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Response of parsley (*Petroselinum crispum*) to different application rates of organic fertilizer

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Abstract

Growth and development response of parsley (*Petroselinum crispum*) to four application rates of organic fertilizers (treatments) was investigated in a field experiment at the Botswana University of Agriculture and Natural Resources (formerly Botswana College of Agriculture) from November 2014 to March 2015. The experiment was laid out in a complete randomised block design (RCBD) with each of the four treatments; 0, 5, 7.5 and 10 kg m^{-2} replicated three times. Data on growth and development parameters *viz.*, plant height, number of leaves, leaf area and plant canopy (spread) was recorded at weekly intervals whereas, stem diameter (thickness), and shoots fresh and dry weights were recorded at the termination of the experiment. In general, significant statistical differences ($P<0.05$) were revealed for plant height, leaf area, number of leaves, stem thickness, canopy diameter and shoots fresh and dry weights. Application rates of organic fertilizers of 10 kg m^{-2} significantly enhanced the performance of the growth and development parameters of parsley with highest application rate revealing numerical superiority. Based on the findings, highest application rate of organic fertilizer is recommended to small scale farmers because its constituents are readily available and are in abundance locally.

Key words: Organic fertilizer, parsley, growth and development parameters

Introduction

Petroselinum crispum (Mill) popularly known as parsley belongs to the family Apiaceae (Mirdad, 2011; Hussain *et al.,* 2015; Borges *et al.,* 2016). It is native to Europe and the Mediterranean region (Hochmuth *et al.,* 1999; Osman and Abd El-Wahab, 2009; Sayilikan *et al.,* 2011). Parsely is an evergreen biennial or short-lived perennial herb (Midrad, 2011) growing to a height of 15-30 cm (Vora *et al.,* 2009). It has strong aromatic compound leaves and inflorescences in the shape of terminal umbels over the leaves, with small yellow-greenish flowers (Borges *et al.,* 2016).

Parsley is widely cultivated on a commercial scale for its strong aromatic edible leaves, fleshy roots (Rumpel and Kaniszewski, 1994; Kmiecik and Lisiewska, 1999) and essential oils (Mylavarapu and Zinati, 2009). The vitamin C rich leaves are used fresh, dried or frozen as a garnish or spice to add flavour to food (Mirdad, 2011). Parsley is a good source of carotene (pro-vitamin A), vitamins B1, B2 and C as well as iron and other minerals (Osman and Abd El-Wahab, 2009). The plant has many medicinal uses that include antispasmodic carminative, diuretic; since it contains essential oil of 0.3% in leaf and 2-7% in the fruit (Midrad, 2011). The oil contains pinene, myrcene, phellandrene, cymene, methatriene, elemene, myristicin and apiole (Petropoulos *et al.,* 2008) and is used in the food industry or as a fragrance in manufacturing perfumes (Diaz-Maroto *et al.,* 2002). In Turkey, parsley is used as medicinal herb to treat diabetic patients (Tunali *et al.,* 1999).

Poor soil fertility is one of the most important biophysical constraints to increasing agricultural productivity in sub-Saharan Africa (Ajayi *et al.,* 2007). The use of inorganic fertilizers is not an alternative for smallholder farmers due to costs associated with their purchase. Organic manures have been used as an alternative resilient way of improving soil fertility (Peyvast *et al.,* 2008a). Organic manures enhances soil organic matter (Debosz *et al.,* 2002; Lal, 2009), improve the soil physical, chemical and biological properties (Eghball and Power, 1999; Santos and Bettiol 2003; Saison *et al.,* 2006) and increase the vegetative growth and yield of many crops (Kurt and Emir, 2004; Gelsomino and Casso, 2006; Mojeremane *et al.,* 2016).

