ZIBELINE INTERNATIONAL PUBLISHING

Science Heritage Journal (GWS)

DOI: http://doi.org/10.26480/gws.02.2020.46.50

ISSN: 2521-0858 (Print)
ISSN: 2521-0866 (Online)
CODEN: SHJCAS

CrossMark

RESEARCH ARTICLE

EVALUATION OF VERMICULITE APPLICATION RATES ON GROWTH AND YIELD OF *BRASSICA NAPUS* (RAPE)

Pisa C[a,b], Parwada C[c], Chiripanyanga S[b], Dunjana N[a]

[a]School of Agricultural, Earth and Environmental Sciences, University of KwaZulu Natal, Pietermaritzburg Campus, P.O. Box X01, Scottsville 3209, South Africa.
[b]Department of Natural Resources Management, Faculty of Earth and Environmental Sciences, Marondera University of Agricultural Sciences and Technology; P O Box 35, Marondera, Zimbabwe.
[c]Department of Horticulture, Faculty of Agricultural Sciences, Women's University in Africa, Marondera, Zimbabwe.
**Corresponding author email: cparwada@gmail.com*

ARTICLE DETAILS

Article History:

Received 21 March 2020
Accepted 23 April 2020
Available Online 05 May 2020

ABSTRACT

Production of leaf vegetables requires intensive soil nutrients management. A 3-year field experiment was carried out to assess effects of vermiculite application rates on the growth and yield of *Brassica napus*. The experiment was conducted during the 2016/17, 2017/18 and 2018/19 summer seasons at the Marondera University of Agricultural Sciences and Technology (MUAST) farm, Mashonaland East Province, Zimbabwe. Vermiculite was applied at five levels of 0 (control), 1, 2, 5 and 10 t ha^{-1} in a completely randomised block design (RCBD) with 3 replicates. Basal and top-dressing fertilizers were applied using the recommended rates in the study area. The *B. napus* leaf width, leaf length, fresh and dry matter yield, leaf nutrient concentration and N and P uptake were measured. Analysis of variance (ANOVA) at p = 0.05 was done to compare the effects of vermiculite application rates on growth and yield of *B. napus*. Growth parameters and yield of *B. napus* significantly (P <0.05) differed among the five levels of vermiculite. Application rates of 5 t ha^{-1} and 10 t ha^{-1} improved leaf width and length, fresh and dry matter yield of *B. napus*. Farmers may therefore apply 5 -10 t ha^{-1} of vermiculite in order to increase rape leaf yields. However, there is need for further researches to determine the optimum application rates of vermiculite are essential.

KEYWORDS

Leaf vegetable, Productivity, Soil conditioning, Soil fertility, Vermiculite.

1. INTRODUCTION

Production of leaf vegetables like *Brassica napus* (rape) for both local and export markets is expanding to meet the increasing population demand (Kuntashula et al., 2004; Munchecheti et al., 2012). The rape is ranked second from tomatoes grown in backyards of small-scale farmers (Mingochi and Luchen, 2000; Ganya et al., 2018). The vegetable is one of the most profitable agricultural enterprises, as it is fast growing and matures early (Jama and van Staaten, 2006). Rape can be grown throughout the year by small-scale farmers under rainfed cropping in the low veld of Zimbabwe (Nyakudya et al., 2010). Like all other vegetables, rape provides minerals, roughage and vitamins when consumed after cooking the fresh or dried leaves. This provides household nutritional security in both communal and urban areas (Nyakudya et al., 2010). However, the production of rape requires intensive management of soil nutrients (Losak et al., 2008). Although rape is relatively easy to grow unlike other Brassicas spp such as broccoli, cauliflower and turnip, low soil fertility can result to a significant reduction of its yield and quality.

Many small-scale farmers in Zimbabwe are concentrated on inherently infertile sandy soils and rely on rainfed crop production, thus face the challenge of low crop productivity (Dhaliwal et al., 2014; Rocktrom and Falkenmark, 2000). Poor soil fertility due to nutrient loss via nutrient mining, erosion and leaching leads to low crop productivity under rainfed conditions (Rockstrom and Falkenmark, 2000). To improve crop productivity there is need holistic soil fertility management, which include the management plant nutrient and soil physical conditions, like structure, porosity and water retention which affect the nutrient uptake efficiency. Addition of soil amendments such as animal manure, fly ash and compost fertilizers have been seen to improve soil conditions (Thompson, 2001). Other soil conditioners that have been used includes perlite and vermiculite can be used to improve the availability and uptake of the nutrients.

