EFFECTS OF ORGANIC NITROGEN SOURCES ON GROWTH, LEAF YIELD AND NITRATE CONTENT OF SWISS CHARD (*BETA VULGARIS* VAR. CICLA)

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Abstract

Swiss chard (*Beta vulgaris var cicla*) is one of the most valuable leafy vegetable that is widely adapted and the most nutritive exotic vegetable. However, it tends to accumulate more nitrates than other leafy vegetables. The nitrates may be converted to nitrite causing infantile methaemoglobinaemia, carcinogenic nitrosamines and even teratogenesis. Swiss chard grows well in organic fertilizers and has less nitrate accumulation. However, there is limited information on the specific type of organic fertilizer to use in order to reduce the amount of nitrate level in Swiss chard. The study was conducted to determine the effects of organic sources of nitrogen on growth, leaf yield and nitrate content of Swiss chard in Kericho County. The treatments consisted of chicken manure, goat manure, cow manure, control and Calcium ammonium nitrate (CAN). The experiment was laid out in a Randomized Complete Block Design with 3 replications. Data was collected on five randomly selected plants per treatment. The variables measured included plant height, number of leaves, leaf length and width, which was done weekly for a period of 8 weeks after transplanting. The plant survival, root and shoot fresh weights were determined on the 8th week after transplanting. The collected data was subjected to analysis of variance using GenStat statistical software and the means separated using Least Significance Difference at $\alpha = 0.05$. Poultry manure had the highest plant height, leaf number, width and length, survival and shoot fresh weight than the other treatments. Root fresh weight was high in CAN treated plants than the other treatments. The CAN treated plants accumulated two times more nitrate than poultry manure treated plants. Among the organic nitrogen sources goat manure accumulated less nitrate than poultry and cow dung manures and this was related to the nitrogen content of the manures. Supplementing goat manure with poultry manure may increase the growth and yield of Swiss chard while maintaining the nitrates at a lower level.

Key words: organic fertilizers, nitrogen, nitrates, Swiss chard

Introduction

The productivity of many African soils is normally limited by nitrogen and phosphorus Mojeremane *et al.* (2015). Nitrogen, normally supplied in the form of organic or inorganic fertilizers, play an essential role in vegetative growth and hence yield and quality of leafy vegetables. Farmers often supply great amounts of inorganic nitrogenous fertilizers to increase the yield of vegetables because they are easy to use and also releases nutrients quickly. However, high inorganic fertilizer inputs can lead to marked deterioration in soil and ground water quality (Zhu et al., 2005), due to leaching, volatilization, denitrification and surface run off. Moreover, they contain just a few mineral nutrients which dissolve quickly in damp soil and give plants large doses of minerals (Masarirambi, 2010), especially nitrates in leafy vegetables beyond

safe limits (Umar et al., 2007; Allessandro and Miceli, 2014).

Vegetables are rich source of vitamins, minerals and antioxidant. The anticancer properties of vegetables and their ability to reduce cardiovascular disease have been proven (Sadeghi et al., 2015). Vegetables constitute a major source of nitrate providing more than 80% of the average daily human dietary intake (Hoque et al., 2010). Leafy vegetables have high nitrate content than root and fruit vegetables (Abd El Hamied, 2001; Salehzaden et al., 2020). Among the leafy vegetables, Swiss chard tends to accumulate more nitrate than others and can be the one that contributes most of daily nitrate intake (Santamaria et al., 1999; Ayaz et al., 2007). Nitrate accumulation in edible part is a problem when eaten as the nitrates may be converted to nitrite causing infantile methaemoglobinaemia, carcinogenic nitrosamines and possibly even teratogenesis (Hord et al., 2009).

Swiss chard is highly appreciated in many parts of the world for its nutritional properties, year round availability, low cost and wide use in many traditional dishes (Gao et al., 2009). Ninfali and Angelino (2013) and Sacan and Yahardag, (2010) reported that bioactive molecules from Swiss chard extracts have anti-diabetic, anti-inflammatory, anti-oxidant and anti-cancer activities. In addition, it is rich in biotine, an important vitamin for the hair (Mihai et al., 2015). Therefore efforts to minimize the accumulation of nitrates in Swiss chard will add value to vegetable products already popular for their nutritional and therapeutic properties (Santamaria, 2006).