The commonly used organic fertilizers include composted animal manure, compost, household wastes, sewage sludge, crop residues; industrial and municipal solid waste (Kochakinezhad *et al.,* 2012; Omidire, 2015). Prior studies demonstrated that they provide nutrients and contribute to the quality of soil by improving the soil structure, chemistry, and biological activity (Krogman *et al.,* 1997; Benton and Wester, 1998; Sarhan *et al.,* 2011; Yanar *et al.,* 2011; Mbatha *et al.,* 2014). Organic fertilizers contain large quantities of macronutrients (Elliot and Dempsey, 1991; Saison *et al.,* 2006) and contribute organic matter to the soil (Sarkar *et al.*, 2003; Peyvast *et al.,* 2007; 2008b; Olfati *et al.,* 2009). Their effect on plants is similar to inorganic fertilizers (Bulluck and Ristaino 2002; Martini *et al.,* 2004; Heeb *et al.*, 2006). However, they release nutrients gradually (Sarkar *et al.*, 2003; Bi *et al.,* 2010) and stay longer in the soil (Mojeremane *et al.,* 2016). They do not pollute the environment (El sayed *et al.,* 2002) which is beneficial to subsequent crops (Ghosh *et al.,* 2004). In addition, they suppress plant pest populations (Yanar *et al.,* 2011), control some plant diseases (DeCeuster and Hoitink, 1999; Viana *et al.,* 2000), prevent soil degradation and reduce water pollution (Swift, 2001).

Parsley can grow and adapt to harsh environments including those with poor soils (Hussain *et al.,* 2015) and has spread from its place of origin and naturalized world-wide over the years. It is a new emerging leafy vegetable crop which has found a market in urban areas in Botswana. Despite its importance, there is no information on how its development is affected by organic fertilizers. The objective of this study was, therefore, to evaluate effects of organic fertilizer as a soil supplement on growth and development of parsley.

Materials and methods

Description of study site: The field experiment was conducted from November 2014 to March 2015 at the Botswana University of Agriculture and Natural Resources (formerly Botswana College of Agriculture), Sebele. Sebele lies about 10 km from the centre of Gaborone the Capital City of Botswana, on latitude 24°34'S and longitude 25°57'E elevated at 994 m above sea level. The climate of Sebele is semi-arid (Legwaila *et al.,* 2012). Soils at the study site are predominantly sandy loams with a low water holding capacity and pH of 6.3 (Legwaila *et al.,* 2014; Madisa *et al.,* 2015).

Experimental design, treatments, crop establishment and management: The experiment was laid out in a randomized complete block design (RCBD) with four treatments, each replicated three times. The four treatments were, control and three application rates of organic fertilizer (5.0, 7.5 and 10.0 kg m^{-2}) designated T_1, T_2, T_3 and T_4, respectively. According to the Organic Fertilizer Instruction Manual (2014) a general combined basal and top dressing application rate of 5 kg m^{-2} is recommended across vegetables and plants. The organic fertilizer is made from a mixture of animal droppings, food waste, bark, wood flour, maize husk and grass. Soil improving agent (microbes) mixed with water for about 20 minutes is sprayed on the prepared raw material. The pile is turned once every two weeks 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 was subjected to high temperature in order to kill all the bacteria and weeds.

The experimental site was cleared mechanically, ploughed and disked and twelve plots measuring 1.5 × 2.0 m, separated by a 0.5 m buffer were demarcated and developed. Plots were levelled using hand tools to provide a medium fine tilth suitable for the growth of the parsley crop after which the organic fertilizer was applied and mixed with soil as per treatment requirement. Prior to sowing parsley seeds were soaked in cold water overnight. Three seeds were then sown in a hole at a depth twice their diameter using an inter row spacing of 30 cm and intra row spacing of 30 cm on 8th December 2014. Seedlings were later thinned out to leave only one seedling per hole to grow. Plots were watered regularly to keep the soil constantly moist. Weeds were removed manually whenever they appeared.

