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Original Article

Foliar application of moringa leaf extract as a bio-stimulant on growth, yield and nutritional quality of brinjal

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A B S T R A C T

Natural plant growth stimulants play important roles in triggering growth and boosting economic yield of crops. A field experiment was conducted at Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Rabi season in order to investigate the effect of moringa leaf extract (MLE) on growth, yield and nutritional quality of brinjal. The experiment was laid out in a randomized complete block design with four treatments and three replications. The treatments were T_1 (control), T_2 (MLE sprayed at 2 weeks after transplanting only), T_3 (MLE sprayed at 2 weeks and 4 weeks after transplanting) and T_4 (MLE sprayed at 2 weeks and after every two weeks thereafter). The MLE was applied @ 25 mL plant^{-1} at different growth stages of brinjal as per treatments. The application of MLE significantly increased the growth and yield parameters such as plant height, shoot length, leaf number, fresh and dry weight of root and shoot, root length, number of flower and fruit, weight and length of the largest fruit and fruit yield. Among all the treatments, the growth and yield parameters were the best in T_4 treatment which produced the highest fruit yield of brinjal (31.6 t ha^{-1}). The same treatment also improved the nutritional quality of brinjal as the content and uptake of macronutrients (N, P, K and S) by leaf and fruit increased significantly with higher application of MLE. Thus, MLE as a foliar spray at growth stages has the potentiality to improve the growth, yield and nutrition of brinjal.

Introduction

Moringa (*Moringa oleifera*) is an important vegetable in many tropical and sub-tropical countries including Bangladesh. In Bangladesh, it is grown in the homestead areas as a multipurpose tree which has both nutritional and medicinal value. Several study reports found that moringa is a highly valued plant with multipurpose effects (Adebayo *et al*., 2011; Anwar *et al*., 2007; Mishra *et al*., 2011). Moringa has now-a-days attained enormous attention because of having antioxidants, macro and micro nutrients in its leaves. Moringa leaf extract (MLE) contains a miracle substance called zeatin that serves as a natural plant growth hormone along with other micronutrients that are involved in various vital plant physiological processes. MLE is also known to have sufficient concentration of cytokinin and gibberellic acid that are vital phytohormones, in addition to other growth-enhancing compounds such as ascorbates, phenolics, and minerals (Makkar *et al.,* 2007). Besides, Fuglie (2000) reported that MLE can accelerate plant growth, strengthen and improve resistance to pests and diseases, increase leaf duration, number of roots and produce more and larger fruits with enhancing yield up to 35%. Many researchers have recently focused that MLE application to plant can provide beneficial nutrient elements, improve antioxidant defense system and enhance vegetative as well as reproductive growth resulting in higher yield and economic benefits under stressed and non-stressed situations (Abohassan and Abusuwar, 2018; Aluko *et al.,* 2017; Emongor, 2015; Hala and Nabila, 2017; Merwad, 2017; Ozobia, 2014; Rady and Mohamed, 2015)

Vegetables play important roles in human nutrition, being mostly low in fat and carbohydrates, but high in vitamins, minerals, dietary fiber and phytochemicals. Most of the people of Bangladesh suffer from malnutrition due to lack of proper knowledge on balanced diet and low intake of vegetables and fruits. FAO recommended that vegetables consumption should be at least 200 g/day/person but the average intake of vegetables by Bangladeshi people is far below the standard (FAO, 2017). Brinjal (*Solanum melongena* L.) is an important vegetable for its commercial

and nutritional value in the world as well as in Bangladesh. Brinjal consists of almost 92.7 percent of water and also rich in terms of fiber, folic acid, manganese, thiamin, vitamin B6, magnesium and potassium contents compared to most other vegetables (Rahman *et al.*, 2016). In Bangladesh, there are 46000 and 80000 acres of land under Kharif and Rabi brinjal cultivation with 160000 and 356000 metric tons of brinjal production respectively (YAS, 2018). However, the production of brinjal in our country is quite less in comparison to other Asian countries like China and India. So, it is necessary to find out proper technology for increasing brinjal production to meet the nutritional demand of the country.

