CIFSRF CARICOM
Food Security Project

Improving the Nutrition and Health of CARICOM populations

(CIFSRF – IDRC Project 106525-002)

ANNEX 7

Final Technical Report (2011 – 2014)

Greenhouse and Open Field Agricultural Diversification

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THEMATIC AREA: **Agricultural Technologies for Food Production**

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CONTENTS

OVERALL PROJECT OBJECTIVE ADDRESSED:

Develop food production systems based on agricultural diversification, conservation of water, and efficient use of land.

RESEARCH PROBLEM AND CONTEXT

Project researchers investigated sustainable protected agriculture and open field production systems to improve and increase production with the aim of further diversifying meals for children in the School Feeding Programme (SFP) with a year-round supply of fruits and vegetables.

Protected Agriculture

Protected agriculture (green house) systems can address the limitations of open field cultivation of vegetables, with the potential to generate additional income for farmers and contribute to improved CARICOM food security by increasing year- round supply of vegetables. Throughout the Caribbean, many entrepreneurs from rural and urban communities have adopted protected agriculture as a strategy to optimize yields, productivity and profit from their enterprises. Despite the potential of this technology, there have been many challenges that affect the optimization of vegetable production under greenhouse conditions in the Caribbean. These challenges include the need for appropriate greenhouse designs for the region's temperature and climatic conditions, development of adaptable, high-yielding and disease-resistant/tolerant crop varieties, development of low cost and sustainable growing media, and management of water resources, plant nutrition and pests and disease. There is also a lack of information regarding best practices for producing vegetables (such as tomato and sweet pepper) under greenhouse agriculture structures.

Greenhouse media play a critical role in ensuring root and plant response under fertilization but most available media are imported and very costly. Local growth media could be used to replace many of these imported media types. This research addressed many of these challenges with an overall aim of enhancing year round availability of local vegetables for school feeding and other markets.

The objectives of the research were:

1. Selection of suitable varieties for production under a protected agriculture structure.
2. Selection of the best media for production under a protected agriculture structure.

Open Field Crop Diversification

Pumpkin is an important traditional vegetable crop produced in Trinidad and Tobago, St. Kitts and Nevis and other CARICOM countries, and it is an important food item for improving the nutritional quality of school lunch menus. Many farmers grow pumpkins because it takes a relatively short time to produce fruits (between 3 and 3 ½ months). Most farmers plant one crop in June/July and the other crop in October/November, and farmers who have access to irrigation systems can often produce the crop year round. Selection of improved varieties could further enhance pumpkin production by local farmers.

For these reasons, the project conducted "open field" crop variety trials to improve the productivity of pumpkin, and to complement the drip irrigation studies with pumpkin, as discussed above. The field trials were also conducted in response to a needs assessment among stakeholders in Trinidad. The results of the needs assessment led to the development of the following specific research objectives:

1. Evaluate the productivity of pumpkin cultivars for the local and export market.
2. Evaluate pumpkin production programmes and determine the impact of production practices on post-harvest quality

A baseline study was conducted to evaluate a promising line developed by the Trinidad and Tobago Ministry of Food Production, along with other local and imported varieties (Crapaud back, Bodles Globe and Future NP-999) that meet the demand for the local and export market. Emphasis was placed on identifying the most suitable variety, with greatest potential for year-round, high-quality produce.

METHODOLOGY

Protected Agriculture

Characterized design for protected agriculture in CARICOM countries

Crop production in the Caribbean is subject to various stresses: water shortage during the dry season, heavy rainfall during the rainy season and insect infestations. Protected agriculture systems using greenhouses protect crops from these extremes. An appropriate greenhouse design and structure has been identified as one of the major challenges facing greenhouse producers in the Caribbean. The challenge is to design a greenhouse in a climate characterized by high levels of irradiation, outdoor temperature and humidity, in which a manageable microclimate can be created that is suitable for crop production and has a low risk for pest and disease infestation and is also adapted to the cropping system. Dr. Mark Lefsrud, McGill University, in consultation with the UWI research team, worked on developing protocols for testing the new Natural Ventilation Augment Cooling (NVAC) greenhouse (ventilation improved by coupling natural ventilation with controlled ventilation using fog misters) to address this challenge. The NVAC greenhouse was designed using AutoCAD.

Quantification of Food Crops Productivity: Tomatoes and Sweet Peppers

Protected agriculture is viewed as a viable technology option to achieve year-round supply of vegetables to the School Feeding Programme. In Trinidad (UWI) and St. Kitts (CARDI), project researchers tested the performance of heat tolerant tomato and sweet pepper varieties in various media types under greenhouse conditions over a 3-year period.

Evaluation of tomato and sweet pepper cultivars using different media under a protected agriculture structure

Comparative greenhouse studies were undertaken at the University of the West Indies (UWI) Field Station in Trinidad, and at the Caribbean Agricultural Research and Development Institute (CARDI) in St. Kitts to investigate growth and yield parameters of two crops, tomato and sweet pepper, grown on contrasting growth media types. Growth media types which are readily available in both islands were assessed.

Studies at UWI, Trinidad

In Trinidad, during 2011-2012, seven tomato cultivars (Hybrid 61, Versatile, Summer Star, IT71, Rhapsody, Caraibe and Striker) and five sweet pepper cultivars (Geneva, Aristotle, Admiral, Bullnose, and Canape) were planted in coconut coir or sharp sand medium in a completely randomized block design. Yield data were taken over a period of four months according to variety, media and marketable yield.

In separate trials, growth and yield parameters of tomato (Calypso) and sweet pepper (California wonder) were tested using seven growth media types:

- Perlite (imported media)
- Vermiculite (imported media)
- Coconut coir (local media)
- Grass compost: Perlite (media mix)
- Spent mushroom substrate: Perlite (media mix)
- TTABA: Perlite (media mix)
- Spent mushroom substrate: sharp sand (local media mix)

During 2013-2014, additional trials were conducted in Trinidad using the best performing growth media from the previous study and two varieties of tomato and sweet pepper from the previous greenhouse trials. The following growth media mixtures were selected for this trial: sharp sand and coconut coir; compost and sharp sand; and compost and coconut coir. The tomato varieties were Mattias and DRW 7719; and the sweet pepper varieties Palladin and Canape. These were planted in a Gable roof greenhouse, a tunnel and in an open field. The cycle of the two crops was six months.

CARDI, St Kitts

In St. Kitts, during 2011-2012, varietal evaluation trials of sweet pepper and tomato began in June 2012 under the protected agriculture structure. Three varieties of tomato (Beverly, Striker and Caraibe) and three varieties of sweet pepper (Crusader, Palladin and Bipode) were evaluated in three different media (coconut coir, soil and manure, and sharp sand). The trial was redesigned to take advantage of the space under the structure and thus differed from that at the UWI. This resulted in eight replications of three varieties and three growing media treatments. "Grow bags" were filled with sharp sand and a soil and manure mix of 1:1 as recommended by the protocol from UWI. One set of bags came already filled with coconut coir. The trial was planted on 21 June, 2012. Three times per week, plants were fertilized manually. Nutrients provided by UWI were used in the production system and included starter (N:P:K 10:52:10), potassium nitrate (N:P:K 13.5:0:46.2), magnesium sulphate and tomato hydroponic fertilizer (N:P:K 4:18:37). Calcium was supplied by using Calmax (N:P:K 2:0:0). It was observed that the plants in the soil/manure mix had a high mortality rate even after supplying the fertilizer. The mixture was changed to a two parts soil to one part manure mix.

