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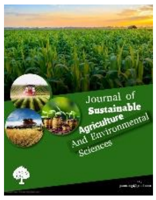

EVALUATION OF DIFFERENT DOSES OF MORINGA LEAF EXTRACT THROUGH FOLIAR APPLICATION ON WHEAT CROP

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ABSTRACT

This research delves into the effects of varying concentrations of moringa leaf extract on wheat growth within a 6 Marla area, employing a randomized complete block design. The primary goal is to determine the most effective moringa concentration for optimizing wheat yield. The study involves six treatments T1, T2, T3, T4, T5 and T5 with concentrations ranging from 0% to 60%, each applied to 1 Marla plots and replicated to ensure reliability. Key parameters including plant population, height, tiller count, grain count per spike, 1000-grain weight, and grain yield were examined. Recommended rates of 50 kg/acre for seed and NPK fertilizer were followed, aligning with irrigated wheat fields in Pakistan. The research aims to establish a connection between moringa extract application and wheat performance. Statistical analyses encompassed ANOVA and post hoc tests to discern significant differences among treatments. The results revealed minor fluctuations in plant population (94.667 to 97.333 plants/m²), plant height (100.33 to 103.33 cm), and tiller count (256.33 to 268.33 tillers/m²), with no statistically significant distinctions. Grain count per spike remained stable, while 1000-grain weight exhibited slight variation (34.667 to 35.667 g). Grain yield ranged from 14.2 to 15.3 kg/Marla. Overall, the study demonstrates that the application of different moringa extract concentrations did not exert substantial influence on the measured wheat growth and yield parameters.

1. INTRODUCTION

The Moringa plant, (*Moringa oleifera* L.), belongs to the Moringaceae family and is well-known for its wide range of biological functions and potential for allelopathy. *M. oleifera*, one of the 13 species of Moringa, is grown around the world (Marrufo *et al.*, 2013). It formerly flourished in sub-Himalayan locations, but today it can be found in tropical and subtropical climates (Anwar *et al.*, 2007; Barreto 2009). The leaves, pods, and seeds of this plant are valuable food sources and have a variety of uses in agriculture, industry, and medicine. They provide vitamins and proteins, as well as aid in the management of health conditions like inflammation and cardiovascular disorders (Barreto 2009; Mbikay 2012; Rashid *et al.*, 2008). The functional elements of the plant are dispersed across its numerous parts, including the leaves, seeds, flowers, bark, and peel. These contain elements such as terpenoids, lipids, vitamins, and hydrocarbons that are essential for development as well as for pathogen and stress protection (Hyldgaard et al., 2012). While phenolic compounds have received a lot of attention in research on the Moringa plant, little is known about the chemical makeup and effects of its aerial portions (Sánchez *et al.*, 2010). According to numerous studies (Anwar & Bhanger 2003; Anwar *et al.*, 2007; Barreto 2009; Ayeb *et al.*, 2014), *moringa oleifera* is a rich source of vital nutrients such as vitamins, proteins, fatty acids, antioxidants, allelochemicals, and plant growth regulators like zeatin and gibberellins.

According to Bulgari et al. (2019), fertilizers are compounds that are used to increase the growth and productivity of crops. As a result of increased worldwide food demand, which is impacted by the rapidly expanding global population, economic development, and climatic changes, agricultural crop cultivation is becoming more and more dependent on synthetic chemical fertilizers (Duan, 2016). As a result, chemical fertilizers have become an integral part of contemporary agriculture, providing plants with necessary minerals including nitrogen, phosphorus, and potassium (Savci, 2012). Exploring natural biostimulants to increase the growth and yield of diverse crops has recently attracted more attention. One such substitute is Moringa leaf extract (MLE), which is obtained from the plant known as moringa, Moringa oleifera Lam. Under both typical and stressed circumstances, its effect on crop growth and yield has been studied (Phiri *et al.*, 2010). Because moringa naturally includes particular biostimulant chemicals, it is a desirable choice. It is abundant, claims ease of cultivation, and has received considerable interest in the scientific community (Jhilik *et al.*, 2017; Khan *et al.*, 2017). Moringa, a member of the Moringaceae family, is extensively distributed throughout tropical and subtropical areas and does best in warm climes (Hassan *et al.*, 2013).

