

Effects of cattle manure on the growth, yield, quality and shelf life of beetroot (*Beta vulgaris* L. cv. Detroit Dark Red)

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ABSTRACT

Beetroot (*Beta vulgaris* L.) is one of the widely and popularly used vegetable as a salad vegetable in the Kingdom of Eswatini: However, there is scarcity of information pertaining to its organic production. A field study laid out in a Randomised Complete Block Design (RCBD) was conducted at the Horticulture Farm, Faculty of Agriculture, Luyengo Campus, at the University of Eswatini to determine the effects of cattle manure on growth, yield, quality and shelf-life of beetroot. Five treatments were applied in this experiment, and included cattle manure applied at 20, 40, 60, and 80 t/ha and a control of inorganic fertilizer, NPK [2:3:2 (22)] applied at 100 kg/ha as basal dressing and limestone ammonium nitrate (LAN) (28) applied at 80 kg as a top dressing. The treatments were replicated four times. The results obtained showed that beetroot grown under the application rate of 80 t/ha exhibited higher values in plant height (32.5 cm), number of leaves (9), leaf area (206 cm²), root diameter (5.1 cm), root length (11.7 cm), root fresh weight/plant (10.8 g), root dry weight/plant (9.2 g), marketable yield/plant (9.2 g) and quality [(aroma (33.5%), flavour (34%), texture (35%)] of the edible part. Plants supplied with 20 t/ha of cattle manure and inorganic fertiliser (control) gave the lowest vegetative growth parameters, quality parameters and marketable yield.

Keywords: Organic fertilisers, yield, organoleptic taste, quality, shelf-life, *Beta vulgaris*

1. INTRODUCTION

Beetroot (*Beta vulgaris* L.) belongs to Chenopodiaceae family [1]. It is indigenous to Asia and Europe. It was first used for food from about the third century, although it had been grown for thousands of years for medicinal purposes [2]. It is grown widely in Germany and France and in lesser amounts in other European countries, Africa and South America. Beetroot has now become a popular salad vegetable. It is mainly used as root vegetables,

leafy vegetable with health benefits, as well as source of dyes and traditional remedy [3]. It has varieties that include silver beet, sugar beet and fodder beet [2].

Good yield of beetroots is obtained by good nitrogen application and optimal spacing within rows. Any cessation in growth of beetroot produces tough, woody roots with uneven colour and inferior flavor, since excessive nitrogen results in lush growth prone to disease at the expense of the root development [4]. Fertilizers and manures are used in agriculture to supplement the not so adequate nutrients which the plant cannot obtain from the soil alone. This usually results in an increase in yield and another aim of the use of fertilizers and manures, not always successful, is to improve the quality of the crop as food for human beings [5].

According to [6], commercial and subsistence farming have been and are still relying on the use of inorganic fertilizers for growing crops. This is because they are easy to use, quickly absorbed and utilized by crops. However, these fertilizers are believed to contribute substantially to human and animal intoxication, including environmental contamination. They commonly contain synthetic materials which are rich in one or more of the essential plant nutrients. Fertilizers are often regarded as substitutes for animal manures, but that is not a correct interpretation of their purpose. Commercial fertilizers make it possible to introduce extra supplies of nutrients into the cycle of growth and decay hence improves fertility [7].

According to [8], many research reports have indicated that there is a research gap in cultivation practices of beetroot such as recommended spacing, fertilizer application rate and other practices. This has resulted to the production and productivity of beetroot to be very low throughout the country. This has resulted to the country importing most of beetroot from South Africa to meet the market demand [9]. The high cost of synthetic fertilizers and the lack of knowledge on how to use them properly are also other factors which cause farmers to fail to produce beetroot in a large scale [8]. Furthermore, synthetic fertilizers have adverse effects to the soil; these effects include decrease in soil fertility, soil and groundwater pollution. Nitrogen and potassium based synthetic fertilizers leach into ground water and increase its toxicity, causing water pollution. They also increase the nitrate levels of soil and damage the natural make-up of soil in the long term. There is dearth of information on beetroot production using cattle manure in our local conditions whereas it is used to improve soil structure and is available in almost every homestead following that almost every family in the Kingdom of Eswatini has cattle. Therefore the focus of this study is to investigate the best cattle manure application rate on beetroot production that will bring optimum yields, quality and prolonged shelf-life of beetroot.

2. MATERIALS AND METHODS

2.1 EXPERIMENTAL SITE

The experiment was conducted at the University of Eswatini, Faculty of Agriculture, Luyengo Campus in the Horticulture Department Farm. Luyengo is situated in the Manzini region, in the Middleveld agro-ecological zone in Eswatini. The geographical location of the experimental site is 26° 34` S and 31° 12` E. The average altitude of this area is 750 m above sea level. This area receives an average rainfall of 980 mm per annum with most of the rain falling between October and March. The average winter temperature is about 15° C while that of summer is about 27°C. Drought hazard is about 40 % [10].

2.2 PLANT MATERIAL

Six weeks old beetroot seedlings (Crimson globe variety) were purchased from a commercial nursery, Vickery Seedlings at Malkerns.

2.3 EXPERIMENTAL DESIGN

The experiment was laid-out in a Randomised Complete Block Design (RCBD). The experiment had five treatments replicated four times. The treatments consisted of cattle manure applied only once at 20, 40, 60 and 80 t/ha, with a control of inorganic fertiliser, NPK [2:3:2 (22)] applied at 100 kg/ha as a basal dressing. Limestone ammonium nitrate [LAN] (28) was applied at 80 kg/ha as a top dressing fertiliser for control plants. The experimental plots were 3×3 m in size and were separated by 1 m footpaths. To ensure that the cattle manure was completely broken down, it was applied one month before transplanting and thoroughly mixed with the soil. Every week it was kept moist to speed up the rate of decomposition. For the control treatment, NPK fertiliser was applied on the day of transplanting and LAN was applied four weeks after transplanting.

