Vol. 18(8), pp. 594-600, August, 2022
DOI: 10.5897/AJAR2021.15727
Article Number: 0A9B26669501
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Evaluation of the residual effect of bioslurry effluent on biological yield and nutritional content of swiss chard (*Beta vulgaris* L.)

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Received 27 July, 2021; Accepted 6 October, 2021

An experiment was conducted to evaluate the residual effect of inorganic fertilizer and bioslurry application on biological yield and nutrient content of Swiss chard. The study was conducted at Döhne Agricultural Development Institute (DADI) (32°31' 34.077" S; 27°27' 37.473" E) in Stutterheim, Eastern Cape, South Africa. Following planting and harvesting of two Swiss chard cultivars (Fordhook giant and Star 1801) in soil incorporated with 10 L Bioslurry (50% Bio), 20 L Bioslurry (100% Bio) and 40 L Bioslurry (200% Bio), NPK 2:3:4 (30) and 0 application (control), Swiss chard was planted in the same plots without any fertilizer applications. One seedling was planted per hill and the intra and inter row spacing was 0.25 and 0.5 m, respectively. The postharvest soil analysis showed that plots that were previously treated with 40 L (200%) Bioslurry had relatively higher soil nutrient elements compared to other treatments. The interactive effect of residual fertilizer and cultivar showed that the plots previously treated with NPK 2:3:2 (30) resulted into significantly higher dry leaf mass in Star 1801 but this effect did not differ significantly with 20 L (100%) and 40 L (200%) Bioslurry in Fordhook giant. The effect on soil pH revealed that the application of fertilizers resulted in reduced pH levels in summer compared to winter irrespective of the treatment. The plant mineral analysis showed that the fertilizer residues did not significantly influence plant mineral uptake and no clear trends were observed for the tested elements.

Key words: Residual effect, bioslurry, biological yield, Fordhook giant, Star 1801.

INTRODUCTION

Poor soil fertility and inadequate supply of plant nutrients are the main constraints to crop production in the agricultural systems (Begum et al., 2017). However, chemical fertilizers are not the most appropriate solution to overcome these constraints, especially for vegetables like Swiss chard that have short growing period and consumed fresh (Bonten et al., 2014). Shaheb et al. (2015) reported that chemical fertilizers are expensive

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and a threat to human health. Hence, the emphasis on finding alternatives to chemical fertilizers such as use of bioslurry, which is cheaper than other sources of nutrients and relatively safe for the environment should be prioritized (Begum et al. 2017). Bioslurry is a renewable source based organic fertilizer that can improve the nutrient status of soil (Shaheb et al. 2015). According to Bonten et al. (2014), bioslurry contains considerably higher amounts of plant nutrients as compared to poultry manure and compost, which improves the soil fertility and crop production. The nutrient quality of bioslurry is higher with less nitrogen losses compared to chemical fertilizer (Islam, 2006). The use of available and cheap cow dung based bioslurry by vegetable farmers ensures sustainability of production and balanced nutrition (Amanullah et al., 2007). Organic fertilizers supply required nutrients, improve soil structure, increase microbial population and maintain the quality of crop produce (Suresh et al., 2004).

Begum et al. (2017) found that the residual effect of organic manures significantly affected the yield of okra. Furthermore, Chattoo et al. (2010) who assessed the residual effect of organic manures and chemical fertilizers on succeeding pea crop in okra-pea rotation, also reported higher yields of okra per hectare. However, Shaheb et al. (2015) reported that the residue of phosphorus (P) and potassium (K) fertilizer were evident where bioslurry with chemical fertilizers was applied. Muhmood et al. (2014) found the similar trend in soil properties after harvest of crop in his studies on Swiss chard and Chilli production using bioslurry and inorganic fertilizer. Similarly, Jeptoo et al. (2013) found that the amount of P and K retained in plots treated with the highest level (7.8 t ha^{-1}) of bioslurry manure were more by 5 and 1.4% in season one and by 30.5 and 3.0% in season two respectively. However, many studies focused mostly on evaluating the bioslurry direct effects as fertilizer and very few studies are available on the residual effect of bioslurry on Swiss chard. Therefore, the main objective of this study was to evaluate the residual effect of bioslurry effluent on biological yield and nutrition content of Swiss chard.