The vermiculite, a hydrated 2:1 magnesium aluminium silicate clay with a large chemically active surface area offering a high cation exchange capacity (CEC), ranging from 50 to 150 meq/100 g, of vermiculite (Loehr et al., 1998; Hindman, 2006; Marwa et al., 2012). The high CEC increases the potential of vermiculite to adsorb cations reducing their loss through leaching. It also has a high-water holding capacity (WHC) and because of these properties it is used as potting media for seedlings (Lila et al., 2017). A group researchers observed that the water absorption capacity and fertiliser retention of hardened

Quick Response Code	Access this article online	
	Website: www.jscienceheritage.com	**DOI:** 10.26480/gws.02.2020.46.50

sulphoaluminate cementitious materials-based materials increased with the increase of vermiculite dosage (Paviou et al., 2007). Vermiculite soil application can therefore increase nutrient availability allowing for a high nutrient uptake efficiency by providing optimum nourishment to the crop while minimizing nutrient losses from the field (Fixen et al., 2010). A group researchers observed an improvement in the agronomic performance of maize, sunflower and cotton after using a vermiculite-based rock fertilizer in sandy soils (Paviou et al., 2007).

They attributed this to an improvement in nutrient uptake efficiency through modification of the soil chemical and physical properties such as pH, cation exchange capacity, water holding capacity and consistence. The application of vermiculite to soil, therefore, has the potential to improve soil condition by adding more loft and texture to keep the soil loose allowing maximum contact of the soil and roots (Klingler, 2015). Vermiculite also allows for optimum soil aeration to the roots and regulate the temperature of the soil. The long-term effects of vermiculite on soil productivity is known, however the short-term effects are still unclear. Therefore, the aim of this study was to increase the productivity of *B. napus* in low fertile soils. Therefore, the specific objective of this study was to assess the effects of different vermiculite application rates on growth and yield of *B. napus*.

2. Materials and Methods

2.1 Site description

A 3-year field experiment was conducted during the 2016/17, 2017/18 and 2018/19 summer seasons at the Marondera University of Agricultural Sciences and Technology (MUAST) farm, Mashonaland East Province, Zimbabwe. The farm is in the Natural Region IIb and located between 18°23′S and 31°48′E. The study area is characterized by highly leached, infertile and acidic sandy loams soils, Lixisol, derived from granite (Van Straaten, 2002; IUSS Working Group WRB, 2015). The MUAST experiences hot, wet summers and dry, cold winters with an average mean annual rainfall ranging between 600 and 900 mm with about 80 % received between November and March (Jackson et al., 1997).

2.2 Experimental design and management

A completely randomised block design (RCBD) with three replicates was used in the study. The blocking factor was the slope. Each experimental plot measured 4 x 3.5 m with a space of 1.0 m between the plots and blocks. In 2016/17, 2017/18 and 2018/19 summer seasons, vermiculite was applied at five levels of 0 (control), 1, 2, 5 and 10 t ha^{-1} and N, P and K at the rate of 35 kg P_2O_5, 70 kg N and 35 kg K_2O. In each plot, a Hobson rape cultivar seedlings was transplanted at 0.4 × 0.3 m (inter-row × intra row) spacing respectively giving 10 rows per plot. At 3 weeks after transplanting (WAT), ammonium nitrate (35% N) was applied as topdressing at a rate of 250 kg ha^{-1}.

Prior to the application of vermiculite in the experimental plots, two soil samples were taken from each plot to a depth of 200 mm. The two samples were randomly mixed to make one compound sample per plot and analysed for soil texture using the hydrometer method after dispersing the soil with sodium hexa-meta-phosphate (Anderson and Ingram, 1996). Soil pH was determined by the $CaCl_2$ method, while organic carbon was determined using the modified Walkley-Black method (Okalebo et al., 2002). Total exchangeable cations were extracted from the soil samples using 1 M ammonium acetate. The exchangeable potassium, magnesium, calcium and sodium in the extract were determined by flame photometry (Na and K) and by atomic absorption spectrophotometry (Ca and Mg) (Okalebo et al., 2002). Total soil N and available P were obtained calorimetrically at a wavelength of 650 nm and 400 nm respectively after extraction by wet digestion using concentrated sulphuric acid and hydrogen peroxide (Okalebo et al., 2002).

