
Response of Rape (*Brassica napus* L.) var. English Giant to Different Levels of Vermicompost in North East, Botswana

Gagopale Bosekeng

Department of Agricultural Research, Horticulture Program, Ministry of Agricultural Development and Food Security, P.O. Box 10275 Francistown, Botswana.

Corresponding author email id: rotlheboseg5@gmail.com

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 rape (*Brassica napus* L.) to different levels of vermicompost. The experiment treatment(s) (T) comprised of pure soil (Treatment 1 (T1)) and four homogeneous mixture of vermicompost (VC) with sandy loam soil (T2 = 25% VC, T3 = 50% VC, T4 = 75% VC and T5 = 100% VC) per pot. Treatments were replicated three times and arranged in a complete randomized design. In each pot, two plants were raised and the data for parameters measured were collected from them. In all parameters studied, performance of rape did not differ statistically on 75% VC and 100% VC except for plant height. Again the level of VC at 75% performed the same as VC at 50% except on leaf width and leaf area. All parameters measured increased with increasing level of vermicompost although number of leaves, plant height and leaf length declined with further addition of vermicompost beyond 75% VC. This suggest that when growing rape in a potting medium, level of vermicompost ranging from 50% VC to 75% VC can be used. The weight of rape leaves showed to be positively correlated with the quantity of vermicompost applied and vermicompost showed to be an excellent organic fertilizer for providing nutrients to plants.

Keywords – *Brassica napus*, Vermicompost, Rape, Growth, Organic Fertilizer.

I. INTRODUCTION

The necessity of healthy body and mind for optimal performance of any daily mankind activity is paramount. Contributing to such wellbeing is a proper and well balanced diet, particularly diet consisting of vegetables. However, escalating population pose a threat of an increase in vegetable demand under the current available agricultural land. Thus, the once off allocated agriculture production land, ought to be exploited for constantly producing favourable leafy vegetables such as rape (*Brassica napus* L.) to compliment diet. According to [1], *B. napus* is second valuable (income) leafy vegetable in Botswana while cabbage (*Brassica oleracea* var. *capitata* L.) is the first. The leaves of *B. napus* are a source of income for small scale farmers and these leaves are rich in vitamin A, thiamine and ascorbic acid [2]. Though this crop is regarded as a leafy vegetable in Botswana, it is mainly cultivated as an oil producing crop in other countries [3]-[6].

Rape can be produced constantly all year round if environmental conditions are conducive and appropriate facilities are availed. However, constant production of vegetables requires a well maintained and nutritious soils with good structure. Most commonly, inorganic fertilizers are predominant in vegetable farming. Nevertheless, the use of inorganic fertilizers alone is incapable of improving soil structure nor retaining biological attributes to the soil that are needed to support plant life. Uncontrolled and unconscious application of inorganic fertilizers has negative consequences on the soil [7], [8]. Furthermore, rampant application of inorganic fertilizers, to some extent disengaged activities of soil microorganisms which assist in the maintenance of soil fertility naturally [8]. It is apparent that inorganic fertilizers are not sole supplier of plant nutrients, other fertilizers referred to as organic, have been reliably utilized in small scale crop production [9]-[11].

Since the commencement of crop production in Botswana till date, organic fertilizers such as kraal and chicken manure have been pivotal in soil amendment. Lately, vermicompost (VC) or earthworm casts has been introduced to small scale farmers but only in southern part of this country. Vermicompost is widely adapted in some Asian, European and Sub-Sahara African countries. In Southern African Development Community (SADC) region it is gaining recognition particularly in South Africa, Malawi and Zimbabwe by small scale farmers [12]. According to [13], vermicompost is referred to as an excretory products of biological degradation of waste substance by the activity of microorganisms and earthworms. Reference [14], highlighted that vermicompost is an environmental friendly organic fertilizer. In comparison to other organic fertilizers such as green manure, animal manure and plant residues (heap/pit) compost, vermicompost have greater agronomic significance in containing predominantly higher nutrient amounts which are readily available to plants [15]-[17], thus, this promptly enhance their utilization by plants upon the addition thereof. However, the amount and quality of elements in vermicompost depend on substrates used in vermicomposting [18]-[20]. Besides, [21], highlighted that this organic fertilizer contain nitrates, exchangeable phosphorus, soluble potassium, calcium and magnesium which are immediately bio-available to plants. Vermicompost showed to be competent in enhancing soil aeration, porosity, bulk density [22], has a greater water holding capacity [23], and this creates a conducive condition for excellent plant growth. Most importantly, crops produced from soils amended with vermicompost are organic, safe and free from chemical residues [17]. Subsequently, vermicompost can enhance the growth of plants by 50-100% and 30-40% over conventional composts and chemical fertilizers respectively [24]. The use of vermicompost is reported to increase the yield of vegetable crops such as *B. oleracea* var. *capitata* [25], spinach (*Spinacia oleracea* L.) [26] and beetroot (*Beta vulgaris* L.) [27], [28]. Other than vegetable crops, work on this organic fertilizer has been reported on legumes [29], cereals [30] and fruit trees [31].

Apart from nourishing plants, vermicompost also serve as a remedy for controlling plant pests and diseases, thus, minimizing the use of synthetic chemicals in plant cultivation [24], [32]. Subsequently, the study conducted by [33], showed that the number of aphids' infestation reduced on *B. oleracea* var. *capitata* grown on soil amended with vermicompost. Similarly, [34] also reported suppression of the number of Tomato leafminer (*Tuta absoluta* Meyrick) attacking tomato (*Lycopersicon esculentum* Mill.) plants. On the other hand, extracts of vermicompost successfully suppressed reproduction or survival of peach aphids (*Myzus persicae* Sulz.) on pot marigold (*Calendula officinalis* L.) plant [35], as well as on citrus mealybug (*Planococcus citri* Risso) and spotted spider mite (*Tetranychus urticae* Kock) on *L. esculentum* and cucumber (*Cucumis sativus* L.) plants [36]. Reniform Nematode (*Rotylenchulus reniformis* Linford & Oliveia) that infested soils in Hawaiian were also suppressed with an application of vermicompost [37]. Again, when incorporating VC into soils where Impatiens (*Impatiens wallerana* J.D. Hook) was cultivated, [38], reported that Damping off disease was managed.

There is no information on the use of vermicompost regarding rape production in Botswana. The present study was therefore, designed to investigate the effect of different levels of vermicompost on growth and production of rape in the North East District, Botswana.

