American-Eurasian J. Agric. & Environ. Sci., 19 (4): 291-300 2019
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2019.291.300

Effects of Stillage and Animal Manures on Soil Organic Matter, Growth, Yield and Quality of Two Bell Pepper Cultivars (*Capsicum annuum* L.)

Mfanzile A. Dzimba, Michael T. Masarirambi, Paul K. Wahome and Phiwokwakhe A. Dlamini

Department of Horticulture, Faculty of Agriculture,
University of Eswatini, P.O. Box: Luyengo M205, Eswatini, Swaziland

Abstract: Pepper is an important vegetable crop nutritionally and for food security in the Kingdom of Eswatini. They are generally produced using synthetic fertilisers which can potentially harm the environment and subsequently be a threat to the achievement of sustainable development goals (SDGs) pertaining to the people and the planet. The objective of this study was to determine the effects of stillage and different types of organic fertilisers and application rates on soil organic matter, growth, yield and quality of two bell (green) pepper cultivars. The cultivars (Capricorn and California Wonder) were grown under open field conditions. The treatments were stillage applied at 6 t/ha; cattle manure applied at 30 t/ha; goat manure applied at 15 t/ha; and chicken manure applied at 10 t/ha. A control of cattle manure was applied at 15 t/ha + inorganic fertiliser (2:3:2 (22) + 5% Zn) applied at 250 kg/ha. The treatments were laid in a randomized complete block design (RCBD). The results showed that stillage application affected growth of both bell pepper cultivars, with the highest plant height of 63.7 cm observed from cultivar Capricorn followed by the control (62.6 cm) in the same cultivar. The lowest plant height of 59.2 cm was observed from cultivar California Wonder supplied with goat manure. California Wonder supplied with stillage had the highest number of marketable fruits (5.7) followed by the control from the same cultivar with 5.1 fruits per plant. Cultivar Capricorn supplied with goat manure had the lowest number of fruits (3.2) per plant. Peppers supplied with stillage had fruits with the highest total soluble solids (5.8) in cultivar Capricorn whilst goat manure application resulted in the lowest values of total soluble solids from both cultivars. It was concluded, therefore, that farmers may use stillage applied at 6 t/ha or continue using the recommendations from the Ministry of Agriculture of cattle manure applied at 15 t/ha combined with inorganic fertiliser (2:3:2 (22) + Zinc) applied at 250kg/ha for prductivity of green pepper under field conditions in Eswatini.

Key words: Capricorn · California Wonder · Stillage · Cattle Manure · Goat Manure · Chicken Manure · Sustainable Development Goals (SDGs)

INTRODUCTION

Bell pepper (*Capsicum annuum* L.) is an important vegetable crop with a good source of nutrients, Vitamin A, C, K and B6, calcium, iron, potassium, zinc, fibre, natural pigments and antioxidant compounds important for human health [1-3]. It is a member of the Solanaceae Family and commonly divided into two groups, pungent and non-pungent, which are also called hot and sweet pepper respectively. Worldwide, there is an increasing interest in the use of organic manures even on pepper production as a trail to compensate the decrease in soil fertility. The need to reduce costs of fertilising crops has revived the use of organic fertilisers [4-5].

Organic fertilizers are essential for the proper development of plants, vegetables, flowers and fruits, as they offer rapid growth with superior quality to all species [6]. They have the nutrients necessary for better development [6-7]. In addition, the organic matter serves as nutrients and energy sources for soil microorganisms [7]. The suitability and usefulness of organic fertilizers has been attributed to high availability of NPK content [7, 8], which is capable of enhancing soil fertility [9]. They also act as a substrate for soil microorganisms which results to the increase microbial activity, the rate of organic material decomposing and releasing nutrient for plant uptake. They improve the physical properties of the soil as well [10-12]. Bhata and Shukla [13] reported

Corresponding Author: M.T. Masarirambi, Department of Horticulture, Faculty of Agriculture, Luyengo Campus, University of Eswatini, P.O. Box: Luyengo M205, Eswatini, Swaziland.

that organic fertiliser (farm yard manure) resulted in significant increase in soil carbon, nitrogen, pH, cation exchange capacity (CEC) and exchangeable Ca, Mg and K which invariably enhanced crop yield and productivity.

In recent years the world has seen a growing awareness of health and environmental issues. Consumers worldwide are becoming concerned about the quality and safety of food that they eat [14]. They are concerned about the effect of pesticides, fertilizers, livestock effluent and veterinary drugs on their health and livelihoods. Organic agriculture is considered to be a viable solution to most of these concerns.

Traditional agricultural methods from Africa and around the world, which have always been organic, have to a great extent inspired today's modern organic agriculture [10]. It must be remembered that artificial fertilizers and chemical based agro-industry is a relatively new development, only becoming prominent in the second half of the 20th century [10]. In Eswatini, the indigenous farming systems that were used in the past could be referred as organic farming. These faming methodologies did not utilize any biocides. The production methodology was dependent on the natural resource base.

