then the sampling site within each row. The recommended [26] variables were, number of plants, plant height (cm) and coverage (%) at 4, 8 and 12 weeks post seeding. A randomized complete block design was used, with three replications and a split-plot arrangement, with the factorial combination between weeding and burning as main plots, and the combination of the two legumes with or without fertilization as subplots. We considered the costs for materials and labor costs per treatment.

4.2. Results and discussion

Climate. – The climatic parameters of precipitation and temperature were recorded from May to September 1993. The monthly average temperature was similar for the periods, ranging from 25.5 to 27.0 °C. The lowest rainfall occurred in July and highest in September with 109 and 360 mm respectively. Rainfall totaled 1257 mm. This caused flooding which affected the establishment of each legume.

Number of plants. - Analysis of variance indicated that there was a highly significant effect ($P < 0.01$) of the species, with 1.77 and 0.55 for *Ap* plants/m^2 plants / m^2 for *Pp*. The number of plants for *Ap* can be considered acceptable, even expected 2 plants/m^2. Flooding caused by high rainfall brought rot of stolons.

The small number of *Pp* plants is also attributed to the seed rot because of soil waterlogging. It has been mentioned [41] that heavy rainfall limits the development of Kudzu (*Pp*). Also, surprisingly, the number of plants decreased as time passes ($P < 0.01$): There were 1.27, 1.18 and 1.0 plants/m^2 for first, second and third samples. Effects such as slashing, burning, and their interaction were not significant ($P > 0.05$), which coincides with other experiment [42]. These authors, who established three species of legumes (*Centrosema pubescens*, *Macroptilium atropurpureum* and *clitoria ternatea*) using total soil preparation, harrowing, plowing and burning, with no significant difference found ($P > 0.05$) among the different methods,and concluded that burning favored the establishment of legumes.

Plant height. - Analysis of variance showed highly significant differences (P <0.01) between the species: *Ap* with 18.3 cm and 9.5 cm with *Pp* (Figure 6). This difference is attributed to *Ap* was seeded with plant material starting its growth as seedling, which gave to Ap an advantage over *Pp* that was sown with seed.

