Cassava (Manihot esculenta, Crantz) Establishment and Adaptability in the Rio Grande Valley

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ABSTRACT

Cassava, (Manihot esculenta, Crantz), a low input, drought-tolerant plant, may have potential in the Lower Rio Grande Valley as a bio-fuel source. To evaluate this possibility, four cassava accessions were received from the USDA, ARS Plant Introduction Station in Mayaguez, PR on 16 Jan. 1996. Cuttings, 15 to 20 cm long, were subsequently propagated in 3.7 L pots containing Metro Mix No. 4 for 10 weeks before field setting in a transition Hidalgo-McAllen fine sandy loam soil at a USDA, APHIS site near McCook, TX. Three plant establishment methods, control (no soil amendment), addition of 15 Mt bagasse·ha^{-1}, or 50 kg cross-linked polyacrylamide•ha^{-1} into the planting trench were evaluated. The 2 x 1.2 m spacings on 15 cm high beds provided 4036 plants·ha^{-1}. Plants received a total of 35.8 cm of water between field planting and harvest (230 days). As the growing season progressed, plants grown in bagasse experienced lower soil moisture (in kg·m^{3}) at the 38 cm depth compared to the other establishment methods. Establishment method had little or no effect on plant size, leaf nutrients, leaf pigment concentrations, root dry matter or root yield. Accessions differed in many of these attributes except root yield, the means of which ranged from 5 to 9 Mt·ha^{-1}. Winter temperatures as low as -5.4 °C resulted in accession spring survival rates between 40 and 72%.

RESUMEN

La yuca (*Manihot esculenta*, Crantz), planta tolerante a la sequía y de poco mantenimiento, puede tener potencial en la parte baja del Valle del Rio Grande como fuente de biocombustible. Para evaluar esta posibilidad, en enero 16 de 1996 se recibió de la estación de producción de plantas del USDA, ARS en Mayaguez, Puerto Rico yuca proveniente de cuatro concesiones. Esquejes de 15 a 20 cm de largo se propagaron subsecuentemente por 10 semanas en macetas de 3.7 litros conteniendo Metro Mix No. 4 antes de establecerse en el campo en una área con suelo de transición franco arenoso fino Hidalgo-McAllen en un sitio cerca de McCook, Texas. Se evaluaron tres métodos para el establecimiento de las plantas: control (ningún aditivo al suelo), adición al surco de 15 t-ha^{-1} de bagazo, y la adición al surco de 50 kg-ha^{-1} de poliacrilamida ligada-cruzada. La distancia de plantación de 2 x 1.2 m en camas de 15 cm de alto produjo 4036 plantas·ha^{-1}. Las plantas recibieron un total de 35.8 cm de agua en el tiempo transcurrido entre la plantación en campo y la cosecha (230 días). A medida que la estación de crecimiento avanzó, las plantas que crecieron en el tratamiento con bagazo experimentaron una humedad del suelo más baja (en kg·m-3) a una profundidad de 38 cm en comparación con los otros métodos de establecimiento. El método de establecimiento tuvo poco o ningún efecto sobre el tamaño de la planta, los nutrientes de la hoja, las concentraciones de pigmento de la hoja, la materia seca de la raiz o el rendimiento de la raiz. Los materiales de las diferentes concesiones difirieron en mucho de estos atributos con la excepción del rendimiento de la raiz, cuyas medias variaron de 5 a 9 t·ha^{-1}. Las temperaturas invernales tan bajas como -5.4°C resultaron en tasas de sobrevivencia primaveral de los materiales de yuca de entre 40 y 72%.

Cassava, a water stress-tolerant root crop, is a staple food source for 0.5 billion people living in the predominantly tropical areas of Africa, Asia, and Latin America. Although plants can grow in low organic, infertile soils, improved germplasm grown under more ideal conditions can generate up to 40 Mt·ha^{-1} of root (El-Sharkawy, 1993), and the plant can be grown in subtropical USA (Bhagsari, 1994). Because of the high starch content in the roots, cassava has been evaluated for its potential as a source for oxygenated fuels (Evenson and Keating, 1978; Anonymous, 1995). One group, having evaluated the economics required for such a system, has proposed developing a cassava-based industrial alcohol industry in south Texas based upon efforts generated in Brazil and Australia and their own proprietary low energy distillation technology (Anonymous, 1995). Unfortunately, little agronomic data currently exists regarding cassava production potential in the Lower Rio Grande Valley (LRGV).