Organic agriculture has grown tremendously over the last decades, both as a commercial production and as an environmentally friendly production method [14-15]. It has been found to be the best model for emerging farmers. A number of countries around the world have seen considerable increase in their organically farmed areas. More than 10% of Switzerland's farmland is organic, Sweden reached 19% in the year 2005 and about 13% of Austria's farms are organic [16]. A number of developing countries are showing significant rates of adoption. There were 1.8 million producers in 2009, an increase of 31% since 2008, mainly due to a large increase in India [15]. Forty percent of the world's organic producers are in Asia, followed by Africa (28%) and Latin America (16%) [15]. The countries with the most producers are India (677,257), Uganda (187,893) and Mexico (128,862) [15]. About 32.2 million hectares are certified according to organic standards internationally (data as at the end of 2007) [15].

The general objective of the study was to provide farmers with new production technologies in order to contribute to food self-sufficiency in Eswatini and at the same time conserving the soil biodiversity and ecosystem. Also the response of bell pepper to stillage compared with other organic fertilisers (cattle manure, goat manure and chicken manure) in terms of vegetative growth, yield and quality and its effects on soil organic matter has never been tested in Eswatini.

The stillage sometimes known as condensed molasses solids (cms) is a by-product of various fermentation processes. Molasses is used as a nutrient substrate in many fermentation industries (e.g. yeast, alcohol and amino acid production and the production of organic acids). In these processes, most of the sucrose content of the molasses is consumed by microbiological action [16]. The resulting liquid waste (known variously as slop, stillage, distiller's wash or vinasse) has very little residual sugar content. It is this waste which is condensed, further processed and marketed as stillage. The stillage is used primarily in feed products for cattle and sheep because its crude protein content consists mainly of NPN (non-protein nitrogen compounds such as free amino acids and betaine). It is also of interest because of its mineral content, most notably potassium [14, 15]. It is also used as a nitrogen-potassium fertilizer, particularly in only mildly condensed form or completely non-condensed form (i.e. 35-50% solids). Stillage in these forms is sprayed onto fields. The volumes of stillage used as fertilizer vary considerably from region to region within Europe owing to differences in the volumes of molasses fermented and the quantities of stillage produced [16]. Across Europe as a whole, more CMS/stillage is used in animal feed than is sprayed on fields as fertilizer - especially when beet and/or cane molasses is comparatively expensive [16].

As far back as 1860, it was standard practice to apply molasses before planting sugarcane in a number of countries [17]. In Mauritius and Hawaii, the application of molasses to cane lands was widespread. It was concluded from research that its beneficial effects were due not only to release of plant nutrients such as potassium and nitrogen, but also to physical improvement in soil structure and an increase in biological activity of beneficial micro-organisms following partial sterilisation of the soil [18]. Other benefits that have been reported include the control of nematodes through certain species of fungi that are able to parasitize plant feeding nematodes [19]. In South Africa, the first formal investigation was carried out by the Tongaat Sugar Company Ltd during the fifties [18], when large areas of the industry were deficient in potassium while in Swaziland it was carried out by Simunye Sugar Estate [17]. Significant yield responses were obtained from molasses applied at rates of up to 13.5 t/ha in four trials and soil analysis confirmed the marked effect it had in restoring depleted potassium levels [16].

The Kingdom of Eswatini sugar industry produces about 150,000 tonnes of Condensed Molasses Soluble (CMS) [17]. According to Turner [17], approximately 120,000 tonnes is sold locally to sugar cane, banana and citrus farmers and 10,000 tonnes is exported while the rest is dumped.

Apart from supplying nutrients, some of the other beneficial effects reported by researchers included a physical improvement in soil structure and an increase in the biological activity of beneficial micro-organisms such as soil fungi, following partial sterilisation of the soil [16, 17, 19]. The soil fungi produce a heavy mycelial growth and coat the soil particles in contact with the molasses. In addition, some species of soil fungi are nematophagous or nematode destroying and can parasitize and kill nematodes [19]. On the other side molasses contains large quantities of fermentable sugars that can temporarily immobilise or tie up plant available nitrogen in organic form, causing leaf yellowing due to a transient N deficiency [16, 19]. For this reason, at least half of the fertiliser N should be applied at about the same time the molasses is applied. Eventually the immobilised N will be released or mineralised and will be taken up by the cane. The rate of N release will depend on how well the soil is aerated. Molasses should not be applied to poorly drained soils.

The response of bell peppers to stillage compared to other common organic fertilisers (cattle, chicken and goat manures) has not been investigated in Eswatini and this makes it very hard for bell pepper farmers to produce high quality peppers organically and with reduced cost. This might be the reason of less bell pepper production in Eswatini. The available farmers in Eswatini do not apply stillage in their crops because they do not know that it is the best source of potassium, it contains organic matter and relatively cheaper. Potassium is one of the most essential nutrients in plants since it regulates the opening and closing of stomata and therefore regulates carbon dioxide (CO_2) uptake. Potassium triggers activation of enzymes and is essential for production of Adenosine Triphosphate (ATP). Bell pepper plants need significant levels of potassium to produce large, high quality fruits. Farmers are also facing problems of revitalising their soil after a period of time under production. This is caused among other things by application of inorganic products/chemicals. Stillage can be a solution to this problem since it contains organic materials. So it is important for farmers to know more on stillage and its benefit to the soil compared to other organic fertilisers for bell pepper production. The aim of the study was to find the effects of stillage and animal manures on soil organic matter, growth, yield and quality of two bell pepper cultivars common in Eswatini.

