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Grain production and tannin contents on lines of *Cajanus cajan* (Pigeon pea) in the humid tropic of México

Rendimiento de grano y contenido de taninos en líneas de *Cajanus cajan* (Guandul) en el trópico húmedo de México

J. Jarillo R.[1], E. Castillo G.[1], B. Valles M.[1], R. Hernández H.[2]

Abstract

Three trials were conducted between 1985 and 1989 in a site with a hot humid climate, in order to estimate the grain production potential of pigeon pea along with its nutritive value. In the first trial, using a native ecotype there were significant interactions between sowing date and the linear ($P \leq 0.0128$) and quadratic ($P \leq 0.0228$) effects of sowing rate. Maximum grain yields were obtained at 18750, 25132 and 26971 hills/ha for the June, August and September 1985 sowings, respectively. In the second trial, the effect of genotype was highly significant ($P \leq 0.005$) upon grain yield. Mean grain yield was 2451 ± 492 kg/ha, and range varied from 1211 to 4401 kg/ha. The third trial also showed a highly significant effect of genotype on grain yield ($P \leq 0.0050$). Average yield was 3105 ± 896 kg/ha and range went from 574 to 4262 kg/ha. Proximate analysis showed the following figures for trial three: dry matter, 86.4-88.6%; ash, 4.3-5.3%; ether extract, 0.6-1.4%; crude fiber, 4.1-6.8%; crude protein, 18.6-27.0%; and nitrogen free extract, 56.3-69.5%. Tannins, as tannic acid, ranged from 0.13 to 0.85%. The effect of genotype was also highly significant ($P \leq 0.0001$) upon hundred seed weight (32.6 ± 1.7 g), seed number per pod (4.2 ± 0.4), days to first (117 ± 8) and 50% (149 ± 3) flowering, and 75% of ripe pods (168 ± 3). Plant height ranged from 1.4 to 3.2 m. It was concluded; August was more efficient due to high yield with fewer plants/ha, the plant height was strongly afected by sowing date; the best material in trial two was ICPL-365 (4400 kg/ha); In the trial three lines with good production included ICPL-6997 and ICPL-265 the local material had performed better (4070 kg/ha) than in trial two; that there is a high potential for production of nutritive grain in this specie for environmental conditions described.
Keywords: *Cajanus cajan*; flowering; grain yield; plant density; proximate analysis; pigeon pea; sowing date; tanins.

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1. Centro de Enseñanza, Investigación y Extensión en Ganadería Tropical (CEIEGT), FMVZ-UNAM, P.O. Box 136, Martínez de la Torre, Veracruz, 93600 México.
2. Universidad Veracruzana, Xalapa, Veracruz, México.

Resumen

En el trópico húmedo de México, entre 1985 y 1989 se realizaron tres ensayos para evaluar el rendimiento potencial de grano y su valor nutritivo en líneas de Guandul (*Cajanus cajan*). En el primer ensayo, donde se utilizó un ecotipo nativo, se encontraron diferencias significativas en su efecto lineal ($P \leq 0{,}0123$) y cuadrático ($P \leq 0{,}0228$) para los factores fecha y densidad de siembra. Los máximos rendimientos de grano correspondieron a 18.750, 25.132 y 26.971 plantas/ha para las siembras de junio, agosto y septiembre de 1985, respectivamente. En el segundo ensayo, se encontró un efecto altamente significativo ($P \leq 0{,}005$) para ecotipo sobre el rendimiento de grano, que promedió 2.451 ± 492 kg/ha, con rango de 1.211 a 4.401 kg/ha. En el tercer ensayo se encontró un efecto altamente significativo ($P \leq 0{,}005$) del genotipo sobre rendimiento de grano. El promedio fue: 3.105 ± 896 kg/ha, y rango: 574 a 4.262 kg/ha. El análisis químico proximal para líneas en este ensayo, resultó en: Materia seca, 86,4-88,6%; cenizas, 4,3-5,3%; extracto etéreo, 0,6-1,4%; fibra cruda, 4,1-6,8%; proteína cruda, 18,6-27,0%; extracto libre de nitrógeno, 56,3-69,5%. La presencia de taninos, (ácido tánico) varió de 0,13 a 0,85%. El efecto de genotipo fue también altamente significativo ($P \leq 0{,}0001$) para peso de cien semillas (32,6 ± 1,7 g), semillas/vaina (4,2 ± 0,4), días a la primera (117 ± 8) y 50% de floración (149 ± 3). La altura de las plantas promedió 1,4 a 3,2 m. Se concluyó; que agosto fue el mes donde se observó mayor eficiencia en relación a la alta producción con pocas plantas/ha, asimismo, la altura de la planta fue afectada por la fecha de siembra; el mejor material, observado en el ensayo dos, fue ICPL-365 (4,400 kg/ha). Por lo tanto, existe potencial para la producción de grano de *Cajanus cajan* para las condiciones locales.