Plant height, leaf number, stem diameter, number of buds, number of flowers and number of fruits were measured bi-weekly.

A multi-parameter PCS tester (Oakton Waterproof Multiparameter PCS Testr 35 Pocket Meter, Vernon Hills, Illinois, USA) was used to measure total dissolvable solids, electrical conductivity, pH, salts and temperature of the leachate every three weeks from August to October 2012.

Open-Field Crop Production of Pumpkin

During 2011-2012, one cycle of pumpkin was planted simultaneously at the UWI Field Station and on farmers' fields in Trinidad. Three pumpkin varieties (Bodles Globe, Future NP-999 and Crapaud back) were evaluated at the UUW Research Station and one variety (Bodles Globe) at the farmers' fields.

During 2013-2014, three pumpkin varieties (Bodles Globe, Future NP-999 and CEStarz) were again planted in the wet and dry seasons using three varying production packages, one of which was the farmers' practice using chicken manure. The other two included production packages from leading input suppliers, Caribbean Chemicals Ltd. and MAFAS Ltd. These production packages were tested to assess their production potential as well as the impact on human health and safety, which was a concern of farmer at a previous workshop. Farmers indicated that they needed information to determine which system was best, and the three varieties were chosen to determine which ones may be best suited for export and for local consumption. Post-harvest studies, which included shelf life and curing were also carried out on harvested produce.

Curing pumpkins extends the shelf-life as research has shown that curing can extend shelf-life for up to 3-months. This process is an essential postharvest operation in the handling system of pumpkins because it hardens the outer rind and induces healing of minor surface physical damage, thereby eliminating any occurrence of secondary microbial invasion and decay. Therefore, we investigated the extent of physical, chemical and sensory quality changes in the three pumpkin cultivars, Bodles Globe, Future NP 999 and Crapaud Back before, during and after curing treatments.

RESEARCH RESULTS AND FINDINGS

Protected Agriculture

Characterized Design for Protected Agriculture in CARICOM Countries

Figure 1 shows the three dimensional AutoCAD model which was prepared to provide computer generated images and dimensions of the three-roofed design, in preparation for prototype construction at McGill University.

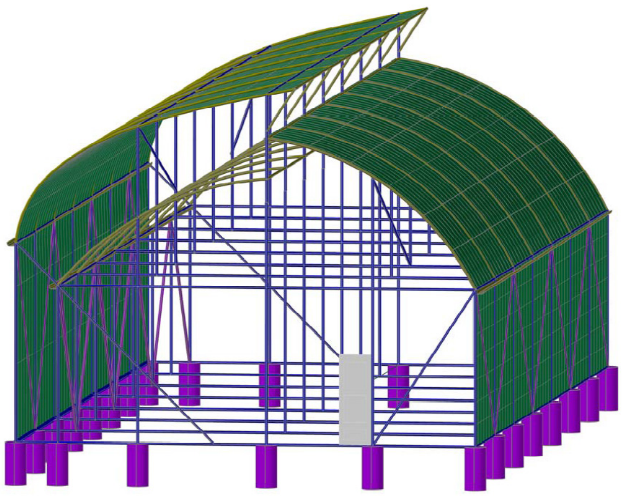


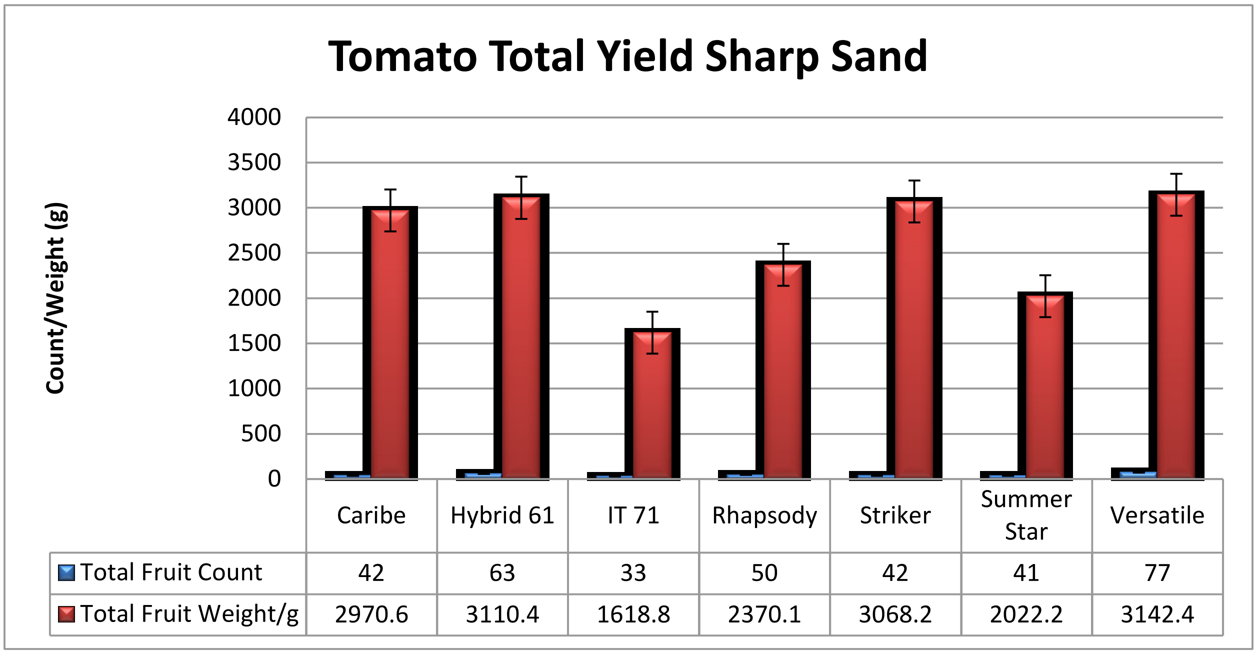
Figure 1: 3D AutoCAD model of NVAC greenhouse

The prototype construction began in spring 2012, and a 10 feet x 20 feet downsized version prototype greenhouse was built to attempt to investigate the air movement and cooling effect first hand (Fateeva, McCartney and Lefsrud, 2012). The prototype of the design was tested at McGill University in the summer months of 2012 because, for logistical reasons, it could not be tested in the Caribbean.

