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Effect of foliar application of moringa (*Moringa oleifera*) leaf extract with recommended fertilizer on growth and yield of okra (*Abelmoschus esculentus*)

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Abstract

A field experiment was carried out at the Crop farm of Eastern University, Sri Lanka during the period June 2018 to September 2018 to study the effects of different concentrations and frequencies of Moringa (Moringa oleifera) Leaf Extract (MLE) as a foliar application on growth and yield of okra (Abelmoschus esculentus) plants. This experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates with the following treatments; T_0 – control (Distilled water), T_1 – 10% MLE at once a week interval, T_2 – 10% MLE at once in two weeks interval, T_3 – 20% MLE at once a week interval, T_4 – 20% MLE at once in two weeks interval, T_5 – 30% MLE at once a week interval and T_6 – 30% MLE at once in two weeks interval. Foliar application of MLE was initiated at two weeks after germination and each plant is sprayed with 25 ml of MLE and the growth performance was recorded at 4, 6 and 7 WAP. The results showed that foliar application of MLE had a significant ($p < 0.05$) effects on tested parameters of okra over the control at all growth stages. MLE with 10% of the foliar application at once a week interval increased plant height, number of branches/plant, number of leaves/plant, leaf area index, dry weight of leaves, stems, roots, total biomass, number of pods/ha and dry weight of pods. The results suggest that under the conditions in the experiment, yield could be increased by three-fold using MLE at 10%. The use of Moringa leaf extract as a plant growth booster is inexpensive, environmentally safe and low-cost technology to improve the yields by the small farmers.

Key words: *MLE, Foliar application, Okra, Yield, Environmentally safe*

Introduction

Okra (*Abelmoschus esculentus*), is called as lady's fingers in English and bhendi in Tamil, is a popular vegetable. Okra is the only vegetable crop belongs to the family Malvaceae (Abeykoon *et al*., 2010). The fibrous and immature fruits are edible and eaten as a vegetable, and boiled/cooked as a curry. Okra is rich in proteins, fat, carbohydrate (Purseglove, 1987), minerals such as calcium, phosphorus, potassium, magnesium, iron and vitamin C (Manal *et al*., 2015). It is used for the medicinal purpose as a plasma replacement or expander of blood volume (Lengsfeld *et al.* 2004, Adetuyi *et al.* 2008) and Kumar *et al.* (2010). It renders iodine which is used for the treatment of goiter (Moaward, 1984) used to remedy numerous illnesses such as diabetes, chronic dysentery genito-urinary disorders and ulcer.

In Sri Lanka, the targeted extent of cultivation of okra in 2016/2017 Maha was 3499 hectares with a total production of 18,275 Metric ton (Mt) in which achieved 1975 hectares and 10,325 Mt with the 56% progress from the target. The targeted total extent of cultivation of okra in 2017/2018 Maha was 3939 hectares and in which the progress is 1588 hectares and 8410 Mt with the 40% progress from the target (Anon., 2016 & 2017). In the Batticaloa district, the targeted extent of cultivation of okra in 2016/2017 Maha was 185 ha with the total production of 1,110 t and the targeted total extent of cultivation for Yala 2017 was 99 ha with the production of 693

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tons (Ministry of Agriculture, 2018). However, the contribution of okra for the national production from Batticaloa district was 4% and 5% in 2012 and 2017, respectively (Census and Statistics, 2010). This may be due to poor soil fertility management, high post-harvest losses. Therefore, yield could be increased by proper fertilizer application methods and time of application in relation to the critical stages of growth in order to obtain high yields. Nutrients can be applied through foliar methods. Foliar application is feeding the plants by liquid fertilizer directly to the leaves. It is the greatest successful than the conventional application like surface, banded on or beneath the soil surface and low-risk method to plants (Aghtape *et al*., 2011) due to the low potential to damage the plant roots. The foliar application may be organic or inorganic form. Inorganic fertilizers are expensive and continuous application leads to the reduction in yields and polluting the environment.

The fertilizer produced from completely natural raw materials called organic fertilizer and the liquid concentrates containing organic elements called liquid organic fertilizers which do not cause damage to the environment. The foliar application of growth promoting compounds are used to improve crop growth and yield (Adams and Adams, 2002; Al-Hakimi and Hamada, 2001; Azeem and Ahmad, 2011). Small-scale-farmers are interested in natural compounds which are cheap and environmentally friendly. Therefore, one of the effective ways to use low-cost technology with natural sources of nutrients (organic materials) to increase the crop yield by small-scale farmers without polluting the environment is the Moringa Leaf Extract (MLE). It tends to reduce the application frequency of inorganic fertilizer to increase the crop yield during the cropping season. Moringa Leaf Extract (MLE) can be used as a bio-stimulant and contains macro and micronutrients, amino acids, ascorbic acids, minerals and growth-enhancing principles (Makkar *et al*., 2007) such as hormone of the cytokinin type. Growth hormone spray will also cause the plants to be firmer and more resistant to pest and diseases. It possesses about 46 antioxidants and the key ones are ascorbate, carotenoids, phenols and flavonoid (Iqbal and Bhanger, 2006). Foliar application of MLE causes longer life-span, heavier roots, stems and leaves, produce more fruit, larger fruit and increase in yield 20-35% (Foidle *et al*., 2001). Bashir *et al*. (2014) documented that MLE significantly increased the average plant height, number of leaves and branches, and yield of the tomato plant. Application of MLE was shown to increase yields of crops such as onions, bell pepper, soybean, sorghum, coffee, tea, chilli, melon and maize (Fuglie, 2000).

This investigation was undertaken to study the effect of different concentrations and frequencies of application of Moringa (*Moringa oleifera*) Leaf Extract (MLE) as a foliar application on growth and yield of okra (*Abelmoschus esculentus*) Cv. Haritha in sandy regosol.

