



A Miracle Multipurpose Tree (*Moringa oleifera*) with Recent Applications in Agriculture

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Various studies have focused on improving crop yield through methods like nursery management, transplanting, seed quality, weeding, and pest control. One promising approach involves using Moringa Leaf Extract (MLE), which contains compounds that may boost seed germination, plant growth, and overall crop productivity. MLE can be applied in different ways: soaking seeds (osmopriming), spraying on leaves (foliar spray), or simply using it to hydrate seeds (hydropriming). MLE has been shown to promote better seedling emergence and growth in maize and enhance the performance of tomato and sweet bell pepper plants. It helps plants grow vigorously, maintain proper water balance, improve cell membranes, and increase antioxidant levels, leading to higher yields and better quality produce.

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1. INTRODUCTION

Moringa oleifera, a versatile tree native to India and Pakistan, is gaining recognition for its various benefits in agriculture. Its leaf extracts are rich in antioxidants and nutrients, acting as natural growth stimulants for crops. These extracts contain essential compounds like zeatin, which promote plant growth and productivity. Studies have shown that applying *Moringa* leaf extract to seeds or as a foliar spray can enhance crop resilience to environmental stresses like drought, salinity, and heavy metals, while also boosting overall yield. Korkmaz, A et al., 2009 [22]

Furthermore, *Moringa* leaves are a rich source of vitamins and minerals, making them valuable for human and animal consumption. Farmers are increasingly turning to organic fertilizers like *Moringa* leaf extract to improve crop production

and soil health. The extract's effect is similar to synthetic hormones due to its cytokinin content, which aids in antioxidant activity and protects cells from damage. Martin, LP 2008 [24]

Research indicates that using *Moringa* extract can increase crop yield significantly, with reports of up to a 40% boost in chili pepper yield. Pepper, being a vital vegetable crop, benefits from *Moringa* extract's growth-promoting properties, aiding in seed germination and overall plant development. However, the effective concentration of *Moringa* leaf extract may vary depending on the plant type and specific conditions. Mishra, SM 2008 [25]

In essence, *Moringa* leaf extract offers a natural and cost-effective solution for farmers to enhance crop growth, improve yield, and promote sustainable agriculture practices [35,36].

Table 1. Effect of *Moringa oleifera* Leaf Extract (MLE) in different crops

Crops	Treatment/mode of application	Outcome	References
Wheat	Foliar Application /blended <i>Moringa</i> leaf extract	The leaf extract from <i>Moringa</i> originating in Faisalabad showed superior performance in enhancing the emergence and vigor of wheat seedlings compared to leaf extracts from Multan origin <i>Moringa</i> and PKM1. This could be because the Faisalabad <i>Moringa</i> extract contained higher levels of biostimulant elements, substances that promote plant growth, essential minerals, and antioxidants. Essentially, the leaf extract from Faisalabad <i>Moringa</i> had stronger biostimulant properties, likely due to its richer composition of beneficial compounds, making it more effective for improving wheat seedling growth and health.	Khan S et al. [1]
Wheat	Seed osmopriming /foliar spray	Using MLE (<i>Moringa</i> leaf extract) at a concentration of 3.3%, either as seed osmopriming (SP) or foliar spray (F), resulted in better growth of both shoot and root lengths, along with improved leaf and root quality compared to water treatment (hydropriming, HP). This improvement could be attributed to the MLE treatments helping maintain soluble stem reserves, which potentially contributed to higher grain weight by delaying leaf aging and supporting grain filling. Additionally, SP and F treatments led to earlier spike emergence and flowering. The combined SP and F treatment showed the highest benefits, followed by SP	Rehman U et al. [2]