Evaluation of sweet pepper and tomato cultivars under a protected agriculture structure

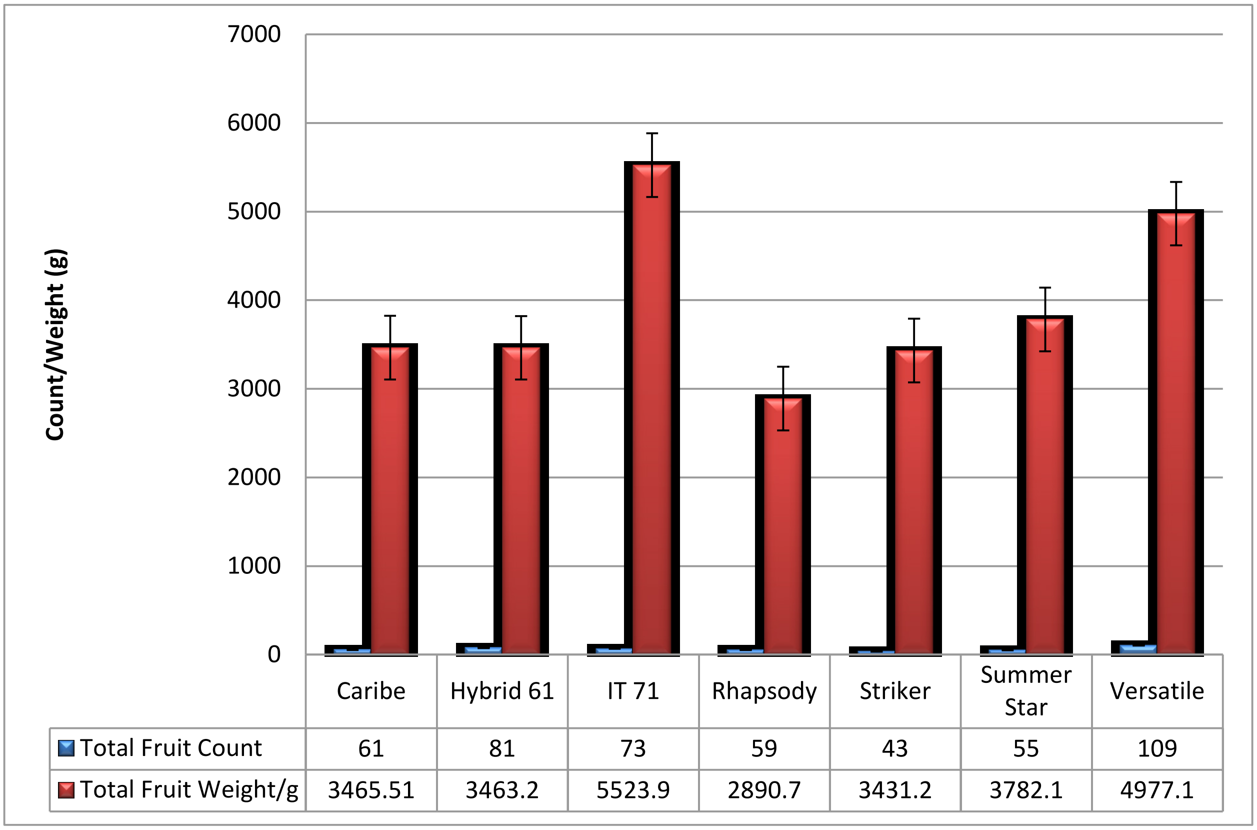
Results from UWI, Trinidad

Generally, coconut coir media produced higher yields both total and marketable (Figures 2 and 3).



	Caribe	Hybrid 61	IT 71	Rhapsody	Striker	Summer Star	Versatile
Total Fruit Count	42	63	33	50	42	41	77
Total Fruit Weight/g	2970.6	3110.4	1618.8	2370.1	3068.2	2022.2	3142.4

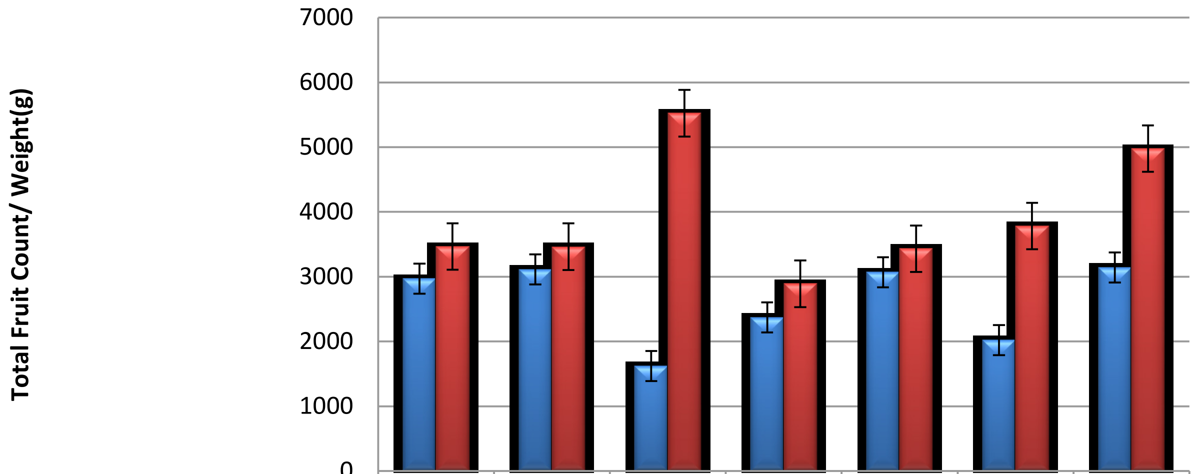
Figure 2: Total yield of tomato in sharp sand



	Caribe	Hybrid 61	IT 71	Rhapsody	Striker	Summer Star	Versatile
Total Fruit Count	61	81	73	59	43	55	109
Total Fruit Weight/g	3465.51	3463.2	5523.9	2890.7	3431.2	3782.1	4977.1