Materials and Method

A field experiment was conducted at the Crop Farm, Eastern University, Sri Lanka (latitude 7^0 43' and longitude 81^0 42') which falls within the dry zone of Sri Lanka during the period June 2018 to September 2018 to study the effect of different concentrations and frequencies of application of Moringa (*Moringa oleifera*) Leaf Extract (MLE) as a foliar application on growth and yield of okra (*Abelmoschus esculentus*) Cv. Haritha in sandy regosol. The climatic condition of the area is characterized by a mean annual rainfall ranging from 1400 mm to 1680 mm. Further, most of the showers are received during the month of October to January brought about by the North-East monsoon. The mean annual temperature varies from 28°C to 32°C and humidity level is 60%-90%. The treatments were laid out in a Randomized Complete Block design (RCBD) with 3 replications. The treatments were; T0- Control (Distilled water), T1- 10% MLE applied once a week interval, T2- 10% MLE applied once in two weeks interval, T3- 20% MLE applied once a week interval, T4- 20% MLE applied once in two weeks interval, T5- 30% MLE applied once a week interval and T6- 30% MLE applied once in two weeks interval. The plot size was 3.6 m x 3.0 m. The seeds were soaked overnight in water to ensure uniform germination. The seeds were planted at the spacing of 60cm between rows and 60cm within rows. All practices were carried out in accordance with the Department of Agriculture recommendation. Sampling was done at 4, 6 and 7 WAP. First two occasions two plants were uprooted for assessment. At harvest, five plants were used for assessment. Field data were collected at 4, 6 and 7 weeks after planting (WAP) and analyzed using SAS 9.1, and means were separated using Duncan's Multiple Range Test (DMRT) test at 5% significant level. Field data were collected at 4, 6 and 7 weeks after planting (WAP) and analyzed using SAS 9.1 and means were separated using Duncan's Multiple Range Test (DMRT) test at 5% significant level.

Preparation of Moringa leaf extract and application

Leaves and tender parts of Moringa were collected, washed, air dried and made into coarse powder and distilled water was added to the prepared powder sample in order to get the required concentration and autoclaved at 121°C, 15 lbs sq^{-1} inch for 20 minutes. Then the hot extract was filtered through double layered cheesecloth and it was allowed to cool at 4°C. Then the filtrate was centrifuged at 5000 × g for 15 minutes and the supernatant was collected and considered as 100% of Moringa Leaf Extract (Rama Rao, 1990 and Yasmeen, 2011). The extract was diluted by adding distilled water at the concentration of 10%, 20% and 30%. Moringa Leaf Extract was sprayed at the rate of 0 ml (control) and 25 ml for each plant at one and two weeks interval, starting from two weeks after germination to pod formation. Foliar applications were done early in the morning for better absorption.

Table 1: Physio-Chemical Properties of Moringa Leaf Extract used for this study

Variables	Unit	Value
Colour	-	Pale brown
pH	-	4.2
EC	uS/cm	5380
Nitrogen	%	0.07
Phosphorous	ppm	131
Potassium	ppm	862
Calcium	ppm	112
Magnesium	ppm	194
Copper	ppm	1.5
Iron	ppm	2.9
Manganese	ppm	1.7
Zinc	ppm	1.3

(Source: CIC Analytical Laboratory, Pelwehera, Sri Lanka)

Results and Discussion

Plant height

Different concentration of MLE significantly influenced ($p<0.05$) the plant height. At 4 WAP, foliar application of MLE increased the plant height of 29.58 cm in T1, followed by T5 (23.22 cm) and T6 (23.12 cm) (Table 2). The lowest plant height of 16.30 cm was recorded in control treatment (T0). At 6 WAP, the highest plant height of 65.22 cm was observed ($p<0.05$) in T1 and T3 (57.77 cm) while the lowest plant height of 36.76 cm was observed in the control treatment (Table 2). No significant difference was observed among the treatments T2, T4, T5 and T6. At 7 WAP, the highest plant height (95.38 cm) was observed in T1 followed by T3 (82.48 cm) (Table 2). The lowest plant height was recorded in T0 (47.40 cm). As the plant grows, height increases with time and the highest plant height was observed in T1 and the lowest plant height was observed in T0. Therefore, the application of MLE at the rate of 10 % concentration at one-week interval increased the plant height. This might be due to the foliar application of MLE which enhanced the growth of okra due to the liberal integration of nutrients, amino acids and growth hormones. This is in agreement with the findings of Taha (2015) who reported that exogenous application of MLE with 10 % concentration increased the plant height of the Jojoba plant. In contrast, foliar application of MLE at 1:32 concentration increased the plant height in maize (Biswas *et al*., 2016), tomato (Culver *et al*., 2012), beans and maize (Mvumi *et al*., 2013). This might be due to zeatin, which is the most common cytokinin in the extract, responsible for the improved plant height.

Table 2: Effects of different concentrations of Moringa Leaf Extract on plant height of okra at different stages of crop

Code	Treatments	WAP		
		4	6	7
T0	Control	$16.98^{c} \pm 1.58$	$35.65^{d} \pm 2.55$	$47.40^{d} \pm 1.07$
T1	10% (once a week)	$29.58^{a} \pm 0.10$	$65.22^{a} \pm 4.65$	$95.38^{a} \pm 1.35$
T2	10% (twice a week)	$24.87^{ab} \pm 0.92$	$44.42^{c} \pm 3.59$	$67.78^{bc} \pm 1.40$
T3	20% (once a week)	$25.87^{ab} \pm 0.50$	$57.77^{ab} \pm 0.73$	$82.48^{b} \pm 1.71$
T4	20% (twice a week)	$25.45^{ab} \pm 0.98$	$52.02^{bc} \pm 1.27$	$73.65^{bc} \pm 1.22$
T5	30% (once a week)	$23.22^{b} \pm 2.40$	$43.78^{cd} \pm 2.63$	$61.25^{d} \pm 0.98$
T6	30% (twice a week)	$23.12^{b} \pm 0.96$	$42.45^{cd} \pm 1.72$	$52.60^{d} \pm 0.79$
	P Value	**0.0009**	**< .0001**	**< .0001**

* p< 0.05- NS; Not Significant
Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Duncan Multiple Range Rest (DMRT).
Value represents mean ± standard error of three replicates.

Number of branches/plants

The total number of branches/plants is statistically ($p < 0.05$) differed among application of MLE as represented in Figure 1. At 4 WAP, the highest number of branches was observed in T1 (3.0) followed by T6 while the lowest number of branches was observed in control treatment (Figure 1). No significant ($p < 0.05$) difference was observed among the treatments T2, T3, T4 and T5. At 6 WAP, foliar application of MLE increased the number of branches/plants. The number of branches/plants was the highest in T1 (5.3) while the lowest number of branches was noticed in the control treatment (1.7). At 7 WAP, the highest number of branches (7.0) was observed in T1 followed by T3 (Figure 1). The lowest number of branches was observed in T0 (1.7). However, T3 was par with T4 (Figure 1). Therefore, the application of different concentrations of MLE was significantly ($p < 0.05$) influenced the number of branches. Therefore, the effect of the application of MLE at the rate of 10% at one-week interval increased the number of branches and this may be because of the abundant supply of macro and micronutrients and growth hormones. These results are in agreement with Fuglie (2000) who reported that foliar application of MLE contains an adequate amount of stimulating substances which encourage the rate of cell-division and cell-enlargement. Zeatin is a growth promoting hormone which is present in the MLE promotes the growth of lateral buds and that in turn increase the number of branches. In okra, foliar application of MLE increased the number of branches with the extract after pounding the 100g of Moringa leaves in 8 liters of water (Anyaegbu, 2015), in cowpea with 1:30 dilution (Maishanu *et al*., 2017) and in tomato with 100 % (Bashir *et al*., 2014). However, in this experiment, the concentration at 10 % was 10 times lesser than that of Bashir *et al*. (2014).

