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Secretariat CFCS
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or from:

CFCS Treasurer
Agricultural Experiment Station
Jardín Botánico Sur
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San Juan, Puerto Rico 00936-1118

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COMPARATIVE YIELD OF FOUR SWEET POTATO (*IPOMOEA BATATAS*) CULTIVARS PLANTED IN SINGLE AND DOUBLE ROWS

J. Broomes. Agronomy Research Variety and Testing Unit (ARVTU), Barbados Agricultural Management Company Ltd. (BAMC)

ABSTRACT: A study was conducted in split-plot design to determine the effect of single- and double-row plantings on the yield of four sweet potato cultivars (local names: 'Manager's Pudding', 'Caroline Lee', 'CBS 49' and 'CBS 32') commonly planted on the estates of the Barbados Agricultural Management Company Ltd. Cuttings were established on raised beds 5.5 ft apart. Single-rows consisted of cuttings placed on the centre of the beds with a spacing of 1 ft intra-row. For the double-rows, cuttings were established on both sides of the bed with 1.5 ft between rows and 1 ft intra-row. Shortly after establishment, the sweet potato was sprayed with Fusilade® (Fluazifop-p-butyl) using the recommended rate for the control of grass weeds. Mono-ammonium Phosphate was manually placed 6 inches away from all cuttings, after they were well established, at a rate of 100 lb per acre. Yield data showed that double-row planting of 'Caroline Lee', 'CBS 49', 'Manager's Pudding' and 'CBS 32' resulted in 21.3%, 31.4%, 16.7% and 16.8% significant decrease in average weight/ tuber, respectively, compared to single-row plantings. The total weight of tubers/ hole also decreased from single- to double-row planting ('Caroline Lee' - 35.7%, 'CBS 49' - 44.7%, 'Manager's Pudding' - 38.5% and 'CBS 32' - 43.5%) due to increased competition for resources in the smaller inter-row space. Smaller tubers were obtained from double-rows. These are suitable for the average household purchaser while the larger tubers from the single-rows are ideal for processors. Data extrapolation showed that the total yield/ acre increased from single- to double-row planting for each cultivar. As one moves from single- to double-row planting, the total number of holes per acre doubles resulting in the expected increase in total yield. Total yield per acre (kg) increased by 28.7% for 'Caroline Lee'; 10.5% for 'CBS 49'; 23% for 'Manager's Pudding'; and 13.0% for the 'CBS 32' cultivar.

Keywords: sweet potato, *Ipomoea batatas*, single-row, double-row, yield, cultivar.

Introduction

In an effort to diversify its operations and also to complement local sugar-cane production, the Barbados Agriculture Management Ltd. (BAMC) established a Food Crop Unit in the year 2011. The food crops were intended to occupy fallow sugar-cane lands as well as to generate additional income. Efforts were primarily concentrated on the cultivation of root and tuber crops such as yam (*Dioscorea alata*), cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*), with minor focus on cash crops such as cucurbits, peppers, etc. Currently, major focus is being placed on the sweet potato within Barbados and the BAMC as it has been identified as critical to building the local food and nutrition security. It is known for its resistance to drought, vigorous growth and its productivity with even the minimum of inputs (FAOSTAT, 2011).

Sweet potato is one of the few domestically produced commodities that is competitive with the imported product in Barbados (Francois, 2000). Barbadians are also discovering new values in relation to sweet potato's pharmaceutical and nutritional content, thereby increasing their consumption (Skeete and Maynard, 2009). Specific to the BAMC, sweet potato is currently the highest income earner among the food crops produced by its Food Crop Unit and so an effort is being made to further improve the agronomic practices related to this crop so as to achieve maximum yields from the available land.