MATERIALS AND METHODS

Experimental Site: The experiment was conducted at Malkerns Research Station in Malkerns under the Manzini region in the Middleveld agro-ecological zone of the Kingdom of Eswatini. Malkerns is located on latitude 26°4’ S and 31°4’ E longitude. The average altitude of this area is 750 m above sea level. The mean annual precipitation is 980 mm with most rain available between October and April. Drought hazard is about 40%. The average summer temperature is 27°C and average winter temperature is 15°C. The soils in Malkerns are classified under the Malkerns soil series [20].

Plant Material: The bell pepper seedlings, variety California Wonder was sourced from the National Agricultural Marketing Board (NAMBoard), Matsapha, Eswatini and variety Capricorn was sourced from Vickery Seedlings, Malkerns, Eswatini. The stillage was obtained from Enviro Applied Products located at Royal Swaziland Sugar Corporation (RSSC) Simunye, Eswatini while cattle, goat and chicken manures were obtained from the University Farm, Luyengo Campus, University of Eswatini.

Experimental Design: The experiment was laid in a randomised complete block design (RCBD). It consisted of two bell pepper cultivars (California Wonder and Capricorn), four treatments and three replications. The pepper seedlings were transplanted in plots of 3.6 x 3.6 m at a spacing of 45 cm between plants and 90 cm between rows. All treatments were applied four weeks before planting. Soil samples were collected from the surface layer (0-15 cm) of all the plots before treatment applications and immediately after bell pepper harvest in January 2019. Five random cores were taken from each plot with a 5-cm diameter tube auger and mixed. Soil samples were taken to soil chemistry lab to laboratory analysis and the results are shown in Table 1.

Treatments: The treatments were stillage applied at 6 t/ha; cattle manure applied at 30 t/ha; goat manure applied at 15 t/ha; and chicken manure applied at 10 t/ha. A control of cattle manure applied at 15 t/ha and (2:3:2 (22) + 5% Zn applied at 250 kg/ha.

Table 1: Physical and chemical properties of soil before treatment and after harvest.

		After harvesting				
	Before application	Control	Stillage	Cattle manure	Goat manure	Chicken manure
Soil pH	4.58	5.27	5.12	5.11	4.81	4.72
Organic carbon (%)	33	37	38	40	40	36
Organic matter (%)	57	63	65	69	69	62
Phosphorus (mg/kg)	4.78	21.99	16.28	11.91	14.38	8.77
Potassium (cmol/kg)	0.48	0.78	2.95	1.14	0.80	0.80

Data Collection: Data were collected 2 weeks after transplanting and at 2 weeks intervals. The data collected included the following parameters: plant height, number of leaves, stem girth, chlorophyll content, number of flowers, number of fruits, yield, fruit diameter, dry matter content and the nutrient composition of bell pepper fresh fruits. Data were collected on six plants selected randomly from each plot and analysis was done on six randomly selected fruits from each plot.

Data Analysis: The data collected was subjected to analysis of variance (ANOVA) using the GEN-STAT [21] program and the means were separated using the Duncan's New Multiple Range Test (DNMRT) at $P \leq 0.05$ where significant differences were detected [22].

RESULTS AND DISCUSSION

Plant Height: There were significant ($P \leq 0.05$) differences in plant height of green pepper cultivars grown under different fertiliser treatments. Stillage treatment had the highest plants than all other treatment in cultivar Capricorn (Table 2). There was no significant ($P \leq 0.05$) differences in the plant height of green pepper from the stillage, control and cattle manure treatment on cultivar California Wonder (Table 2). The highest plant height was obtained in Capricorn grown under stillage treatment and the lowest plant height was obtained in California Wonder grown under goat manure treatment. Stillage treatment also had the highest plant height in cultivar California Wonder. Ozores-Hampton [23] reported that different fertiliser treatments have different qualitative and quantitative effects on plant height. The green pepper grown under stillage treatment had the tallest plants in both cultivars. This could probably be due to the fact that the nutrient stillage were immediately available to the plants and were continuously released for a long period. Stillage effects on plant is seen immediately [24]. In other organic fertilisers, the nutrients are not available immediately [25]. In case of inorganic fertilisers, nutrients are immediately available to the plant upon application although they do not last longer than organic fertiliser [26]. Goat manure treatment resulted in the lowest among all treatment on plant height in both cultivars (Table 2).