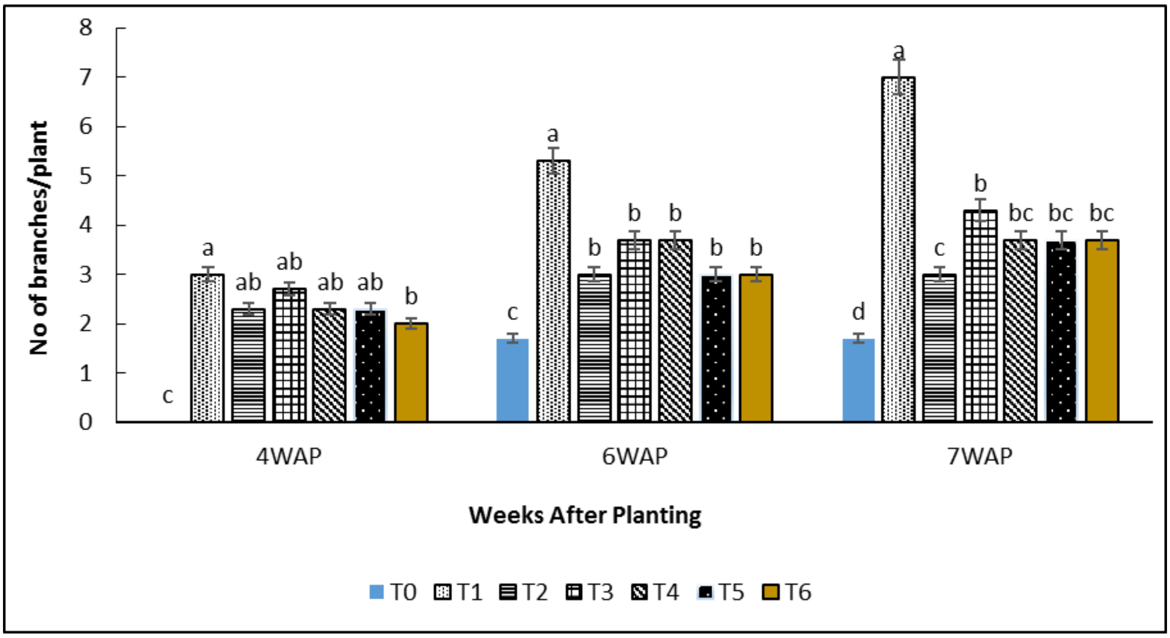

Figure 1: Effects of different concentrations of Moringa Leaf Extract on number of branches per plant at different stages of crop.

Number of leaves/plants

Figure 2 shows the effects of MLE on the number of leaves/plants of okra at different stages of growth. The application of MLE had a significant effect ($p < 0.05$) on the number of leaves/plants compared to that of control. As time proceeds, the effect on the number of leaves/plants also increased. The highest number of leaves/plants were observed in T1 and the lowest number of leaves/plants was reported in T0 (Figure 2). In general, the highest number of leaves was observed in T1 and the lowest number of leaves was obtained in T0 at different stages of growth. Iqbal (2014) reported that MLE determines the vegetative growth of plants and the role of cytokinins in increasing cell division resulting in a higher number of leaves (Emongor, 2015). Therefore, application of MLE at the rate of 10% concentration at one-week interval heightened the number of leaves per plant. Foliar application of MLE improved the number of leaves as reported by Kehinde-Fadare and Salami (2018) in sweet corn (1:16); cereal forages (1:10 v/v) (Abusuwar and Abohasaan, 2017) and in garlic (10 g of Moringa leaves/ liter of water MLE with 200 ppm glutamine and 100 ppm cysteine) (Hegazi *et al*., 2016). In contrast, Emongor (2015) reported that increasing MLE concentration (11%, 20%, 33% and 50%) reduced the number of leaves of snap bean.

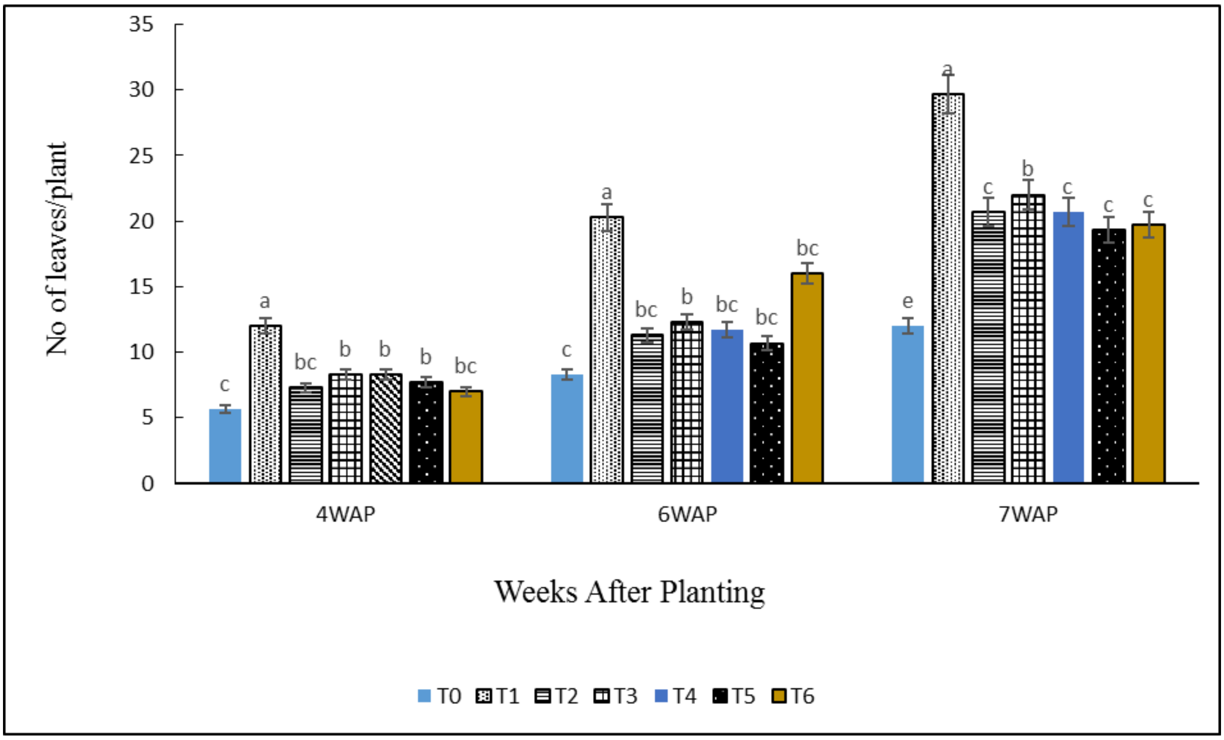

Figure 2: Effects of different concentrations of Moringa Leaf Extract on number of Leaves per plant at different stages of crop

