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Agronomic evaluation of the cultivated yam bean (*Pachyrhizus* spp.) germ plasm under West African conditions

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Abstract

The yam bean (*Pachyrhizus spp.*) is a legume root crop usually known as a vegetable crop. Three cultivated species are distinguished: Amazonian yam bean (*P. tuberosus*), Mexican yam bean (*P. erosus*) and Andean yam bean (*P. ahipa*), but interspecific hybrids are fertile and vigorous. The crop might have the potential to be used like soybean and cassava. The 1000-seed weight is high (from 180 to 230 g), seeds have a high protein (26 to 32 %) and oil (22 to 26%) content with about 20% carbohydrates of seed weight. However, for consumption the compound rotenone (about 1% seed weight) has to be extracted or destroyed. Tubers are characterized by high moisture content (usually about 80 % of fresh tuber weight), but Chuin cultivars of *P. tuberosus* have a low moisture content (about 70 %) and are used like cassava. The tuber includes starch as the main component and has a high protein content (8 to 15% of dry matter). Agronomical data for the yam bean is limited. In total 34 accession were grown in Benin at two locations – one under drought stress conditions – with and without pruning of reproductive parts. With pruning of reproductive parts the average tuber yield across both locations ranged from 6 to 45 t ha^{-1}, 21 to 80 t ha^{-1} and 10 to 38 t ha^{-1} for the Amazonian, Mexican and Andean yam bean, respectively. In a combined utilization of tubers and seeds tuber yield ranged from 5 to 29 t ha^{-1}, 10 to 49 t ha^{-1}, 6 to 27 t ha^{-1} and seed yield form 1.5 to 2.9 t ha^{-1}, 3.5 to 4.6 t ha^{-1} and 2.6 to 2.7 t ha^{-1} for the Amazonian, Mexican and Andean yam bean, respectively. The tuber dry matter content across both locations ranged from 18 % to 36 % of fresh tuber weight with 8 to 15 % raw protein content on dry matter basis. From all species tubers were processed to 'gari' after traditional starch extraction. Moreover, yam bean seed oil was extracted after heating of seeds for 30 minutes in 80^o C water. Yam bean accessions could be made available by CIP Lima (Peru) and can be freely distributed from country to country. In conclusion attractive yam bean material could be identified for West Africa.

Introduction

The yam bean is locally grown in Central America, South America, South East Asia and some African countries (Sørensen 1996, Sørensen et al., 1997). Unlike its close relatives the soybean and the *Phaseolus* beans, the yam bean is exclusively used for its tuberous roots. The seeds of the yam bean are not used due to the alcaloid rotenone (about 1% of seed weight). However, the 1000-seed weight is high (from 180 to 230 g), seeds have a high protein (26 to 32 %) and oil (22 to 26%) content with about 20% carbohydrates of seed weight (Grüneberg et al. 1999). Usually the yam bean is considered as a vegetable root crop due to the high moisture content of the tuber. The crop has attained recent research interest due to the found of high dry matter 'chuin' cultivars from Amazonian Peru which are consumed like cassava. Currently the cultivated yam beans are divided into three species: The Amazonian yam bean (*P. tuberosus*), the Andean yam bean (*P. ahipa*) and the Mexican yam bean (*P. erosus*) (which is also cultivated in Asia) (Fig. 1). However, crosses between all three species result in fertile and vigorous hybrids (Grüneberg et al. 2003). The information about the genetic diversity and agronomic potential of the yam bean is very limited.

Materials and Methods

A total of 34 accessions representing better agronomic types from diverse ecogeographical backgrounds were used for the present study. The accessions consist of 14 *P. ahipa* lines, 14 *P. erosus* accessions and 6 *P. tuberosus* accessions, evaluated at two locations (Songhai and Niaouli) in Benin (West Africa). The location Niaouli was affected by drought stress. Two treatments were applied at each location: pruning (to increase tuber production) and no pruning of reproductive parts. In total 35 agronomic traits were recorded (the most important are listed in table 1, details are reported by Zanklan 2003).

