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Response of Ethiopian Mustard (*Brassica carinata* A. Braun) to Different Levels of Vermicompost in North East, Botswana

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Abstract A pot experiment was carried out in a net shade in Impala Research Station, North East District of Botswana, to investigate the response of Ethiopian mustard (*Brassica carinata* A. Braun) to different levels of vermicompost. The experiment treatments comprised of pure soil (Treatment 1 (T1)) and homogeneous mixture of vermicompost and sandy loam soil (T2 = 25% VC, T3 = 50% VC, T4 = 75% VC and T5 = 100% VC). In each pot, two plants were raised and the data of parameter measured were collected from them. The results showed that increasing the dosage of vermicompost, significantly increased number of leaves, plant height, leaf length, leaf width, leaf area and leaf weight. The performance of Ethiopian mustard did not differ significantly at a range between 50% VC and 100% VC in all measured parameters. Leaf length, leaf width and leaf area reached higher values at 75% VC. This suggest that level 75% VC can be used in a potting medium when growing Ethiopian mustard as a leafy vegetable.

Keywords: *Brassica carinata, vermicompost, ethiopian mustard, leafy vegetable, growth*

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1. Introduction

Ethiopian mustard (*Brassica carinata* A. Braun) also known as Abyssinian mustard, has in recent years been introduced as a leafy vegetable crop in Botswana. This crop is believed to be resulting from natural hybridization of *Brassica nigra* (L.) W.D.J. Koch, with *Brassica oleracea* (L.), followed by the chromosome doubling of the hybrids [1]. Ethiopian mustard is a native plant of highlands of Ethiopian plateau in Africa [2,3] and believed to have been cultivated since antiquity [3,4]. Though it was initial grown in Ethiopia as leafy vegetable and oil producing crop [5], it spread across other countries in some continents such as Europe [6,7], America [8,9] and Asia [10,11] in compensating other oil producing crops such as *B. napus* [6,12]. However, the oil of *B. carinata* contain high amount of erucic acid [7,13], which results in unpleasant tastes, making it unfavourable for human consumption [14,15]. To produce edible oil, oil processors adulterate it with other seed oil like niger seed (*Guizotia abyssinica* Casa) [16] or cotton seed (*Gossypium hirsutum* L.) [15]. Other than adulterating *B. carinata* oil, zero erucic acid line have been developed [5]. According to [9] and [12], oil generated by Ethiopian mustard seeds have become one of the most important source of biofuel that can be used globally.

Other than its use for oil purposes, *B. carinata* is reckoned as one of African indigenous vegetable. Its leaves can be cooked and used as edible vegetable [17,18]. The leaves of *B. carinata* has special nutritional components like minerals, vitamins, trace elements, dietary fiber, and protein [17]. It produces more leaves per plant than kale (*Brassica oleracea* L. var *acephala* DC.) [19] or rape (*Brassica napus* L.) [20]. It can also be harvested continually for market without cessation of plant growth [19]. Other traits that qualifies *B. carinata* as leafy vegetable are marketable leaves and late flowering habit [21]. Moreover, its ability to withstand complex environmental conditions [22,23] and being less infested by notorious pests such as aphids [24], compared to other leafy vegetables, makes it a suitable crop for food security. Though it is mainly cultivated for its leaves in this country, it is susceptible to bolting than other members of Brassica family cultivated locally [Personal observation]. Despite the fact that bolting remains a pinnacle for seed development [25], it is a stumbling block regarding leaf elongation because as soon as it commences, assimilates will be highly concentrated to seed development rather than leaves. This results in reduction of leaf area, consequently, making the leaves unmarketable.

Nutrients deficiency is also a bottleneck in the production of *B. carinata* [26] and this can be rectified by the use of fertilizers. Synthetic fertilizers (chemical fertilizers) have been predominantly used to address nutrients deficiency in various crops since the green revolution. But these synthetic fertilizers are detrimental to environment and human race if not used appropriately [27,28]. Moreover, [29] highlighted that even if synthetic chemicals are applied at lower dose, they still pose a serious threat to the environment. In spite of threat posed by synthetic chemicals, the essentiality of crop cultivation remains paramount. This, then compelled scientists to come up with fertilizers which can supplement nutrients at the same time being environmentally friendly. Thus, vermicompost (an organic fertilizer), can be an alternative. According to [30], vermicompost is a 100% pure eco-friendly fertilizer which improve the quality as well as quantity of yield. [31] reported that vermicompost has a high level of nutrient such as nitrogen, phosphorus and potassium in comparison to composts produced without the use of worms such as animal and plant waste compost. [32], highlighted that an enhancement of growth in leaf size and leaf fresh weight increases with the increasing doses of vermicompost. Several studies were conducted to investigate performance of oilseeds and leafy vegetables using vermicompost [33-39]. Whereas, information regarding the use of vermicompost on *B. carinata* is limited. In addition, it was reported that the use of vermicompost significantly increase the yield of vegetable crops such as rape [40], cabbage [41], spinach [42], beetroot [43,44] and Radish [45].

