Evaluation of agronomic practices for the establishment of Pinto peanut (*Arachis pintoi*) in native pastures of Mexico

Evaluación de diferentes prácticas agronómicas para el establecimiento de cacahuate forrajero (*Arachis pintoi*) en pasturas nativas de México

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Resumen

Se realizaron tres experimentos en un clima cálido y húmedo para evaluar el establecimiento de *Arachis pintoi* CIAT 17434: 1) cero labranza y labranza reducida, con fertilización (P, K, Mg, Ca, Zn, Cu y B) o sin fertilización; 2) control de la vegetación nativa con herbicida o chapeo, con quema o sin ella; y, con o sin fertilizante fosforado; y 3), siembra, por semilla, de tres accesiones CIAT de *Arachis pintoi*: 17434, 18744 y 18748, usando semilla en vainas. Los suelos de los sitios experimentales fueron Ultisoles, ácidos (Durustults), con un rango de pH de 4.1 a 5.2, y una capa impermeable situada entre 0 y 25 cm de profundidad. Se evaluó: número y altura de plantas, y suelo cubierto por la leguminosa, a 4, 8 y 12 semanas después de la siembra. En el experimento 1, se muestrearon cuadrantes dentro de cada parcela de tratamiento. En los experimentos 2 y 3 se empleó un diseño de bloques completos al azar con 3 bloques como repeticiones. Se realizaron

Abstract

Three land preparation management experiments were conducted in a hot and humid climate, in order to evaluate the establishment of *Arachis pintoi* CIAT 17434: 1) reduced and zero tillage, with fertilisation (P, K, Mg, Ca, Zn, Cu and B) or without fertilisation; 2) control of native pasture growth with herbicide or slashing, burned or not, with or without P fertiliser; and 3) planting of three *Arachis pintoi* CIAT accessions: 17434, 18744 and 18748, using seed pods. Soils in the experimental sites are acid Ultisols (Durustults), with a range in pH from 4.1 to 5.2, and an impermeable hardpan between 0 and 25 cm deep. The following variables were measured: Plant number, plant height and soil covered by the legume at 4, 8 and 12 weeks after planting. Experiment 1 was an unreplicated trial with treatments applied over an area larger than usual in agronomic experiments. Several fixed quadrats were sampled within each treatment plot. In

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análisis de varianza de acuerdo con el diseño experimental utilizado. En el experimento 1, el efecto principal de tratamientos sobre el número de plantas fue altamente significativo en las épocas de invierno, verano y sequía. El tiempo requerido para alcanzar un 50% de cobertura fue de 21 semanas para T2 (labranza mínima, sin fertilización) en invierno; 21 semanas para T4 (cero labranza, sin fertilización) en sequía; y 20 semanas para T1 (labranza mínima, con fertilización) y T4 en el verano. En el experimento 2, el efecto principal del tiempo después de la siembra fue altamente significativo para todas las variables de respuesta. El tratamiento herbicida+quema produjo plantas con los tallos más altos (21.0±1.6 cm) que el tratamiento de herbicida-sin quema (14.5±1.1 cm). La fertilización con P no incrementó la cobertura de la leguminosa. El tratamiento chapeo sin quema y sin fertilización resultó en una menor cobertura que el tratamiento herbicida+quema+fertilización. En el experimento 3, la cobertura de las leguminosas se incrementó en el tiempo (4, 8 y 12 semanas) de forma lineal, pero sin diferencias entre las accesiones. La siembra de agosto requirió 45, 46 y 56 días para cubrir un 5% del terreno con las accesiones CIAT 17434, CIAT 18744 y CIAT 18748, respectivamente. Estos resultados dan a los productores la oportunidad de seleccionar la mejor alternativa acorde a sus condiciones específicas; sin embargo, la mejor alternativa fue aquella que involucró el uso de herbicida, por ser más efectiva al mejorar el establecimiento en comparación con la práctica de chapeo.