2.4 DATA COLLECTION

Data was collected at weekly intervals starting from two weeks after transplanting (WAT). Data collection was made by random sampling of five plants and the same plants were used throughout the duration of the experiment. Data was collected on:

- a) Plant height;

- b) Leaf number;
- c) Leaf size: length and width of leaves;
- d) Leaf area: leaf area was calculated using the formula; $-193.518 + 8.6327 L \text{ (cm)} + 14.017 W \text{ (cm)}$ [11];
- e) Chlorophyll content: chlorophyll content in the leaves of the beetroot plants was determined using a Chlorophyll meter (CCM-200 plus, Opti-Sciences, Inc. 8 Winn Ave Hudson, NH 03051, USA);
- f) Stem diameter: a Vernier caliper was used to measure the diameter of beetroot (Pierre Vernier, 1637, Ornas, France).
- g) Bulb fresh weight;
- h) Bulb dry weight: the dry weight was measured after oven drying at 75°C until constant weight was achieved;
- i) An organoleptic test was conducted to determine the quality of the beetroot: the beetroot was cooked with raw water and was given to 20 people to taste grade. No flavour was added to the beetroot before giving the 20 people. A score chart was used to determine the organoleptic test.
- j) The shelf-life of the beetroot was determined by storing them at room temperature for a period of 10 days [12]. The harvested roots were kept for shelf-life studies in a laboratory at ambient temperature. Shelf life of roots was assessed based on visual parameters. The number of days was computed from the day of harvest until the produce started senescence.

2.5 DATA ANALYSIS

The data collected was subjected to analysis of variance (ANOVA) using GEN-STAT Statistical package [13]. Where significant differences were detected, mean separation was done using Duncan New Multiple Range Test (DNMRT) at 5% probability level [14].

3.0 RESULTS

3.1 SOIL ANALYSIS AND MANURE ANALYSIS

Soil chemical properties were analysed at Soil Chemistry Laboratory in the Crop Production Department of the University of Eswatini, Luyengo Campus. The results are as shown in Table 1.

Table 1: Soil analysis results

Item	Content
pH	5.35
P	53.4 cmol/kg
K	0.073 cmol/kg
Mg	1.09 mg/kg
Ca	1.18 mg/kg

Cattle manure properties were analysed at the Soil Chemistry Laboratory in the Crop Production Department of the University of Eswatini, Luyengo Campus. The results are as shown in Table 2.

Table 2: Cattle manure analysis results

Item	Content
pH	8.07
P	1.01 ($\mu\text{g}/\text{kg}$)
K	6.50 (cmol/kg)
Mg	4.83 (cmol/kg)
Ca	0.90 (cmol/kg)

3.2 VEGETATIVE GROWTH PARAMETERS

3.2.1 PLANT HEIGHT

There were no significant ($P > 0.05$) differences in plant height of beetroot from the different treatments throughout the experiment. At 6 WAT the highest plant height (32.5 cm) was obtained from 80 t/ha and the lowest (31.0 cm) was recorded from plants supplied with 60

t/ha of cattle manure. The second highest plant height was obtained from plants provided with 20 t/ha of cattle manure (Figure 1).

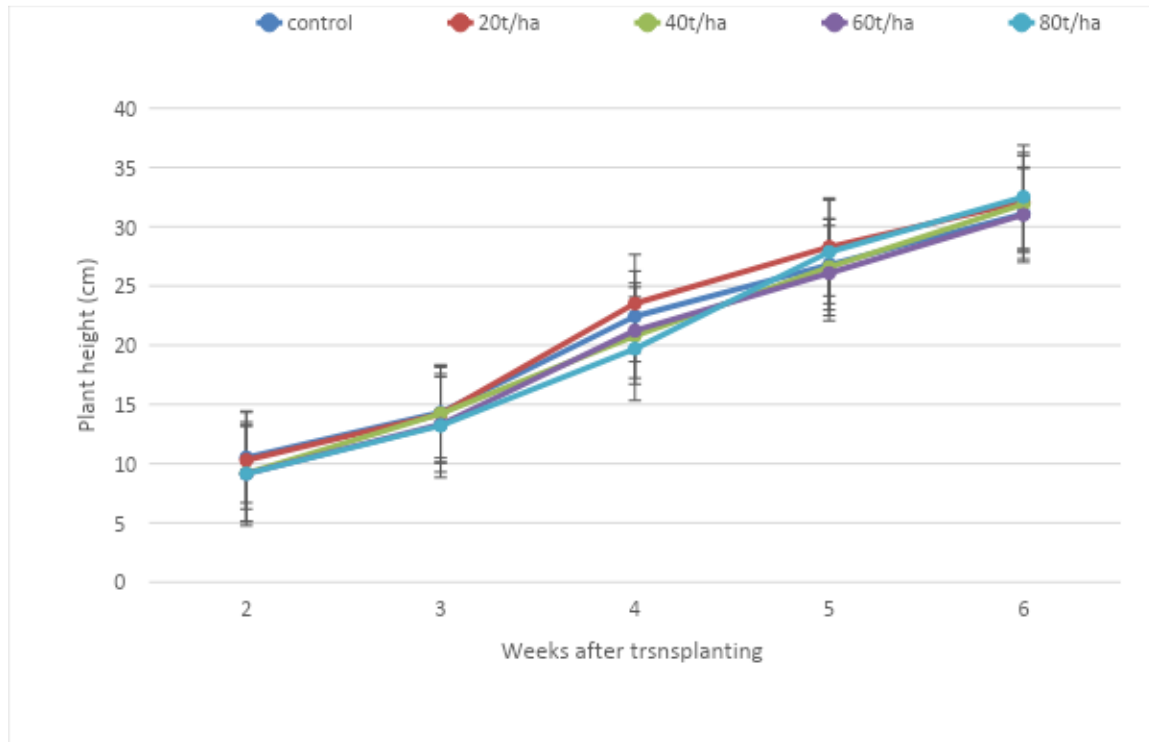


Figure 1: Effects of cattle manure on plant height of beetroot. Vertical bars represent standard error (SE) below and above the mean.