2.3 Data collection

Measurements were taken from the two middle rows leaving out 2 outer plants from both ends of the rows. Rape leaf length and width, fresh and root dry biomass yields were determined biweekly from 3 to 11 WAT. All the leaves were plucked out expect for the top three leaves. Fresh weight was determined within an hour of harvesting. The leaves were then oven dried at 70°C until a constant weight was reached. Oven dried leaves were ground to pass a < 0.25 mm/ 60 mesh sieve and total nutrients (N, P, K, Ca, Mg and Na) extracted by wet digestion using concentration sulphuric acid, selenium powder, lithium sulphate and hydrogen peroxide mixture (Anderson and Ingram, 1996). Nitrogen was determined in an aliquot of digest after colour development with sodium nitroprusside using a spectrophotometer while total P was determined using the molybdenum blue colouration method (Okalebo et al., 2002). The amounts of potassium, magnesium, calcium and sodium in the digest were determined by flame photometry (Na and K) and by atomic absorption spectrophotometry (Ca and Mg) (Okalebo et al., 2002). After the final harvest soil was collected from each plot and analysed for total N and total P and the cations Ca, Mg, K using standards methods described (Anderson and Ingram, 1996).

2.4 Statistical analysis

Analysis of variance (ANOVA) was done to compare the effects of vermiculite application rates on the growth and yield of *B. napus*. The means were separated using the least significance difference level ($LSD_{0.05}$ = $t_{0.05}$ x SE 0.05). Tukey's Honesty test at α = 0.05 significance level was also used to separate means for some of the measured parameters. All analyses were done using Genstat 14.

3. Results

3.1 Soil characterization

The soil was characterized by most (77%) sand and least (9%) silt particle with an acidic pH of 5.3 (Table 1).

Table 1: Selected soil properties at the Marondera University of Agriculture and Technology Farm

Soil property	pH	EC	TN	Min. N	P	K	Ca	Mg	Na	TEB	Clay	Silt	Sand
				mg/kg				me%					
		µS/cm	%									%	
	5.3	172	0.21	8	54	0.20	0.84	0.41	0.00	1.45	14	9	77

Min.N refers to incubated N which represents available N

3.2 Growth parameters

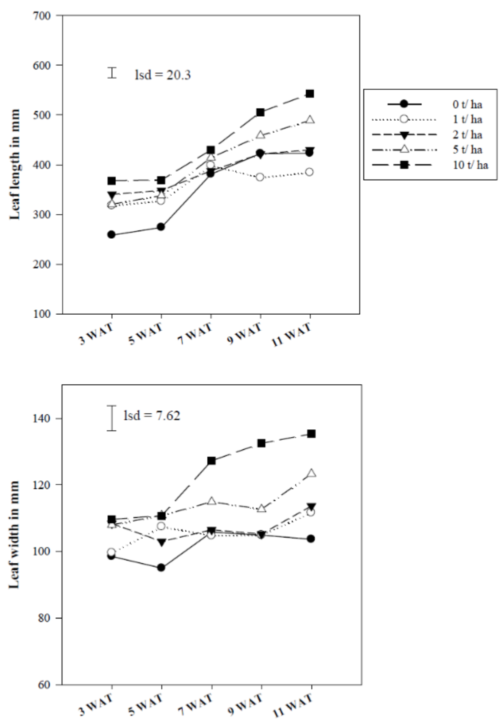

Figure 1: Effect vermiculite application rates on; a) leaf length, b) leaf width

The *B. napus* leaf length was increasing with time from the first harvest and significantly (P<0.05) varied amongst the vermiculite application rates throughout the three growing seasons. The 0 and 10 t ha^{-1} vermiculite application rates produced shortest and longest leaves respectively (Figure 1). The leaf length was not significantly (P>0.05) different at 3 to 7 WAT in 1, 2 and 5 t ha^{-1} vermiculite application rates. At 11 WAT the leaf length was noted to be in the following ascending order 10 > 5 > 2 > 1 > 0 t ha^{-1}. The leaf width had a similar trend to of leaf length throughout the study period. At 3 WAT the leaf width in 0 and 1 t ha^{-1} vermiculite application rates did not significantly (P>0.05) differ. However, the leaf width under the 2, 5 and 10 t ha^{-1} vermiculite application rates were significantly (P < 0.05) different from 3 to 11 WAT (Figure 1).