In Botswana, both *B. carinata* and vermicompost are still limited to small scale producers. *B. carinata* is currently cultivated solely as an accompaniment for relish and is not yet exploited as a potential oil crop and the information on its performance is still lacking. However, the use of synthetic fertilizers is more prevalent than organic fertilizers particularly vermicompost. The present investigation was formulated to study the response of *B. carinata* to different levels of vermicompost in North East of Botswana.

2. Materials and Methods

2.1. Description of Experimental Site

A pot experiment was carried out in a net shade in Impala Research Station (21°08 – 21°11S', 21°35' – 27°37' E), North East District in Botswana between the months of June and September, 2018. The area is flat with an altitude of 1020 m above sea level. The area is occasioned by local climatic conditions of low rainfall and dry periods (between April and October) and wet season (between November and March). The annual rainfall is about 630 mm.

2.2. Experimental Design

Experimental pots measuring a height of 20 cm, 24 cm wide at the top and 7.5 cm wide at the base with five perforations at the bottom for drainage, were used. Pots were set in a complete randomized design and was replicated three times. Experiment treatments comprised of pure soil as control and four levels of homogeneous mixture of vermicompost (prepared using dairy dung and the earthworm (*Eisenia fetida*)) and sandy loam soil collected from the depth of 0 cm to 10 cm in Impala Ranch. Contents of vermicompost and the soil used are shown in Table 1 and Table 2 respectively.

Table 1. Chemical composition of vermicompost (prepared using dairy dung and the earthworm (*Eisenia fetida*))

Parameters	Value
Electrical conductivity (dS m^{-1})	187
pH	6.98
Organic matter (%)	21.8
Total nitrogen (N) (%)	1.05
Available phosphorus (P) (%)	0.95
Available potassium (K) (%)	0.58
Magnesium (Mg) (%)	0.64
Calcium (Ca) (%)	2.39
Carbon (C) (%)	9.2
Iron (Fe) (%)	1.51
Sodium (Na) (mg kg^{-1})	633
Copper (Cu) (mg kg^{-1})	93.4
Manganese (mg kg^{-1})	1017
Boron (B) (mg kg^{-1})	25.7
Zinc (Zn) (mg kg^{-1})	392

Table 2. Soil properties of the experiment collected from 0 cm to 20 cm depth in Impala Ranch

Properties	Value
Soil texture	Clay-loam
Cation-exchange-capacity (meq/100 g)	0.65
pH	6.75
Nitrate (%)	10.20
Phosphorus (P) (mg L^{-1})	12.00
Potassium (K) (mg L^{-1})	43.10
Magnesium (Mg) (mg L^{-1})	62.5
Calcium (Ca) (mg L^{-1})	<0.001
Sodium (Na) (mg L^{-1})	5.00

Each treatment was thoroughly mixed to obtain a homogeneous mixture of vermicompost and sandy loam soil before filling the experimental pots. The treatments consisted of the following;

Treatment 1 (control) = T1 0% VC (4 kg soil of pure soil)

Treatment 2 (T2) = 25% VC (3 kg soil + 1 kg vermicompost)

Treatment 3 (T3) = 50% VC (2 kg soil + 2 kg vermicompost)

Treatment 4 (T4) = 75% VC (1 kg soil + 3 kg vermicompost)

Treatment 5 (T5) = 100% VC (0 kg soil + 4 kg vermicompost).

After filling each pot with the mixture, five seeds of Ethiopian mustard were sown manually at a uniform depth of 2 cm. Each pot was saturated with water and on daily bases, water was applied to each pot to maintain 70% of field capacity. At seven days after emergence, plants were thinned to two plants per pot and these plants were used for data collection. Measurements obtained from the two plants per pot were used to determine the average values of each parameter measured per pot. Cultivar 'Mbey green', was used since it is the only cultivated cultivar in the area.