3.2.2 NUMBER OF LEAVES

The results showed no significant ($P > 0.05$) differences on leaf number of beetroot at 3, 4, and 5 WAT. However, at 2 WAT and 6 WAT the results showed significant ($P < 0.05$) differences among the treatments. At 6 WAT, the highest leaf number (10) was obtained from plants provided with 60 t/ha and the lowest (9) from those supplied with 20 t/ha of cattle manure. The second highest number of leaves was obtained from the control plants (Figure 2).

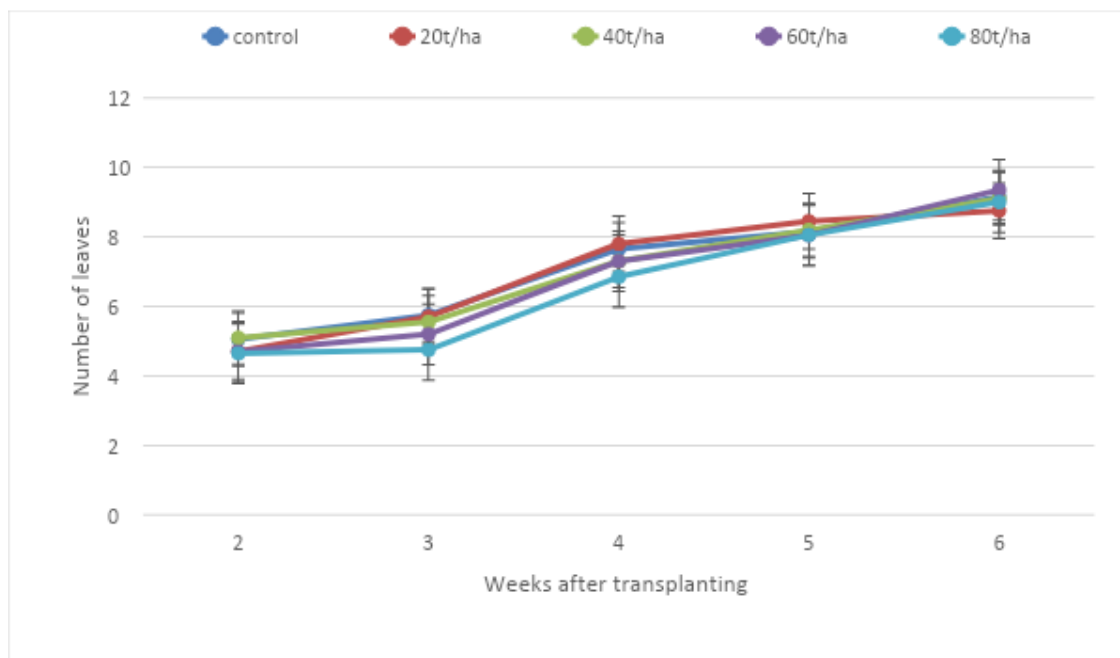


Figure 2: Effects of cattle manure on the number of leaves of beetroot. Vertical bars represent standard error (SE) below and above the mean.

3.2.3 LEAF AREA

There were no significant ($P > 0.05$) differences in leaf area of beetroot from the different treatments at 5 and 6 WAT. However, the results showed significant ($P < 0.05$) differences on leaf area of beetroot at 2, 3, and 4 WAT. At 6 WAT the highest leaf area (206 cm^2) was obtained from plants supplied with 80 t/ha and the lowest (134 cm^2) was recorded from plants provided with 20 t/ha of manure. The second highest leaf area was obtained from plants provided with 60 t/ha of cattle manure (Figure 3).

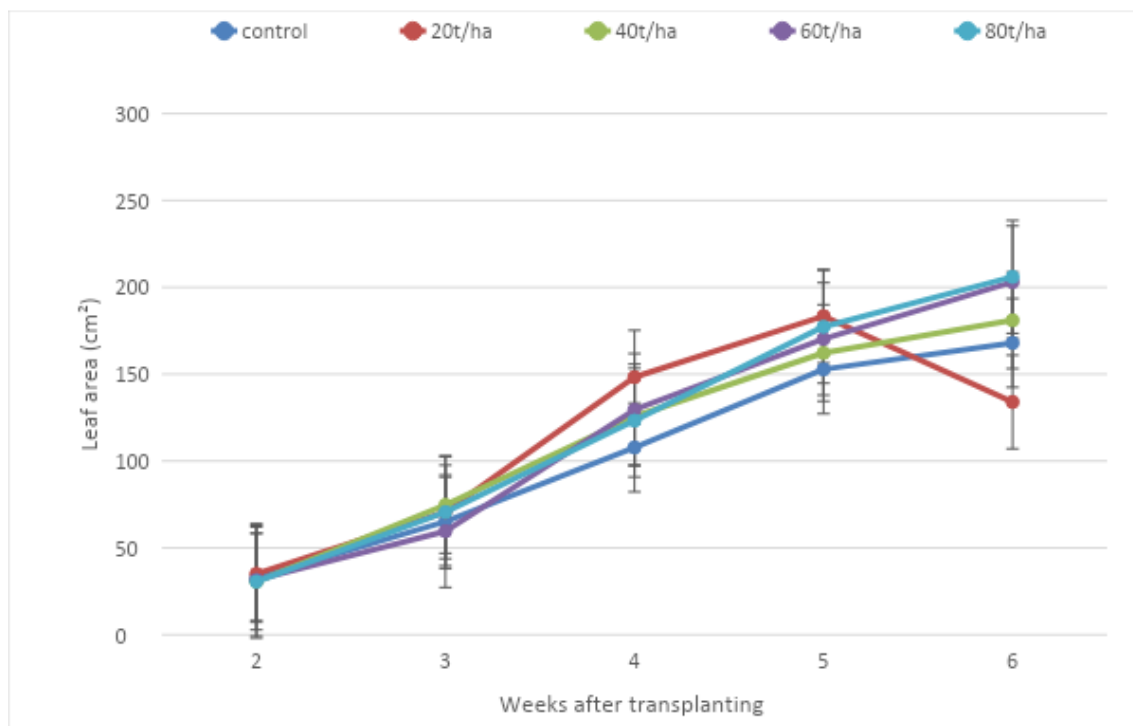


Figure 3: Effects of cattle manure on leaf area of beetroot. Vertical bars represent standard error (SE) below and above the mean.