In our country, farmers are highly dependent on inorganic fertilizers as source of plant nutrients and the imbalanced use of chemical fertilizers is associated with land and soil degradation as well as environmental pollution (Phiri and Mbewe, 2010). The negative consequences of excess inorganic fertilizer on the environment and human health are on the rise. Therefore, it is high time to search for alternative safe and eco-friendly organic sources of plant nutrients to improve plant and soil health. It was reported that in sustainable farming system, application of organic fertilizers improves crop production and maintains soil fertility (Galbiattia *et al*. 2007). So, MLE as a bio-stimulant having a number of plant growth promoters, mineral nutrients and vitamins in a naturally balanced composition could be beneficial for growth and development of vegetable crops. Although a very few literatures cited the effect of MLE on growth and yield of vegetable crops, the use of MLE to enhance growth and yield of vegetable crops in Bangladesh has not yet been thoroughly investigated. So, more research is needed to elucidate its effects for developing sustainable agricultural practices in our country. The present study was undertaken to investigate the effect of foliar application of MLE on growth, yield and nutritional quality of brinjal.

Materials and methods

Experimental site and soil

The experiment was carried out at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU), Mymensingh. The Geographical location of the research field is $24^0 75'$ N latitude and $90^0 50'$E longitude at an elevation of 18 m above the sea level. The soil belongs to the Sonatala series of Non-Calcareous Dark Grey Floodplain Soils of Old Brahmaputra Floodplain (AEZ-9). The land is moderately well drained and sufficient sunshine is available through the experimental period. The soil was silt loam in texture with pH 6.48, organic matter content 1.93%, total N 0.132%, available P 7.08 ppm, exchangeable K 0.067 me%, available S 11.83 ppm and cation exchange capacity 11.7 meq/100g soil.

Treatments and experimental design

The experiment was laid out in a randomized complete block design (RCBD) with three replications and four treatments. The four treatment combinations were T_1 Foliar spray with water (control), T_2 (MLE foliar spray at 2 weeks after transplanting), T_3 (MLE foliar spray at 2 weeks and 4 weeks after transplanting) and T_4 (MLE foliar spray at 2 weeks after transplanting and after every two weeks thereafter). The experimental area was divided into three blocks representing the replication and each block was subdivided into four unit plots where the four treatments were distributed randomly. The total number of plots was 12. The unit plot size was 2.5 m × 2 m. The spacing between blocks was 1.25 m and the plots were separated from each other by a space of 0.25 m.

Seedling transplanting

Brinjal (hybrid variety named BARI Begun-8) was used as a test crop in this experiment. About 35-days-old brinjal seedlings were transplanted in the experimental plots on the 25th October 2018. The seedlings were uprooted from the seedbed carefully to avoid damage of the root system and transplanted in the afternoon followed by light irrigation for their better establishment. The line to line and plant to plant distance was 60 cm and 50 cm respectively. During daytime, banana leaf sheath were used to provide shade to protect young seedlings from scorching sunlight up to 5 days until their establishment in the soil and kept open at night for allowing them to receive dew. On the border of the experimental plots, a number of extra seedlings were also planted for gap filling.

Fertilizer application

The full amount of triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc oxide were added during final land preparation as basal dose at the rate of 23, 46, 5 and 2 kg ha^{-1}, respectively according to the Fertilizer Recommendation Guide (FRG, 2012). Urea was applied in three installments as top dressing and the rate was 135 kg ha^{-1}. The first split was applied at 15 days after transplanting (DAT) while the second and third split were applied at 30 and 45 DAT, respectively.

Collection of moringa leaves and preparation of MLE

Young leaves of moringa trees were collected from different places of Bangladesh Agricultural University Campus, Mymensingh. For preparation of MLE, about 100 g young leaves were taken into a mortar with a pinch of water (10 ml/100 g fresh material) and ground with a pestle. The juice was extracted by hand pressure and filtered through a cheese cloth. The collected extract was re-filtered using Whatman filter paper No. 2. The extract was diluted with distilled water at a ratio of 1:30 (v/v) and then sprayed directly on the brinjal plants as described by Fuglie (2000). The freshly prepared extract was then stored at 0ºC temperature and only taken out when needed for use.

Application of MLE in the field

The prepared MLE was sprayed @ 25 mL $plant^{-1}$ as per treatments using hand sprayer in the late afternoon. Special attention was given for complete coverage of brinjal plants with spray materials and to avoid drifting of spray materials from one plot to another.

