The yam bean project at CATIE, Costa Rica

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1. SUMMARY

The Yam Bean project which incorporates several countries in an international network promoting research of the *Pachyrhizus* genus was established at the Agronomic Center for Research and Training (CATIE) in 1989. This project received economical support from Denmark through the Royal Agricultural and Veterinary University. Currently CATIE preserves 172 accessions of five species including 34 inter-specific crosses.

During the new phase of the project, which began in October 1992, research actions have addressed the evaluation of adaptability and behavior of several accessions under different environmental conditions. Experiments have been established in the cities of Alajuela and Turrialba, Costa Rica, and during 1996, an essay was also implemented in the locality of David, Panama.

Research at CATIE has been conducted on agronomical practices to study the effect of flowers removal and planting distances over the yield of tubers for several yam bean accessions. These studies have been replicated in the area of David, Panama.

A flowers removal test was carried out employing 2,4-D herbicide; nevertheless, results indicate that this product can be harmful to yam bean plants. It is necessary to continue this type of tests since flowers removal requires a lot of hand labour.

One of the most important studies during this phase of the project, was the evaluation of the association yam bean - cassava. Two experiments were established, one of which served as a postgraduate thesis work at CATIE.

Support was also provided to two students from the University of Costa Rica (Chemical Engineering School) for two projects related with the rotenone extraction feasibility using *P. erosus* seeds. Due to the seed potential as rotenone source, an essay was designed and executed to evaluate the production capacity of seeds from three *P. erosus* accessions.

Finally, several plots were planted at CATIE with *P. erosus* and *P. tuberosus* accessions to multiply them and obtain seeds (regeneration). Advantage was taken of this activity to measure some interesting characteristics.

The general objective of this project was the characterization and evaluation of yam bean germplasm, integrating research of agronomic practices to select genotypes for future improvement studies and also to offer management recommendations in order to obtain adequate yields under different climatic and soil conditions.

2. MATERIALS AND METHODS

Random design blocks with four replicates were employed for experiments which aim was to evaluate accessions under different site conditions. For most agronomical practices essays, divided plot designs were utilized.

Flower were removed in all experiments in order to avoid tuberization competence, except for the experiment related to seeds production. None of the essays received fertilization and insecticides (piretrines) were only applied in few occasions to control *Diabrotica* genus insects.

3. RESULTS AND DISCUSSION

3.1 Seed production and multiplication

During 1994, forty three yam bean accessions, with low quantities of seeds, were planted to set seed for further experiments. During the month of December, when most plants were in the flowering and pod formation stage, a period of high precipitation affected the plot causing the death of six accessions (TC552, TC550, TC536, TC535, TC 534 and TC238), mainly from *Pachyrhizus tuberosus*. Other accessions survived but with low numbers of plants.

Tables 1 and 2 shows the number of plants per accession and some characteristic evaluated during the crops cycle. Some pod information were registered by using additional plants from other site and these do not present flowering data.

From accession TC238 one plant survived but only one pod was harvested at the end of the cycle. Cross X-50-1-23 presented the highest number of plants evaluated at flowering; nevertheless, most of them died in December and only a total of 15 pods were harvested. Some accessions showed few plants due to seed low germination rates.

Accessions TC531, TC238, TC555, TC554 and EC600 had white flowers; nevertheless, this characteristics was not recorded in the remaining genotypes, though most of them exhibited violet color.

Twelve *P. erosus* and 14 *P. tuberosus* accessions were planted, in February, 1996 to obtain seeds and prepare herbarium samples. The distance used in the planting was 2 m between rows and 1 m between plants. The size of each row was 4 m long for a maximum of 5 plants per accession.

Table 3 shows the number of plants evaluated for *P. tuberosus* accessions and the average of days at flowering.

It can be observed that Ecuador accessions TC550 through TC555, showed a flowering average inferior to 100 days. The remaining accessions, all from Peru but TC239, exceeded the 100 days, except accession TC354. The predominant flower color was white. Accession TC352 presented its flowering period 212 days after planting.

The accession TC553 resulted with 5 different plants (Table 4).

A herbarium was prepared with accessions TC239, TC360, TC361, TC362, TC550, TC551, TC552, TC553, TC554 and TC555. This material was sent to Dr. Marten Sorensen, Project Coordinator based in Denmark.

Table 1. Days at flowering and pods length (cm) of 35 yam bean accessions planted for seed multiplication in 1994

Accession	Planting	Days at flowering					Pods length (cm)				
	date	n	Average	Maximum	Minimum	C.V.	n	Average	Maximum	Minimum	C.V.
EC004	15 FEB.	-	-	-	-	-	30	10.8	12.0	9.5	6.3
EC041	12 SET.	sever.	80	-	-	-	30	10.3	13.3	6.4	14.2
EC043	15 FEB.	-	-	-	-	-	30	11.0	12.5	9.1	8.6
EC225	29 JUN.	2	113	113	113	0	5	12.5	14.3	11.5	8.8
EC232	29 JUN.	2	100	103	97	4.2	22	9.7	12.7	5.8	17.2
EC350	15 JUN.	3	165.7	173	156	5.3	30	11.0	13.0	10.0	6.7
EC352	15 FEB.	-	-	-	-	-	30	11.3	13.4	8.4	9.7
EC353	29 JUN.	1	124.0	-	-	-	30	10.7	12.9	9.0	7.5
EC509	20 MAY.	-	-	-	-	-	30	11.5	14.0	9.3	9.2
EC511	26 AGO.	-	-	-	-	-	30	11.7	14.5	7.8	10.4
EC526	29 JUN.	4	150.5	169	125	14.7	30	11.6	14.2	7.2	15.2
EC528	29 JUN.	1	97.0	-	-	-	-	-	-	-	-
EC532	2 SET.	sever.	83	-	-	-	30	12.6	14.3	9.7	9.9
EC548	29 JUN.	3	122.7	155	103	23.0	30	9.4	11.9	5.5	17.0
EC549	15 FEB.	-	-	-	-	-	2	9.1	9.7	8.5	9.3
EC555	15 FEB	-	-	-	-	-	9	9.5	11.5	8.0	12.7
EC556	29 JUN.	1	106.0	-	-	-	17	11.2	12.5	9.0	8.9
EC558	29 JUN.	5	108.4	113	103	4.7	30	11.4	14.0	8.5	11.3
EC600	15 JUN.	3	169.3	183	156	8.0	30	9.8	12.2	6.3	13.8
EC601	29 JUN.	8	92.6	113	82	11.2	30	10.9	12.6	8.4	10.8
TC238	29 JUN.	1	124.0	-	-	-	1	11.5	-	-	-
TC354	15 JUN.	1	148.0	-	-	-	30	16.1	20.0	12.2	13.0
TC359	15 JUN.	1	153.0	-	-	-	4	16.7	16.8	16.7	0.3
TC531	29 JUN.	3	157.3	164	144	7.3	30	13.5	22.4	8.2	27.3
TC554	29 JUN	1	97.0	-	-	-	4	11.4	14.8	8.3	23.4
TC555	29 JUN.	3	91.0	91	91	0	6	12.6	14.6	11.5	8.7
TC556	29 JUN.	3	140.0	144	138	2.5	30	17.6	22.2	10.5	14.2
EW230	29 JUN.	4	109.2	113	103	4.0	30	11.2	13.4	8.0	10.6
EW354	15 FEB.	-	-	-	-	-	18	9.1	11.0	7.0	11.0
PW055	29 JUN.	2	133.5	142	125	9.0	12	11.0	12.6	9.0	12.0
X-23-3-1-7	29 JUN.	5	98.8	113	91	8.4	15	11.7	13.5	8.8	10.0
X-47-1-1	29 JUN.	1	169.0	-	-	-	7	13.9	16.4	10.2	15.1
X-47-1-2	29 JUN.	2	95.0	97	91	3.6	9	11.2	12.5	10.0	8.0
X-50-1-23	29 JUN.	13	86.5	106	77	11.6	15	9.1	13.0	6.5	17.7
X-72-3	29 JUN.	9	87.8	103	77	10.1	30	11.8	15.2	8.9	13.5

n = Number of plants or plot evaluated
C.V. = Coefficient of variance (%)
* = Estimated (with less than de 100 seeds)

Table 2. Pods width, seeds/pod and seeds weight of 35 yam bean accessions

Accession	Pods Width (mm)				Seeds/Pod				Weight of 100 seeds (g)
	Average	Maximum	Minimum	C.V.	Average	Maximum	Minimum	C.V.	
EC004	14.4	16.0	13.2	4.7	7.6	9	6	12.4	19.9
EC041	11.9	15.3	9.8	10.7	7.5	11	2	26.3	23.9
EC043	13.5	14.6	12.0	5.2	8.6	11	6	14.4	19.0
EC225	14.7	15.9	12.4	9.4	7.4	9	6	15.4	25.0*
EC232	13.0	15.0	10.5	8.9	5.3	8	2	34.2	24.8
EC350	14.7	16.4	13.4	4.9	7.9	10	6	12.1	16.3
EC352	12.7	14.8	10.7	7.6	6.6	10	3	24.4	15.5
EC353	12.9	14.4	11.0	7.1	8.3	11	6	13.1	17.1
EC509	13.1	14.9	10.6	7.7	8.7	11	5	17.2	20.0
EC511	13.2	17.5	10.7	11.1	7.4	10	4	18.9	25.4
EC526	14.3	16.6	10.6	10.4	6.9	9	3	24.3	23.7
EC529	13.6	15.1	11.6	5.8	8.8	10	6	13.3	20.0
EC532	12.9	14.9	10.8	8.0	8.2	10	5	15.2	31.3
EC548	11.6	13.5	10.1	7.7	5.9	9	2	35.4	24.7
EC549	10.9	11.6	10.2	9.1	8.0	9	7	17.7	17.7*
EC555	13.6	14.3	13.0	2.8	4.9	8	3	31.4	20.5*
EC556	11.5	12.7	10.6	5.4	7.9	9	5	13.4	25.0
EC558	14.5	17.2	11.6	9.3	6.4	9	4	25.2	30.5
EC600	14.4	17.5	11.8	8.2	6.9	9	5	18.9	23.3
EC601	13.1	15.8	10.3	10.8	6.7	9	3	21.9	21.2
TC238	15.3	-	-	-	5.0	-	-	-	-
TC354	17.1	19.6	14.0	7.2	7.4	11	3	25.6	42.4
TC359	17.3	19.1	16.5	7.0	6.7	8	6	14.2	36.7*
TC531	14.0	17.2	11.7	10.1	7.0	10	3	26.5	53.7*
TC554	13.7	14.9	12.7	6.6	5.0	7	3	36.5	36.4
TC555	12.4	13.6	11.6	6.5	7.2	11	5	31.1	25.2*
TC556	17.9	22.4	12.5	13.2	6.7	9	3	24.8	58.0
EW230	14.3	17.4	11.9	10.3	7.4	9	5	14.0	27.3
EW354	10.7	11.6	8.4	9.2	6.7	9	4	19.6	9.0*
PW055	9.5	10.5	8.6	6.3	7.2	10	4	27.7	14.2*
X-23-3-1-7	13.2	15.4	11.0	9.5	8.3	11	5	18.5	18.6
X-47-1-1	13.9	14.9	11.6	8.5	6.4	7	5	12.2	44.2*
X-47-1-2	14.7	16.8	13.4	7.1	8.1	10	7	13.0	18.0*
X-50-1-23	12.8	16.4	10.6	13.4	4.4	8	2	43.6	18.6*
X-72-3	15.7	18.3	12.9	8.6	5.5	10	2	37.8	27.7