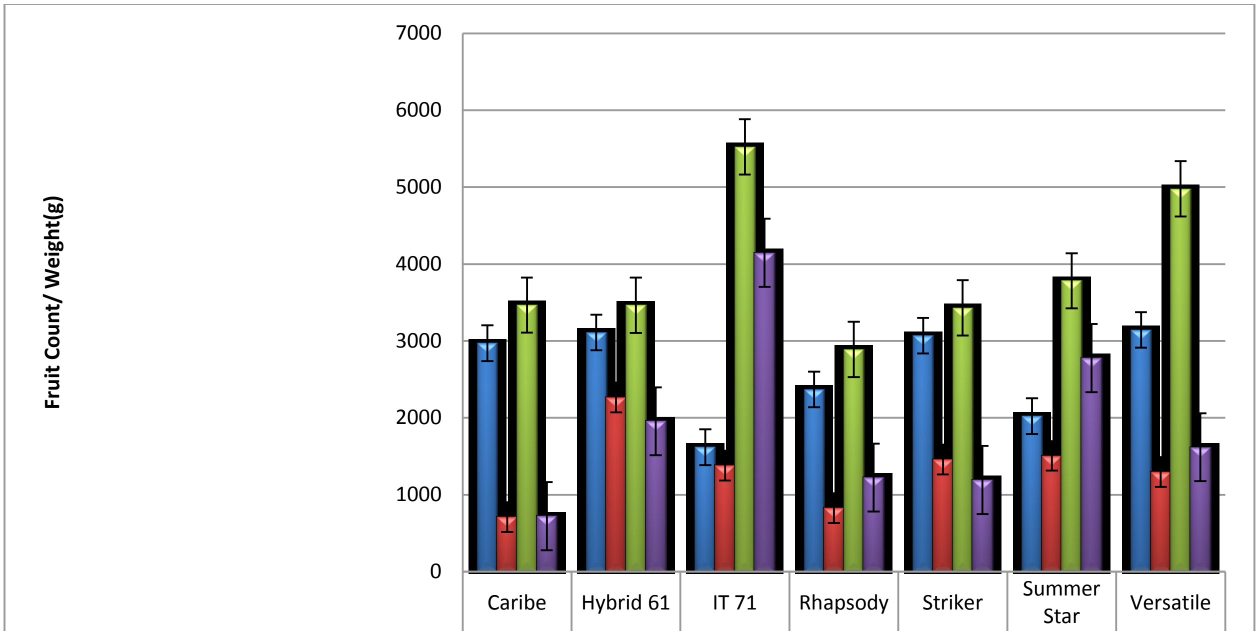
Figure 3: Total yield of tomato in coconut coir

Although IT71 produced the heaviest tomatoes, the fruit count was low. Versatile produced the most tomatoes per plant. Hybrid 61 started out as a very slow producer, but in January 2011, it started to speed up in production and generally maintained its yields almost consistently in both media, making it one of the steadiest producers. Hybrid 61, Versatile and Rhapsody set fruit earlier than the others. Rhapsody was the lowest producer overall, with an average fruit count but lower overall weight yield. Rhapsody produced the largest tomatoes and Caribe the smallest. There were problems in the general management of the greenhouse, which may have contributed to the low yields and concomitant high pathological and physiological disorders. Overall, IT71 and Versatile performed the best. Trials were repeated to improve greenhouse management, including fertilizer regime (Figures 4 and 5).



	Caribe	Hybrid 61	IT 71	Rhapsody	Striker	Summer Star	Versatile
Total Fruit Weight/g Sharp Sand	2970.6	3110.4	1618.8	2370.1	3068.2	2022.2	3142.4
Total Fruit Weight/g Coconut Coir	3465.51	3463.2	5523.9	2890.7	3431.2	3782.1	4977.1

Figure 4: Comparison of total yield of tomato in sharp sand and coconut coir



	Caribe	Hybrid 61	IT 71	Rhapsody	Striker	Summer Star	Versatile
Total Fruit Weight/g Sharp Sand	2970.6	3110.4	1618.8	2370.1	3068.2	2022.2	3142.4
Total Marketable Fruit Weight/g Sharp Sand	708.8	2266.1	1379.7	825.9	1459.1	1505.5	1294.9
Total Fruit Weight/g Coconut Coir	3465.51	3463.2	5523.9	2890.7	3431.2	3782.1	4977.1
Total Marketable Fruit Weight/g Coconut Coir	719.8	1955.2	4145.9	1222.9	1192.2	2777.5	1617.8

Figure 5: Comparison of total tomato yield with marketable yield in different media

Influence of Growing Media on Growth and Yield Parameters of Tomato and Sweet Pepper

Repeated measures analysis showed significant differences for all growth variables among media treatment over time for both crops. Growth media containing compost were taller, with greater stem diameters and flower numbers than soil constituent media. This resulted in a greater number and weight of fruits for the compost treatments. Performance under these conditions was enhanced by chemically active organic media components, which is encouraging as these are produced locally (Figures 6, 7 and 8).