MATERIALS AND METHODS

Study location

A greenhouse experiment was conducted in summer (November-January) 2017 and repeated in winter (June –August) 2018 at Döhne Agricultural Development Institute (DADI), (32°31'34.077" S; 27°27'37.473" E) in Stutterheim, Eastern Cape Province of South Africa.

Plant material (cultivar selection)

Two cultivars of Swiss chard (*Beta vulgaris* L.) namely; Fordhook giant and Star1801 commonly grown in the farming communities of the Eastern Cape were used. The certified seeds of these cultivars were sourced from the commercial seed companies. The two cultivars differ morphologically to each other in that; the Fordhook giant is characterized by green leaves and a white stalk while Star1801 has thick, succulent, dark green leaves and a yellow stalk.

Treatments

This experiment was a succession to a previously conducted experiment. Therefore, there was no fertilizer treatment applied and the seedlings were planted in corresponding treatment as in the previous experiment. The fertilizer treatments in the previous experiment were organic (Bioslurry) and inorganic (NPK) fertilizers. Bioslurry was collected from a biogas digester in Nyara Village, Komga (32°44'53''S; 28°08'47''E) and it produced from 100% cow-dung. Its application on the previous experiment was based on soil chemical analysis and plant requirements. The different bioslurry treatment application rates were as follows: Control (C) no fertilizer application, 10 L Bioslurry (50% Bio), 20 L Bioslurry (100% Bio) and 40 L Bioslurry (200% Bio). The inorganic fertilizer was NPK 2:3:4 (30) and its application was also based on soil chemical analysis and plant requirements for optimal plant growth and yields.

Experimental design

The experiment was a split plot laid out in a Randomised Complete Block Design (RCBD) replicated three times with the cultivar allocated to the main plot while subplots allocated to the residual effect of the previously applied fertilizer treatments.

Experimental procedure

A 300 m^2 greenhouse was cleaned and disinfected with spore-kill (Didecyldimethylamonium chloride). The surface of the greenhouse was then covered with a black landscape fabric in order to avoid contact between the soil surface and the established plots. The river sand obtained from the Barnard Camp River Valley at DADI was sieved through a 2 mm wire-mesh screen to ensure removal of stones and plant residues prior to the establishment of plots. Ten plots measuring 4.5 m² were established within the greenhouse and were replicated three times. A space of 1 m was allocated between the plots and 2 m between replicates. Although there was no fertilizer treatment applied in the current experiment, the fertilizer treatments applied in the previous experiment, were: Control, 50, 100, and 200% of Bioslurry effluent and the recommended rate of inorganic fertilizer NPK 2:3:4 (30). After harvesting, prior to planting of the current experiment, soil was analysed to determine its nutrient composition (Table1). At planting, one seedling of the two cultivars was transplanted separately into plots with corresponding fertilizer treatment as in previous experiment, using a plant spacing of 0.25 m between plants and 0.5 m between rows. Each plot measured 4.5 m², which resulted into 28 plants per plot and this is equivalent to 28 000 plants ha^{-1}. Transplants were irrigated as per the Swiss chard requirements until harvest at 60 days after transplanting (DAP). Agronomic practices such as weeding and pesticide application were carried out following the standard practices.

Data collection

At harvesting (60 DAP), ten (10) plants per replicate were selected randomly and tagged for data collection. The biological yield

Table 1. Postharvest nutrient composition of sand incorporated with bioslurry and inorganic fertilizer prior to planting for residual effect experiment for both summer and winter seasons.