C.V. = Coefficient of variance (%)
* = Estimated (with less than de 100 seeds)

Table 3. Average of days at flowering and flower color in 14 *Pachyrhizus tuberosus* accessions

Accession	Plants evaluated	Days at flowering	Flowering days range Minimum	Flowering days range Maximum	Flower color
TC239	2	100.5	97	104	White
TC352	1	212.0	--	--	White
TC353	4	119.0	110	144	White
TC354	5	93.4	84	105	White
TC355	3	130.3	121	139	White
TC360	1	194.0	--	--	White
TC361	2	107.5	104	111	White
TC362	2	128.5	128	129	White
TC550	3	95.7	91	102	Violet
TC551	4	87.7	81	97	White
TC552	5	85.2	74	91	White
TC553	5	87.8	74	102	Violet white
TC554	5	90.2	74	111	White
TC555	3	85.7	84	89	White

Table 4. Characteristic of each plant from accession TC553

Plant No.	Characteristic: Flower color	Leaf color	Leaf shape	Growing habit
1	White	Green	Whole	Bushy
2	Violet	Dark green	Whole	Bushy
3	Violet	Green	Palmate	Bushy
4	Violet	Green	Whole	Climbing
5	White	Green	Whole	Climbing

3.2 Characterization of 14 *Pachyrhizus tuberosus* accessions

Fourteen *Pachyrhizus tuberosus* accessions were planted both to increase the amount of available seeds and to register some desirable characteristics under Turrialba environmental conditions, in February, 1995. A distance between rows (4.5 m long) of 1 m and among plants of 0.25 m was utilized. Seeds germination was relatively low and so in most accessions only less than 5 plants were evaluated.

Flowers and days at flowering

Tables 5, 6, 7, 8, 9 and 10 show the average figures obtained regarding the characteristics under evaluation. Most accessions had white flowers. However, flowers from accession TC536 were violet with lighter longitudinal lines. The initiation of the flowering stage varied from 69.4 days (TC554) to 131.5 days (TC535) after planting (Table 5); nevertheless, accessions TC360 and TC352 showed a much late flowering period which was not recorded. In a subsequent planting of these two accessions, the flowering period was recorded and it was 194 and 212 days after planting, respectively (7th Biannual Reports). Flower concentration varied in plants showing a climbing tendency. For instance, most flowers from accessions TC211, TC353 and TC354 were observed on the upper part of the plants while in other non-bushy accessions, flowers were observed in the whole plant.

Leaves

Length and width of the leaf was evaluated in 30 randomly selected leaves from all available plants. Accessions TC352, TC353, TC354 and TC359 showed leaf shapes different from the remaining accessions; they were less palmate, more longer instead of wider and with less average width (Table 6).

Pods

Pods and seeds were stored in a dry room with controlled humidity ranging from 25 to 30%. Characteristic recording was conducted after 40 days, when seeds humidity content had reached almost 12%.

Accessions TC360 and TC238 had a pod length of 12.2 cm and 14.4 cm, respectively; the remaining genotypes showed lengths between 16 and 20 cm. Differences regarding pod width were found mainly in accessions TC531, TC534 and TC535 showing an average width superior to 24 mm which is comparatively higher than the one shown by the remaining accessions (Table 7). A similar behavior was observed regarding seed length and width. Accessions with higher pod width also showed the highest seed width values.

The number of pods per plant showed a high variation due to the reduced number of plants evaluated. The lowest total pods plus seed weight corresponded to accessions TC353 (3 g/pod) and TC238 (3.5 g/pod); this last material also presented a reduced length. The highest total pods plus seeds weight corresponded to accessions TC531, TC534 and TC535 with values superior to 8 g/pod; these accessions were the only ones to produce red seeds (Table 9).

Seeds

The average number of seeds per pod ranged from 6.7 for TC360 to 10.1 seeds for TC552 and TC554; nevertheless, the variation range is higher within accessions, as observed when maximum and minimum values of each accession were compared (Table 8).

Seed harvest was conducted 157 days after planting for accessions TC534, TC554 and TC238 and after 245 and 236 days for accessions TC534 and TC531 respectively (Table 9). Early flowering genotypes also produced seed earlier, occurring the same with late materials.

The relationship seed-husk indicates that there is a tendency to produce more husk than seed; most of these accessions had more than 50% husk (Table 9).

Roots

Regarding production of enlarged roots, very few plants showed good size roots, but it has to be taken into account that no deflowering or flowers elimination was conducted (Table 10).

In general terms, it is important to continue with the characterization process of *P. tuberosus* since it shows good development and adjustment to the conditions under evaluation. It is important to eliminate flowers in order to study its effect over roots development and quality.

Table 5. Flower color and days at flowering of *Pachyrhizus tuberosus* accessions

Accession	Flower color	Days at flowering				
		n	Average	Maximum	Minimum	C.V.
TC210	Violet	5	115.2	136	110	10.0
TC211	-	2	113.0	123	103	12.5
TC238	White	10	86.6	98	80	7.9
TC353	White	10	96.6	98	88	3.3
TC354	White	5	98.0	98	98	-
TC359	White	5	110.4	116	94	9.4
TC531	White	2	127.5	136	119	9.4
TC534	White	1	129.0	129	-	-
TC535	-	2	131.5	136	127	4.8
TC536	Violet*	16	84.0	115	75	12.9
TC552	White	15	76.0	98	70	10.7
TC554	White	5	69.4	70	67	1.9

* With lighter color longitudinal lines

n = Number of observations
C.V. = Coefficient variation (%)

Table 6. Leaf characteristics of *Pachyrhizus tuberosus* accessions

Accession	Leaf width (mm)					Leaf length (cm)				
	n	Average	Maximum	Minimum	C. V.	n	Average	Maximum	Minimum	C.V.
TC210	30	14.8	17.3	11.6	9.7	30	13.7	16.7	10.8	9.9
TC211	30	15.2	21.3	9.9	17.1	30	13.8	19.2	9.5	15.9
TC238	30	20.0	22.6	16.3	9.0	30	14.6	17.0	12.3	8.7
TC352	26	7.9	11.2	5.2	22.0	26	14.1	20.0	9.2	23.6
TC353	30	10.3	12.8	7.6	12.8	30	19.1	23.0	14.4	12.6
TC354	30	10.6	13.5	7.7	11.8	30	19.7	25.3	16.0	12.2
TC359	30	9.4	12.6	7.1	17.4	30	17.6	24.0	13.2	18.0
TC360	30	13.2	17.2	10.8	9.2	30	12.3	15.0	10.2	9.7
TC531	30	15.6	20.3	12.2	11.2	30	14.9	20.0	11.8	12.4
TC534	30	14.9	18.8	10.7	11.3	30	14.9	18.0	11.6	11.6
TC535	30	14.0	18.0	10.8	14.2	30	13.3	16.5	10.3	12.3
TC536	30	17.0	21.3	12.5	15.5	30	13.9	18.9	9.5	15.8
TC552	30	26.0	29.0	22.4	7.9	30	19.2	21.8	15.5	9.2
TC554	30	25.1	31.1	17.6	13.8	30	18.7	22.2	13.5	12.5

n = Number of observations
C.V. = Coefficient variation (%)

Table 7. Pod characteristics of *Pachyrhizus tuberosus* accessions

Accession	Pod Width (mm)					Pod length (cm)				
	n	Average	Maximum	Minimum	C.V.	n	Average	Maximum	Minimum	C.V.
TC210	40	16.4	19.2	14.0	6.7	40	17.2	22.2	12.8	11.0
TC211	40	16.0	18.6	13.6	6.9	40	17.2	20.5	12.5	9.3
TC238	40	15.8	17.7	12.5	8.2	40	14.4	19.0	10.5	13.9
TC352	40	16.7	19.0	14.8	6.0	40	16.3	19.5	12.5	8.5
TC353	40	16.9	19.7	15.2	6.5	40	17.8	22.0	15.0	7.9
TC354	39	16.4	18.3	14.8	5.4	39	16.6	19.1	13.7	7.8
TC359	40	18.0	20.5	16.0	6.1	40	18.1	20.5	14.0	7.7
TC360	40	15.4	19.3	12.4	7.8	40	12.2	14.6	8.7	10.6
TC531	40	24.2	28.0	20.2	7.0	40	19.9	23.6	11.4	13.0
TC534	40	25.4	32.0	21.8	8.7	40	19.6	23.6	14.0	13.2
TC535	40	24.2	29.0	20.2	8.2	40	18.9	23.5	11.3	16.4
TC536	40	15.6	17.5	13.8	5.8	40	18.4	22.1	13.2	9.2
TC552	40	14.1	16.0	13.2	4.2	40	18.8	21.4	15.3	9.0
TC554	40	14.8	16.2	13.6	4.0	40	19.1	22.0	16.4	7.3

n = Number of observations
C.V. = Coefficient variation (%)