Number of Leaves: There were significant ($P \leq 0.05$) differences in the number of leaves in green pepper cultivars across all different fertiliser treatments. Cultivar Capricorn had a higher number of leaves based on the observation of the study when compared to California Wonder (Table 3). There were no significant ($P \leq 0.05$) differences in number of leaves between stillage treatment

Table 2: Plant height at 2, 4, 6, 8 and 10 weeks after transplanting as influenced by stillage, cattle, goat and chicken manure

		Weeks after transplanting				
Treatment	Cultivar	2	4	6	8	10
Control	Capricorn	18.9b	29.2b	38.5b	50.5b	57.2b
	California	16.4c	26.7c	36.0c	48.0c	54.7de
Stillage	Capricorn	19.8 a	30.1 a	39.4 a	51.4 a	58.1 a
	California	17.1 c	27.3 c	36.7 c	48.7 c	55.4 cd
Cattle manure	Capricorn	14.7 d	20.9 d	30.3 d	46.3 d	56.0 c
	California	14.0 de	20.3 de	29.6 de	45.6 de	55.3 cd
Goat Manure	Capricorn	13.4 ef	19.7 ef	29.0 ef	45.0 ef	54.7 de
	California	12.8 f	19.1 f	28.4 f	44.4 f	54.1 e
Chicken manure	Capricorn	14.1 de	20.3 de	29.7 de	45.7 de	55.4 cd
	California	13.1 f	19.4 f	28.7 f	44.7 f	54.4 e

Mean values within the same column followed by the same letter are not significantly different from each other at $P \leq 0.05$. Mean separation by DNMRT.

Table 3: Number of leaves at 2, 4, 6, 8 and 10 weeks after transplanting as influenced by stillage, cattle, goat and chicken manure

		Weeks after transplanting				
Treatment	Cultivar	2	4	6	8	10
Control	Capricorn	16.2 a	22.2 a	28.2 a	32.2 a	33.2 a
	California	14.3 b	20.3 b	26.3 b	30.3 b	31.3 d
Stillage	Capricorn	16.1 a	22.1 a	28.1 a	32.1 a	33.1 a
	California	14.2 bc	20.2 bc	26.2 bc	30.2 bc	31.2 d
Cattle manure	Capricorn	14.3 b	20.3 b	26.3 b	30.3 b	32.3 b
	California	12.3 d	18.3 d	24.3 d	28.3 d	30.3 e
Goat Manure	Capricorn	14.0 c	20.0 c	26.0 c	30. c	32.0 c
	California	12.1 d	18.1 d	24.1 d	28.1 d	30.1 e
Chicken manure	Capricorn	14.2 bc	20.2 bc	26.2 bc	30.2 bc	32.2 bc
	California	12. d	18.0 d	24.0 d	28.0 d	30.0 e

Mean values within the same column followed by the same letter are not significantly different from each other at $P \leq 0.05$. Mean separation by DNMRT.

and the control in both cultivars, but were significantly ($P \leq 0.05$) different from cattle manure, goat manure and chicken manure. The highest number of leaves was obtained in cultivar Capricorn from the control treatment (Table 3), while cultivar California Wonder gave the lowest number of leaves when grown using chicken manure (Table 3). The green pepper grown under the control treatment had the highest number of leaves in both cultivars. Nutrients are readily available to the plants upon application of inorganic fertilisers and stillage [10, 24, 25]. The best treatment in the number of leaves was the control followed by stillage. The control and stillage treatment proved to be significantly better than all other treatment in all varieties.

Stem Girth: There were significant ($P \leq 0.05$) differences in the stem girth in green pepper cultivars across all different fertiliser treatments. Cultivar California Wonder had a significantly ($P \leq 0.05$) higher stem girth than cultivar Capricorn (Table 4). The green pepper grown from the stillage treatment had the largest stem girth in cultivar California Wonder (Table 4). There were no ($P \leq 0.05$) significant differences in stem girth of plants provided with stillage and the control in cultivar California Wonder (Table 4). There were no significant ($P \leq 0.05$) differences in stem girth in green pepper plants between cattle manure, goat manure and chicken manure treatment in cultivar California Wonder while there was a significant ($P \leq 0.05$) difference between cattle manure treatment and the control in cultivar Capricorn (Table 4). The green pepper grown from the stillage treatment had the largest stem girth in both cultivars (Table 4). Stillage performed well due to the availability of nutrients since it is liquid [26-28]. Goat manure treatment had the lowest stem girth on both cultivars (Table 4).

Chlorophyll Content: There were no significant ($P \leq 0.05$) differences in the chlorophyll content in green pepper cultivars across all different fertiliser treatments. Cultivar California Wonder had higher chlorophyll contents in all treatment than cultivar Capricorn (Table 5). Stillage treatment had the highest chlorophyll content in both varieties. The highest chlorophyll content was observed in cultivar California Wonder when compared to Capricorn under the stillage treatment. It was reported by Islam [25] and Nadir [26] that sugar cane treated with stillage became dark green with more chlorophyll content. This was attributed to readily available nutrients from inorganic fertilisers to the crop plant [23]. Goat manure and chicken manure had plants with the lowest chlorophyll content in both cultivars.

Yield Components: Different levels of organic fertiliser applications behaved differently in terms of yield parameter as was shown by the significant ($P<0.05$) differences in number of flowers, number of fruits, fruit diameter and marketable yield. The highest number of fruits (Figure 2), marketable yield (Figure 3) and the largest fruit dimeter (Figure 4) was obtained from bell pepper treated with stillage in all cultivars. Cultivar Capricorn has a naturally higher yield than cultivar California Wonder. The highest number of fruits per plant in cultivar California Wonder and also highest number of fruits in cultivar Capricorn were obtained from stillage treatment. The lowest average number of fruits was obtained from chicken manure treatment. Plants under the stillage treatment had the highest yield per hectare in cultivar California Wonder and the control had the highest

Table 4: Stem girth at 2, 4, 6, 8 and 10 weeks after transplanting as influenced by stillage, cattle, goat and chicken manure.

