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Effect of Different Application Rates of Organic Fertilizer on Growth, Development and Yield of Rape (*Brassica napus* L.)

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ABSTRACT:A field experiment was carried out at Botswana College of Agriculture content farm, Sebele about 10 km from the center of Gaborone city to evaluate the effect of different application rates of organic fertilizer on growth, development and yield of rape from November 2014 to March 2015. The experiment was laid out in a complete randomized block design (RCBD) with four different application rates of organic fertilizer being 0, 5, 7.5 and 10 kg m^{-2} each replicated three times. Plant parameters measured were; plant height, leaf number, leaf area and leaf fresh weight. For plant height and number of leaves a non-significant treatment effect was observed for the first 7 weeks and 8 weeks respectively whereas, plants provided with 10 kg m^{-2} of organic fertilizer significantly ($p<0.05$) increased plant height and number of leaves in the last 4 weeks and 3 weeks respectively. Similarly, the highest application rate of 10 kg m^{-2}significantly ($p<0.05$) increased the leaf area and fresh weight for the entire period of study as compared to the rest. In general, soil amended with the highest application rate of organic fertilizer outperformed other treatments and produced a relatively higher market yield of rape. Therefore, the use of organic fertilizer is recommended to farmers because its constituents are readily available locally.

KEYWORDS:Botswana, organic fertilizer, leafy vegetable, rape and fertilizer application rate

I. INTRODUCTION

Leafy vegetables are highly important in maintaining health and preventing diseases including malnutrition deficiencies because they are rich in vitamins, minerals and fiber [1]. Rape (*Brassica napus* L.) has been an important crop for many decades. It is grown mainly for oil in northern Europe and North America and for its edible leaves in Africa and Asia [2, 3]. It is a major leafy vegetable crop grown during times of the year when temperatures are low [4, 5]. In southern Africa, the crop is grown under irrigation [6]. Compared to cereals, rape does well in fertile soils and yields are frequently limited by nitrogen (N) deficiency [3, 7]. Rape requires two times more N compared to most cereal crops [8, 9]. Yields had been reported to increase with higher rate of N input [10, 11, 12].

Most agricultural soils in southern Africa have poor physical conditions due to low organic matter content. Nitrogen, Phosphorus (P) and Potassium (K) are major essential elements required by plants for their physiological mechanisms of growth. The productivity of many African soils is normally limited by N and P deficiency which is a major constraint to small holder vegetable producers in sub-Sahara Africa. Botswana soils are poor sandy soils that lack nutrients and require organic manures and/or chemical fertilizers to successfully produce vegetable crops like rape [1]. Continuous cropping without inputs of organic or inorganic fertilizer is common in Botswana and elsewhere. Nutrient

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losses through harvest, soil erosion and leaching also contribute to low soil fertility [13, 14, 15]. Commercial vegetable farmers have resources which enable them to use inorganic fertilizers to improve soil fertility. In contrast, the use of inorganic fertilizers by smallholder vegetable producers in Botswana and other developing countries is very low [16] and is limited by their prohibitive costs and the pollution they cause to the environment [17, 18].

Some smallholder vegetable producers rely on the use of organic fertilizers such as farmyard manure, sewage sludge, crop residues, industrial waste and compost to provide nutrients to their crops [19, 20, 21]. Organic fertilizers play a direct role in plant growth as sources of all required macro and micronutrients in available forms released during mineralization [22]. Applying organic fertilizers to soils increases the organic matter content [23] that in turn improves the soil physical properties [24, 25, 26] and chemical characteristics [26, 27, 28, 29, 30]. In addition, they provide essential nutrients [25, 28, 31] that increase crop yields [32, 33]. Organic fertilizers provide nutrients in a way similar to their inorganic fertilizers counterparts [34, 35, 36, 37, 38, 39, 40]. However, they do not pollute the environment [32] and have also shown to supress plant pest populations [20] and control some crop diseases [41, 42]. There is little information on the use of organic fertilizers in the production of leafy vegetables in Botswana. The present study was therefore carried out to investigate the effect of different application rates of organic fertilizer on growth, development and yield of rape in Botswana.