Intercultural operations

The transplanted seedlings were watered by a watering can at every morning and afternoon for a week after transplanting for their rapid and well establishment. Flood irrigation was also given in the field at 31 DAT and 46 DAT. The other intercultural operations such as gap filling, weeding, fencing and pesticide application were done as and when necessary.

Crop harvesting and data collection

As fruit initiation and maturation in plants were not similar, the harvesting of the crop was not possible on a particular date. The crop was harvested at full maturity for the first time on the 20 March, 2019 and lasted on the 31 March, 2019. During harvesting, every plant was uprooted by hand.

Data on growth and yield parameters such as plant height, root length, dry weight of root, shoot length, no. of branch plant^{-1}, fresh and dry weight of shoot, number of leaf, flower and fruits, fresh weight of fruits, weight, length and diameter of the largest fruit, fruit weight plant^{-1} and fruit yield ha^{-1} were recorded at the time of harvesting.

Preparation and analysis of plant samples

The leaf and fruit samples of brinjal were dried in an oven at 65° C temperature for about 48 hours and then ground by a grinding machine to pass through a 20-mesh sieve. The ground plant samples were collected in paper bags separately, placed in a desiccator and analyzed for determination of macronutrient contents (N, P, K and S). The N, P, K and S contents were determined following semi-micro Kjeldahl method, modified Olsen method, NH_4OAc extraction method and $CaCl_2$ extraction method, respectively. After chemical analysis of plant samples, the nutrient uptake was calculated from the nutrient content and yield of the crop.

Statistical analysis

The recorded data on different parameters were statistically analyzed to get the level of significance using the MSTAT–Computer package program (Russell, 1986). The differences among treatment means were compared by Duncan's New Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Results and discussion

Effect of MLE on growth parameters of brinjal

Application of MLE significantly influenced growth parameters of brinjal such as plant height, shoot length, no. of leaf plant^{-1}, fresh and dry weight of shoot, root length, fresh and dry weight of root except no. of branches plant^{-1}(Table 1).The highest plant height (93.67 cm) was found in T_4 treatment (MLE foliar spray at 2 weeks after transplanting and after every two weeks thereafter) followed by T_3 (MLE foliar spray at 2 weeks and 4 weeks after transplanting). Treatment T_2 (MLE foliar spray at 2 weeks after transplanting) and T_1 (control) exerted statistically similar effect on plant height. The highest shoot length (69.22 cm) was also recorded in T_4 treatment followed by T_3 (66.94 cm) whereas the lowest shoot length was found in control treatment (T_1). The highest no. of leaf plant^{-1} was observed in T_4 treatment which is statistically at par with T_3 and the lowest no. of leaf was found in control plots. The highest and the lowest fresh weight of shoot and fresh weight of root were recorded in treatment T_4 and T_1 respectively. The highest value of dry shoot weight (6.95 g) was found in T_4 treatment followed by T_3 (5.8 g) and the lowest fresh shoot weight was found in control treatment which was statistically similar with treatment T_2. The highest root length was observed in T_4 treatment which was statistically at par with T_3 and T_2 and the lowest root length was found in control plots. The highest dry weight of root (29.00 g) was recorded in T_4 treatment which was statistically similar with T_3 and the lowest dry root weight was obtained from control (17.39 g). These results are in agreement with the findings of Muhamman *et al.* (2013), Ozobia, (2014), Rady *et al.* (2015), Rana *et al.* (2019), Yusuff and Abiola, (2019) and Hoque *et al.* (2020) who reported increased plant height, fresh weight and dry weight of shoot and better crop growth rate in different vegetable crops including tomato, eggplant, common bean, cauliflower, cucumber and cabbage respectively with foliar application of MLE compared to control.