Table 8. Seed characteristics of 14 *Pachyrhizus tuberosus* accessions

Accession	Seed length (cm)					Seed width (mm)					Seed number/pod				
	n	Average	Maximum	Minimum	C.V.	n	Average	Maximum	Minimum	C.V.	n	Average	Maximum	Minimum	C.V.
TC210	20	12.0	14.3	10.2	9.1	20	9.4	13.8	7.3	14.3	40	7.6	11	4	23.7
TC211	20	11.4	13.8	10.4	9.0	20	8.5	9.8	7.5	7.6	40	8.6	12	5	18.6
TC238	20	10.8	12.2	8.9	7.4	20	8.4	13.7	7.0	15.7	40	7.2	11	4	22.2
TC352	20	12.3	18.3	10.0	15.4	20	8.9	9.5	8.0	4.9	40	7.5	10	5	16.0
TC353	20	10.8	12.7	9.1	10.1	20	9.0	9.8	8.1	4.1	40	9.8	13	7	13.2
TC354	20	9.9	11.3	8.4	8.0	20	8.9	9.8	8.3	4.7	39	9.2	12	6	13.0
TC359	20	11.0	12.7	9.4	9.0	20	9.2	9.7	8.4	4.0	40	9.0	12	5	20.0
TC360	20	9.9	11.2	8.5	6.5	20	8.2	9.4	6.8	7.7	40	6.7	9	3	20.9
TC531	20	13.3	14.6	12.2	5.2	20	10.3	11.0	9.4	4.3	40	8.0	11	4	22.5
TC534	20	12.8	14.0	11.6	7.0	20	10.2	11.6	9.0	7.8	40	7.1	10	5	22.5
TC535	20	13.6	15.5	12.2	5.9	20	10.5	11.8	9.0	6.7	40	6.7	10	3	28.3
TC536	20	11.2	12.3	10.0	6.2	20	9.4	13.7	7.9	15.7	40	8.1	10	5	13.6
TC552	20	10.2	11.5	8.2	8.8	20	7.4	8.4	5.2	12.0	40	10.1	12	8	8.9
TC554	20	11.0	12.2	10.0	6.3	20	8.0	9.3	7.2	6.1	40	10.1	12	5	14.8

n = Number of observations
C.V. = Coefficient variation (%)

Table 9. Yield characteristics of pods and seeds from *Pachyrhizus tuberosus* accessions

Accession	Days at harvest[1]	Pod/plant[2]	Pods +seed (g/pod)	Seed weight (g/pod)	Seed weight %	Husk weight %	Weight of 100 seeds (g)	Bad quality seed (%)[3]	Seed color	Seed shape	Observations
TC210	229	117.5 (4)	6.2	3.0	48.0	52.0	40.6	3.9	Black	Elongated rounded	Climbing plant
TC211	229	46.5 (2)	5.6	2.1	38.2	61.8	35.4	34.7	Dark violet	Rounded	Upper part flowering
TC238	157	8.6 (10)	3.5	1.7	49.5	50.5	27.3	7.9	Black	Elongated rounded	Bushy
TC352	222	69.0 (1)	4.3	2.3	54.0	46.0	31.6	3.3	Black	Flatten	
TC353	179	48.7 (10)	3.0	1.7	57.6	42.4	24.5	3.3	Orange brick	Flatten	Upper part flowering curved pods
TC354	179	42.0 (5)	5.0	2.5	49.0	51.0	28.2	0.6	Orange reddish	Flatten	Flower in upper part
TC359	187	71.8 (5)	5.3	2.2	41.0	59.0	36.2	4.1	Orange	Flatten	
TC531	236	85.5 (2)	8.8	3.8	43.8	56.2	53.8	6.9	Red	Flatten	
TC534	245	87.0 (1)	8.5	3.2	37.4	62.6	53.8	7.0	Red	Flatten	
TC535	215	73.0 (2)	8.1	2.7	33.3	66.7	49.8	1.1	Red	Flatten rounded	
TC536	158	26.4 (16)	----	2.7	----	----	48.7	2.1	Black	Rounded	
TC552	157	19.8 (15)	6.5	3.6	55.1	44.9	42.2	2.4	Black	Rounded	Bushy
TC554	157	16.2 (5)	5.9	3.4	57.9	42.1	34.1	3.7	Black	Rounded	Curved pods, bushy

1 Days at harvest after planting

2 The number of plants evaluated is indicated in parenthesis

3 Percentage based on seed quantity

Table 10. Characteristics of enlarged roots of *Pachyrhizus tuberosus* accessions

Accession	Evaluated Plants	Harvested Roots	Average per root Weight (g)	Length (cm)	Diameter (cm)
TC210	4	0	—	—	
TC211	2	0	—	—	
TC238	10	Very little rotten roots	—	—	
TC352	1	0	—	—	
TC353	10	2	132.5	11.9	3.3
TC354	5	0	—	—	
TC359	5	3	210.7	12.9	4.6
TC531*	2	3	1122.0	15.3	6.6
TC534	1	0	—	—	—
TC535	2	1	2050.0	29.5	8.3
TC536	16	6	417.0	16.1	6.1
TC552	15	1	66.0	9.2	7.2
TC554	5	0	—	—	—

* Branched roots

3.3 Evaluation of yam bean accessions (*Pachyrhizus erosus*) in two sites of Costa Rica

The results of this evaluation correspond to four experiments conducted in two sites of Costa Rica. Two of the essays were established at the University of Costa Rica; The Fabio Baudrit M. Agricultural Station, located in San Jose de Alajuela at 10° 1' north latitude and 84° 16' west longitude with an altitude of 840 masl. It presents an average annual temperature of 21.4 °C, an annual precipitation of 2000 mm and a relative humidity of 75.6%. The other two essays were established at CATIE in Turrialba at 602 masl., 9° 53' north altitude, 83° 38' west longitude with an daily average temperature of 22.5 °C, 2645 mm annual rainfall and a average annual relative humidity of 87.7%.

The first two experiments were planted in July, 1992 and in September, 1992 in Alajuela and Turrialba, respectively; the harvest was conducted in December, 1992 and in February, 1993 respectively. Table 11 shows the results obtained. The statistical analysis at both sites showed highly significant differences between treatments.

In Alajuela the average yield was 100.2 t ha^{-1} with a maximum 125.8 t ha^{-1} from accession EC523 and a minimum 51.6 t ha^{-1} from accession EC534. Three accession groups could be observed, according to the Duncan test.

The experiment established in Turrialba had five accessions common to the prior essay (EC511, EC509, EC032, EC531 and EC534) all with low yields. It can be observed (Table 11) that the genotypes evaluated in Alajuela are superior to the ones from Turrialba which strongly indicates the influence of environmental conditions (climate and soil). In both experiments, accession EC511 had the second position regarding average yield.

The second part of this work involved planting two experiments at the same sites but using also the same accessions. Planting in Turrialba was conducted on April 27 and harvest on October 18, 1993. In Alajuela, planting was conducted on July 13 and harvest on December 21, 1993.

The analysis of variance for the roots weight variable (t ha^{-1}) indicated significant differences between accessions in Turrialba and highly significant differences for those in Alajuela.

Table 12 presents yields comparison for ten materials in both sites. In Alajuela the highest tuberous roots production was 60.3 t ha^{-1} for accession EC557 and the lowest yield was 31.2 t ha^{-1} for accession EC117. In Turrialba. the best average was 38.3 t ha^{-1} for accession EC550 which was also statistically different to the rest of averages which did not show statistical variations among themselves. This accession showed a high yield performance in both sites.

As in previous experiments, the Alajuela site shows very favorable conditions for high yields. The general average was 48.8 t ha^{-1} approximately double from that obtained in Turrialba. Likewise, some accessions showed yields in Alajuela with values superior to 50% in regards to Turrialba's (Table 12).

Furthermore, it was observed that yield varied according to the region; for example, lines EC557 and EC236 presented the best yields in Alajuela but, were in fourth and sixth positions, respectively, in Turrialba. The lowest yield (EC117) in Alajuela was in fifth position in Turrialba.

For future research, it will be important to compare sites during the same periods (same planting and harvest date) and to evaluate planting periods within each site.

Table 11. Fresh weight of tuberous roots of 10 yam bean accessions evaluated in Alajuela and 10 accessions evaluated in Turrialba

Alajuela			Turrialba		
Accession	t ha^{-1}	Duncan (p=0.01)	Accession	t ha^{-1}	Duncan (p=0.01)
EC523	125.8	a	EC536	57.2	a
EC511	124.7	a	EC511	56.5	a
EC541	104.4	b	EC201	55.1	a b
EC548	103.8	b	EC532	52.0	a b c
EC539	102.1	b	EC510	48.3	a b c d
EC509	101.3	b	EC509	38.7	d
EC533	96.9	b	EC534	40.2	c d
EC032	96.1	b	EC032	43.6	b c d
EC531	95.7	b	EC531	46.1	a b c d
EC534	51.6	c	EC120b	39.3	c d
C.V.(%)	10.7			16.5	

C.V.= Coefficient of variance

Table 12. Fresh weight of tuberous roots of 10 yam bean accessions evaluated at two sites

Alajuela			Turrialba	
Accession	t ha^{-1}	Duncan (p=0.01)	t ha^{-1}	Duncan (p=0.01)
EC557	60.3	a	25.2	b
EC236	59.8	a	23.5	b
EC550	54.8	a b	38.3	a
EC502	51.5	a b c	25.6	b
EC533	48.7	b c	28.0	b
EC204	47.6	b c	23.4	b
EC214	45.9	b c	21.4	b
EC120A	44.3	c	18.3	b
EC503	44.1	c	23.0	b
EC117	31.2	d	24.3	b
C.V.(%)	13.1		25.5	

C.V.= Coefficient of variance

3.4 Production of tuberous roots of six *Pachyrhizus erosus* accessions

When this experiment was established, the original objective was to evaluated seed production of six *P. erosus* accessions; nevertheless, flowering was very scarce favoring roots development. Thus, the purpose was changed to determine tuberous roots yield of three accessions from Mexico (EC201, EC205, EC502), one from Malaysia (EC109), Nigeria (EC226) and Costa Rica (EC509).

Planting was done on September 25, 1995 and harvest on February 16, 1996. This experiment was located in Cabiria (CATIE) under a random blocks design with four replicates. The experimental plot consisted of 4 rows separated by 0.60 m and 4 m long. For the evaluation. the two central rows were harvested leaving two plants in each edge as borders.

At harvest time, roots were grouped into three sizes: small-sized weighing less than 300 g. medium-sized weighing between 300 and 600 g. and large-sized weighing more than 600 g.

Table 13 presents the characteristics evaluated, showing total averages and results of the variance analysis. Statistical differences were found only for the variables number of large roots ha^{-1}, roots total weight, and number of cracked roots ha^{-1}.