However, there have been some constraints to this effort. There is limited published information on the yields of local sweet potato cultivars in Barbados and so projecting yields can be a challenge. In addition to this, the producers within the Food Crop Unit have identified two recurrent issues which are (1) large sweet potatoes (> 500 g) that are not suitable for sale on the local fresh market as the average household consumer prefers the smaller potato, and (2) limited/ few sweet potatoes per plant which can impact on sales whether it be in-field by the rod (a pole 10 ft in length used as a sale unit) or market sales by the pound. Research has shown that as the spacing between sweet potato cuttings increases, the total number of tubers decreases, while the yield of larger tubers increases (Schultheis, Walters and Adams, 1999). At present, BAMC's sweet potato is planted on single rows with 1 ft intra-row spacing and 5 ½ ft inter-row. Ultimately, it is the aim of the producer to increase the marketable sweet potato yields without a drastic increase in production costs. One such was to achieve this may be to further reduce the spacing between sweet potato plants by planting two rows per bed (double-row) instead of the traditional one row per bed (single-row). There are no studies investigating the effect of single- and double-row planting on the yield of Barbadian cultivars. Therefore, this study was executed with the following objectives:

1. To determine the effect of cultivar and single- and double-row planting on the number, size and weight of sweet potato tubers.
2. To determine the effect of single- and double-row planting on the average yield per acre for each cultivar.
3. To identity optimum inter-row spacing for four sweet potato cultivars.

Materials and Methods

The study was conducted using a split-plot design to determine the effect that single- and double-row planting would have on the yield of four sweet potato cultivars, three of which are commonly planted on the BAMC estates. As shown in Table 1, these were cultivars 'Manager's Pudding', 'Caroline Lee' and 'CBS 49'. One other cultivar called 'CBS 32' was obtained from the germplasm located at the West Indies Cane Breeding Station.

Table 1. The cultivars used in the establishment of the trial and a brief description.

No.	Cultivar	Skin Colour	Flesh Colour	Shape of Tuber	Time to Maturity
1.	Caroline Lee	White/ Cream	White	Round	3 - 4 months
2.	CBS 32	Red-Brown	Deep Orange	Oval	3 – 4 months
3.	CBS 49	Cream	Orange	Elongated	3 - 4 months
4.	Manager's Pudding	Red	White/ Cream	Round	3 months

Site Selection

The trial was established on the lands allocated to the Agronomy Research and Variety Testing Unit at Groves, St. George, Barbados. These soils are described as a yellow-brown association of predominately smectoid clays with average drainage and are known to respond well to tillage and fertilization. The field selected had been under sugar-cane production prior to being planted with the sweet potato and did not have a known incidence of nematodes.

Land Preparation

Firstly, the allocated land was mechanically harrowed and then furrowed in order to break up clumps into loose, friable soil. After a month, where the soil would have been further broken down by the wind and rain, the soil was moulded up into raised beds to allow the sweet potato to develop without restriction, to allow adequate drainage and to make future harvesting easier. The established beds were 5 ½ ft apart which is the regular spacing of all BAMC beds.

Crop Establishment

Vine cuttings, also known as slips, ranging in length from 30 to 40 cm (12 to 15 inches) were selected from healthy plants. Each cutting had 3 to 4 healthy nodes and was planted at a 45° angle. An effort was made to use the apical region of the vines as this is more likely to be free of pest infestations and also gives better yields (Titus, 2008). For the single-rows, cuttings were placed in the centre of the beds with a spacing of 12 inches (1 ft) between plants within the row. For the double-rows, cuttings were established on both sides of the bed with 18 inches (1.5 ft) between rows and 12 inches intra-row. The cuttings were established in the middle of the wet season to ensure an adequate supply of water as no irrigation was available.

Fertilization and Weed Control

Shortly after establishment, the trial plot was sprayed with Fusilade® (Fluazifop-p-butyl) using the recommended rate for the control of grass weeds (1 to 2 L/ acre). The plot was weeded manually twice there-after until the crop cover was properly established. The plot was also baited with rat poison. Following the regular practices of BAMC food-

crop producers, only Mono-ammonium Phosphate (MAP) was supplied to the sweet potato. This was manually applied to the cuttings after establishment at a rate of 50 kg per acre.