II. MATERIALS AND METHODS

2.1. Description of Experimental Site

A pot experiment on the effect of different levels (rate(s)) of vermicompost on *B. napus* was carried out in a s-

-hade net in Impala Research Station (21°08' – 21°11'S, 21°35' – 27°37' E), North East District of Botswana, from June to 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

Vermicompost used was sourced from Sebele Research Station while clay loam soil was collected from the surface soil (0 – 20 cm) of Impala Research station and their compositions are shown in Table 1 and 2 respectively. Both vermicompost and clay loam soil were thoroughly mixed to obtain homogeneous mixture before filling the experimental pots except on the control experiment. Pots measuring 20 cm height, 24 cm wide at the top and 7.5 cm wide at the base with five perforations at the bottom for drainage, were arranged in a complete randomized design with three replications. Experiment treatments comprised of pure soil and homogeneous mixtures of pure soil and vermicompost were as follows; Treatment 1 (T1) control = 0% VC (4 kg soil + 0 kg vermicompost), 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) and Treatment 5 (T5) = 100% VC (0% kg soil + 4 kg vermicompost).

Tables 1. Chemical composition of vermicompost (prepared by waste of vegetables and dairy dung as a substrate of the earthworm (*Eisenia fetida* Savigny).

Parameters	Value
Electrical conductivity (dS m ⁻¹)	77
pH	8.19
Organic matter (%)	20.0
Total nitrogen (N) (%)	0.83
Available phosphorus (P) (%)	0.45
Available potassium (K) (%)	0.56
Magnesium (Mg) (%)	0.44
Calcium (Ca) (%)	2.19
Carbon (C) (%)	8.9
Iron (Fe) (%)	1.36
Sodium (Na) (mg kg ⁻¹)	665
Copper (Cu) (mg kg ⁻¹)	45.5
Manganese (mg kg ⁻¹)	554
Boron (B) (mg kg ⁻¹)	23.8
Zinc (Zn) (mg kg ⁻¹)	192

After filling each pot with the mixture, five seeds of *B. napus* (var. English giant) were sown manually at uniform depth of 2 cm in each pot. English giant variety was used since is the common cultivated variety in the area. Watering was done daily to each pot up to the field capacity from date of sowing until the last harvesting week. Thinning was undertaken at three leaf stage and two healthy seedlings were retained in each pot on which data was collected. The experiment was conducted for a period of three months.

Table 2. Contents of the soil used during the experiment.

Properties	Value
Soil texture	Clay-loam
Cation-exchange-capacity (CEC) (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

2.3. Data Collection

2.3.1. Number of Leaves

Total number of active green leaves on plant were physically counted and recorded. This was done weekly starting at second week after emergence till 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 using a standard ruler. This was done weekly at the same time whenever number of leaves were recorded.

2.3.3. Leaf Length (cm)

B. napus leaves are not uniform in length and width, therefore, at each harvest, the largest leaf length of both plants from each pot were measured using a standard ruler and the average was determined. The length of leaves were taken from the tip of lamina to the end of petiole where it was cut at harvesting.

2.3.4. Leaf Width (cm)

The same largest leaves which were used to obtain leaf length, were also used in measuring the widest leaf width. The leaf width were measured at the widest lobes of the lamina perpendicularly to the lamina midrip, using a standard ruler and the average was determined.

2.3.5. Leaf Area (cm²)

Leaf area was determined on harvested large mature leaves using method of Ambasht (1988), cited by [39] as follows;

$$\text{Actual area} = L \times B \times K$$

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

2.3.6. Leaf Weight (g)

Harvesting was done on matured leaves and was carried out three times consecutively at an interval of 14 days. After harvesting, leaves were weighed to obtain fresh weight. The fresh weight of all leaves harvested from each pot per harvest were summed up to determine the total leaf weight.

2.4. Data Analysis

Analysis of variance was done on all measured parameters using SAS software (version 9.4), except where stated. Significance difference between means of treatment was evaluated for LSD at $P < 0.05$ using Tukey's multiple test.

III. RESULTS AND DISCUSSIONS

3.1. Number of Leaves

Different levels of VC significantly ($P < 0.05$) influenced the development of leaves and as the level of VC increased, leaf number also increased (Table 3). The number of leaves (4.29) produced on T1 were significantly different to number of leaves produced across the treatments. Leaf number raised on T2 were statistically identical to those produced by plants raised on level 50% or 100%.

Table 3. Response of rape (*Brassica napus*) var. English giant to different levels of vermicompost (VC).

Treatment (T)	Leaf number	Plant height (cm)	Large leaf length (cm)	Large leaf width (cm)	Leaf Area (cm ²)	Leaf weight (g)
1	4.29 c	7.37 c	5.72 c	3.65 d	12.91 c	0.003 c
2	6.13 b	14.71 b	9.78 b	6.78 c	41.21 c	0.017 c
3	6.50 ab	16.52 ab	14.48 a	9.18 b	82.70 b	0.028 bc
4	7.13 a	19.25 a	17.15 a	11.30 a	118.26 a	0.040 ab
5	6.67 ab	15.19 b	17.06 a	12.00 a	129.73 a	0.052 a

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).

The highest number of leaves (7.13) was recorded from 75% VC while the lowest number of leaves (4.29) was from control treatment. Though level 75% recorded the highest number of leaves, these number was not significantly different from the number of leaves recorded on level 50% VC and 100% VC. A decline, though not significant in number of leaves from 7.13 to 6.67 was noted from the current study as VC level increased from 75% to 100%. Vermicompost treatments levels had also effect on growth trend of leaves at different growth stages (Figure 1a). From the fifth to the seventh week after emergence, VC at 75% gave competitive number of leaves, whereas the lowest number of leaves were observed from control treatment during the entire growth period. In addition, a positive correlation ($R^2 = 0.76$) between VC application rate and number of leaves developed was noted (Figure 2a). Reference [40], highlighted that increasing the dosage of vermicompost in the growing medium triggers the raise of nitrate amount which boosts enlargement of plant cells, hence, vigorous growth. The result of this study showed that vermicompost have maximum effect on increasing leaf number. Where vermicompost was not applied (control), number of leaves significantly retarded. This results are in confirmatory with the findings

of [41] on broccoli (*Brassica oleracea* L. var. *italica* Plenck) and [42] on lettuce (*Lactuca sativa* L. var. *Crispa*). Similarly, *L. esculentum* leaf number was reported to increase with application of vermicompost compared to control [43]. However, number of leaves at a dose above 75% VC declined, and these results are in similar trend of results that were obtained by [44] on carrot (*Daucus carota* L.) and of [45] on stevia (*Stevia rebaudiana* Bertoni).