In Table 14 can be observed that based on the variable big roots ha^{-1}, it is possible to differentiate two accession groups: those with values superior to 20000 roots ha^{-1} and those with less than 10000 large roots ha^{-1}. On the other hand, accessions EC226, EC109 and EC509, from the second group, showed a higher number of small roots. In the variable roots total weight, accessions EC201, EC502 and EC205 (Mexican origin) had a higher yield than accessions EC226 (Nigeria), EC109 (Malaysia) and EC509 (Costa Rica) though this difference was not as significant as in the large roots characteristic. The difference between both groups can be explained by the fact that Mexican genotypes are the result of several years of genetic improvement.

The best yields were obtained with accessions EC502 (35.3 t ha^{-1}) and EC201 (36.3 t ha^{-1}) but these also showed a high number of cracked roots (51% and 40% respectively). This is a physiological problem probably due to the fast growth and high humidity under CATIE conditions.

Table 13. Total averages and statistical difference obtained from the variance analysis for different variables evaluated

Variable	Average	Pr > F Treatments	C.V. (%)
Small-sized roots ha^{-1}	36308	0.1395^{NS}	30.2
Medium-sized roots ha^{-1}	18220	0.3410^{NS}	48.0
Big-sized roots ha^{-1}	14966	0.0233^{*}	49.0
Total roots ha^{-1}	69495	0.0711^{NS}	5.1
Small-sized roots (t ha^{-1})	7.1	0.7577^{NS}	39.1
Medium-sized roots (t ha^{-1})	8.0	0.3411^{NS}	50.9
Big-sized roots (t ha^{-1})	12.8	0.0950^{NS}	62.0
Total roots weight (t ha^{-1})	27.9	0.0503^{*}	27.7
Small-sized roots weight (g)	199	0.2516^{NS}	22.2
Medium-sized roots weight (g)	437	0.0856^{NS}	7.5
Big-sized roots weight (g)	815	0.1051^{NS}	25.0
Cracked roots ha^{-1}	20.7	0.0054^{**}	44.6

NS = No significance
* = Significant differences
** = Highly significant differences
C.V.= Coefficient of variance

Table 14. Average accession values for each variable evaluated

Variable	Accessions[1]					
	EC201	EC502	EC205	EC226	EC109	EC 509
Small-sized roots ha^{-1}	28725	28303	33557	48314	37895	41056
Medium-sized roots ha^{-1}	21818	23793	11111	14554	21133	16910
Big-sized roots ha^{-1}	20417 a	21713 a	21882 a	8056 b	8472 b	9258 b
Total roots ha^{-1}	70960	73809	66550	70923	67500	67224
Small t ha^{-1}	7.5	5.5	6.4	8.2	8.0	7.1
Medium t ha^{-1}	10.3	10.7	5.1	6.2	8.6	7.1
Big t ha^{-1}	18.5	19.0	16.7	10.0	5.3	7.2
Total weight t ha^{-1}	36.3 a	35.3 a	28.2 ab	24.3 ab	21.9 b	21.3 b
Small g/root	250	194	199	176	197	178
Medium g/root	469	457	457	416	411	419
Big g/root	912	828	761	1066	615	721
Cracked roots ha^{-1}	28573 ab	37616 a	15526 bc	12143 c	10002 c	20483 bc

[1] Averages showing the same letter are not statistically different (Duncan, $p = 0.05$)

3.5 Evaluation of 11 F_3 crosses

An experiment was established which covered from February 28 (planting) to July 17 (harvest) 1995, in order to study the adaptation and behavior of 11 yam bean crosses in F_3 generation. A random block design was employed with 5 replications and 12 treatments (11 F_3 crosses and accession EC532, as check).

Planting was done at a distance between rows of 0.4 m and between plants of 0.20 m in 4 furrow plots of 4 m each. The useful plot included the 2 central furrows leaving three plants on each border (maximum 30 plants per plot). The size of the useful plot was 2.4 m^2 for a planting density of 125000 plants per hectare.

The initiation of the flowering period varied from 63.6 to 78.7 days after planting for X-40-1B-16 and X-88-1-1 respectively. Most genotypes flowered after 70 days of planting for which X-40-1B-16 can be considered an early flowering material. It is important to note that variation also existed among plant from each cross, being possible to observe flowering differences (Table 15).

All genotypes showed violet flower plants and in several cases, with different color intensities; in 9 crosses there were also white flowers (Table 15). Leaf color, leaf shape and plants height differences were also observed in the field.

Table 16 shows roots yielding of each cross and of accession EC532 which was the check.

The variance analysis indicated highly significant differences for small size, medium size and total roots.

Most roots showed small size; several accessions did not produce medium or big size roots. Yields are relatively low: 3 crosses (X-40-1B-16, X-165-6, X-165-7) and the check (EC532) surpassed the 20.0 t ha^{-1}; the remaining materials showed yields lower to 15.0 t ha^{-1}. The variation found was high and thus the resulting F_3 crosses segregation. It is important to indicate that the best yielding correspond to F_3 crosses from species *Pachyrhizus erosus* and *P. ahipa*.

The variables roots diameter and length were analyzed for each accession, finding highly significant differences. In each repetition a maximum of 10 roots were measured though in some cases no enlarged roots were produced. These characteristics also show variation both between and among crosses (Table 17). The genotypes shown the best root diameter also had the best yield.

In this type of research, it is also important to select plants showing good adaptability, high yield and root quality. Following this study, it is relevant to continue a genetic improvement process to obtain uniform and adapted genotypes to the new environment conditions.

Table 15. Days at flowering and flower color of 11 yam bean F_3 crosses

Treatment	Crosses	Flowering initiation DAP	Flowers color
1	X-148-1 (*P.ahipa* x *P. tuberosus*)	75.2	V. W
2	X-148-5 (*P. ahipa* x *P. tuberosus*)	69.6	V. LV. DV. W
3	X-149-1 (*P. ahipa* x *P. tuberosus)*	77.2	V. VO
4	X-149-2 (*P. ahipa* x *P. tuberosus)*	73.2	V. W
5	X-165-6 (*P.erosus* x *P. ahipa)*	74.0	V. LV. DV. W
6	X-165-7 (*P. erosus* x *P. ahipa)*	74.0	V. LV. DV. W
7	X-40-1B-16 (*P. erosus* x *P. ahipa)*	63.6	V. LV. DV. W
8	X-47-1-3 (*P. ahipa* x *P. tuberosus)*	71.0	V. LV. W
9	X-47-1-4 (*P. ahipa* x *P. tuberosus*)	66.4	V. W
10	X-88-1-1 (*P. tuberosus (P. ahipa* x *P. erosus)*	78.4	V. LV. DV
11	X-88-1-7 (*P. tuberosus (P. ahipa* x *P. erosus)*	76.6	V. W
12	EC532 (check)	73.0	V. LV

DAP= Days after planting. average of 5 replicates

Flower colors: V = Violet, DV= Dark violet, LV = Light violet, W = White

Table 16. Production of tuberous roots (t ha^{-1}) in 11 yam bean crosses evaluated in Turrialba, according to root size and total weight

Crosses	Roots Size [1) Small](#)		Medium		Large		Total Weight	
X-40-1B-16	12.3	abc	9.0	ab	2.1	a	23.4	a
X-165-6	11.5	bc	11.3	a	0	a	22.8	a
EC532	17.1	a	5.1	bcd	0	a	22.2	a
X-165-7	14.5	ab	6.3	abc	0	a	20.8	a
X-47-1-3	12.5	abc	2.7	cd	0	a	15.3	a
X148-5	7.6	cd	0.3	d	2.9	a	10.8	bc
X-88-1-1	4.7	d	2.1	cd	1.8	a	8.6	bc
X-149-1	7.9	cd	0	d	0	a	7.9	bc
X-149-2	7.1	cd	0	d	0	a	7.1	bc
X-88-1-7	5.9	d	0	d	0	a	5.9	c
X-148-1	5.1	d	0	d	0	a	5.1	c
X-47-1-4	4.9	d	0	d	0	a	4.9	c

1) Averages comparison by Duncan (p= 0.05)

Table 17. Roots length and diameter of 11 yam bean F_3 crosses evaluated in Turrialba

Crosses	Average diameter (cm)		Minimum value (cm)	Maximum value (cm)	Average length (cm)		Minimum value (cm)	Maximum value (cm)
X-165-6	7.3	a	2.4	13.3	7.6	bc	2.9	17.0
X-40-1B-16	7.1	a	3.0	14.0	6.9	b	3.6	21.0
EC532	7.1	a	3.8	13.1	7.1	c	4.1	9.0
X-165-7	6.7	ab	3.6	10.9	7.2	c	3.4	11.0
X-47-1-3	5.5	bc	2.2	9.8	9.8	a	3.4	15.0
X-88-1-1	5.1	cd	1.9	11.2	9.0	ab	3.0	15.5
X-148-5	4.2	cde	1.5	8.2	9.6	a	4.4	16.0
X-88-1-7	4.1	cde	1.9	6.6	9.2	ab	4.3	13.2
X-149-1	4.0	de	2.2	8.0	6.9	c	3.6	11.0
X-47-1-4	3.8	de	1.8	5.8	7.3	c	3.4	9.8
X-148-1	3.6	e	1.2	6.1	9.6	a	5.5	16.7
X-149-2	3.5	e	1.5	7.5	9.6	a	4.6	16.1

1) Averages comparison by Duncan (p=0.05)

3.6 The effect of reproductive pruning on fresh tuber yield

An experiment with 5 accessions was established in order to examine the effect of reproductive pruning on fresh tuber yield on *P. erosus* when cultivated under field conditions at Cabiria (CATIE, Turrialba; 9°53' N. 83° 38 W. 603 masl).

The experiment was set during the period between April 20 (planting) and September 20 (harvest), 1994 (= 153 days). A completely randomized plot design with four replications was used. The factors evaluated were as follows: reproductive pruning (removal of flowers) and non-pruned for each of the four replications and with the five accessions as sub-plots.

The tuber yields increased significantly when the test plants were reproductively pruned. The observed differences in response among accessions must be due to genotype variations. A six fold increase in tuber yield was recorded for accession EC536 as a result of flowers elimination (Table 18).

A significant negative correlation was observed between reproductive growth (flowering and pod filling) and roots tuberization. Reproductively pruned plants yield was higher in the early flowering accessions as the strongest competition for assimilates/photosynthesis between the reproductive shoot formation and the tuber growth occurs during the initial stages.

Further investigations are needed to evaluate the significance of different planting periods and to study the physiological traits related to tuber formation of different genotypes.

Finally, it is important to evaluate the possible effect(s) of reproductive pruning on tuber quality.

Table 18. Effect of flowers elimination on total yield of tuberous roots (t ha^{-1}).