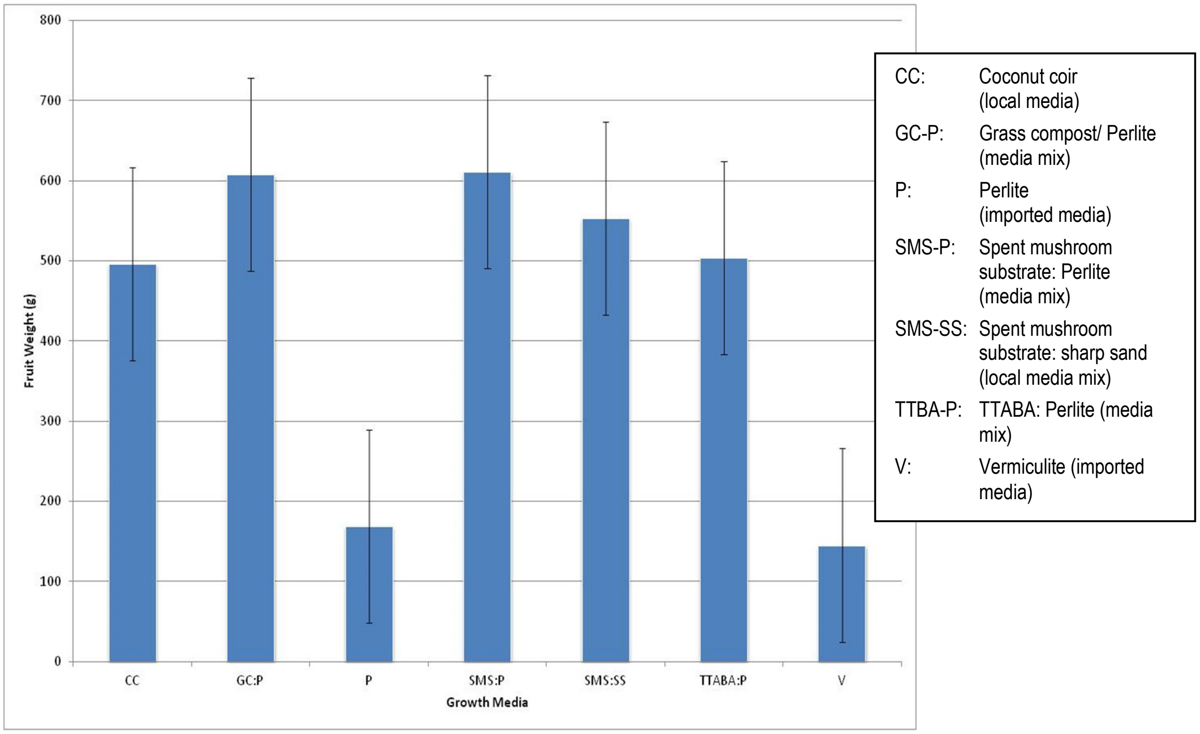


Figure 6: Total yield of sweet pepper for seven media types

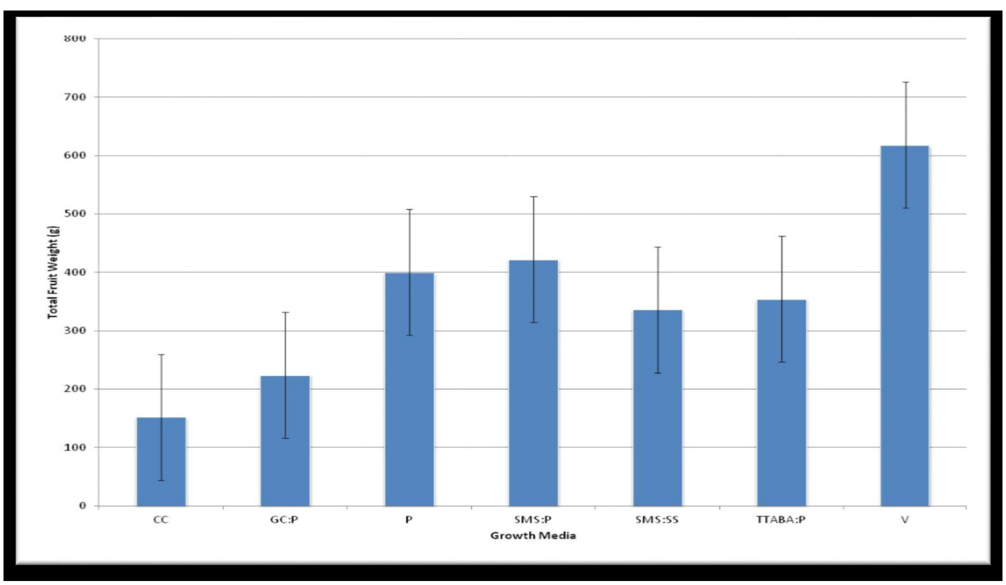


Figure 7: Total yield of tomato grown under seven growth media types

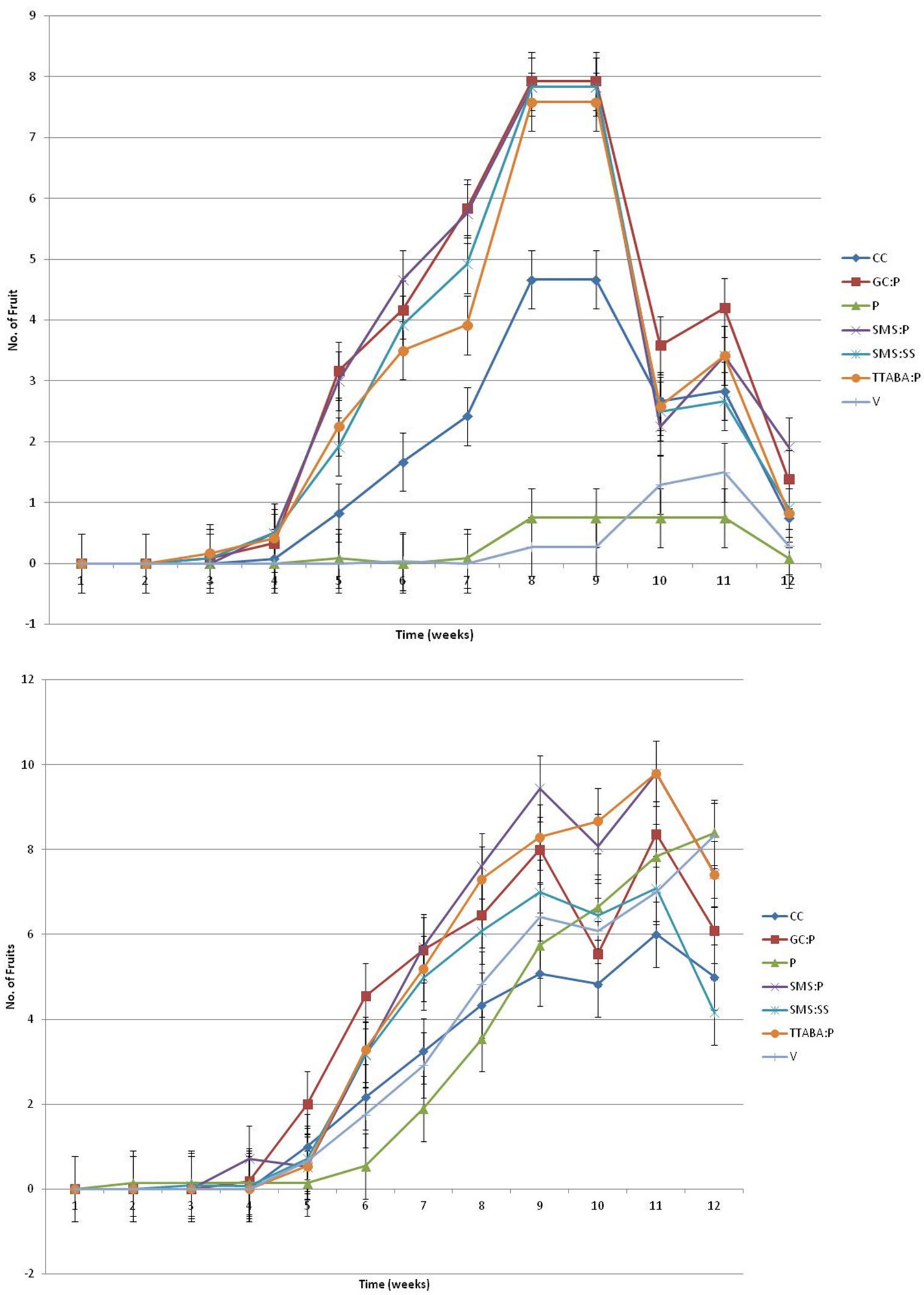


Figure 8: Total number of fruits produced under each growth media type for sweet pepper and tomato

The tomato varieties, Mattias and DRW 7719 and sweet pepper varieties, Palladin and Canape were grown in three types of soilless growth media: sharp sand: coconut coir (SS/CC), coconut coir: perlite (CC/perlite) and compost: perlite (Compost/perlite).

The tomato variety DRW 7719 had the faster growth rate in all three media types. The sweet pepper variety Palladin had a faster growth rate in the sharp sand: coconut coir media; while Canape had higher rates in the other two media (Figure 9).