The moringa produces a significant amount of biomass because of its quick and ongoing growth. According to several studies (Sohaimy *et al.*, 2015; Rady et al., 2015; Zulfiqar *et al.*, 2020), it has leaves that are particularly rich in important elements such minerals, proteins, vitamins (A and C), amino acids, dietary fiber, -carotene, riboflavin, phenolics, and free prolines. Ascorbate, phytohormones, particularly cytokinins like zeatin, auxins, and gibberellins are also plentiful in these leaves (Howladar *et al.*, 2014; Nasir *et al.*, 2016). Due to its high concentration of plant secondary metabolites, including osmoprotectants (Yasmeen *et al.*, 2011; Batool *et al.*, 2020), Moringa leaf extract (MLE) also exhibits excellent antioxidant capacities. Moringa's extract is a unique natural plant biostimulant due to its well-balanced composition of phytohormones, antioxidants, and mineral elements (Yasmeen *et al.*, 2013; Gopalakrishnan *et al.*, 2016). Environmentalists, academics, and scientists from all around the world are interested in developing Moringa leaf MLE as a biostimulant (Rady *et al.*, 2015). Aqueous extracts, pressured hot water extraction, and solvent-based techniques are a few of the different types of MLE extraction that are available. The potential of MLE to contribute to the production of wholesome and safe food through environmentally sustainable agricultural practices is pivotal in evaluating the nutritional advantages and market viability of moringa leaf powder (Rahman et al., 2020). Consequently, enhancing the growth and yield of food crops using safe and natural biostimulants like MLE has become increasingly essential in contemporary times (Elzaawely *et al.*, 2017).

Triticum aestivum L., the technical name for wheat, maintains a significant place among cereal crops and provides vital nutrition to close to one-third of the world's population. This essential grain provides more than half of the daily caloric needs and around half of the daily protein intake (Dhanda *et al.*, 2004). It is a perpetual struggle to produce enough wheat to meet the demands of the expanding population. Enhancing wheat output depends on a number of things. For instance, it has been shown that sowing at the right time, particularly early and timely sowing, has a favorable impact on yield (Akhtar et al., 2006; Sattar *et al.*, 2010). Another important factor influencing the yield has been discovered as the caliber of the seeds utilized in growing (Farooq *et al.*, 2008). Furthermore, high-yielding wheat cultivars' accessibility and acceptance have a major impact on crop productivity (Hussain et al., 1998). Optimizing yields relies heavily on the skillful control of inputs like irrigation and fertilizers (Mullaa *et al.*, 1992; Kibe *et al.*, 2006). Achieving good yields requires effective weed management as well (Abouziena *et al.*, 2008). One of the earliest food crops to be cultivated was wheat, a member of the Poaceae family. It continues to be a crucial dietary staple in many areas, taking up the majority of agricultural land. The need to feed populations that depend on wheat as their main food supply has prompted researchers to look for environmentally friendly methods that can increase both yield and quality. The employment of agronomic methods that promote environmental well-being is required to increase yields responsibly (Olofsdotter *et al.*, 1997).

The production of cereal crops is being impacted by the high cost and restricted supply of synthetic fertilizers, particularly for small farmers. For both food and business, wheat is a crucial cereal crop (Khan *et al.*, 2020; Prasad *et al.*, 2016). Using efficient techniques is essential for increasing wheat output (Merwad & Abdel-Fattah, 2017). Wheat has benefited from the application of Moringa leaf extract (MLE) in terms of growth and yield (Jhilik et al., 2017; Rehman *et al.*, 2017). When compared to control plants, Merwad & Abdel-Fattah (2017) discovered that MLE treatments considerably improved a number of yield indices like biomass, grain weight, and protein content.