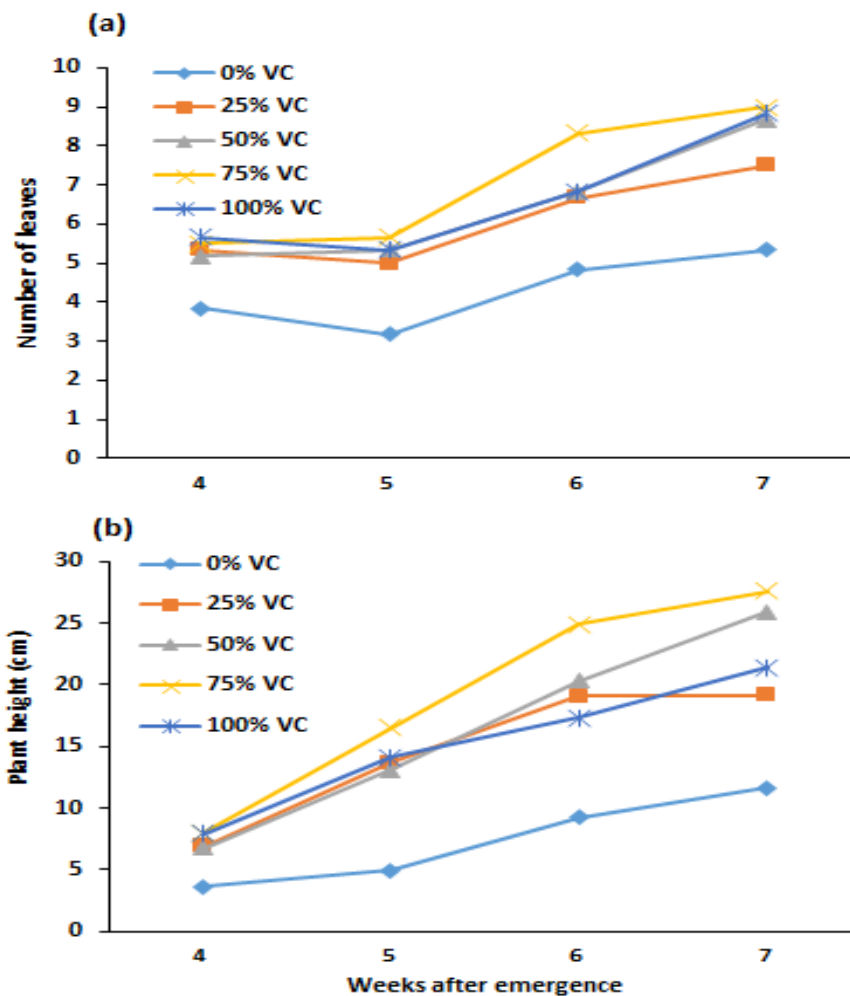
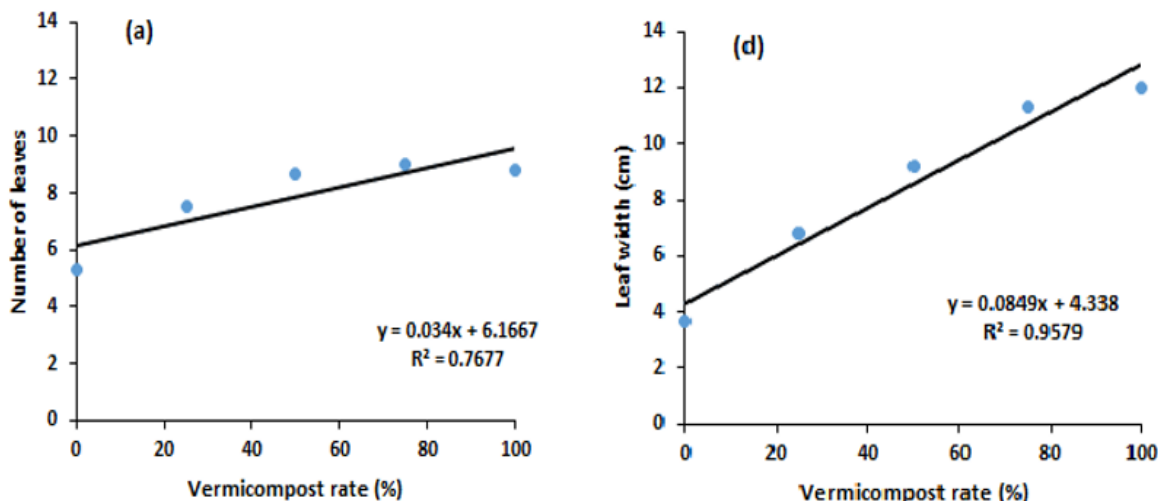


Fig. 1. Number of leaves (a) and plant height (b) on rape (*Brassica napus* L.) var. English giant in response to vermicompost levels starting from the 4th week until 7th week after emergence.