Leaf area index (LAI)

The change in LAI with time and with treatments are presented in Table 3. Application of MLE significantly influenced ($p < 0.05$) the LAI. The LAI was increased up to 7WAP. At 4 WAP, maximum LAI was observed in T1 (0.45) and minimum LAI was observed in T2 (0.30), T6 (0.25) and T0 (0.22) (Table 3). At 6 WAP, the highest LAI was observed in T1 (0.74) and the lowest value was observed in T0 (0.43). At 7WAP, the highest LAI was recorded in T1 (0.86), T4 (0.84) and T3 (0.82) while the lowest LAI was in control treatment T0 (0.56) (Table 3). Therefore, the increase in LAI was due to the increase in leaf area. This might be due to the significant contribution of nitrogen present in MLE which caused cell division, cell enlargement and the overall plant growth. This ensures in promoting vegetative growth. Thus, resulting in an increased number of leaves and leaf area and consequently LAI. This is in concurrence with the studies of Chattha *et al.* (2018) who reported that application of 1:30 MLE increased the LAI of wheat and garlic with 3% MLE (Hassan *et al.*, 2017). This is also in accordance with the study of Fuglie (2000) and Tetley and Thimann (1974) who testified that zeatin in the MLE sustains greater leaf area for photosynthetic activity and leaf chlorophyll content. Higher leaf area led to greater LAI. Rady *et al.* (2015) observed that the biosynthesis of cytokinin stimulate the translocation of stem reserves to recent shoots results in healthy plant growth, prevents premature leaf senescence retain higher leaf area for photosynthetic activity.

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Table 3: Effects of different concentrations of Moringa Leaf Extract (MLE) on leaf area index (LAI) at different stages of crop

Code	Treatments	WAP		
		4	6	7
T0	Control	$0.22^{b} \pm 0.02$	$0.43^{e} \pm 0.08$	$0.56^{c} \pm 0.04$
T1	10% (once a week)	$0.45^{a} \pm 0.08$	$0.74^{a} \pm 0.04$	$0.86^{a} \pm 0.04$
T2	10% (twice a week)	$0.30^{b} \pm 0.00$	$0.58^{c} \pm 0.04$	$0.85^{b} \pm 0.02$
T3	20% (once a week)	$0.34^{ab} \pm 0.03$	$0.68^{ab} \pm 0.04$	$0.82^{a} \pm 0.04$
T4	20% (twice a week)	$0.32^{ab} \pm 0.01$	$0.59^{bc} \pm 0.08$	$0.84^{a} \pm 0.04$
T5	30% (once a week)	$0.32^{ab} \pm 0.02$	$0.53^{cd} \pm 0.04$	$0.73^{b} \pm 0.04$
T6	30% (twice a week)	$0.25^{b} \pm 0.00$	$0.47^{de} \pm 0.08$	$0.70^{b} \pm 0.00$
	P Value	**0.0114**	**0.0016**	**0.0003**

* p< 0.05- NS; Not Significant
Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Duncan Multiple Range Rest (DMRT).
Value represents mean ± standard error of three replicates.

Dry weight of leaves

Effect of MLE on the dry weight of leaves/ha at 4, 6 and 7 WAP is given in Table 4. Application of MLE significantly influenced ($p < 0.05$) to the dry weight of leaves/ha of okra. At all three stages, T1 recorded the maximum dry weight of leaves/ha and at 4 WAP and 6 WAP, T0 recorded the minimum dry weight of leaves/ha (Table 4). The increase in dry weight of leaves/ha was mainly due to the addition of leaves from the plant. This was attributed to the effect of MLE. The MLE enriched with crude protein and growth promoting hormone namely; auxins and cytokinin (Makkar and Becker, 1996). It caused to increase the plant growth such as plant height, the number of branches and number of leaves that helped to increase the dry weight of leaves. Therefore, application of MLE at the rate of 10% at one-week interval increased the dry weight of leaves/ha. This finding is consistent with Hashish *et al*. (2016) who documented that MLE increased the dry weight of leaves of *Alstonia scholaris* (the type of timber plant) compared with the control treatment.

Table 4: Effects of different concentrations of Moringa Leaf Extract on dry weight of leaves/ha at different stages of crop

Code	Treatments	WAP		
		4	6	7
T0	Control	$21.80^{c} \pm 3.97$	$74.10^{c} \pm 7.98$	$194.83^{b} \pm 21.93$
T1	10% (once a week)	$79.13^{a} \pm 12.60$	$284.27^{a} \pm 22.10$	$432.07^{a} \pm 18.91$
T2	10% (twice a week)	$48.10^{bc} \pm 6.19$	$141.07^{b} \pm 11.75$	$242.73^{b} \pm 44.99$
T3	20% (once a week)	$60.13^{ab} \pm 7.03$	$162.97^{b} \pm 8.28$	$264.23^{b} \pm 28.38$
T4	20% (twice a week)	$51.90^{b} \pm 6.51$	$151.10^{b} \pm 20.60$	$244.10^{b} \pm 22.31$
T5	30% (once a week)	$42.53^{bc} \pm 4.90$	$131.00^{b} \pm 13.96$	$210.03^{b} \pm 30.98$
T6	30% (twice a week)	$33.27^{bc} \pm 9.32$	$125.67^{b} \pm 8.31$	$195.83^{b} \pm 29.72$
	P Value	**0.0066**	**< .0001**	**0.002**

* p< 0.05- NS; Not Significant
Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Duncan Multiple Range Rest (DMRT).
Value represents mean ± standard error of three replicates.