Crops	Treatment/mode of application	Outcome	References
		alone, in terms of plant height, tiller number, and both biological and grain yields per plant. This suggests that MLE, containing zeatin, a cytokinin, sustained the green leaf area for photosynthesis and promoted better grain filling, resulting in improved grain yield when used as SP alone or in combination with foliar spray. Abdalla, MM 2012 [17]	
Tomato	Sprayed at the stem base of the plant	In the experiment, tomato plants were subjected to different treatments, including Moringa leaf extract solutions of varying concentrations and a control group treated with distilled water. Four growth parameters—plant height, number of leaves, number of branches, and number of flowers—were measured weekly over five different time points. Across the study area, there was a noticeable increase in these parameters. Compared to the control group, which had the lowest average values for all growth parameters, the plants treated with Moringa leaf extract showed significant improvement in growth and yield. They exhibited upright growth, fresh leaves, regular branching, healthy fruits, and consistent flowering throughout the trials, indicating the beneficial impact of Moringa leaf extract on tomato plant growth and development.	Bashir, K A et al. [3]
Tomato	Spray (applied at 2 and 4 weeks)	In the experiment, different application timings of Moringa extract were tested on tomato plants, with a control group treated with 80% ethanol (ME), and treatments where Moringa extract was applied at various intervals: once at 2 weeks (M1), twice at 2 and 4 weeks (M2), and every 2 weeks until maturity starting from 2 weeks after germination (M3). Results showed that Moringa extract significantly improved the growth and yield of tomatoes in both greenhouse and field settings. It notably increased above-ground dry matter yield, root dry matter weight, and plant height. Yields progressively increased from M1 to M3, with the highest yields observed in plants treated with Moringa extract every 2 weeks until maturity (M3). Therefore, the study recommends applying Moringa extract at the M3 timing for optimal results in enhancing tomato growth and yield.	Culver M et al. [4]
Onion	Foliar application of concentration 2%, 4%, 3.2%, 3.7%.	In the experiment, different foliar spray treatments were applied to crops at specific intervals. The treatment labeled T, involving three sprays of 2% brassica + 2% Moringa at 15, 30, and 45 days after sowing (DAS), resulted in the highest seed yield (2942 kg/ha), biological yield (13721 kg/ha), and	Mohammed R, et al. [5]

Crops	Treatment/mode of application	Outcome	References
		harvest index (21.44%). Another treatment, labeled T7, with the same spray frequency but using only 2% brassica + 2% Moringa, produced the highest number of siliques per plant (394.18), number of seeds per silique (28.93), and 1000-seed weight (4.63 g). Additionally, T7 showed significantly higher leaf area indices, crop growth rates, and net assimilation rates compared to other treatments. Abdalla, MM al el 2013 [18].	
Sunflower	Foliar sprays.	Different concentrations (5%, 10%, 15%, and 20%) of Moringa leaf extract were used as foliar sprays at different times. Results revealed that all concentrations of Moringa suppressed sunflower germination, but the 5% concentration was effective in enhancing seedling growth and development. Furthermore, experiments demonstrated that Moringa leaf extract sprays at 45 and 60 days after sowing increased sunflower seed yield. This suggests that foliar application of Moringa leaf extract has the potential to economically boost sunflower seed yield.	Anwar F, et al., 2003. [19].& Iqbal, MA et al., 2014. [26]. [27].
Maize	Leaf extract spray	Applying Moringa leaf extract two weeks after emergence and every two weeks thereafter (T5) significantly boosted various growth parameters and yield components of maize. T5 resulted in the highest grain yield (9.2 t/ha), stover yield (10.1 t/ha), and harvest index (48%), compared to treatments without Moringa leaf extract (T1 or T2), which had lower yields (6.3 t/ha for grain yield, 8.6 t/ha for stover yield, and a harvest index of 42%). These findings highlight the importance of using Moringa leaf extract for enhancing the growth and yield performance of maize.	Biswas, A K, et al. [6].
Cotton	Foliar Application	The study found that all treatments improved the growth, number of bolls per plant, boll weight, and ultimately increased the seed cotton yield and fiber quality of Bt cotton cultivar CIM 598, as well as another cotton cultivar, compared to the control. Economic analysis showed that combining foliar application of MLE (Moringa leaf extract) and potassium nitrate was cost-effective for maximizing seed cotton yield and income.	Yasmeen A et al. [7]
Pepper	Foliar application of MLE	The study tested two concentrations of MLE (Moringa leaf extract), 1:10 and 1:20, applied at intervals of one and two weeks. Data on stem girth, plant height, number of leaves, and fruit yield were collected. Results showed significant differences between the two MLE concentrations regarding their impact on pepper growth and yield. Foliar application of	Matthew A.[8]