Harvest

Before random sampling was undertaken, the sweet potatoes were tested for readiness. The principle harvest maturity measurement for sweet potatoes is root size. Sweet potatoes do not mature as fruits do but continue to grow as long as conditions allow. Hence, the tubers are usually harvested at a size suitable for the intended market (Ministry of Fisheries, Crop and Livestock, 2004). However, because of the nature of this trial, other indicators such flowering vines, foliage senescence (Lebot, 2009) and the exudation of creamy latex from the cut tuber (CARDI, 2008) were used to maintain uniformity.

Statistical Analyses

All data was analyzed using PASW Statistics 18, Release Version 18.0.0, IBM SPSS Inc., 2009, Chicago, IL.

Results and Discussion

As shown in Table 2, results indicate that cultivar had a significant effect on the tuber count/ plant, length and width of tuber (mm) and the average weight per tuber (g). 'Manager's Pudding' has a greater yield potential than all other cultivars evaluated. Results show that even though 'Manager's Pudding' had the lowest number of tubers per plant at 4.9, it had the highest average weight/ tuber (230.4 g) and also had the highest total weight of tubers per plant at 1008.1 g, illustrating that the tubers of this cultivar were indeed heavier. In contrast, cultivar 'CBS 32' averaged the highest number of tubers per plant at 6.5 but it produced the lowest average weight/ tuber of 138.8 g and the lowest total weight of tubers per plant (876.4 g). With regards to length of the tuber, 'CBS 49' was the longest at 130.3 mm, closely followed by Manager's Pudding at 125.4 mm. The 'CBS 32' was least in length at 104.6 mm. 'Caroline Lee' had the widest tubers with an average of 61.0 mm while the 'CBS 32' and 'CBS 49' were the least wide at 51.1 and 53.0 mm, respectively. This measurement was reflected in the shape of the tubers as the tubers of the 'Caroline Lee' and 'Manager's Pudding' were rounder that the more elongated tubers of the cultivars "CBS 32' and 'CBS 49'. The average weight of the tubers from all cultivars fell below 500 g illustrating that these tubers would be acceptable on the fresh market for household consumers due to their smaller size and subsequent ease of use. The cultivars are very different in terms of physically characteristics, so even though a high yielding crop is desired, the producer should also take the wants of the consumer into account before selecting a cultivar for planting.

Table 3 shows that single- and double-row planting had a significant effect on all parameters of the yield of the sweet potato with the exception of width (mm). For tuber count/ plant, length (mm), average weight of tuber (g) and total weight of tubers per

plant (g), the value decreased from single-row planting to double-row planting. This is an indicator that with the increase in rows, there is a subsequent decrease in yield as seen by the reduction in the number, size and weight of tubers. Research indicates that because of the increase in rows from one to two per bed, there is increased competition for limited resources such as land space, sunlight, nutrients and moisture, resulting in the production of smaller tubers. On the converse side, it should also be noted that with an increase in space, the sweet potato plant produces tubers which are larger in size. With decreased competition for resources, the tubers develop rapidly over a shorter period of time as evidenced by their larger size (Schultheis, Walters and Adams, 1999).

Table 2. The effect of cultivar on the yield of sweet potato.

Parameter	Tuber Count/ Hole	Length (mm)	Width (mm)	Average Weight/ Tuber (g)	Total Weight of Tubers per Plant (g)
Caroline Lee	5.2±2.2 b	108.0±30.4 a	61.0±14.0 a	194.5±90.4 a	957.2±467.1
CBS 32	6.5±2.4 a	104.6±13.3 a	51.1±9.1 c	138.8±61.2 b	876.4±484.7
CBS 49	5.0±2.4 b	130.3±22.9 b	53.0±15.3 bc	220.3±170.7 a	946.5±568.9
Manager's Pudding	4.9±1.8 b	125.4±57.5 b	58.2±29.6 ab	230.4±134.6 a	1008.1±525.6
Total	5.4±2.3	117.1±36.6	55.8±18.9	196.0±126.0	947.0±512.0
P	0.00	0.00	0.14	0.00	N.S

Table 3. The effect of single- and double-row planting on the yield of sweet potato.