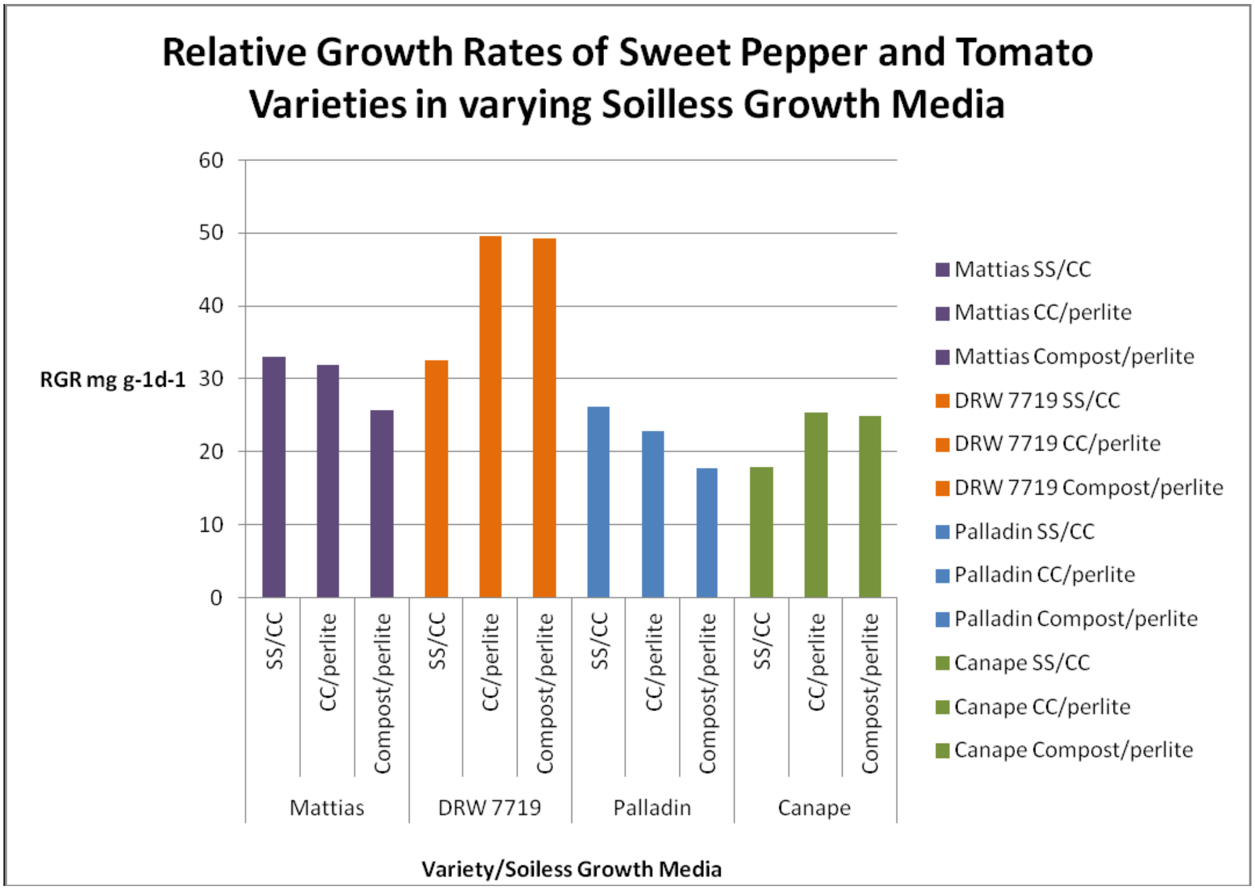


Figure 9: The Relative Growth Rates of Mattias, DRW 7719, Palladin and Canape in Soilless Growth Media

Green house results from CARDI, St Kitts

In St. Kitts (CARDI), three varieties of tomato (Beverly, Striker and Caraibe) and three varieties of sweet pepper (Crusader, Palladin and Bipode) were evaluated in three different media (coconut coir, soil and manure and sharp sand).

Analyses (conducted by laboratories of Agro-services International, Inc., Florida) of the media and water used in the trial revealed a pH of 7.7 for the water; for greenhouse production a lower pH is desirable. The pH of the media was 5.8 for coconut coir, 7.6 for the sharp sand and 8.1 for the soil and manure mixture. All three media had a nitrogen content well below the critical level. Potash, sulphur, phosphate and boron were all above the critical level in the soil and manure mixture. Coconut coir had adequate amounts of magnesium, potassium boron and manganese, while the calcium/magnesium and magnesium/potassium ratios were optimum in the gravel medium.

An analysis of variance conducted on the data indicated that plants grown in coconut coir performed best and those grown in the soil and manure mixture the worst. The tomato variety Striker and the sweet pepper variety Crusader gave the highest yields. There was significant interaction between media and variety in terms of the tomato: all the varieties had their best yields in the coir while medium and worst yields were in the soil and manure mixture. The interaction was not significant for sweet pepper at the 5% level. There was a significant difference between the media when the parameters of pH, electrical conductivity, total dissolved solids, salts and temperature were examined. In the sweet pepper trial, the soil and manure mixture had significantly higher pH than the other two media but was not significantly different from coconut coir when total dissolvable solids, electrical conductivity, salts and temperature were examined.

Open Field Production of Pumpkin

Results indicated that Bodles Globe outperformed other varieties in terms of yield. However, from the sensory evaluation, the Future NP-999 was preferred due to its taste, texture and physical appearance.

Results on the farmer holdings were not too promising as yields were very low and the produce was not true to type as a result of crossing of genetic materials (other pumpkin varieties were grown in the vicinity of the farmers' trial and cross pollination occurred). At the research station, results indicated that Bodles Globe outperformed other varieties in terms of yield. However, from the sensory evaluation Future NP-999 was preferred due to its taste, texture and physical appearance. Skin and flesh firmness and percentage fresh weight losses were increased as curing progressed (Table 1).

Curing promoted the intensity of the yellow flesh colour in one cultivar, Future NP 999, more than other test cultivars. The cooking quality of cultivar, Future NP 999 had the highest rating pre and post curing.

Table 1: Quality parameters of pumpkin cultivars before, during and after curing

Quality parameters	cv. Bodles Globe			cv. Future NP 999			cv. Crapaud Back		
	Day 0	Day 9	Day 18	Day 0	Day 9	Day 18	Day 0	Day 9	Day 18
Fresh weight loss (%)	0.0a	12.6b	34.5c	0.0a	13.8b	32.9c	0.0a	13.5b	34.1b
Skin firmness (g/force)	2793a	2865b	3096c	3085a	3230b	3203b	2886a	2900ab	3027b
Flesh firmness (g/force)	607.5a	801.1b	1121.6c	697.3a	920.2b	1440.5c	631.4a	823.3b	1123.8c

Future NP 999 had the best flesh colour towards the completion of the curing process. This cultivar had superior sensory quality attributes and purchasing and marketability scores compared to the other cultivars (Tables 2 and 3).

Table 2: Colour changes in pumpkin cultivars before, during and after curing.