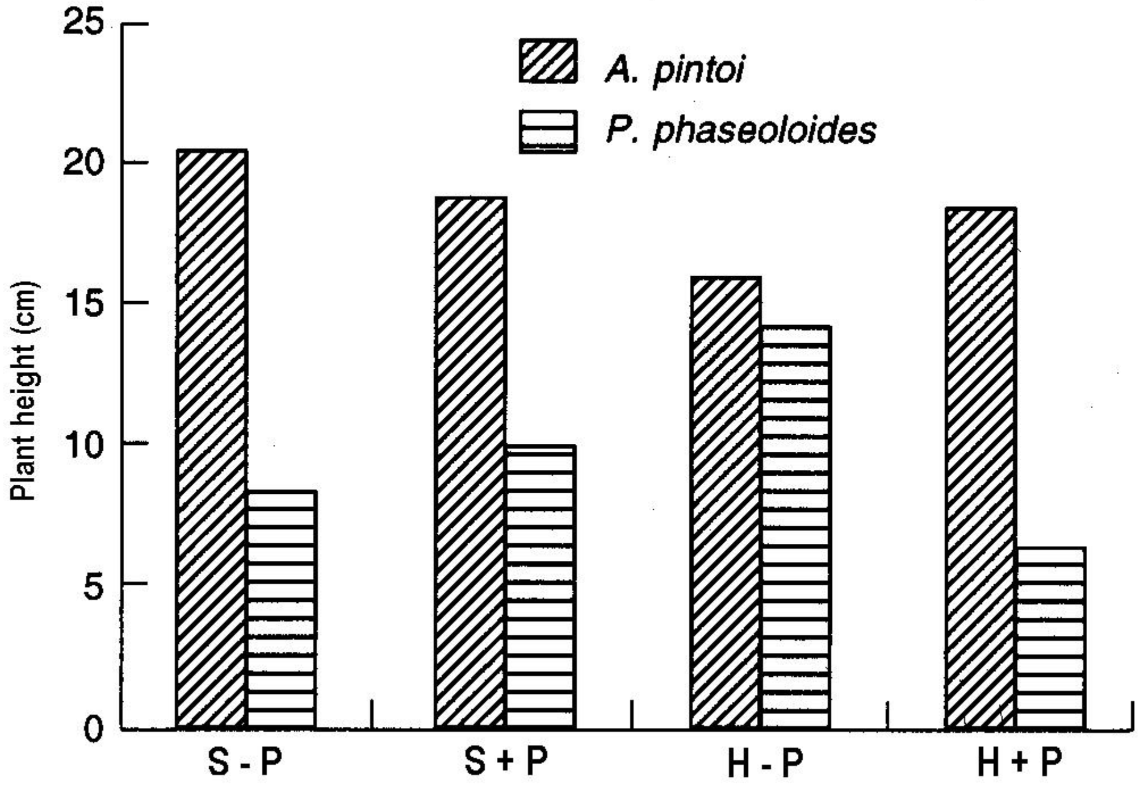

Figure 6. Effect of type of control weeds (herbicide –H- and slashing –S-), with and without P fertilizer over plant height of *Arachis pintoi* and *Pueraria phaseoloides*.

The interaction slashing X burning was highly significant (P <0.01). The application of H+B resulted in greater plant height with 16.0 cm, followed by S-B with 15.6 cm, being H-B method the lowest height with 11.1 cm. In the case of H+B, the plant height was attributed to no competition between the legume and native grasses; also, burning causes release of soil nutrients that legumes can absorb quickly, making their establishment more effectively.

Burning, releases mineral nutrients immobilized in plant tissues, and others are transformed into simple soluble salts, readily available to the plant [43]. In the treatment of S-B, the largest plant height was mainly due to competition for sunlight by the grass. Competition for sunlight between *Aeschynomene*, seeded with the grass *Hemarthria altissi-*

ma resulted in greater height during legume establishment [44]. Here, the combination of H-B produced lesser height.

Sampling at 4, 8 and 12 weeks showed highly significant differences (P <0.01) with 7.10, 12.23 and 22.39 cm, respectively (Figure 7). This increase in plant height in time was an expected effect.