3.3 *Brassicus napus* Leaf yield

Table 2: Dry matter yield of rape (t ha^{-1}) for 11 WAT.

	0 t ha^{-1}	1 t ha^{-1}	2 t ha^{-1}	5 t ha^{-1}	10 t ha^{-1}	LSD
3 WAT	0.145^{a}	0.132^{a}	0.127^{a}	0.150^{a}	0.203^{b}	**0.024**
5 WAT	0.109^{a}	0.134^{b}	0.213^{c}	0.282^{d}	0.372^{e}	**0.011**
7 WAT	0.076^{a}	0.204^{b}	0.2035^{b}	0.307^{c}	0.408^{d}	**0.023**
9 WAT	0.084^{a}	0.450^{b}	0.517^{c}	0.673^{d}	0.851^{e}	**0.033**
11 WAT	0.126^{a}	0.674^{b}	0.984^{c}	2.468^{d}	3.561^{e}	**0.067**
Cumulative yield	0.540^{a}	1.594^{b}	2.044^{c}	3.880^{d}	5.395^{d}	**0.033**

Results are for measurements done on a net plot of 1.8 m^{2}. Values followed by the same superscript alphabetical letters are not significantly different at p<0.05 according to Tukey's HSD. (Data points are the mean of the three replicates).

3.4 Fresh weight

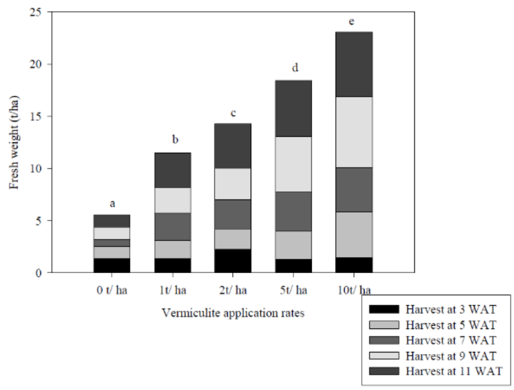

Figure 2: Fresh (saleable) yield of rape per vermiculite application rate

Fresh yield was increasing at each time of harvesting and significantly (P<0.05) different amongst vermiculite application rates (P < 0.05) (Figure 2). The 10 t ha^{-1} application rate had the highest fresh yield as from 5 up to 11 WAT and the fresh yield lowest in the 0 t ha^{-1} (Figure 2). The trend of dry matter was observed to be significantly (P< 0.05) the same to that of fresh yield (Table 2). Highest (5.40 t ha^{-1}) and lowest (0.52 t ha^{-1}) dry matter were obtained under the 10 t ha^{-1} and 0 t ha^{-1} vermiculite application rates respectively.

3.5 Roots dry matter biomass

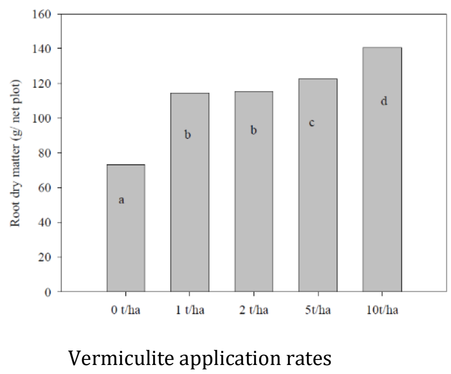

Figure 3: Root dry biomass at 11 WAT. Bars followed by the same superscript alphabetical letters are not significantly different at p<0.05 according to Tukey's HSD. (Data points are the mean of the three replicates).

Root biomass significantly (P < 0.05) varied amongst vermiculite application rates though the 1 and 2 t ha^{-1} plots did not differ significantly (P > 0.05) (Figure 3). The root biomass was highest in the 10 t ha^{-1} and lowest in 0 t ha^{-1} vermiculite application rates.

