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Foreword

After quite a long interval without a new issue of CARDI Review, this is the first of three issues which will appear in the next few months. The two papers in this issue both have the same three authors listed with five additional authors for the second paper.

The first paper examines the issue of planting densities for hot pepper and arrives at the conclusion that yields could be increased by planting at higher intra-row densities. The second paper showcases work which is being undertaken to mitigate against the effects of climate change which already appears to be a factor which farmers have to deal with. Ten sweet potato cultivars and landraces were evaluated during the severe Trinidad dry season of 2014. There were some clear conclusions as to the most drought tolerant: but results like this will, of course, need to be verified by further evaluations in different geographic environments. They also need to be repeated in other harsh climatic conditions before definite conclusions can be drawn. Nevertheless, much more is now known about the relative performance of the ten cultivars and landraces.

F B Lauckner
Editor, CARDI Review

Evaluation of plant population densities for hot pepper in Trinidad and Tobago

Herman Adams[1], Bruce Lauckner[1] and Gaius Eudoxie[2]

[1]Caribbean Agricultural Research and Development Institute, P.O. Bag 212, University of the West Indies, St. Augustine Campus, St. Augustine, Trinidad and Tobago
Email: hadams@cardi.org

[2]Department of Food Production, Faculty of Food and Agriculture, University of the West Indies, St Augustine, Trinidad and Tobago
Email: Gaius.Eudoxie@sta.uwi.edu

ABSTRACT

Research results from the neotropics showed a high positive correlation between plant population densities and yields of marketable berries in hot pepper (*Capsicum chinense* Jacq.). Densities were compared on a Piarco Series soil (Ultisols of the Aquoxic Tropudults sub-group) during 2011 in central Trinidad on cv. Moruga Red to determine the density that will produce the highest yields of berries, mean berry weights and mean plant developmental traits. The 16 different densities ranged from 60 x 30 cm to 150 x 120 cm. The split-plot design comprised four levels of between-row spacings of 60, 90, 120, and 150 cm. The sub-plots represented four levels of within-row spacings, viz.: 30, 60, 90, and 120 cm. The 16 treatments were replicated thrice thus producing 48 gross plots of 6 x 6 m each. The nett plots in the centre of the gross plots measured 4.88 x 4.57 m (22 m^2). A principal finding was that the highest plant population densities, 60 x 30 cm, 90 x 30 cm, 120 x 30 cm and 150 x 30 cm yielded the highest weight of berries per nett plot (P = 0.001). Another conclusion was that the different densities had no effect on mean weights of the berries (P = 0.080), mean plant height (P = 0.702), mean width of plant canopy (P = 0.46) and mean number of secondary lateral branches per plant (P = 0.655). The results from this study should guide farmers to adopt higher plant population densities.

Keywords: *Capsicum chinense* Jacq., chillies, hot peppers, spacing, Trinidad and Tobago

INTRODUCTION

There is a high consumption of fresh hot peppers in Trinidad and Tobago, both at the household and food service industry level, with significant quantities going into processing for pepper based products and for export to North America and the United Kingdom (Singh et al. 2007). There is a need to expand the local production of hot pepper since processors periodically have to import pepper mash to augment local supplies of fresh pepper either on account of shortfall in supplies or due to relatively higher prices prevailing on the local market (Singh et al. 2007). With the demand for efficient use of land resources in Small Island Developing States (SIDS), hot pepper farming in Trinidad and Tobago is fraught with inefficiencies of which the major one is low plant population densities. The average national yield (Adams, 2004; Adams et al. 2007) of hot pepper berries is 10 - 15 t/ha. This can be doubled or tripled through the use of higher plant population densities coupled with good agricultural practices.

A literature search disclosed five papers dealing directly with the effects of plant population density on hot pepper of the same species (*Capsicum chinense* Jacq.) that is commercially grown in the Caribbean. It is different from the chilies (*Capsicum annuum* L.) mostly grown in Mexico and other parts of the world and which dominate the global hot pepper trade (Campodonico, 2002). A study by Skeete et al. (2004) in Barbados found that population density had the greatest impact on yield which was increased 67% by doubling plant density. Adams et al. (2001), also in Barbados, concluded that a population density of 40,000 plants/ha produced a yield higher than the farmer practice (9,570 plants/ha) by 123%. The higher densities of the hot pepper cultivar, West Indies Red, did not affect berry sizes and shapes. O'Keefe and Palada (2002), in St Croix, found that different optimal intra-row spacings for three hot pepper varieties produced the highest yields of berries as follows: West Indies Red (18,436 kg/ha) at 91 x 41 cm (27,222 plants/ha); Habanero (18,753 kg/ha) at 91 x 61 cm (18,150 plants/ha); and Yellow Scotch Bonnet (14,717 kg/ha) at 91 x 61 cm (18,150 plants/ha).

The closer intra-row spacing was the optimal for the West Indies Red variety unlike the wider spacing for Habanero and Yellow Scotch Bonnet. In Trinidad, Indalsingh and Antoine (2006), using the cultivar 'Local Red', showed that 27,777 plants/ha yielded 150,000 kg/ha as compared to 45,800 kg/ha for the lowest plant population density. At the same time, berry quality was not affected. Skeete (2009) planted at a population density four times that of the average farmer in Barbados and obtained a yield higher by 2.5 times at the first picking.