Season	Treatment	Properties						
		pH	N	P	K	Exchangeable cations (cmol+ kg)		
		(KCL)	(%)	(mg L^{-1})		Ca (mg L^{-1})	Mg (mg L^{-1})	Zn (mg L^{-1})
Summer 2017	50% Bio	4.36	0.04	6	46	754	174	1.4
	100% Bio	4.49	0.05	6.7	40	672	124	1.3
	200% Bio	4.38	0.05	7	67	762	115	0.3
	NPK	3.89	0.05	107.5	278	521	68	1.5
Winter 2018	50% Bio	4.59	0.05	13.2	57	367	117	0.3
	100% Bio	5.02	0.06	17.9	71	372	142	0.3
	200% Bio	5.75	0.07	17.5	86	399	130	0.3
	NPK	6.76	0.06	134.1	22	0	4	0.0

parameters, namely; fresh and dry shoot mass was measured. Samples were then oven dried at 65°C for 48 h and weighed to obtain dry leaf mass. Nutrient content of leaves was determined using the Kjeldahl method at Döhne Analytical Laboratory.

Statistical analysis

Data was subjected to analysis using statistical software Statistica (Version 13.2) (Stat-Soft Inc. Tulsa, OK, USA). A two-way Analysis of Variance (ANOVA) was performed for each parameter in each treatment and cultivar. The Least Significant Difference ($LSD_{(0.05)}$) values were at the p= 0.05 confidence level. The interactive effects of cultivar and treatments were analysed as a two-way factorial using the same statistical version.

RESULTS AND DISCUSSION

Soil nutrient composition after harvesting

The results of soil nutrient composition after harvesting for nutrient elements such as nitrogen (N), phosphorus (P), potassium (K), calcium (ca), magnesium (Mg) and zinc (Zn) for both summer and winter growing seasons are presented in Table 1. During summer, there was a decrease in residual soil pH. The highest value was obtained when 100%Bioslurry (4.49) was previously applied followed by the application of 200%Bioslurry (4.38) while the lowest was obtained in plots that were previously treated with NPK (3.89). A constant N content in the soil was observed in all treatments (0.05%) except where 50% Bioslurry (0.04%) was previously applied, the highest P (107.5 mg L^{-1}) was obtained in plots that were previously fertilized with NPK, while the residual effect of 50% Bioslurry (6 mg L^{-1}) showed the lowest P content. The analysis of K showed that the highest K was found in NPK (278 g L^{-1}), while the lowest was obtained where 100% Bioslurry (40 mg L^{-1}) was applied. As shown in Table 1, the residual effect of NPK tended to dominate in the nutrient content of different elements in summer, with some exceptions for elements Ca and Mg. However, the results show that the residual effect of bioslurry resulted in higher mineral content in winter compared to NPK, with an exception of P, which showed highest values in winter (134.1 mg L^{-1}).

Residual effect of fertilization on biological yield (g/plants) of swiss chard

The results of the current study showed that the residual effect of fertilization has significantly ($p\leq 0.05$) affected the biological yield of Swiss chard for both fresh leaf mass (FLM) and dry leaf mass (DLM) parameters (Table 2). The highest FLM (287.48 g $plant^{-1}$) was obtained in plants grown in plots that were treated with NPK. The lowest FLM (116.95 g $plant^{-1}$) was obtained in plants grown in plots that did not receive any fertilizer in the previous season (Control) and this effect differed significantly to other treatments. Similarly, transplanting of Swiss chard seedlings in plots previously treated with NPK resulted into significantly higher DLM (22.53 g $plant^{-1}$) compared to other treatments, while the lowest DLM (9.60 g plant-1) was obtained in the control plots.

Interactions between residual effect of fertilization and cultivar on biological yield (g/plant) of swiss chard

The results of the study showed that the interaction between cultivar and fertilization significantly ($p\leq 0.05$) affected the biomass production of Swiss chard for DLM, while no significant residual effect was observed for FLM (Table 3). Transplanting Swiss chard seedlings of Star 1801 in plots that were previously fertilized with NPK

Table 2. Residual effect of fertilization on biological yield (g plant^{-1}) fresh leaf mass (FLM) and dry leaf mass (DLM) of Swiss chard.