2. METHODOLOGY

This research investigates the influence of moringa extract on wheat growth across a 6 Marla area. The primary objective is to pinpoint the most effective moringa concentration for optimizing wheat yield. The layout design chosen for this experiment is a randomized complete block design (RCBD). The process entails determining appropriate moringa doses, structuring plot layouts, and gathering data. Adopting a randomized arrangement, six 1 Marla plots are designated for treatments, with replication to enhance reliability. The primary focus is to assess moringa's impact on wheat by evaluating key parameters such as plant population (m^2), plant height (cm), tiller count (m^2), grain count per spike, 1000-grain weight (g), and grain yield (kg/acre). Recommended rates include 50 kg/acre for seed and NPK fertilizer with a 70:35:30 ratios, tailored to irrigated wheat fields in Pakistan, the research seeks to establish a relationship between moringa extract application and wheat performance.

2.1.Moringa Extract Doses and Treatments

2.2.1. T1 Control (0% MLE)

For the control group, you won't be adding any moringa extract, so the solution will consist of only the solvent (e.g., water).

2.2.2. T2 (20% MLE)

To prepare a 20% moringa extract solution, you would mix 20 parts of moringa extract with 80 parts of the solvent (e.g., water). If you want to make 1 liter (1000 mL) of the solution:

Moringa Extract (in mL) = 1000 mL × 0.20 = 200 mL

Solvent (e.g., water) (in mL) = 1000 mL - 200 mL = 800 mL

2.2.3. T3 (30% MLE)

For a 30% solution, you would mix 30 parts of moringa extract with 70 parts of the solvent.

Moringa Extract (in mL) = 1000 mL × 0.30 = 300 mL

Solvent (e.g., water) (in mL) = 1000 mL - 300 mL = 700 mL

2.2.4. T4 (40% MLE)

For a 40% solution, you would mix 40 parts of moringa extract with 60 parts of the solvent.

Moringa Extract (in mL) = 1000 mL × 0.40 = 400 mL

Solvent (e.g., water) (in mL) = 1000 mL - 400 mL = 600 mL

2.2.5. T5 (50% MLE)

For a 50% solution, you would mix equal parts of moringa extract and the solvent.

Moringa Extract (in mL) = 1000 mL × 0.50 = 500 mL

Solvent (e.g., water) (in mL) = 1000 mL - 500 mL = 500 mL

2.2.6. T6 (60% MLE)

For a 60% solution, you would mix 60 parts of moringa extract with 40 parts of the solvent.

Moringa Extract (in mL) = 1000 mL × 0.60 = 600 mL

Solvent (e.g., water) (in mL) = 1000 mL - 600 mL = 400 mL

2.2.Extracting Moringa Leaf Extract

Begin by collecting clean moringa leaves, drying them in shade, and grinding them into powder. Extract using water or ethanol by steeping the powder, then strain to separate the liquid.

2.3.Applying Moringa Leaf Extract:

Dilute the extract with water to desired concentration. Apply via foliar spray on leaves or soil drench at the plant's base. Choose early morning or late afternoon for foliar application. Test on a small scale before full use, and have control groups for accurate comparison.

2.4.Data Collection:

Monitor and record plant growth parameters, including Plant Population (m^2), Plant Height (cm), No. of Tillers (m^2), No. of grain per spike, 1000 Grain weight (g) and Grain Yield kg/acre. at regular intervals throughout the growth period. Measure grain yield at harvest time, recording the quantity of harvested grains.

2.5.Statistical Analysis:

Perform analysis of variance (ANOVA) to determine the significance of differences among treatment means. If significant differences are observed, conduct post hoc tests to identify specific treatments that significantly affect wheat growth and yield. Present the results using graphs, tables, and descriptive statistics.

The (table 1) shows the results of a study that investigated the effects of different doses of moringa leaf extract (MLE) on the growth and yield of wheat crop. The table shows the mean values for each parameter, with the letter "a" indicating that the value is not significantly different from the control treatment.