Crops	Treatment/mode of application	Outcome	References
		MLE at the 1:20 concentration, with a two-week interval, resulted in the highest values for pepper growth and yield parameters. Therefore, it is recommended for pepper producers to use this concentration and interval for optimal results. Anwar F et al., 2003 [19]	
Pepper	Effect of (MLE) on Pepper Seed Germination.	The results showed that using Moringa leaf extract at a concentration of 4% for soaking seeds for 6 hours improved germination percentage, rate, index, and velocity coefficient. Similarly, applying the same 4% concentration as a foliar spray on pepper seedlings in the nursery supported various parameters like height, weight (fresh and dry), number of leaves, and leaf area. This treatment also led to maximum plant growth and superior early and total fruit yield. Additionally, MLE at 4% concentration increased average fruit weight, length, and diameter, and enhanced fruit chemical contents such as carbohydrates, ascorbic acid, potassium (K), and calcium (Ca) elements.	Zhang, X., 2004 [44]
Fennel	Foliar application of MLE leaf extracts	The best results were observed with individual treatments of aqueous MLE at 5% or BA at 100 ppm, followed by 5% ethanolic MLE or 50 ppm BA, compared to the control and other treatments. Combining 5% aqueous or ethanolic MLE with 100 ppm BA resulted in the highest values for all studied parameters. These combinations led to significant increases in fruit yield per area, volatile oil percentage, and oil yield per area compared to the control, with increments ranging from 46.3% to 91.1%. The main component of volatile oil was methyl chavicol (estragole), ranging from 77.5% to 87.3%, with minor compounds including myrcene and limonene. The combination of 5% aqueous MLE and 100 ppm BA was found to be the most effective in reducing the concentration of methyl chavicol, an undesirable component in fennel oil. Therefore, spraying fennel plants with 5% aqueous MLE plus 100 ppm BA is recommended for achieving higher vegetative growth, fruit yield, and oil yield.	S.S.A. Abdel-Rahman et al.2015 [9] & Rehman, H et al., 2015 [36] & Rehman, H et al., [37]
Hollywood Plum	Sprayed with (0%, 4%, 5%, 6%)	Trees were sprayed with varying concentrations of Moringa leaf aqueous extract (0%, 4%, 5%, and 6%) at different growth stages. Plums treated with 6% Moringa leaf extract showed significantly better results in terms of fruit setting, yield, fruit weight, firmness, color, soluble solid content (SSC), titrable acidity (TA) ratio,	Makkar, HPS., et al 2007 [23]

Crops	Treatment/mode of application	Outcome	References
		ascorbic acid, anthocyanin content, antioxidant activity, and reduced fruit drop compared to other treatments. Therefore, foliar applications of 6% Moringa leaf aqueous extract can effectively enhance fruit set, yield, fruit quality, and nutritional content of "Hollywood" plum.	
Kinnow	Sprayed with 3% MLE, 0.6% ZnSO ₄ and 0.25% K ₂ SO ₄ .	Combining MLE (Moringa leaf extract), K (potassium), and Zn (zinc) applications at the fruit set stage resulted in lower fruit drop and higher fruit set, yield, fruit weight, juice weight, soluble solid contents (SSC), vitamin C, sugars, total antioxidants, and total phenolic contents. The activities of SOD and CAT enzymes in fruit juice were significantly increased with 3% MLE application. Therefore, the combined foliar application of 3% MLE, 0.6% ZnSO ₄ , and 0.25% K ₂ SO ₄ at the fruit set stage can effectively enhance leaf nutrient status, fruit yield, and quality of 'Kinnow' mandarin trees.	Yasmeen, A., et al . 2012[41] & 2013 [42] 201[43]
Mungbean	There were six treatments having different concentrations of extracts (2.5, 5.0, 7.5, 10.0, 12.5 and 15.0%).	The experimental treatments involved two and three foliar sprays of 2% brassica, Moringa, and a combination of both at specific intervals. The treatment labeled T resulted in the highest seed yield (2942 kg/ha), biological yield (13721 kg/ha), and harvest index (21.44%). However, the treatment labeled T7 produced the highest number of siliques per plant (394.18), number of seeds per siliques (28.93), and 1000-seed weight (4.63 g). T7 also showed significantly higher leaf area indices, crop growth rates, and net assimilation rates compared to other treatments.	Verdcourt B, 2018 [40]
Spray on three leguminous and forages crops	Spray four concentrations of Moringa leaf extract (C1, C2, C3 and C4).	The treatments included four concentrations of Moringa leaf extract (C1, C2, C3, and C4) along with distilled water as a control. Results showed that the highest concentration, C1, had the highest levels of inorganic elements and growth hormones compared to the other concentrations. C1 significantly increased growth and forage yields of alfalfa and clitoria, as well as growth and grain yield of mung bean. In 2015, C1 increased the number of pods, pod dry weight, seed dry weight, and shelling out turn of mung bean by 85%, 60%, 47%, and 92%, respectively, compared to the control. Similarly, in 2016, there were corresponding increments of 40%, 47%, 27%, and 94%, respectively, for the same characteristics.	R.A. Abohassan and A.O. Abusuwar [10] & ShM, T., et al 2017 [39]
Purple nut sedge	MLE was applied into pots with	The growth of two maize hybrids, P-33H25 and FH-810, was studied under well-watered	Anser Ali et al. [11] & Fuglie, L