Determination of plant growth and development parameters: Ten plants were randomly selected and tagged from each plot for data collection throughout the study. Plant height and plant canopy diameter were measured weekly from week 1 to 9 after development of true leaves (four weeks after sowing) using a meter ruler from the base to the apical bud and distance across the plant canopy through the stem respectively. Stem diameter was measured at the base of tagged plants using a calibrated vernier caliper at the end of the study. The number of leaves per plant was quantitatively measured for the same period by counting. Leaf area of mature leaves was measured using a graph paper. All tagged plants were harvested at the end of the experiment to determine both fresh and dry leaf weights using a bench top electronic balance model PGW 4502e. Leaves were dried at 60°C in an oven until constant weight was achieved.

Data analysis: Data was subjected to analysis of variance (ANOVA) using Analytical Software (2003). F-test was used and means comparison tests carried out using Least Significant Difference (LSD) at $P \leq 0.05$.

Results and discussion

Plant height: Plant height was measured after development of true leaves (four weeks after sowing) (Table 1). The results in week 1 show that T_4 plants were significantly (P<0.01) taller compared to other treatments. The height of plants grown in T_2 was statistically at par with T_3, a trend which was observed for most part of the study. The control plants (T_1) were significantly (P<0.01) shorter than their counterparts grown in soil amended with different rates of organic fertilizer for the entire period of the study. A general increase in plant height was observed with increase in organic fertilizer application rate. Many studies conducted elsewhere using different plants have reported similar results. Ondieki *et al.* (2011) observed that plant height in African nightshades increased with an increase in the compost manure application rate. Agbo *et al.* (2012) observed significantly taller *Solanum scabrum* in soils amended with 30 t ha^{-1} of manure compared to the control and 10 t ha^{-1}. Mojeremane *et al.* (2016) recorded the tallest tomato plants grown in plots amended with 7.5 and 10.0 kg m^{-2} of organic fertilizer compared to the control

Table 1. Effect of organic fertilizer on plant height (cm) and leaf area (cm^2)

Treatments	Plant height (cm)									Leaf area
	Weeks after development of true leaves									
	1	2	3	4	5	6	7	8	9	9
T_1	4.30^c	5.77^c	6.77^c	7.50^c	9.20^b	10.57^b	11.63^b	12.87^b	13.90^c	11.33^d
T_2	6.53^b	8.10^b	8.97^{bc}	10.10^{bc}	11.57^b	12.43^b	13.27^b	14.77^b	15.53^{bc}	12.53^c
T_3	7.50^{ab}	8.67^b	9.83^b	11.40^b	12.57^b	13.33^b	14.57^b	16.47^b	18.37^b	13.87^b
T_4	8.93^a	11.10^a	13.23^a	15.50^a	16.70^a	18.10^a	19.93^a	22.47^a	23.60^a	16.10^a
Significance	**	**	**	**	*	*	*	**	**	**
LSD (P=0.05)	1.47	2.10	2.42	3.38	3.66	4.14	4.37	3.67	3.38	0.41
CV (%)	10.80	12.48	12.49	15.23	14.63	15.21	14.74	11.05	9.48	1.53

**Highly significant at P <0.01, *significant at P <0.05. Means separated by Least Significance Difference (LSD) Test at $P \leq 0.05$, means within columns followed by the same letter 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 1-9 are dates from 05-01-2015 to 02-03-2015 respectively.

and 5 kg m^{-2} application rate. Organic fertilizer improves the soil chemical, physical and biological properties (Debosz *et al.,* 2002; Zhang *et al.,* 2012) which probably occurred in the present study. Increased plant growth in organic fertiliser amended soils has been attributed to readily available nutrients that are easily absorbed by plant roots (Ajari *et al.,* 2003). The residual effects of organic fertilizers have also been reported to benefit succeeding crops (Sharma and Mittra, 1991; Ghosh *et al.,* 2004).