All the studies agreed that hot pepper yields increased with higher plant population densities. Similar conclusions were arrived at by other authors working with *C. annuum* L. and *C. chinense* Jacq. in other regions of the world. However, Moirangthem et al. (2012) in India concluded that the best spacing for the cultivar Bhoot (*C. chinense* Jacq.) with regards to growth parameters and yield components was 105 x 105 cm which did not agree with the studies above which gave highest yields from closer spacings. Motsenbocker (1996) in Louisiana, USA, working with *C. annuum var annuum* L. CV 'Golden Greek', stated that generally plants grown at the narrowest spacings produced the lowest fruit yield per plant but the most fruit per hectare. Cavero et al. (2001) studied direct seeded paprika pepper (*C. annuum var annuum* CV 'Agridulce SIA') and concluded that fruit number and weight per plant decreased with increasing plant population densities. However, the increase in fruit yield per hectare as plant population density increased was as a result of the larger number of fruits per hectare. Therefore there is general agreement between researchers on this phenomenon.

A determination of the optimal plant population densities for the commercial landraces of Trinidad and Tobago will lead not only to increases in yields but also to a reduction in the cost of production since the closer spaced plants will shade out weeds more effectively and lower the rate of evapotranspiration thus consuming less water.

METHODOLOGY

The specific objective of this work was to determine the plant population density that will produce the highest yields of marketable hot pepper berries. The study used the improved landrace, Moruga Red, grown in central Trinidad during 2011. The cultural practices were applied evenly to all treatments including the following components of an updated production system (Adams et al., 2007): ground cover of black plastic mulch, drip irrigation system used also for fertigation, Integrated Pest Management (IPM) with judicious use of biocides, and an overall plant nutrition regime aimed at higher yields.

The site for this study was a field at the Sugarcane Feed Centre in Longdenville, central Trinidad on soils classified by Smith (1983) as the Piarco Series, Ultisols of the Aquoxic Tropudults sub-group.

The experiment was laid out in a split-plot design where the main plots were four levels of between-row spacings of 60, 90, 120, and 150 cm. The sub-plots represented four levels of intra-row spacings, viz.: 30, 60, 90, and 120 cm. The experiment was replicated three times thus producing 48 gross plots. The main treatments and the sub-treatments were randomised. Each gross plot measured 6 x 6 m (36 m^2) and the nett plot 4.88 x 4.57 m (22 m^2) on the ground.

Weed management started with brushcutting; the weeds were mowed and the stubble ploughed into the soil with the first cut. Afterwards, the stale seedbed technique was applied: that is weeds were left to emerge and at the stage of the most vigorous early growth they were sprayed with a systemic herbicide, Glyphosate (*N*-(phosphonomethyl)glycine). This was repeated before the final rotor tillage. The pre-emergent herbicide, Prowl (pendimethalin), was sprayed over the moist soil just before transplanting. During early crop growth and thereafter, manual weeding was applied around the plants whilst the drains were sprayed with Glyphosate.

Soil ameliorants and fertilisers were determined based on the results of soil analyses (Table 1). The rates of application and the types of soil ameliorants were chosen with the aim of maintaining the levels of the macro- and micro-nutrients required to support a high yielding hot pepper crop planted at high plant population densities. Hydrated limestone at the rate of 2.2 t/ha was manually broadcast in the first week of May 2011 over the deep ploughed (20 cm) field. Well cured cow pen manure was spread right after the limestone at 4.5 t/ha and both were incorporated into the soil at a depth of 15 - 20 cm by a rotor tiller. The field was left to weather for 2 weeks after which 168 kg/ha granular compound fertilisers (NPK 12:12:17+2) was manually broadcast and incorporated by the final pass of the rotor tiller.

Table 1 Selected properties of the soil of the experimental site at the Sugarcane Feed Centre, Central Trinidad in 2011.

Sample depth (cm)	pH	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	EC (mmhos)
0 - 15	6.60	0.90	69	13	20	2	131
15 - 30	5.10	0.14	74	7	20	2	101

Black plastic mulch was spread over the fully prepared soil on cambered beds after incorporation of the soil ameliorants. The drip irrigation system was also laid out beforehand and covered with the mulch, the edges of which were sealed and anchored with soil.

Transplanting on 1 and 2 June 2011 was immediately followed by drenching the planting holes with a booster dose of water soluble fertiliser (NPK 20:20:20 + micro-nutrients) at 1 kg dissolved in 170 L water. A total of 3 kg was applied on the entire experimental plot. A systemic insecticide, Admire (imidacloprid) at 25 ml/100 L water, and the systemic fungicide Acrobat, (dimethomorph+mancozeb) at 48 g/100 L water, were added to the drench solution. This solution was applied by watering can at a rate of 0.25L to each transplant.

Daily monitoring of the crop discovered the appearance of pests such as aphids (*Aphis* spp) and whiteflies (*Bemisia* spp). Fruit worms (*Heliothis* spp.), mites and midges appeared more frequently during the fruiting stage. Fortnightly sprays of Cure 1.8 C (abamectin) alternated with Neem (azadirachtin), were applied. Heavier infestations of mites and midges were controlled with sprays of Fastac (alphacypermethrin). The fungicide, Insignia (pyraclostrobin), was added to the above sprays to manage anthracnose on berries, leaf spots and root rots caused by *Pythium* spp, *Rhizoctonia* spp, *Phythophthora* spp, and *Fusarium* spp. The above fungicide was alternated with Banrot (thiophanate-methyl+etridiazole) to manage root rots caused mainly by *Phythophthora* spp during the rainy season.

Seedlings which were stunted or died within a week of transplanting were replaced with well developed plants of the same age. Nutrient levels in the rhizosphere were maintained by fortnightly fertigations with the same water soluble fertiliser used after transplanting at the same rate as the drench (3 kg in 510 L water).