The use of organic materials as soil amendment has been accorded considerable attention for reclamation of degraded soils for nutrient recovery and increase crop production using available resources (Ahmad et al., 2014; Ewulo, 2005). However, the results are site specific depending on soil type, climatic conditions and cultural practices. Swiss chard grows well in organic fertilizers and has less nitrate accumulation (Drost et al., 2010). However, the farmers don't know the specific type of organic fertilizer to use in order to reduce the amount of nitrate level in Swiss chard that is acceptable to regulator while maximizing the quality and yield. The objective of the study was to determine the effects of organic sources of nitrogen on growth, leaf yield and nitrate content of Swiss chard.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at the University of Kabianga, School of Agriculture and Biotechnology farm, Kericho County. The site lies at an altitude of 2163M above sea level and latitude of 0°49'0 N, 35º 49'60 E . The mean rainfall is 900-1200mm per annum with two distinct peaks in the months of May and October. The temperature ranges from 10°C to 29°C. The soils are Nitisols which are acidic, moderately deep and well drained (Jaetzold and Schmidt, 1982).

Experimental Design and treatments

The experiment was laid in a Randomized Complete Block Design (RCBD) with five treatments and three replications. The five treatments included well decomposed poultry manure, cow manure, goat manure, inorganic fertilizers (DAP & CAN) and the control (not treated with any fertilizer).

Plant material and data collection

The Swiss chard seedlings were raised in the nursery for four weeks thereafter transplanting done at a spacing of 15cm by 30cm. The

decomposed manures were mixed with the soil two days before transplanting. For the inorganically treated plots, DAP was used during transplanting and CAN at 50kgN/ha was added at one week after transplanting. Cultural practices like watering, weeding, pest and disease management were carried out as required.

Five plants per treatment were selected randomly for data collection. The parameters measured were weekly plant height, number of leaves, leaf length and width for a period of 8 weeks after transplanting. The nitrate content, plant survival, root and shoot fresh weights were determined on the 8th week after transplanting.

Soil and Manure analysis

The manures were collected from the University of Kabianga's Farm, and placed in the greenhouse for three weeks to decompose. Samples from the three manures and soil from the field were collected and analyzed for the available nutrient contents at KALRO, Tea Research Foundation (TRI), Kericho. For nitrogen analysis the Kjeldahl method was used (Cline et al., 1986). The other nutrients: phosphorus, potassium, magnesium, calcium, zinc, manganese and copper were analysed using Atomic absorption spectrophotometer.

Nitrate analysis

The nitrate level was determined on weighed leaf samples that were dried in a thermostatically controlled air-oven at 60^{o} C and weighed before being ground to pass through 600 ìm mesh sieve. For determination of nitrates, about 0.1g of the Swiss chard powder was weighed and suspended in 10 ml distilled water. The suspension was incubated at 45^{o} C for 1 hour to allow complete leaching of the nitrate, and then filtered through Whatman No. 41 filter paper. The concentration of the nitrate-N in the filtrate was determined by the method of Cataldo et al. (1975).

Data analysis

The collected data was subjected to analysis of variances (ANOVA) using GenStat statistical software (Payne et al., 2006) and the means separated using Least Significance Difference (LSD) at 5% level of significance.

RESULTS

Mineral nutrient composition of the soil and organic nitrogen sources

The poultry manure had relatively higher mineral nutrient content than the goat and cattle manures except iron that was relatively higher in goat manure than the other organic manures. The pH of goat and cattle manures was highly alkaline compared to the poultry manure (Table 1a). The nitrogen content of the soil was relatively low compared to the other mineral nutrients (Table 1b).

Plant growth parameters

The use of fertilizers promoted growth of Swiss chard. The inorganic source of nitrogen produced significantly ($p < 0.05$) lower plant height, leaf number, height and width than poultry manure however, it was not significantly different from goat and cattle manures for leaf number, height and width (Table 2). Among the organic nitrogen sources of fertilizers, poultry manure produced high plant height, leaf number, leaf height and width followed by cattle and goat manures (Table 2).