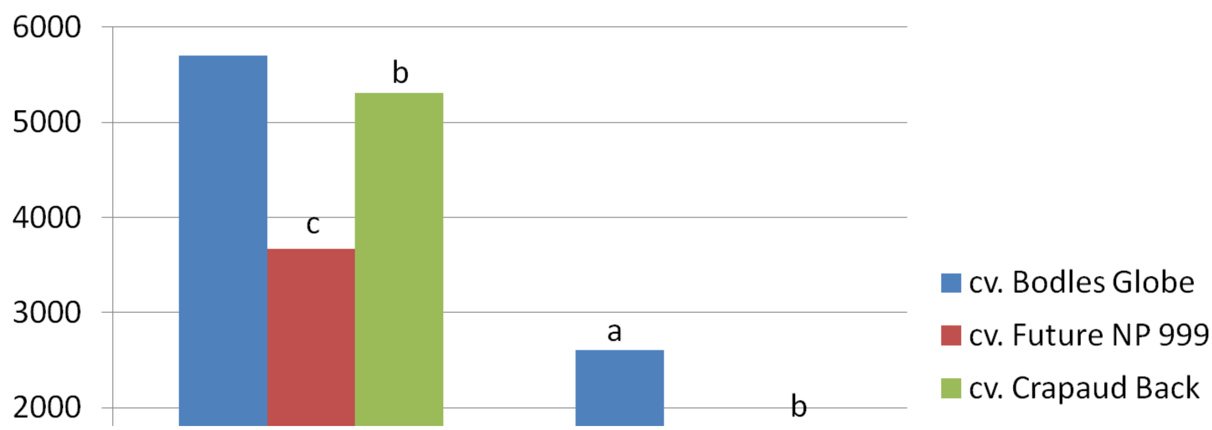
Colour	cv. Bodles Globe			cv. Future NP 999			cv. Crapaud Back		
	Day 0	Day 9	Day 18	Day 0	Day 9	Day 18	Day 0	Day 9	Day 18
Skin L	63.70d	62.90d	63.50d	53.81c	50.0b	42.28a	73.19g	71.90f	68.81e
a	2.25a	4.44b	9.88f	8.38e	7.98e	7.01d	6.98d	5.22c	4.59b
b	20.90c	23.45d	28.80f	20.34c	17.56b	15.09a	28.88f	26.66e	24.35d
Flesh L	66.50f	61.11b	56.60a	66.36ef	66.77f	67.30f	65.96e	65.34d	63.21c
a	21.04d	22.97e	24.66f	9.26a	9.33a	9.30a	21.40d	18.96c	16.41b
b	75.05e	72.22d	61.85a	65.85b	67.01bc	70.35c	68.62c	66.34bc	65.83b

Table 3: Consumer preference and sensory evaluation of pumpkin cultivars before and after curing

Sensory/Consumer Preference	cv. Bodles Globe		cv. Future NP 999		cv. Crapaud Back
	Day 0	Day 18	Day 0	Day 18	Day 18
Colour Score	+2.50	+1.85	+1.67	+0.54	+2.46
Texture Score	+2.33	+0.46	+2.00	+1.46	+1.08

Taste Score	+1.67	-1.00	+1.67	+1.36	+0.69
Sweetness Score	0.83	-0.85	1.67	+1.62	+1.46
Cooking Quality Score	+1.60	+0.23	+1.75	+1.85	+062
Overall Acceptability Score	+2.00	-0.54	+1.83	+1.69	+0.46
Purchase Preference Score	+2.00	-0.27	+3.20	+1.5	+1.00
Recommended For Local Market Score	+1.67	-1.10	+3.2	+1.64	+0.56

Progressive increases in percentage fresh weight losses were noted before, during and after curing for each cultivar. Fruit length for each of the three cultivars was significantly different. Other fruit dimensions such as fruit diameter and cavity volume for cv. Bodles Globe and cv. Crapaud Back were almost twice as much compared to cv. Future NP 999.(Figures 10 and 11)



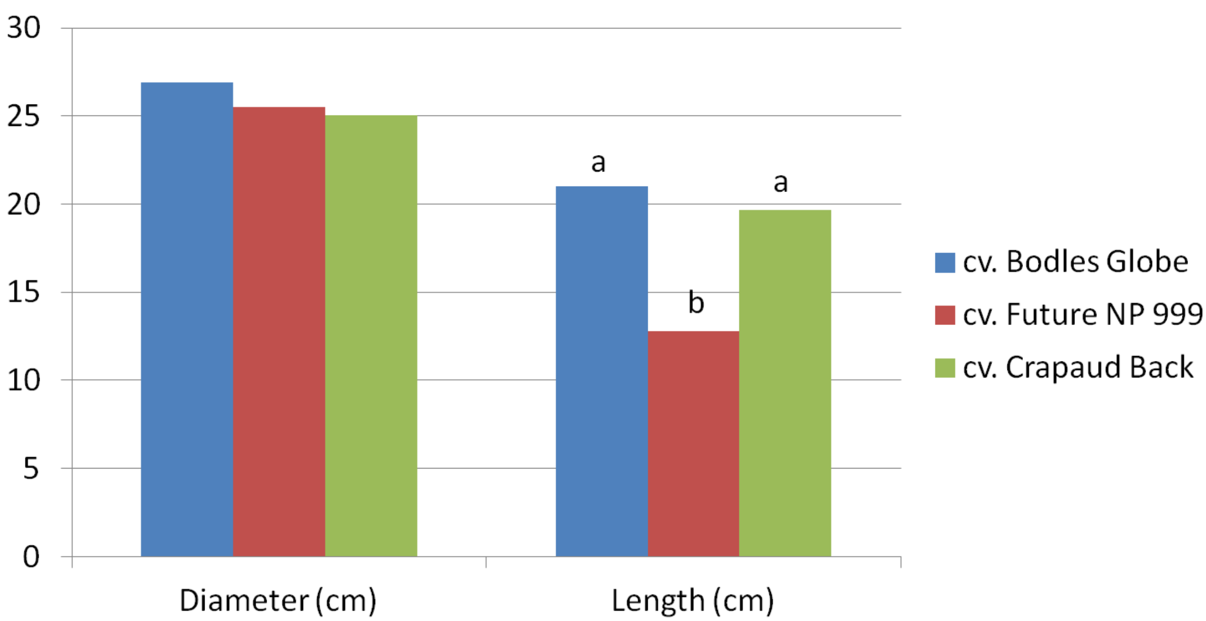


Figure 10: Pre-cured pumpkin fresh weight and cavity volume

Figure 11: Pre-cured pumpkin fruit dimensions

In repeat trials, open-field testing of pumpkin varieties showed local and regionally developed varieties as having great potential for local and export markets. CEStarz and Bodles Globe, two pumpkin lines developed in the Caribbean, had higher yields (2,675 kg/ha and 2,500 kg/ha, respectively), superior taste qualities or nutrient content than the imported variety, Future NP-999 (2,450 kg/ha).

Of the three varieties tested, the Bodles Globe variety demonstrated a shelf life two weeks longer than the other two varieties, and pumpkins grown using the farmers' treatment (well composted manure – 2800 kg/ha) had the highest performance compared to the two other high-input production systems tested (MAFAS Ltd. (2700 kg/ha) and Caribbean Chemicals (1600 kg/ha) Production guides). (Figures 12 and 13).