3.6 Foliar analyses

Table 3: Total phosphorus, nitrogen calcium, potassium and magnesium removed by harvesting

	0 t ha^{-1}	1 t ha^{-1}	2 t ha^{-1}	5 t ha^{-1}	10 t ha^{-1}	LSD
N %	0.036^{a}	0.063^{b}	0.070^{c}	0.085^{d}	0.091^{e}	**0.001**
P %	0.264^{a}	0.637^{b}	0.678^{c}	0.905^{d}	0.969^{e}	**0.011**
K %	0.710^{b}	0.788^{a}	0.637^{c}	0.762^{c}	0.764^{d}	**0.008**
Ca %	1.016^{b}	1.057^{c}	0.979^{b}	0.917^{a}	0.881^{a}	**0.042**
Mg %	0.162^{c}	0.168^{d}	0.141^{a}	0.153^{b}	0.172^{d}	**0.005**

Values followed by the same superscript alphabetical letters are not significantly different at p<0.05 according to Tukey's HSD. (Data points are the mean of the three replicates). Total nutrient uptake was determined by adding nutrient content determined biweekly

The quantity of leaf N and P was significantly (P<0.05) different amongst vermiculite application rate (Table 3). Highest (0,091%) and lowest (0.036 %) leaf nitrogen content were recorded in the 10 and 0 t ha^{-1} vermiculite application rates respectively. Phosphorus was highest (0.969%) and lowest (0.264%) in the 10 and 0 t ha^{-1} respectively. Potassium was significantly (P <0.05) the same in 0 and 1 t ha^{-1} but varied significantly (P < 0.05) in the 2, 5 and 10 t ha^{-1} vermiculite application rates (Table 3). The quantities of leaf Ca descendent in the following order of 1 > 0 > 2 > 5 > 10 t ha^{-1} (Table 3). Leaf Ca content 0 and 2 t ha^{-1} vermiculite application rates was significantly (P< 0.05) the same. Leaf magnesium content varied significantly (P< 0.05) among the vermiculite application rates. Highest (0.172 %) in and lowest (0.141 %) leaf magnesium content were recorded in the 10 t ha^{-1} and 2 t ha^{-1} vermiculite application rates respectively (Table 3). Highest and lowest concentrations of N and P were obtained in the 10 t ha^{-1} and 0 t ha^{-1} vermiculite application rates respectively.

3.7 Soil characteristics in the experimental plots at the MUAST farm at 11 WAT

Table 4: Soil nutrients (N, P, K, Ca, and Mg) content and pH

Vermiculite application rate	N	P	K %	Ca	Mg	pH
0 t ha^{-1}	0.003^{a}	0.731	0.058^{a}	0.09^{a}	0.056^{a}	5.28^{a}
1 t ha^{-1}	0.003^{a}	0.737	0.077^{a}	0.161^{a}	0.064^{ab}	5.26^{a}
2 t ha^{-1}	0.004^{a}	0.778	0.084^{a}	0.136^{a}	0.071^{b}	5.40^{b}
5 t ha^{-1}	0.009^{b}	0.790	0.084^{a}	0.156^{a}	0.076^{b}	5.43^{b}
10 t ha^{-1}	0.013^{b}	0.757	0.146^{b}	0.291^{b}	0.076^{b}	5.79^{c}
LSD	**0.004**	**0.071**	**0.05**	**0.07**	**0.012**	**0.045**

Values followed by the same superscript alphabetical letters are not significantly different at p<0.05 according to Tukey's HSD. (Data points are the mean of the three replicates).

The soil parameters at 11 WAT were significantly (P<0.05) different from initial soil properties in respective plots (Tables 1 & 4). Nitrogen, K, Ca and Mg were significantly (P<0.05) different amongst vermiculite application rates. The 10 t ha^{-1} recorded the highest N, K, Ca, Mg and pH while the 0 t ha^{-1} vermiculite application rate had the lowest N, P, K, Ca and Mg (Table 4). Phosphorus content however did not differ significantly among vermiculite application rate. Nitrogen in the 0, 1 and 2 t ha^{-1} vermiculite application rates was significantly (P< 0.05) the same amongst the respective vermiculite application rates but varied in 5 and 10 t ha^{-1} vermiculite application rates. Potassium and calcium in the 10 t ha^{-1} vermiculite application rate differed significantly (P<0.05) from all the other vermiculite application rate which did not differ from each other (Table 4). Magnesium content in the 0 tha^{-1} vermiculite application rate differed significantly (P<0.05) from other application rates except the 1 t ha^{-1} which was not significantly different from the 2, 5 and 10 t ha^{-1} vermiculite application rate.