The field was irrigated with pond water applied through drip lines. The emitters in the drip lines were spaced 30 cm apart so that each plant at the closest within-row spacing received water. At the wider spacings water dripped onto the plant root and also into the empty spaces within the rows. Halfway through the crop it was observed that the drip lines were blocked with impurities from the pond water. Therefore, the use of the drip lines was replaced by watering can. The plants were irrigated and fertilised at the same rate as previously.

Developmental traits of plants were recorded at each picking from five random plants per plot. These traits were as follows:

- Mean plant height (cm)
- Mean width of plant canopy (cm) - diameter of plant canopy
- Mean number of lateral branches

The mean berry weight (g) was recorded from ten random berries per plot at each picking.

During each picking the berries were graded in the field by placing those damaged in a separate container. This was followed by a further discarding of non-marketable berries during the bagging and weighing process. Following this discarding, the yields of marketable berries from the nett plots were recorded.

RESULTS AND DISCUSSIONS

The time between transplanting and first picking was 80 days. Ten more pickings ensued at intervals which varied due to the load of ripe berries on the plant. Peak crop performance was recorded during the heaviest rainy weather; lower yields were obtained during the drier spells. Between-row spacings did not appear to have an effect on yield performance. Berry yields for intra-row spacings of 30,60, 90 and 120 cm (kg/nett plot of 22 m^2) are presented in Figure 1. Yield patterns were similar for all spacings, showing a general fluctuating trend until week 5, peaking at week 6, declining during weeks 7 and 8 and then increasing until the final picking. Yields remain highest for the 30 cm intra-row spacing, although the differences were only significant at week 5, 6, and 10 associated with higher average yields. Variability in average yield across pickings maybe related to variability in soil moisture content which was higher when rain fell as compared to periods of hot dry weather.

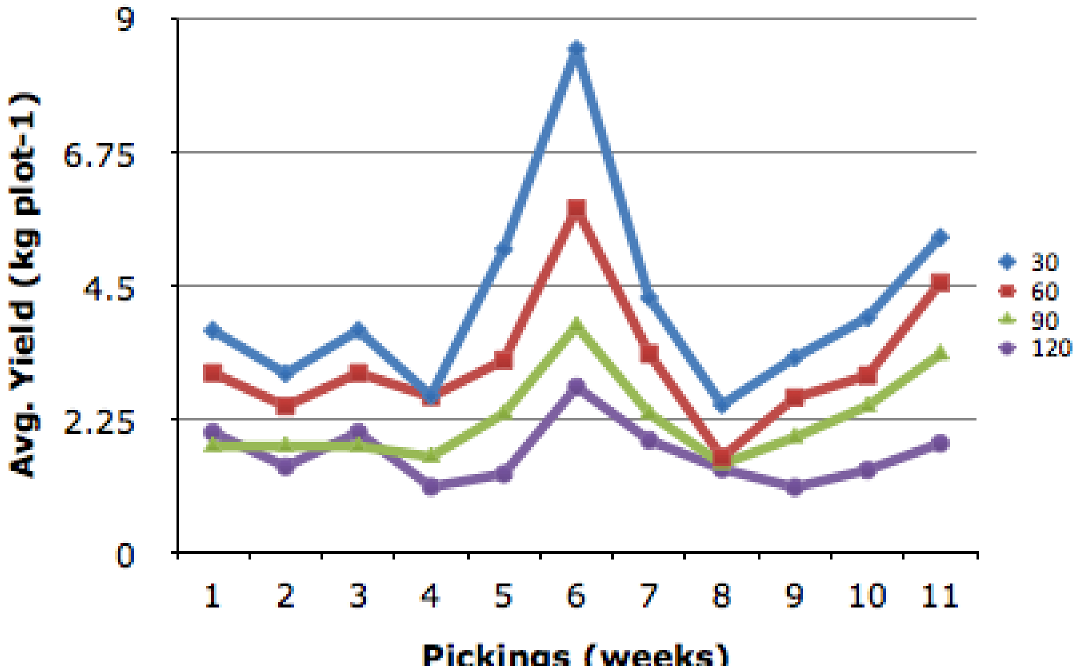

Figure 1 Average yield of hot pepper over 11 weekly pickings for four different intra-row spacings, 30, 60, 90 and 120 cm

The data (Table 2) show that there were no statistically significant differences ($P > 0.05$) between the 16 treatments for the following berry and plant characters:

Table 2 Effects of treatments on mean values for plant height, mean canopy width, mean number of branches and mean weight of berries

Spacing (cm x cm)	Mean plant height (cm)	Mean canopy width (cm)	Mean number of branches	Mean weight of berries (g)
60 x 30	101.8	120.2	3.6	12.5
60 x 60	102.9	119.0	3.5	12.9
60 x 90	78.8	104.2	3.2	11.7
60 x 120	85.4	118.5	4.2	11.1
90 x 30	108.1	133.4	3.3	13.2
90 x 60	100.9	131.3	4.1	12.5
90 x 90	96.1	128.6	4.2	12.7
90 x 120	101.0	148.8	4.4	11.8
120 x 30	103.0	140.1	4.4	12.3
120 x 60	105.8	138.5	4.8	12.4
120 x 90	89.0	118.3	4.0	11.1
120 x 120	92.7	127.5	4.1	12.0
150 x 30	124.2	157.4	4.4	13.1
150 x 60	99.9	151.6	5.4	12.6
150 x120	97.2	149.8	5.3	12.4
150 x 150	96.9	141.4	4.5	11.5
P	0.702	0.457	0.655	0.080

The evidence that mean weight of fully developed berries was not affected by the changing treatments, varying spacings between plants, has important implications both for field production and marketing. Similarly the main treatments had no impact on mean plant height, mean canopy width or the mean number of lateral branches per plant. This last trait was observed to have a direct effect on the number of fruit bearing axils on the plants; the larger the number of lateral branches the larger number of branch axils.