Results

Significant differences between pruning and no pruning of reproductive parts were observed for tuber fresh matter yield, tuber dry matter yield, total biomass and harvest index for tuber dry matter yield in all yam bean species (Table 2). The fresh matter yield was highest in *P. erosus* (for accession EC533 and ECKEW about 80.0 t ha^{-1} were observed across locations, results not presented). The tuber dry matter content was considerably higher in *P. tuberosus* than in *P. ahipa* and *P. erosus*. The genotypic variance for tuber fresh matter yield and tuber dry matter yield was large in all three species and usually larger than the variance component due to genotype by environment interactions and the error term. For tuber dry matter content the genotypic variance was significant for *P. tuberosus* and *P. ahipa*, whereas for *P. erosus* no significant genotypic variance was observed for tuber dry matter content (Table 3). Two accessions from each yam bean species were processed to 'gari' (Fig. 2), which is a major food product in West Africa (usually processed from cassava). The composition of 'yam bean gari' is given in table 4. Moreover, yam bean seed oil was extracted after heating of seeds for 30 minutes in 80^{o} C water (results not presented).

Table 1. Agronomical characters evaluated, code and procedure of measurement

Traits	Code	Procedure and time of recording
Tuber fresh yield	TUBY	t ha^{-1} – at physiological maturity – 24 plants from 4 rows
Tuber dry matter yield	TDMY	TDMY = TUBY x DM
Tuber dry matter content	DM	in % – measured on sun dried samples
Vines and Leaves Dry Weight	VLW	t ha^{-1} – at physiological maturity – 24 plants from 4 rows, sun dried
Total biomass	BIOM	BIOM = TDMY + VLW + PODY
Seed yield	SEEY	t ha^{-1} – at physiological maturity – 24 plants from 4 rows
Harvest index for tuber	HIT	HIT = (TDMY / BIOM) x 100
Damage of tubers by Nematodes	DTN	Scores from 0 to 6; 0 = no damage. 6 = high damage
Damage of tubers by Insects	DTI	Scores from 0 to 6; 0 = no damage. 6 = high damage
Number of tubers per plant	NTP	Counted – at harvest – 6 plants within plot center
Protein content	PRO	in % DM – elementary analysis – calculated from N x 6.25-
Starch content	STA	in % DM – Polarimetric ICC Standard No. 123/1
Saccharose content	SAC	in % DM – Enzymatic
Fructose	FRUC	in % DM – Enzymatic
Glucose	GLUC	in % DM – Enzymatic
Fibre	FIB	in % DM – Enzymatic