Crops	Treatment/mode of application	Outcome	References
	distilled water.	and water deficit conditions with silicon application. Silicon was added to the soil at a rate of 100 mg/kg. Plants were subjected to two levels of soil water content: 100% and 60% of field capacity. In drought-stressed plants of both hybrids, silicon application significantly increased various growth parameters including plant height, stem diameter, number of leaves, cob length, number of grains per cob, 100 grain weight, grain yield, and biological yield. This improvement was accompanied by enhanced photosynthetic rate and reduced transpiration rate. In conclusion, applying silicon to drought-stressed maize plants enhanced their growth and yield, likely due to improved photosynthesis and reduced water loss through transpiration.	et al., 2008 [20]
Bean	Sprayed twice with Moringa leaf extract (MLE).	Phaseolus vulgaris plants were exposed to NaCl and/or CdCl ₂ stress starting from the second week of growth. They were then sprayed twice with Moringa leaf extract (MLE) at 21 and 28 days after sowing (DAS), and sampled at 35 DAS for growth and chemical analyses, with yield measured at the end of the experiment. Exposure to NaCl and/or CdCl ₂ stress significantly reduced growth traits, photosynthetic pigment levels, green pod yield, and pod protein content. However, subsequent foliar application of MLE helped alleviate the stress caused by NaCl and/or CdCl ₂ , leading to significant enhancement of the aforementioned parameters. The stresses increased electrolyte leakage (EL), lipid peroxidation, and plant Cd ²⁺ content, while decreasing membrane stability index (MSI) and relative water content (RWC). However, foliar application of MLE in the absence of stress improved MSI and RWC, and minimized plant Cd ²⁺ content, but did not affect EL and lipid peroxidation. Proline content and the activity of antioxidant enzymes increased significantly in response to MLE, as well as to NaCl and/or CdCl ₂ stress.	Saad M. Howladar [12] & Temu, AE., 2005 [38]
Potato tubers	Using silicon (Si) and Moringa Seed extract (MSE) for reducing heavy metal contamination.	Various phosphate fertilizers, including ordinary super phosphate and rock phosphate, were applied at a rate of 100 kg P ha ⁻¹ before sowing. Additionally, potassium silicate (20% SiO ₂) was added at a rate of 6 L ha ⁻¹ , and microbially synthesized elicitor (MSE) was added at a rate of 150 L ha ⁻¹ in three equal doses during the last 10 minutes of drip irrigation with the 2nd, 4th, and 6th	Elrys, A. S.et al. [13] & Phiri, C., 2010 [32]