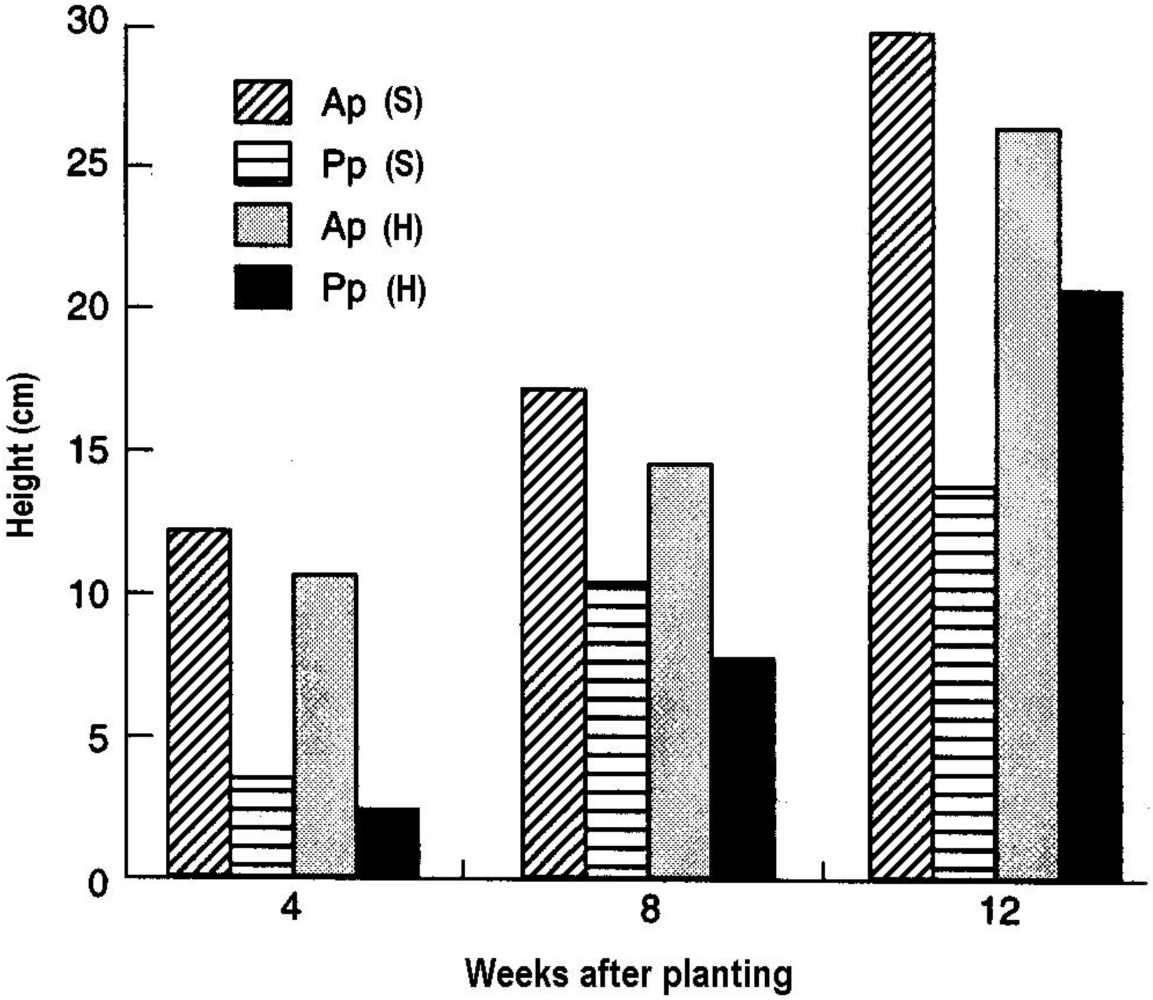

Figure 7. Effect of type of control weeds (herbicide –H- and slashing –S-), durin the three climatic evaluation seasons over the plant height of *Arachis pintoi* (Ap) and *Pueraria phaseoloides* (Pp).

The interactions species x weeding x fertilization, and weeding x species x sampling were significant (P <0.05), while weeding x fertilization x species x sampling were highly significant (P <0.01). Most probably is that the latter would have been highly significant because it contained the first two.

These results coincide with those of an experiment in Cuba [45], who evaluated different methods of control vegetation during the establishment of *Leucana leucocephala*, and reported

http://dx.doi.org/10.5772/53318

that the best method was the application of systemic herbicide, achieving a plant height of 162.5 m and plant coverage of 96% to 5 months post seeding, concluding that the best promoter of the successful establishment of this legume was the control of vegetation.

Coverage. - The analysis of variance showed highly significant differences (P <0.01) between species: *Ap* showed a coverage of 2.6% and 0.5% Kudzu. We also found highly significant difference (P <0.01) between samples, with 0.7, 1.2 and 2.8% at 4, 8 and 12 weeks post seeding. The species x sampling interaction was highly significant (P <0.01). *Ap* was the best species, averaging 1.2, 2.0 and 4.6% while *Pp* averaged 0.2, 0.5 and 0.9% for the same samples (Figure 8).