2.3. Data Collection

2.3.1. Number of Leaves

Total number of active green leaves on both plants in each pot were counted and recorded. This was done weekly starting from the fourth week to the eighth week after emergence.

2.3.2. Plant Height (cm)

Plant height was measured from the top soil in the pot to the tip of the tallest leaf of the plants per pot using a standard ruler. This was done at the same time whenever number of leaves was recorded.

2.3.3. Leaf Length (cm)

Ethiopian mustard leaves are not uniform in length and width, thus, at each harvest, the largest leaves harvested from both plants per pot were used to measure the leaf length and the average was determined. Measurements were done using a standard ruler from lamina tip to the point of intersection of the lamina and the petiole.

2.3.4. Leaf Width (cm)

The same largest leaves used in obtaining leaf length, were used to measure the widest width of leaf perpendicular to the lamina mid-rip and the average was determined. Measurements were done using a standard ruler.

2.3.5. Leaf Area (cm^2)

Leaf area was determined on harvested largest leaves using method of Ambasht [1988] as cited by [46] as follows:

Actual area = L x B x K

- L – length of the leaf
- B – Breadth (width) of the leaf
- K – Constant factor (0.6).

2.3.6. Leaf Weight (g)

Harvesting started when the plants were mature and was carried out three times consecutively at an interval of 14 days. After harvesting, all the leaves from each plant per pot were weighed to obtain fresh weight (g) per plant. Thereafter, all the weights of leaves per harvest were summed up to determine the total leaf weight from each pot.

2.4. Data Analysis

Analysis of variance was done on all the measured parameters to determine significance of differences between means of treatments using SAS program, and Tukey's test for LSD at P<0.05, except where stated.

3. Results

3.1. Number of Leaves

Data regarding the number of leaves showed significant (P<0.05) differences with the increasing levels of vermicompost (Table 3). The lowest number of leaves (4.79) was recorded from control (pure soil), while the highest number of leaves (9.29) was recorded from treatment receiving 100% vermicompost. Moreover, results indicate that, the number of leaves produced on control treatment were significantly different from all the treatments and this was the same case with T2. Though level 100% VC gave the highest number of leaves, it was not significantly different from level 50% VC and 75% VC. Vermicompost treatments levels also had effect on growth trend of leaves at different growth stages (Figure 1). The highest number of leaves were obtained at the highest applied level of vermicompost whereas the lowest number of leaves were observed from control treatment at the seventh week after emergence. A sharp increase of number of leaves was noted on plants raised on 50% VC, 75% VC and 100% VC after the 5^{th} week of emergence unlike of those plants receiving 25% VC or the ones grown on control. Only leaves of plants raised on pure soil showed symptoms of nitrogen deficiency.

3.2. Plant Height (cm)

The level of vermicompost showed significant (P<0.05) difference pertaining to plant height (Table 3). The shortest plants (7.02 cm) were recorded on control which was significantly shorter than all treatments. Plant heights of control were followed by heights of plants (16.44 cm) sown on 25% vermicompost which was also significantly different from all the treatments. The tallest plants (21.58 cm) were recorded at 100% VC though they were not significantly taller than the heights of plants at 50% VC and 75% VC which were 20.00 cm and 21.48 cm respectively. Vermicompost treatment levels also had effect on growth trend of plant height at different growth stages (Figure 1) and it shows an increasing trend with time. The tallest plants were noted at the second highest level of vermicompost and the shortest plants were observed from control treatment at the seventh week after emergence.

Table 3. The response of Ethiopian mustard to different levels of vermicompost (VC)

Treatments	Number of leaves	Plant height (cm)	Large leaf length (cm)	Large leaf width (cm)	Leaf Area (cm^2)	Leaf Weight (g)
T1	4.79 c	7.02 c	6.26 c	3.89c	14.86b	0.003b
T2	6.50 b	16.44 b	10.44 b	7.54b	48.46b	0.013b
T3	8.88 a	20.00 a	15.76 a	10.49a	99.30a	0.033ab
T4	9.04 a	21.48 a	17.37a	12.45a	123.23a	0.047a
T5	9.29 a	21.58 a	16.24a	11.71a	115.41a	0.052a

The values followed by different small letter(s) in the same column are significantly different at P<0.05 according to Tukey's multiple range test (Tukey's test). T1 = 0% VC (4 kg soil + 0 kg VC) used as a control, T2 = 25% VC (3 kg soil + 1 kg VC), T3 = 50% VC (2 kg soil + 2 kg VC), T4 = 75% VC (1 kg soil + 3 kg VC) and T5 = 100% VC (0 kg soil + 4 kg VC).