Palabras clave

Arachis pintoi, preparación del terreno, vegetación del terreno, cubierta del suelo.

experiments 2 and 3 the design was a randomised complete block design with 3 blocks as replicates. Analyses of variance were done with linear additive models in accordance to the experimental design. In experiment 1, the main effect of treatment on plant number was highly significant in winter, rainy and dry seasons. The time taken to reach 50% cover was 21 weeks for T2 (reduced tillage, no fertilisation) in winter; 21 weeks for T4 (zero tillage, no fertilisation) in dry season; and 20 weeks for T1 (reduced tillage, with fertilisation) and T4 in rainy season. In experiment 2, the main effect of time after planting was highly significant on all response variables. The treatment herbicide+burning produced taller plants (21.0±1.6 cm) than herbicide-no burning (14.5±1.1 cm). P fertilisation did not increase legume cover. The treatment including slashing without burning and without fertiliser had significantly less legume cover than the herbicide+burning+fertilisation treatment. In experiment 3, legume cover increased linearly with time (4, 8 and 12 weeks), although without differences in slope among accessions. August planting took 45, 46 and 56 days to cover 5% of the soil to accessions CIAT 17434, CIAT 18744 and CIAT 18748, respectively. The results offer a range of practices to cattle producers from which they could select the best one according to their specific conditions. However, the best practice was the use of herbicides, which was more effective in improving establishment than the slashing technique.

Key words

Arachis pintoi, land preparation, plant vegetation, soil cover.

Introduction

The establishment of a plant is the most critical phase in pasture development. In tropical areas it was a common practice to start with forest clearing and burning, followed by two or more cropping cycles. As soil fertility declined, the land was either abandoned or converted to pastureland. Grazing by cattle and burning every so often to eliminate scrubby weeds created a savanna type vegetation of grasses and some scarce herbaceous legumes [León, 2006]. This was the mechanism by which many tropical forests ended up as pastures. In Mexico, such induced grasslands are called *gramas nativas* or "native gramma", consisting of a mixture of grasses of the *Paspalum*, *Axonopus*, *Cynodon* and *Setaria* genera, with small population contributions of herbaceous legumes from the *Desmodium*, *Centrosema*, *Rynchosia* and *Calopogonium* genera [Bosman *et al.*, 1990]. While introduced grasses such as those of the *Brachiaria* genus have become popular in latter years, the native grass pastures are still the main source of feed for cattle. The benefits of incorporating legumes into tropical grasslands have been documented elsewhere [Humphreys, 1991; Mannetje, 1997; 2000].

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 shows better persistence than other legumes and also has high nutritive value and palatability [Argel, 1994; Lascano; Hernández *et al.*, 1995; Ibrahim and Mannetje, 1998].

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 [Argel, 1994].

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.

Materials and methods

Site characteristics

Three experiments were conducted during 1991 and 1996 at the *Centro de Enseñanza, Investigación y Extensión en Ganadería Tropical* of the Faculty of Veterinary Medicine and Zootechnics of the National Autonomous University of México. 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.

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The climate is hot and humid, with rain 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 [Karbassi *et al.*, 1970; Ivory and Whiteman, 1978a; 1978b]. 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 1a). Total rainfall during experiment 1, December 1991 to September 1992, was 39% above average (figure 1b). 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 1b).