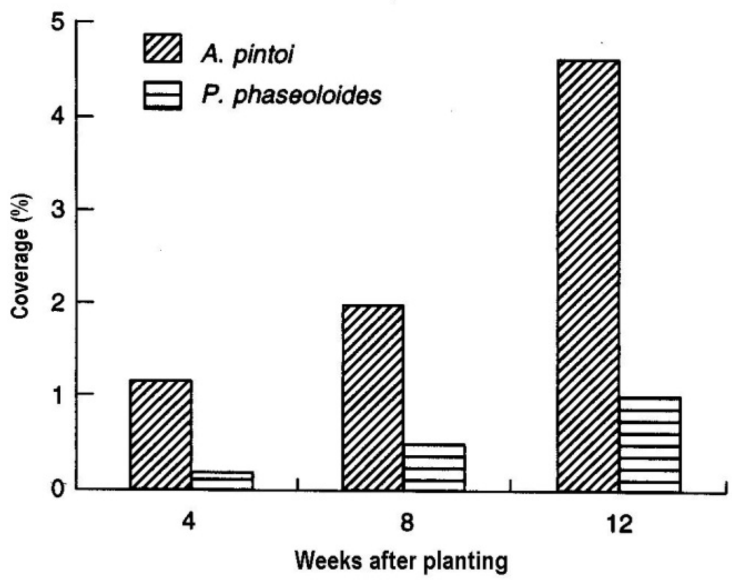

Figure 8. Soil coverage (%) according to the total experimental area, by *Arachis pintoi* (Ap) and Pueraria phaseoloides (Pp) at 4, 8 and 12 weeks afetr planting date.

The interaction slashing x fertilization x burning was also significant (P <0.05), resulting in the best combination of the H+B+P with 2.5% coverage, followed by S-B-P with 1.9%. Burning + fertilization promoted a good establishment of legumes. The combinations in which was planted after herbicide application, showed no significant differences for the variable coverage.

The burning x slashing x sampling interaction was also significant (P 0 <0.05). In the third sampling, treatment H+B+P was the best combination of coverage averaging 4.2%, followed by H-B-P with 2.4%. The other combinations were not significantly different from each other. The combination S+B+P coverage reached 3.7%, which is the highest value, which shows that the burning had positive influence on legume development, although interacted differently with the type of weeding and fertilizing.

The elimination of competition below and above ground, by applying H+B+P promotes the successful establishment of legumes. The lack of competition, plus the application of P, allowed to establish successfully the legume Siratro (*Macroptilium atropurpureum*) on the native grass [25].

The higher cost of treatment to establish *Ap*, was the S+B+P, or S+B-P (USD $ 195.00/ha), whereas the application of H-B-P was less expensive to establish *Pp* (USD $ 86.00/ha). Herbicide application was more economical compared to the slashing treatment. (Table 11).

4.3. Conclusions

The banded herbicide application without application of fertilizer is the best method for introducing vegetatively Ap in native grass pastures in north-central region of Veracruz State, Mexico.

Treatments				Cost (USD/ha)
Slashing	-B	- P	*A. pintoi*	173.43
			P. phaseoloides	117.16
		+ P	*A. pintoi*	193.43
			P. phaseoloides	137.15
	+ B	- P	*A. pintoi*	175.85
			P. phaseoloides	118.12
		+ P	*A. pintoi*	194.80
			P. phaseoloides	138.12
Herbicide	- B	- P	*A. pintoi*	142.15
			P. phaseoloides	85.57
		+ P	*A. pintoi*	162.15
			P. phaseoloides	105.57
	+ B	- P	*A. pintoi*	143.21
			P. phaseoloides	86.53
		+ P	*A. pintoi*	106.53

Table 11. Economic costs of treatments on the establishment of *Arachis pintoi* and Pueraria phaseoloides. Mexico, August 1996.

5. Establishment of *Arachis pintoi* CIAT 17434 by two tillage methods in a native pasture of Veracruz, Mexico

In the humid tropics of Mexico, native pastures are affected by climatic variations from one season to another that make it difficult, to obtain stable yields of forage during the year.

Also, financial constraints of most producers in the tropics must be considered when trying to introduce forage species [40]; so it is justified, evaluate and implement systems-on planting native vegetation, different from the traditional, in order to encourage the adoption of new and improved grass species, the lower potential economic costs.

In order to improve the botanical composition of native pasture in north-central region of Veracruz, Mexico, was evaluated two methods of establishment to incorporate the forage legume *Arachis pintoi* CIAT 17434.