Palabras claves: *Cajanus cajan*, floración, producción de grano, densidad de plantas, análisis proximal, pigeon pea, fecha de siembra, taninos.

Introduction

Legumes are undoubtedly the most viable alternative to improve the diet of men and domestic animals. Legumes seeds were among the first sources of human food. Legumes are 2-3 times richer in protein than cereal grains and many also contain oil. Leguminous mulches have always been used as a source of nutrient-rich organic matter and nitrogen for crops. Recently, legumes have become important as high quality forages for livestock both in cultivated pastures and in naturally ocurring associations (7).

As in all munsoonal-type climates of the world, the Mexican tropics suffer critical periods in which lack of soil moisture impedes pasture growth, causing cattle productivity to decline or even halt completely. As a result, grazing steers need from 4 to 5 years to reach market weight of 450 kg, cows do not get pregnant, do not restablish their body condition and stop giving milk (9, 10). During the 1970s and the mid 1980s, it was difficult for Mexican researchers to find a pasture legume that could withstand overgrazing, a situation common in the Mexican tropics, due to poor management and lack of fodder conservation practices.

Pigeon pea (*Cajanus cajan* (L.) Millsp), was introduced long ago to Mexico but has attained importance only as a backyard crop in rural areas. It was proposed it could be an acceptable source of cured forage high in crude protein for use during periods with limited grazing. It was also recognized the need to study factors asociated with seed production, since often times promising plant introductions are not properly promoted among farmers because of the lack of seed.

Recognizing the importance of pigeon pea for human and animal nutrition in the tropics and because it is known to marginal soils and climates conditions of tropical Mexican grazinglands, a research line was established with two general objectives. First, to estimate the grain production potential and second, to determine the ability to produce nutritious forage for ruminants. This article presents the effects of date of sowing, sowing rate and grain yield of *Cajanus cajan* lines.

Materials and methods

Location, climate and soils. The trials were conducted at the Center for Teaching, Research and Extension in Tropical Animal Husbandry (CEIEGT) of the Faculty of Veterinary Medicine and Zootechnics of the National Autonomous University of México. The Center is located at the piedmont zone of the México's eastern range known as the Sierra Madre Oriental (20° 03' N, 97° 03' W, 151 m elevation). Climate is hot humid. Weather records taken daily between 1980 and 1989 indicate that the coldest month is January (18 ± 2.1°C), the hottest is June (27.4 ± 0.09°C) and the average mean temperature is 23.4 ± 0.5°C. The driest month is March (56 mm ± 28 mm), the rainiest is September (345 mm ± 167 mm) and the mean yearly rainfall is 1839 mm ± 378 mm.

Monthly average temperatures for the period May 1985 to April 1986, which comprised trials one and two, were 2°C below the 10- years mean for each month (figure 1a). June was still the hottest but below the historical average (25.3°C vs 27.4°C); January 1986 was almost 3°C below its historical mean (15.2°C vs 18.0°C). July was the month with the most rain instead of the typical September; and February was the driest, instead of March. Mean temperature for the same period was 20.8°C and rainfall was 1627 mm, below historical means.