In addition to industrial uses, cassava can be utilized as feed stock (e.g. as an agglutinant for shrimp feed), and for fresh or processed (e.g. chips, tapioca) food (Wheatley et al.,

Table 1. Agronomic performance of four cassava accessions on 3 Oct. 1996, 180 days after initial field planting, and the percentage of plants on 26 Mar. 1997 surviving winter freeze events as low as -5.4 °C[z].

	Ht	Width	Depth	Vol.[y]	H:(W+D)/2	Plant stand	Post-winter survival[x]
	m	m	m	m3	ratio	%	%
Accession:							
Chilena	1.36b	1.50a	1.66ab	3.70ab	0.59b	58.2b	27.7b
Llanera	1.80a	1.18b	1.40bc	3.11b	0.96a	91.8a	47.2b
PI 12903	1.58ab	1.22ab	1.34c	2.86b	0.86a	87.5a	72.2a
Jordan	1.62ab	1.49a	1.75a	4.86a	0.69b	77.0ab	40.3b
	**	**	**	0.09[w]	**	**	*

[z]No significant treatment or treatment by cultivar interactions.
[y]Vol. = Ht x width x depth.
[x]Analysis performed on arc sine-square root transformed percent survival. Untransformed means shown.
[w]Probability of a greater 'F' value. *,** = significant at P=0.05 and PI-0.01, respectively. Mean separation at probability level shown.

1995).

Cross-linked polyacrylamides (CLP) have been used in the horticultural bedding plant industry, in re-forestation, and in dry land horticultural crop production systems. The charged polymer can hold up to 400 times its original weight in water. Bagasse, a by-product in the processing of sugar from sugarcane, is usually burned as a fuel, but has also been developed into a horticultural medium after milling (Dobbs, 1982).

The objective of this study was to evaluate several cassava accessions for their root biomass production potential in the LRGV and to develop a simple establishment planting protocol through the use of simple or locally available soil amendments.

MATERIAL AND METHODS

Four cassava accessions, received from the USDA, ARS Plant Introduction Station in Mayaguez, Puerto Rico as cuttings, were propagated on 17 Jan. 1996. Each cutting was placed in a 3.7 L pot containing Metro Media Mix No. 4 and propagated in a greenhouse set at 30 °C day / 18 °C night. On 3 Apr. plants were transplanted into a transition Hidalgo-McAllen fine sandy loam soil near McCook, TX, which had previously been treated with 187 L Telone·ha^{-1}. The site had a pH range of 7.4 to 7.9, and average salt, NO_3, P, K, and Ca soil concentrations of 425, 52, 70, 530, and 5800 ppm, respectively. Percentage organic matter and cation exchange capacity of the soil was 1.4 % and 12.5 meq·100 g^{-1}, respectively. Three main plot treatments consisting of control, 15 Mt bagasse·ha^{-1}, and 50 kg·ha^{-1} of the cross-linked polyacrylamide (CLP), 'Hydrosource' (Western Polyacrylamide, Inc., Jay, OK), were established in planting furrows. Furrows were established using a modified lilliston cultivator, which created 15-cm raised beds on 2 m centers. Within each establishment treatment (row), the four cassava accessions 'Chilena', 'Llanera', 'PI 12903', and 'Jordan' were planted 1.2 m apart (4036 plants·ha^{-1}). Each subplot consisted of 4 plants. All wind damaged plants were replaced within the first month of field planting. Nitrogen fertilizer, as NH_4NO_3, was added at the rate of 50 kg·ha^{-1} on 11July. The planting received 35.8 cm of water between field planting and harvest, 44 % in the form

Table 2. Leaf pigments (mg/g dry wt. basis) and SPAD readings of four cassava accessions on 31 July 1996, 120 days after transplanting[z].