3. RESULTS

Table 1. Effects of different doses of moringa leaf extract (MLE) on the growth and yield of wheat crop

Treatment	Plant Population (m^2)	Plant Height (cm)	No. of Tillers (m^2)	No. of grain per spike	1000 Grain weight (g)	Grain Yield kg/acre
T1 0%MLE	96.667a	100.33a	264.00a	39.000a	34.667a	14.2a
T2 20%MLE	95.333a	101.67a	263.00a	38.667a	35.333a	14.8a
T3 30%MLE	94.667a	102.33a	268.33a	37.333a	35.000a	14.9a
T4 40%MLE	95.000a	103.33a	258.00a	38.333a	37.000a	14.4a
T5 50%MLE	96.333a	101.33a	267.67a	36.333a	35.333a	15.1a
T6 60%MLE	97.333a	100.67a	256.33a	37.000a	35.667a	15.3a

3.1.Plant population (m^2)

The results of this evaluation, focusing on plant population in square meters (m^2), are presented in the table. The experiment comprised six distinct treatments, each involving a different concentration of Moringa leaf extract. The treatments ranged from a control group with no extract application (T1) to treatments with concentrations of 20%, 30%, 40%, 50%, and 60% Moringa leaf extract (T2 to T6, respectively). The observed plant population for each treatment was as follows: In the control group (T1), the plant population was recorded as 96.667 plants per square meter. The application of 20% Moringa leaf extract (T2) resulted in a slightly reduced plant population of 95.333 plants per square meter. Similarly, the populations for the 30% (T3), 40% (T4), 50% (T5), and 60% (T6) Moringa leaf extract treatments were 94.667, 95.000, 96.333, and 97.333 plants per square meter, respectively.

3.2.Plant Height (cm):

The study titled "Evaluation of Different Doses of Moringa Leaf Extract through Foliar Application on Wheat Crop" aimed to elucidate the effects of various doses of Moringa leaf extract on wheat crop performance, particularly in terms of plant height. The table presents the measured plant heights (in centimeters) for each treatment group, ranging from the control group (T1) with no Moringa leaf extract, to increasing concentrations of extract in subsequent treatments (T2 to T6). The results indicate slight fluctuations in plant height across the treatment groups, with values ranging from 100.33 cm for the control group (T1) to 103.33 cm for the treatment with 40% Moringa leaf extract (T4). However, it is important to note that these differences in plant height do not exhibit a consistent upward or downward trend with increasing doses of Moringa leaf extract.

3.3.Number of Tillers (m²):

The investigation into the effects of varying doses of Moringa leaf extract on the wheat crop's tillering performance is a key aspect of the study titled "Evaluation of Different Doses of Moringa Leaf Extract through Foliar Application on Wheat Crop." The table displays the number of tillers per square meter (m²) for each treatment group, ranging from the control group (T1) with no Moringa leaf extract, to increasing concentrations of extract in subsequent treatments (T2 to T6). The results demonstrate slight variations in the number of tillers across the treatment groups, with counts ranging from 256.33 tillers/m² for the treatment with 60% Moringa leaf extract (T6) to 268.33 tillers/m² for the treatment with 30% Moringa leaf extract (T3). However, the observed differences in tiller count among the treatment groups do not exhibit a consistent trend correlating with the escalating doses of Moringa leaf extract. The shared subscript "a" designates homogeneity in tiller counts, indicating that the differences observed are not statistically significant based on the current data.

3.4.Number of Grain per Spike:

Upon analyzing the effect of varying doses of Moringa leaf extract on the number of grains per spike, it is evident that there were no substantial differences observed among the treatments. The control group (T1) displayed an average of 39.000 grains per spike, while the treatments receiving Moringa leaf extract at 20% (T2) through 60% (T6) recorded slightly lower values. However, these differences are not statistically significant, indicating that the application of different doses of Moringa leaf extract did not result in any noticeable alteration in the number of grains formed per spike.

3.5.1000-Grain Weight:

In terms of the 1000-grain weight, an important indicator of grain quality, the outcomes showcased a consistent trend across the treatments. Although there were minor fluctuations, all treatment groups demonstrated values that remained within a narrow range. The control group (T1) had a 1000-grain weight of 34.667 grams, while the treatments with Moringa leaf extract at concentrations ranging from 20% (T2) to 60% (T6) yielded 1000-grain weights ranging from 35.333 to 35.667 grams. These negligible variations suggest that the application of different doses of Moringa leaf extract did not have a substantial impact on individual grain weight.