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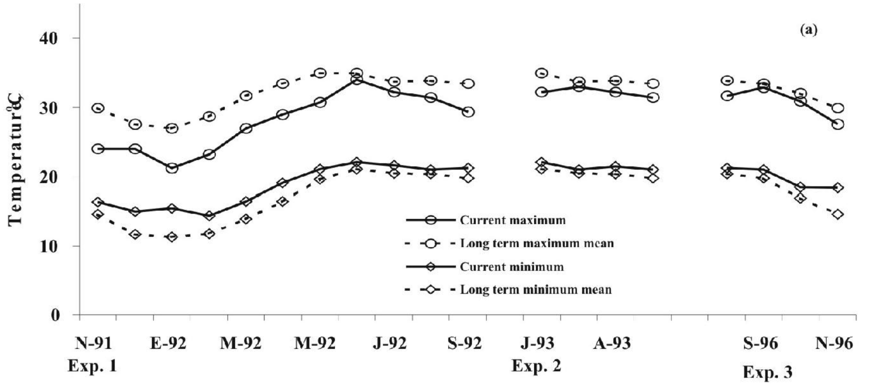
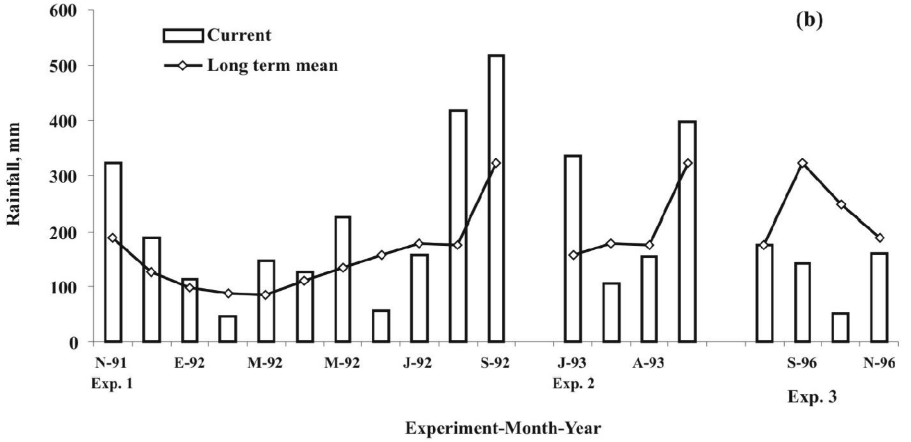
Figure 1. Current and long term monthly temperatures (a) and rainfall (b) for the 3 experiments.





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 an 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 (Toledo, 1986).

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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).

A. pintoi was planted on sub-plots of 500 m^2 on November 29, 1991 (winter season), March 2, 1992 (dry season) and July 2, 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 quadrant 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 quadrant 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 quadrant, regardless of type of tillage. Fertiliser was broadcast 30 days after planting.

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 and enhance legume establishment and early growth, following the approach described by Cook and Ratcliff (1985) 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

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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 of the legume was done between June 28 and July 3. Application of herbicide and herbicide plus burning, and slashing or slashing plus burning, was done 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 immersing 1 kg of profusely nodulated *A. pintoi* ground roots in a solution of 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 quadrants (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 the time of sowing in a 0.07 m deep hole adjacent to the planting position.

Experiment 3. Establishment 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 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 a 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.

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 quadrant, 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 quadrant area covered by the legume) measured with the aid of a 1 m^2 quadrant, divided into 25 squares, which was placed over the row. These measurements were done on weeks 4, 8 and 12 after planting [Toledo and Schultze-Kraft, 1982]. 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 quadrants 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. In this one, the 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 [Steel and Torrie, 1980]. 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. Mean comparisons using Tukey's test were done when necessary.

Results

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 1). There was no significant treatment per 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 taken 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 2).

Table 1. Effect of treatments on the number of plants of *Arachis pintoi* CIAT 17434 (pl/m2) 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	$1.36^{b} \pm 0.06$	$0.78^{a} \pm 0.06$	$2.56^{a} \pm 0.17$
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** ± 0.04	$0.68^{NS} \pm 0.02$	1.72** ± 0.10

$P \leq 0.0001$.

Table 2. Mean ± standard error for weeks taken to reach 50% cover by *A. pintoi* CIAT 17434 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

$P \leq 0.01$.

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 (figure 2). 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).