Effect	FLM	DLM
	(g plant^{-1})	
C	116.95^{d}	9.60^{d}
50% Bio	149^{cd}	11.98^{cd}
100% Bio	170.96^{bc}	15.15^{bc}
200% Bio	210.62^{b}	17.37^{b}
NPK	287,48^{a}	22.53^{a}
Mean:	185.2	15.32
Cv (%)	031	0.29
p value:	0.00	0.00

Values in a column followed by a different letter are significantly different at P≤ 0.05. p value: probability value.

Table 3. Interactions between the residual effect of fertilization and cultivar on biological yield (g plant-1) [fresh leaf mass (FLM) and dry leaf mass (DLM)] of Swiss chard.

Cultivar	Treatment	FLM	DLM
		(g)	
Fordhook giant	C	110.40	8.35^{f}
Fordhook giant	50% Bio	156.65	14.21^{cde}
Fordhook giant	100% Bio	184.72	16.69^{bc}
Fordhook giant	200% Bio	252.15	20.05^{ab}
Fordhook giant	NPK	253.82	21.38^{ab}
Star 1801	C	123.50	10.85^{def}
Star 1801	50% Bio	141.34	9.74^{ef}
Star 1801	100% Bio	157.21	13.62^{cde}
Star 1801	200% Bio	169.10	14.70^{cd}
Star 1801	NPK	303.13	23.69^{a}
Means		**185.21**	**15,33**
Cv (%)		**0.32**	**0.31**
p Value		***0.111***	***0.052***

resulted into significantly higher DLM (23.69 g plant^{-1}) but the effect did not differ significantly with Fordhook giant plants from NPK (21.38 g plant^{-1}) and 200%Bioslurry (20.05 g plant^{-1}) respectively. The lowest response of residual effect showed that Fordhook giant plants grown in plots that were not fertilized in the previous season produced significantly lower DLM (8.35 g plant^{-1}). Although not significant, the highest residual effect for FLM (303.13 g plant^{-1}) was obtained in Star1801 plants grown in the NPK plots, while the lowest was obtained where no fertilizer was applied.

Residual effect of fertilization on nutrient content of swiss chard

Results of the study showed that the residual effect of fertilization did not significantly ($p \leq 0.05$) influence the nutritional content of Swiss chard for total nitrogen (TN), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe) and zinc (Zn) (Table 4). However, the highest TN (29.96%) was obtained in plots that were previously fertilized with NPK and the lowest TN (10.19%) was obtained in plots that were fertilized with 200% Bioslurry. The highest P (8.91%) content was obtained through the residual effect of 100% Bioslurry, while 200% Bioslurry showed the poorest residual effect. The analysis of K showed that the application of NPK in the previous season resulted in the higher plant K (9.29%) content and 200%Bioslurry demonstrated a poor residual effect as observed with P. The residual effect of fertilizer showed that the highest Ca (14.57%) content was found in control treatment, while the lowest (3.54%)

Table 4. The residual effect of fertilizer treatments on nutritional content of Swiss chard.

Effect	TN	P	K	Ca	Mg	Fe	Zn
	(%)					(mg/kg)	
C	18.14	8.76	8.20	14.57	8.41	2 899.04	1 220.66
50Bio	16.99	7.76	7.51	12.97	8.48	4 126.06	1 094.85
100Bio	15.70	8.91	6.79	12.80	18.88	3 228.97	1 233.06
200Bio	10.19	7.01	4.77	8.56	8.06	2 393.61	1 251.81
NPK	29.96	7.01	9.29	3.54	3.88	5 841.87	896.58
Mean:	18.196	7.902	7.352	10.488	9.542	3697.91	1139.392
Cv (%)	0.36	0.10	0.21	0.38	0.52	0.33	0.12
p Value:	*0.11*	*0.96*	*0.69*	*0.16*	*0.43*	*0.59*	*0.94*