3.3. Leaf Length (cm)

The longest leaf length (17.37 cm) was recorded from T4 and the shortest leaf length (6.26 cm) was recorded from control treatment (Table 3). Though T4 produced the longest leaves, its leaf length did not differ significantly (P<0.05) with the length of leaves recorded from T3 and T5 which recorded 15.76 cm and 16.24 cm respectively. Length of leaves produced from T2 differed significantly with all treatment levels, and the same was observed with leaf length recorded from control treatment.

3.4. Leaf Width (cm)

The effect of different application rate of vermicompost on leaf width was significant at P<0.05 (Table 3). Leaf width significantly increased with increasing levels of vermicompost. Significantly narrow leaves (3.89 cm) were attained at zero dosage of vermicompost, compared to all the treatments. The size of leaves produced from control treatment was followed by those of leaves attained when vermicompost was applied at 25%, which was also significantly different from all the treatments. Though T4 produced widest leaves (12.45 cm), its width was not statistically different from leaves produced on T3 and T5, which recorded 10.49 cm and 11.71 cm respectively.

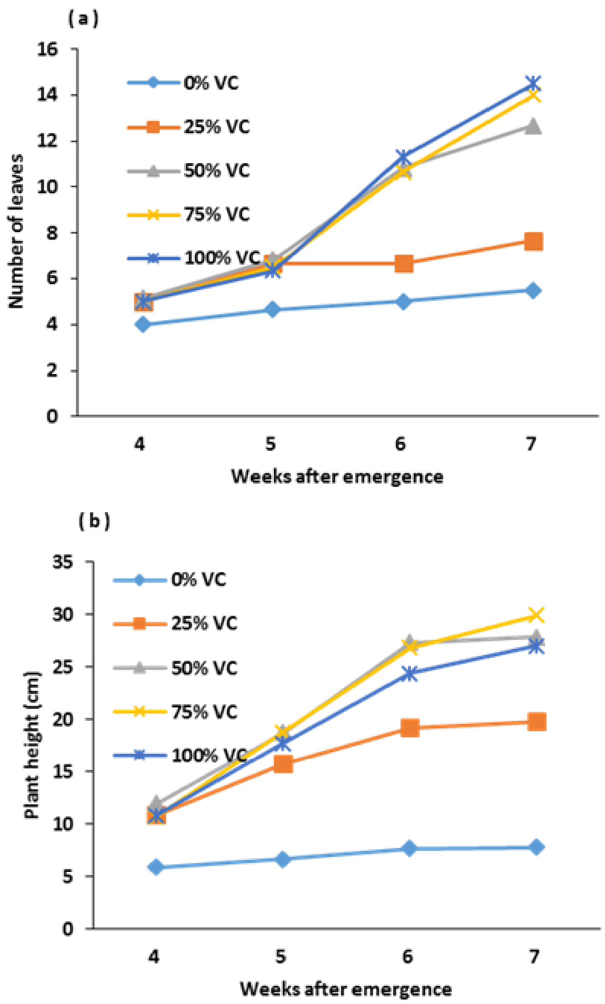

Figure 1. Number of leaves (a) and plant height (b) of Ethiopian mustard in response to five levels of vermicompost (VC) starting at 4th week until 7th week after emergence

3.5. Leaf Area (cm^2)

Leaf area significantly (P<0.05) increased with increasing levels of vermicompost (Table 3). Leaves with significant small area (14.86 cm^2 and 48.46 cm^2) were attained in T1 and T2 respectively compared to all the treatments. Though T4 produced leaves of maximum area (123.23 cm^2), they were not statistically different from leaves produced from T3 and T5.

3.6. Leaf Weight (g)

The results in Table 3, shows that the total weight of Ethiopian mustard leaves was significantly (P<0.05) influenced by different levels of vermicompost. The lowest weight was recorded on control treatment compared to the highest treatment level of vermicompost. Weight of the leaves varied from 0.003 g harvested from T1 to 0.152 g harvested from T5. Control treatment and T2 produced significantly less weight of leaves compared to T4 and T5. Moreover, T3 produced leaf weight that was not statistically different from all the treatments.