Table 1. Effect of moringa leaf extract on growth parameters of brinjal

Treatments	Plant height (cm)	Shoot length (cm)	No. of branches plant^{-1}	No. of leaf plant^{-1}	Fresh weight of shoot (g)	Dry weight of shoot (g)	Root length (cm)	Fresh weight of root (g)	Dry weight of root (g)
T_1	81.39c	61.08c	17.33	35.33c	47.70d	4.17c	20.31b	45.28d	17.39c
T_2	83.77c	62.38c	17.66	38.33bc	56.14c	4.74c	21.39ab	51.56c	22.22b
T_3	89.55b	66.94b	18.39	41.33ab	64.84b	5.8b	22.61a	56.06b	25.67a
T_4	93.67a	69.22a	19.17	44.33a	87.72a	6.95a	24.45a	60.89a	29.00a
CV (%)	12.61	10.99	24.59	9.62	16.10	22.06	17.62	22.43	11.42
Level of Sig.	**	**	NS	**	**	**	**	**	**

Figures in a column having common letter (s) do not differ significantly. CV=Co-efficient of variation, NS= Non significant, ** = Significant at 1% level of probability, Treatment details:
T_1 =Control (foliar spray with water), T_2 = MLE sprayed at 2 weeks after transplanting, T_3 =MLE sprayed at 2 weeks and 4 weeks after transplanting, T_4 =MLE sprayed at 2 weeks after transplanting and after every two weeks thereafter

Effect of MLE on yield parameters and yield of brinjal plant

Yield components of brinjal including no. of flower plant^{-1}, no. of fruit plant^{-1}, weight of the largest fruit (g), length of the largest fruit (cm), fruit weight plant^{-1} (kg) and fruit yield (t ha^{-1}) were significantly affected by different treatments while the diameter of the largest fruit (cm) remained significantly unaffected (Table 2). The highest number of flower plant^{-1} was obtained from T_4 treatment (14.66) followed by T_3 and the lowest number of flower plant^{-1} was recorded in control treatment (10.66). Treatments T_4, T_3 and T_2 exerted similar influence on the number of fruit plant^{-1} and showed higher values than control treatment. The maximum weight of the largest fruit (93 g) was recorded at T_4 treatment which was statistically similar with that observed in T_3 treatment. The minimum weight of the largest fruit (58.53 g) was observed in T_1 (control) which was statistically similar with the result obtained from treatments T_2 and T_3. The maximum length of the largest fruit was observed in T_4 treatment which was not statistically different from T_3 and the minimum value was found in T_1. The highest fruit weight plant^{-1} (0.79 kg) was noted at T_4 treatment while the lowest weight of fruit (0.34 g) was noted at T_1 treatment. The highest yield of brinjal fruit (31.6 t ha^{-1}) was found in T_4 treatment and the lowest yield of brinjal (13.6 t ha^{-1}) was recorded in T_1 treatment that received no MLE. The percent increase in fruit yield over control has been presented in Fig. 4.1. The fruit yields were increased over control in the treatments where MLE was sprayed ranging from 6.4 to 18 t ha^{-1} (Table 2).

Table 2. Effect of moringa leaf extract on yield parameters and yield of brinjal

Treatments	No. of flower plant^{-1}	No. of fruit plant^{-1}	Weight of the largest fruit (g)	Length of the largest fruit (cm)	Diameter of the largest fruit (cm)	Fruit weight plant^{-1} (kg)	Fruit yield (t ha^{-1})
T_1	10.66c	7.66b	58.53b	22.72b	2.39	0.34d	13.6d
T_2	12.64b	10.00a	60.83b	23.11b	2.88	0.50c	20.0c
T_3	13.34b	10.66a	82.80ab	27.67a	2.69	0.66b	24.8b
T_4	14.66a	11.34a	93.00a	29.39a	2.81	0.79a	31.6a
CV (%)	15.53	12.06	13.87	18.22	16.66	17.66	13.83
Level of Sig.	**	**	**	**	NS	**	**

Figures in a column having common letter (s) do not differ significantly, CV=Co- efficient of variation, NS= Non significant, ** = Significant at 1% level of probability, Treatments details:
T_1 =Control (foliar spray with water), T_2 = MLE sprayed at 2 weeks after transplanting, T_3 =MLE sprayed at 2 weeks and 4 weeks after transplanting, T_4 =MLE sprayed at 2 weeks after transplanting and after every two weeks thereafter

The treatments with MLE caused 47.05 to 132.35 percent increase in fruit yield over control (Figure 1). Similarly Emongor *et al.* (2015), El-Mageed *et al.* (2017) and Rana *et al.* (2019) found significant positive effects of MLE application on yield components and better yields of vegetables with various doses of MLE. Many researchers reported that application of MLE improved growth and yield performance of crop due to the presence of zeatin (a cytokinine related hormone) in the extract (Makkar *et al.*, 2007; Mvumi *et al.*, 2013; Abdalla, 2013).

