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The effect of sugarcane stillage on the yield of butternut squash (*Cucurbita moschata*) grown at Tambankulu Estates, a semi-arid region in the north eastern Lowveld of Eswatini.

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Abstract— *An experiment was conducted to compare the effect of sugarcane distillery waste (stillage) and chemical fertilizer (N:P:K; 2:3:2 (22)) on the yield of butternut squash (Cucurbita moschata) grown under rain-fed conditions at Tambankulu Estates in the north eastern Lowveld of Eswatini. The experiment was run for a period of two years. Three levels of fertilizer, 43 kg, 86 kg and 129 kg and three levels of stillage 296 liters, 585 liters and 876 liters were applied to plots each measuring 450 m^2.Yield (fruit weight) and fruit size (fruit length and diameter) characteristics were measured at harvest. Data was subjected to the analysis of variance as per the design of the experiment. Yield and fruit length showed highly significant differences between the factors and levels whereas there were no significant differences in diameter. The highest yield of 960 g/fruit was recorded for stillage when applied at 585 liters followed by the highest concentration of 876 liters that yielded 950 g/fruit. The lowest level of fertilizer yielded the lowest yield of 721 g/fruit, with the two higher levels of fertilizer yielding the same 810 g/fruit. The control treatments with no fertilizer or stillage yielded the same lowest yield on average 550 g. The results of the experiment show that distillery waste (stillage) can be effectively used in the production of butternut squash in place of 2:3:2 (22) fertilizer.*
Keywords— ***Sugarcane stillage, fertilizer, butternut squash.***

I. INTRODUCTION

Butternut squash (*Cucurbit moschata*) is an important summer commercial crop grown by smallholder farmers in Southern Africa and is a type of winter squash (Department of Agriculture, Forestry and Fisheries, 2011). Butternut squashes are increasing in popularity because the opportunity of production and keeping of quality are good and sunburn is not a major problem. The harvested fruit is hardy and can be left on theland for a month or two. It has a sweet, nutty taste similar to that of a pumpkin. It has yellow skin and orangefleshy pulp. When ripe, it turns increasingly deep orange, and becomes sweeter and richer with time. It grows on a vine which a plus for farmers since local material could be used.It is the most commonly and regularly grown delicious vegetable among the cucurbits because it is a rich source of vitamin A, phosphorusand calcium (Yavuz, et al., 2015). It is also an excellent source of fibre, vitamin E, vitamin C, manganese, magnesium and potassium.The young and tender shoots make good vegetable salads.

The cultivation of this vegetable in Eswatini using sugarcane stillage as a source of fertilizer has not been investigated. Sugarcane stillage an organic waste, such as press mud or filter cake, is generated as a by-product of most sugarcane industries and characterized as a soft, spongy, amorphous, and dark brown to brownish material (Ghulam et al.,2012; Wynne and Meyer, 2002). It is generated during the purification of sugar by carbonation or sulphitation processes. Both the processes separate clear juice on top and mud at the bottom. It is considered as rejected waste material of sugarcane industries that cause problem of storage and pollution to the surrounding of sugar mills on its accumulation (Bhosale et al.,2012). It also supplies a good amount of organic manure (Bokhtiar et al.,2001) and can be an alternate source of plant nutrient (Rajagopal et al., 2014) and act as a soil ameliorates (Khan et al., 2016).

Sugarcane production is the biggest agricultural industry in Eswatini with over 60 000 hectares of land under irrigated sugarcane (SSA, 2014). There are three main

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sugarcane processing factories, Mhlume and Simunye sugar factories in the north eastern part of the country and Ubombo in the southern part. From these factories, stillage is produced as a by – product to be dumped in suitable areas like landfills. If improperly applied, the stillage can cause environmental problems, such as ground water pollution. This experiment was done to determine the effect of sugarcane stillage on the yield of butternut squash (*Cucurbita moschata*) grown under rain fed conditions. The results of are to be used to help local farmers in the proper disposal of stillage and the cultivation of vegetables.

II. MATERIALS AND METHODS

Location

The field experiment was conducted at Tambankulu Estates in the north eastern part of the Lowveld of Eswatini. This siteis located at a latitude of 26.13°S, longitude 31.93°E, and an altitude of 219 m above sea-level. The area receives an annual rainfall of about 600 mm. The soils are mostly the alluvial type which are deep red, well structured (medium to heavy clays) and free draining.

Experimental layout and crop management

The experiment was laid out as a split-plot, with stillage and fertilizer regimes as the main plots (factors) with each factor having three levels. The levels were split into three subplots namely; recommended, less than recommended and more than recommended. Stillage and fertilizer were not applied in the control plots. Butter nut seeds were manuallysown on the 9th of December, 2009, at a spacing of 75 cm between rows and 60 cm within rows, with one plant perstation (2.2 plants per m^2). Each plot was 450 m^2.