	Chlorophyll 'a'	Chlorophyll 'b'	Chlorophyll total	Chlorophyll a:b ratio	Total carot-enoids	Chlor: carot. ratio	SPAD Reading[y]
Accession:							
Chilena	5.40a	1.75a	7.16a	3.1ab	1.90a	3.7a	47.0a
Llanera	4.15bc	1.33b	5.58b	3.2a	1.52b	3.6ab	35.5b
PI 12903	3.43c	1.04c	4.47b	3.3a	1.27b	3.4b	28.8b
Jordan	5.17ab	1.76a	6.93a	2.9b	1.84a	3.7a	44.0a
	**	**	**	**	**	0.07[x]	**

[z]No significant treatment or treatment by cultivar interactions.
[Y]Minolta Model 502; avg. of six readings per plot.
[x]Prob. > 'F' value. ** = significant at P=0.01. Mean separation at prob. level shown.

Table 3. Nutrients (dry wt. basis) from leaves of four cassava accessions growning under three establishment methods and sampled on 31 July 1996[z].

	N	Ca	Mg	S	P	NO_3	Al	Mn	Fe	Zn	Cu
	%					mg•kg-1					
Treatment:											
Control	4.48	1.93	0.61	0.32	0.32	743	210b	192b	139b	48	8.3
CLP	4.29	2.18	0.73	0.30	0.28	684	256a	219a	157a	50	8.1
Bagasse	4.48	2.01	0.64	0.31	0.31	753	221b	199ab	155a	51	8.3
	NS	NS	NS	NS	NS	NS	**	0.09[y]	**	NS	NS
Accession:											
Chilena	4.91a	1.70c	0.57b	0.33a	0.31b	987a	246ab	172c	178a	49b	9.3a
Llanera	4.13c	2.63a	0.80a	0.29b	0.26c	562b	187c	198b	135b	45b	6.9b
PI 12903	4.23bc	2.03b	0.87a	0.32a	0.36a	759b	268a	269a	144b	64a	8.4a
Jordan	4.41b	1.80bc	0.41c	0.29b	0.29bc	599b	215bc	175c	146b	39b	8.3a
	**	**	**	**	**	**	*	**	**	**	**

[z]No significant interactions. K and Na concentrations, which were 1.56% and 257 mg/kg, respectively, were not affected by treatment or accession.

[y]Prob. > 'F' value. NS,*,**= Not significant or significant at P=0.05 and P=0.01, respectively. Mean separation at prob.level shown.

of rainfall.

Seasonal soil moisture at 38, 76, and 114 cm was monitored by neutron probe (Troxler, Raleigh, NC). Leaf chlorophyll was estimated with a Minolta Model 502 SPAD meter and leaf blades sampled for pigments, mineral nutrients and total leaf N on 31 July. After sampling, leaves were frozen, lyophilized, ground through a 40 mesh (0.36 mm^2) screen and stored at -20 °C until analyzed. Mineral elements were determined by ICP, percent total N by the Leco combustion method (Plank, 1992), and pigments by the spectrometric method of Welburn and Lichtenthaler (1984).

Plant stand and biomass measurements were made on 3 Oct. On 19 Nov., roots from representative plants within each subplot were dug by hand and sorted into 5 size classes: <10, 10-15, 15-20, 20-25, and > 25 cm in length. Roots from each size class were weighed and subsamples for dry matter (DM) determination were removed with a 1-cm dia. cork bore from the largest size class.

The experimental design was a split plot, with four replications. Establishment methods were main plots and accessions were subplots. Differences between means were tested using the PDIFF option of the LSMEANS statement of PROC GLM of SAS Version 6.04.