4. Discussion

There was a significant difference in the leaf length and width amongst vermiculite application rates with 10 t ha^{-1} and 0 t ha^{-1} of vermiculite recording largest and smallest leaves respectively. The leaf size is influenced by amount of nutrient uptake by the plants. The larger leaves in the 10 t ha^{-1} than 0 t ha^{-1} of vermiculite application rate could be due to enhanced nutrients uptake. The nutrient uptake efficiency is affected by the soil physical and chemical conditions like porosity, water holding capacity and pH. High quantities of the vermiculite could have positively modified the soil properties and this could explain the noted high *B. napus* productivity under the 10 t ha^{-1} vermiculite application rate. The vermiculite is a clay mineral which is layered so its application to soils improves porosity and water holding capacity. Soil water can move into the inter layer spaces inhibiting it from draining out of the rhizosphere thus improving the soil water holding capacity. This water would be available for plant uptake since it is a medium for nutrient transport in the soil. In the < 10 t ha^{-1} vermiculite application rates, water stress could have reduced nutrient uptake by crops due to decreased transpiration and impaired active nutrient absorption and transport mechanisms of the roots (Muchecheti et al., 2012). Although nutrient and water absorption are independent processes, they are intimately linked to each other (Clark et al., 2005).

Soil pH has a very strong influence on nutrient availability and solubility as it affects the form in which the element exist in soils. Acidic pH (< 7) is associated with nutrient fixation making then unavailable for plant uptake. The application of 10 t ha^{-1} vermiculite was seen to improve soil pH as at the end of the trial the pH had risen to 5.8 from 5.3. The raised pH could have enhanced the solubility and availability of nutrients for the rape growth and biomass accumulation. This was possible as most plant nutrients are readily available at pH range of 5.5- 6.5. Vermiculite at 10 t ha^{-1} raised the soil pH to 5.8 (Table 4) allowing th phosphorous to be in the available form of H_2PO^- which can be taken up by the plants (Klingler, 2015). No pH changes were observed in the 0 and 1 t ha^{-1} plot and these recorded smaller leaves than the 2 and 5 t ha^{-1} vermiculite application rate that recorded an increase in pH (5.4). Improved nutrient supply enhances electron transport increasing photosynthetic activity, hereby increasing plant growth (Figueroa et al., 2010; Musara & Chitamba, 2015). High nitrogen uptake increases leaf area development and increased overall crop assimilation. Photosynthesis was positively influenced primarily by increasing leaf area through increase in cell number (Kumari, 2011).

Nitrogen uptake increased with increasing vermiculite application rate and this corresponded well with the increase in leaf length and leaf width. A group researcher observed that an increase in the amount of N availed by the prunnings of leguminous tree species used increased the leaf area (Muchecheti et al., 2012). Phosphorus uptake was also increased with increasing vermiculite rates. The availability of soil P is greatly determined by the soil pH because it influences the reaction of P with the different ions and minerals (Fixen et al., 2010). Under acidic conditions, iron (Fe) and aluminium (Al) greatly affects the availability of P or while Ca fixes P at alkaline conditions. Improved P uptake has a positive effect on root growth. The most essential function of phosphorus in plants is in energy storage and transfer and its deficiency in *B. napus* restricts both top and root growth (Musara and Chitamba, 2015). Root biomass at the end of the experiment was in the order of 10 > 5 >2 > 1 >0 t ha^{-1}. The 10 t ha^{-1} vermiculite application rate had the highest root biomass meaning the crop was able to explore larger soil volume and thus, take up nutrients more efficiently. This improved nutrient uptake by plants especially phosphorus, which is immobile in the soil resulting in early vigour, high growth rate, and high nutrient use efficiency (Lilaibo et al., 2017). The higher leaf size attained following soil amendment with 10 t ha^{-1} followed by 5 t ha^{-1} also indicates vigorous growth which is desirable for high leaf yields and large sizes are quality attributes, determining the desirability of leaf vegetables on the market (Muchecheti et al., 2012).

The fresh (saleable leaves) and dry matter yield of rape were in the order of 10 > 5 > 2 > 1 > 0 t ha^{-1}. Fresh saleable yield was 23 t ha^{-1} and 5 t ha^{-1} in the 10 t ha^{-1} and 0 t ha^{-1} vermiculite application rates respectively. Application of 10 t ha^{-1} gave yield that was close to the potential yield of 24-40 t ha^{-1} of the rape variety used in this trial and this was noted as from 5 to 11 WAT (Ganya et al., 2018). The higher the rate of vermiculite the higher the fresh and dry matter yield that could have caused by increased nutrient uptake efficiency with vermiculite application. A group researcher credited increases in fresh yield with increasing N availability as N favored more vegetative growth producing plants with a higher total green leaf area per plant (Ganya et al., 2018). Increase in growth parameters also increases the synthesis of more plant metabolites thereby increasing fresh yield of leaves (Kumari, 2011).