Dry weight of stems

The dry weight of stem/ha showed statistically significant ($p<0.05$) variation due to the application of MLE (Table 5). In general, the trend was for an increase in dry weight of stems per hectare increased with time. The magnitude of increase varies with the treatments. At 4 WAP, the maximum dry weight of stems was observed in T1 and minimum dry weight was observed in T0 (Table 5). At 6 WAP, the maximum dry weight of stems was recorded in T1 while T0 represented the minimum dry weight of stems (Table 5). At 7 WAP, foliar application of MLE increased the dry weight of stems/ha and the maximum dry weight was found from T1 (531.73 kg/ha) and no significant difference was observed among the other treatments tested i.e. T0, T2, T3, T4, T5 and T6. Therefore, application of MLE had significantly influenced the dry weight of stems/ha. The increase in dry weight of stems/ha in T1 was twice that of control. This might be due to the presence of growth promoting factors and macro and micronutrients and the phytohormones in the MLE which enhanced the growth of the plants. Thus, the weight of the plant parts was increased. This also due to ascorbic acid content in the plant which induced better shoot growth (Zhang and Schmidt, 1999). In this investigation, application of MLE at the rate of 10% (T1) concentration at one-week interval influenced to increase the dry weight of stems/ha. This is in accordance with Hashish *et al*. (2016) who reported that MLE increased the stem dry weight of *Alstonia scholaris* (timber plant) compared with the control treatment.

Table 5: Effects of different concentrations of Moringa Leaf Extract on dry weight of stems/ha at different stages of crop

Code	Treatments	WAP		
		4	6	7
T0	Control	19.78^{c} ± 2.48	81.4^{g} ± 39.55	255.57^{b} ± 6.10
T1	10% (once a week)	50.80^{a} ± 13.47	267.7^{a} ± 22.29	531.73^{a} ± 21.11
T2	10% (twice a week)	27.90^{bc} ± 4.07	129.3^{d} ± 14.35	294.60^{b} ± 28.39
T3	20% (once a week)	35.78^{ab} ± 13.91	162.2^{b} ± 17.88	365.70^{b} ± 39.61
T4	20% (twice a week)	28.03^{bc} ± 7.47	131.0^{c} ± 3.81	301.33^{b} ± 35.61
T5	30% (once a week)	24.47^{bc} ± 2.09	126.5^{e} ± 3.23	287.07^{b} ± 27.01
T6	30% (twice a week)	18.03^{bc} ± 2.55	121.3^{f} ± 31.94	280.50^{b} ± 51.55
	P Value	**0.0203**	**< .0001**	**0.0299**

* p< 0.05- NS; Not Significant
Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Duncan Multiple Range Rest (DMRT).
Value represents mean ± standard error of three replicates.

Dry weight of roots

Effect of different concentrations of MLE on the dry weight of roots/ha is given in Table 6. At all stages of the crop, T1 recorded the maximum dry weight of roots and T0 was recorded the minimum dry weight of roots. The percentage of increase dry weight of roots in T1 (10% at once a week) was 83.56%, 76.97% and 60.84% during 4, 6 and 7 WAP (Table 6). This might be due to the release of crude protein and carbohydrate which influence root system architecture and especially, due to the presence of a significant amount of phosphorous in the MLE which promote the root development. Similar results have been reported in soybean by (Ogbuehi *et al*. (2017). There is a potential increase in the number of roots/plant by the application of MLE and this in turn, increased the dry weight/ha because of the increment of dry matter accumulation. Mvumi *et al*. (2013) reported that the application of MLE (1:32 v/v) at every 2 weeks to maturity from two weeks from germination increased the root dry weight of maize and common beans.

Table 6: Effects of different concentrations of Moringa Leaf Extract on dry weight of roots/ha at different stages of crop

Code	Treatments	WAP		
		4	6	7
T0	Control	$1.77^{c} \pm 0.69$	$18.15^{c} \pm 4.06$	$64.63^{b} \pm 8.72$
T1	10% (once a week)	$10.77^{a} \pm 1.45$	$78.84^{a} \pm 7.11$	$165.07^{a} \pm 15.44$
T2	10% (twice a week)	$6.73^{b} \pm 0.47$	$41.39^{bc} \pm 9.98$	$106.37^{ab} \pm 13.05$
T3	20% (once a week)	$7.60^{ab} \pm 1.89$	$46.66^{b} \pm 1.18$	$139.60^{ab} \pm 55.85$
T4	20% (twice a week)	$6.87^{b} \pm 1.27$	$44.91^{b} \pm 1.54$	$107.17^{ab} \pm 24.32$
T5	30% (once a week)	$5.60^{b} \pm 0.70$	$35.56^{bc} \pm 3.95$	$104.70^{ab} \pm 25.01$
T6	30% (twice a week)	$4.83^{bc} \pm 1.01$	$28.19^{bc} \pm 1.60$	$72.03^{ab} \pm 12.64$
	P Value	**0.003**	**0.0023**	**NS**

* $p < 0.05$- NS; Not Significant
Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Duncan Multiple Range Rest (DMRT).
Value represents mean ± standard error of three replicates.

Total dry weight (leaves, stems, roots and pods)

Effect of foliar application of MLE on crop total dry weight/ha is presented in Table 7. MLE significantly influenced ($p < 0.05$) the total dry weight/ha. At 4 WAP, foliar application of MLE increased the total dry weight/ha in T1 followed by T4 (Table 7). The minimum dry weight was observed in T0 (33.33 kg/ha). At 6 WAP, maximum dry weight was observed in T1 and the lowest dry weight was observed in the control treatment (176.52 kg/ha). At 7WAP, maximum dry weight of plants (1175.8 kg/ha) was observed in T1 (Table 7). Therefore, application of MLE at one week interval with 10% concentration showed a significant difference in total dry weight/ha compared to the control treatment. This may be attributed to the effect of zinc and gibberellin present in MLE which played an important role in the production of biomass. Because, zinc increased the biomass production in plants (Cakmak, 2008). As well as, gibberellin which enriched in MLE respond to increase the total dry matter of the plants. A similar result has been reported by Tuna *et al.* (2008) in maize plants while Zaki and Rady (2015) reported that the application of MLE at 1:30 increased the total plant dry weight of common bean and in rocket plant with 2% MLE (Abdalla, 2014).