5.1. Materials and methods

5.1.1. Location

Centre for Teaching, Research and Extension in Tropical Animal Husbandry of the Faculty of Veterinary Medicine, of the National University of Mexico (UNAM), located in the municipality of Tlapacoyan, Veracruz, Mexico, 20 ° 03 'north latitude and 97 ° 03' west longitude, 151 m. The climate is hot and humid on the type Af (m) (e), with an average temperature of 23.4 ° C and an average annual rainfall of 1980 mm. Soil characteristics are presented in the Table 12.

Properties	Soil depth (cm)			
	0-10	10-20	20-30	30-40
Texture (%)				
Sand	22.2	8.6	-	18.2
Clay	47.0	70.9	-	57.5
Silt	30.8	20.5	-	24.4
Chemicals				
pH	5.0	5.1	5.3	5.3
O.M. (%)	3.5	1.7	1.0	1.2
P (ppm)	5.0	6.4	4.4	2.0
S (ppm)	32.0	54.4	41.6	34.1
Ca (meq/100 g)	5.1	5.0	4.2	4.0
Mg	1.8	1.5	1.4	1.4
K	0.8	0.3	0.3	0.3
Al	0.2	0.1	0.1	0.1
CEC (meq/100 g)	7.1	6.8	5.7	5.5
Al saturation (%)	2.8	1.5	1.7	1.8

Table 12. Chemical and physical characterisics of the experimental soil. Veracruz, Mexico.

The study was conducted during the three seasons representative of this region: winter or "North" from November to February; drought: March to June, rain or summer: July to October. Weather conditions for the experimental period by time are presented in Figure 9.

Experimental design and treatments. We used a completely randomized design with factorial arrangement of 2 x 2: Conventional or minimum tillage, and fertilization or not, within each period and 12 observations (no repetitions) per treatment (T), resulting in:

T1 = Conventional tillage plus fertilizer

T2 = Conventional tillage without fertilizer

T3 = Minimum tillage plus fertilizer

T4 = Minimum tillage without fertilizer

T1 and T3 were: P (22), S (25), K (18), Mg (20), Ca (100), Zn (3), Cu (2) and B (1) kg / ha. Each period included a an experimental area, with dimensions of 50 m x 40 m (2000 m^2), divided into two parts along: one, conventional tillage; and another with minimum tillage. Then each part was subdivided again in width to the treatments with and without fertilization. Each treatment involved 12 observations (no repeats) within the corresponding area of 9 m^2 each for thorough preparation, and 18 m^2 for minimum tillage.

Land preparation. In T1 and T2, were allocated strips of 3 m x 20 m, alternating with native grass, where the vegetation was slashed with desvaradora, followed by 4 to 5 passes of harrow and plowed with a hoe. On the strips, the distance between rows and plants within them was 80 and 50 cm, respectively. The legume is seeded with a seed depth of 15 cm.

Minimum tillage. For T3 and T4, there was a land clearing with machete, were traced rows of 20 m long, spaced every two meters, and the rows were holes (seed points) every 50 cm, diameter and depth of 20 and 15 cm, respectively.

Planting dates were in Nov 29/1991, March 2/1992 and jul 15/1992, with plant material, placing 3-4 stems of 15 cm long, with only three or four leaves in the air. After 30 days, treatments were applied "with" and "without fertilization. These works were carried out in each season and in the corresponding area. Weed control was made with a hoe, in the first three months, for each treatment and time.

Variables. Data were collected at 4, 8, and 12 weeks post-seeding for number of plants, and 4, 8, 12 and 24 weeks for coverage. The useful area was 9 m^2 (T1 and T2) and 18 m^2 (T3 and T4). The first variable was the number of facilities within the useful area and in the second, the proportion was estimated visually apparent that the legume covered the area. The data were analyzed separately for each planting season, using ANOVA, and Tukey's test was used to compare means [9]. Regression coefficients were estimated to number of plants (linear) and coverage (exponential) to observe trends.