II. MATERIALS AND METHODS

Description of study site:

The field experimentwas conducted from October 2014 to February 2015 at Botswana College of Agriculture (BCA), Sebele. Sebele lies about 10 km from the centre of Gaborone City on latitude 24˚34'S and longitude 25˚57'E elevated at 994 m above sea level. The climate of Sebele is semi-arid [43]. Soils are predominantly sandy loams (76% sand, 10% silt and 14% clay) with low water holding capacity (1.2 meq/100 g) and pH of 6.3 [44, 45, 46].

Experimental design, treatments and crop establishment:

The experiment followed a complete randomized block design (RCBD) with four treatments, each replicated three times. The four treatments were three different application rates of organic fertilizer being 5.0, 7.5 and 10.0 kg m^{-2} designated T_2, T_3 and T_4 respectively, and the control (0 kg m^{-2}) designated T_1. The Organic Fertilizer [47] instruction manual used recommends a general combined basal and top dressing application rate of 5 kg m^{-2} across the vegetables and plants. The site was cleared mechanically, ploughed and disked before seedbeds were marked and demarcated. There were twelve seedbeds each measuring 1.5 × 2.7 m and separated by a buffer of 0.5 m. Seedbeds were leveled using hand tools to provide a medium fine tilth for the growth of the rape crop. The organic fertilizer was then applied to seedbeds and mixed with soil per treatment requirement. English giant one of the most commonly grown variety of rape in Botswana was used. Seeds were sown on seedling trays on the 26 October 2014 and kept in net shade for three weeks. On the 16 November 2014 vigorous seedlings were transplanted into their well-prepared seedbeds. The inter row spacing of 50 cm and intra row spacing of 30 cmwas used [48].

Organic fertilizer composition and production process:

According to the Organic Fertilizer [47] instruction manual, a mixture of animal droppings, food waste, bark, wood flour, maize husk and grass was used as raw material. Soil improving agent (microbes) mixed with water for about 20 minutes is sprayed on prepared raw material. The pile is turned once every two weeks and this is continued for 5 months to activate the bacteria. The temperature and moisture content is maintained at 40−75°C and 50−60% respectively throughout the process. After 5 months, the product is treated at high temperature to kill all the bacteria and weeds. The product is then packaged in bags with plastic inner lining to preserve moisture.

Crop management: Seedbeds were regularly watered to keep the soil moist and weeds were manually removed by hand whenever they appeared. An insecticide, chlorpyrifos (chemical formula; $C_9H_{11}Cl_3NO_3PS$) was applied twice on the 21-12-2014 and 13-02-2015 to control cutworms (*Agrostis* spp) and American bollworm *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae).

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Plant growth, development and yield parameters: Plant height, leaf number and area were measured weekly whereas fresh weight and yield were determined at harvest on ten randomly selected plants from each seedbed. Plant height was measured using a meter ruler from the base to the tip of apical leaf. The number of leaves was measured quantitatively by counting. For leaf area a non-destructive quantitative method was used, five largest leaves were traced on a grid paper with squares each measuring 1 cm by 1 cm whilst still attached to the crop [49]. The mean was used in each seedbed. Fresh leaf weight was measured using a bench top electronic balance model PGW 4502e [50] in turn this was used to determine the marketable yield. Five fully developed leaves were randomly sampled from each seedbed and means were presented.

Statistical analysis: Raw data was subjected to analysis of variance (ANOVA) using the STATISTIX-8 program. Where a significant F-test was observed and means comparison tests were carried out using Least Significant Difference (LSD) at $p \leq 0.05$ to separate treatment means.