Treatment	EC114	EC509	EC511	EC523	EC536
	Accession				
Pruned	13.8	15.3	17.8	18.9	29.7
Non-pruned	9.4	9.3	9.6	8.7	4.8

3.7 Flower removal in cultures of yam bean (*P. erosus*) using 2,4-D

This study was undertaken to evaluate the effect of two concentrations of 2,4-D as a chemical method to eliminate flowers in order to increase the yield of tuberous roots in the cultivation of yam beans. The experiment was conducted at the CATIE, Turrialba, Costa Rica. A randomized design with 4 block stands and 3 treatments was used. The treatments involved the application of 2 concentrations of 2,4-D (50 and 100 ppm) and a treatment involving manual reproductive pruning using a pruning secateurs. The yam bean accession used was EC532 planted at 0.5 x 0.2 m. Plants treated with the two concentrations of 2,4-D produced significantly less compared to pruned plants which yielded 53.0 t ha^{-1}. Plants treated with the concentration of 50 ppm and 100 ppm produced 28.9 t ha^{-1} and 25.6 t ha^{-1}, respectively. The results showed that the concentration of 100 ppm has a damaging effect on the yam bean plants which reduce the production of roots and leaves. It is recommendable to evaluate other concentrations of 2,4-D, the response of different accessions of yam beans and the most suitable period for the application of the chemical.

3.8 Yield performance of yam bean as a result of different planting distances

The purpose of the present investigation was to study and to evaluate the quantitative and qualitative yield performance of three genotypes/accessions of yam bean (*P. erosus*) under three different planting distances.

The experiment was set at Cabiria, CATIE. A three factor squared experiment was laid out in a randomized divided plot design with three replications. The evaluated factors were as follows: accessions (3 levels) in the main plots and distances (3 levels) in the sub-plots. The distances used were 0.75 m between the ridges with double rows 0.25 m apart, and 0.10 m. 0.15 m and 0.20 m between plants. This resulted in planting densities of 266 667 plants ha^{-1} at a distance of 0.10 m within rows, 177 778 plants ha^{-1} at 0.15 m. and 133 333 plants ha^{-1} at a distance of 0.20 m.

The existence of differences among accessions for total production of tuberous roots was demonstrated (Table 19). It was also found that interaction between accessions, planting distances and the resulting number of small sized tubers and total number of tubers exist. Therefore, it should be concluded that it is necessary to evaluate the optimal distance for each accession in order to obtain optimum tuber size and quality.

A negative correlation was found between planting distances and the number and weight of both the small sized tubers and the total figures. The planting distance of 0.1 m (266 667 plants ha^{-1}) does not appear to be optimal for any of the three accessions evaluated because of the production of a high number of small size tuberous roots and a relatively low average weight per tuber. Thus, it will be important for future experiments to evaluate the yield performance with a separation of tuber sizes as the accessions with similar weights may differ in number of small size tubers. It is also important to examine the capacity and characteristics of each genotype to produce small size tubers at large planting distances/low planting densities.

Further studies are needed using other genotypes, other planting distances between rows and different spacing between ridges; for instance, maintaining the same planting density and varying distance between plants.

The future development of yam bean in Central America will depend on the knowledge of individual accessions available and its appropriate agronomic management.

Table 19. Average of number and total weight of roots from three yam bean accessions using three planting distances, Turrialba, Costa Rica

Variable	Distance (m)	Accession EC032	Accession EC509	Accession EC534	Average[1]
Roots number ha^{-1}	0.10	245556	237778	183334	222222 a
	0.15	153086	140247	118519	137284 b
	0.20	128888	126666	111111	122222 c
	Average	175843 a	168231 a	137654 b	
$t\ ha^{-1}$	0.10	35.9	33.2	30.6	33.2 a
	0.15	31.2	31.1	32.3	31.6 ab
	0.20	27.5	31.3	20.9	26.6 b
	Average	31.6 a	31.9 a	28.0 a	

1 Averages showing the same letter are considered statistically equal (Duncan, $p = 0.01$)

3.9 Production of *P. erosus* tuberous roots in association with cassava (*Manihot esculenta*)

Two experiments were established to observe the behavior and yield of several yam bean accessions under monocultural conditions and inter-cropping association with the cassava variety "Valencia". The experiments were located at the "Cabiria", CATIE. Yam bean was planted twice (two cycles) during one cassava cycle. A Sub-sub divided plots design was used considering the following aspects: two culture cycles, two systems (inter-cropping and monoculture) and two *P. erosus* accessions for the first experiment (8 treatments) and 5 accessions for the second essay (20 treatments). Planting distance for cassava was 2 m between rows and 1 m between plants for a density of 5000 plants ha^{-1}. In the spaces between cassava and the first experiment, three *P. erosus* rows were established with a distance among them of 0.40 m and between plants of 0.20 m (75000 plants ha^{-1}). Distance between cassava and *P. erosus* rows was 0.60 m. This last distance was 0.40 m for the second experiment in which four *P. erosus* rows were planted between cassava rows for a density of 100000 plants ha^{-1}. The period covered by the first experiment went from August, 1994 to May, 1995 and the second experiment went from August, 1995 to May, 1996.

First Experiment Results

Fresh weight of tuberous roots showed significant differences between planting systems in terms of number of large, medium, and total amount of roots. Weight of large, medium and total amount of roots increased significantly in the monoculture system. The large roots weight was low in the inter-cropping system (2.8 t ha^{-1}) but increased considerably (approx. 6 times) in monoculture systems (17.1 t ha^{-1}). It was observed that accession EC509 was more affected by the cassava shade than accession EC041; it is important to evaluate other accessions in order to select the ones which adapt better to inter-cropping systems. The tuberous roots yield was influenced by light competition due to shade by the cassava foliage but yield of yam bean and cassava together offer an excellent alternative to increase roots and protein production per unit area per year.

P. erosus plants had the advantage of being nitrogen fixing materials and also organic matter sources coming from plant residues incorporated to the soil. The rapid development and its growth habit make it an excellent cover crop to diminish weeds competence during the first stages of cassava development.

The average production of cassava roots in association was 18.0 t ha^{-1}; this yield is near to the typical average of the "Valencia" variety (Rodríguez, 1994).

Second Experiment Results

Most variables analyzed in this experiment showed significant triple interactions cycle*accession*system (Table 20). The variable small-size roots weight presented cycle by system interaction and cycle per accessions but not triple interaction.

The results indicate a evident difference between cycles and systems for all accessions. In the variable roots total weight, the first cycle (August-January) surpassed cycle two (January-May) by 2.5 times with a difference between cycles of 22.7 t ha^{-1} (Table 21). The *P. erosus* system without cassava showed the best roots yield for both cycles surpassing in 10.4 t ha^{-1} the cassava system. The difference between cycles also indicates differences regarding planting times, showing that *P. erosus* shows a more favorable growth when it develops between August and December, and the difference between systems indicates that cassava competence for light and nutriments is prejudicial for roots development. The magnitude of these differences varies according to the different accessions. Figure 1 shows that the yield response depends on each accession (interaction). The difference between systems in cycle 1 is 9.2 and 10.6 t ha^{-1} in cycle 2, meaning that it is similar, though yield per system in each cycle is very different (Table 21).

Accessions EC509 (average 19.0 t ha^{-1}) and EC032 (average 20.6 t ha^{-1}) showed the lowest yield while accessions EC201 (35.9 t ha^{-1}) and EC560 (28.1 t ha^{-1}) presented the highest yield; accession EC531 occupied an intermediate position (27.5 t ha^{-1}).

Cassava root yield decreased to 10.8 t ha^{-1} which means 7.6 t ha^{-1} less than the first experiment (Table 22). It is possible that environmental conditions could affect negatively this period, but it should be also considered that plant density of yam bean was higher in this experiment which increased competence with cassava.

Accession EC509 showed a low yield and it was less affected by competence with cassava, but it resulted highly affected by the cycle, suggesting a very different response to climatic changes which occur from one planting period to the next (Table 23). Accession EC201 was affected by the system, particularly in cycle 2. It can be considered that this accession had an acceptable production in both cycles, excluding the cassava inter-cropping during the second cycle (Figure 1).

Foliage yield was clearly affected by cassava shade, especially in cycle 2. Accessions EC201, EC509 and EC531 showed similar foliage weight in cycle 1 systems. Regarding cycle 2, such differences were bigger, mainly for accessions EC032 and EC560 (Figure 2). It is important to mention that accessions EC032, EC509 and EC560 developed much more foliage in cycle 2 without cassava, which affected roots yields due to its competence with tuberization.

The results of both experiments indicate that it is not convenient to growth *P. erosus* during the second growth period because yield become reduced. Nevertheless, it is necessary to conduct more investigations with less *P. erosus* planting density which could improve roots size although yield could remain low.

Table 20. Significance obtained through the variance analysis for variables evaluated in the second experiment of *P. erosus* planted in association with cassava

Variation source	Freedom grades	Roots number ha^{-1} (Pr > F)				Roots weight. t ha^{-1} (Pr > F)				Foliage weight, t ha^{-1} (Pr > F)
		Small	Medium	Large	Total	Small	Medium	Large	Total	
Model	49	0.0001**	0.0001**	0.0001**	0.3137ns	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**
Replicate (Rep)	3	0.0049**	0.1128ns	0.7645ns	0.0571ns	0.4491ns	0.1153ns	0.8466ns	0.7258ns	0.6799ns
System (Syst.)	1	0.0049**	0.0089**	0.0089**	0.0258*	0.0496*	0.0206*	0.0075**	0.0114*	0.0066**
Rep • Syst.	3	0.6041ns	0.2238ns	0.0966ns	0.9193ns	0.2355ns	0.1553ns	0.0796ns	0.0031**	0.2324ns
Accession (Acce.)	4	0.0001**	0.0001**	0.0001**	0.6073ns	0.6406ns	0.0001**	0.0001**	0.0001**	0.0001**
Syst. • Acce.	4	0.2355ns	0.5099ns	0.0001**	0.8237ns	0.1101ns	0.2754ns	0.0001ns	0.0001**	0.0001**
Rep. • Syst. • Acce.	24	0.3422ns	0.0173*	0.0386*	0.5553ns	0.4092ns	0.0181*	0.0087**	0.0001**	0.1816ns
Cycle	1	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0001**	0.0338**
Cycle • Syst.	1	0.9694ns	0.0017**	0.0186*	0.4949ns	0.0001**	0.0045**	0.0067**	0.1421ns	0.0001**
Cycle • Acce.	4	0.3224ns	0.0017**	0.0500*	0.7581ns	0.0004**	0.0579ns	0.0210*	0.0043**	0.0001**
Cycle • Acce • Syst.	4	0.0203*	0.0001**	0.0442*	0.6958ns	0.0686ns	00001**	0.0260*	0.0004**	0.0211*
C.V. (%)		18.5	26.9	56.7	9.8	19.0	27.8	52.2	13.3	20.4