		Weeks after transplanting				
Treatment	Cultivar	2	4	6	8	10
Control	Capricorn	0.37 c	0.57 c	0.87 c	0.97 c	1.07 c
	California	0.43 a	0.63 a	0.93 a	1.03 a	1.13 a
Stillage	Capricorn	0.40 b	0.60 b	0.90 b	1.00 b	1.10 b
	California	0.43 a	0.63 a	0.93 a	1.03 a	1.13 a
Cattle manure	Capricorn	0.33 d	0.53 d	0.83 d	0.93 d	1.03 d
	California	0.38 bc	0.58 bc	0.88 bc	0.98 bc	1.08 bc
Goat Manure	Capricorn	0.34 d	0.54 d	0.84 d	0.94 d	1.04 d
	California	0.38 bc	0.58 bc	0.88 bc	0.98 bc	1.08 bc
Chicken manure	Capricorn	0.34 d	0.54 d	0.84 d	0.94 d	1.04 d
	California	0.38 bc	0.58 bc	0.88 bc	0.98 bc	1.08 bc

Mean values within the same column followed by the same letter are not significantly different from each other at $P \leq 0.05$. Mean separation by DNMRT.

Table 5: Chlorophyll content at 2, 4, 6, 8 and 10 weeks after transplanting as influenced by stillage, cattle, goat and chicken manure.

		Weeks after transplanting				
Treatment	Cultivar	2	4	6	8	10
Control	Capricorn	74.4 b	82.4 b	87.4 b	89.7 a	90.6 a
	California	73.9 b	81.9 b	87.4 b	91.2 a	91.7 a
Stillage	Capricorn	75.6 a	83.6 a	89.1 a	91.4 a	91.9 a
	California	75.8 a	83.7 a	89.3 a	91.6 a	92.1 a
Cattle manure	Capricorn	58.8 c	65.3 c	69.3 c	71.5 bc	75.0 b
	California	58.6 c	65.1 c	70.3 c	72.4 b	75.9 b
Goat Manure	Capricorn	55.8 e	62.3 e	66.3 d	69.4 c	70.9 c
	California	58.5 c	65.0 c	69.0 c	71.3 bc	72.8 c
Chicken manure	Capricorn	56.9 d	63.4 d	67.4 d	71.2 bc	72.7 c
	California	56.8 d	63.4 d	67.4 d	71.4 bc	72.9 c

Mean values within the same column followed by the same letter are not significantly different from each other at $P \leq 0.05$. Mean separation by DNMRT.

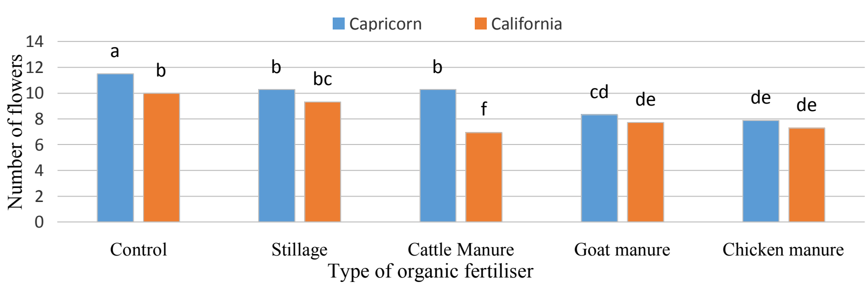

Fig. 1: Effects of organic fertilisers on total number of flowers per plant in green pepper. Bars followed by the same letter not significantly different. Mean separation performed using DNMRT at $P \leq 0.05$.

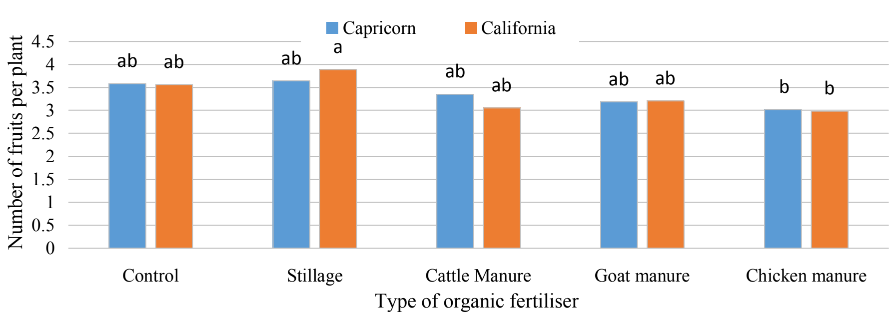

Fig. 2: Effects of organic fertilisers on the total number of fruits per plant in green pepper. Bars followed by the same letter are not significantly different from each other. Mean separation performed using DNMRT at $P \leq 0.05$.