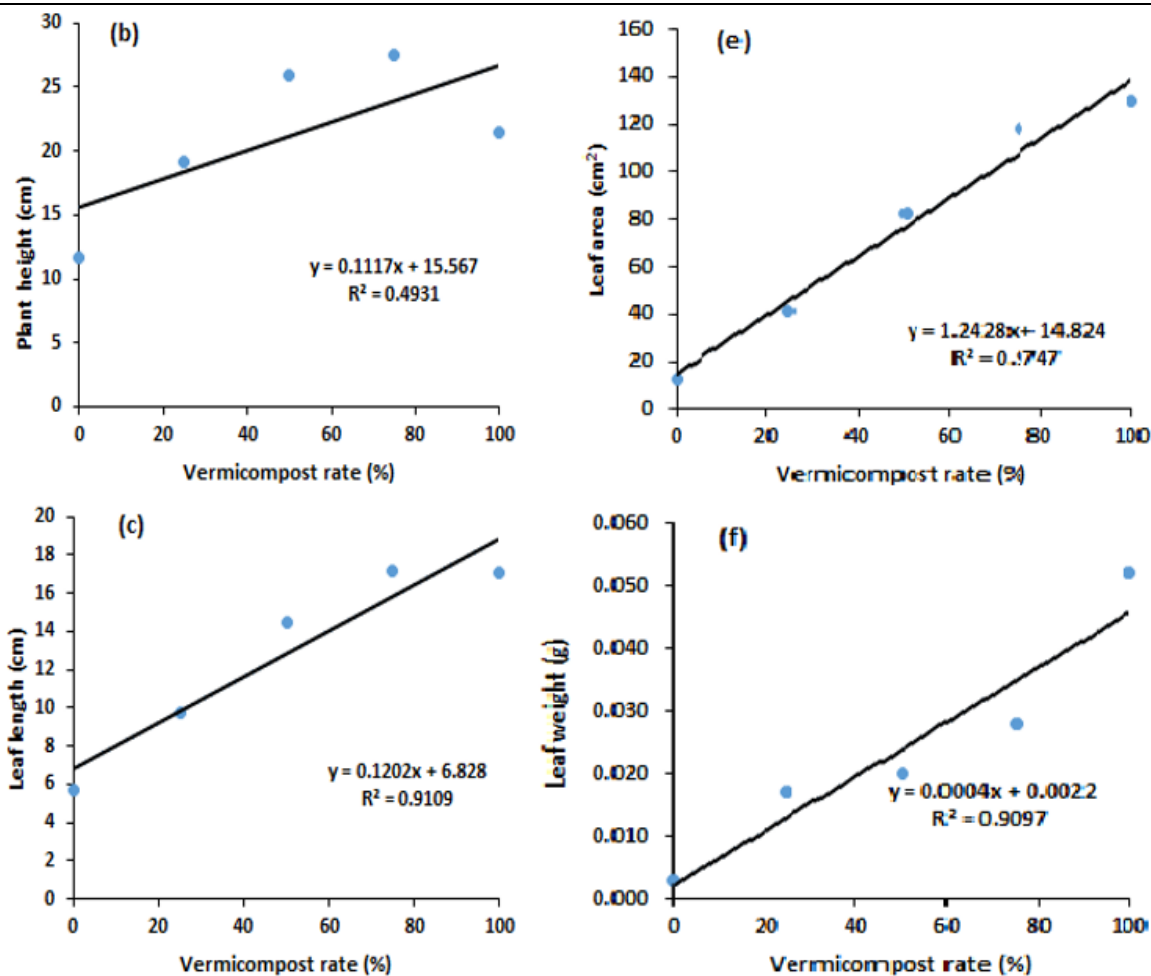


Fig. 2. Correlation between application rate of vermicompost on (a) number of leaves, (b) plant height, (c) leaf length, (d) leaf width, (e) leaf area and (f) leaf weight of rape (*Brassica napus* L.).

According to [46], the decline in plant growth as the amount of vermicompost increase, is caused by humic substances on vermicompost that catalyze the growing of plants with increasing the concentration, but causing plant inhibition at higher concentration. This phenomenon was also reported on the seedlings of *L. esculentum* [47] when seedlings that were grown on 100% VC produced fewer leaves, and they attributed this to the amount of salt in the media, the aeration of the soil, heavy metal toxicity or plant phytotoxicity. During this study, monkeys invaded the crops at the fourth week after emergence, hence, this account for a slight decline in number of leaves at fifth week after emergence (Figure 1a).

3.2. Plant Height (cm)

Levels of VC showed significant ($P < 0.05$) difference pertaining to plant height (Table 3). A somewhat weaker but still positive correlation ($R^2 = 0.49$) was observed between VC application rate and plant height (Figure 2b). The tallest plants (19.25 cm) were recorded at 75% VC though it was not significantly different from heights of plants at 50% VC, which were 16.52 cm. The shortest plants (7.37 cm) were recorded on control and were significantly shorter than heights of plants produced on the rest of the treatments. There was no significant difference of heights on plants raised on level 25% VC and 50% VC. In addition, level of 50% VC did not produce plant height that differed with heights of plant grown on 75% VC and 100% VC. Plant height significantly declined from 19.25 cm to 15.19 cm as VC level was raised from 75% to 100%. Vermicompost treatment levels

also had effect on growth trend of plant height at different growth stages (Figure 1b) and it shows an increasing trend with time, except at the seventh week after emergence where VC dosage was at 25%. 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. This results corroborates the findings of [48] on *B. oleracea* var. *italica*. Taller plants resulting from an increased dose of VC might be due to cell elongation, cell enlargement and cell division induced by auxins, cytokinins and alkaloids as a constituent of VC [31], causing appreciable higher plant growth. Reference [49] also highlighted that gibberilins and cytokinins from vermicompost in aqueous solution have significant effect on the growth of plants. The decline in plant height as VC application reached 100% from this study, is in supportive to the findings of [50], who reported a reduced growth of *L. esculentum* seedlings in the treatment consisting of 100% vermicompost and they ascribed this to salt concentration and poor water holding capacity.

3.3. Leaf Length (cm)

The longest leaf length (17.15 cm) was recorded on T4 (75% VC) and the shortest leaf length (5.72 cm) was recorded from control treatment (Table 3). Though T4 gave longest leaves, its leaf length did not differ significantly from length of leaves recorded on T3 and T5 which recorded 14.48 cm and 17.06 cm respectively. Length of plants produced on T1 differed significantly from the rest of treatment levels and the same was with those plants produced on T2. A strong correlation ($R^2 = 0.91$) between VC application rate and leaf length existed from this study (Figure 2c). Though from the current study it appears that leaf length was triggered by the amount of dosage received, vermicompost at a dosage of 75%, produced higher values regarding leaf length but was statistically similar with the length of plants grown on 50% VC and 100% VC. Similar trend of results were obtained [51] on Ethiopian mustard (*Brassica carinata* L.). Reference [52], ascribed this to the greater amount of readily availability of major plant nutrients particularly nitrogen in vermicompost which is a major constituent for formation of chlorophyll molecule.

3.4. Leaf Width (cm)

Leaf width significantly ($P < 0.05$) increased with increasing level of VC and a strong correlation ($R^2 = 0.95$) occurred between rate of VC and leaf width (Figure 2d). Narrowest leaves (3.65 cm) were attained on T1, while T5 yielded the widest ones (12.00 cm). Treatment T4 and T5 produced leaf width which were not statistically different from each other (11.30 cm and 12.00 cm respectively), and both differed significantly from leaves of plants from T1, T2 and T3. However, T1, T2 and T3 gave leaf width which differed significantly from each other. From the current study, crops receiving doses of 50% VC, 75% VC and 100% VC produced leaf widths that were not statistically different, although crops receiving the dosage of 75% VC produced the widest leaf width, whereas, at any dosage above 75% VC, leaves reduced in their breadth. This trend was also noted on different parameters on previous studies regarding vermicompost amendments on various crops [53]-[55]. 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 [46].