3.2.4 CHLOROPHYLL CONTENT

There were no significant ($P > 0.05$) differences in chlorophyll content of beetroot from the different treatments at 2, 3, 4, 5, and 6 WAT. At 6 WAT the highest chlorophyll content (36.6) of beetroot was obtained from the control plants and the lowest (34.7) was recorded from plants grown using 40t/ha of cattle manure. The second highest chlorophyll content was obtained from plants grown using 20 t/ha of cattle manure (Figure 4).

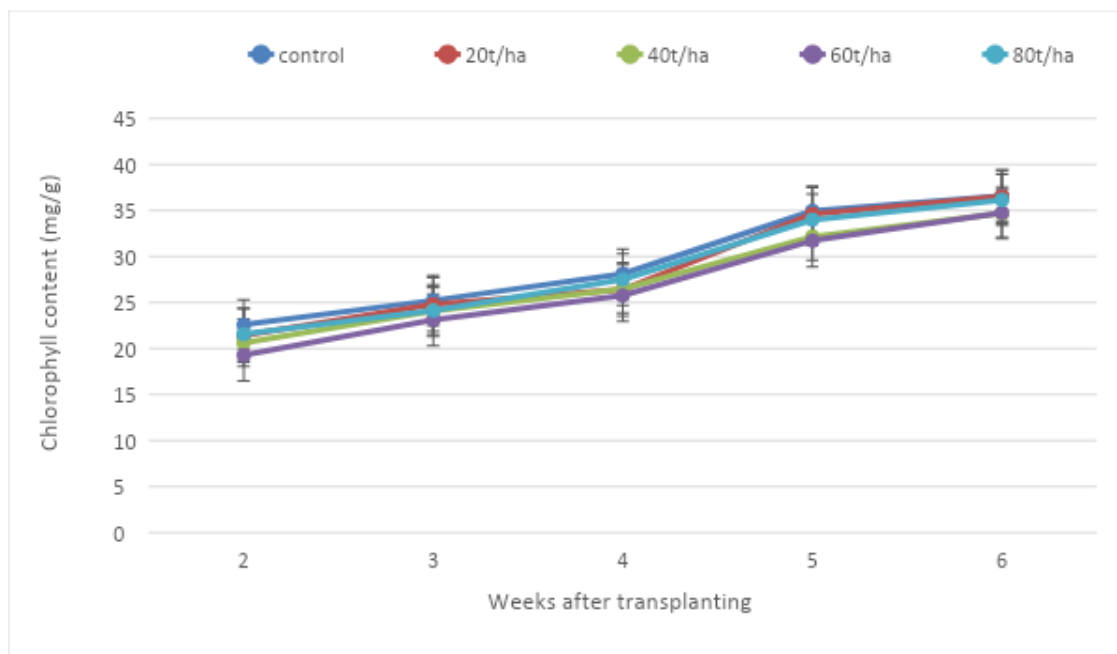


Figure 4: Effects of cattle manure on chlorophyll content of beetroot. Vertical bars represent standard error (SE) below and above the mean.

3.2.5 ROOT LENGTH

There were significant ($P < 0.05$) differences detected in the root length of beetroot from the different treatments (Figure 5). The longest root length (11.7 cm) of beetroot was recorded from plants provided with 80 t/ha and the shortest root length (9.1 cm) was recorded from those provided with 40 t/ha of cattle manure. The second highest root length was recorded from plants provided with 20 t/ha cattle manure (Figure 5).

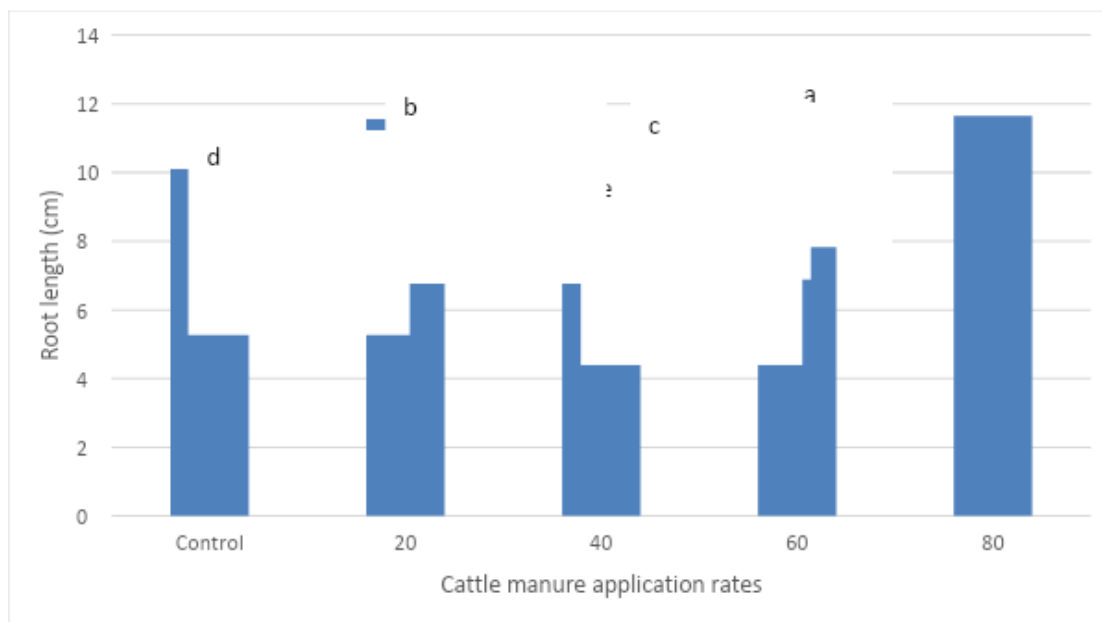


Figure 5: Effects of cattle manure on the root length of beetroot. Bars followed by the same letter are not significantly different. Mean separation done using DNMRT at P = 0.05.