5.2. Results

5.2.1. Winter season

Number of plants. At this time, the average/treatment at 4, 8 and 12 weeks was 12.2, 15.3, 14.5 and 14.7 plants/9 m^2. A significant effect (P≤0.01) by fertilizer and ages was observed; by the contrary, the interaction week x treatment was not significant. The overall average was 14.1 plants/9 m^2 with a coefficient of variation of 20.0%. Treatments 2, 3 and 4 had better performance at 12 weeks.

Regarding the rate of appearance of plants, expressed this as the time in weeks to bring a new plant, was similar among treatments 2, 3 and 4 in winter and rainy seasons, while T1 needed more time to build a new plant (Table 13).

Planting season	T1	T2	T3	T4
	Weeks by treatment			
Winter	3,8	1.5	2.0	1.7
Dry	9.0	33.3	-	25.0
Rainy	1.0	0.6	0.5	1.0

Time in weeks to bring a new plant.

Table 13. Appearance rate* of *Arachis pintoi* plants on each planting season. Veracruz, Mexico.

Coverage. At 12 weeks, the best coverage was in T2 (P≤0.01) with 28%, while while T1 and T3 were similar, with 22.9% and 19.0% respectively. On the contrary, coverage at T4 was 18%. The overall average for this variable during the winter season was 22.1% with a coefficient of variation of 38%.

There were statistical differences between treatments (P≤0.05), exceeding 28% of T2 with coverage, while T1 and T3 were similar, with 22.9% and 19.0% respectively. The average for T4 was 18.2%. The overall average for this variable during the winter season was 22.1% with a coefficient of variation of 38%.

Figure 10A shows the increase in coverage during the establishment period, for each treatment at 4, 8, 12 and 24 weeks. There is a considerable increase for all treatments from week 12. The maximum coverage at 24 weeks is presented in conventional tillage treatments.

The rate of coverage of the ground, expressed as the average time in weeks for the plants to cover 10% of area, is presented in Table 14.

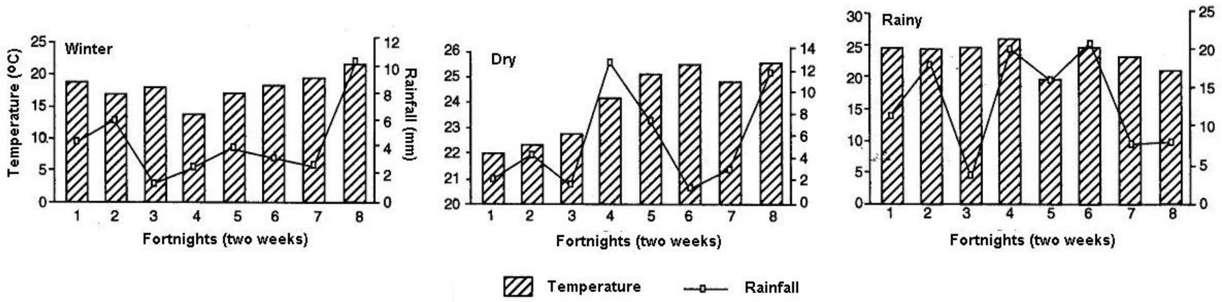

Figure 9. Temperature and rainfall on each one of the planting seasons of *Arachis pintoi*. Veracruz, Mexico.

Planting season	T1	T2	T3	T4
	Weeks by treatment			
Winter	2.9	2.6	3.8	4.2
Dry	4.7	4.2	3.5	2.2
Rainy	2.2	2.8	2.6	2.0

Table 14. Time in weeks to *Arachis pintoi* cover 10% of soil. Veracruz, Mexico.

5.2.2. Dry season

Number of plants. The averages for this variable were: 21.15, 19.75, 32.5 and 31.9 plants/9m^2 assessment considering each week. T1 and T2 were statistically equal, but different from T3 and T4 (P≤0.05).

In conventional tillage, were less plants than at minimum tillage treatments. Theere are not significance for age effect, neither its interaction with soil treatment Table 13.