3.5. Leaf Area (cm²)

Leaf area significantly ($P < 0.05$) increased with increasing levels of vermicompost (Table 3 and Figure 2e). Leaves with significant small area (12.91 cm² and 41.21 cm²) were attained from T1 and T2 respectively compared

to all the treatments. Though T5 produced leaves of maximum area (129.73 cm²), they were not statistically different from leaves produced from T4 (118.26 cm²). Plants raised on 50% VC produced leaf area that was significantly different from the rest of treatments. Reference [56], also reported enhancement of growth on leaf area of plants applied with vermicompost than on pure soil. The same was also noted in earlier studies when pure garden soil (control) gave the lowest growth of leaf area of *B. napus* compared to when soil was amended with various levels of conventional compost [39]. An increase in leaf area as application of vermicompost increases, might be due to adequate micro and macro elements which might have enhanced higher metabolic process, synthesis of carbohydrates and phytohormones in the leaves [57].

3.6. Leaf Weight (g)

Table 3, shows that the total weight of *B. napus* leaves was significantly ($P < 0.05$) influenced by different levels of VC. Lightest leaves were recorded on T1, which was statistically similar with T2. Highest weight of leaves was recorded on T5, which was statistically identical with weight of leaves produced on T4. Treatment T1 and T2 produced leaves with significantly less weight compared to T4 and T5. Whereas, T3 produced leaf weight that was not statistically different from weight of leaves of T4. A positive correlation existed between leaf weight and all parameters measured from this study (Figure 3a-e). This study indicates that leaf weight increased as the level of vermicompost increased. These results are in relation with findings of [39], when studying different application levels of compost on *B. napus*. According to [58], application of vermicompost in the soil develop microbial activity resulting in more addition of nutrients for crop growth which in return triggers more yield. Significant rise in leaf weight was also reported upon the increasing doses of vermicompost on *L. sativa* [42]. The increase in leaf weight could be ascribed to more photosynthesis from leaf length, leaf width and leaf area which exhibited strong correlation with the increase of VC (Figure 3c, d, e). Reference [59], also reported a positive correlation between length and width of leaves on weight of cabbage head. Likewise, [60] reported a relatively similar results when studying effects of inorganic and organic fertilizers on yield and economic of *B. oleracea*. Subsequently, [61], reported a positive correlation between leaf area and dry weight on *B. napus*.

IV. CONCLUSIONS

Vermicompost is an excellent organic fertilizer for providing nutrients to plants. This was revealed from this study as all parameters studied such as number of leaves, plant height, leaf length, leaf width, leaf area and leaf weight responded positively to levels of vermicompost. All parameters increased with increasing levels of vermicompost although the number of leaves, plant height and leaf length declined with further addition of vermicompost beyond 75% VC. However, the decline in values of these parameters did not bring any substantial differences on the outward leaf weight as leaves attained when VC was 50% to 100% resulted in statistically the same weight. Thus, when producing *B. napus* using media amended with VC, an amount of 50% to 75% of VC can be used as beyond this, crop performance turn to decline. The weight of rape leaf is closely correlated with the quantity of vermicompost applied.