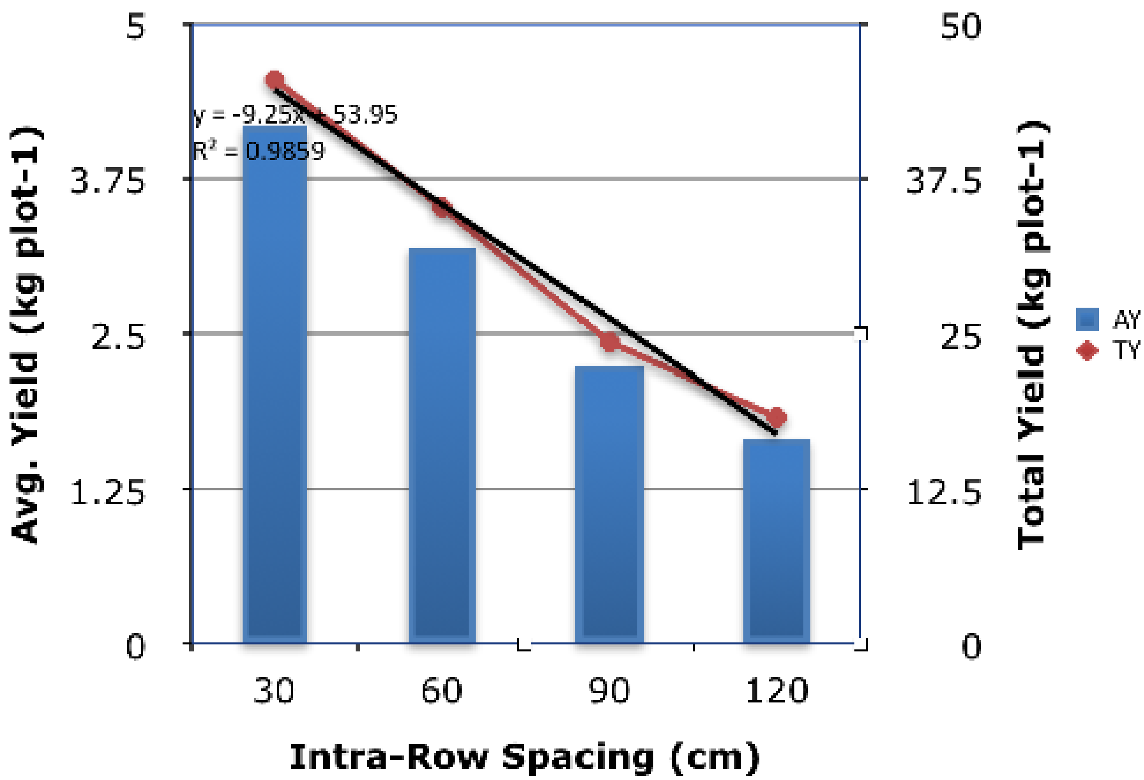

Figure 2 Average and total yield of hot pepper for four intra-row spacings

Statistical analysis revealed significant (P=0.001) main effects of intra-row spacing on average and total marketable berry yield (Figure 2). Increasing intra-row spacing resulted in decreasing average and total yield per plot. A linear relationship (R^2=0.985) was observed between total yield and intra-row spacing, with an almost three fold decrease when spacing increased from 30 am to 120 cm. It is interesting that only the intra-row spacing significantly affected marketable yield, suggesting that population density was not the only factor affecting yield. Since the crop is planted in rows closer spacing along the row irrespective of between row spacing may enhance nutrient use efficiency through greater root density, reduced loss and competition from weeds. Five previous studies agreed with this finding. Adams et al (2001); in Barbados O'Keefe and Pallada (2002) in St.Croix; Skeete et al (2004) also in Barbados; Indalsingh and Antoine (2006) in Trinidad; Skeete (2009) again in Barbados concluded that hot pepper yields steadily increased as in- row spacing decreased.

CONCLUSIONS

The main conclusions drawn from this study are viz.:

1. All the treatments with plants spaced the closest intra-row at 30 cm produced higher yields. Between rows spacings did not affect yields.
2. There were no significant differences ($P > 0.05$) between the 16 different plant population densities for the mean berry weight; this has important implications both for field production and marketing as yields and berry quality can remain high regardless of the plant spacing.
3. This study shows that the optimum within row spacing for the Moruga Red hot pepper variety is 30 cm.
4. Spacing did not affect the number of lateral branches. This means that fruit set which mainly takes place in the branch axils can be increased also through closer spacing.
5. Farmers may wish to utilise closer within-row spacings of 30 cm in the effort of increasing berry yields of hot pepper.