III. RESULTS AND DISCUSSIONS

Plant height

There were no significant differences statistical in plant height among treatments from weeks 1 to 4 (Table 1), but application rate of 10 kg m^{-2} had slightly taller plants than their counterparts across the treatments. From weeks 5 to 11 plants provided with 10 kg m^{-2} of organic fertilizer were significantly ($p<0.05$) taller than the control plants. However, the plants did not differ statistical with the ones provided with 5 and 7.5 kg m^{-2} of organic fertilizer (Table 1). The increase in height of plants amended with 5, 7.5 and 10 kg m^{-2} of organic fertilizer is probably due to release of nutrients which promoted vigorous plant growth through efficient photosynthesis [51, 52, 53, 54]. Plant height is an important component that helps to determine plant growth [55]. Findings of the present study are in agreement with studies conducted on other crops which reported that organic fertilizers (e.g. farm yard manure) enhance plant growth [56, 57, 58, 59, 60]. The positive effect of organic fertilizer on plant height in this study could be due to improved soil fertility [52, 53,61]. Organic fertilizer contain large amounts of nutrients and positively affect plant growth and yield by improving the chemical, physical and biological properties of soil [62, 63] which might have happened in the present study. It is also possible that the application of organic fertilizer activated the soil microbial biomass, hence improved soil fertility [64]. Since organic fertilizer constitutes a slow release source of plant nutrients [65, 66, 67] this could have affected the growth of the plants in the first four weeks hence the non-significant treatment effect.

Table 1.Mean crop height (cm) of rape as influenced by organic fertilizer.

Treatment	Crop age (weeks after developing true leaves)										
	1	2	3	4	5	6	7	8	9	10	11
T_1	2.83	3.93	6.05	8.00	9.61^{b}	9.16^{b}	5.22^{b}	5.97^{b}	7.40^{b}	10.80^{b}	14.80^{b}
T_2	2.58	4.07	6.96	9.00	9.93^{ab}	10.08^{ab}	6.93^{ab}	10.53^{ab}	13.44^{a}	16.57^{a}	20.31^{a}
T_3	2.87	4.52	7.95	10.03	12.05^{ab}	11.70^{ab}	8.94^{ab}	12.77^{a}	15.08^{a}	18.49^{a}	21.75^{a}
T_4	3.00	4.95	8.10	10.06	13.33^{a}	14.46^{a}	9.75^{a}	13.20^{a}	15.95^{a}	18.71^{a}	22.13^{a}
Sig.	ns	ns	ns	ns	*	*	*	*	*	*	*
LSD 0.05	ns	1.32	2.39	2.42	3.67	4.40	4.12	5.12	5.09	5.20	5.78
CV (%)	9.39	15.11	16.49	12.98	16.38	19.39	26.72	24.15	19.63	16.13	14.76

* Significant at $p<0.05$, ns non-significant at $p>0.05$. Means separated by Least Significance Difference (LSD) Test at $p<0.05$. Means within columns followed by the same letters are not significantly different. Where T_1, T_2, T_3 and T_4 are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m^{-2} respectively and weeks 1−11 are dates from 05-12-2014 to 20-02 2015 respectively.

Leaf number

A non-significant treatment effect was revealed from weeks 1 to 8, however plants amended with 10 kg m^{-2} had superior absolute numbers which decreased with each decrease in level of organic fertilizer applied (Table 2). The highest number of plant leaves in the present study was recorded in plants amended with 10 kg m^{-2} of organic fertilizer which was significantly ($p<0.05$) higher than the control but not statistical different with plants amended with 5 and 7.5 kg m^{-2} from weeks 9 to 11 (Table 2). Masarirambi *et al*. [68] recorded the highest number of leaves in lettuce plants amended with 60 t ha^{-1} chicken manure compared to the control. Organic fertilizers are crucial in enhancing soil

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fertility[69, 70]. Increased soil fertility following organic fertilizer application might have increased the number of leaves as observed in other crops [71, 72, 73]. The application of organic fertilizer to the soil at 5, 7.5 and 10 kg m^{-2} may have improved soil fertility and soil structure, increased soil organic matter and enhanced microbial activity [74, 75, 76]. The non-significant treatment effect observed from weeks 1 to 8 could possibly be explained by the fact that organic fertilizers are slow release fertilizers. Organic fertilizers releases nutrients more slowly but store them longer in the soil [77], thereby ensure a long residual effect [78]. The nutrients from organic fertilizer support rapid root development [79] which might have enhanced leaf growth towards the end of the study.

