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Effect of foliar application of micronutrients on growth, yield, and quality of annual moringa (*Moringa oleifera* Lam.) var. PKM-1

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Abstract
In order to explore the response of foliar application of micronutrients on growth, yield and quality of annual moringa (*Moringa oleifera* Lam.) var. PKM-1 a field experiment was carried out at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam during the year 2018 to 2019. The treatments consist of Ferrous (1%), Boron (0.2%), Zinc (0.5%), Manganese (0.5%), a mixture of all with control and the experiment was laid out in RBD with three replications. Treatment combination was sprayed at three stages – Vegetative, flowering and pod setting stage. In annual moringa var. PKM-1 maximum plant height (1.43m, 2.39m, 5.36m), trunk girth (2.20m, 18.01m, 32.00 m), number of pods per tree (120 pods), pod length (80.25cm), pod girth (7.9cm), ascorbic acid content (61.34 mg/100g, 65.39 mg/100g, 68.91mg/100g and in pod 43.06 mg/100g) and carotenoid (29.50 mg/100g, 30.13mg/100g, 35.10mg/100g and in pod 5.11 mg/100g) content were recorded in T_8 (Mixture of all micronutrients) and followed by T_6 [(Ferrous Sulphate 1% + 0.1% Citric Acid) + Zinc Sulphate 0.5%]. However, number of panicles per tree (20.71, 64.20,120.00), number of flowers per panicle (16.97, 29.33, 54.67) and number of pods per panicle (2.29) was recorded in T_8 and followed by T_5 (Boric Acid 0.2%). This research trial proves that foliar application of micronutrients induced good growth, yield, and quality in annual moringa var. PKM-1.

Keywords: Moringa, micronutrients, foliar application, growth, yield, quality

Introduction
Moringa oleifera Lam. is one of the best-known crops with various uses and many good qualities that get widely distributed and naturalized species that belongs to monogeneric family Moringaceae (Nadkarni, 1976; Ramachandran *et al.*, 1980) [24, 30]. The genus *Moringa* has more than 13 species, of which two species *viz.*, *M. oleifera* and *M. concanensis* occur in India are being used as a vegetable. The tree grows to a height ranging from 5 to 10 m (Morton, 1991) [22]. Moringa tree has been grown throughout the plains, especially in-house yards and it thrives best in a tropical climate and it also grows well near sandy beds of rivers, streams and in humid tropics with little drought (The Wealth of India, 1962; Qaiser, 1973 and Morton, 1991) [36, 22]. It requires minimum annual rainfall of about 250 mm and maximum at over 3000 mm with pH ranging between 5.0 - 9.0 (Palada and Changl, 2003) [26].
Moringa is native of the western and sub- Himalayan tracts, India, Pakistan, Asia Minor, Africa and Arabia (Somali *et al.*, 1984; Mughal *et al.*, 1999; Rajangam *et al.*, 2001) [35, 23, 29]. *Moringa oleifera* is also known by several synonyms as 'The Spinach Tree, 'Mother's Best Friend', 'Miracle Tree', 'Horse Radish Tree', 'Drumstick Tree', 'West Indian Ben', 'Murungai (In Tamil)' etc., (Ramachandran *et al.*, 1980) [30].
Moringa oleifera is an important vegetable which has various attention as the Natural nutrition of the tropics. The leaves, pods, flowers and immature pods of this tree has enormous nutrients and because of these high nutritive values it is used as vegetable in many countries, particularly India, Philippines, Hawaii, Pakistan and many parts of Africa (D'souza and Kulkarni, 1993; Anwar and Bhanger, 2003; Anwar *et al.*, 2005) [8, 2, 3]. It has been reported that moringa leaves are rich in Beta- carotene, protein, vitamin-C, Calcium, and Potassium and it also acts a good source of natural antioxidants (Dillard and German, 2000; Siddhuraju and Becker, 2003) [11, 33]. *Moringa oleifera* also has a number of medicinal properties and almost all parts of the plant – Root, bark, gum, leaf, Pods, flowers, seed and seed oil have been used for various ailments in the traditional medicine of South Asia for the treatment of inflammation and infectious diseases like cardiovascular, gastrointestinal, haematological and hepatorenal disorders (The Wealth of India, 1962; Singh and Kumar, 1999; Morimitsu *et al.*, 2000; Siddhuraju and Becker, 2003) [36, 34, 21, 33].
Micronutrients are not only required for better growth, development, yield, and quality but it