3.6.Grain Yield per Acre:

Turning to the grain yield per acre, the results underscored the consistency among the treatments. The grain yield values for each treatment remained within a relatively narrow range. The control group (T1) achieved a grain yield of 14.2 kg/Marla, while the treatments receiving Moringa leaf extract at concentrations ranging from 20% (T2) to 60% (T6) yielded grain yields between 14.8 and 15.3 kg/Marla. These findings suggest that the varying doses of Moringa leaf extract did not lead to significant differences in overall wheat productivity.

4. DISCUSSION

It has been demonstrated through research by (Nouman *et al.* 2012) and other earlier investigations that the plant moringa (*Moringa oleifera*) has advantageous components that support plant growth. The possible phytotoxicity of moringa has, however, been highlighted in papers by researchers like (Foidl *et al.*, 2001; Bennett et al., 2003). In spite of this, all prior study has shown that moringa generally promotes crop development. It's interesting how our research deviates from these conclusions. We concentrated particularly on the results of wheat crops exposed to the foliar spyra of moringa. Unexpectedly, our findings show that the use of foliar spyra from the moringa plant had no statistically significant influence on the development of wheat crops. In a study by (Ndubuaku *et al*., 2015), they found that giving foliar MLE to cassava plants significantly improved some growth characteristics, such as the plants' height and the quantity of leaves they generated. A study by (Hoque *et al.*, 2022) also validated this conclusion. They applied a 5% solution of aqueous MLE, which appears to be an extract from some kind of plant, in their procedure. One liter of distilled water was combined with 100 grams of fresh leaves to generate this solution. The total growth and yield of mustard plants responded most well to this treatment.

This was noticed and covered in a study conducted in 2020 by Rahman and colleagues. It's interesting how our own research's conclusions differed from these earlier ones. Although statistically different, applying MLE at the heading stage closely followed MLE at the four growth stages for values of 1000 grain weight (40.85 g), biological yield (13.65 t ha-1), grain yield (3.19 t ha-1), and harvest index (23.39); this may be because MLE at the heading stage can "stay green" for the duration of the grain filling period or because it can remobilize soluble carbohydrates (stem reserves) during grain filling (Stoy, 1965). However, our study also showed that several factors, like Plant height, plant population and numbers of tiller, were not significantly impacted by moringa leaf extract (MLE). The study's use of various MLE doses, which might have affected the results, is one possible explanation for these non-significant results. T1 Control (0% MLE), T2 (20% MLE), T3 (30% MLE), T4 (40% MLE), T5 (50% MLE), and T6 (60% MLE) were the doses used in our investigation. The non-significant outcomes seen in some measures may have been caused by the different MLE doses used in various treatments. Emphasizing the complexity of MLE's effects on the investigated characteristics, it is possible that the interplay between these doses and additional environmental or plant-specific factors affected the results. To completely understand the association between MLE dosages and the observed effects in these particular parameters, more research is required. In conclusion, MLE's early application maintained consistent impacts on growth phases, perhaps as a result of its capacity to support leaves and remobilize carbohydrates.

CONCLUSION

In conclusion, the study examined the effects of varying doses of Moringa leaf extract (MLE) on key parameters of wheat growth and yield. The results demonstrate a consistent trend across the treatments, indicating that the MLE doses did not significantly impact plant population, plant height, number of tillers, number of grains per spike, 1000-grain weight, or grain yield. The subtle fluctuations observed in some parameters were not consistently associated with the increasing MLE concentrations. These findings suggest that the selected doses of MLE, administered through foliar application, did not exert discernible effects on the measured aspects of wheat crop performance. Further investigations are warranted to explore alternate strategies or concentrations that may lead to more pronounced enhancements in wheat productivity. In the previous study, moringa significantly improved wheat crop growth. However, our current research shows that moringa's impact is not significant. This difference could be due to various factors like temperature, although we didn't gather climate data as our focus was solely on moringa's effect on crop growth.