Table 1a: Mineral nutrient composition of the organic nitrogen sources

Type of Manure	Ph	%N	%P_2O_5	%K2O	%CaO	%MgO	%Mn	Zn(ppm)	Cu(ppm)	Fe(ppm)
Cow dung	8.93	2.02	0.51	1.51	2.15	0.53	0.90	13	6	163
Goat	9.55	1.27	0.74	1.61	2.31	0.96	0.95	27	6	167
Poultry	7.20	2.06	0.97	1.69	2.39	1.01	0.95	40	7	162

Table 1b: Mineral nutrient content in the soil at the site of planting

	%Moisture content	% Nitrogen	Available P (mg/kg)	Available K (cmolkg)	Available Mg (cmolkg)	Available Ca (cmolkg)	pH
Soil	14.3	0.27	15.1	4.14	2.33	9.31	5.2

Table 2a: Effects of Nitrogen sources on growth of Swiss chard at 2 and 4 weeks after transplanting

Treatments	Week 2 after transplanting				Week 4 after transplanting			
	Plant height	Leaf number	Leaf height	Leaf width	Plant height	Leaf number	Leaf height	Leaf width
Poultry Manure	17.05c	4.67c	9.13d	5.03d	20.39d	5.53c	11.06d	6.09c
Cattle Manure	12.47b	3.67b	6.40c	3.46c	15.02c	4.53b	7.46c	3.99b
Goat Manure	10.1b	3.53b	4.92b	2.87b	11.49b	4.06b	5.84b	3.36b
Inorganic (CAN)	9.66b	3.27b	5.63bc	3.13bc	13.02bc	4.13b	7.29c	4.06b
Control	6.36a	2.67a	3.21a	1.85a	6.17a	2.53a	2.89a	1.66a

[a]Means followed by similar letters along the row are not significantly different from each other at $\alpha = 0.05$.

Table 2b: Effects of Nitrogen sources on growth of Swiss chard at 6 and 8 weeks after transplanting

Treatments	Week 6 after transplanting				Week 8 after transplanting			
	Plant height	Leaf number	Leaf height	Leaf width	Plant height	Leaf number	Leaf height	Leaf width
Poultry manure	25.12e	7.33c	13.79d	7.26c	27.30e	8.53c	14.79d	7.90c
Cattle manure	20.56d	6.00b	9.24c	4.66b	22.56d	6.83b	10.24c	4.86b
Goat manure	14.00b	5.53b	7.31b	4.11b	15.00b	6.13b	8.31b	4.50b
Inorganic (CAN)	17.35c	5.46b	9.55c	4.93b	18.35c	6.47b	10.55c	4.93b
Control	5.84a	1.53a	2.68a	1.68a	6.84a	1.50a	3.68a	1.89a

[a]Means followed by similar letters along the row are not significantly different from each other at $\alpha = 0.05$.

Leaf yield and nitrate content

Application of fertilizers promoted shoot and root fresh weights. Goat manure produced significantly ($p < 0.05$) lower shoot fresh weight than poultry, CAN and cattle manures. Poultry manure had the highest SFW than the other treatments (Table 3). The root fresh weight was significantly higher in poultry manure than the other treatments. Cattle, goat and CAN had statistically similar RFW. The percent survival from the organic sources of fertilizers was significantly higher than the

control and CAN. However, the percent survival from the latter two treatments was not significantly different from each other (Table 3). The nitrate content of the leaves significantly ($p < 0.05$) increased from the control (16.07) followed by goat, cattle, poultry (29.4) with inorganic fertilizers having the highest (58.17) nitrate content (Table 3).

Table 3: Effects of Nitrogen sources on leaf yield and nitrate content of Swiss chard at 8 weeks after transplanting

Treatments	Shoot fresh weight (g)	Root fresh weight (g)	Survival rate (%)	Nitrate content
Poultry manure	33.15c	21.25c	90.5b	29.4d
Cattle manure	14.44b	8.62b	86.9b	26.67c
Goat manure	6.26a	7.47b	79.77b	22.57b
Inorganic (CAN)	14.74b	7.91b	45.27a	58.17e
Control	1.05a	0.64a	34.53a	16.07a

[a]Means followed by similar letters along the row are not significantly different from each other at $\alpha = 0.05$.