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Evaluation of sweet potato landraces and cultivars for climate change resilience to drought

Herman Adams[1], Bruce Lauckner[1], Gaius Eudoxie[2], Compton Paul[1], Norman Gibson[1], Brent Eversley[1], Kistian Flemming[1], and Nazir Ali[1]

[1] Caribbean Agricultural Research and Development Institute, P.O. Bag 212, The University of The West Indies, St. Augustine, Trinidad and Tobago
Email: hadams@cardi.org

[2]Department of Food Production, Faculty of Food and Agriculture, University of the West Indies, St Augustine, Trinidad and Tobago
Email: Gaius.Eudoxie@sta.uwi.edu

ABSTRACT

The sweet potato, [*Ipomoea batatas* (L.) Lam.], is an important staple food in the Caribbean and other sub-tropical and tropical regions. Food security is threatened in these developing countries particularly by drought brought about by climate change. It is felt that sweet potato can be a crop able to withstand drought and thus contribute to food security. Hence, this trial was implemented to determine drought resistant sweet potato landraces and cultivars. During the period 1 February to 3 June 2014, ten landraces and cultivars of sweet potato were evaluated at the Sugarcane Feeds Centre, in Central Trinidad. The trial was laid out in a randomised block with four replicates. The ten landraces and cultivars were Carrot, Certain, Chickenfoot (local control), John, Maggie, Margarita, Nina, O49, R368 and TIS9191. Data were recorded on the climate, plant morphological characters above ground, plant morphology below ground, storage root yield and pest occurrence.

From the analyses of variance and correlations computed on the data after 3 months drought, it was concluded that the landrace, Certain, yielded the largest quantity of marketable storage roots (1.3 kg per plot, $P < 0.001$), the highest mean weight of fresh biomass per hill (2.6 kg, $P < 0.001$), the largest number of leaves (110, $P < 0.001$) and the longest adventitious roots (28.3 cm, $P=0.003$) per hill. Margarita, Carrot and O49 also exhibited drought tolerance, but at a lower level than Certain. Also, fresh biomass yields at 3 and 4 months after planting were good indicators of final storage root yields in the dry season sweet potato crop.

Key words: sweet potato, *Ipomoea batatas*, drought resistance, cultivars, landraces, storage roots

INTRODUCTION

Small Island Developing States (SIDS) are likely to suffer disproportionately from the enhanced effects of Climate Change. CDERA (2003) indicated a number of negative effects including:

- A 1.5 - 2 ^{0} C increase in temperature
- Subsequent increase in evapotranspiration losses
- Decreased precipitation
- Projections by 2050 for the length of the rainy season - down by 7 - 8 %
- Projections by 2050 for the length of the dry season - up by 6 - 8 %

To mitigate against the above, it is important to determine the responses of landraces and introduced cultivars to the effects of more severe dry seasons.

The sweet potato, [*Ipomoea batatas* (L.) Lam.], is an important staple food crop in the tropical, developing world including the Caribbean (Woolfe 1992). The global sweet potato industry production in 2013 was 110,746,163 MT (FAOSTAT 2013), of which the Caribbean countries produced an estimated 1,103,661 MT. Imports of sweet potato into the Caribbean were negligible for the same year. Some small quantities were processed into value added products such as sweet potato chips, ice cream, bakery products (composite flour), confectionaries, starch and drinks (Adebisola et al. 2009)

The sweet potato landraces and cultivars used in this study, among others, were recently characterised and the data put into a database of the Ministry of Food Production, Trinidad and Tobago (Seesahai and Ramlal 2008). Ten other landraces and cultivars were evaluated in three agro-ecological zones in Antigua and yields from January and October plantings were much higher than April and July plantings. (Robin and Browne 2008). Pertaining to uses, (Adebisola et al. 2009) determined the physicochemical properties of starches from 21 Caribbean sweet potato cultivars that were related to their uses in the production of noodles, pasta, bread and weaning food formulations.

CARDI has been mandated by CARICOM (2011) via its Regional Food and Nutrition Security Action Plan to target sweet potato as a high priority crop in the fight for sustainable food security. In addition, the national food action plans of many Caribbean States (e.g. the National Food Production Plan 2012-2015 of Trinidad and Tobago) target increased production of sweet potato. For this reason, it was critical to evaluate the popular landraces and cultivars of sweet potato in Trinidad and Tobago to determine their ability to produce high yields of storage roots even under drought conditions.

MATERIALS AND METHODS

This trial was designed to measure the response of ten Caribbean, sweet potato landraces and cultivars to drought reflected in low soil moisture and hot and dry environmental conditions.

The trial was sited in a field at the Sugarcane Feeds Centre (SFC) in Longdenville, Central Trinidad (Latitude 10^0 31' 20" N and Longitude 61^0 21' 53" W). The land is 35 m above sea level. The soil is classified (Smith, 1983) as the Piarco Series, Ultisols of the Aquoxic Tropudults sub-group. Deep ploughing (25 - 30 cm) followed a brushcut and preceded rotor tillage, which mixed limestone (6.8 t/ha) and bovine liquid manure (67,312 L/ha), previously applied, into the ploughed layer of the soil. Ridges were formed on the cambered beds 90 cm apart. The trial was laid out as a randomised block design with four replicates. Each gross plot contained 24 hills of each sweet potato landrace or cultivar. Thus the ten landraces and cultivars occupied 240 hills per block (8.8 m^2). The entire four blocks along with a guard row occupied 396 m^2. The trial was planted on 1 February 2014 and the final harvest was done on 3 June 2014, when the crop was 4 months old. The trial was conducted during the dry season.

The landraces and cultivars were: Carrot, Certain, Chickenfoot, John, Maggie, Margarita, Nina, O49, R368 and TIS919. Chickenfoot the most popular landrace grown by farmers in Trinidad and Tobago, was the control.