From June 1988 to May 1989 (third trial) weather was closer to typical with regard to temperature, but was different from the expected values (Fig. 1b). The hottest month was again June (25.6°C), but this time the coldest was February (15.9°C). The months with most and least rainfall were June (260.5 mm) and November (4.5 mm) respectively. For this particular period,

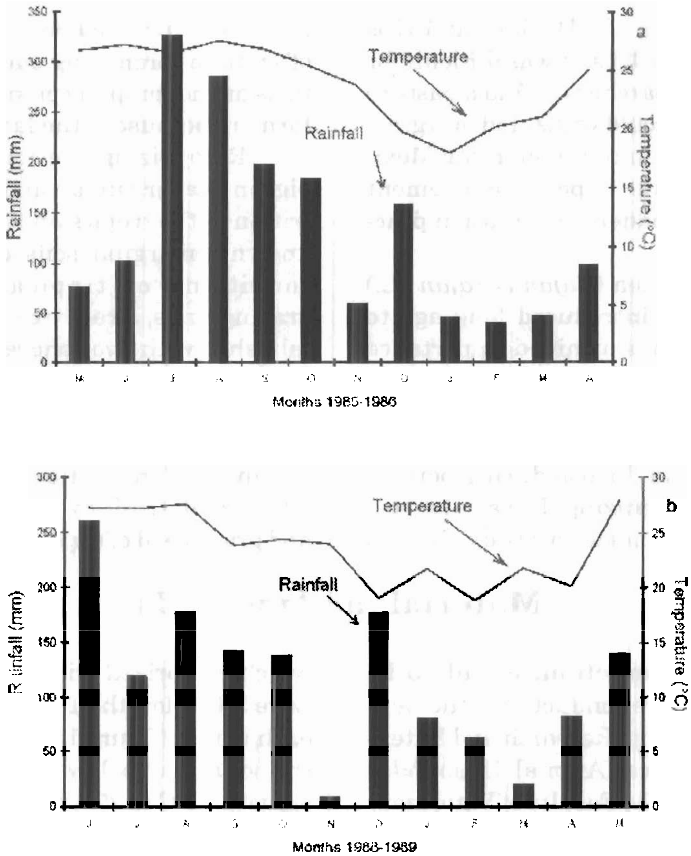

Figure 1. Monthly mean weather conditions (rainfall and temperature) during (a) the first and second trial; and (b) third trial.

mean temperature was 21.5°C and rainfall was 1358 mm; thus, this growth cycle was hotter than May 1985 to April 1986.

Soil in the experimental site is classified as Ultisol, with pH 5.2 and an *A* horizon at a maximum depth of 20 cm. There is not a *B* horizon. Horizon *C* is an acid hardpan formed with material that was transported, deposited and compacted. Due to microrelief, soils are prone to waterlogging during the wet and northern wind periods and thus horizon *A* exhibits gleyization (8).

Seed Sources: For trial one, seed were collected from backyards of rural homes near the Center. Seed of lines used in trials Two and Three were provided by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Hyderabad, India (table1). In fact, seed for the second trial was part of Pigeon pea Observation Nursery 1984 (PON-84) led by this institution.

Trial one

Sowing date and rate and grain yield. The study took place

Table 1. List of ICRISAT lines used in trials two and three.

1[a]	ICPL-267[b]	7	ICPL-138	13	ICPL-227	19	ICP-7035
2	ICPL-312	8	C-322	14	ICP-6997	20	Gwalior-3
3	ICPL-1	9	ICPL-332	15	ICPL-8354	21	NP(WR)15
4	ICPL-87	10	ICP-8862	16	ICPL-265	22	ICPL-365
5	ICPL-6	11	ICPL-270	17	HY-3C	23	ICP-9150
6	PPE-54-2	12	ICPL-343	18	ICP7946E1	24	Local

[a] Progressive number; [b] ICRISAT register

from June 1985 to January 1986. Sowing dates were 21 June, 1 August and 3 September 1985, and sowing rates were 10000, 20000 and 40000 hills/ha. A separate block of land was chosen at random for each sowing date and each combination of four replications by three sowing rates was randomly assigned to 12 plots within that block; Thus, the experimental design was of a nested nature and statistically analyzed as such. Plot size was 6 x 5 m. Response variables were grain yield (kg/ha), and plant height (m) and diameter at stem's base (cm) when plants reached, on the average, 50% flowering.