Table 7: Effects of different concentrations of Moringa Leaf Extract on total dry weight of plants/ha at different stages of crop

Code	Treatments	WAP		
		4	6	7
T0	Control	$33.33^{c} \pm 7.11$	$176.52^{d} \pm 24.44$	$530.5^{c} \pm 32.16$
T1	10% (once a week)	$140.70^{a} \pm 26.17$	$640.67^{a} \pm 48.10$	$1175.8^{a} \pm 13.52$
T2	10% (twice a week)	$82.73^{b} \pm 9.18$	$317.71^{bc} \pm 29.94$	$665.3^{bc} \pm 78.30$
T3	20% (once a week)	$103.50^{ab} \pm 22.81$	$378.92^{b} \pm 25.77$	$797.3^{b} \pm 110.03$
T4	20% (twice a week)	$86.80^{b} \pm 14.13$	$335.67^{bc} \pm 16.13$	$679.7^{bc} \pm 90.59$
T5	30% (once a week)	$72.60^{bc} \pm 3.84$	$299.59^{bc} \pm 13.34$	$623.1^{bc} \pm 44.03$
T6	30% (twice a week)	$56.13^{bc} \pm 9.82$	$279.57^{c} \pm 20.14$	$568.0^{bc} \pm 89.60$
	P Value	**0.0044**	**< .0001**	**0.0009**

* p< 0.05- NS; Not Significant
Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Duncan Multiple Range Rest (DMRT).
Value represents mean ± standard error of three replicates.

Number of pods/plants

Exogenous application of MLE significantly influenced ($p<0.05$) the number of pods/plants. At 4 WAP, no significant difference was observed among the treatments tested (Table 8). At 7 WAP, the maximum number of pods/plants was observed in T1 followed by T3 and the minimum number of pods/plants was observed in T0 (Table 8). This is in accordance with Bashir *et al*. (2014) who reported that MLE increased the number of pods/plant (by 2.85%). MLE at 10% concentration at one week interval was best in this investigation. This might be due to the presence of indole acetic acid (IAA) and gibberellins (GA_3) in MLE increased the number of pods. These results were parallel to those of Khandaker *et al*. (2018) who reported that IAA and GA_3 increased the number of okra pods. The micronutrients that are enriched in MLE also influenced to fruit set. Zinc improves the number of fruits and this might be due to the involvement of zinc in photosynthesis, activation of enzyme systems, protein synthesis and carbohydrate translocation. The results of this investigation are in agreement with the findings of Ogbuehi (2018) who reported that the application of 10% MLE increased the number of pods of soybean. Similar results have been reported in *Solanum melongena* (2 kg Moringa leaves/20 L water) (Ozobia, 2014) and in pepper (4% MLE) (Hala and Nabila, 2017). The exogenous application in the form of foliar spray significantly affects the number of flowers. It leads to the highest number of pods and pod yield (weight) under the foliar application of MLE30 (Azra Yasmeen, 2011).

Table 8: Effects of different concentrations of Moringa Leaf Extract (MLE) on number of pods/plant at different stages of crop

Code	Treatments	WAP	
		6	7
T0	Control	0.7 ± 0.33	2.7^{e} ± 0.33
T1	10% (once a week)	2.3 ± 0.33	7.7^{a} ± 0.33
T2	10% (twice a week)	1.0 ± 0.00	5.0^{c} ± 0.00
T3	20% (once a week)	2.0 ± 0.99	6.3^{b} ± 0.33
T4	20% (twice a week)	1.7 ± 0.33	5.3^{c} ± 0.33
T5	30% (once a week)	1.3 ± 0.33	4.0^{d} ± 0.00
T6	30% (twice a week)	1.3 ± 0.58	3.3^{de} ± 0.33
	P Value	**NS**	**< .0001**

* p< 0.05- NS; Not Significant
Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Duncan Multiple Range Rest (DMRT).
Value represents mean ± standard error of three replicates. NS means no significant difference.

Dry weight of pods

At 7 WAP, dry weight of pods/ha was significantly (p<0.05) increased with the application of MLE (Table 9). The highest yield was recorded with T2 followed by T3 and T4 treatments. The lowest yield was recorded with T0 (Control treatment). Therefore, application of MLE significantly influenced (p<0.05) the dry weight of pods/ha by 3 fold in T1, and 1.8 and 1.75 fold in T3 and T4, respectively compared to that of control treatment. MLE had a pronounced effect on yield and application of MLE at the concentration of 10% at the one-week interval (T1) could increase the dry weight of pods by 134% (Table 9), the beneficial effect of MLE was shown by many investigations (Thomas and Howarth (2000), Fuglie (2000) Jason (2013), Muhammad *et al.* (2013) and Bashir *et al.* (2014), Oluwagbenga and Odeghe (2015) and Aluko (2016)).

Thomas and Howarth (2000) and Azooz *et al*. (2004) detailed that MLE increases the growth parameters such as leaf area, chlorophyll content and the number of leaves/plant which sequentially increases the photosynthesis and phot-assimilates. The higher level of assimilates translocated to the pods and that resulted in higher yield. Application of MLE also increases the number of flowers which in turn encourages weight of pods as reported by (Azra Yasmeen, 2011). Fuglie (2000) outlined that MLE increases the yield by 20 to 35%. This might be due to the effect of zeatin in the MLE. It was also reported that Zeatin improved the number of leaves which increases the photosynthetic area and resulted in higher yield (Thomas and Howarth (2000). In addition, due to the biosynthesis of cytokinin which promotes cell-division rate, cell-enlargement, ultimately resulted in higher yield (Fuglie, 2000). Thus, in this investigation, application of MLE at one week interval with the concentration of 10% showed the highest value of the dry weight of pods/ha. In tomato, dry weight of fruit was increased with the application of MLE (1:32) (Culver *et al*., 2012), and in pepper, yield increased with MLE (1:20) (Aluko,

2016) and with MLE 4% (Hala *et al.*, 2017). Similar results have been reported by Muhammad *et al.* (2013) and Bashir *et al.* (2014) in tomato, Ozobia (2014) in eggplant and Oluwagbenga and Odeghe *et al.* (2015) in pepper.

Table 9: Effects of different concentrations of Moringa Leaf Extract (MLE) on dry weight pods (kg/ha) at different stages of crop

Code	Treatments	WAP	
		6	**7**
T0	Control	$2.82^{b} \pm 1.41$	$15.42^{d} \pm 1.49$
T1	10% (once a week)	$9.83^{a} \pm 0.88$	$46.94^{a} \pm 1.65$
T2	10% (twice a week)	$5.99^{ab} \pm 0.53$	$21.56^{c} \pm 1.65$
T3	20% (once a week)	$7.05^{ab} \pm 3.52$	$27.75^{b} \pm 0.19$
T4	20% (twice a week)	$8.70^{ab} \pm 1.85$	$27.06^{b} \pm 1.62$
T5	30% (once a week)	$6.49^{ab} \pm 1.71$	$21.28^{c} \pm 0.74$
T6	30% (twice a week)	$4.41^{ab} \pm 2.21$	$20.04^{c} \pm 1.09$
	P Value	**0.2979**	**< .0001**

* p< 0.05- NS; Not Significant
Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Duncan Multiple Range Rest (DMRT).
Value represents mean ± standard error of three replicates.