3.2.6 ROOT FRESH AND DRY WEIGHTS

There were significant ($P < 0.05$) differences detected in the root fresh weight of beetroot from the different treatments at 2, 3, 4, 5, and 6 WAT (Figure 6). At 6 WAT the highest root fresh weight/plant (10.8 g) of beetroot was recorded from treatment 80 t/ha and the lowest size (7.3 g) was recorded from the control plants. The second highest root fresh weights were obtained from plants provided with 20 t/ha of cattle manure (Figure 6). The root dry weight on the other hand showed no significant ($P > 0.05$) differences. Plants supplied with 80 t/ha of cattle manure showed the highest root dry weight (8.2 g) while the control plants gave the lowest (4.7 g) root dry weight (Figure 6). The second highest root dry weight (6.9 g) was obtained from plants provided with 40 t/ha of manure.

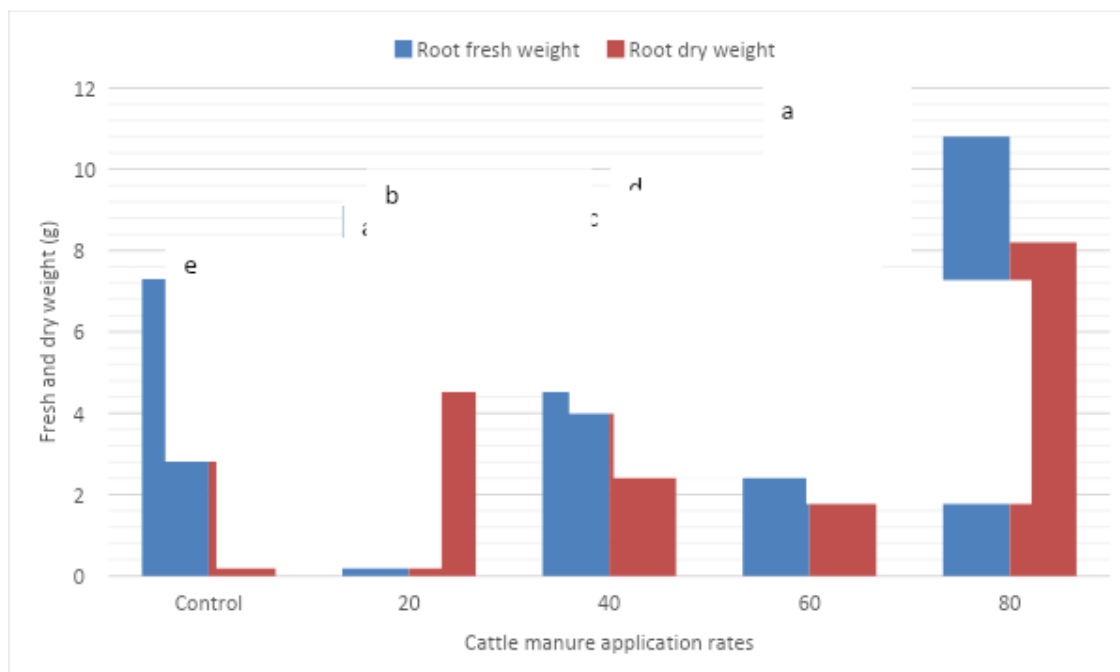


Figure 6: Effects of cattle manure on the root fresh and dry weights of beetroot. Bars followed by the same letter are not significantly different. Mean separation done using DNMRT at P = 0.05.

3.3 QUALITY PARAMETERS

3.3.1 BEETROOT DIAMETER

There were significant ($P < 0.05$) differences detected in the diameter (size) of beetroot from the different treatments at 2, 3, 4, 5, and 6 WAT (Figure 7). At 6 WAT the highest diameter (5.1 cm) of beetroot was recorded from treatment 80 t/ha of cattle manure and the lowest diameter (4.0 cm) was recorded from the control. The second highest beetroot diameter was obtained from plants provided with 40 t/ha of cattle manures (Figure 7).