REFERENCES

1. Abdel-Rahman, S. S. A., & Abdel-Kader, A. A. S. (2020). Response of Fennel (Foeniculum vulgare, Mill) plants to foliar application of moringa leaf extract and benzyladenine (BA). South African Journal of Botany, 129, 113-122.
2. Abdel-Rahman, S.S.A., & Abdel-Kader, A.A.S. (2020). Response of Fennel (Foeniculum vulgare, Mill) plants to foliar application of moringa leaf extract and benzyladenine (BA). South African Journal of Botany, 129, 113–122.
3. Abouziena, H. F., Shararafaida, A. A., & El-desoki, E. R. (2008). Efficacy of cultivar selectivity and weed control treatments on wheat yield and associated weeds in sandy soils. World Journal of Agricultural Sciences, 4, 384-389.
4. Akhtar, M., Cheema, M. S., Jamil, M., & Ali, L. (2006). Effect of time of sowing on some important characters of wheat, Triticum aestivum genotypes. Journal of Agricultural Research, 44, 255-258.
5. Anwar, F., & Bhanger, M. I. (2003). Analytical characterization of Moringa oleifera seed oil grown in temperate regions of Pakistan. Journal of Agricultural and Food Chemistry, 51, 6558-6563.
6. Anwar, F., Latif, S., Ashraf, M., & Gilani, A. H. (2007). Moringa oleifera: A food plant with multiple medicinal uses. Phytotherapy Research, 21, 17-25.
7. Barreto, M. B., De Freitas, J. V. B., Silveira, E. R., Bezerra, A. M. E., Nunes, E. P., & Gramosa, N. V. (2009). Constituintes químicos voláteis e não-voláteis de Moringa oleifera Lam., Moringaceae. Brazilian Journal of Pharmacognosy, 19, 893-897.
8. Batool, S., Khan, S., & Basra, S. M. A. (2020). Foliar application of moringa leaf extract improves the growth of moringa seedlings in winter. South African Journal of Botany, 129, 347–353.
9. Bennett, R.N., Mellon, F.A., Foidl, N., Pratt, J.H., Dupont, M.S., Perkins, L., & Kroon, P.A. (2003). Profiling glucosinolates and phenolics in vegetative and reproductive tissues of the multi-purpose trees Moringa oleifera L. (Horseradish tree) and Moringa stenopetala L. Journal of Agricultural Food Chemistry, 51, 3546-3553.
10. Bulgari, R., Franzoni, G., & Ferrante, A. (2019). Biostimulants application in horticultural crops under abiotic stress conditions. Agronomy, 9, 306.
11. Dhanda, S. S., Sethi, G. S., & Behl, R. K. (2004). Indices of drought tolerance in wheat genotypes at early stages of plant growth. Journal of Agronomy and Crop Science, 190, 6-12.
12. Duan, Y., Xu, M., Gao, S., Liu, H., Huang, S., & Wang, B. (2016). Long-term incorporation of manure with chemical fertilizers reduced total nitrogen loss in rain-fed cropping systems. Scientific Reports, 6, 33611.
13. El Ayeb-Zakhama, A., Ben Salem, S., Sakka-Rouis, L., Flamini, G., Ben Jannet, H., & Harzallah-Skhiri, F. (2014). Chemical composition and phytotoxic effects of essential oils obtained from Ailanthus altissima (Mill.) Swingle cultivated in Tunisia. Chemistry & Biodiversity, 11, 1216-1227.
14. El Sohaimy, S. A., Hamad, G. M., Mohamed, S. E., Amar, M. H., & Al-Hindi, R. R. (2015). Biochemical and functional properties of Moringa oleifera leaves and their potential as a functional food. Global Advances in Research Journal of Agricultural Science, 4, 188–199.
15. Elzaawely, A. A., Ahmed, M. E., Maswada, H. F., & Xuan, T. D. (2017). Enhancing growth, yield, biochemical, and hormonal contents of snap bean (Phaseolus vulgaris L.) sprayed with Moringa leaf extract. Archives of Agronomy and Soil Science, 63(5), 687-699.
16. Farooq, M., Basra, S. M. A., Rehman, H., & Saleem, B. A. (2008). Seed priming enhances the performance of late-sown wheat by improving chilling