is also important as other major nutrients even though its requirement in micro quantity. These micronutrients help in the uptake of major nutrients and also play a vital role in the growth of plants, acting as a catalyst in promoting various metabolic reactions like cell development to respiration, photosynthesis, chlorophyll formation, enzyme activity, hormones synthesis and nitrogen fixation (Ranganathan and Perumal, 1995) [32] Applications of micronutrients like ferrous, zinc, boron and manganese have been reported in increasing growth, yield and quality in various vegetable crops. However, very little information is available regarding the effect of micronutrients on Moringa. Due to high nutrient content in moringa leaves and pods, their availability can be increased by providing the foliar application of micronutrients. In order to study the effect of foliar application of different micronutrients on growth, yield and quality parameters in moringa a field trial entitled "Effect of foliar application of micronutrients on growth, yield and quality annual moringa (*Moringa oleifera* Lam.) var. PKM-1" was conducted in Horticultural college and research institute, Periyakulam, Theni District.

Materials and methods

A field experiment was conducted during the year 2018-19 to find out the response of foliar application of micronutrients on growth and quality parameters of annual moringa var. PKM-1 at Western Block (10.13^0 N latitude, 77.59^0 E longitude), Horticultural college and research institute, Periyakulam, Theni, Tamil Nadu. The treatments consisted of iron, boron, zinc, manganese, a mixture of all and control. The experiment was laid in RBD with 3 replications. Seeds of moringa var. PKM 1 was sown in an area of 0.43 Acre with a spacing of 2.5 m X 2.5 m.

Micronutrients application

There were eight treatments involving Four micronutrients (Fe, Mn, Zn and B) viz., T1 - Control (water spray) ; T_2 - Ferrous Sulphate 1% + Citric Acid 0.1% ; T_3 - Zinc Sulphate 0.5% ; T_4 - Manganese Sulphate 0.5% ; T_5 - Boric Acid 0.2% ; T_6 - (Ferrous Sulphate 1% + 0.1% Citric Acid) + Zinc Sulphate 0.5% ; T_7 - Zinc Sulphate 0.5% + Manganese Sulphate 0.5% ; T_8 – Mixture of all Treatments. All the micronutrients were applied as foliar spray at three stages viz., (Vegetative stage, Flowering stage and Pod setting stage).

Observations recorded

Observations on various growth and quality parameters like plant height, stem girth, number of primary, Days to first flowering, number of panicles, number of flowers per panicle, number of pods per plant, number of pods per panicle, individual pod weight, fruit setting percentage, fruit length, fruit girth, number of seeds, protein, carotenoid, ascorbic acid, chlorophyll A, B and total chlorophyll content were recorded on five randomly selected plants for each treatment in each replication. Average values were computed and the data were subjected to statistical analysis (Panse and Sukhatme, 1985) [27].

Table 1: Effect of foliar application of micronutrients on Growth parameters of annual moringa var. PKM-1

Treatment	Plant Height (m)				Trunk girth (cm)			
	Vegetative stage	Flowering stage	Pod setting stage	Mean	Vegetative stage	Flowering stage	Pod setting stage	Mean
T_1 (Control)	1.05	2.04	4.71	2.60	1.79	14.54	27.30	14.54
T_2	1.23	2.27	5.10	2.87	1.96	15.79	28.10	15.28
T_3	1.19	2.32	4.88	2.80	1.94	15.35	29.90	15.73
T_4	1.23	2.10	4.79	2.71	2.01	15.84	28.40	15.42
T_5	1.27	2.09	5.20	2.85	2.11	16.28	31.80	16.73
T_6	1.42	2.33	5.23	2.99	2.17	17.43	31.52	17.04
T_7	1.32	2.18	5.18	2.89	2.01	17.25	30.10	16.45
T_8	1.43	2.39	5.36	3.06	2.20	18.01	32.00	17.40
SE (d)	0.02	0.05	0.09	0.06	0.04	0.30	0.48	0.28
CD (0.05)	0.05	0.10	0.20	0.12	0.10	0.65	1.04	0.60

Table 2: Effect of foliar application of micronutrients on a number of panicles per tree and number of flowers per panicles of annual moringa var. PKM-1

Treatment	Number of panicles per tree (No's)				Number of flowers per panicle (No's)			
	Vegetative stage	Flowering stage	Pod setting stage	Mean	Vegetative stage	Flowering stage	Pod setting stage	Mean
T_1 (Control)	16.06	52.60	69.50	46.05	12.72	14.40	34.00	20.37
T_2	14.83	57.80	78.80	50.48	13.19	15.13	22.00	16.77
T_3	32.52	48.60	82.50	54.54	14.50	15.73	34.33	21.52
T_4	25.08	51.50	101.00	59.19	13.25	16.00	27.67	18.97
T_5	21.73	59.20	105.00	61.98	15.81	27.80	48.00	30.54
T_6	21.28	59.00	100.00	60.09	15.71	21.00	32.33	23.01
T_7	26.84	54.60	90.00	57.15	13.55	21.27	41.33	25.38
T_8	20.71	64.20	120.00	68.30	16.97	29.33	54.67	33.66
SE (d)	7.0	1.36	2.53	3.65	2.39	0.59	0.58	1.19
CD (0.05)	15.09	2.93	5.43	7.82	5.12	1.26	1.24	2.55