Parameter	Tuber Count/ Hole	Length (mm)	Width (mm)	Average Weight/ Tuber (g)	Total Weight of Tubers per Plant (g)
Single-row	6.3±2.3 a	124.7±31.2 a	58.9±13.9	246.7±160.4 a	1298.7±573.4 a
Double-row	5.0±1.9 b	113.3±38.6 b	54.3±20.9	170.7±95.6 b	771.2±370.7 b
Total	5.4±2.3	117.1±36.6	55.8±18.9	196.0±126.0	947.0±512.0
P	0.00	0.23	N.S	0.00	0.00

Yield data from Table 4 shows that there was a significant difference between cultivars planted in single- and double-rows for the parameters of tuber count per plant, width of tuber (mm) and average weight per tuber within the plant (mm). For most parameters, there was a decrease in the value from the single-row planting to double-row as evidenced by the percentage change value in brackets. The percentage change in the tuber count/ hole ranged from 1.9% 'CBS 49' to 28.1% for 'Caroline Lee'. This illustrates that the 'CBS 49' is less responsive is terms of the number of tubers it produces with increased competition. However, one should note that even though the 'CBS 49' showed little change in tuber count per plant, it showed the largest decrease in the average weight per tuber with a 31.4% change from single- to double-row planting. There was only an increase in the length (mm) of the 'CBS 32' tubers and in the width of the 'Caroline Lee' and 'Manager's Pudding' tubers from single-row to double-row. As stated before, the decrease in most values is expected because of the increased competition for resources among plants with the reduction in space, resulting in suppressed growth of the tubers from the different cultivars used (Mortley et al., 1991).

Table 5 shows the extrapolated data of the average yield of sweet potato tubers from an acre of production. It is seen that for single-row planting, the total yield per acre ranged from 9775.7 kg for cultivar 'CBS 32' to 10740.3 kg for 'Manager's Pudding'. For double-row planting, the total yield per acre ranged from 11048.4 kg for 'CBS 32' to 13212.1 kg for 'Manager's Pudding'. These values fall above the range quoted for Caribbean sweet potato yields of 3629 to 9071 kg per acre (CARDI, 2008). The extrapolated value for cultivar 'CBS 32' at single-row spacing is grossly lower than the 23859.4 kg per acre reported by Skeete and Maynard (2009) of the Ministry of Agriculture, Barbados. However, the authors of that report gave no indication of spacing used in the establishment of their trial. The difference in figures may therefore be due to variations in agronomic practices, soil type, rainfall, pest and disease incidence, etc. Table 5 also shows that the total yield per acre (kg) increases from single- to double-row planting for each cultivar. From single- to double-row planting, the total number of plants per acre doubled. Even though it was seen that the total yield per plant decreased from single- to double-row planting, the doubling of the number of sweet potato plants within the acre resulted in an increase in the total yield per acre. Total yield per acre (kg) increased by 31.8% for 'Caroline Lee', 23.0% for 'Manager's Pudding', 13.0% for 'CBS 32' and 10.5% for 'CBS 49'. Although these increased yields appear significant, an economic analysis of the spacing data should be undertaken in order to determine if the increase in inputs (labour, cuttings, etc.) is truly reflected in the output (yield of tubers) so as to ensure the best returns on a substantial investment (Schultheis, Walters and Adams, 1999).

Table 4. The effect of the interaction of cultivar and single- and double-row planting on the yield of sweet potato.