4. Discussion

Chlorotic and stunted leaves due to nutrients deficiency get disadvantaged in harvesting sunlight needed for photosynthesis. This is result of insufficient supply of plant nutrients. Thus, in return, deter the formation of chlorophyll and consequently unprofitable plants are produced. As a dose of fertilization increases, tendency of crops to grow enormously in certain dimensions is spontaneous and this might be attributed to an increase in photosynthesis due to large leaves developed. Increasing the dosage of vermicompost in the growing medium, triggers the raise of nitrate amount [47]. This boosts enlargement of plant cells, hence, vigorous growth. This was evident in this study as number of leaves, plant height, leaf length, leaf width, and leaf area as well as leaf weight increased when the level of vermicompost was increased. The same was also noted in earlier studies when pure garden soil (control) gave the lowest growth of leaf area of *Brassica napus* compared to when soil was amended with various levels of compost [48]. A similar trend was also reported on ornamental plants by [49], when investigating the effect of different levels of vermicompost on growth and development of Dragon tree (*Dracaena marginata*). Furthermore, the results are also in agreement with those of research conducted on lettuce (*Lactuca sativa* L.), which showed an enhancement of growth in leaf size upon increasing doses of vermicompost [32]. The development of leaves after five weeks from sowing, mainly on plants receiving 25% VC and those of control, did not grow rapidly like those of plants receiving more than 25% VC. This might be linked to bolting incidences (though not statistically analyzed), as the plant now concentrated to seed development, which was more evident and initiated weeks earlier on plants receiving 25% VC than all the treatments. This demonstrated that bolting as a critical trait for seed production, tend to have an effect on the elongation of leaves needed for fresh market.

Though from the current study it appears that leaf enlargement was triggered by the amount of dosage received, crops receiving doses of 50% VC, 75% VC and 100% VC were not statistically different in all manner of leaf growth. But the dosage of 75% VC produced higher values regarding leaf length, leaf width and leaf area, whereas, at any dosage above 75% VC, these parameters retard, nonetheless not significant. This trend was also noted on different parameters on previous studies regarding vermicompost amendments on various crops [48,49,50,51]. This tendency is in connection with humic substances on vermicompost that catalyze the growing of plants with increasing the concentration, but causing plant inhibition at higher concentration [52]. Often, the greater proportion of vermicompost in growing media has been outperformed by smaller proportions in increasing plant growth [53]. When fertilizing rape with various organic fertilizers, [54], highlighted that nitrogen is the main nutrient contributing to leaf growth in leafy crops. Perhaps this might be the reason contributing to vigorous growth which was noted as the application dose increased in this study.

Application of vermicompost, spontaneously escalated an increase in leaf weight significantly. However, from the application rate of 50% VC up to 100% VC, leaf weight attained was not statistically different. These results are in relation with findings of [48], when studying different application levels of compost on *B. napus*. The same was also noted by [49]. Subsequently, [38], recorded a significant increase in yield of rapeseed with an increased dosage of vermicompost. Effect of increasing doses of vermicompost also played a role in the yield of wide array of crops such as potato (*Solanum tuberosum* L.) [54], Indian mustard (*Brassica juncea*) [37], spinach (*Brassica oleracea*) as well as Turnip (*Brassica compestris*) [55], guto kola (*Centella asiatica*) and golden gram mung bean (*Vigna radiate*) [56]. The higher leaf weight recorded from T3, T4 and T5 could be attributed not only to the vermicompost treatments but also to the number of leaves which were increasing significantly with increasing vermicompost dosage.

5. Conclusions and recommendations

Vermicompost, enhance plant development. As the dosage of vermicompost increased, number of leaves, plant height, leaf length, leaf width, leaf area increased and leaf weight spontaneously increased resulting in greater photosynthetic rate. Performance of Ethiopian mustard did not differ significantly at a range between 50% VC and 100% VC. However, as soon as addition of vermicompost amount to 75%, trait (leaf area) qualifying *B. carinata* as a competitive leaf vegetable reaches its maximum elongation and at any addition of vermicompost beyond 75%, the growth remains statistically at par. Thus, this suggest that if vermicompost is to be used as a potting medium with pure soil, a dose amounting to 75% VC could be used. Vermicompost is excellent input for providing nutrients to plants and if used in cultivation of crops, it can help in reducing the amount of synthetic fertilizers.

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Declaration of Interest

The author declare no conflict of interests.

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