Conclusion

Foliar application of MLE 10% at the weekly interval was effective in improving the plant height, number of branches/plant, number of leaves/plant, leaf area index, dry weight of leaves, stems, roots, total biomass, pods and number of pods. MLE is a natural growth stimulant which is inexpensive, environmentally safe and sound low-cost technology for increasing crop yields.

References

Abdalla, M. M. (2014). Boosting the growth of rocket plants in response to the application of *Moringa oleifera* extracts as a biostimulant. *Life Science Journal*, 11(11): 1113-1121.

Abeykoon, A. M. K. C. K., Fonseka, R. M., Paththinige, S. and Weerasinghe, K. W. L. K. (2010). Fertilizer requirement for densely planted okra (*Abelmoschus esculentus* L.). *Tropical Agricultural Research*, 21(3): 275-283.

Abusuwar, A. O. and Abohassan, R. A. (2017). Effect of *Moringa olifera* leaf extract on growth and productivity of three cereal forages. *Journal of Agricultural Science*, 9(7): 236-243.

Adams, B. D. and Adams, W.W. (2002). Antioxidants in photosynthesis and human nutrition. *Science*, 298(5601): 2149-2153.

Adetuyi, F. O., Osagie, A. U. and Adekunie, A. T. (2008). Effect of postharvest storage techniques on the nutritional properties of Benin indigenous okra *Abelmoschus esculentus* (L) Monech. *Pakistan Journal of Nutrition*, 7(5): 652-657.

Aghtape, A. A., Ghanbari, A., Sirousmehr, A., Siahsar, B., Asgharipour, M. and

Tavssoli, A. (2011). Effect of irrigation with wastewater and foliar fertilizer application on some forage characteristics of foxtail millet (*Setaria italica*). *International Journal of Plant Physiology and Biochemistry*, 3(3): 34-42.

Al-Hakimi, A.M.A. and Hamada, A.M. (2011). Counteraction of salinity stress on wheat plants by grain soaking in ascorbic acid, thiamin or sodium salicylate. *Biologia Plantarum*, 44(2): 253-261.

Aluko, M. (2016). Moringa leaf extract on the growth and yield of pepper (*Capsicum annuum* L). *ARPN Journal of Agricultural and Biological Science*, 11(3): 107-109.

Anonymous, (2016). Agricultural Statistics, Socio Economic and Planning Centre, Department of Agriculture, Sri Lanka.

Anonymous, (2017). Agricultural Statistics, Socio Economic and Planning Centre, Department of Agriculture, Sri Lanka.

Anyaegbu, P. O. (2015). Comparative evaluation of effects of leaf extracts of selected fallow species and N.P.K (15:15:15) fertilizer on the performance of okra, *Abelmoschus esculentus* in Abuja, Nigeria. *Report and Opinion*, 7(10): 39-46.

Azeem, M. and Ahmad, R. (2011). Foliar application of some essential minerals on tomato (*Lycopersicon esculentum*) plant grown under two different salinity regimes. *Pakistan Journal of Botany*, 43: 1513-1520.

Azooz, M. M., Shaddad, M. A. and Abdel-Latef, A. A. (2004). The accumulation and compartment-ation of proline in relation to salt tolerance of three sorghum cultivars. *Indian Journal of Plant Physiology*, 9: 1-8.

Azra Yasmeen (2011). Exploring the potential of moringa (*Moringa oleifera*) leaf extract as natural plant growth enhancer. Ph. D. Thesis. Department of Agronomy, Faculty of Agriculture, University of Agriculture, Faisalabad, Pakistan.

Bashir, K. A., Bawa, J. A. and Mohammed, I. (2014). Efficacy of leaf extract of drumstick tree (*Moringa Oleifera* Lam.) on the growth of local tomato (*Lycopersicon esculentum*). *IOSR Journal of Pharmacy and Biological Sciences*, 9(4): 74-79.

Biswas, A. K., Hoque, T. S. and Abedin, M. A. (2016). Effects of moringa leaf extract on growth and yield of maize. *Progressive Agriculture*, 27(2): 136-143.

Cakmak, I. (2008). Enrichment of cereal grains with zinc:agronomic or genetic biofortification. *Plant and Soil*, 302: 1-17.

Chattha, M. U., Khan, I., Hassan, M. U., Chattha, M. B., Nawaz, M., Iqbal, A., Khan, N. H., Akhtar, N., Usman, M., Kharal, M. and Ullah, M. A. (2018). Efficacy of extraction methods of *Moringa oleifera* leaf extract for enhanced growth and yield of wheat. *Journal of Basic and Applied Sciences*, 14: 131-135.

Culver, M., Fanuel, T. and Chiteka, A. Z. (2012). Effect of moringa extract on growth and yield of tomato. *Greener Journal of Agricultural Sciences*, 2(5): 207-211.

Emongor, V. E. (2012). Guidelines on good agricultural practices in the production of Moringa (*Moringa oleifera* Lam). *Scripta Horticulturae*, 15: 115-132.

Emongor, V. E. (2015). Effects of moringa (*Moringa Oleifera*) leaf extract on growth, yield and yield components of snap beans (*Phaseolus vulgaris*). *British Journal of Applied Science and Technology*, 6(2): 114-122.

Foidle, N., Makkar, H. P. S. and Becker, K. (2001). The potential of *Moringa oleifera* for agricutural and industrial uses, the miracle tree: The multipurpose attributes of moringa. *CTA publications*, 45-76.

Fuglie, L. J. (1999). The Miracle Tree: *Moringa oleifera*: Natural nutrition for the tropics. Church World Service, Dakar, 68.

Fuglie, L. J. (2000). The Miracle Tree: *Moringa oleifera*: Natural nutrition for the tropics. The miracle tree: the multiple attributes of moringa, 172.

Hala, H. A. and Nabila, A.E. (2017). Effect of *Moringa oleifera* leaf extract (MLE) on pepper seed germination, seedling improvement, growth, fruit yield and its quality. *Middle East Journal of Agriculture*, 6(2): 448-463.