Nitrogen levels affect the rate of leaf expansion and final size which ultimately contributes to the yield. High yields obtained in the 10 t ha^{-1} and 5 t ha^{-1} of vermiculite could be due to adequate water uptake which could have been promoted by improved water holding capacity due to vermiculite soil incorporation. A study carried out showed water retention in soil with an increase in vermiculite dosage (Lilaibo et al., 2017). Water availability influences the uptake of nutrients by the roots and in the plant (Clark et al., 2005). Application of vermiculite in soils also raises the soil CEC resulting to greater nutrient retention which are later made available for plant utilization (Kumar and Rawat, 2002). Soils with low nutrients retention capacity lose nutrient to horizons below the root zone through leaching. High application rates of the vermiculite could have caused retention of soil nutrients around the *B. napus* root zone hence high productivity (Fixen et al., 2010).

5. Conclusion

Application of vermiculite generally resulted to enhanced soil productivity by increasing the total leaf size, root dry biomass and the total fresh weight of the *B. napus*. The yield of *B.napus* was found to increase with an increase in the quantity of vermiculite applied. The vermiculite application rate of 5-10 t ha^{-1} resulted to highest *B. napus* productivity hence recommended for Lixisols. Nevertheless, further research is necessary to determine the maximum vermiculate application rate in the Lixisols.

Acknowledgements

Marondera University of Agricultural Sciences and Technology for research funds, land and laboratory space and Grassland Research Station for laboratory space and equipment.

References

Anderson, J.M, Ingram, I. 1996. International Union of Biological Sciences; International Society of Soil Science; UNESCO. Programmed on Man and the Biosphere.

Clark, L.J., Gowing, D.J., Lark, R.M., Leeds-Harrison, P.B., Miller, A.J., Wells, D.M., Whalley, W.R, Whitmore, A.P. 2005. Sensing the physical and nutritional status of the root environment in the field: a review of progress and opportunities. Journal of Agricultural Science, Cambridge, 143, Pp. 347–358.

Dhaliwal, J.K., Saroa, G.S., Dhaliwal, S.S., 2014. Effect of nutrient management techniques on phosphorus availability in basmati-wheat system. International Journal of Science, Environment and Technology, 3 (4), Pp. 1602 – 1608.

Figueroa, F.L., Israel, A., Neori, B., Martinez, E.J., Malta, A., Put, S., Inken, R., Marquardt, R., Abdala, R., Korbee, N., 2010. Effect of nutrient supply on photosynthesis and pigmentation to short-term stress (UV radiation) in *Gracilaria conferta* (Rhodophyta). Mar Pollut Bull, 60, Pp. 1768-1778.

Fixen, B., Paul, E., Tom, W., Bruulsema, W., Tom, L., Jensen, R.M., Scott Murrell, T., Steve, B., Phillips, Q. R, Mike Stewart. W. 2010. The fertility of North American soils, Better Crops, 94, Pp. 6-8.

Ganya, S., Svotwa, E., Katsaruware, R.D., 2018. Performance of Two Rape (*Brassicanapus*) Cultivars under Different Fertilizer Management Levels in the Smallholder Sector of Zimbabwe. International Journal of Agronomy. https://doi.org/10.1155/2018/2351204

Hindman, J.R., 2006. Vermiculite. In Industrial minerals and rocks, commodities, markets and uses,7th ed., eds. J. E., Kogel, N. C. Trivedi, M. J. Barker, and S. Krukowski. Society of Mining, Metallurgy, and Exploration. Trivedi, N.C, Barker, M.J. and Krukowski, S. (Eds.). Industrial Minerals and Rocks, Commodities, Markets and Uses. 7th edition. Society of Mining, Metallurgy and Exploration, Pp. 1015-1026.

IUSS Working Group WRB. 2015. World Reference Base for Soil Resources 2014, update 2015, International soil classification system for naming soils and creating legends for soil maps. World Soil

Resources Reports No. 106. FAO, Rome.

Jackson, J.E., Turner A.D, Matanda, M.L. 1997. Smallholder Horticulture in Zimbabwe, University of Zimbabwe Publications, Harare, Zimbabwe.