Values in a column with no letters are insignificantly different at P≤ 0.05. p value: probability value, Cv (%): Coefficient of variance.

was observed in the fertilizer residues of NPK. In respect of Mg, the highest content (3.88%) was obtained in plants grown where 100% Bioslurry was applied and the lowest was obtained in plants grown in NPK fertilizer residues. The results for Fe showed that the residual effect of NPK produced the highest content (5 841.87 mg kg^{-1}) and the lowest (2 393.61 mg kg^{-1}) was obtained in 200% Bioslurry. Regarding Zn, the highest content (1 251.81 mg kg^{-1}) was obtained where 200% Bioslurry was applied (1 233.06 mg kg^{-1}) and the lowest (896.58 mg kg^{-1}) was obtained in plots previously fertilized with NPK.

DISCUSSION

Organic manures play a pivotal role in plant growth and development. These manures supply the required plant nutrients, improve soil structure and water holding capacity, increase microbial population, while also promoting plant growth (Dauda et al., 2008; Jeptoo et al., 2013). The postharvest soil nutrient analysis from this study revealed the changes in soil pH in both summer and winter seasons. There was a decrease in residual soil pH during the summer season in all treatments. These results confirmed the findings of Shaheb et al. (2015) who reported that where bioslurry and chemical fertilizer was applied, lower residual pH units were obtained. However, in winter, the results demonstrated that the soil pH increased with the increasing fertilizer application rates. NPK application exhibited the highest pH value, while application of 50% Bioslurry resulted in lower pH value. The results concur with findings of Musse et al. (2020) who reported that application of liquid bioslurry reduced the soil pH compared to inorganic fertilizers at postharvest. However, Muhammad (2011) reported that application of liquid bioslurry slightly improved the postharvest soil pH although the improvement was not significant compared to inorganic fertilizer.

The application of NPK and bioslurry demonstrated a positive contribution on the residual nutrient content of N, P, K and Zn in summer; however, Ca and Mg concentration declined from NPK application compared to bioslurry. A constant N concentration in the soil was observed in all the treatments at 0.05% except where 50% Bioslurry treatment was applied (0.04%) in summer. An increase in residual N content was observed in winter, whereby highest N content (0.07%) was found where 200% Bioslurry was applied. This might be due to the gradual release of nutrients from its slow rate of decomposition than NPK fertilizer, which releases the nutrients quickly into the soil. The results contradict the findings of Debebe and Itana (2016) who reported that after the experiment, the soil treated with mineral fertilizer contained higher N than soil treated with bioslurry.

The results showed that there was a slight decline in the amount of P and K in all fertilizer treatments in summer. These results are in line with the results of Alemneh (2011) and Debebe and Itana (2016); who reported that the soil nutrient content after experiment showed lower P concentration than before the experiment. Similar results were found by Biramo (2017), who reported that P status of soil after crop harvest was improved when chemical fertilizers and higher rates of bioslurry were added to the soil. Brady (1990) earlier reported that most crops do not take up more than about 10-15% of the P added in fertilizers during the first year of application. The author further stated that this is due not only to the tendency of the soil to fix the added P but also to the slow rate of movement of this element to the plant roots in the soil solution.

The current study results indicated that the highest K was obtained where 200%Bioslurry was applied followed by 100%Bioslurry. According to Shaheb et al. (2015) bioslurry is the organic fertilizer that contains considerable amount of plant nutrients and can improve the soil fertility. The author further reported the highest available K in soil after crop harvest in plots where cow-dung bioslurry was applied. Khuram et al. (2015) also reported the highest K concentration in soil after harvest where 100% bioslurry treatment was applied. According to Biramo (2017), the fertilizing effect of bioslurry increases significantly with increase in application. With respect to cultivars, although not significant, Fordhook giant plants produced the highest values compared to Star 1801 plants in terms of FLM and DLM. These results confirm the findings of Angeny (2017), who reported that cultivars showed no difference in yield. Moreover, the results are in line with findings of Maboko and Du Plooy, (2013) who stated that the highest yield was obtained with Fordhook giant cultivar.