RESULTS AND DISCUSSION

Establishment method. The addition of amendments had little or no positive benefit to cassava performance (Tables 1-4). Leaf blade Fe concentration was lowest in unamended soil compared to the other two treatments (Table 3). Manganese and Al concentrations were slightly higher in the CLP treatment. Bagasse application tended to reduce the percentage by weight of roots '>25 cm' in length (P=0.14) and root DM, (P=0.10; Table 4). Unamended soil tended to have fewer roots in the 10-15 and 15-20 cm size classes. By 130 days after field planting, soil moisture levels in the bagasse treatment were less than those of the other treatments at the 38 cm depth only

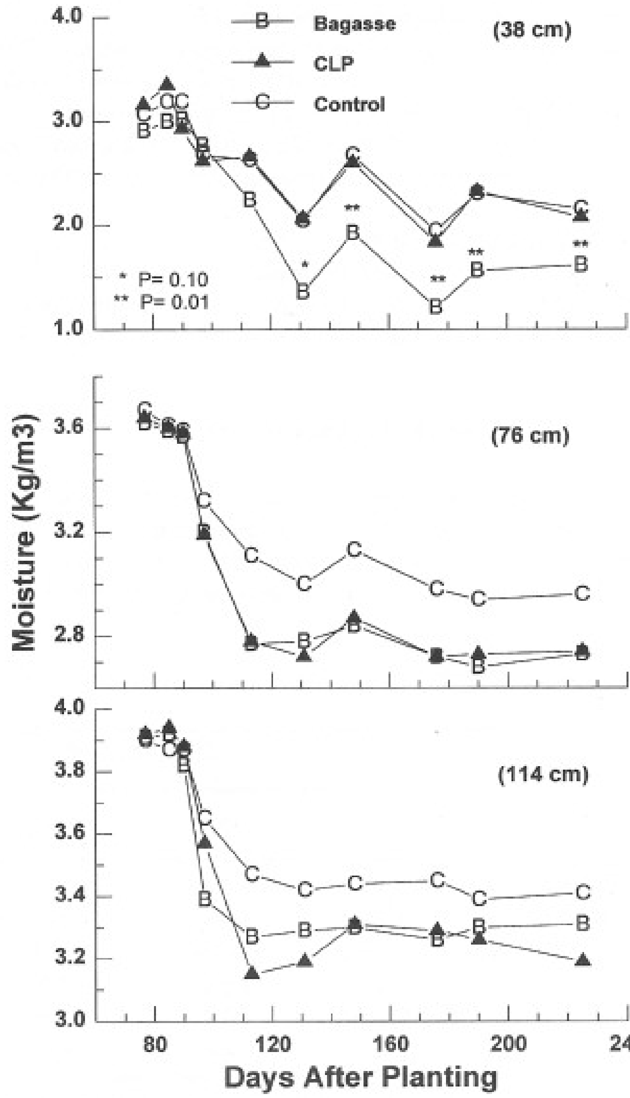

Fig. 1. Seasonal soil moisture in control, bagasse, and clp treatments at 38, 76, and 114 cm depths

Table 4. Cassava root dry matter, total yield and percent of total yield by size class as harvested on 19 Nov. 1996, 230 days after transplanting[z].

	Dry Matter	Yield[y]	Size class (in cm) <10	10-15	15-20	20-25	>25
	%	Mt•ha^{-1}	%				
Treatment:							
Control	26.5a	8.4	8.1	5.1b	9.1b	18.6	59.1a
CLP	25.3ab	6.0	3.0	9.2ab	15.4ab	9.8	62.7a
Bagasse	24.2b	6.9	5.4	15.8a	22.0a	17.1	39.6b
	0.10[x]	NS	NS	0.12	0.24	NS	0.14
Accession:							
Chilena	23.2b	5.3	5.2	8.7	20.8a	23.8a	41.4bc
Llanera	22.4b	7.8	6.8	13.9	21.6a	17.4a	40.2c
PI 12903	21.2b	9.0	6.4	13.1	6.9b	5.0b	68.7a
Jordan	34.7a	5.7	3.1	4.6	14.4ab	16.0ab	61.8ab
	0.01	NS	NS	NS	0.10	0.10	0.04

[z]No significant interactions.
[y]Not adjusted for plant stand.
[x]Prob. > 'F' value. Mean separation at prob. level shown.