Jama, B., van Straaten, P., 2006. Potential of East African phosphate rock deposits in integrated nutrient management strategies. An Acad Bras Cienc, 78, Pp. 781-790.

Klingler, D. 2015. 21st Century Homestead. Organic food, 2, Pp. 90-103.

Kumar, M., Rawat, T.S., 2002. Effect of nitrogen and spacing on the quality and yield of cabbage (*Brassica olarecea* L. var. Capitata). Agricultural Science Digest., 22, 90-92.

Kumari, S., 2011.Yield response of wheat (*Triticum aestivum* L.) to early and late application of nitrogen: flag leaf development and senescence. Journal of Agricultural Science, 3, Pp. 170-182.

Kuntashula, E., Mafongoya, P.L., Sileshi, G., Lungu, S., 2004. Potential of biomass transfer technologies in sustainable vegetable production in the wetlands (DAMBOS) of eastern Zambia. Experimental Agriculture, 40, Pp. 37–51.

Li, L., Xiangming, Z., Yanlin, L., Chenchen, G., Lingchao, L., Xinghua, F., Wenhong T., 2017. Water absorption and water/fertilizer retention performance of vermiculite modified sulphoaluminate cementitious materials, Construction and Building Materials, 137, Pp. 224–233.

Loehr, B., Seif, A.A., Nyambo, B., 1998. Vegetable IPM in Africa: current status and future prospects with emphasis on eastern and southern Africa. Acta Horticulturae, 513, Pp. 99–104.

Losak, T., Hluseki, J., Kracmar, S., Varga, L., 2008. The effects of nitrogen and Sulphur fertilization on yield and quality of Kohlrabi (Brassica olarecea). Revista Brasileira de Ciˆencia do Solo, 32, Pp. 697–703.

Marwa, E.M.M., Meharg, A.A., Rice, C.M, Hillier, S., 2012. Characterisation of vermiculites from the Neoproterozoic Mozambique Belt of Tanzania for agricultural applications Third RUFORUM Biennial Meeting, 24 - 28, Entebbe, Uganda.

Mingochi, D.S., Luchen, S.W., 2000. Improved vegetable production practices for small holder farmers in Zambia. A reference manual for field extension workers. Small holder irrigation and water use programme Document No. 1. MAFF, FAO. Field.

Muchecheti, F.I., Madakadze, C., Soundy, P., 2012. Production of rape (*Brassica napus* L.) on soils amended with leguminous tree prunings: yield responses in relation to the chemical composition of the tree prunings. African Journal of Agricultural Research, 7, Pp. 3541–3549.

Musara, C., Chitamba, J., 2015. Growth rate and yield of *Brassica napus* in response to *Acacia angustissima* leaf biomass application. Journal of Animal & Plant Sciences, 25, Pp. 510–518.

Nyakudya, I.W., Jimu, L., Marashe, M., Katsvanga, C.A.T., 2010. Comparative growth and yield responses of rape (*Brassica napus* L.) to different soil fertility management amendments. Electronic Journal of Environmental. Agricultural and Food Chemistry, 9, Pp. 207–214.

Okalebo, J.R., Gathua, K.W, Woomer, P.L. 2002. Laboratory methods of soil and plant analysis: A working manual. 2nd Edition. SACRED Africa; Nairobi.

Pavlou, G.C., Ehaliotis, C.D, Kavvadias, V.A., 2007. Effect of organic and inorganic fertilizers applied during successive crop seasons on growth and nitrate accumulation in lettuce. Scientia Horticulturae, 111, Pp. 319- 325.

Rockstrom, J., Barron, J., Fox, P., 2003. Water productivity in rainfed agriculture: Challenges and opportunities for smallholder farmers in drought-prone tropical agroecosystems. Water Productivity in Agriculture: Limits and Opportunities for Improvement, 145–162.

Rockström, J., Falkenmark, M., 2000. Semiarid crop production from a hydrological perspective – gap between potential and actual yields. Critical Reviews of Plant Science, 19, Pp. 319–346.

Thompson, W.H. (ed.). 2001. Test Methods for the Examination of Composting and Compost. The United States Composting Council Research and Education Foundation. The United States Department of Agriculture.

van Straaten, P. 2002. Rocks for Crops: Agrominerals of sub-Saharan Africa. ICRAF, Nairobi, Kenya, Pp. 338.