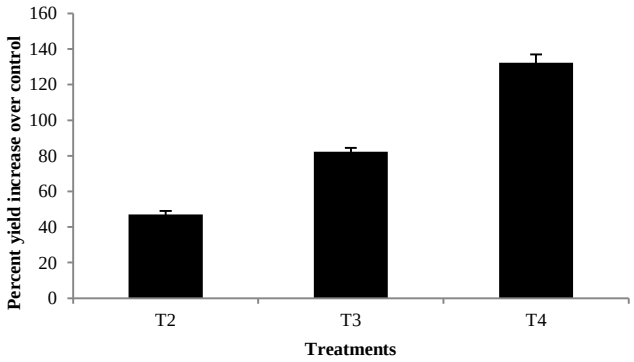

Figure 1. Percent increase in fruit yield of brinjal over control as influenced by different treatments

Effect of moringa leaf extract on nutrient content in brinjal leaf and fruit

Application of MLE showed significant effects on the nutrient content (N, P, K and S) in leaf and fruit of brinjal (Table 3). The N content of brinjal leaf and fruit significantly varied with MLE application. The highest N content in brinjal leaf and fruit (2.30% and 0.89%, respectively) was obtained from T_4 treatment (MLE foliar spray at 2 weeks after transplanting and after every two weeks thereafter). The lowest N contents in brinjal leaf and fruit (0.92% and 0.59%, respectively) were observed in T_1 (control). The highest P contents in brinjal leaf and fruit (0.86% and 0.77%, respectively) were found in T_4 treatment which were statistically similar with those recorded in T_3 treatment. The lowest content of P in brinjal leaf and fruit (0.58% and 0.38%, respectively) was recorded in T_1 (control). The treatments T_1 and T_2 were statistically similar for fruit P content. The highest K contents in brinjal leaf and fruit (0.43% and 0.36%, respectively) were observed in T_4 treatment which was not statistically dissimilar with T_3 treatment. The lowest K contents in brinjal leaf and fruit (0.23% and 0.15%, respectively) were found in T_1 treatment which were statistically similar with those recorded in T_2. The highest S contents in leaf and fruit (0.39% and 0.24%, respectively) were obtained from T_4 treatment. The lowest S contents in brinjal leaf and fruit (0.09% and 0.06%, respectively) were obtained in T_1 treatment. The results of our study were accorded to those of several comparable studies of some researchers (Sivakumar and Ponnusami, 2011; Abdalla and EI-Khoshiban, 2012) suggesting that the increased uptake and accumulation of some macronutrient elements such as N, P, K and S in several plants under investigation as a consequence of application of moringa leaf extract. Hoque *et al.* (2020) also found increased N, P, K and S contents in cabbage head due to application of MLE. Merwad (2017) found the highest percent increase of N, P, and K accumulation in pea for shoot and for seed with foliar application of 4% MLE.

Table 3. Effect of moringa leaf extract on nutrient contents in brinjal leaf and fruit

Treatments	% N		% P		% K		% S	
	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit
T_1	0.92c	0.59b	0.58c	0.38b	0.23b	0.15b	0.09c	0.06c
T_2	1.08bc	0.67b	0.69b	0.50b	0.30ab	0.19b	0.22b	0.10bc
T_3	1.35b	0.82ab	0.75ab	0.67a	0.38a	0.26ab	0.29ab	0.16b
T_4	2.30a	0.89a	0.86a	0.77a	0.43a	0.36a	0.39a	0.24a
LSD	0.32	0.49	0.44	0.75	0.05	0.05	0.01	0.01
CV (%)	13.50	17.64	22.25	10.41	9.61	16.87	8.04	9.56
Level of Sig.	**	**	**	**	**	**	**	**

Figures in a column having common letter (s) do not differ significantly, CV=Co- efficient of variation, ** = Significant at 1% level of probability, Treatments details:
T_1 =Control (foliar spray with water), T_2 = MLE sprayed at 2 weeks after transplanting, T_3 =MLE sprayed at 2 weeks and 4 weeks after transplanting, T_4 =MLE sprayed at 2 weeks after transplanting and after every two weeks thereafter