Cultivar	Row Type	Tuber Count/ Plant	% Change* in Tuber Count/ Plant	Length of Tuber (mm)	% Change in Length of Tuber	Width of Tuber (mm)	% Change in Width of Tuber	Average Weight/ Tuber (g)	% Change in Average Weight/ Tuber	Total Weight of Tubers/ Plant (g)	% Change in Total Weight of Tubers/ Plant
Caroline Lee	Single	6.4±2.6	(28.1)	125.9±40.2	(21.3)	60.7±15.6	0.7	226.8±111.7	(21.3)	1255.7±441.1	(35.7)
	Double	4.6±1.6		99.1±19.1		61.1±10.5		178.4±74.1		808.0±441.1	
CBS 32	Single	8.0±2.4	(27.5)	102.7±13.6	2.7	53.8±12.4	(7.6)	156.3±82.2	(16.8)	1234.3±661.3	(43.5)
	Double	5.8±1.9		105.5±13.3		49.7±6.7		130.0±46.2		697.5±209.4	
CBS 49	Single	5.1±2.7	(1.9)	142.7±26.7	(10.7)	64.2±18.6	(26.2)	344.6±236.5	(31.4)	1348.6±642.5	(44.7)
	Double	5.0±2.3		124.2±18.0		47.4±9.6		158.2±70.6		745.4±405.0	
Manager's Pudding	Single	5.5±2.0	(18.1)	127.5±25.9	(2.4)	56.7±11.4	4.1	259.2±112.3	(16.7)	1356.1±605.7	(38.5)
	Double	4.5±1.5		124.4±68.4		59.0±35.5		216.0±143.7		834.1±382.1	
Total	Single	6.3±2.7	(20.6)	124.7±31.2	(9.1)	58.9±13.9	(7.8)	246.7±160.4	(30.8)	1298.7±573.4	(40.6)
	Double	5.0±1.9		113.3±38.6		54.3±20.9		170.7±95.6		771.2±370.7	
P		0.048	-	N.S	-	0.035	-	0.001	-	N.S	-

* **% Change refers to % change in parameter from single- to double-row**

Table 5. Average yield per acre from each cultivar in single- and double-rows (extrapolated data) BAMC's single inter-row spacing = 5 ½ ft, intra-row spacing = 1 ft.

Cultivar	Plants per Acre (Single-Row)	Average Yield per Acre (kg) – Single-Row	Plants per Acre (Double-Row)	Average Yield per Acre (kg) – Double-Row	% Increase in Yield
Caroline Lee	Approx. 7 920	9945.1	Approx. 15 840	12798.7	28.7
CBS 32		9775.7		11048.4	13.0
CBS 49		10680.9		11807.1	10.5
Manager's Pudding		10740.3		13212.1	23.0

Conclusions

In terms of yield, cultivar 'Manager's Pudding' showed greatest potential while 'CBS 32' showed the lowest yield potential. However, before suggestions are made as to which cultivar to plant, the producer must consider market preferences and needs as cultivars carry different characteristics, for example, flesh and skin colour, size and eating quality.

It can also be concluded that double-row planting results in lower yields in terms of the number of tubers per plant, size and weight of individual tubers as well as the weight of all tubers per plant. However, it should be noted that both single- and double-row planted resulted in tubers of desired weight, that is, less than 500 g per tuber. These tubers are ideal for sale on the local fresh market as household consumers usually prefer the smaller tubers due to ease of handling.

Finally, although there was a reduction in the yield of tubers from single- to double-row planting among all cultivars tried, the overall yield per acre increased (extrapolated). However, final suggestions should not be made toward double-row planting for an increase in yield until an economic analysis of all factors is conducted.

Recommendations for Establishment of Future Trials

1. Ensure that there is timely harvesting of the sweet potato crop to avoid pest and disease infestation. The cultivar 'Caroline Lee' showed particular susceptibility to the scarabee/ sweet potato weevil (*Cylus formicarius*) in the drier conditions.
2. Rat baiting is essential as the rodents seem to prefer the orange-fleshed sweet potato cultivars ('CBS 32' and 'CBS 49').
3. The effect of a more complete fertilizer regime on sweet potato yield should be investigated. High levels of nitrogen can cause excessive plant vining. However, the sweet potato could benefit from the addition of potash to the soil though improved root development (CARDI, 2008).

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