Table 2. Mean number of leaves of rape as influenced by organic fertilizer.

Treatment	Crop age (weeks after developing true leaves)										
	1	2	3	4	5	6	7	8	9	10	11
T_1	4.10	4.93	7.27	10.87	13.77	12.37	8.87	9.58	11.24^{b}	13.85^{b}	17.06^{b}
T_2	5.03	5.33	8.30	13.57	15.93	14.30	10.47	12.76	14.91^{ab}	18.65^{ab}	21.63^{b}
T_3	5.43	6.43	9.30	14.57	18.77	19.23	12.87	15.87	17.86^{a}	21.73^{a}	26.68^{a}
T_4	5.10	7.59	11.43	17.93	29.97	20.30	14.53	18.00	20.61^{a}	24.70^{a}	28.43^{a}
Sig.	ns	ns	ns	ns	ns	ns	ns	ns	*	*	*
LSD 0.05	ns	2.00	4.16	7.86	6.27	9.67	ns	6.01	6.91	6.66	6.69
CV (%)	13.57	16.31	22.97	27.66	18.08	29.34	19.87	21.40	19.85	16.89	14.28

** Highly significant at p<0.01, * significant at p<0.05, ns non-significant at p>0.05. Means separated by Least Significance Difference (LSD) Test at p< 0.05. Means within columns followed by the same letters are not significantly different. Where T_1, T_2, T_3 and T_4 are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m^{-2} respectively and weeks 1−11 are dates from 05-12-2014 to 20-02 2015 respectively.

Leaf area

In Table 3 the effect of different application rates of organic fertilizer on leaf area was significant at p<0.05. Leaf area differed significantly among the treatments from weeks 1 to 11 with plants amended with 10 kg m^{-2} of organic fertilizer significantly increasing the leaf area as compared to the rest (Table 3). This is in agreement with Bharadwaj [80] who reported that organic fertilizer increased the leaf area of two wheat varieties compared to the control. Nitrogen (N) is one of the main plant nutrients affecting plant growth and yield [81] and leaf area increase with increase in N level [82]. Increased leaf area in soil amended with organic fertilizer could probably be attributed to N availability which promoted leaf area during vegetative development and also helped to maintain functional leaf area during the growth period [83].

Table 3.Effect of organic fertilizer on leaf area (cm^2) of rape.

Treatment	Crop age (weeks after developing true leaves)										
	1	2	3	4	5	6	7	8	9	10	11
T_1	5.82^{d}	7.66^{d}	15.73^{b}	14.39^{c}	26.87^{c}	34.12^{c}	44.06^{c}	50.95^{c}	60.12^{c}	87.59^{c}	96.12^{b}
T_2	9.95^{c}	13.26^{c}	18.86^{b}	26.34^{b}	35.39^{bc}	45.82^{b}	52.85^{b}	59.43^{b}	66.26^{b}	93.80^{bc}	99.53^{b}
T_3	13.42^{b}	20.08^{b}	31.21^{a}	37.77^{a}	43.51^{ab}	49.99^{b}	55.83^{b}	63.88^{b}	69.33^{b}	99.48^{ab}	103.81^{b}
T_4	22.62^{a}	26.25^{a}	32.22^{a}	40.28^{a}	49.39^{a}	59.78^{a}	67.96^{a}	75.80^{a}	85.35^{a}	106.56^{a}	113.65^{a}
Sig.	**	**	**	**	*	**	**	**	**	*	*
LSD 0.05	2.99	4.71	5.43	6.26	9.81	8.01	8.47	4.76	4.49	9.16	7.97
CV (%)	11.57	14.02	11.10	10.12	12.66	3.46	7.68	3.81	3.20	4.74	3.86

** Highly significant at p<0.01, * significant at p<0.05. Means separated by Least Significance Difference (LSD) Test at p<0.05. Means within columns followed by the same letters are not significantly different. Where T_1, T_2, T_3 and T_4 are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m^{-2} respectively and weeks 1−11 are dates from 05-12-2014 to 20-02 2015 respectively.