Crops	Treatment/mode of application	Outcome	References
Brinjal	Application of the Moringa extracts on the soil.	irrigations. Results showed that adding phosphate fertilizers increased fresh tuber yield, dry weight yield, NPK uptake, and the activity of catalase, peroxidase, superoxide dismutase, and glutathione reductase in potato plants, whether applied alone or combined with silicon and MSE. However, the accumulation of Cu, Cd, and Ni in potato was higher with the single addition of rock phosphate fertilizer compared to super phosphate fertilizer. The highest reduction in heavy metal accumulation in potato leaves, tubers, and soil was observed with the combination of MSE treatment and super phosphate fertilizer. It is recommended to apply MSE at a rate of 150 L ha ⁻¹ along with ordinary super phosphate fertilizer for optimal potato crop growth. Howladar SM 2014 [21] &	Anyaegbu Polycarp Ozobia [14] & Olson, ME, 2010 [31]
Rocket plants	Foliar spray with the aqueous extracts at rates of 1, 2 and 3%.	Foliar spraying rocket plants with aqueous extracts of Moringa oleifera leaves and twigs at rates of 1%, 2%, and 3% showed promising results. The 2% leaf and 3% twig extract concentrations significantly increased all growth parameters, including plant height and fresh and dry herb weight. Additionally, they enhanced photosynthetic rates, chlorophyll levels, carotenoids, total sugars, total protein, phenols, ascorbic acid, and essential nutrients like N, P, K, Ca, Mg, and Fe, along with growth-promoting hormones. Furthermore, bio-organic manuring with these extracts reduced lipid peroxidation, Absciscic acid levels, and the activity of antioxidant enzymes. Overall, Moringa oleifera leaf and twig extracts can be recommended as effective bio-organic fertilizers for various crops due to their productivity, nutritive value, antioxidant properties, ease of preparation, low cost, and environmentally friendly nature.	Mona M. Abdalla [15] & Nambiar, VS., 2005 [28] Rady MM,2015 [33]

Table 2. Some chemical constituents of MLE Component and values

Some chemical constituents of MLE Component	Value (mg g ⁻¹ DW)
Amino acids	106.20
Proline	21.00
Total soluble sugars	248.70
Ash	102.00
Calcium	28.00
Magnesium	6.70
Potassium	25.10
Phosphorus	8.10
Sodium	0.75
Iron	1.60
Manganese	0.84
Zinc	0.27
Copper	0.14
Soluble phenols	6.20
Total carotenoids	3.10
Total chlorophyll	3.96
Ascorbic acid (mg 100g ⁻¹ FW)	242.40
Phytohormones (µg g⁻¹ DW):	
Indole-3-acetic acid	0.83
Gibberellins	0.74
Zeatin	0.96
Abscisic acid	0.29`

Source: Rehman et al. [2] Olaniyi, JO., 2010 [30]

Table 3. Nutrients composition of leaf, seed and root

S.No.	Nutrient	Leaf	Seed	Root
1	Energy values (Kcal/100 g)	426.12	426.12	384.05
2	Crude proteins (%)	27.60	28.02	5.02
3	Crude lipids (%)	20.00	33.78	6.33
4	Carbohydrates (%)	33.93	28.77	76.75
5	Ash (%)	11.60	3.03	4.97
6	Thiamine B ₁ (mg/100 g)	18.47	-	-
7	Riboflavin B ₂ (mg/100 g)	14.82	-	-
8	Pyridoxine B ₆ (mg/100 g)	57.29	-	-
9	Ascorbic acid (mg/100 g)	773.30	94.74	48.13
10	Niacin B ₃ (mg/100 g)	50.35	-	-
11	Calcium (mg/100 g)	13.45	2.84	3.99
12	Sodium (mg/100 g)	104.06	129.03	514.80
13	Potassium (mg/100 g)	20.81	-	15.4

Source: (Igwilo et al. [16] & Njoku OU et al., [29])

2. CONCLUSION

Agronomic traits was refer for controlling yield and most of the yield-related traits. This behavior of crops had similar patterns in their interactions with different foliar applications during the field trials. Application of Moringa extract with different concentration have a good potential for

improving growth and yield of crops since Moringa extract has some nutritional potentials. Application of extract with 50% concentration and twice application should be adopted for onion, since it is easier to get all year round and in large quantities for large hectare of farm land. Moringa, with emerging awareness regarding as a potential crop with the 597 multiple uses, as

found from various studies in the past years. Besides, its role in agriculture, as animal feed, forage crop, natural plant growth enhancer and bio-pesticide has also been established along with high nutrient content, nutraceutical nature.

HIGHLIGHTS

Moringa extract has role in agriculture, as animal feed, forage crop, natural plant growth enhancer and bio-pesticide. It has also been established along with high nutrient content, nutraceutical nature.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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