5.2.3. Coverage

The best coverage (>25%) was at at 3 and 4 treatments (P≤0.05). Figure 10B shows the soil coverage at each evaluation frequency. An outsatndinh behaviour was observed for T1 after 8 weeks, achievinig 80% coverage to 24 weeks.

The age effect and its interaction with treatments were statistically significant. The shortest time to cover 10% of soil was during dry and rainy seasons at T4 (Table 14).

5.2.4. Rainy season

Number of plants. At this time, the largest number of plants/9 m^2 occurred at treatments 1 and 2 (23.0 plants), compared to T3 and T4 (17.3 and 14.3 plants, respectively). Was observed an increase of plants at 8 weeks, mainly in conventional tillage treatments. The shortest time or highest rate of occurrence of plants in T1 and T4 was 1.0 weeks in time for the emergence of a new plant.

5.2.5. Coverage

During the rainy season, soil coverage was similar among treatments (Figure 10C). The overall average was 34.5% with a coefficient of variation of 26.1%. For the rate of ground coverage, the lowest average time was observed in T4 with 2.0 weeks to cover 10% of the area (Table 14).

5.2.6. Number of plants in each season

The average of plants/m2 was largest during the rainy season (19.4 plants) followed by winter season (14.2 plants), and dry season (8,7 plants). The analysis of variance and regression coefficients for number of plants/season are shown in Table 15.

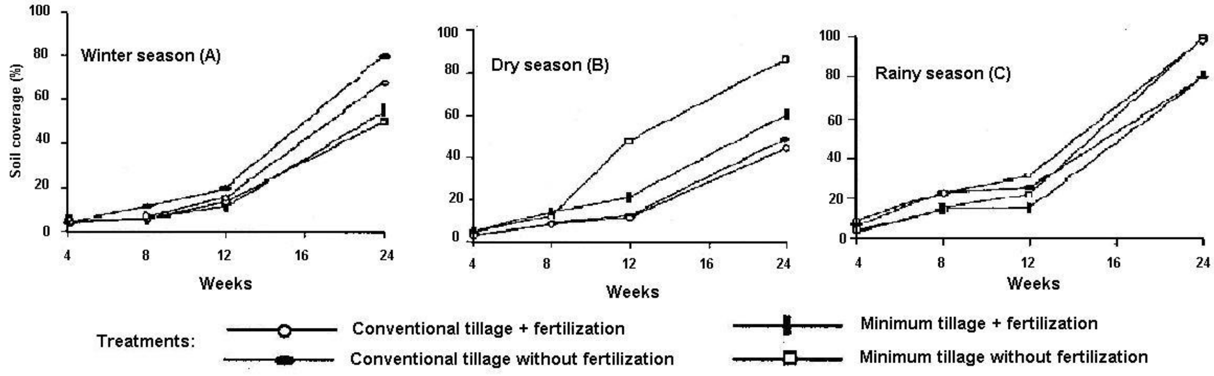

Figure 10. Percentages of soil coverage by *Arachis pintoi* planted in winter (A), dry (B) and rainy (C) seasons. Veracruz, Mexico.

Source of variation	df	Winter		Dry		Rainy	
		MS	P>F	MS	P>F	MS	P>F
Treatments (T)	3	64.85	0.0001	185.64	0.0001	681.34	0.0001
Weeks (lineal)	1	384.00	0.0001	2.34	0.5901	2860.16	0.0001
T x W (lineal)	3	11.58	0.2532	1.37	0.9161	68.80	0.3772
Error	136						
Coefficients		a	b	a	b	a	b
T1		10.08	0.26	6.14	0.11	14.80	1.03
T2		9.94	0.66	6.33	0.03	10.05	1.62
T3		10.49	0.50	11.07	-0.03	2.73	1.62
T4		10.11	0.57	10.30	0.04	6.50	0.98

Table 15. Analysis of variance and regression coefficient for number of plants by planting season of *Arachis pintoi*. Veracruz, Mexico.

5.2.7. Soil coverage and age of plants

The best percentages of soil coverage by *A. pintoi* occurred at 24 weeks, highlighting the rainy season planting date. Table 16 shows the analysis of variance and regression coefficients between soil coverag and age of plants on each season.