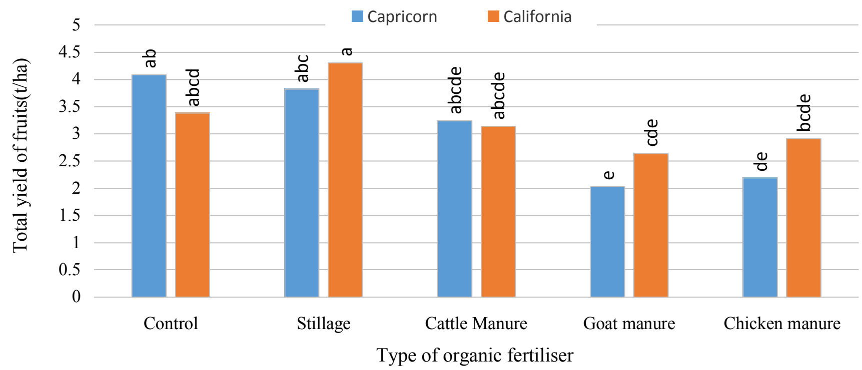

Fig. 3: The effects of organic fertilisers on total yield per hectare in green pepper. Bars followed by the same letter are not significantly different from each other. Mean separation performed using by DNMRT at P≤0.05.

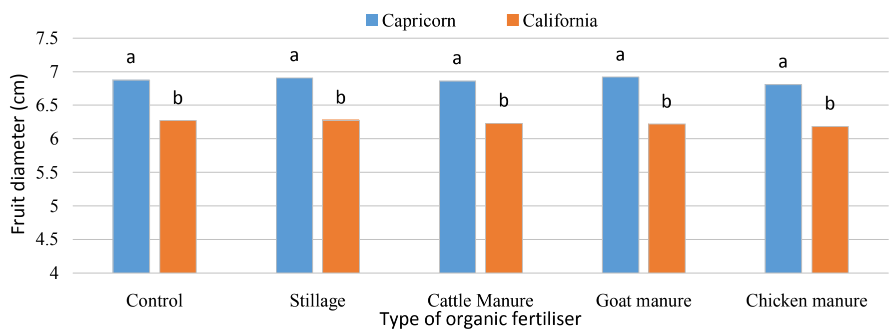

Fig. 4: Effects of organic fertilisers on fruit diameter in green pepper. Bars followed by the same letter are not significantly different from each. Mean separation performed using DNMRT at P≤0.05.

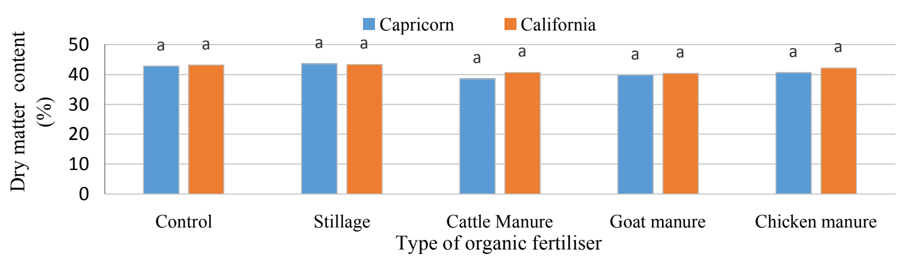

Fig. 5: Effects of organic fertilisers on dry matter content in green pepper. Bars followed by the same letter are not significantly different from each. Mean separation performed using by DNMRT P≤0.05.

yield in cultivar California Wonder. Cultivar California Wonder had smaller fruit size as compared to variety Capricorn. Similarly, cultivar California Wonder also had higher number of fruits per plant hence the more yield [29]. The lowest yield was obtained from the goat manure treatment.

Quality: There were slight differences between the different organic fertiliser treatments in terms of quality parameter which are dry matter content, total soluble solids and potassium and iron levels. There were no significant differences among treatments on dry matter content, total soluble solids and iron levels (Figure 5, 6 and 8). The difference was only observed in potassium levels since stillage treatment had higher levels of potassium than the other treatments (Figure 7). The highest dry matter content was obtained from cultivar Capricorn under stillage treatment but was not significantly higher than all the other treatments in all cultivars. There were no effects of the different treatments on the dry matter content. The dry matter content was almost the same in all treatments and cultivars. For TSS, there were no significant differences between the control and stillage treatments. This was because the control and stillage consisted of readily available nutrients immediately after transplanting. Plants under stillage

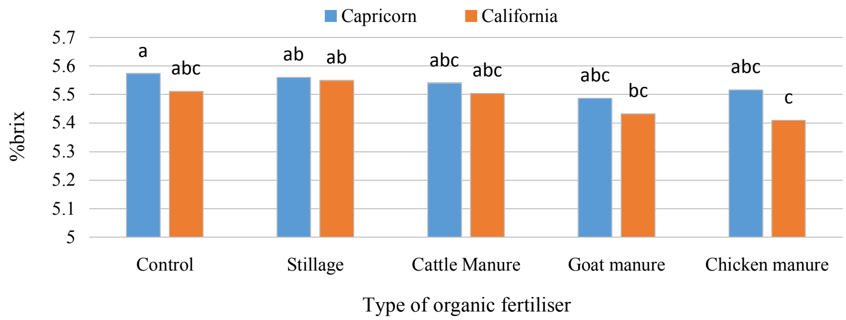

Fig. 6: Effects of organic fertilisers on total soluble solids in green pepper. Bars followed by the same letter are not significantly different from each other. Mean separation performed using DNMRT at P≤0.05.