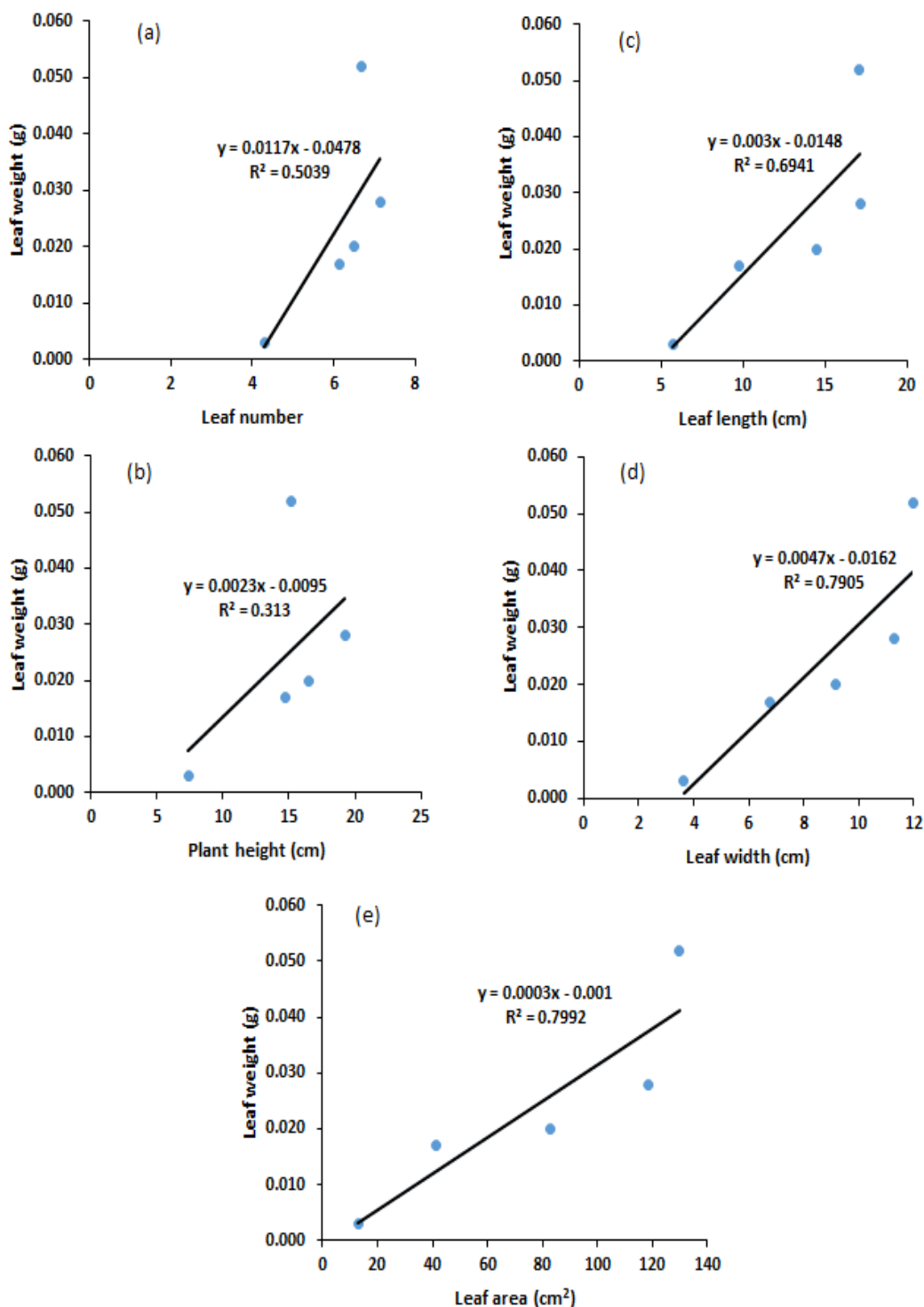


Fig. 3. Correlation between leaf weight and (a) leaf number, (b) plant height, (c) leaf length, (d) leaf width and (e) leaf area of rape (*Brassica napus* L.).

ACKNOWLEDGEMENTS

I am thankful to the Department of Agricultural Research under the Ministry of Agricultural Development and Food Security, Botswana, for providing necessary facilities. My gratitude also to Mr Z. Madzonga, Mrs L.C. Bosekeng and Mr M. Ithuteng for their valuable input and all the field assistants (FA's) under the supervision of Ms D. Kaisara.

REFERENCES

- [1] Department of Crop Production. (2016). Horticulture- Early warning report (March). Ministry of Agricultural Development and Food Security, Gaborone, Botswana.
- [2] Ganya, S., Sivotwa, E. and Katsaruware, R.D. (2018). Performance of two rape (*Brassica napus*) cultivars under different fertilizer management levels in the smallholder sector of Zimbabwe. *International Journal of Agronomy*. 1 - 7. <https://doi.org/10.1155/2018/2351204>.
- [3] Ozturk, O. (2010). Effects of source and rate of nitrogen fertilizer on yield, yield components and quality of winter rapeseed (*Brassica napus* L.). *Chilean Journal of Agricultural Research*. 70(1), 132 – 141.
- [4] Rameeh, V. (2012). Evaluation of the planting dates effects on yield and yield associated traits in rapeseed advanced lines. *International Journal of Agriculture Innovations and Research*. 1(1), 7 – 11.
- [5] Namvar, A. and Khandan, T. (2014). Bio priming and mineral fertilizers effects on agronomical performance of rapeseed (*Brassica napus* L.). *Ekologija (Ecology)*. 60(3), 54 – 63.
- [6] Ren, T., Li, H., Lu, J., Bu, R., Li, X., Cong, R. and Lu, M. (2015). Crop rotation-dependent yield responses to fertilization in winter oilseed rape (*Brassica napus* L.). *The Crop Journal*. 3, 396 – 404.
- [7] Onder, M., Ceyhan, E. and Kahraman, A. (2011). Effects of agricultural practices on environment. International conference on biology, environment and chemistry, IPCBEE, IACSIT press, Singapore, 24, 28 – 32.
- [8] Gupta, R., Yadav, A. and Garg, V.K. (2014). Influence of vermicompost application in potting media on growth and flowering of marigold crop. *International Journal of Recycling of Organic Waste in Agriculture*. 3(1), 1 – 7.
- [9] Chang, E.-H., Chung, R.S. and Wang, F.-N. (2008). Effect of different types of organic fertilizers on the chemical properties and enzymatic activities of an Oxisol under intensive cultivation of vegetables for 4 years. *Soil Science and Plant Nutrition*. 54, 587 – 599.
- [10] Mojeremane, W., Motladi, M., Mathowa, T. and Legwaila, G.M. (2015). Effect of different application rates of organic fertilizer on growth, development and yield of Rape (*Brassica napus* L.). *International Journal of Innovative Research in Science, Engineering and Technology*. 4(12), 11680 – 11688.
- [11] Aderinoye-Abdulwahab, S.A. and Salami, S.T. (2017). Assessment of organic fertilizer usage by vegetable farmers in ASA Local Government area of Kwara State, Nigeria. *Agro search*. 17(1), 101 – 114.
- [12] Terence, M., Tuarira, M., Moses, M. and Jefta, T. (2015). Use of vermicompost as a soil supplement on growth and yield of rape (*Brassica napus*). *Journal of Global Innovations in Agricultural Social Sciences*. 3(1), 25 – 31.
- [13] Kovacic, P., Salamun, P., Smoleń, S. and Renčo, M. (2018). Impact of vermicompost as component of growing medium on phytomass formation of Radish (*Raphanus sativus* L.). *Agriculture (Polnohospodárstvo)*. 64(3), 106 – 115.
- [14] Thiruneelakandan, R. and Subbulakshmi, G. (2014). Vermicomposting: A superlative for soil, plant and Environment. *International Journal of Innovative Research in Science, Engineering and Technology*. 3(1), 930 – 938.
- [15] Orozco, F.H., Cegarra, J., Trujillo, L.M. and Roig, A. (1996). Vermicomposting of coffee pulp using the earthworm *Eisenia fetida*: Effects on C and N contents and the availability of nutrients. *Biology and Fertility Soils*. 22, 162 – 166.
- [16] Khan, A. and Ishaq, F. (2011). Chemical nutrient analysis of different composts (*Vermicompost* and *Pitcompost*) and their effect on the growth of a vegetative crop *Pisum sativum*. *Asian Journal of Plant Science and Research*. 1(1), 116 – 130.