Plant leaf area: The effect of organic fertilizer on plant leaf area was highly significant. Maximum and minimum leaf area was recorded in plants grown in T_4 and T_1, respectively (Table 1). Leaf area increased with application rate. The increase in leaf area with increase in organic fertilizer application rate observed in this study is consistent with Mojeremane *et al.* (2015) who found out that the leaf area of rape amended with 10.0 kg m^{-2} of organic fertilizer was significantly higher compared to 5.0 and 7.5 kg m^{-2} and the control treatment. The increase in leaf area of plants grown in the organic fertilizer amended soils compared to the control could probably be attributed to N availability which enhanced leaf development. According to Valentinuz and Tollennar (2006), leaf area increases with increase in N, which probably occurred in the present study.

Number of leaves: Number of leaves differed significantly among treatments throughout the study (Table 2). Different organic fertilizers rates (T_2-T_4) produced plants with more leaves than the control (T_1) treatment. The maximum and minimum number of leaves was recorded in T_4 and T_1. There was no difference in the number of leaves between T_2 and T_3 for most part of the study. A similar trend was observed between T_1 and T_2. At termination of the study, maximum mean number of leaves was recorded in T_4 (405.00) followed by T_3 (288.67), T_2 (227.67) and lastly T_1 (217.00). Overall, the number of leaves increased with increasing application rate of organic fertilizer. Earlier studies conducted elsewhere on other plant species have also reported similar results (Hoque *et al.*, 2004; Oad *et al.,* 2004; Xu *et al.*, 2005; Hasanuzzaman *et al.,* 2008; Abolusoro and Abolusoro, 2012; Masarirambi *et al.,* 2012; Agu *et al.,* 2016; Mojeremane *et al.,* 2016). It is possible that macro and micro nutrients released from the organic fertilizer stimulates leaf production (Edu *et al.,* 2015).

Stem thickness: Mean stem thickness measured at the end of study (Table 3) show that parsley plants grown in soils amended with different rates of organic fertilizer produced plants with significantly (P<0.01) thicker stems than the control. Stem thickness did not differ statistically among the different application rates of organic fertilizer. Overall, stem thickness increased slightly with increasing organic fertilizer application rate. This is in agreement with Mojeremane *et al.* (2016) who reported slightly thicker tomato plants in plots amended with 10 kg m^{-2} followed by 7.5 kg m^{-2} and 5 kg m^{-2}, respectively. This result is also consistent with Hou *et al.* (2013) who recorded thicker stems in tomato plants grown in different rates of organic fertilizer compared to the control. The application of organic fertilizer to soil is a very effective method of supplying plants nutrients without polluting the environment (El-Sayed *et al.,*

Table 2. Effect of organic fertilizer on plant leaf number

Treatments	Leaf number (weeks after development of true leaves)								
	1	2	3	4	5	6	7	8	9
T_1	8.67^c	15.33^b	21.33^c	37.00^c	60.67^b	84.33^c	113.00^c	134.33^c	217.00^c
T_2	12.33^b	18.33^b	27.33^{bc}	43.67^{bc}	84.33^b	112.00^c	165.33^b	199.67^b	227.67^c
T_3	10.67^{bc}	20.00^b	34.67^b	74.33^{ab}	115.33^b	179.33^b	205.67^b	240.33^b	288.67^b
T_4	15.00^a	30.00^a	51.33^a	97.33^a	195.00^a	285.00^a	304.00^a	359.33^a	405.00^a
Significance	**	**	**	*	**	**	**	**	**
LSD (P=0.05)	2.13	5.17	11.95	34.84	58.58	51.06	42.48	50.78	50.13
CV (%)	9.15	12.37	17.76	27.65	25.76	15.47	10.79	10.89	8.82

**Highly significant at P <0.01 and *significant at P <0.05. Means separated by Least Significance Difference (LSD) Test at $P \leq 0.05$, means within columns followed by the same letter 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 1-9 are dates from 05-01-2015 to 02-03-2015.