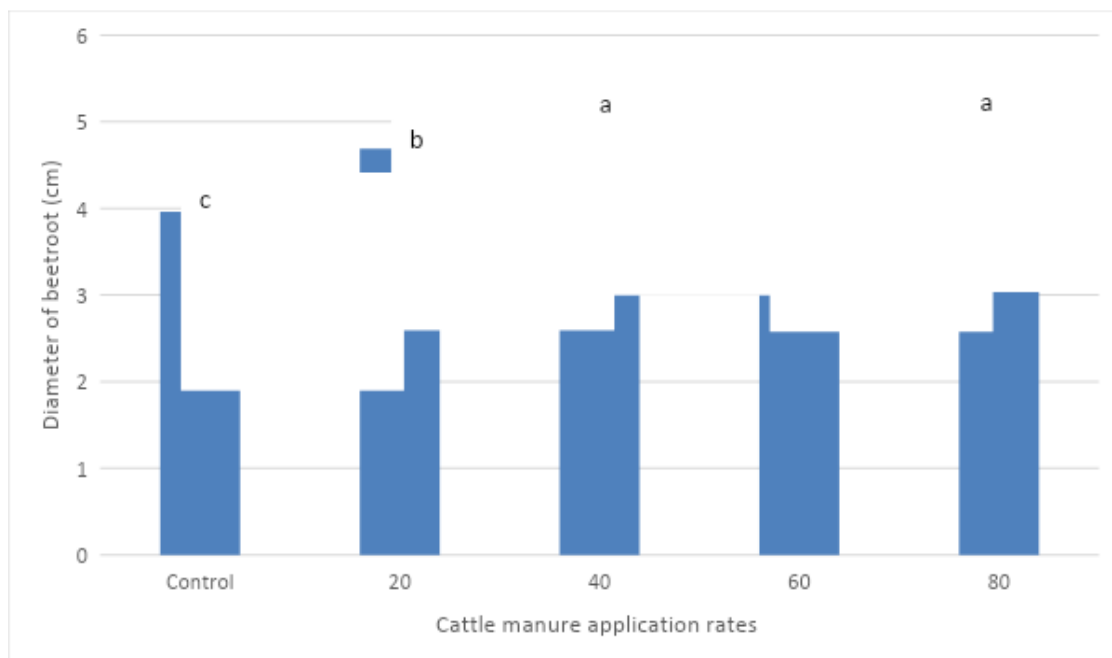


Figure 7: Effects of cattle manure on the diameter of beetroot. Bars followed by the same letter are not significantly different. Mean separation done using DNMRT at P = 0.05.

3.3.2 ORGANOLEPTIC TEST RESULTS

There were significant ($P < 0.05$) differences detected in the quality of beetroot from the different treatments in terms of aroma, flavour and texture (Figure 8). The highest aroma (33.5%) was obtained from plants supplied with 80 t/ha of cattle manure and the plants supplied with control had the lowest aroma (29%). The second highest aroma (33%) in beetroot was obtained from plants grown using 60 and 40 t/ha of cattle manure (Figure 8). The highest flavour (34%) was obtained in plants provided with 80 t/ha and the control plants had the lowest flavour (24.5%). The second highest flavour (33%) was obtained from 40 t/ha. The highest texture (35%) was recorded from plants provided with 80 t/ha and the lowest (29%) was obtained from plants with 20 and 40 t/ha. The second highest texture (34%) was obtained from plants provided with 60 t/ha (Figure 8).

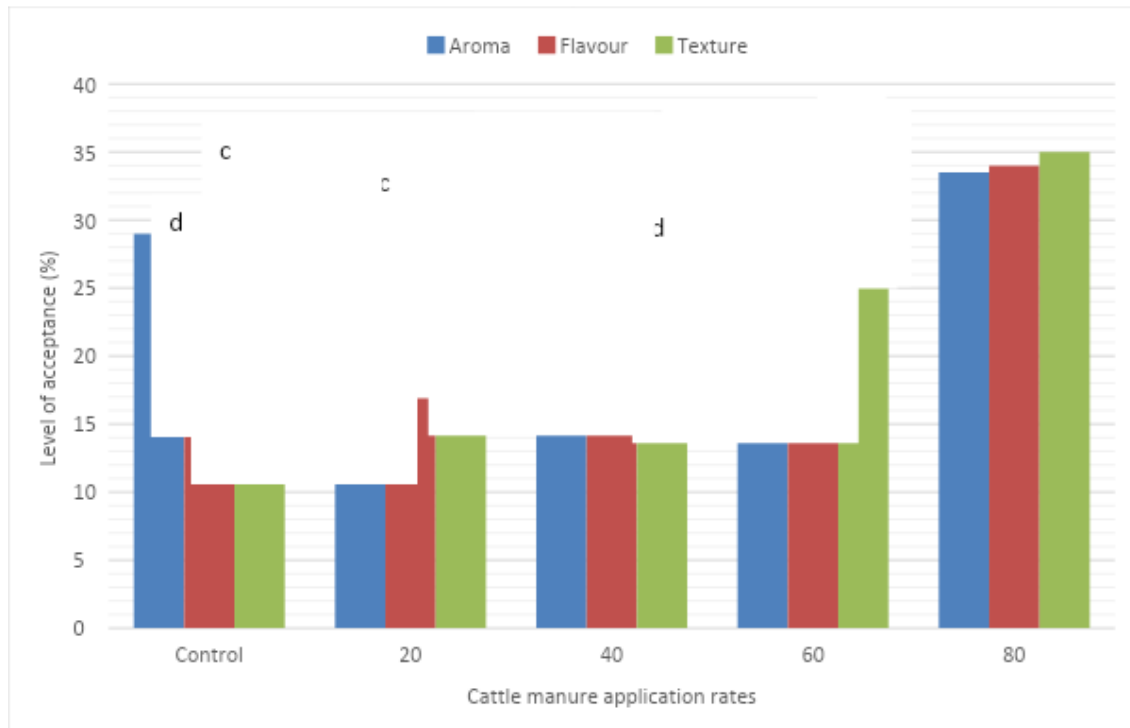


Figure 8: Effects of different rates of cattle manure on the quality of beetroot. Bars followed by the same letter not significantly different. Mean separation done using DNMRT at $P = 0.05$.

3.3.3 SHELF-LIFE OF BEETROOT

There were significant ($P < 0.05$) differences in the duration the beetroot remained in good conditions in the different treatments (Figure 9). The highest shelf-life (6 days) was obtained from plants provided with 80 t/ha of cattle manure and the lowest (3 days) from the control. The second highest shelf-life was obtained from plants provided with 60 and 40 t/ha of cattle manures (Figure 9).