The parameters indicating resilience or susceptibility to the climate change drivers such as drought and high temperatures (Omotobora 2013; Ekanayake 1990) were categorised and recorded as follows:

A. Climatic

- Weekly rainfall (mm) during the crop cycle;
- Daily maximum temperature (^{0}C) during the crop cycle;

B. Microclimate

- Soil moisture content (%)
- C. Plant morphology above ground
- Plant stand per plot
- Number of leaves per hill
- Vine length (cm) per hill
- Biomass yield (kg) per hill 12 weeks after planting
- Biomass yield (kg) per hill at harvest

D. Plant morphology below ground

- Number of string roots per hill 12 weeks after planting
- Length (cm) of string roots per hill 12 weeks after planting
- Number of storage roots per hill 12 weeks after planting
- Diameter (cm) of storage roots per hill 12 weeks after planting

E. Marketable storage root yield

- Weight (kg) of marketable storage roots per hill at harvest

F. Pests

- Pest infestation (0-5) per plot: 0 = absence 1 = 20%; 2 = 40%; 3 = 60% and 4 = 80% and 5 = 100% infestation of all plants in the plots

Crop care measures were applied when necessary. Two manual weeding and three herbicidal sprays were applied. The herbicides which were alternated thrice were pendimethalin (pre-plant), glyphosate isopropyl amine and paraquat. Additionally, insect pests were sprayed thrice with insecticides (azadirachtin, diazinon, abamectin, alphacypermethrin and thiodicarb) from a knapsack sprayer during the crop cycle. The insecticides were mixed in solutions of two at a time depending on the insect pests present on the crop.

At planting the cuttings were soaked in an insecticidal solution of abamectin and acetamiprid (4 ml in 1 L water) against the sweet potato weevil *Euscepes postfasciatus* Fairmaire. The planting holes were drenched with a solution of 10-50-10 + 1 MgO + trace elements (fertiliser) at 2 ml in 1 L water, tolclofos-methyl at 0.6 ml in 1 L water (fungicide) and diazinon at 0.5 ml in 1 L water (insecticide). At 4 and 6 weeks after planting, granular fertiliser 12-24-12 at 57 g per hill and 16-8-24 at 85 g per hill were mixed into the soil, respectively.

The data was subjected to statistical analyses utilising the GENSTAT (2013) computer software analysis of variance and correlation routines. The means were compared by the least significance difference at 0.05% probability level.

RESULTS AND DISCUSSION

A. Climatic

The dry season lasted for the trial duration (1 February- 3 June, 2014). Figures 1 & 2 show the mean daily maximum temperature and the weekly rainfall over the crop cycle at the SFC for the dry season during the 4 month crop cycle. After week 3, mean daily maximum temperature (averaged over weekly periods), was always above 30 °C and peaked at 32 °C. The first week experienced 30 mm rainfall, the second dropped sharply to about 7 mm; for the rest of the period until week 16, weekly rainfall was generally well below 10 mm, except for three occasions. The dry season ended in the 17th week when the rainfall increased to 25 mm.

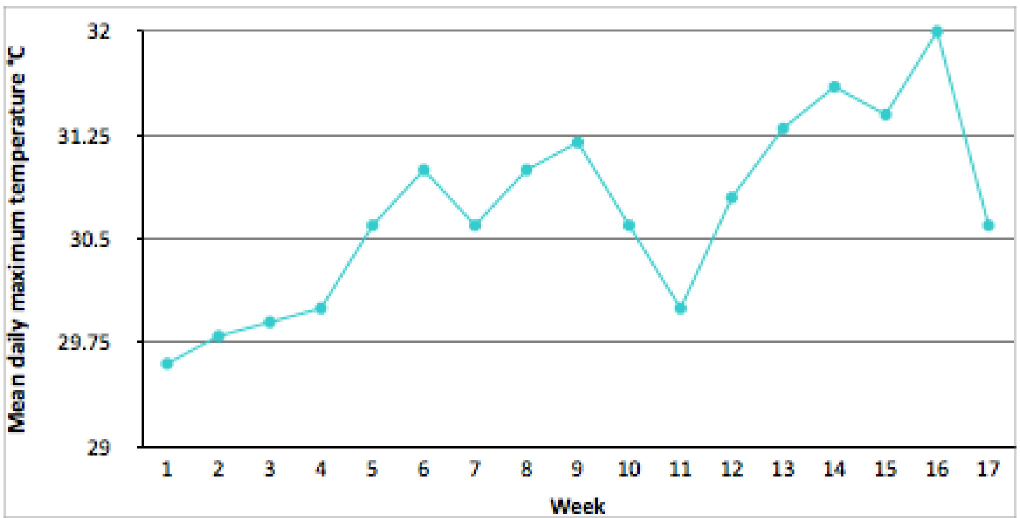

Figure 1 Mean daily maximum temperature (oC) over the crop cycle (1 February – 3 June 2014) at Sugarcane Feed Centre (SFC) Longdenville, Central Trinidad