* Significance at 5%

** Highly significant at 1%

ns No significance

C.V.= Coefficient of variance

Table 21. Averages of total tuberous roots yield obtained for the second yam bean experiment in association with cassava

Accession	Total root weight ($t\ ha^{-1}$)				Average
	Cycle 1		Cycle 2		
	With cassava	Without cassava	With cassava	Without cassava	
EC032	26.1	39.6	5.6	11.1	20.6
EC201	41.7	52.6	13.1	36.2	35.9
EC509	29.4	31.4	5.1	10.0	19.0
EC531	33.8	37.7	12.0	26.4	27.5
EC560	33.6	49.4	9.6	19.7	28.1
Average	32.9	42.2	9.1	20.7	

Average per cycle: 1 = 37.5 2 = 14.9
Average per system: with cassava = 21.0 without cassava = 31.4

Table 22. Average cassava yield ($t\ ha^{-1}$) in association with yam bean

Experiment No.	Plant density (plants ha^{-1})		$t\ ha^{-1}$ (cassava)
	yam bean	cassava	
First	75000	5000	18.4
Second	100000	5000	10.8

Table 23. Temperature, solar radiation, rainfall and relative humidity per month during the two cycles of yam bean sowing in the second experiment. Turrialba, 1995-1996

Cycle	Month (1995-1996)	Temperature			Solar radiation MJ/m^2 *	Rainfall (mm)	Relative humidity (%)
		Maximum	Minimum	Average	Dairy average	Month total	Average
1	August	30.4	18.8	22.9	20.0	210	87.5
	September	29.7	19.0	22.9	17.4	282	88.7
	October	30.0	18.6	22.4	16.8	278	88.1
	November	28.7	18.9	22.2	11.5	164	89.9
	December	29.0	18.4	22.4	15.5	64	88.4
2	January	26.7	17.3	21.2	13.4	219	88.4
	February	26.6	16.6	20.9	15.4	766	88.0
	March	27.8	17.5	21.6	17.3	72	86.6
	April	28.9	17.7	22.4	18.1	28	85.8
	May	29.2	19.3	22.8	16.3	392	88.3

* MJ/m^2 = Mega Jouls/square meter

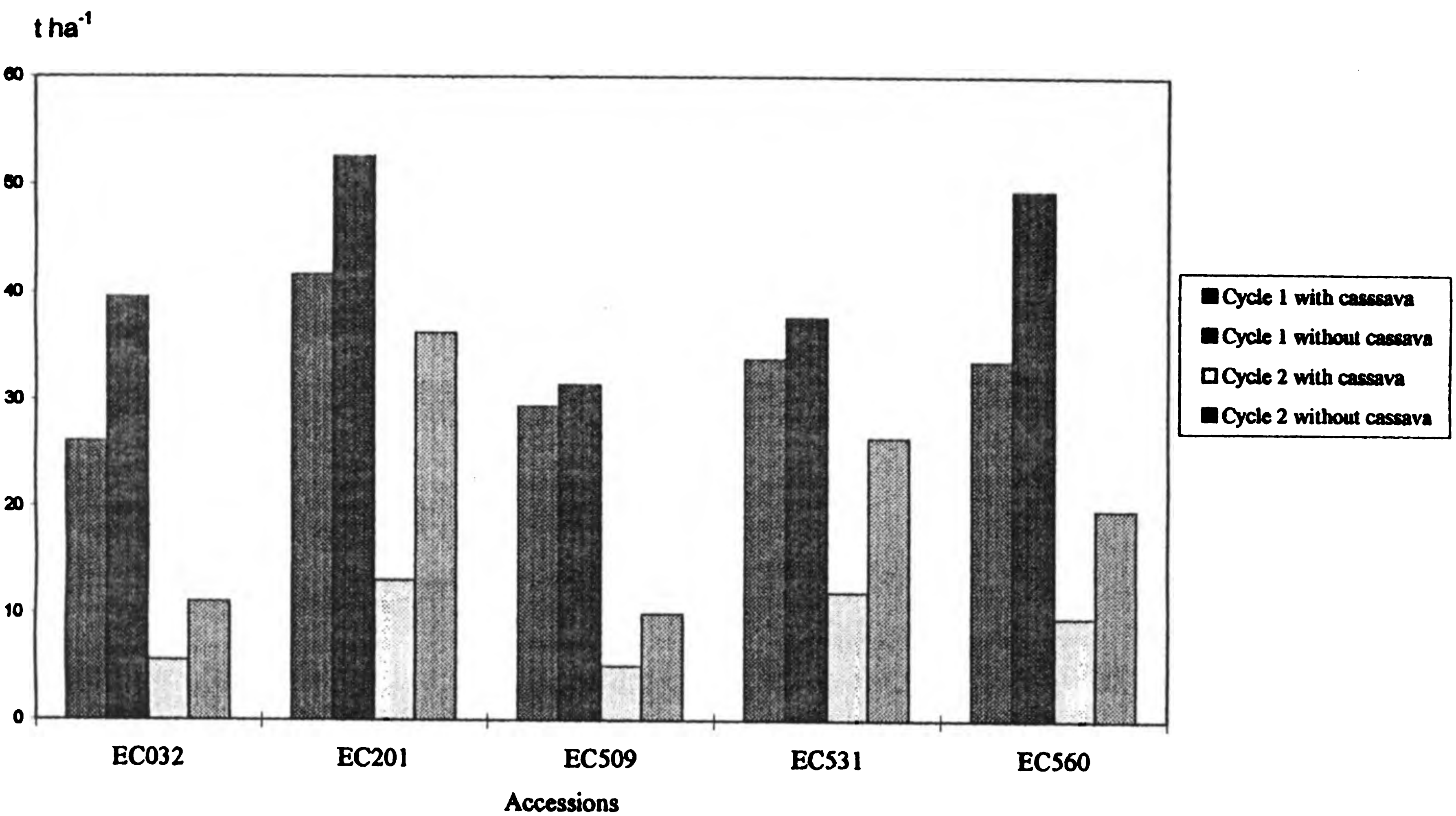

Figure 1. Cycle interaction per system per accession for yam bean total weight of roots.

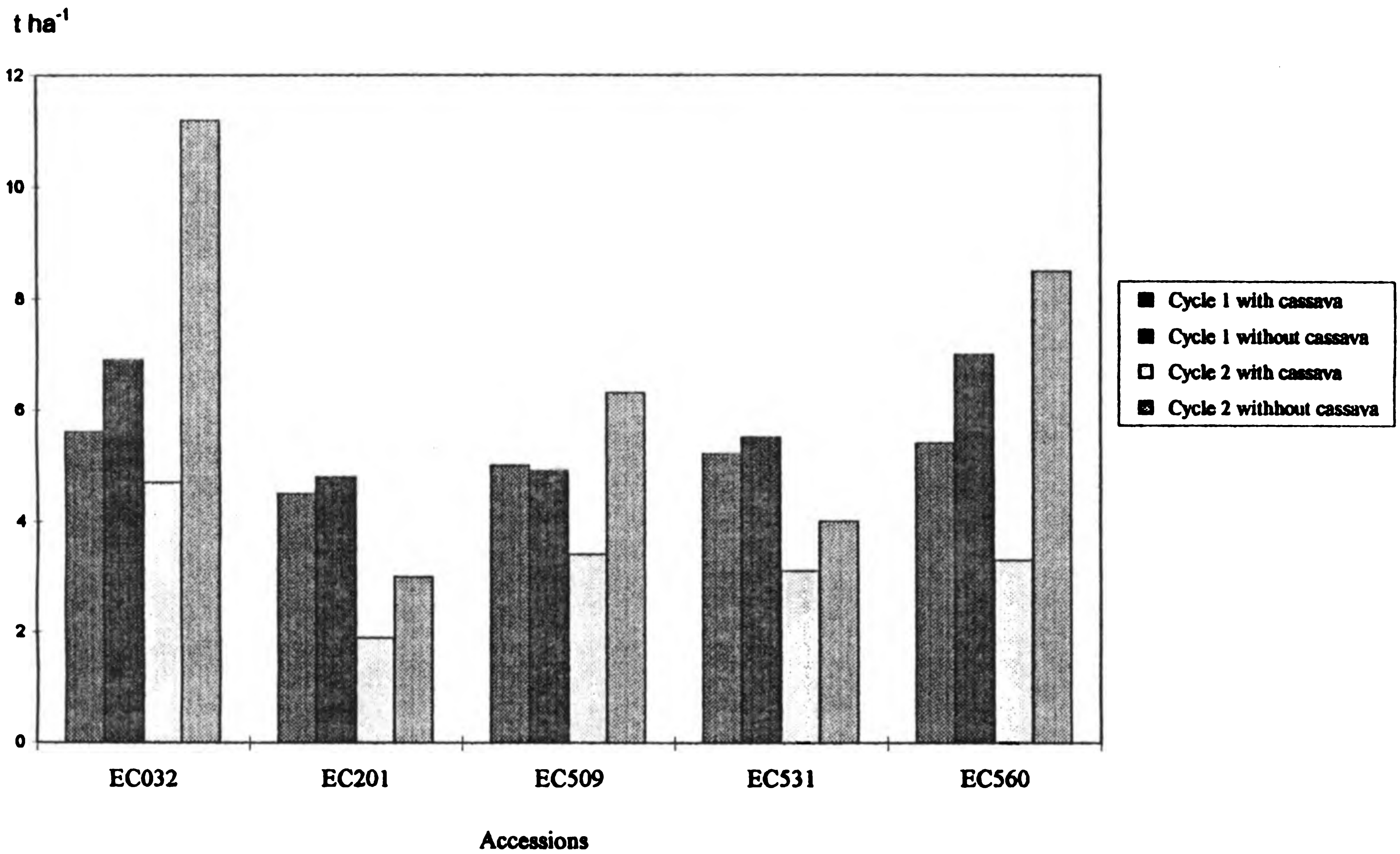

Figure 2. Cycle interaction per system per accession for yam bean foliage weight.