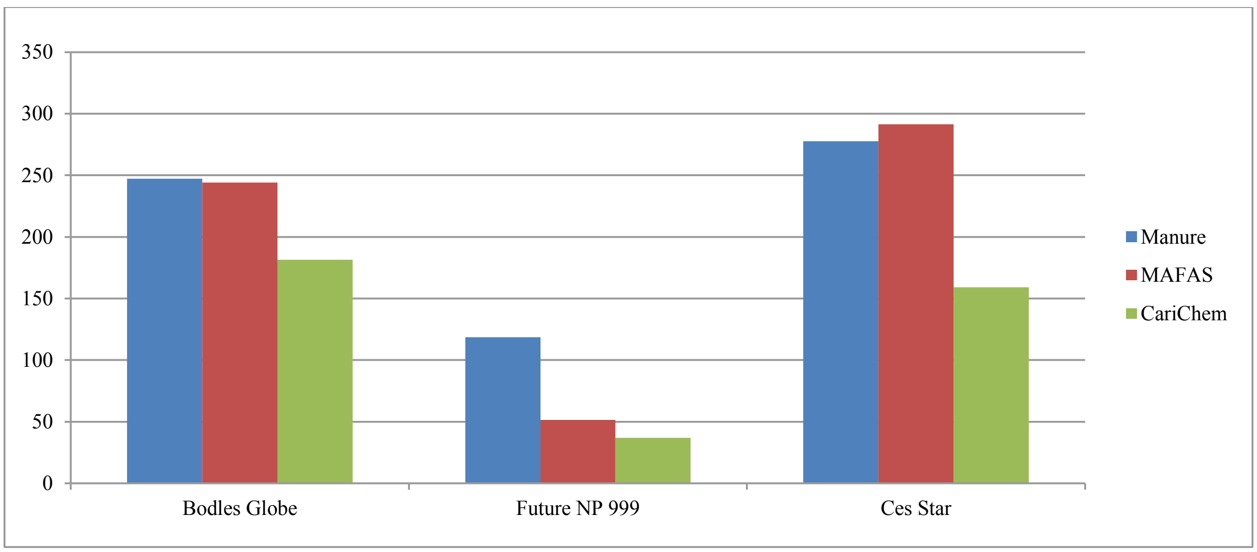


Figure 12. Pumpkin yield (kg/plot) of varieties under various production systems (Manure (Farmers' package) MAFAS and CariChem (Commercial packages) (wet season)

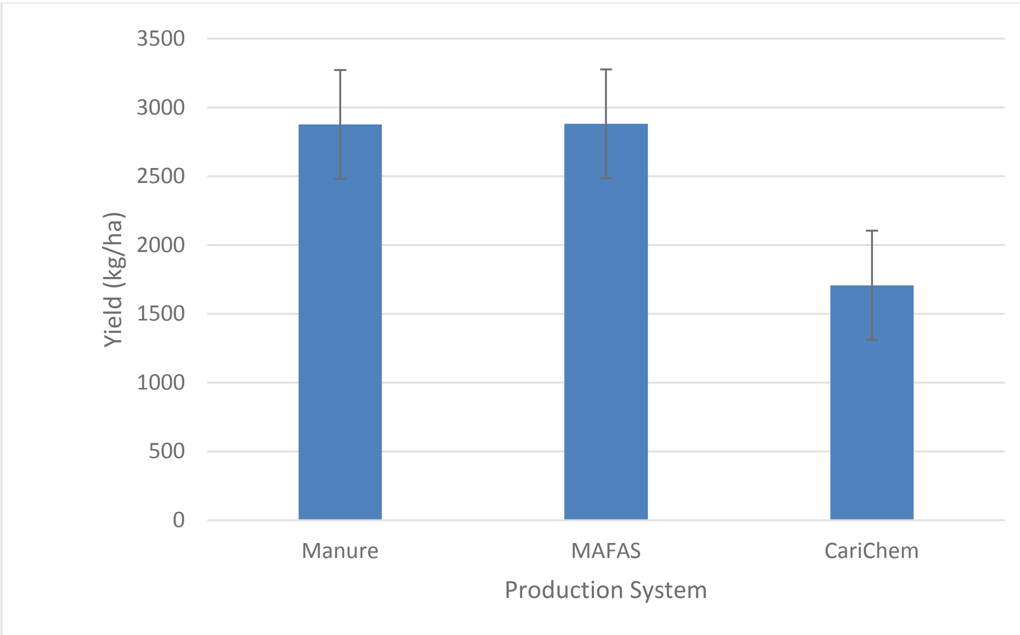


Figure 13. Effect of production system on yield (dry season)

Investing in these regionally developed varieties would harness and secure local genetic resources including seeds, making them more available and accessible for wider use by farmers. Further, our findings suggest that the use of fully composted manure, combined with appropriate curing, could enhance the productivity and quality of pumpkins, and extend the availability of this crop in the off-season production periods. Microbiological analyses conducted on cooked and un-cooked samples of Future NP-999, Bodles Globe and CEStarz pumpkin varieties grown under different production systems showed that samples tested negative for total aerobic plate counts, yeast and mould, *Staphylococcus* spp., *Listeria* spp., *Salmonella* spp. and *E.coli* spp.

OUTCOMES

1. Greenhouse trials conducted during dry and wet seasons showed that year-round supply of tomato and sweet pepper can be achieved. Findings revealed higher marketable yields under the fully enclosed Gable roof greenhouse than under the semi-protected Tunnel for both varieties of tomatoes and sweet peppers.
2. The project achieved, under greenhouse conditions, greater production of tomato and sweet pepper with locally available plant growing media than with imported media
3. Curing of pumpkin can enhance food quality. The nutritive value of pumpkins increases with proper curing procedures. CEStarz was the only variety to show such an increase post-curing under manure treatments. Results therefore indicate that fully composted manure can further enhance the production

and quality of pumpkins for farmers at a much reduced cost and proper curing procedures can lead to the extended availability of pumpkin in off-season production periods.

These preliminary findings suggest that farmers can be encouraged to use low cost production systems that are sustainable to achieve greater yields and maintain a year round supply of pumpkins through proper curing and storage practices.

LESSONS LEARNT

In the last three years, the focus was on researching and developing agricultural technologies to enhance year round production and diversification of food to increase supply to the school feeding programme.

We learned that some of the constraints to agricultural productivity could be addressed by adopting technologies for protected agriculture in order to mitigate the impact of mechanical damage and susceptibility to pest and disease of tomato and sweet pepper crops under open field cultivation.

Improvement in crop management practices by farmers, including selection of varieties, time of planting, appropriate selection of growth media, and adoption of water management strategies, could enhance crop productivity and diversity under both greenhouse and open field conditions of cultivation in CARICOM countries.

While the following situations presented challenges to the conduct of the research activities, they also presented invaluable learning opportunities for future work:

- The NVAC greenhouse (natural ventilation augmenting cooling), which was designed as part of the project outputs to address the critical challenges of humidity and high temperatures faced by Caribbean farmers, was tested under Canadian summer conditions at McGill University. However, it could not be tested in the Caribbean due to logistic difficulties such as administrative delays.
- In Trinidad, challenges were encountered in convincing farmers to participate in participatory research trials in protected agriculture. Because of the high cost and for bio-security reasons, many greenhouse producers are reluctant to allow UWI researchers to enter their structures.
- In St. Kitts (CARDI), there were mineral deficiencies in the sweet pepper and tomato plants; however, this was addressed based on laboratory findings. There were also technical difficulties with the fertigation system and the greenhouse was damaged during the hurricane season of 2012. This damage resulted in delays in repeating trials and when repeat trials were unsuccessful, the project was abandoned.