Prior to sowing, the soil received full preparation, and sowing took place when it was estimated that soil moisture was at field capacity. Distance between furrows and hills were respectively 1 x 1 m, 1 x 0.5 m, and 0.5 x 0.5 m for each sowing rate, respectively. Three seed were planted per hill and each hill was thinned to one plant 6 weeks after sowing. Triple superphosphate was applied in order to provide a minimum of 35 kg of P/ha. Days from sowing to emergence, to first and 50 % flowering, rainfall (mm) and temperature (°C) were also recorded. Weed and disease control was done as needed. Pods were harvested when ripe, but prior to natural opening.

Trial two

Grain yield of pigeon pea lines. The experiment began in July 1985 and ended in April 1986. Treatments were 23 lines provided by ICRISAT and the local line, which was a control and was used also for guard rows in the lines with little seed available. A randomized complete block design, with two blocks was used. Plot size was 2 x 4 m. Response variables were number of seeds per pod, seed weight and grain yield (kg/ha).

Sowing took place on fully prepared, and close to field capacity soil, using one to three seeds per hill, depending on seed availability. No fertilizer was applied; weeding and disease and pest control was done as needed. Pods were harvested when they were dry enough to resist handling without opening. Lines1 to 6, 7 to 19 and 20 to 24 were sown at 0.15, 0.30 and 0.45 m between hills, respectively; in all cases distance between furrows was 0.8 m.

Trial three

Grain yield and nutritive value of pigeon pea lines. This experiment began in June 1988 and ended in May 1989. ICRISAT provided 21 lines, but on (C-322) failed to germinate in the field. Again, the local control was present but this time the seed used originated from the second trial. There were 21 lines. A randomized complete-block design with three replicates was used. Plot size was 2.4 X 3.0 m. Three seed were sown per hill on fully prepared soil close to field capacity. Distance between hills were 0.15, 0.30 and 0.45 m for lines 1 to 5, 7 to 18 and 19 to 22, respectively. Plots were not fertilized but were inspected periodically in order to detect and control pests and diseases. Response variables were seed weight, number of seeds per pod, color of seeds, days to first and 50% flowering, flower color, plant height, grain yield (kg/ha), and in grain: crude protein (%) and presence of tannins. Pods were harvested when ripe, but before natural opening occurred. Grain was kept in sealed plastic bags, at room humidity and temperature but under shade. Tannin content was determined by the Folin-Dennis method (3, 6) and expressed as tannic acid percent. Proximate chemical composition was determined by AOAC techniques (1).

Results

Trial one

Table 2 presents the analysis of variance for grain yield and plant height and stem diameter at 50% flowering. The significant interactions between sowing date and the linear and quadratic components of sowing rate indicated that rates for maximun grain yield were different for the three dates. Figure 2 illustrates curves obtained from quadratic regression equations. Maximum grain yield was obtained at a density approximately of 25000 plants/ha for June and September, and 15000 plants/ha for August. Based on yield obtained, September was the best month to sow *Cajanus cajan,* but considering production per plant, August was more efficient due to high yield with fewer plants/ha.

Plant height was strongly affected by sowing date, and in fact, this variable constituted most of the high coefficient of determination given by model (table 2). Mean heights were 2.93 ± 0.09, 2.51 ± 0.18 and 1.58 ± 0.18 m for June, August and September sowing dates. Orthogonal comparisons indicated statistical differences between August and June ($P \leq 0.0192$) and June and September ($P \leq 0.0009$). Stem width was significantly less ($P \leq 0.0156$) as sowing date advanced: 3.4 ± 0.5, 2.3 ± 0.6 and 1.7 ± 0.3 mm for June, August and September sowings, respectively. Probability for the difference between June and August was close to significance ($P \leq 0.0575$), but the difference between June and September was highly significant ($P \leq 0.0051$). The linear component of sowing rate had a highly significant effect ($P \leq 0.0009$) that was negative; regression analysis indicated that an increase of 10000 hills/ha decreased stem width by 8 mm.

Grain yield was correlated with plant height ($r = 0.55$, $P \leq 0.0006$) and stem width ($r = 0.39$, $P \leq 0.0190$); the latter two were also highly correlated between them ($r = 0.77$, $P \leq 0.0001$).