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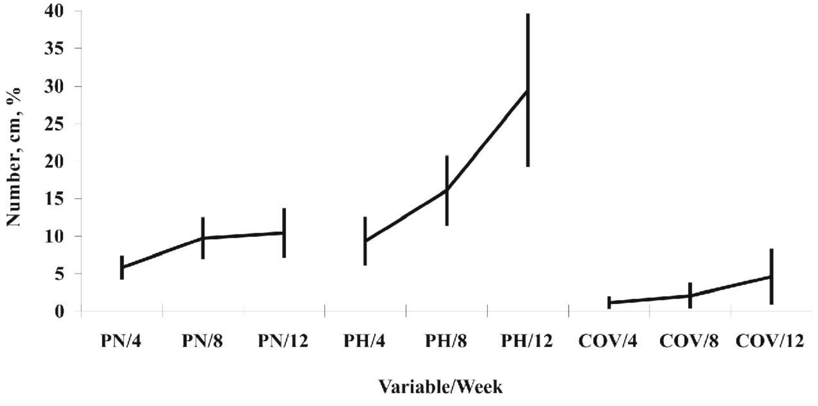
Figure 2. Effect of time after planting (4, 8 and 12 weeks) on *A. pintoi* CIAT 17434 plant number (PN, number/m^2), plant height (PH, cm) and legume cover (COV, %). The vertical lines are the standard deviations.



When herbicide was applied, the burned plots produced taller plants than the non-burned ones (P= 0.01). The opposite happened on slashed plots (P<0.05) (table 3).

Table 3. Combined effect of vegetation control x burning treatments upon *A. pintoi* CIAT 17434 mean plant height (PHT, cm).

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	

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 4).

Table 4. Combined effect of vegetation control x burning x P-fertilization treatments upon *A. pintoi* CIAT 17434 mean cover (COV, %, ± standard error).

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

$P \leq 0.01$.

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), without any differences in slope among accessions (figure 3). The regression equations of cover *vs.* time showed that for the August planting 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 5). Maximum height at the end of the establishment period was greater for August (27.4 cm) than for September (18.2 cm).