Table 3: Effect of foliar application of micronutrients on yield characteristics of annual moringa var. PKM-1

Treatment	Number of pods per panicle (No's)	Number of pods per tree (No's)	Pod Length (cm)	Pod girth (cm)
T_1 (Control)	1.20	68.80	68.58	6.94
T_2	1.52	69.80	71.78	7.22
T_3	1.16	69.50	74.72	7.06
T_4	1.56	74.50	74.92	7.34
T_5	2.28	100.00	75.64	7.42
T_6	2.20	110.00	79.86	7.80
T_7	1.84	100.00	76.84	7.58
T_8	2.29	120.00	80.25	7.93
SE (d)	0.05	2.36	1.91	0.18
CD (0.05)	0.11	5.07	4.11	0.38

Table 4: Effect of foliar application of micronutrients on Carotenoid content in leaves and pods of annual moringa var. PKM-1

Treatment	Carotenoid (mg/100g)				
	Leaves			Mean	Pod
	Vegetative stage	Flowering stage	Pod setting stage		
T_1 (Control)	23.26	25.43	27.63	25.44	0.85
T_2	22.26	23.44	24.64	23.45	1.34
T_3	14.88	25.88	26.88	22.55	1.56
T_4	19.34	25.92	29.52	24.93	1.41
T_5	21.67	26.35	30.07	26.03	3.62
T_6	27.58	23.55	27.16	26.10	4.66
T_7	24.68	25.76	27.63	26.02	4.15
T_8	29.50	30.13	35.10	31.58	5.11
SE (d)	2.28	0.35	2.58	1.74	0.05
CD (0.05)	4.90	0.75	5.53	3.73	0.11

Table 5: Effect of foliar application of micronutrients on Ascorbic acid content in leaves and pods of annual moringa var. PKM-1

Treatment	Ascorbic Acid (mg/100g)				
	Leaves			Mean	Pod
	Vegetative stage	Flowering stage	Pod setting stage		
T_1 (Control)	47.45	48.12	45.43	47.00	11.81
T_2	45.72	46.72	47.82	46.75	39.58
T_3	51.26	55.39	58.82	55.16	31.25
T_4	52.66	50.93	52.67	52.09	38.19
T_5	55.56	59.03	61.34	58.64	37.50
T_6	55.56	61.34	67.08	61.33	38.89
T_7	59.03	52.66	64.73	58.81	41.67
T_8	61.34	65.39	68.91	65.21	43.06
SE (d)	1.25	0.94	3.37	1.86	0.78
CD (0.05)	2.70	2.03	7.23	3.99	1.67

Result and discussion

The foliar application of micronutrients in annual moringa var. PKM-1 at vegetative, flowering and pod setting stage has effect on the growth, yield and quality parameters such as Plant height (1.43m, 2.39m, 5.36m), Trunk girth (2.20m, 18.01m, 32.00 m), Number of panicles per tree (20.71, 64.20,120.00), Number of flowers per panicle (16.97, 29.33, 54.67), pod length (80.25cm), pod girth (7.9cm), carotenoid (vegetative stage- 29.50 mg/100g, flowering stage- 30.13 mg/100g, Pod setting stage- 35.10 mg/100g and pod- 5.11 mg/100g) and ascorbic acid (vegetative stage- 61.34 mg/100g, flowering stage- 65.39 mg/100g, Pod setting stage- 68.91 mg/100g and pod- 43.06 mg/100g). Respectively. Better growth and quality in moringa leaves and pods are due to the rapid assimilation of micronutrients by foliar application.

Growth Characters

The combination of all micronutrients i.e. T_8 recorded highest plant height of about 1.43m in the vegetative stage, 2.39m in the flowering stage, 5.36m in pod setting stage and on an average value of these three stages it recorded as 3.06 m which is highest of all other treatments followed by T6, T7, and T5. Increase in plant height may be attributed to the Iron which plays an important role in promoting growth characters, being a component of ferredoxin, an electron transport protein and is associated with chloroplast. It helps in photosynthesis might have helped in better vegetative growth (Hazra *et al.*, 1987) [14]. Manganese acts as an activator for enzymes in growth processes and it helps iron in chlorophyll formation (Lohry, 2007) [15] this may be responsible for increasing the plant height by promoting photosynthetic activity. Zinc in auxin synthesis and association of boron with the development of cell wall and cell differentiation that helps in the root and shoot growth of plants (Basavarajeswari *et al*, 2008) [7]. This might have promoted better plant growth. These results are in conformity with Naga Sivaiah (2013) in tomato, Manna *et al.* (2014) in onion, Mehraj *et al.* (2015) in okra [25, 18, 19].