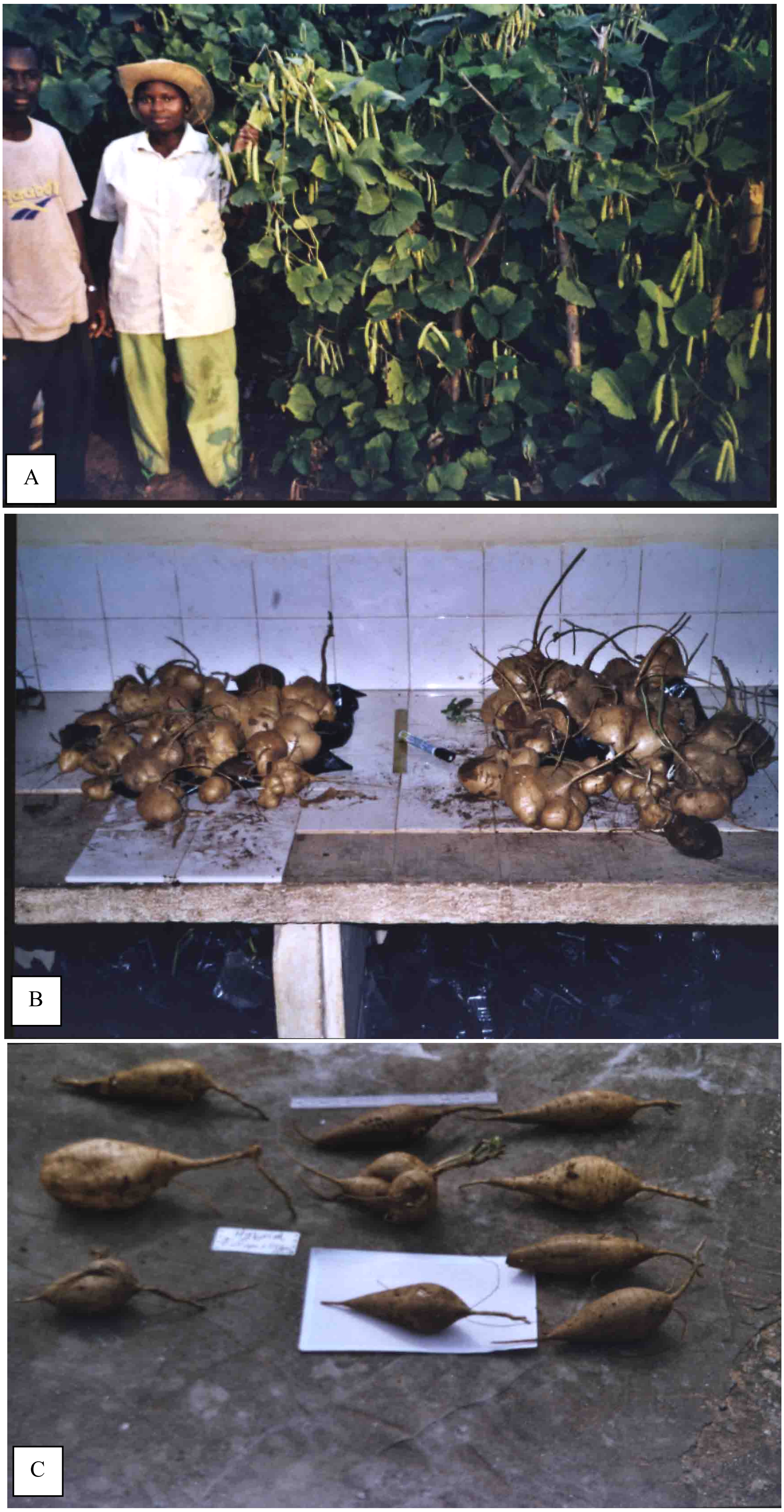

Fig. 1. The Mexican yam bean (*P. erosus*) without pruning (A), tubers of the Mexican yam bean (B), tubers of hybrids between the Amazonian and the Andean yam bean (C).

Table 2. Effect of pruning on the mean of 15 agronomic characters across accessions and locations for the yam bean.

Traits		Amazonian yam bean (*P. tuberosus*) 6 accessions		Mexican yam bean (*P. erosus*) 14 accessions		Andean yam bean (*P. ahipa*) 14 accessions	
	MSE	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned
TUBY (t ha^{-1})	41.64	20.61	13.92**	44.61	23.35**	20.02	12.44**
TDMY (t ha^{-1})	3.75	6.79	4.29**	8.52	4.25**	4.51	2.72**
DM (%)	11.92	31.91	30.00	21.59	20.77	23.01	22.25
VLW (t ha^{-1})	2.90	9.12	9.48	7.34	7.41	2.11	2.20
BIOM (t ha^{-1})	8.45	15.89	18.10**	15.86	24.17**	6.60	9.48**
SEEY (t ha^{-1})	-	-	2.21	-	5.17	-	2.07
HIT (%)	81.97	45.63	23.70**	50.28	17.58**	61.78	28.70**
DTN[a]	0.02	2.67	2.67	0.77	0.75	3.34	3.38
DTI[a]	0.47	2.00	1.83	1.93	1.95	4.29	4.21
NTP	0.07	1.22	1.22	1.30	1.21	1.40	1.51
PRO (%)	2.42	10.54	10.70	11.86	11.82	9.02	9.02
STA (%)	-	-	55.01	-	42.90	-	46.96
SAC (%)	-	-	3.20	-	4.31	-	5.40
FRUC (%)	-	-	3.17	-	6.49	-	6.05
GLUC (%)	-	-	2.86	-	4.42	-	5.67

(a) Damage by Nematodes and Insects measured on a score from 0-6; MSE= Mean Square of Error (pooled estimate for all species); (**) significant difference between the treatments at the level 0.01.