(Fig. 1). The reason for this is not clear, unless bagasse initially stimulated root growth and subsequently developed roots then depleted soil moisture at a more rapid rate than did roots from the other establishment methods. Soil moisture increased with depth of soil. Storage roots appeared in the upper 45 cm of soil, regardless of establishment treatment.

Accessions. After 6 months in the field, plant stand was lowest in 'Chilena' (Table 1). Accessions varied in height, in-row width, and across-row depth. 'Llanera' and 'PI 12903' were more erect in shape compared to 'Chilena' and 'Jordan'. The order of biomass, as estimated by plant volume, was 'Jordan' >> 'Chilena' > 'Llanera' > 'PI 12903'. Soon after field planting, shoots of 'Chilena' plants were damaged more by high winds than other accessions. Shoot damage could have been minimized had plants been hardened off before taking them to the field.

Mean stem diameter at the soil line ranged between 31.4 to 37.7 mm between accessions, but was not significant. Stem diameter was correlated with plant volume (r=0.72, P=0.01) but not root weight and could be used as a rapid approximation of plant biomass.

A substantial freeze event of -5.4 °C on 19 Dec. 1996 and two additional sub-zero freezes in Jan. 1997 resulted in post-winter survival rates of less than 50% in all accessions except 'PI 12903'.

'PI 12903' plants generally became chlorotic as the growing season progressed. At times, all but the apical 'PI 12903' leaves of some plants would abscise. Chlorophyll estimates, based on SPAD readings, supported this visual observation and were correlated with actual leaf chlorophyll (r=0.88, P=0.0l) and total carotenoids (r=0.90, P=0.0l; Table 2). 'Llanera' and 'PI 12903' tended to have lower leaf blade pigment and N, but higher Ca, Mg, and Mn concentrations than did 'Chilena' and 'Jordan'.

Total root yields were not significantly different between accessions (Table 4). However, there were accession differences in root yields based upon root length. 'PI 12903' had the highest percentage of its yield in the '>25' cm size class and significantly lower percent root yield in the 15-20 and 20-25 cm root size classes than did 'Chilena' and 'Llanera' (P=0.10). 'Jordan' followed a similar pattern in root size distribution to 'PI 12903', but was not significantly different than the other accessions in these three size classes. Plant volume was significantly correlated with root yield in all accessions except 'Jordan' (correlations not shown), whose roots appeared to be most susceptible to pathogen attack. Root DM was at least 50% higher in 'Jordan' than in any of the other accessions.

The selection of a less calcareous, lower pH soil might have improved yields of 'PI 12903' and 'Llanera' by reducing iron chlorosis and leaf drop. The experiment-wise relationship between leaf blade Fe and total chlorophyll was weak (r=0.28, P=0.05) and was not significant in any of the individual accessions.

The CLP was not allowed to hydrate prior to planting and may have also been applied at too low a rate. Supplemental sprinkler irrigations were applied only to reduce soil moisture tensions that could cause stress-induced leaf defoliation. Furthermore, the efficacy of CLP's are reduced by soil salinity and high pH. Under laboratory conditions, hydration rates for the CLP and bagasse samples were 1:200 and 1:6, respectively. Milling the bagasse might have improved the hydration rate, but would probably not justify the added expense in this application.

In summary, the establishment treatments selected were not significantly different than planting in soil without amendments. 'Llanera' and 'PI 12903' accessions were generally more erect, had less vegetative growth or plant volume, higher mean yields, better plant stand, and exhibited more chlorosis than did 'Chilena' and 'Jordan'. Adjusting for DM and plant stand, mean root yields (dry wt. basis) of 'PI 12903' and 'Jordan' would have been numerically similar and higher than the other accessions evaluated.

Although cassava plants are capable of producing nominal yields in the LRGV, further research is needed with regard to germplasm and soil type selection and to develop an integrated production system in order to maintain continuity of supply and attain the economic yields necessary for industrial use.

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