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

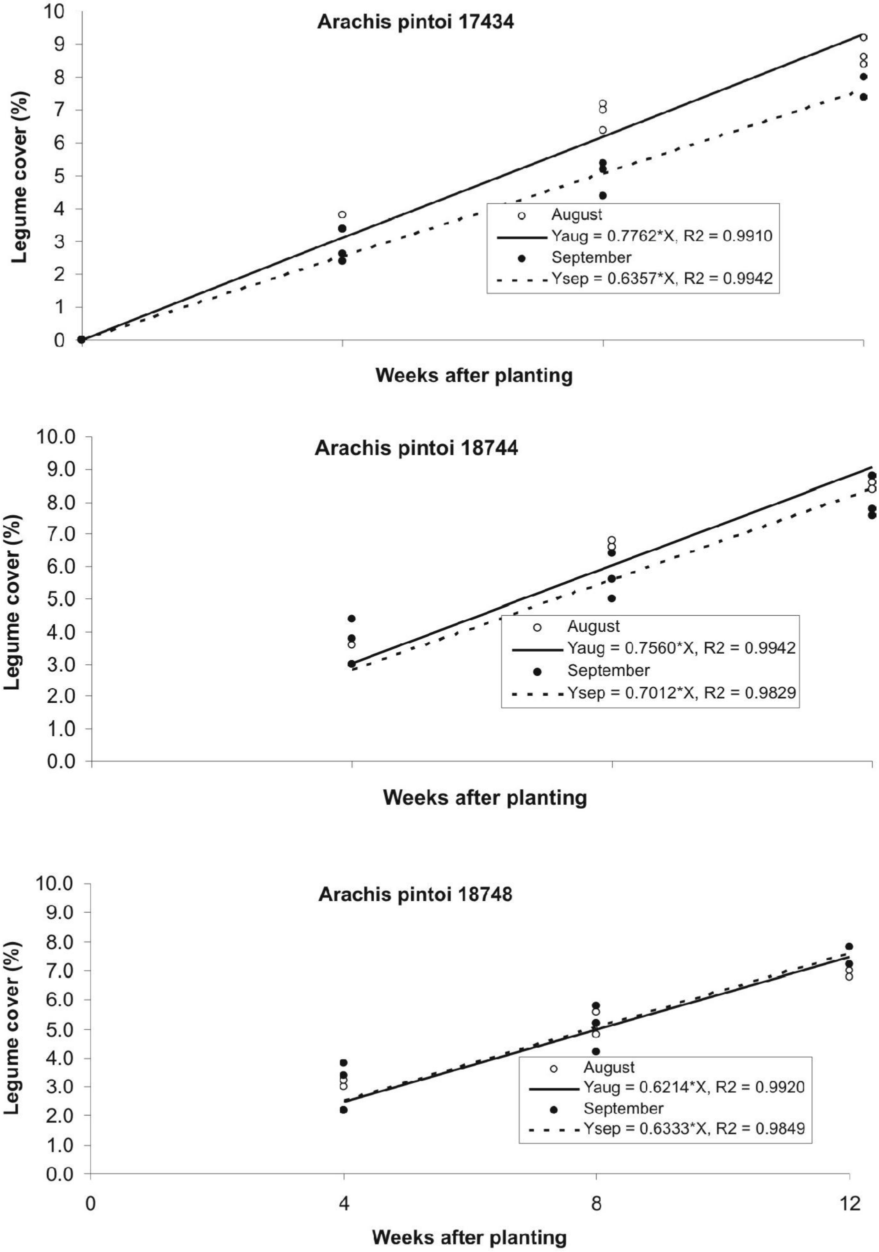

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Table 5. Mean ± standard error of cover (COV, %), plant number (PN, plants/50 m^2) and plant height (PH, cm) per month of planting by accession combination in experiment 3.

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 $P \leq 0.01$.
NS= Non-significant.

Discussion

A species may be adapted itself to a given environment, but this is no guarantee that it will establish well. Thus, the agronomist and the farmer must do everything possible to ensure successful establishment in the shortest time [Chambliss *et al.*, 2000].

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 did not disappear and was significant. Other trials conducted in the same region have indicated the advantage of reduced tillage over zero tillage to vegetatively establish *A. Pintoi* [Núñez, 1997]. The literature shows a general agreement among researchers about the fact that some sort of soil disturbance is necessary to assure establishment [Chambliss *et al.*, 2000; Schulke, 2000].

Cook and Ratcliffe [1984], suggested 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 what was found by Cook and Ratcliffe [1984]; 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) [Núñez, 1997].

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. Rebafka *et al.* [1993], found that application of 16 kg P ha^{-1} as single superphosphate to *A. hypogaea* failed to increase the total dry matter production significantly in all three years of the experiment, depressing also molybdenum soil concentration and total N uptake; on the contrary, using triple superphosphate enhanced dry matter production, N and Mo uptake. 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 $\mu g\ g^{-1}$ soil on 0-30 cm depth), could limit N mineralization [Valles *et al.*, 2008], resulting in a poor legume performance.

The main benefits of burning are elimination of competition from other plants as well as improved seed-soil contact, since high temperatures improve granulation at soil surface. However, competition from existing vegetation is avoided only for a short time after planting. Furthermore, burning can soften the seeds from volunteer species that could lead to weed encroachment [Blackett and Clem, 1997]. Burning may also be applied after herbicide suppression of the existing vegetation, in which case the avoidance of competition for the planted species would last longer.

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. *A. pintoi* is a slow-establishment legume [Johns, 1994; Pizarro and Rincón, 1994; Rivas and Hollman, 2000], even when it is fertilised or inoculated as it was done here. Probably this performance affected the rate of soil coverage and plant height, requiring more time for the legume to express its potential to growth.

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 [Villarreal and Vargas, 1996; Argel and Villarreal, 1998]. 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 [Stur and Horne, 2001]. 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 by Rivas and Hollman [2000], Pizarro and Rincón [1994] and Johns [1994]. 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 time.

Conclusions

Neither fertilisation nor burning was 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.

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