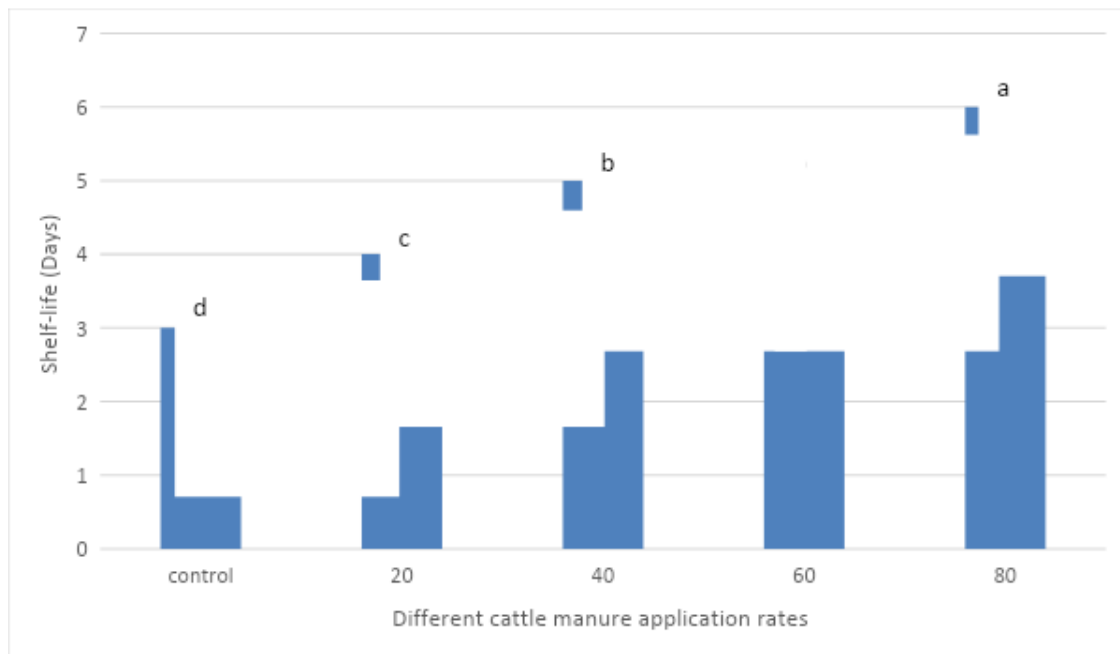


Figure 9: Effects of cattle manure on the shelf-life of beetroot. Bars followed by the same letter are not significantly different. Mean separation done using DNMRT at P = 0.05.

3.3.4 MARKETABLE YIELD

There were significant ($P < 0.05$) differences detected in the marketable yield (mass) of beetroot for all the treatments (Figure 10). The highest yield (9.2 t/ha) was obtained from plants provided with 80 t/ha cattle manure and the lowest yield (5.8 t/ha) was recorded from the control plants. The second highest marketable yields were obtained from plants provided with 40 t/ha of cattle manure (Figure 10).

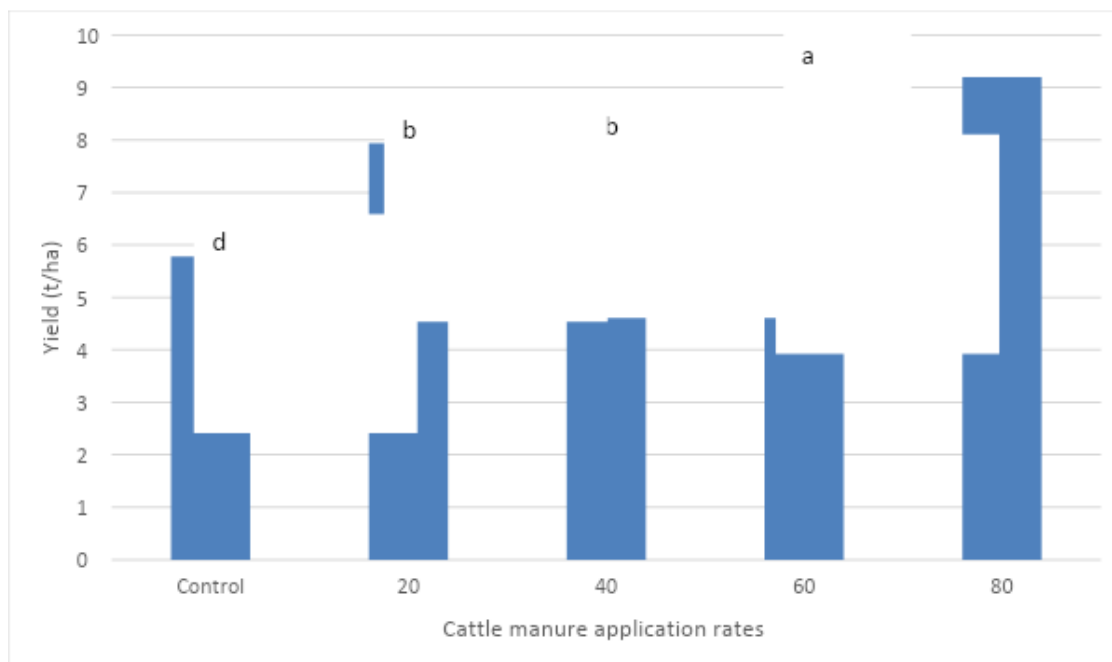


Figure 10: Effects of different rates of cattle manure on marketable yield of beetroot at 6 WAT. Bars followed by the same letter not significantly different. Mean separation done using DNMRT at P = 0.05.

4.0 DISCUSSION

The beetroot plants fertilised with cattle manure at 80 t/ha gave the highest plant height and 60 t/ha recorded the lowest plant height. Similar results were reported by [15] in okra. According to [16] the increase in plant height is attributed to the fact that addition of organic manures increases the plant growth characteristics such as plant height and number of leaves. Tovihoudji et al. [17] reported that organic manures are known to have both macro- and micro-nutrients required for crop growth, development and final economical yield.