Hashish, Kh. I., Mazhar, A. A. M., Abdel Aziz, N. G., Mahgoub, M. H. and Mahmoud, S. A. (2016). Influence of moringa extract application on growth and chemical constituents of *Alstonia scholaris* grown in sandy soil polluted by cadmium. *International Journal of PharmTech Research*, 9(8): 69-76.

Iqbal, S. and Bhanger, M. I. (2006). Effect of season and production on antioxidant activity of *Moringa oleifera* leaves grown in Pakistan. *Journal of Food Composition and Analysis*, 19: 544-551.

Jason, p. (2013). Pepe's fruit trees. www.pepesplants.com (Accessed on 10.9.2018).

Kehinde-Fadare, A. F. Ayodeji, E. and Salami, A.E. (2018). Potentials of *Moringa oleifera* Leaf Extracts as Biostimulant on the Field Performance of Sweetcorn. *Journal of Biology, Agriculture and Healthcare*, 8(12): 50-56.

Khandaker, M. M., Azam, H. M., Rosnah, J., Tahir, D. and Nashriyah, M. (2018). The effects of application of exogenous IAA and GA3 on the physiological activities and quality of *Abelmoschus esculentus* (Okra) var. Singa 979. *Tropical Agricultural Science*, 41(1): 209-224.

Kumar S., Dagnoko S., Haougui A., Ratnadass A., Pasternak D., Kouame C. (2010). Okra (*Abelmoschus* spp.) in West and Central Africa: potential and progress on its improvement. *African Journal of Agricultural Research,* 5: 3590-3598.

Lengsfeld, C., Titgemeyer, F., Faller, G. and Hensel, A. (2004). Glycosylated compounds from okra inhibit adhesion of *Helicobacter pylori* to human gastric mucosa. *Journal of Agricultural and Food Chemistry*, 52(6): 1495-1503.

Maishanu, H. M., Mainasara, M. M., Yahaya, S. and Yunusa, A. (2017). The use of moringa leaves extract as a plant growth hormone on cowpea (*Vigna anguiculata*). *Traektoria Nauki = Path of Science*, 3(12): 3001-3006.

Makkar, H. P. S. and Becker, K. (1996). Nutritional value and anti-nutritional components of whole and ethanol extracted of *Moringa oleifera* leaves. *Animal Feed Science and Technology*, 63: 211-228.

Makkar, H.P.S., Francis, G. and Becker, K. (2007). Bioactivity of phytochemicals in some lesser-known plants and their effects and potential applications in livestock and aquaculture production systems. *Animal*, 1: 1371-1391.

Manal, A. M., Hassan, A. and Ali, H. M. (2015). The nutritional composition of three cultivars of okra (*Abemoschus esculentus* L.) seeds flour. *World Journal of Dairy and Food Sciences*, 10(2): 122-131.

Ministry of Agriculture (2018). Area and production of okra. http://www.agrimin.gov.lk/web/index.php/statistics (Accessed on 2.7.2018).

Moaward, F. G., Abdelwhab, B. M., Abdelnahun, F. M. and Shehaya, F. W. (1984). *Annual of Agricultural science*, 21: 603 – 613.

Muhammed, R., Olorukooba, M. M. Akinyaju, J. A. and Kambai, E. A. (2013). Evaluation of different concentrations and frequency of foliar application of moringa extract on growth & yield of onion, (*Allium cepa* L). *Agrosearch*, 13(3): 196-205.

Mvumi, C., Tagwira, F. and Chiteka, A. Z. (2013). Effect of moringa extract on growth and yield of maize and common beans. *Greener Journal of Agricultural Sciences*, 3(1): 55-62.

Ogbuehi, H. C. and Agbim, J. U. (2018). Impact of *Moringa oleifera* leaf extract on biochemical contents and yield of soybean (*Glycine max* L.). *International Journal of Advanced Research in Science, Engineering and Technology*, 5(2): 5162-5168.

Ogbuehi, H. C., Emeribe, E. O. and Asagwara, J. O. (2017). Soil application of moringa leaf extract on root development and root exudates of soybean (*Glycine max* L.). *International Journal of Agriculture Innovations and Research*, 6(2): 325-330.

Oluwagbenga, D. and Odeghe, O.T. (2015). Response of sweet bell pepper to moringa leaf extract and oregano bio-degradable fertilizer. *Asian Journal of Agricultural Biology*, 3(4): 117-123.

Ozobia, A. P. (2014). Comparative assessment of effect of Moringa extracts, NPK fertilizer and poultry manure on soil properties and growth performance of *Solanum melongina* in Abuja, North Central Region of Nigeria. *Journal of Agricultural and Crop Research*, 2(5): 88-93.

Purseglove, J.W. (1987). Tropical crops dicotyledons. Language Book Society Longman, London. United Kingdom.

Rady, M. M., Gamal, F., Mohamed, A. M. and Yasmin, H. M. (2015). Integrated application of salicylic acid and *Moringa oleifera* leaf extract aleviates the salt induced adverse effects in common bean plants. *Journal of Agricultural Technology*, 11(7): 1595-1614.

Rady, M. M., Varma, B. and Howladar, S. M. (2013). Common bean (*Phaseolus vulgaris* L.) seedlings overcome NaCl stress as a result of presoaking on *Moringa oleifera* leaf extract. *Scientia Horticulturae*, 162: 63-70.

Taha, L. S., Taie, H. A. A. and Hussein, M. M. (2015). Antioxidant properties, secondary metabolites and growth as affected by application of putrescine and moringa leaves extract on jojoba plants. *Journal of Applied Pharmaceutical Science*, 5(1): 30-36.

Tetley, R. M. and Thimann, K. V. (1974). The metabolism of oat leaves during senescence, respiration, carbohydrate metabolism and the action of cytokinins. *Plant Physiology*, 19(54): 294-303.

Thomas, H., Howarth, C. J. (2000). "Five ways to stay green. Journal of Experimental Botany, (51): 329-337.

Tuna, A. L., Kaya, C., Dikilitas, M. and Higgs, D. (2008). The combined effects of gibberellic acid and salinity on some antioxidant enzyme activities, plant growth parameters in maize plants. *Environmental and Experimental Botany*, 62: 1-9.

Zaki, S. S. and Rady, M. M. (2015). *Moringa oleifera* leaf extract improves growth, physiochemical attributes, antioxidant defense system and yields of salt stressed *Phaseolus vulgaris* L. plants. *International Journal of ChemTech Research*, 8(11): 120-134.

Zhang, X. and Schmidt, R. E. (1999). Bio stimulating turfgrass, ground maintenance. http://license. icopyright. Net, 1-4.