Table 3. Variance components due to genotypes (G), genotype by environment interactions (GE) and the error term (Error) of agronomic traits estimated from treatment pruning of reproductive parts

Traits	Amazonian yam bean (*P. tuberosus*) 6 accessions			Mexican yam bean (*P. erosus*) 14 accessions			Andean yam (*P. ahipa*) 14 accessions		
	G	GE	Error	G	GE	Error	G	GE	Error
TUBY	178.45**	163.88**	18.25	259.63**	136.85**	124.58	110.32**	112.31**	25.07
TDMY	11.34**	8.41[+]	8.58	9.97**	9.74**	8.34	5.68**	5.48**	1.74
DM	32.82*	-14.16	36.10	0.47	2.17[+]	4.31	3.54*	-2.62	10.61

([+]), (*), (**) significant at the levels 0.1, 0.05 and 0.01.

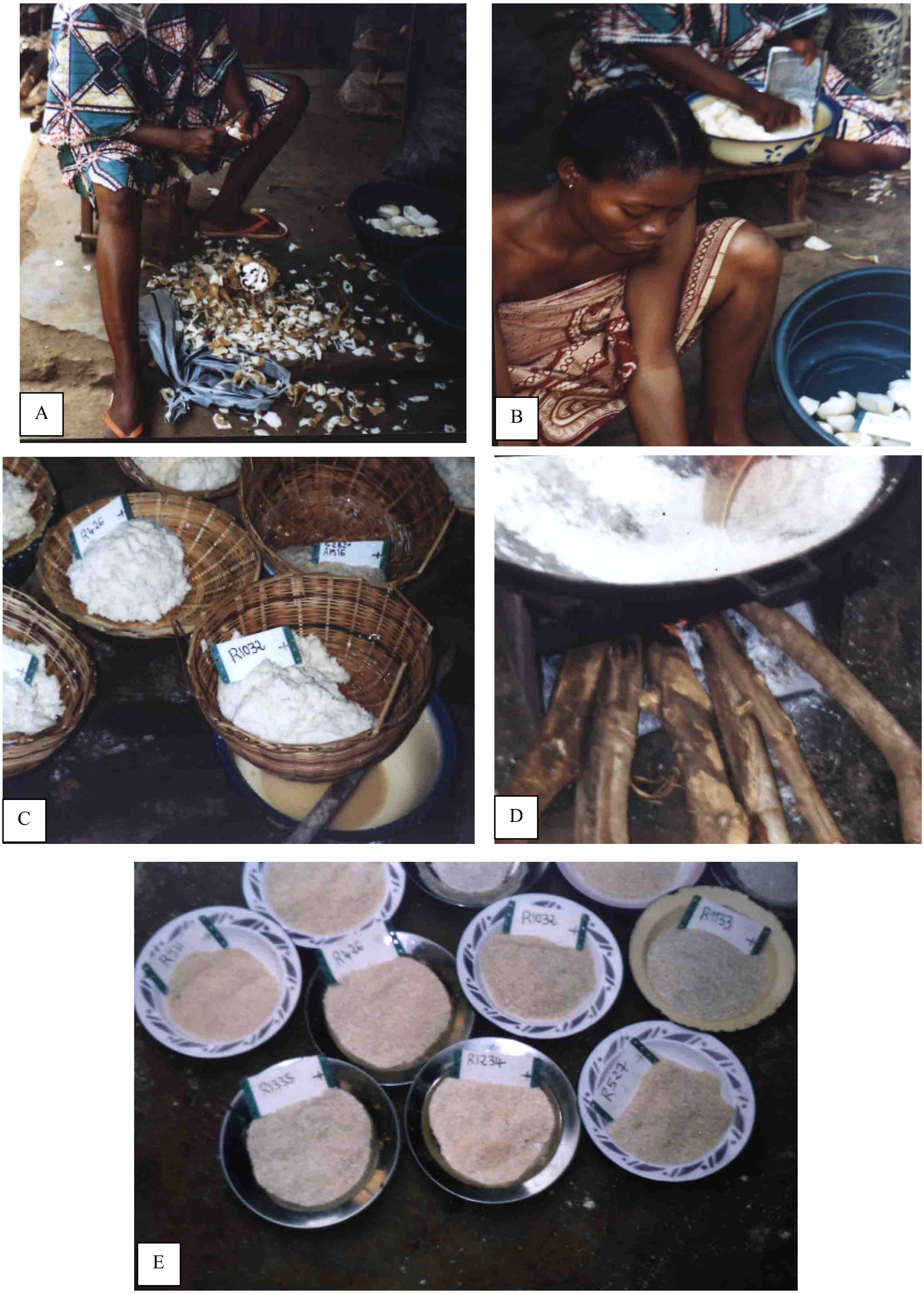

Fig. 2. Gari processing from yam beans; removing of tuber skin (A), milling of tuber samples (B), extraction of starch from milled tuber samples (C), roasting of milled tuber remainings (after starch extraction) to gari (D), gari samples developed from Amazonian, Mexican and the Andean yam bean (E).

Table 4. Composition of fresh yam bean tubers and 'yam bean gari' from samples taken at the non-stress location Songhai; (TC = Amazonian yam bean *(P. tuberosus),* EC = Mexican yam bean (*P. erosus*), AC = Andean yam bean (*P. ahipa*), FM = fresh matter, DM = dry matter).

	Yam bean tubers (unpeeled)						Yam bean gari					
Accession	dry matter % FM	raw protein % DM	starch % DM	total fibre % DM	insol. fibre % DM	sol. fibre % DM	dry matter % FM	raw protein % DM	starch % DM	Total fibre % DM	insol. fibre % DM	Sol. Fibre % DM
TC353[a]	32.0	11.3	53.0	18.3	13.1	5.2	91.6	5.2	63.9	21.1	18.7	2.4
TC354 [a]	27.4	11.1	50.3	12.2	8.89	3.3	90.7	7.0	51.0	25.6	21.7	4.0
ECKEW [b]	13.4	11.0	39.1	17.7	13.5	4.2	91.6	4.7	57.7	23.8	19.7	4.1
EC533	13.1	9.4	46.6	15.7	10.8	4.9	91.0	3.7	64.4	21.1	18.9	2.2
AC209	17.6	7.9	53.9	13.4	7.0	6.4	90.9	6.2	53.3	27.5	24.3	3.2
AC525 [a]	20.9	8.8	56.1	14.0	8.2	5.8	91.5	6.3	60.8	23.5	21.5	2.0