Effect of moringa leaf extract on nutrient uptake by brinjal leaf and fruit

Like nutrient contents, application of MLE significantly affected the uptake of nutrients (N, P, K and S) by brinjal leaf and fruit (Table 4). The N uptake by brinjal leaf and fruit varied significantly due to application of MLE. The highest N uptake by leaf and fruit (570.4 kg ha^{-1} and 281.24 kg ha^{-1}, respectively) was obtained from T_4 treatment (MLE sprayed at 2 weeks after transplanting and every two weeks thereafter). The lowest N uptake by brinjal leaf and fruit (125.12 kg ha^{-1} and 80.24 kg ha^{-1}, respectively) was recorded in T_1 treatment (control). The P uptake by brinjal leaf and fruit differed significantly due to foliar application of MLE. The highest P uptake by leaf and fruit (271.76 kg ha^{-1} and 243.32 kg ha^{-1}, respectively) was found in T_4 treatment whereas the lowest P uptake by leaf and fruit (78.88 kg ha^{-1} and 51.68 kg ha^{-1}, respectively) was obtained in T_1 treatment. The highest K uptake by leaf and fruit (132.72 kg ha^{-1} and 113.76 kg ha^{-1}, respectively) was obtained from T_4 treatment (MLE sprayed at 2 weeks after transplanting and every two weeks thereafter). The lowest K uptake by leaf and fruit (31.08 kg ha^{-1} and 20.4 kg ha^{-1}, respectively) was recorded in T_1 treatment. The highest S uptake by leaf and fruit (123.24 kg ha^{-1} and 75.84 kg ha^{-1}, respectively) was obtained from T_4 treatment. The lowest S uptake by brinjal leaf and fruit (12.24 kg ha^{-1} and 8.16 kg ha^{-1}, respectively) was observed in T_1 treatment. Several comparable studies confirmed the current data. The increased uptake and accumulation of N, P, K and S in several plants were found as a consequence of foliar application of MLE (Merwad and Abdel-Fattah, 2017; Hala and Nabila, 2017; Jhilik *et al.*, 2018; Hoque *et al.*, 2020). As the leaves of moringa plant have been reported to be a rich source of important nutrient elements (Yameogo *et al.*, 2011and Moyo *et al.*, 2011), MLE improves uptake of beneficial elements and increases the nutrient status of plants.

Table 4. Effect of moringa leaf extract on nutrient uptake by brinjal leaf and fruit

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit
T_1	125.12d	80.24d	78.88d	51.68d	31.08d	20.4d	12.24d	8.16d
T_2	216.0c	134.0c	138.0c	100.0c	59.80c	38.00c	44.00c	20.00c
T_3	334.8b	203.36b	186.0b	166.16b	94.24b	64.48b	71.92b	39.68b
T_4	570.4a	281.24a	271.76a	243.32a	132.72a	113.76a	123.24a	75.84a
CV (%)	12.73	21.37	9.67	12.44	12.39	14.19	15.66	8.25
Level of Sig.	**	**	**	**	**	**	**	**

Figures in a column having common letter (s) do not differ significantly, CV=Co- efficient of variation, ** = Significant at 1% level of probability, Treatments details:
T_1 =Control (foliar spray with water), T_2 = MLE sprayed at 2 weeks after transplanting, T_3 =MLE sprayed at 2 weeks and 4 weeks after transplanting, T_4 =MLE sprayed at 2 weeks after transplanting and after every two weeks thereafter

Conclusion

Moringa oleifera is one of the best natural, eco-friendly and cheap plant growth stimulants enriched with phytohormones, phenolics, vitamins and minerals. Application of MLE can play a vital role in increasing crop growth and improving crop with higher nutritional value. The present study suggests that the MLE had significant positive effect on growth parameters of brinjal such as plant height, length of shoot and root, number of leaves $plant^{-1}$, fresh weight and dry weight of root and shoot. Application of MLE significantly improved various yield components of brinjal including number of flowers and fruits, length and weight of the largest fruit. MLE increased fruit yield of brinjal under field condition and the highest frequency of moringa application during growth stages of the crop gave the highest yield. The maximum application of MLE on brinjal caused 132.35% increase in fruit yield over control. Foliar application of MLE on brinjal can improve the content and uptake of nutrients *viz:* N, P, K and S in leaf, fruit and in total. Further research in other vegetable crops is necessary to confirm the novel effect of MLE and its use in sustainable agricultural practices in Bangladesh.

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