Beetroot plants supplied with 60 t/ha of cattle manure had the highest number of leaves and those provided with 20 t/ha of cattle manure gave recorded the lowest number of leaves. According to [18], the increase in the number of leaves was due to increased solubilisation effect and availability of nutrients by the addition of organic manures which relatively results in better development of more leaves. Opeyemi and Adegboyega (2003) [19] noted that animal manure increased number of leaves, stem girth and leaf length of *Celosia argentea*. This was in agreement with the work of [20], who reported that organic manure increase nutrient status of the soil through gradual release of nutrients to the soil.

The leaf length and width of beetroot plants responded positively in all the treatments. There was a steady increase in the leaf length and width of beetroot over the growing period. The increase in leaf length and width of beetroot led to an increase in the leaf area of the plants. However, plants planted with 80 t/ha of cattle manure, showed a great increase in leaf area from 3 to 6 WAT. Similar results were reported by [1], who stated that in nature the competition effect may be completely absent until population density reaches some threshold at which resources become limited. According to [7], this is due to the fact that, when regularly used as fertilizer, cattle manure, can adjust plant nutrient ratios to be more in line with crop requirements, which help to improve crop growth and is normally noticed through leaf size increase.

The highest chlorophyll content was obtained from the control plants. Cattle manure applied at 40 t/ha induced the lowest chlorophyll content in this investigation. The results obtained from this study were in contrast to what [21] reported. They reported that organic manure increase chlorophyll content in plant leaves of spinach beet (*Beta vulgaris var. bengalensis* L.). [22; 23] reported an improvement in chlorophyll content of chilli leaves with increasing manure application rates. More chlorophyll content in leaves might be due to macro and micro nutrients supplied by FYM particularly nitrogen which is an important constituent of chlorophyll [21].

The highest root length was obtained from plants that were supplied with 80 t/ha of cattle manure and the lowest was recorded from plants provided with 40 t/ha of cattle manure. Chitti et al. (2018) [1] reported similar results on beetroot planted with farm yard manure (FYM) and poultry manure. According to [24], the application of organic manures to the soil, will improve the physical condition of the soil by the better aggregation of soil particles. According to [25], soil treated with cattle manure was found to be loose, which probably provided adequate aeration and moisture into the soil and improved soil microbial activities which resulted in higher growth and maximum root yield and above biomass of crops.

Cattle manure applied at 80 t/ha resulted in beetroot plants with a high root fresh weight while the control recorded the lowest. Similar results were reported by [26] who reported that the highest fresh root weights were shown in goat and cow dung manures in a study on *Corchorus olitorius*. Said (1997) [16] also reported that organic manures increase plant growth characteristics such as fresh root and shoot weights. Agbede (2008) [27] reported that organic manure increases nitrogen, phosphorus and potassium content of the soil. Olanikan (2006) [28] noted that organic manure increase organic matter status of the soil and enhance crop production.

Beetroot plants planted with cattle manure at 80 t/ha recorded the highest root dry weight and the lowest root dry weight was obtained from the control. Similar results were reported by [29] in beetroot. Lairon (2009) [30] reported that organic plant product tend to have more dry matter. Said (1997) [16] also reported that the addition of organic manures increase the plant growth characteristics such as plant height, number of leaves and shoot per plant including fresh and dry root weights.

The highest diameter of beetroot was obtained from plants supplied with 80 t/ha of cattle manure and the lowest diameter of beetroot was recorded from the control plants. da Silva Curvêlo et al. (2018) [31] reported similar results while working on beet production and post-harvest characteristics. Boru et al. (2017) [32] also obtained similar results on the tuberous root diameter, in a study on sweet potato. Chitti et al. (2018) [1] reported that the higher root diameter recorded may be attributed to enhanced cell division and quick cell multiplication. For crops that are cultivated for their root and tubers, FYM manure creates the reduction of soil bulk density so that the roots freely extend to scavenge available nutrient and moisture so that it increases its diameter [33].

The highest marketable yield was recorded with the application of 80 t/ha of cattle manure. The control plants had the lowest marketable yield of beetroot. Rumble (1998) [34] reported that animal manure application increase beetroot yield. According to [35], this is due to the fact that organic manures improve soil structure, resulting in significant increase in soil carbon, nitrogen, pH, cation exchange capacity and exchangeable Ca, Mg and K, which invariably enhance the development of plants. Ouda and Mahadeen (2008) [36] reported that organic manures also activates many species of living organisms which release phytohormones that stimulates plant growth and absorption of nutrients and such organisms need nitrogen for multiplication.

Plants provided with 80 t/ha of cattle manure gave the highest quality in terms of aroma, flavour and texture of beetroot while the control plants had. The effect of cattle manure on the aroma, flavour and texture was significantly affected by the different treatments [37]. Results close to this were found by [38]. Furthermore, numerous factors affect plant composition and performance, such factors include; variety, state of ripening, soil type and condition, irrigation, fertilization and climate [39; 40].

The storage of beetroot was significantly affected by the different application rates of cattle manure. The longest storage (shelf-life) life was recorded with the application of 80 t/ha of cattle manure. The control showed the shortest shelf-life of beetroot. Similar results were obtained by [1] who reported that the small size beetroot loses quality (sugars) faster than the big sized beetroot. This is supported by the results provided by [41] reported that small

sugar beet may have somewhat higher sugar losses during storage than large beets. Olsson (2011) [42] also showed that sugar losses during storage were correlated to the number of degree days to which the beets were exposed during storage.

5.0 CONCLUSION

The study revealed that organic manure which in this case was cattle manure improved the growth performance, yield, quality and shelf life of beetroot. Application of cattle manure in higher amounts (80 t/ha) gave the best results in terms of yield which was followed by 40 t/ha. The use of cattle manure at 80 t/ha in the production of vegetable crops like beetroot should be encouraged, because its application has resulted in increased growth, yield, quality and shelf-life of beetroot as compared to the lower application rates.

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