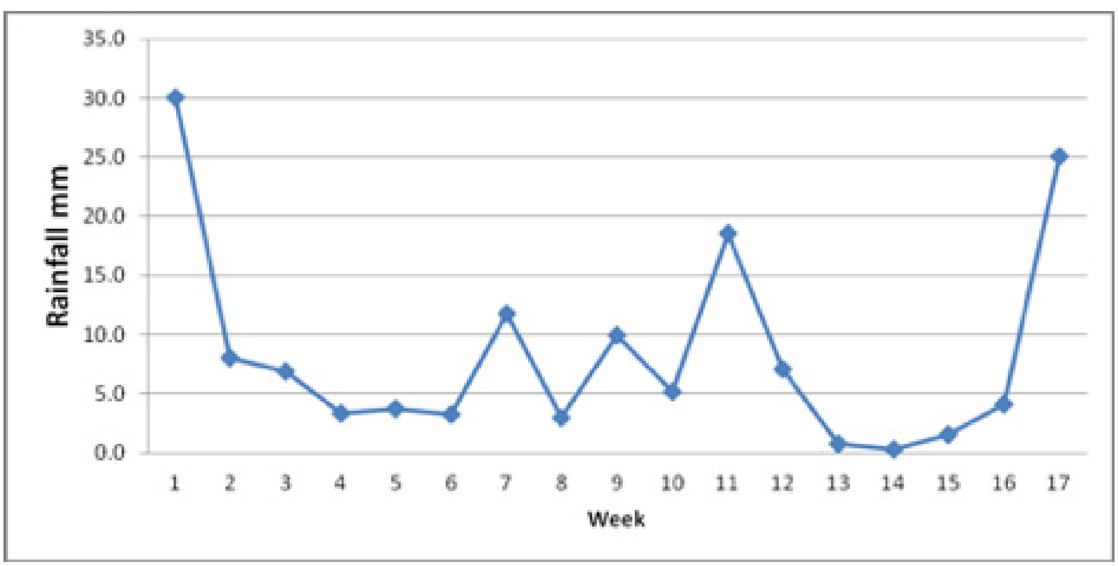

Figure 2 Weekly rainfall (mm) over the crop cycle (1 February – 3 June 2014) at Sugarcane Feed Centre (SFC) Longdenville, Central Trinidad

B. Microclimate

The mean soil moisture content over the trial period was between 10 and 13% (Table 1).

C. Plant morphology above ground (Table 1)

Table 1 Data on the twelve parameters measured for the sweet potato climate change evaluation of 10 landraces and cultivars at the Sugarcane Feed Centre at Longdenville, Central Trinidad in 2014

Accession name	Mean weekly soil moisture content (%)	Mean weekly plant stand per plot	Mean weekly number of leaves per hill	Mean weekly vine length (cm) per hill	Mean biomass yield (kg) per hill at 12 wk	Mean biomass yield (kg) per hill at harvest	Mean number of string roots per hill at 12 wk	Mean length (cm) of string roots per hill at 12 wk	Mean number of storage roots per hill at 12 wk	Mean diameter (mm) of storage roots per hill at 12 wk	Mean pest infestation per plot (0-5)	Mean weight of marketable storage roots per hill at harvest (kg)
Carrot	10.5	22	68	45.5	0.9	2.0	9.5	14.3	9.0	23.2	0.0	0.89
Certain	10.3	22	110	51.2	2.6	4.1	8.3	28.3	3.8	14.7	0.1	1.28
Chicken foot	11.9	22	107	34.0	1.1	2.2	9.3	15.4	5.0	9.2	0.0	0.38
John	10.5	20	53	39.1	0.7	1.1	5.0	16.6	3.5	6.8	0.1	0.08
Margarita	11.8	23	94	102.0	1.1	2.2	5.0	18.9	6.0	21.9	0.0	0.70
Maggie	10.2	21	93	37.2	1.2	1.5	8.5	27.3	3.3	7.5	0.0	0.39
Nina	13.2	23	95	37.1	1.0	1.8	9.3	16.1	5.3	10.3	0.0	0.57
O49	11.6	21	100	61.2	1.8	3.1	7.0	16.0	2.5	22.8	0.3	0.64
R368	11.2	24	85	70.0	1.0	1.5	6.5	17.1	6.8	18.8	0.0	0.52
TIS9191	10.5	23	85	52.1	1.0	2.0	8.8	17.9	4.0	19.0	0.0	0.65
LSD (5%)	2.8	2.0	20.3	10.2	0.7	0.9	4.3	7.3	3.4	14.4	0.1	0.39
P	0.451	0.053	< 0.001	< 0.001	< 0.001	< 0.001	0.252	0.003	0.018	0.132	< 0.001	< 0.001

Mean weekly plant stand per plot
The number of plants per plot varied between 20 for the landrace John to 24 plants for the cultivar R368. The differences between the landraces and cultivars were not quite significant (P=0.053). However, as the differences were relatively small, it can be assumed that the accessions were managed equitably thus permitting valid comparisons among them.

Mean weekly number of leaves per hill
The differences among the landraces and cultivars for the mean number of leaves per hill were statistically very significant (P<0.001). The smallest number of leaves was produced by the landrace, John, and the greatest number of leaves was counted on the landrace, Certain. The accessions leading in this trait were Certain, Chickenfoot and O49 all with over 100 leaves.

Mean weekly vine length per hill

The landraces and cultivars differed very significantly ($P<0.001$) in this trait. The shortest vines were produced by Chickenfoot (34.0 cm), Maggie (37.2 cm), Nina (37.1 cm) and John (39.1 cm). The longest vine growth was measured on Margarita (102.0 cm). The other landraces and cultivars hovered around the grand mean of 53 cm.

Mean total biomass per hill at 12 weeks after planting

Very significant differences ($P<0.001$) among the landraces and cultivars were observed for this attribute. The mean total biomass per hill at 12 weeks after planting ranged from 0.7 kg for John, the least, to 2.6 kg for Certain, the most productive landrace for this trait in the trial.

Mean total biomass per hill at harvest

The mean weight of the total biomass above and below ground per landrace and cultivar at harvest differed very significantly ($P<0.001$) ranging from 1.1 kg per net plot for John to 4.1 kg for Certain. This parameter also indicated the landraces and cultivars which were more productive, despite the dry conditions that prevailed during the trial.

D. Morphological plant attributes below ground (Table 1)

Mean number and mean length of string roots per hill 12 weeks after planting

The total number of roots per hill can be roughly categorised as storage and string (adventitious) roots. The former develop into storage roots which store energy and grow into edible marketable roots. On the other hand, the string roots mainly transport water and plant nutrients from the soil into the above ground parts of the plant, where photosynthates are produced and returned to the storage roots (CIP 2014). Thus the string roots apart from anchoring the plant into the ground physically, indirectly contribute to the yield of edible, marketable roots. Both parameters are important to plant nutrition and indirectly to the production of yield of storage roots.