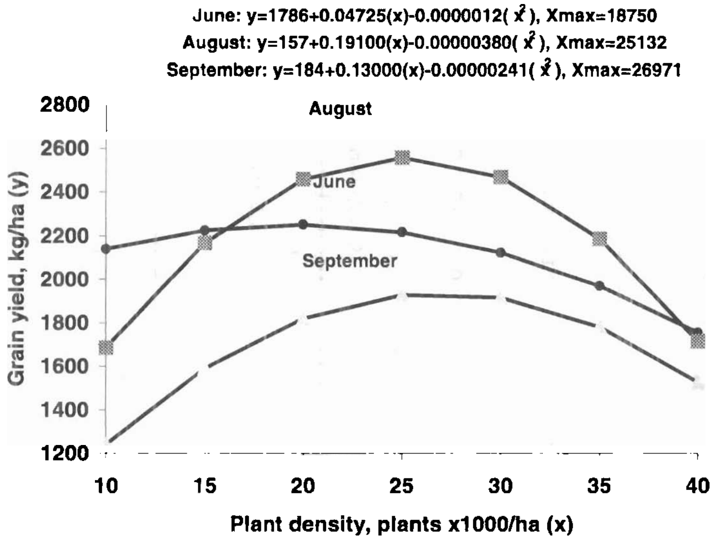

Figure 2. Grain yield of pigeonpea (*Cajanus cajan*) as affected by sowing date and plant density (trial one) in a site with hot-humid climate and Ultisol soils of Veracruz State, México.

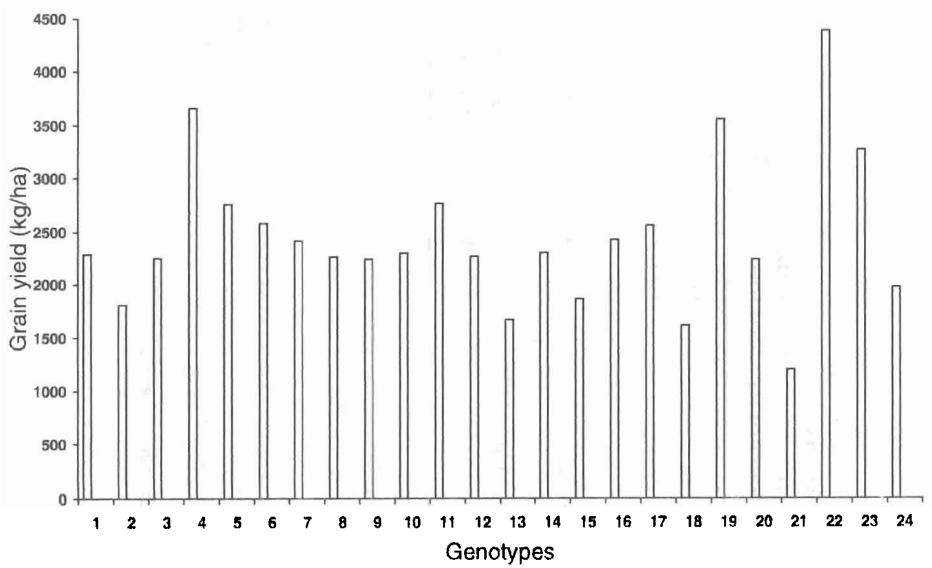

Figure 3. Yield comparisons of 24 *Cajanus cajan* genotypes on the second trial.

Table 2. Analysis of variance for grain yield, plant height and stem width at 50 percent flowering of pigeon pea (*Cajanus cajan*) grown in a hot humid climate and Ultisol soils in the State of Veracruz, México, in trial one.

Source of Variation	Degrees of freedom	Mean squares* Grain yield (kg/ha)	(P > F)	Plant height (m)	(P > F)	Stem width (cm)	(P > F)
Planting date (F)	2	310900	0.0530	0.17700058	0.0030	0.82185817	0.0156
Replications within F	9	75050		0.01486481			
Planting rate (PR)	1	1721540	0.0001	0.00533651	0.6533	0.8080079	0.0009
PR2	1	1908054	0.0001	0.00503810	0.6625	0.35659286	0.1620
F x PR	2	198288	0.0128	0.03300079	0.2995	0.11521567	0.1319
F x PR2	2	166195	0.0228	0.04703095	0.1877	0.10126607	0.1647
Error (b)	18	35377		0.02558148		0.50716670	
R-Square		0.89		0.96		0.96	
Mean		1830.11		2.34		2.48	
Std. Dev.		188.09		188.09	0.22		
Coef. of var (%)		10.3				9.1	

* Derived from type III sums of squares.