(a) available by the germ plasm acquisition and distribution unit of the International Potato Centre (CIP CGIAR), PO-Box 1558, Lima 12, Peru; webmaster~cip@cgiar.org
(b) available by the Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AB, UK; info@rbgkew.org.uk

Discussion

Fresh tuber yield in the Mexican yam bean (*P. erosus*) was in the average of 14 accessions and two locations about 45 t ha^{-1} with pruning and 23 t ha^{-1} without pruning of reproductive parts. Taking into consideration that these figures were obtained from the average over landraces with no application of fertilizer, inoculum and pesticides (and when compared with figures from Thailand with yields of 18 - 24 t ha^{-1} (Ratanadilok and Thanisawanyangkura 1998) and from Sierra Leone with yields of 10 - 23 t ha^{-1} (Belford et al. 2001)), the production potential of the yam bean in Benin and other West African countries is promising. Reproductive pruning is enhancing tuber production by avoiding the competition between tuber and pod formation. However, improving the tuber dry matter content in *P. erosus* - which is the yam bean species with the largest eco-geographic distribution (Central and South America, South East Asia, West Africa) – requires incooperation of high dry matter from *P. tuberosus* since there is no significant genetic variance for this trait in *P. erosus*.

Conclusions

- The yam bean has a high yield potential and a considerable genetic variation for genetic improvement.
- The yam bean may be of interest for the food industry (Bergthaller et al. 2001, Forsyth et al. 2002) as well as for small scale food processing.
- The yam bean may provide higher food quality than traditional root crops (i.e. cassava, sweet potato or yam) and it has the potential to increase soil fertility (N-fixation, P-efficiency).
- We think the crop merits further investigation.

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