Table 3. Effect of organic fertilizer on plant canopy and stem thickness (cm)

Treatments	Canopy diameter (cm) Weeks after development of true leaves									Stem thickness
	1	2	3	4	5	6	7	8	9	9
T_1	5.37^c	7.23^c	8.73^c	10.53^c	12.70^c	14.77^c	17.07^c	20.10^c	23.30^c	1.80^b
T_2	7.07^{bc}	8.50^{bc}	10.07^{bc}	12.90^{bc}	17.00^{bc}	20.90^{bc}	24.43^{bc}	27.50^b	30.60^{bc}	2.30^a
T_3	8.70^{ab}	11.13^{ab}	12.20^{ab}	17.33^b	21.17^{ab}	25.40^b	29.33^b	32.53^b	35.47^b	2.53^a
T_4	10.37^a	13.67^a	16.67^a	22.77^a	26.50^a	34.27^a	39.17^a	43.27^a	47.63^a	2.67^a
Significance	**	*	**	**	**	**	**	**	**	*
LSD (P=0.05)	2.13	3.36	3.24	5.11	5.73	7.30	7.81	7.34	7.51	0.48
CV (%)	13.51	16.61	13.61	16.12	14.82	15.33	14.21	11.91	10.97	10.36

**Highly significant at P <0.01, *significant at P<0.05. Means separated by Least Significance Difference (LSD) Test at $P \leq 0.05$, means within columns followed by the same letter 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 1-9 are dates from 05-01-2015 to 02-03-2015.

2002). The increase in stem thickness observed in the present study may be attributed to the improved physical, chemical, and biological properties of soil stimulated by the application of the organic fertilizer (Al-Fraihat *et al.*, 2011).

Plant canopy diameter: Plant canopy diameter was significantly (P<0.05) affected by different organic fertilizer application rates (Table 3). In week 1 and 2 of measurement, T_4 plants had a significantly higher canopy diameter than T_1 and T_2. There was no significant difference in plant canopy diameter between T_3 and T_4, T_2 and T_3 as well as between T_2 and T_1 for most part of the study. Overall, the canopy diameter increased with increase in organic fertilizer application rate. This is consistent with Mojeremane *et al.* (2016) who found out that the canopy diameter of tomato plants increased with increasing rate of organic fertilizer application. The increase in canopy diameter in organic fertilizer amended plots could be attributed to improved soil fertility (Atiyeh *et al.,* 2000; Hashemimajd *et al.,* 2004; Abafita *et al.,* 2004). Prior studies reported that organic fertilizers restore soil fertility (Krogman *et al.,* 1997; Benton and Wester, 1998) and increase productivity because they release macro and micronutrients required by plants (Chaterjee *et al.,* 2005).

Fresh and dry weights: Plant fresh and dry weights were significantly (P<0.05) affected by different application rates of organic fertilizer (Table 4). The effect of different organic fertilizer application rates on fresh plant weight was significant (P<0.01) with plants grown in T_4 revealing the highest weight than the other treatments. The fresh weight of plants grown in T_2 was statistically similar to T_3. The control (T_1) gave the least plant fresh weight. Results show that the effect of different application rates of organic fertilizer on plant dry weight was significant (P<0.05). The highest amount of plant dry weight was obtained in T_4 whereas plants grown in T_1, T_2 and T_3 respectively were statistically at par.

Table 4. Effect of organic fertilizer on plant fresh and dry weights (g).

Treatments	Fresh weight	Dry weight
T_1	67.30^c	14.96^b
T_2	119.53^b	22.74^b
T_3	96.94^b	19.84^b
T_4	149.13^a	31.60^a
Significance	**	*
LSD (P=0.05)	39.05	8.66
CV (%)	18.06	19.46

**Highly significant at P<0.01 and *significant at P<0.05. Means separated by Least Significance Difference (LSD) Test at $P\leq$ 0.05, means within columns followed by the same letter 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.

All measured parsley parameters increased with the increase in level of organic fertilizer. Thus it can be concluded that to obtain higher yield, applying organic fertilizer at 10 kg m^{-2} is recommended. The poor performance of plants in the control (T_1) treatment is due to the insufficient supply of plant nutrients resulting in reduction of plant productivity.

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