Fertiliser application and plant protection

Fertilizer and stillage were applied manually at the time of planting. Weeds were initially managed by herbicides and secondary weeds were manually uprooted using hoes. Bravoand Metafort 60SL were sprayed in a mixture at 800 ml per ha,in 500-1000 litres of water per hectare, every 14-21 days, inorder to control fungal diseases: powdery mildew (*Erysiphecichoracearum*, Jaczewski) and bacterial diseases.

Soil and stillage Properties

Soil samples were collected in each main block before planting and after planting just before harvesting using an auger in a zig-zag pattern within a depth of 0 to 20 cm and sent to Omnia Chemtech laboratory for analysis (Omnia, 2019). The samples were analysed for the following physico-chemical properties; bulk density, pH, sulphur, nitrogen, phosphorus, potassium, calcium, magnesium, sodium and electrical conductivity. Stillage samples were sent to Enviro Applied Products commercial laboratory (Enviro Applied Products, 2019)for chemical analysis.

Yield (growth) parameters of the butternut fruit

Yield (growth) parameters at harvest, fruit size, average fruit length (longitudinal) and equatorial diameter were measured using a digital scale and calliper.

III. RESULTS AND DISCUSSION

Stillage Analysis

The results of the chemical components of stillage are shown in Table 1. While most of the components have results with units of parts per million, nitrogen (N), Phosphorus (P), potassium (K) and chloride (Cl) have units of percentages since they were analysed following Kjeldahl's method (Labconco, 2008).

Table.1: The physicochemical properties of the stillage applied in the butternut squash experiment

N	P	K	Cl	Fe	Cu	Mn	Zn	Ca	S	Sr	Bi	Sn	Ti
1.53 %	1.50 %	3.59 %	1.55 %	133 ppm	130 ppm	31.3 ppm	220 ppm	5944 ppm	4731 ppm	25.2 ppm	24 ppm	19 ppm	6 ppm

The result shows that stillage contains more potassium (K) and about equal amounts of nitrogen, phosphorus and chloride. It also contains a lot of calcium and sulphur when compared to zinc, copper, iron and manganese. In addition, the product contain trace amounts of titanium (Ti), tin (Sn), bismuth (Bi) and strontium (Sr) which all have alkali properties.

Soils analysis before and after planting

The results of the soil chemical analysis before planting and at harvesting of the butternut squash are shown in Table 2 and Table 3 respectively.

Table.2: The physicochemical properties of the soil before planting the butternut squash experiment

Bulk density (kg/m^3)	pH	S (ppm)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	EC (s/m)
1251	5.56	10	52.7	8	79	1270	523	67	1.48

Calcium and magnesium contents of the soil were much higher than the other chemicals, with calcium the highest.

Table.3: The physicochemical properties of the soil after harvesting the butternut squash experiment

		Bulk Density (Kg/m^3)	pH	S (ppm)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	EC (s/m)
	Control	1251	5.5	16	53	7	79	1270	523	67	1.48
Stillage	LC	1099	6.0	7	60	22	112	2020	878	198	1.40
	RC	1066	6.0	19	64	1	138	1990	819	234	1.48
	MC	976	6.8	4	67	7	226	4830	724	467	4.07
Fertilizer	LC	944	4.8	11	60	21	138	1420	707	47	1.23
	RC	1015	6.4	11	67	30	177	4000	1260	234	1.94
	MC	985	6.4	20	80	42	122	3210	1100	290	1.78

where; LC - low concentration, RC - recommended concentration, and MC - more than recommended concentration

Table 3 shows that the application of stillage and fertilizer in the soil had a reduction effect on the bulk density and the soil sulphur content. Fertilizer tended to have a slightly bigger reduction in bulk density than stillage and stillage had a bigger reduction in soil sulphur compared to the fertilizer treatments. Soil pH was slightly increased by both stillage and fertilizer. Both stillage and fertilizer resulted in increases in the availability of the other chemical elements, nitrogen, phosphorus, potassium, calcium, magnesium and sodium. Stillage did not affect the electrical conductivity of the soil except when applied at more than the recommended concentration which resulted in an increased soil EC. Increasing the concentration of fertilizer tended to increase the electrical conductivity of the soil.

Butternut squash yield (length, diameter and weight)

Butternut squash yield (fruit length (cm), fruit diameter (cm) and fruit weight (grams)) results are shown in Table 4 below.