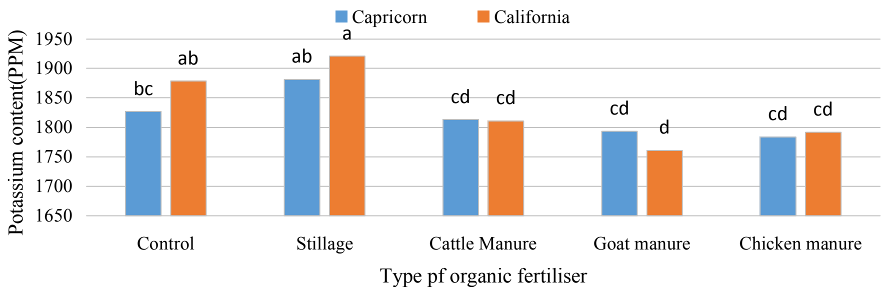

Fig. 7: Effects of organic fertilisers on potassium content in fruit of green pepper. Bars followed by the same letter are not significantly different from each. Mean separation was performed using DNMRT at P≤0.05.

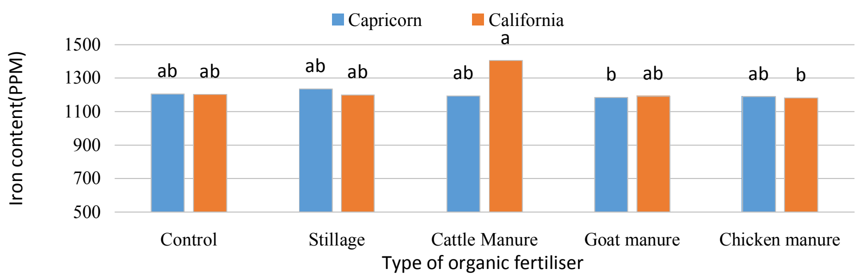

Fig. 8: Effects of organic fertilisers on Iron content in fruit of green pepper. Bars followed by the same letter are not significantly different from each. Mean separation was performed using DNMRT at P≤0.05.

treatment had the highest potassium content in both cultivars. This was due to the fact that stillage has a higher potassium content (about 6%) [27] than all other treatment fertilisers.

Soil Chemical Properties: The soil analysis revealed that all treatments increased significantly the amount of phosphorus in the soil (Table 1). The highest phosphorus was found in the control. The lowest phosphorus was found in soil applied with chicken manure. In soil treated stillage had higher potassium content than all treatments. This was expected since stillage had the highest potassium [25]. Low potassium content in soil under the inorganic fertiliser /control treatment was attributed to K use/uptake by the plants [30].

CONCLUSION

The results of this study revealed that different bell pepper cultivars responded differently to the different organic fertilisers. The highest growth parameters (plant height, stem girth, number of leaves and chlorophyll content) were obtained in bell pepper supplied with stillage in both cultivars while the lowest was observed in bell pepper supplied with goat manure. The highest yield components were obtained in stillage treatment in both cultivars while the lowest was obtained in goat manure treatment. Plants treated with stillage produced fruits with the high quality on average although not significantly different from the other treatments in both cultivars. The control and the stillage treatments performed better than all other treatments in terms of yield in both cultivars.

It is there for recommended that stillage can be used for green pepper production under field conditions in Eswatini. It is also recommended that cultivar Capricorn can be used for bigger fruits while cultivar California Wonder can be used for higher yields (tons/ha) in green pepper production.