DISCUSSION

The mineral nutrient content (nitrogen, calcium, phosphorus, zinc, magnesium) of poultry manure was higher than the goat and cattle manures except iron that was higher in goat manure (Table 1). Poultry manure also promoted better growth performance than the other organic nitrogen sources and inorganic N source (CAN) (Tables 2 and 3). Poultry manure has been shown to increase the plant height and number of leaves (Usman, 2015; Alessandro and Miceli, 2014; Gulser, 2005) in tomatoes, Swiss chard and spinach respectively. This was possibly due to the high nitrogen content in poultry manure than the cattle and goat manure. Moreover, 30% of nitrogen from poultry litter has been reported to be in urea or ammonium form and is therefore readily available to plants (Sunassee, 2001). Adequate supply of nitrogen is associated with vigorous vegetative growth resulting from high photosynthetic activities (Warren et al., 2000). It was also noted that the control had high number of leaves on the 4thweek compared to the 8th week after transplanting and this was possibly due to depletion of nitrogen available in the soil due to high rainfall experienced during the growing season as was also reported by Abebe and Feyisa (2017). The organic nitrogen sources, apart from supplying nutrients, they also improve biological properties such as increased microbial populations for biological activity, soil's physical properties such as structure and aggregation and water holding capacity and drainage (Buresh and Dobermann, 2010) that make them withstand the impacts of rainfall.

Among the organic sources of fertilizers poultry manure produced higher shoot fresh weight (SFW), leaf height and width followed by cattle and goat manures though the three parameters from the latter two treatments were not significantly different from the inorganic N source. Research on the effect of organic nitrogen in vegetables such as *Corchorus olitorius* has shown that poultry manure also improves the girth of leaves (Ayeni and Oye, 2017; Senjobi, 2013), and shoot height and width of leaves in *Lactuca sativa* L. (Liu et al., 2014). Nitrogen is essential for cell division and low nitrogen in the cattle and goat manures could have reduced leaf blade growth

by decreasing mitotic and post mitotic rates as has been reported by Kavanova et al., (2008).

Since the soils in the study region are acidic in nature and also low in phosphorus, the organic fertilizers with high pH (Table 1) moderated the soil pH thereby enhancing the availability of most nutrients for the growth of Swiss chard. Poultry manure has been linked with reduction of soil acidity apart from soil nutrient enrichment (Olatunji and Oboh, 2012; Sunassee, 2001). The plots with inorganic nitrogen source were treated with DAP and CAN, and the percent survival was significantly lower than from the organically treated fields. This could have been attributed to leaching of CAN and reduced soil pH due to the ammonium ions from DAP fertilizer which was applied during transplanting. Low pH reduces availability of essential nutrients for growth (Manoharan et al., 1995).

Leaf surface area, size of individual leaves and leaf thickness have been shown to increase in plants treated with nitrogen. Poultry manure with high nitrogen content recorded significantly higher shoot fresh weight than the other treatments (Tables 1a and 3). Nitrogen function in accumulation of biomass as it is utilized from roots and leaves, due to its major role in vegetative growth in vegetables. It is an essential component of protein, nucleic acids, chlorophyll and growth hormones (Barker et a., 1974). Inorganic N source produced significantly higher root fresh weight than the other treatments (Table 3) and this could be due to enhanced root growth by DAP which was applied during transplanting in inorganically treated plots.

The nitrate content in the leaves of Swiss chard increased with increased amount of nitrogen in the treatments. Hailay and Haymanot (2019) also reported similar findings in Swiss Chard. The inorganic N source recorded the highest level of nitrate than the organic N sources as has also been recorded in Lettuce (Liu et al., 2014) and this could be due to slow release of nutrients by organically treated plants (Herencia et al., 2014). Substitution of inorganic fertilizer with chicken and cow manure showed reduced nitrate accumulation and increased shelf life of fresh basil (Falla and Omran, 2018). Increased vegetable yield and reduced nitrate levels has also been reported with organic fertilizers in a tomato-celery-tomato system (Shuyan et al., 2017). Control had the least nitrate content due to limited N in the soil and hence limited N absorbed by the plants.

Conclusion

Organic N sources promoted the growth and yield of Swiss chard. Among the nitrogen sources, poultry manure had better growth and yield performance than the other treatments due to high nutrient content. Nitrate content in the leaves also increased with N content in the treatments. The organically treated plants had lower nitrate content than the inorganic N source which is beneficial to the human body. Supplementing goat manure with poultry or inorganic fertilizers may increase the growth and yield of Swiss chard while maintaining the nitrates at a lower level.

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Declaration of Interest Statement

There is no conflict of interest

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