Table.4: Butternut squash yield (fruit length (cm), fruit diameter (cm) and fruit weight (grams)) measured at harvest

		Butternut Squash Length (cm)	Butternut Squash Diameter (cm)	Butternut Squash weight (gm)
Control		17.1	30.7	547.7
Stillage	LC	18.5	30.3	770.1
	RC	20.0	31.7	960.3
	MC	19.9	31.3	952.0
	Mean	**19.5**	**31.1**	**894.1**
Fertilizer	LC	16.2	31.9	721.1
	RC	17.6	33.0	810.0
	MC	17.5	32.8	809.7
	Mean	**17.1**	**32.5**	**780.3**
	Significance	**	NS	**
	Interaction	NS	NS	**

*Values showing ** stand for significant differences at P < 0.01 probability level, whereas NS represents a non-significant value.*

Butternut squash fruit length was significantly increased by the application of stillage whereas fertilizer did not seem to improve the fruit length.

There were no significant differences in fruit diameter between the stillage and fertilizer treatments. The fertilizer treatments however showed a slightly bigger diameter compared to the stillage treatments.

There were highly significant differences in butternut fruit weight between the stillage and fertilizer treatments compared to the control. The mean weight for the stillage treatments was 894.1 g when compared to 780.3 g for the fertilizer treatment. Also, the weight for the fertilizer treatments was highly significantly ($P < 0.01$) greater than the control which was 547.7 g. This shows that the application of either stillage or fertilizer resulted in an

increased butternut fruit weight. These results are similar to those reported by Van Antwerpen, et al., (2003)
Figure 1 shows the effect of fertilizer and stillage concentration on the weight of butternut squash. Increasing the concentration beyond the recommended dosage seems to have no effect on the weight.

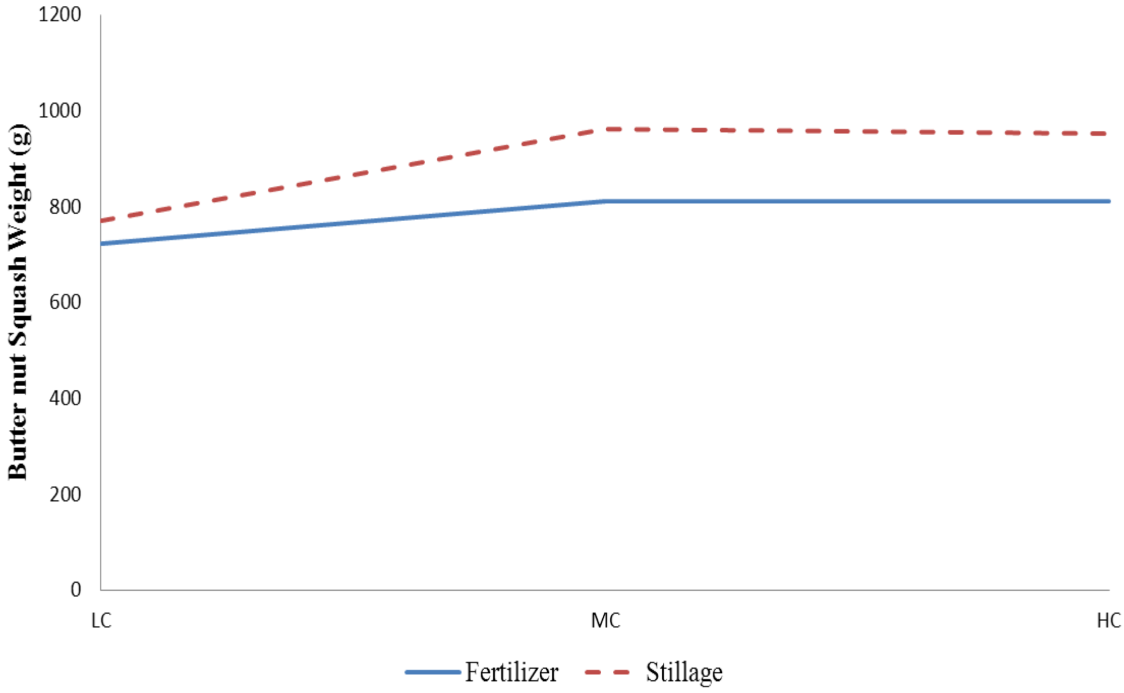

Fig 1.Showing the effect of the concentration of fertilizer and stillage on the weight of butternut squash.

IV. CONCLUSION

It can be concluded from the results of this experiment that the application of stillage result in improved soil chemical properties and increased butternut squash fruit yield (length and weight) when compared to fertilizer (N:P:K; 2:3:2 (22)). However, applying more than the recommended dose of stillage and or fertilizer seems to reduce yield.Depending on the economics, stillage is a better alternative to chemical fertilizer.

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