Field germination took place 6 days after sowing (DAS), regardless of sowing date (21 June, 1 August and 3 September). First flowering date and days to first flowering were 19 October and 120 days, 8 November and 99 days and 22 November and 80 days for June, August and September sowing. Date and days to 50% flowering were in the above order of sowings, 19 November and 151 days, 26 November and 117 days and 4 December and 92 DAS.

Trial two

The average for weight per seed was of 10 mg, and the number of seed per pod were of 4.1 ± 0.7. The analysis of variance revealed a significative effect ($P \leq 0.05$) for grain yield. The average for 23 ICRISAT lines was of 2470 ± 690 kg/ha, while for local material had a mean of 1990 kg/ha. This is a difference of 24% favourable to ICRISAT lines. The coefficient of variation (CV) was of 28%. The best material was ICPL-365, which yielded 4400 kg/ha (figure 3).

Trial three

Only 21 lines were evaluated for grain yield, as three lines failed. Average for seed weight was of 107 mg. The mean number of seed per pod was of 4 ± 0.4 with a CV of 10.5%, but that number varied significatively among lines ($P \leq 0.01$). Seed color was beige, spotted with brown tones around of micropyle, for ICPL-343, HY-3C, NP(WR)15 and ICPL-9150. Seed of the other lines were brown. Stem colors were either brown or green.

HY-3C, NP(WR)15 and ICPL-343 had open branches. Remaining showed branches loads to up and inclined at top. Days to the beginning of flowering averaged 117 DAS, with significative differences among lines ($P \leq 0.01$). Days to 50% of flowering also varied effect ($P \leq 0.01$). The average was 49 days with standard deviation of 7.6 days. Flowers were yellow color.

The lines varied in height with some reaching 2 m at 85 DAS (ICPL-1, ICPL-87 and ICPL-6); while others reached 2.75 m at 185 DAS (ICP-332 and ICPL-6997). Lines ppe-45-2, ICPL-6, ICPL232, ICPL-8863, ICPL-237, ICPL-8354, ICPL-265, ICP-7035 and local material reached 3.2 m at 178 DAS, and Gwalior 3, NP(WR)15 and ICPL-365 reached 3.25 m at 188 DAS.

Average grain production was of 3100 ± 900 kg/ha, with a CV of 29%, or 26% more than in trial Two. Figure 4 illustrates the production of each line. In this trial, the local material had performed better (4070 kg/ha) than in trial Two. Other lines with good production included ICP-6997 and ICPL-265 (numbers 14 and 16 in figure 4).

Crude protein concentration in grain averaged 20.9 ± 2.0%, with a range of 16.2% to 23.8%. By contrast, tannin content in seed varied widely among lines (CV=56%). The average for this variable was of 0.39% ± 0.22% in a range of 0.13% to 0.85%. The local line had a value of 0.14% (table 3). Other variables in seed were: dry matter, 86.4-88.6%; ash, 4.3-5.3%; ether extract, 0.6-1.4%; crude fiber, 4.1-6.8 %; and nitrogen free extract, 56.3-69.5%.

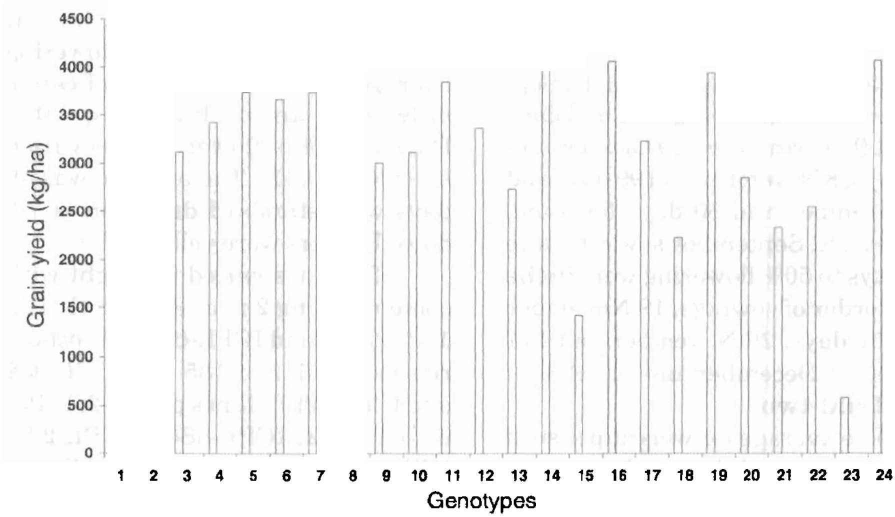

Figure 4. Yield comparisons of 21 *Cajanus cajan* genotypes on the third trial.