Yield performance

Overall fresh weight of rape as affected by application of organic fertilizer showed that plants amended with 10 kg m^{-2} of organic fertilizer significantly (p<0.05) increased in weight as compared to the rest (Table 4). This implies that the higher the application rate of organic fertilizer the higher the yield of rape. The higher increase in yield parameters such as fresh weight, plant height, leaf number and leaf area of rape could be attributed to the nutrient contents of the organic fertilizer used which encouraged better plant growth. The findings of the present study are supported by Adebayo and

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Akoun [84] and Moyin-Jesu [85] who reported that organic fertilizers supported crop performance and increased crop yield. Xu *et al.* [86] revealed that the yield and quality of leafy vegetables grown with organic fertilizers grew better and resulted in a higher total yield than those grown with synthetic fertilizers only. The increase in the yield under soil amended with organic fertilizers was also observed in cubergine and carrots [87], as well as on potatoes [88]. The pigment content has also been identified as an important index in determining the quality of rape crop [89]. In the present study plants grown with organic fertilizer amended soil were greener than those of the control. The plants in the control seedbeds had lighter green leaves and most of the leaves were purple which probably indicated insufficient supply of minerals in the soil. Application of organic fertilizers probably increased nitrogen in the soil which positively affected leaf fresh weight and quality of the leaves because nitrogen stimulates plant vegetative growth and increases leaf area; as a result increment in the leaf area increases the rate of plant photosynthesis and thus higher leaf quality and leaf weight. This is in line with the findings of different studies elsewhere on spinach [89, 90].

Table 4.Effect of organic fertilizer on leaf fresh weight and yield (4.05 m^2) of rape.

Treatment	Mean leaf fresh weight (g)	Mean bundle weight (g)	Mean harvest 1		Mean harvest 2		Mean harvest 3		Mean total harvest	
			No of bundles	Fresh weight (g)	No of bundles	Fresh weight (g)	No of bundles	Fresh weight (g)	No of bundles	Fresh weight (g)
T_1	9.94b	248.50	5	1242.50c	6	1491.00c	6	1491.00c	17	4225.00c
T_2	13.74b	343.50	5	1717.50b	6	2061.00bc	7	2404.50bc	18	6183.00bc
T_3	15.08ab	377.00	5	1885.00b	7	2639.00b	9	3393.00b	21	7918.00b
T_4	20.18a	504.50	8	4036.00a	15	7567.50a	18	9081.00a	38	19171.00a
Sig.	*	-	-	**	-	**	-	**	-	**
LSD 0.05	6.32	-	-	267.47	-	1013.40	-	1012.20	-	2886.00
CV (%)	21.46	-	-	6.03	-	14.75	-	12.38	-	15.41

** Highly significant at $p<0.01$, * significant at $p<0.05$, (-) not analyzed. Means separated by Least Significance Difference (LSD) Test at $p< 0.05$. Where a bundle was comprised of 25 leaves. T_1, T_2, T_3 and T_4 are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m^{-2} respectively and harvest 1, 2 and 3 are dates as follows: 19-12-2014, 16-01-2015 and 20-02-2015 respectively.

Soils amended with 10 kg m^{-2} of organic fertilizer produced a relatively higher marketable yield of rape and decreased with decrease in organic fertilizer applied across the rounds of harvest (Table 4). The harvested bundles of rape also increased with rounds of harvests. Macro plant nutrients in organic fertilizers (nitrogen, phosphorus and potassium) are released slowly over a long time, they become available to plants roots at a slower rate therefore the nutrients are less likely to leach out of the soil.Only a fraction of these nutrients

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is usable by the crop the first year with more becoming available in subsequent years [65]. Otherwise the increase in yield over time could be attributed to growth of plants, since larger plants produce more. Studies by Rao [91] indicated that the soil amended with organic fertilizers tends to release relatively large amounts of nitrogen into the soil to boost yield.

IV. CONCLUSION AND RECOMMENDATION

The findings showed that application of organic fertilizer greatly enhanced growth, development and yield performance of rape in terms of plant height, leaf number, leaf area and fresh weight. The use of organic fertilizer is therefore recommended to farmers because its constituents are readily available locally.

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