tolerance. Journal of Agronomy and Crop Science, 194(1), 55-60.
17. Foidl, N., Makkar, H.P.S., & Becker, K. (2001). The potential of Moringa oleifera for agricultural and industrial uses. In Proceedings of the 1st What development potential for Moringa products? (pp. 47-67). Dares-Salaam, Tanzania.
18. Gopalakrishnan, L., Doriya, K., & Kumar, D. S. (2016). Moringa oleifera: A review on nutritive importance and its medicinal application. Food Science & Human Wellness, 5, 49-56.
19. Hassan, F. G., & Ibrahim, M. A. (2013). Moringa oleifera: Nature's most nutritious and multipurpose tree. Sudanese International Journal of Science Research and Publications, 3, 2250–3153.
20. Hoque, T.S., Abedin, A., Kibria, M.G., Jahan, I., & Hossain, M.A. (2022). Application of moringa leaf extract improves growth and yield of tomato (Solanum lycopersicum) and Indian Spinach (Basella alba). Plant Science Today, 9, 137–143.
21. Howladar, S. M. (2014). A novel Moringa oleifera leaf extract can mitigate the stress effects of salinity and cadmium in bean (Phaseolus vulgaris L.) plants. Ecotoxicology and Environmental Safety, 100, 69–75.
22. Hussain, A., Maqsood, M., Ahmad, A., Aftab, S., & Ahmad, Z. (1998). Effect of irrigation during various development stages on yield, component of yield and harvest index of different wheat cultivars. Pakistan Journal of Agricultural Science, 34(1), 104-107.
23. Hyldgaard, M., Mygind, T., & Meyer, R. (2012). Essential oils in food preservation: Mode of action, synergies, and interactions with food matrix components. Frontiers in Microbiology, 3, 1-24.
24. Jhilik, N. Z., Hoque, T. S., Moslehuddin, A. Z. M., & Abedin, M. A. (2017). Effect of foliar application of Moringa leaf extract on growth and yield of late-sown wheat. Asian Journal of Medical and Biological Research, 3, 323–329.
25. Khan, S., Basra, S. M. A., Afzal, I., & Wahid, A. (2017). Screening of Moringa landraces for leaf extract as biostimulant in wheat. International Journal of Agriculture and Biology, 19, 999–1006.
26. Khan, S., Basra, S. M. A., Nawaz, M., Hussain, I., & Foidl, N. (2020). Combined application of Moringa leaf extract and chemical growth promoters enhances the plant growth and productivity of wheat crop (Triticum aestivum L.). South African Journal of Botany, 129, 74–81.
27. Kibe, A. M., Singh, S., & Kalra, N. (2006). Water-nitrogen relationships for wheat growth and productivity in late sown conditions. Agricultural Water Management, 84(1-2), 221-228.
28. Marrufo, T., Nazzaro, F., Mancini, E., Fratianni, F., Coppola, R., De Martino, L., Agostinho, A. B., & De Feo, V. (2013). Chemical composition and biological activity of the essential oil from leaves of Moringa oleifera Lam. cultivated in Mozambique. Molecules, 18(9), 10989-11000.
29. Mbikay, M. (2012). Therapeutic potential of Moringa oleifera leaves in chronic hyperglycemia and dyslipidemia: A review. Frontiers in Pharmacology, 3, 1-12.
30. Merwad, A. R. M., & Abdel-Fattah, M. K. (2017). Improving productivity and nutrients uptake of wheat plants using Moringa oleifera leaf extract in sandy soil. Journal of Plant Nutrition, 40, 1397–1403.
31. Mullaa, D. J., Bhatti, A. U., Hammond, M. W., & Benson, J. A. (1992). A comparison of winter wheat yield and quality under uniform versus spatially variable fertilizer management. Agriculture, Ecosystems & Environment, 38, 301-311.
32. Nasir, M., Khan, A. S., Basra, S. M. A., & Malik, A. U. (2016). Foliar application of moringa leaf extract, potassium and zinc influence yield and fruit quality of 'kinnow' mandarin. Scientia Horticulturae, 210, 227–235.
33. Ndubuaku, U.M., Ndubuaku, T.C.N., Ike, E., & Ezeaku, P.L. (2015). Effects of Moringa oleifera leaf extract on