Source of variation	df	Winter		Dry		Rainy	
		MS	P>F	MS	P>F	MS	P>F
Treatments (T)	3	986.39	0.0001	4933.92	0.0001	696.84	0.0001
Weeks (lineal)	1	102416.09	0.0001	93319.28	0.0001	193155.43	0.0001
T x W (lineal)	3	1300.38	0.0001	2932.31	0.0001	958.32	0.0001
Error	184						
Coefficients		Winter season		Dry season		Rainy season	
T1		$Y=2.42(exp.^{0.1396x})$		$Y=2.42(exp.^{0.1095}x)$		$Y=2.42(exp.^{0.1068}x)$	
T2		$Y=2.42(exp.^{0.1405}x)$		$Y=2.42(exp.^{0.1140}x)$		$Y=2.42(exp.^{0.1064}x)$	
T3		$Y=2.42(exp.^{0.1155}x)$		$Y=2.42(exp.^{0.1095}x)$		$Y=2.42(exp.^{0.1305}x)$	
T4		$Y=2.42(exp.^{0.1133}x)$		$Y=2.42(exp.^{0.1326}x)$		$Y=2.42(exp.^{0.1472}x)$	

Table 16. Analysis of variance and regression coefficient for soil coverage by planting season of *Arachis pintoi*. Veracruz, Mexico.

5.3. Discussion

Although the two ways to establish *Arachis pintoi* tested here are not the only ones, the results with conventional tillage are attractive, in the frequencies tested. In this regard, the method [46], using a planting implement, designed for them, allowed that two months after planting shown good development. Here, at 24 weeks, the ground cover in all treatments was above 80%, while the total coverage (100%) in treatments with conventional tillage was achieved approximately eight months post-planting.

Should be noted that the availability of plant material is an advantage in the evaluation of the species, as well as attempts to disseminate the same among low-income producers, because of the ease of material handling.

The null effect of fertilization on the establishment of *Arachis pintoi* found here, was also observed in Colombia [47], who applied seed and fertilizer pellets to a degraded pasture of *Brachiaria*. The fertilizers were the same as those applied here, except Zn, Cu and B, although in much smaller quantities. This lack of effect could be explained based on the relatively short period of observation (12 and 24 weeks for number of plants and coverage, respectively) per day, such as to indicate their presence nutrients to the crop, especially in the case of P, which is referred to their low mobility in soil.

A study in this same experimental field [48], reports that when *A. pintoi* was planted by seed coverage was achieved over 90% at 12 weeks of age. In Puerto Rico, accessions CIAT: 18744, 18747 and 18748 evaluated in an Oxisol had a high rate of spread at 16 weeks with 90% ground cover and low incidence of weeds [49]. This coverage is lower than that obtained in Colombia, were researchers established *Arachis pintoi* by vegetative associated with *B. dictyoneura*, and 20 weeks of age achieved a coverage of 40 to 45% [50].

During the experiment, the climate in CEIEGT, was very variable. This is because the region is in a climatic transition zone between the regions: coastal (subhumid) on the east, and Sierra Madre Oriental (wet), to the west, which creates a very unstable microclimate between and within years. Evidence of this was the precipitation that was 40% above the annual average and in the dry season, rainfall was 60% higher than that in the last 10 years. So, this season should be considered "atypical" and therefore the results may not be reliable. Unlike precipitation, the temperature is somewhat variable.

5.4. Conclusions

Based on the information presented, we conclude that: (1) establishing methods involving a conventional land preparation proved to be the best, both for number of plants to cover. (2) Although were not evaluated seasons, the best results were achieved in the r.ainy season (3) No effect was observed for either fertilization treatments. (4) whereas in the dry season rainfall was well above average, the results obtained at this time, must be taken with caution. (5) is suggested to evaluate Arachis pintoi in locations with different climate and soil, in addition to testing planting seasons. (6) must also consider the possibility of evaluating new methods of establishment, both plant material, as with sexual seed.

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