3.10 Research conducted in David, Chiriqui, Panama

During 1996 three experiments were established in David, Chiriquí, Panama in order to evaluate the behavior of ten yam bean accessions under the site conditions and also to study the effect of flower pruning and of three planting distances on tuberous root production. This research was developed in collaboration with Ing. Ariel Jaén S. from the School of Agricultural Sciences, University of Panama.

The three experiments were planted between January 22 and 24 and harvest on August. During the last part of the experiments heavy rainfalls took place and several plots were lost due to tuber rottenness. It is convenient to evaluate other planting times, planning a harvest during the dry period of this area, from January through March.

The flower pruning and planting distance experiments are a replica of the experiments previously reported on these same agronomic practices.

Behavior of 10 yam bean accessions

Planting distance was 0.75 m between ridges and 0.20 m between plants. Two plant rows were established in each ridge for a density of 133334 plants ha^{-1}.

The variance analysis results and the number and total weight root average per accession variable are shown on tables 24 and 25, respectively. The variables tubers total and foliage fresh weight did not indicate any statistical differences. The total of tubers surpassed the number of cultivated plants indicating that some plants produce more than one root. This total was similar between accessions though there were differences in the proportion of non-commercial (less than 300 g) and commercial (more than 300 g) tubers. The highest proportion of commercial roots was presented in accessions EC550 and EC509 (28 and 23%) and the lowest was for accession EC117 (7.2%). It is necessary to improve this trait since the amount of commercial tubers produced by all accessions was relatively low. It is also important to evaluate other accessions as well as other cultural practices and planting times which could favor an increase in roots size.

Regarding the weight variable, results are comparable to those observed for roots quantity with exception of accessions EC550 and EC509 which obtained a higher weight of commercial roots.

The foliage weight did not present statistical differences between accessions though it could be observed for example, a wide difference between accessions EC117 (21.3 t ha^{-1}) and EC205 (9.4 t ha^{-1}). Accession EC117 showed the highest foliage weight but lower yield and accession EC205 obtained the lower foliage weight and high yield (third place). This result does not allow to generalize that an inverse relationship occurs between these two characteristics because other accessions such as EC502 and EC509 have high yields and also high foliage weights.

It can be suggested that the genetic difference observed between accessions would causes different responses regarding growth under the same environmental conditions. Therefore it is interesting to continue research on this field.

Table 24. Significance (value Pr > F) for variables evaluated in the experiment with ten yam bean accessions. David, Panama, 1996.

Variable		Variation sources		
		Repetition	Accession	C. V (%)
Roots/he	Commercial	0.0131*	0.0061**	40.6
	Non-commercial	0.5025^{NS}	0.0453*	11.2
	Total	0.6094^{NS}	0.8780^{NS}	6.0
Roots weight t ha^{-1}	Commercial	0.0134*	0.0084**	40.4
	Non-commercial	0.1638^{NS}	0.0014**	13.4
	Total	0.1881^{NS}	0.0001**	17.4
Foliage (t ha^{-1})		0.0562^{NS}	0.0738^{NS}	28.5

NS = Non significative
* = Significative difference
** = Highly significative difference
C.V. = Coefficient of variance

Table 25. Number and total weight of root averages for each one of the ten yam bean accessions planted in David, Panama, 1996.

Accession	Roots ha^{-1}			t ha^{-1}			Foliage t ha^{-1}
	Commercial	Non-commercial	Total	Commercial	Non Commercial	Total	
EC550	37397 a	97603 c	135000	16.1 a	11.2 d	27.3 a	14.5
EC502	25438 abc	114670 abc	140109	12.0 ab	14.3 ab	26.2 ab	16.6
EC205	22558 abc	118538 abc	141095	9.8 abc	15.5 a	25.3 ab	9.4
EC509	31882 ab	107739 bc	139621	12.3 ab	12.2 bcd	24.5 ab	17.3
EC560	22820 abc	119146 abc	141966	9.9 abc	12.5 bcd	22.4 abc	13.7
EC510	15852 c	124772 ab	140624	7.5 bc	14.1 abc	21.6 abc	15.1
EC532	20936 bc	117746 abc	138682	8.7 bc	12.0 bcd	20.8 bcd	15.2
EC503	21670 bc	118860 abc	135113	8.5 bc	11.5 cd	17.9 cde	16.0
EC214	11447 c	132244 a	143691	4.8 c	10.9 d	15.7 de	19.4
EC117	9839 c	129269 ab	136648	4.4 c	9.8 d	13.1 e	21.3

Flower pruning effect on production of yam bean tuberous roots

The only characteristics which showed significant differences in the deflowering treatment were: weight of small roots (less than 300 g) and total roots weight. There was no interaction between variables (Table 26). More than 1 kilogram weight roots were not found.

Once again it was demonstrated the effect of competence between tuberization and flowers production. The average total roots weight with flowers removal (22.8 t ha^{-1}) surpassed in more than double yield without flower pruning (10.7 t ha^{-1}).The effect observed per accession was similar to the one obtained in Turrialba (Table 27).

Accession EC536 was the most affected when flowers were not removed showing a total weight reduction of 17.2 t ha^{-1} which represents almost three times less in yield. Accession EC523 showed a similar behavior. Accession EC114 was the least affected. The previous results validate those obtained in Turrialba though no accessions vs. deflowering interactions were presented.

Accession EC509, which showed the highest small roots weight had at the same time the highest total weight (19.5 t ha^{-1}) and it was only statistically different to accession EC511.

Although there was no significative difference for foliage, it was observed that without flower pruning, fresh weight of foliage was higher (Table 27). It is possible that the tuberization stimulus due to flowers removal competes with foliage development.

Table 26. Significance for variables evaluated for the experiment on deflowering effect over production of yam bean roots, David, Panama, 1996

Source of variation	Freedom grades	Pr >F Roots size		Pr>F Roots weight, t ha^{-1}			Pr>F Foliage weight t ha^{-1}
		Small	Medium	Small	Medium	Total	
Repetition	3	0.4023^{NS}	0.6262^{NS}	0.2561	0.5474^{NS}	0.4266^{NS}	0.9011^{NS}
Flower pruning	1	0.0694^{NS}	0.0893^{NS}	0.0473*	0.1011^{NS}	0.0100**	0.4619^{NS}
Rep. • flower pruning	3	0.0550	0.3872	0.1218	0.3954	0.0991	0.0015
Accession	4	0.7194^{NS}	0.6769^{NS}	0.0099**	0.7332^{NS}	0.0412*	0.4514^{NS}
Flower pruning • accession	4	0.6604^{NS}	0.9342^{NS}	0.3500^{NS}	0.9018^{NS}	0.1327^{NS}	0.8240^{NS}
C.V (%)		14.1	56.6	21.9	62.3	25.7	48.7

NS = Non-significant difference
* = Statistically significant difference
** = Highly significant difference
C.V. : Coefficient of variance

Table 27. Flower pruning effect on yam bean tuberous roots production and fresh weight. David. Panama, 1996.

Variable	Flower pruning treatment	Accessions					
		EC114	EC509	EC511	EC523	EC536	Average
Small roots t ha^{-1}	With	13.6	15.5	10.7	15.7	15.9	14.3 a
	Without	11.8	12.8	7.2	9.1	10.2	10.2 b
	Average	12.7 a	14.1 a	9.0 b	12.4 a	13.1 a	
Total roots t ha^{-1}	With	18.4	24.6	19.2	24.5	27.6	22.8 a
	Without	12.1	14.4	7.2	9.3	10.4	10.7 b
	Average	15.2 ab	19.5 a	13.2 b	16.9 ab	19.0 a	
Foliage weight t ha^{-1}	With	10.3	8.5	10.1	6.6	5.9	8.3 a
	Without	13.9	11.7	11.5	8.7	12.7	11.7 a
	Average	12.1 a	10.0 a	10.8 a	7.7 a	9.3 a	

Averages with the same letter are considered statistically equal (Duncan, p = 0.05)

Effect of three planting distances on tuberous production of three yam bean accessions

Table 28 shows that the variables statistically significant were: number of small roots, total roots and weight of small roots. Significant differences were observed in distances for the three variables and in accessions for the variable quantity of small roots. There was no interaction between any of the parameters analyzed.

The variables quantity, weight of small roots and total roots, showed the highest values at distance 0.10 m with a significant difference in relation to the remaining distances. It is important to consider that a high value in the variable root total weight does not mean a good production since this can be based on a high amount of small non-commercial roots. Table 28 indicates that the total weight is larger at distance 0.10 m but not statistically different from distances 0.15 and 0.20 m, indicating that the higher weight at distance 0.10 m is due to a very high number of small roots.

Differences were observed in small roots per accession, showing a significative low quantity in accession EC032 though regarding the weight variable it was similar to EC509 and EC534; this means, less number of roots but of higher size in accession EC032. Total weights are very similar for the three accessions although the difference regarding roots quantity is high, especially those of small size. Accession EC534 showed a high number of roots but low weight (Table 29).

Accessions showed a different behavior to the one observed in Turrialba; nevertheless, the same inverse relationship was observed between distance and number and weight of small roots and with regard to totals. Once again, it is concluded that the planting distance of 0.10 m is not convenient because it produces a high non commercial number of small size roots.

Table 28. Significance for variables evaluated in the experiment of three planting distances. David, Panama, 1996.

Source of variation	Freedom grades	Pr >F Roots size			Pr>F Roots weight, t ha^{-1}			Pr>F Foliage weight t ha^{-1}
		Small	Mediums	Total	Small	Medium	Total	
Repetition	3	0.3719^{NS}	0.0647	0.4233	0.5357	0.5404	0.4466^{NS}	0.3195
Distances	2	0.0003**	0.3578^{NS}	0.0011**	0.0242*	0.9034^{NS}	0.1733^{NS}	0.2778^{NS}
Rep. * Distances	6	0.2950	0.9104	0.3179	0.2560	0.4708	0.3830	0.4009
Accession	2	0.0072**	0.5357	0.1164^{NS}	0.2093^{NS}	0.4759^{NS}	0.8598^{NS}	0.1639^{NS}
Dist. * access.	4	0.0896^{NS}	0.8608	0.3518^{NS}	0.2190^{NS}	0.7819^{NS}	0.7285^{NS}	0.7568^{NS}
C V.(%)		23.4	62.8	22.8	41.4	58.1	41.9	72.3

NS = Non-significant difference
* = Statistically significant difference
** = Highly significant difference
C.V. Coefficient of variance

Table 29. Average yield of number and total root yield of three yam bean accessions with three planting distances, David, Panama, 1996.