Discussion

Grain yields differed between the trials, due probably to the differences in sown densities used: 2.7, 4.1 and 8.3 plants/m^2. Many of the lines produced small yields at low densities. This agrees with observations of Wallis *et al.* (12) who reported grain yields of 3.0, 4.0, 4.6 and 5.0 t/ha using densities of 10, 20, 30, 40 and 50 plants/m^2.

The seed weight average was similar in Two and Three trials. Remananda (11) mentioned a range of seed from 3 to 26 g. The correlation coefficient of seed weight and grain yield, was negative and significant ($P < 0.01$); i.e., incomplete compensation in yield components. Grain yield diminished as seed weight increased. The number of seed per pod found here is within the range reported by Remananda (11): 1.7 to 7.6.

The best performing lines had yellow flowers. This is according with Allen and Allen (4) who had mentioned that *Cajanus cajan* present basically two colors: yellow for ecotypes of early maturity, and red for later maturity.

Days to 50% flowering and 75% maturation of pods were generally larger than those observed by Remananda (11) who found 55 and 237 days and, 97 and 299 days for days at 50% and 75%, respectively; in contrast to 166 and 284 days in the present study. Remananda mentioned that the number of flowering days is related directly to pod maturity; and explained that maturity ranges are very important for adaptability of *Cajanus* to different agroclimatic regions and production systems. The precocity of some lines such as ICPL-1 ICPL-87 and

ICPL-6 that began flowering from 58 to 72 DAS, could be an important characteristic in zones where climate favourable to *C. cajan* are not persist more than 90 days.

In the second trial, lines that yielded above average behaved poorly in respect to days to floration and pod maturity. This could indicate that the best lines in terms of grain yield were the earliest in terms of flowering.

From the analysis of rainfall respect to grain yield is possible to consider a negative effect from the high monthly precipitations during the first trial (164 mm) that caused a decreasing in grain yield. Akinola *et al.*, (2) proved that *Cajanus cajan* improve its grain yield when annual rainfall is less than 1500 mm. Others aspects must be considered in order to explain the behaviour. In the first trial some plots were sown in a flooding area. This condition caused sanitary problems to the plants as presence of bacteria not identified that gave damage to leaves in 38% to lines ICPL-332, ICPL-343, ICPL-8354 and ICPL-6997. For the last genotype, the damage was more intense, and probably this was the reason that it produced low yield. That some lines as ICPL-87 reached a height of 1.4 m could be a advantage for regions where winds are a serious problem.

Respect to behaviour for grain yield of local genotype this, in 1985 yielded 1990 kg/ha; but in 1988 it was obtained 4070 kg with a density of 27000 plants/ha. Thereby, is possible that environmental conditions on this trial could have been favoured to this genotype. The harvest of grain yield could cause some problems, because 4 to 5 handharvests are necessary as pods mature progressively.

The content of protein could be high; however, Braham *et al.* (5) reported that rats supplied with *Cajanus cajan* showed deficiencies for the essential amino acids, tryptophane and methionine.

Considering both evaluations (trials Two and Three) respect to grain production, and tannin content from the last trial, is possible to select the lines ICPL-265, ICPL-365 and local genotype as the best materials; although is necessary new experiments in order to confirm this selection.

To conclude, the best yields were related with best protein content; presence of tannins was minimum. Hence, *Cajanus cajan* is promissing legume for this region. The three sowing date were diferent in grain yield. The maximun grain yield was obtained at a density approximately of 25000 plants/ha for August. In the trial two, the best material was ICPL-365 which yielded 4400 kg/ha in the three trial; the local material had performed excellent (4070 kg/ha).

Acknowledgement

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