According to Parry et al. (2005), the organic manures are known to have the ability to supply both macro and micro nutrients required for crop growth, development and the economic yield. Biomass yield of Swiss chard tended to increase with an increase in bioslurry application level. With regards to residual effect of fertilization on FLM, plants grown where NPK was applied yielded the highest followed by plants grown where 200% Bioslurry was applied and the lowest was obtained in plants grown in control treatment. Niyokuri et al. (2018), reported that the residual effects of bioslurry applied at 2.0, 2.5 and 3.0 L ha^{-1} resulted in a significant increase in plant mass compared to control. According to Haque et al. (2018), bioslurry supplied greater amount of nutrients which influenced nutrient uptake of the test crop. Similarly, Jeptoo et al. (2013) reported that plants treated with the highest level of bioslurry had more yield compared to control.

With regards to residual effect of fertilization on DLM, the highest yield was obtained when NPK was applied followed by bioslurry application, while the lowest was obtained in control treatment. Biramo (2017) reported that chemical fertilizer application resulted in maximum fresh weight as compared to control treatment. Haraldsen et al. (2011) reported that plant nutrients in a liquid bioslurry are more readily available to plants when compared to NPK as the fertilizer requires moisture to be accessible to plants.

The results of this study showed that the interaction between cultivar and fertilization significantly affected the DLM of Swiss chard. The highest DLM, was attained in Star 1801 (23.69 g $plant^{-1}$) fertilized with NPK but this was not significantly different to Fordhook giant plants where NPK (21.38 g $plant^{-1}$) and 200% Bioslurry (20.05 g $plant^{-1}$) was applied. The lowest DLM was attained in Fordhook giant plants grown under control treatment. These findings are in agreement with the findings of Maboko and Du Plooy (2013) who reported that Ford Hook Giant yielded higher dry mass at harvesting, which did not differ significantly compared to Star 1801 cultivar.

The current study revealed that the previous fertilization did not have significant residual effect in nutrient content of Swiss chard for all nutrient elements.

CONCLUSION AND RECOMMENDATIONS

This study showed that plots that were previously treated with 40 L (200%) Bioslurry had relatively higher soil nutrient elements compared to other treatments. The interactive effect of residual fertilizer and cultivar showed that the plots previously treated with NPK 2:3:2 (30) resulted into significantly higher dry leaf mass in Star 1801 but this effect did not differ significantly with 20 L (100%) and 40 L (200%) Bioslurry in Fordhook giant. The effect on soil pH revealed that the application of fertilizers resulted in reduced pH levels in summer compared to winter irrespective of the treatment. The plant mineral analysis showed that the fertilizer residues did not significantly influence plant mineral uptake and no clear trends were observed for the tested elements. The competitive residual effect of 40 L (200%) Bioslurry in comparison with NPK 2:3:2 (30) for DLM in the cultivar x fertilizer interaction suggested that bioslurry applied at higher rates could have a long lasting but positive effect on plant growth and thus could be used as an alternative under conditions where expensive inorganic fertilizers are limited. Further studies on the residual effect on plant mineral uptake are recommended as no clear residual effects were found on the plant mineral content in the current study.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ETHICAL STATEMENT

There was no involvement of animals in this study.

ACKNOWLEDGEMENTS

The authors extend sincere gratitude to the Department of Rural Development and Agrarian Reform (DRDAR) and the Nelson Mandela University (NMU) Postgraduate Research Scholarship for funding this study and also appreciate the capable research team of Döhne Agriculture Development Institute (DADI) in the Directorate: Plant and Crops Production Research for their devotion and contribution towards success of this work.

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