The mean number of these string roots per hill was statistically the same for all ten landraces and cultivars ($P=0.25$). However, the mean total length of string roots per hill was very significantly different ($P=0.003$) among the landraces and cultivars. The least was Carrot with 14.3 cm and the longest was Certain with 28.3 cm. Physiologically, it is the total length of the string roots per hill that would be more important to the final yield of edible and marketable roots. The mean length of these string roots is by no means the full measure of the part they play in the overall network of fibrous roots. They do, however, give a good indication of the relative size and effect on yield of the full root system.

Hence, it can be concluded that the landraces best adapted to drought, by virtue of the longest string root system, were Certain (28.3 cm) and Maggie (27.3 cm).

Mean number and mean diameter of storage roots per hill at 12 weeks after planting

The mean number of storage roots per hill of the 3 month old sweet potato crop is a good indicator of productivity in the face of low soil moisture of around 10 - 13% and high, ambient maximum temperatures ranging from 30 – 32 ^{o}C. The differences between the landraces and cultivars for this indicator of productivity were statistically significant ($P=0.018$). The mean number of storage roots per hill ranged from 2.5 for the landrace O49, to 9.0 for Carrot, the most productive sweet potato landrace with respect to the mean number of storage roots per hill. The mean storage root diameter per hill 12 weeks after planting ranged from 6.8 mm for John to 23.2 mm for Carrot. However, there was considerable variation between the individual tubers and as a result, there were no significant differences (P=0.132) in mean root diameter among the landraces and cultivars.

E. Marketable storage root yield (Table 1)

The mean yields of marketable storage roots per hill at harvest (4 months after planting) ranged from 0.1 kg for John to the highest of 1.3 kg for Certain, which was statistically greater (P<0.001) than all the other landraces and cultivars. There were five landraces and cultivars (Carrot, Margarita, TIS9191, O49 and Nina) which yielded from 0.5 - 0.9 kg marketable storage roots per hill. It can therefore be concluded, given that the yield of marketable storage roots per hill of sweet potato is the truest economic indicator of resilience to drought and high soil temperatures (Omotobora 2013), that the landrace, Certain, was the most resistant accession in this trial. The nine other accessions exhibited less tolerance than Certain, as determined by the mean yield of marketable storage roots in this trial.

F. Pests

Pest infestation during the trial was very low with the mean pest score per plot below 1 (20%) for each accession. The mean score per plot ranged from 0.01 to 0.3. The differences among the landraces and cultivars, however, were statistically very significant (P<0.001). The lowest pest infestation per plot was 0.01 as recorded for Carrot, Chickenfoot, Margarita and Nina.

CORRELATIONS

The correlations between marketable yield of storage roots and some other parameters are listed in Table 2.

Table 2 Correlations between marketable storage root yield and other parameters measured for the sweet potato climate change evaluation of 10 landraces

	Correlation	P
Mean biomass yield (kg) per hill 12 weeks after planting	0.536	<0.001
Mean biomass yield (kg) per hill at harvest	0.651	<0.001
Mean number of string roots per hill 12 weeks after planting	0.016	0.923
Mean length (cm) of string roots per hill 12 weeks after planting	0.102	0.535
Mean number of storage roots per hill 12 weeks after planting	0.251	0.124
Mean diameter (cm) of storage roots per hill 12 weeks after planting		0.016

The yield of marketable storage roots was positively and relatively highly correlated with the mean total biomass yield at 12 weeks after planting (0.536) and later at harvest (0.651). These two correlations were statistically very significant (P < 0.001) whilst the only other significant (P=0.016) correlation (0.385) was between the yield of marketable storage roots and the mean diameter of storage roots per hill.

Additionally, there was no significant correlation between pest infestation and the mean yield of marketable storage roots.

CONCLUSIONS AND RECOMMENDATIONS

From the data generated, the following main conclusions pertinent to drought tolerance/resistance of the 10 sweet potato landraces and cultivars in the dry season of 2014, can be drawn:

- Landraces Certain, Chickenfoot and the cultivar O49 produced the largest mean number of leaves per hill which gave them an advantage in leaf area available for photosynthesis;
- Landrace Margarita produced the longest mean vine length per hill at harvest (4 months after planting);
- Landrace, Certain, produced the heaviest total biomass above and below ground 12 weeks after planting and 1 month later at harvest. The weight of total biomass yield was the best indicator for selection of the most productive sweet potato landraces and cultivars under drought conditions in this trial;
- The landraces best adapted to drought by virtue of the longest string root systems per hill, were Certain, Margarita and Maggie.
- Carrot was the most productive sweet potato landrace with respect to the mean number of storage roots per hill. However, all 10 landraces and cultivars displayed statistically the same mean storage root diameter per hill 12 weeks after planting;
- The landrace, Certain, was the most resilient to drought in this trial due to the production of the highest marketable yield of storage roots per hill at harvest.

Hence, by adopting the definition (CIP 2014) that "a resilient genotype is one that has a high diversity of traits to respond to different drought scenarios" and considering all aspects of the data presented, it can be concluded that the most drought resilient landraces and cultivars in this trial were Certain, Carrot, Margarita, TIS9191 and O49, in descending order, during the 2014 dry season.

ACKNOWLEDGEMENTS

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P.O. Bag 212
University of the West Indies
St. Augustine Campus, St. Augustine
Trinidad and Tobago

Email: infocentre@cardi.org
Website: www.cardi.org
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