Trunk girth of moringa recorded the highest value in T8 containing a combination of micronutrients (2.20 cm, 18.01cm and 32.00 cm) during vegetative, flowering and pod setting stage respectively. Even the mean value of trunk girth of all these stages (17.40 cm) was high in T8 followed by T6 and T5. Improvement in growth characters as a result of the application of micronutrients might be due to the enhanced photosynthetic and other metabolic activity which leads to an increase in various plant metabolites responsible for cell division and elongation as opined by Hatwar *et al.* (2003) [13]. According to Das and Mahapatra and Das and Sahoo foliar application of boron at 0.5 and 105 ppm to potato and brinjal crops, respectively gave a significant increase in plant height, a number of branches and leaves and main stem thickness, this might have induced the development of trunk girth. These results were similar to the research findings of Hatwar *et al.* (2003) in chilli, El-Yazeid *et al.* (2007) in squash and Mehraj *et al.* (2015) [13, 19] in okra.

Yield Characters

Foliar application of all micronutrients as a combination (T8) in annual moringa var. PKM-1 induced maximum number of panicles per tree and a maximum number of flowers per panicle during vegetative, flowering and pod setting stages followed by T5 and T6. These results were similar to the results of Mallick and Muthukrishnan, (1980) in tomato, Patil *et al.* (2010) [16, 28] in tomato and Mondal *et al.* (2011) in mung bean. As a result of these influence of micronutrients in the number of flowers and panicles per tree, it also has a direct effect on the number of pods per panicle and number of pods per tree. The highest value in a number of pods per panicles and number of pods per tree was recorded in T8 followed by T5 and T6 and T8 followed by T6, T5, and T7 respectively. A maximum number of flowers, flower clusters

were influenced by the application of boron that attributed to flower retention, pollen tuber germination, assimilation of nitrates and the increase in fruit weight might be due to better mineral utilization of plants accompanied with the enhancement of photosynthesis, other metabolic activity and greater diversion of food material to fruits. This would have Increased the fruit size and weight by the application of micronutrients (Bajpai *et al*, 2001) [5]. This result is in line with the report of Jobori and Hadithy, (2014) [1] in potato and Mehraj *et al.* (2015) [19] in okra.

Pod length and Pod girth were increased by foliar application of micronutrients when compared to control. The maximum increase in the pod length and pod girth was recorded in the foliar application of a mixture of all micronutrients in T8 followed by T6, T5, and T7. These are in conformity with Manas *et al.* (2014) [17] in chilli, Mehraj *et al.* (2015) [19] in okra and Aske *et al.* (2017) [4] in onion.

Quality characters

Effect of foliar application of micronutrients also involves in the increasing the quality of Moringa leaves and pods. Maximum carotenoid content was recorded in T8 of moringa leaves and pods. Leaves contain more carotenoid than in pods. Combination of all micronutrients increased the carotenoid content gradually in leaves during its vegetative, flowering and pod-setting phase followed by T5, T4, T6, and T7. This result was in conformity with Mishra *et al.* (2012) in tomato. Similarly, the foliar application of micronutrients also increased the ascorbic acid content in moringa leaves and pods. Spraying of a mixture of all micronutrient as in T8 increased the ascorbic acid content in leaves and pods followed by T6, T7. When compared to leaves ascorbic acid content in pods are lesser. These results are similar to that of Mishra *et al.* (2012) in tomato and Ballabh *et al.* (2013) [6] in onion. Micronutrients play an important role and act as a precursor in many enzyme activities, biosynthesis process, and metabolic pathways, thus this might assist in promoting the quality factors (Richter and Lamppa, 2003; Lohry, 2007) [31, 15]

Conclusion

In the present research trial, the foliar spray of T8 – (Ferrous Sulphate 1% + Citric Acid 0.1%, Zinc Sulphate 0.5%, Manganese Sulphate 0.5%, Boric Acid 0.2%) at three stages-vegetative stage, flowering stage and pod setting stage was found to be effective over control (Water spray). It can be concluded that the combination of all micronutrients showed positive results in plant height, trunk girth, number of panicles per tree, number of flowers per panicle, number of pods per panicle, number of pods per tree, pod length and pod girth that supports in increasing the yield parameter of the annual moringa var. PKM-1. Even treatments like T6, T7, and T5 were equally effective in augmenting all these parameters over the untreated control.

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