Variable	Distance (m)	Accession EC032	EC509	EC534	Averages
Small	0.10	177415	260327	289926	242556 a
Roots	0.15	112299	124383	135701	124128 b
number ha^{-1}	0.20	81621	91173	101934	91576 b
	Average	123779 b	158628 a	175854 a	
Roots	0.10	234360	298739	325907	286331 a
Total	0.15	182102	164868	196826	181265 b
number ha^{-1}	0.20	131111	135284	148798	138398 b
	Average	182524	199630	223840	
Small root	0.10	23.0	33.6	43.2	33.3 a
yield	0.15	18.9	23.9	21.6	21.5 b
t ha^{-1}	0.20	17.3	12.5	16.4	15.4 b
	Average	19.7	23.3	27.0	
Total root	0.10	45.5	47.4	60.0	50.8
yield	0.15	46.7	41.8	37.1	41.9
t ha^{-1}	0.20	35.0	31.5	35.7	34.1
	Average	42.2	40.3	44.2	
Foliage	0.10	11.4	15.1	9.5	12.0
t ha^{-1}	0.15	16.9	29.2	12.6	19.6
	0.20	12.6	14.8	11.4	12.9
	Average	13.6	19.7	11.2	

Averages with different letters are statistically different

3.11 Other yam bean uses

Yam bean offers besides its edible roots, seeds with rotenone and other compounds which have insecticide properties that due to their biodegradation characteristics and low toxicity for mammals, become an alternative to the use of synthetic insecticides to control specific pest. Rotenone and other rotenoids are found in at least 68 species of the Leguminosae family (Jiménez, 1994).

Due to a current worldwide concern to preserve the environment, rotenone has been applied as an agricultural insecticide to control several pest and for veterinary purposes to eliminate livestock and other domestic animal parasites. In the international market, one gram of pure rotenone cost approximately one dollar (Rodríguez, 1996).

Field experiments evaluating the utilization of *P. erosus* seed extract as a low-cost plant protective agent are reported by Adjahossou and Sogbenon (1994) in a crop cowpea (*Vigna unguiculata*) and Halafihi (1994) in garden cabbage (*Brassica oleracea*). Both studies demonstrated that good control of leaf-eating insects using an aqueous solution of ground seeds can be obtained, but with little or no control of leaf-piercing insects.

The main objectives of the research conducted at the Phytogenetic Resources Unit on seeds production were to know the production potential of several genotypes under specific conditions and to address alternative uses of this crop.

The rotenone extraction and feasibility studies aimed at establishing an insecticide extraction factory were based on the interest shown by professors and students from the University of Costa Rica's Chemistry School. The Phytogenetic Resources Unit provided the genetic material and technical advice to conduct the research.

3.11.1 Evaluation of three *P. erosus* accessions for seed production under Turrialba conditions

Seed production is an activity necessary to propagate varieties commonly used for root commercial production. Nevertheless, it can also be an important grain production activity to extract rotenone at commercial levels. There is very few information available regarding yam bean seed production, for which the main objective of this experiment was to determine seed capacity production of three yam bean accessions under CATIE conditions in Turrialba, Costa Rica.

A completely randomized block design was employed with three treatments (three accessions) and four replications. The accessions evaluated were: EC032, EC509 and EC510. Planting was done in September, 1994, and seed were harvested by the end of April, 1995.

Table 30 presents the variables under study and the statistical significance obtained through the analysis of variance. Averages obtained per accession in each variable are shown in Table 31.

Accession EC509 showed the highest seed yield (1062.4 kg ha^{-1}), followed by EC032 (733.7 kg ha^{-1}) and then EC510 (271.1 kg ha^{-1}). This same order remained for pods number, seeded pods weight and husk weight variables.

Seed yield was relatively low when compared with the 3386 kg ha^{-1} reported by Heredia (1990) for San Miguelito (EC201) variety in Celaya, Guanajuato, Mexico. Nevertheless, yield can be increased selecting a better planting time since a higher amount of inflorescences was observed when planting was conducted between January and March. There is also a possibility to increment seed yield increasing planting density. On the other side, a long rainy period in December, had a negative effect on subsequent seed production.

The variables seeded pods weight and seed weight showed statistical differences between the three accessions; the variable husk weight did not show any statistical differences between EC032 (13.8 g/plant) and EC509 (18.2 g /plant). For these three accessions, husk weight was higher than seed weight, representing 57, 55 and 53 percent of seeded pods total weight for accessions EC510, EC032 and EC509, respectively.

The production of tuber roots after eight months of planting was high; nevertheless, most of it had no commercial value because roots were too big (approximately 963.4 and 1208 g/plant) and cracked. Roots yield did not show statistical differences between accessions, though difference between EC510 and EC509 was 26551 t ha^{-1}, that is 245.1 g/plant. As the yield increased,. seed production decreased probably due to competence between sexual reproduction processes (flowering, pods and seed) and tuberization processes.

Seed production of yam bean varieties employed because of their tuberous root has the disadvantage of tuberization competence; nevertheless, regarding seed production for rotenone extraction purposes, it is recommended to select accessions with little or not tubers formation to avoid flowering competence. This selection activity should also consider the amount of seeds produced and their rotenone content.

3.11.2 Rotenone studies

Two thesis at the B.S. level, were supported related to commercial feasibility of rotenone extraction from yam bean seeds (*P. erosus*). The first thesis (Jiménez, 1994) developed a new analysis method for rotenone in seed extracts, using high pressure liquid chromatography (HPLC). Besides, the rotenone content per seed gram was established as 0.0049 gram on humid base, employing for this purpose a Sohxlet extractor. A general flow diagram was proposed for rotenone extract process. It was suggested to conduct further studies and to determine the economic feasibility of this process

Table 30. Total average and statistical significance obtained through analysis of variance, for twelve variables studied in David, Panama, 1996

Variable	Total Average	Pr > F Treatments	C.V. (%)
Shoots/inflorescence	23.4	0.0669^{NS}	13.7
No. pods per hectare	463013	0.0049**	19.9
Pods weight + seed (kg ha^{-1})	1604.8	0.0077**	20.0
Seeds weight (kg ha^{-1})	727.1	0.0052**	20.6
Husk weight (kg ha^{-1})	877.6	0.0132*	20.4
Pods per plant	6.9	0.0049**	19.9
Pods + seeds per plant (g)	24.1	0.0077**	20.0
Seed weight per plant (g)	10.9	0.0052**	20.6
Husk per plant (g)	13.2	0.0132*	20.4
Tuberous roots per hectare	75086	0.4700^{NS}	12.2
Tuberous roots weight (t ha^{-1})	84.7	0.2697^{NS}	24.5
Root weight per plant (g)	1115	0.2134^{NS}	16.7

*= Significant differences
**= Highly significant differences
NS= No significant differences
C.V.= Coefficient of variance

Table 31. Averages per accession (treatments) for each variable evaluated, David, Panama, 1996

Variable	EC032[1]	EC509[1]	EC510[1]
Shoots/inflorescence	27.0	22.9	20.4
No. pods per hectare	465174 b	676605 a	175345 c
Pods weight + seed (kg ha^{-1})	1657.4 b	2275.2 a	640.8 c
Seeds weight (kg ha^{-1})	733.7 b	1062.4 a	271.1 c
Husk weight (kg ha^{-1})	923.5 a	1212.7 a	369.7 b
Pods per plant	7.0 b	10.1 a	2.6 c
Pods + seeds per plant (g)	24.9 b	34.1 a	9.6 c
Seed weight per plant (g)	11.0 b	15.9 a	4.1 c
Husk per plant (g)	13.8 a	18.2 a	5.5 b
Tuberous roots per hectare	71512	73976	79770
Tuberous roots weight (t ha^{-1})	84.0	71.7	98.3
Root weight per plant (g)	1173.6	963.4	1208.5

1 Averages showing the same letter are not statistically different (Duncan)

Since seeds are rich in oil content (approximately 30% of their weight) and this could become an important by-product, it was recommended to determine their characteristics and potential uses. Furthermore, it was suggested to define and to quantify other seed compounds besides rotenone, since some of them have insecticide action which could make the use of *Pachyrhizus erosus* seeds even more attractive.

The second thesis (Rodríguez, 1996) involved an economic analysis to determine the possibility to extract rotenoids at industrial scale from yam bean seeds. An economic analysis of the project was conducted for a period of 10 years of operation plus a year to build the factory. The internal revenue rate was 13%, the current net value, $711 000 and the recovering period was 5.1 years. These economic parameters indicate that the project could be profitable. From the sensibility analysis, it was concluded that the project is sensible to variations regarding buying price of raw material and solvents though in lesser level than for equipment acquisition variations.

The variable which mostly affected the project profitability was the product's selling price. It is risky to run a processing plant that may have to sell their products at lower prices than those in the market and on the contrary, the profits increase is very significant if the price increases. Although the conclusion was that the project is feasible, it was recommended to conduct a deeper marketing research both at national and international levels a positive finding should encourage to continue research in order to improved species with higher yields ha^{-1} and to characterize the rotenoids content in other *Pachyrhizus* genus species. Furthermore, it was recommended to conduct quality tests required to characterize the by-products (oil and flour) to attain higher economic benefits and find more uses for these yam bean.

4. CONCLUSIONS AND RECOMMENDATIONS

1. Several accessions were found with acceptable yields and good performance under the different conditions, thus, it is also important to select genotypes not only because of their yield but for quality. It is recommended, as a first step, to conduct a systematic characterization of all available accessions including *P. tuberosus* materials and interspecific crosses or hybrids. A preliminar selection of useful genotypes should be incorporated into regional breeding programs.

2. The results about rotenone extraction at industrial levels indicated that this crop has a great potential as source of this natural insecticide. Research lines should be oriented to the characterization of accessions for their rotenone, oil and other rotenoids contents. Research should be also developed regarding seed production capacity and genotypes selection based on the previously mentioned characteristics. It is recommended to do a marketing evaluation for rotenone at the international level to define the commercial importance of the yam bean.

3. Since it has been demonstrated the need to remove flowers to increase tuberization; there is a possibility to select accessions which require less of this practice due to their low inflorescence production. The research on agronomic practices is fundamental for the integrated development of the crop.

4. The investigation on crops associated to yam bean and cassava permits to conclude that it is a crop which allows a better utilization of natural resources. Yam bean plants fix nitrogen and it is source of organic matter which can be incorporate into the soil. The rapid development and growth habits of this plant makes it an excellent cover crop to minimize weed competence. Finally, it is important to point out that this crop has a high production capacity without using fertilizers, besides presents few disease and pest problems. Because of this, yam bean would be an important part within the organic agriculture system.

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