morphological and physiological growth of cassava and its efficacy in controlling Zonocerus variegatus. African Journal of Biotechnology, 14, 2494–2500.

34. Nouman, W., Siddiqui, M.T., & Basra, S.M.A. (2012). Moringa oleifera leaf extract: An innovative priming tool for rangeland grasses. Turkish Journal of Agriculture and Forestry, 36, 65-75.
35. Olofsdotter, M., Navarez, D., & Rebulanan, M. (1997). Rice allelopathy – Where are we and how far can we get? In The Brighton Crop Protection.
36. Phiri, C. (2010). Influence of Moringa oleifera leaf extracts on germination and early seedling development of major cereals. Agricultural and Biological Journal of North America, 1, 774–777.
37. Prasad, R., & Hochmuth, G. J. (2016). Environmental nitrogen losses from commercial crop production systems in the Suwannee River Basin of Florida. PLoS ONE, 11, e0167558.
38. Rady, M. M., & Mohamed, G. F. (2015). Modulation of salt stress effects on the growth, physio-chemical attributes and yields of Phaseolus vulgaris L. plants by the combined application of salicylic acid and Moringa oleifera leaf extract. Scientia Horticulturae, 193, 105–113.
39. Rashid, U., Anwar, F., Moser, B. R., & Knothe, G. (2008). Moringa oleifera oil: A possible source of biodiesel. Bioresource Technology, 99, 8175-8179.
40. Rehman, H. U., Basra, S. M. A., Rady, M. M., Ghoneim, A. M., & Wang, Q. (2017). Moringa leaf extract improves wheat growth and productivity by delaying senescence and source-sink relationship. International Journal of Agriculture and Biology, 19, 479–484.
41. Sánchez, E., García, S., & Heredia, N. (2010). Extracts of edible and medicinal plants damage membranes of Vibrio cholerae. Applied Environmental Microbiology, 76, 6888-6894.
42. Sattar, A., Cheema, M. A., Farooq, M., Wahid, M. A., Wahid, A., & Babar, B. H. (2010). Evaluating the performance of wheat cultivars under late-sown conditions. International Journal of Agriculture and Biology, 12, 561-565.
43. Savci, S. (2012). Investigation of effect of chemical fertilizers on environment. Procedia Engineering, 1, 287-292.
44. Stoy, V. (1965). Photosynthesis, respiration, and carbohydrate accumulation in spring wheat in relation to yield. Physiologia Plantarum Suppl., IV (1-25).
45. Warrier, A., Bhardwaj, S.N., & Pande, P.C. (1987). Effect of benzyladenine on grain growth in aestivum wheat. Plant & Cell Physiology, 28, 735-739.
46. Yasmeen, A. (2011). Exploring the Potential of Moringa (Moringa oleifera) Leaf Extract as Natural Plant Growth Enhancer. Ph.D. Thesis, University of Agriculture, Faisalabad, Pakistan.
47. Yasmeen, A., Basra, S. M. A., Wahid, A., Nouman, W., & Rehman, H. (2013). Exploring the potential of Moringa oleifera leaf extract (MLE) as a seed priming agent in improving wheat performance. Turkish Journal of Botany, 37, 512-520.
48. Zulfiqar, F., Casadesús, A., Brockman, H., & Munné-Bosch, S. (2020). An overview of plant-based natural biostimulants for sustainable horticulture with a particular focus on moringa leaf extracts. Plant Science, 295, 110194.