- [17] Sinha, R.K., Hahn, G., Singh, P.K., Suhane, R.K. and Anthonyreddy, A. (2011). Organic farming by vermiculture: Producing safe, nutritive and protective foods by earthworms (Charles Darwin's friends of farmers). *American Journal of Experimental Agriculture*. 1(4), 363 – 399.
- [18] Guerrero III, R.D. (2009). Earthworm culture for vermicompost and vermimeal production and for vermiceutical application in the Philippines (1978 – 2008) – A review. *Dynamic Soil, Dynamic Plant*. 3(2), 28 – 31.
- [19] Manaig, E.M. (2016). Vermicomposting efficiency and quality of vermicompost with different bedding materials and worm food sources as substrate. *Research Journal of Agriculture and Forestry Sciences*. 4(1), 1 – 13.
- [20] A'ali, R., Jafarpour, M., Kazemi, E. and Pessarakli, M. (2017). Effects of raw materials on vermicompost qualities. *Journal of Plant Nutrition*. 40(11), 1635 – 1643.
- [21] Jayakumar, M., Sivakami, T., Ambika, D. and Karmegam, N. (2011). Effect of turkey litter (*Meleagris gallopavo* L.) vermicompost on growth and yield characteristics of Paddy, *Oryza sativa* (ADT-37). *African Journal of Biotechnology*. 10(68), 15295 – 15304.
- [22] Haque, A.T.U., Khan, N.A. and Barman, S.K. (2018). Vermi-compost in agricultural production in Bangladesh. *International Journal of Natural and Social Sciences*. 5(2), 61 – 68.
- [23] Bellitürk, K. (2018). Some evaluations about use of vermicompost in agricultural activity of Thrace Region, Turkey: A review. *Journal of Rice Research*. 6(2), 1 – 6. doi:10.4172/2375-4338.1000193.
- [24] Sinha, R.K., Agarwal, S., Chauhan, K., Valani, D. (2010). The wonders of earthworms & its vermicompost in farm production: Charles Darwin's friends of farmers', with potential to replace destructive chemical fertilizers from agriculture. *Agricultural Sciences*. 1(2), 76 – 94.
- [25] Ishfaq Akbar, P., Kumar, V. and Mohan, B. (2010). Influence of Bio-organic nutrition on the performance of cabbage (*Brassica oleracea* var. *capitata* L.) cv. Pride of India. *Advance Research Journal of Crop Improvement*. 1(2), 165 – 167.
- [26] Dupare, A. and Nimbarte, S. (2012). Comparative study of quality attributes of spinach grown on vermicompost and artificial fertilizer. *Asian Journal of Home Science*. 7(1), 42 – 47.
- [27] Kibatu, T. and Mamo, M. (2014). Vermicompost and vermiwash on growth, yield and yield components of Beetroot (*Beta vulgaris* L.). *World Applied Sciences Journal*. 32(2), 177 – 182.
- [28] Mbithi, M.A., Mwanarusi, S. and Mwangi, M. (2015). Effect of different rates of vermicompost on growth and yield of Beetroot (*Beta vulgaris* L.). *Egerton Journal of Science and Technology*. 15, 30 – 43.
- [29] Moghadam, M.K., Darvishi, H.H. and Javaheri, M. (2014). Effect of Bacteria and Vermicompost on phenology and growth of soybean (*Glycine max* L.) in sustainable agricultural systems. *International Journal of Advanced Biological and Biomedical Research*. 2(9), 2534 – 2539.
- [30] Biri, A., Kaba, S., Tadesse, F., Dechassa, N., Sharma, J.J., Zewidie, A. and Chavhan, A. (2016). Effect of vermicompost and nitrogen application on striga incidence, growth, and yield of sorghum (*Sorghum bicolor* (L.) Monech) in Fedis, eastern Ethiopia. *International Journal of life Sciences*. 4(3), 349 – 360.
- [31] Arancon, N.Q., Edwards, C.A., Bierman, P., Welch, C. and Metzger, J.D. (2004). Influences of vermicomposts on field strawberries: 1. Effects on growth and yields. *Bioresource Technology*. 93, 145 – 153.
- [32] Arancon, N.Q., Edwards, C.A., Yardim, E.N., Oliver, T.J., Byrne, R.J. and Keeney, G. (2007). Suppression of two-spotted spider mite (*Tetranychus urticae*), mealy bug (*Pseudococcus* sp) and aphid (*Myzus persicae*) populations and damage by vermicomposts. *Crop Protection*. 26, 29 – 39.
- [33] Getnet, M. and Raja, N. (2013). Impact of vermicompost on growth and development of cabbage, *Brassica oleracea* Linn. and their sucking pest, *Brevicoryne brassicae* Linn. (Homoptera: Aphididae). *Research Journal of Environmental and Earth Sciences*. 5(3), 104-