REFERENCES

1. Greenleaf, W.H., 1986. Breeding vegetable crops, chapter 3. In: Basset MJ (ed) Pepper breeding. The AVI Publishing Company Inc., Westport, Connecticut, USA.
2. Deepa, N., C. Kaur, B. George, B. Singh and H.C. Kapoor, 2007. Antioxidant constituents in some sweet pepper (*Capsicum annuum* L.) genotypes during maturity. LWT-Food Sci. Technol., 40: 121-129.
3. Howard, L.R., S.T. Talcott, C.S. Brenes and B. Villalon, 2000. Changes in phytochemical and antioxidant activity of selected pepper cultivars (*Capsicum* spp.) as influenced by maturity. J. Agric. Food Chem., 48: 1713-1720.
4. Delate, K. and C.A. Camberdella, 2004. Agro-ecosystem performance during transition to certified organic grain production. Agron. J., 96(5): 1288-1298.
5. Farhad, W., M. F. Saleem, M. A. Cheema and H. M. Hammad, 2009. Effect of poultry manure levels on the productivity of spring maize (*Zea mays* L.). J Anim. Plant Sci., 19(3): 122-125.
6. Masarirambi, M.T., P. Dlamini, P. K. Wahome and T.O. Oseni, 2012. Effects of chicken manure on growth, yield and quality of lettuce (*Lactuca sativa* L.) 'Taina' under a lath house in a semi-arid Sub-tropical environment, J. Agric. and Environ. Sci., 12(3): 399-406.
7. Silva, T.R.B., T. Bortoluzzi, C.A.T. Silva and C.R. Arieira, 2012. A comparison of poultry litter applied like organic fertilizer and that applied like chemical fertilizer in corn development. Afr. J. Agric. Res., 7(2): 194-197.
8. Waddington, S.R., 1998. Organic matter management: from science to practice. Soil Fert., 3(62): 24-25.
9. Thomas, G.A., 1997. Toxicity identification of poultry litter aqueous leachate. Soil Fert., 8(61): 251-252.
10. Nasef, M.A., A.A. Khalil, F.M. Ghazal and El-Emam, 2004. The residual effect of organic manures with or without bio-fertilizer applied to wheat grown on sandy, calcareous and clay soils on growth and NPK uptake of rocket plants. Egypt J. Agric. Res., 82(2): 235-246.
11. Palada, M.C., A.M. Davis, S.M.A. Crossman, C. Rables and E.A. Chichester, 2004. Sustainable crop management practices for improving production of culinary herbs in the Virgin Island. Acta Hort., 629: 289-298.
12. Khalid, K.H.A. and A.M. Shafei, 2005. Productivity of dill (*Anethum graveolens* L.) as influenced by different organic manure rates and sources. Arab Univ. J. Agric. Sci., Ain. Shams Univ., Cairo., 13(3): 901-913.
13. Bhata, K.S. and K.K. Shukla, 1982. Effects of continuous application of fertilisers and manure on physical properties of eroded alluvial soil. J. Ind. Soc. Soil., 30: 32-36.
14. Food and Agriculture Organization (FAO), 2016. Food and quality as affected by organic farming. Twenty - second FAO Regional Conference for Europe, Porto, Portugal.
15. IFOAM, 2014. The World of Organic Agriculture, Statistics and Emerging Trends. Retrieved 15 June 2018.
16. Cleasby, T.G., 1959. Use of molasses on the land: a report of four experiments being carried out by the Tongaat Sugar Company Ltd. Proc S Afr Sug Technol Ass., 33: 95-102.
17. Turner, P.E., J.H. Meyer and A.C. King, 2002. Field evaluation of concentrated molasses stillage as a nutrient source for sugarcane in Swaziland. Proc. S. Afri. Sug. Technol. Ass., 76: 61-69.
18. Doty, R., 1933. A Bibliography on the use of molasses as a fertiliser. Proc Hawaiian Sugar Tech., pp: 165-168.
19. Tianco, A.P., 1983. Molasses as a fertiliser and soil amendment. Proc Philippines Sugar Tech., 30: 469-472.
20. Murdorch, G., 1968. Soils and land capability in Swaziland. Ministry of Agriculture. Mbabane, Swaziland.
21. Payne, R.W., 2009. GenStat. Wiley Interdiscip. Rev. Comput. Stat. 1(2): 255-258. John Wiley & Sons, Inc. New York. New York. USA.
22. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. Second edition. John Wiley and sons, New York, NY, USA.
23. Ozores-Hampton, M., P.A. Stansly, R. McSorley and T.A. Obreza, 2005. Effects of long-term organic amendments and soil solarisation on pepper and watermelon growth, yield and soil fertility. HortSci., 40(1): 80-84.

24. Yang, S.C., 1968. The effect of alcoholic slops application upon the soil properties and cane yield. Report Taiwan Sugar Exp. Station, 46: 35-51.
25. Islam, M.M., A.J.M.S. Karim, M. Jahiruddin, N.M. Majid, M.G. Miah, M. Mustaque Ahmed and M.A. Hakim, 2011. Effects of organic manure and chemical fertilizers on crops in the radish-stem amaranth-Indian spinach cropping pattern in homestead area. Aust. J. Crop. Sci., 5(11): 1370-1378.
26. Nadir, A. and Da Gloria, 1977. Study on the application of Vinasse for fertilization. Published by Codistil Translation Service. Paris. France.
27. Ng Kee Kwong, K.F. and J.P. Paul, 1999. Vinasse as a Potassium Fertiliser for Sugarcane. Revue Agricole. et Sucriere, 76: 34-37.
28. Wang, P.L., S.W. Li, Y. Chan, C.S. Tsai and S.J. Chang, 1996. Nutrient recycling of the alcoholic slops by land furrow and sprinkle irrigation in sugarcane fields. Proc Int Soc. Sug. Cane Technol., 22: 56-62.
29. Ballard, R.E., J.W. McClure, W.H. Eshbaugh and K.G. Wilson, 1970. A chemosystematic study of selected taxa of Capsicum. American J. Bot., 57(2): 225-233.
30. Mehrvarz, S., M.R. Chaichi and H.A. Alikhani, 2008. Effects of phosphate solubilizing microorganisms and phosphorus chemical fertilizer on yield and yield components of barley (*Hordeum vulgare* L.). J. Agric. Environ. Sci., 3(6): 822-828.