- 112.
- [34] Mohamadi, P., Razmjou, J., Naseri, B. and Hassanpour, M. (2017). Population growth parameters of *Tuta absoluta* (Lepidoptera: Gelechiidae) on tomato plant using organic substrate and bio fertilizers. *Journal of Insect Science*. 17(2), 1 – 7.
- [35] Yassen, A.A., Abd El-Salam, A.M.E., Salem, S.A., Sahar, M.Z. and Khaled, S.M. (2015). Impact of vermicompost on growth; development and green peach aphid *Myzus persicae* Sulzer (Hemiptera: Aphididae) infestations in Pot Marigold. *Global Advanced Research Journal of Agricultural Science*. 4(12), 911 – 918.
- [36] Edwards, C.A., Arancon, N.Q., Vasko-Bennett, M., Askar, A., Keeney, G. and Little, B. (2009). Suppression of green peach aphid (*Myzus persicae*) (Sulz.), citrus mealybug (*Planococcus citri*) (Risso), and two spotted spider mite (*Tetranychus urticae*) (Koch.) attacks on tomatoes and cucumbers by aqueous extracts from vermicomposts. *Crop Protection*. doi: 10.1016/j.cropro.2009.08.011.
- [37] Gabour, E.I., Marahatta, S.P. and Lau, J.-W. (2015). Vermicomposting: a potential management approach for the reniform nematode, *Rotylenchulus reniformis*. *Nematropica*. 45(2), 285 – 287.
- [38] Ascitutto, K., Rivera, M.C., Wright, E.R., Morisigie, D. and Lopez, M.V. (2006). Effect of vermicompost on the growth and health of *Impatiens wallerana*. *International Journal of Experimental Botany*. 75, 115 – 123.
- [39] Eswaran, N. and Mariselvi, S. (2016). Efficacy of vermicompost on growth and yield parameters of *Lycopersicon esculentum* (Tomato). *International Journal of Scientific and Research Publications*. 6(1), 95 – 108.
- [40] Jadhav, P.B., Patel, D.J., Kireeti, A., Patil, N.B., Dekhane, S.S., Harad, N.B. and Jadhav, K.P. (2014). Effect of different levels of vermicompost on growth and yield of radish cv. Local variety. *International Journal of Information Research and Review*. 1(2), 29 – 31.
- [41] Shapla, S.A., Hussain, M.A., Mandal, M.S.H., Mehraj, H. and Jamal Uddin, A.F.M. (2014). Growth and yield of Broccoli (*Brassica oleracea* var. *italica*) to different organic manures. *International Journal of Sustainable Crop Production*, 9(2), 29 – 32.
- [42] Adiloglu, S., Acikgoz, F.E., Solmaz, Y., Caktu, E. and Adiloglu, A. (2018). Effect of vermicompost on the growth and yield of Lettuce plant (*Lactuca sativa* L. var. *crispa*). *International Journal of Plant and Soil Science*. 21(1), 1 – 5.
- [43] Joshi, R. and Vig, A.P. (2010). Effect of vermicompost on growth, yield and quality of tomato (*Lycopersicon esculentum* L.). *African Journal of Basic and Applied Sciences*. 2(3-4), 117 – 123.
- [44] Hasan, M.M., Ali, M.A., Rubel, M.M.K., Shah, M., Alzahrani, Y. and Hakeem, K.R. (2018). Influences of vermicompost and organic mulching on growth, yield and profitability of carrot (*Daucus carota* L.). *Journal of Agriculture Biotechnology*. 3(1), 19 – 31.
- [45] Zaman, M.M., Chowdhury, M.A.H., Islam, M.R. and Uddin, M.R. (2015). Effects of vermicompost on growth and leaf biomass yield of Stevia and post-harvest fertility status of soil. *Journal of the Bangladesh Agricultural University*, 13(2), 169 – 174.
- [46] Atiyeh, R.M., Lee, S., Edwards, C.A., Arancon, N.Q. and Metzger, J.D. (2002). The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bio resource Technology*. 84, 7 – 14.
- [47] Atiyeh, R.M., Arancon, N.Q., Edwards, C.A. and Metzger, J.D. (2000). Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes. *Bio resource Technology*. 75, 175 – 180.
- [48] Mohanta, R., Nandi, A.K., Mishra, S.P., Pattnaik, A., Hossain, M.M. and Padhiary, A.K. (2018). Effects of integrated nutrient management on growth, yield, quality and economics of sprouting broccoli (*Brassica oleracea* var. *italica*) cv. Shayali. *Journal of Pharmacognosy and Phytochemistry*. 7(1), 2229 – 2232.
- [49] Kumar, A. and Gupta, R.K. (2018). The effects of vermicompost on growth and yield parameters of vegetable crop radish (*Raphanus sativus*). *Journal of Pharmacognosy and Phytochemistry*. 7(2), 589 – 592.
- [50] Atiyeh, R.M., Edwards, C.A., Subler, S. and Metzger, J.D. (2001). Pig manure vermicompost as a component of a horticultural bedding plant medium: effects on physicochemical properties and plant growth. *Bio resource Technology*. 78, 11 – 20.
- [51] Bosekeng, G. (2019). Response of Ethiopian mustard (*Brassica carinata* A. Braun) to different levels of vermicompost in North East, Botswana. *World Journal of Agricultural Research*. 7(3), 112 – 118.
- [52] Yadav, K.K., Nagaich, K.N. and Lekhi, R. (2019). Effect of integrated nutrient management on leaf nutrient status, yield and quality of spinach (*Beta vulgaris* L.) var. Pusa Jyoti. *International Journal of Chemical Studies*. 7(3), 1053 – 1058.
- [53] Tatleri, M., Abdossi, V. and Ardebili, Z.O. (2013). The effects of different levels of vermicompost on growth and development of *Dracaena marginata*. *International Research Journal of Applied and Basic Sciences*. 4(4), 784 – 786.
- [54] Mupondi, L.T., Mkeni, P.N.S. and Muchaonyerwa, P. (2014). Vegetable growth medium components: Effects of dairy manure-waste paper vermicomposts on physicochemical properties, nutrient uptake and growth of tomato seedlings. *International Journal of Agricultural Research, Sustainability, and Food Sufficiency*. 2(2), 23 – 31.
- [55] Gonzales, L.M.R., Caralde, R.A. and Aban, M.L. (2015). Response of Pechay (*Brassica napus* L.) to different levels of compost fertilizer. *International Journal of Scientific and Research Publications*. 5(2), 1 – 4.
- [56] Ramnarain, Y.I., Ori, L. and Ansari, A.A. (2018). Effect of the use of vermicompost on the plant growth parameters of Pak Choi (*Brassica rapa* var. *chinensis*) and on the soil structure in Suriname. *Journal of Global Agriculture and Ecology*. 8(1), 8 – 15.
- [57] Jabeen, A., Narayan, S., Hussain, K., Khan, F.A., Ahmad, A. and Mir, S.A. (2017). Organic production of spinach beet (*Beta vulgaris* var. *bengalensis*) through the use of manures and biofertilizers. *Journal of Pharmacognosy and Phytochemistry*. 6(6), 10 – 13.
- [58] Alam, M.A.U., Hoque, M.E., Laily, U.K., Khatun, M.U.S., Islam, M.K. and Mollah, S.H. (2017). Growth and yield performance of cabbage under different combinations of vermicompost and fertilizers. *International Journal of Advanced Research in Biological Sciences*. 4(6), 79 – 86.
- [59] Chaudhary, S.K., Yadav, S.K., Mahto, D.K., Sharma, R.P. and Kumar, M. (2018). Response of growth, yield attributes and yield of cabbage (*Brassica oleracea* var. *capitata*) to different organic and inorganic sources of nutrients in Magadha Plain of Bihar. *International Journal of Current Microbiology and Applied Sciences*. 7, 4748 – 4756.
- [60] Lodhi, P., Singh, D. and Tiwari, A. (2017). Effect of inorganic and organic fertilizers on yield and economics of Broccoli (*Brassica oleracea* var. *italica*). *International Journal of Current Microbiology and Applied Sciences*. 6(8), 562 – 566.
- [61] Hunkova, E., Zivcak, M. and Olsovska, K. (2011). Leaf area duration of oilseed rape (*Brassica napus* subsp. *napus*) varieties and hybrids and its relationship to selected growth and productivity parameters. *Journal of Central European Agriculture*. 12(1), 1 – 15.

AUTHOR'S PROFILE

First Author

Gagopale Bosekeng, Department of Agricultural Research, Horticulture Program, Ministry of Agricultural Development and Food Security, P.O. Box 10275 Francistown, Botswana.