Research Article

Effect of Moringa Leaf Extract and Acetylsalicylic Acid on Growth and Yield of Radish (*Raphanus sativus* L.)

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Abstract | Radish (*Raphanus sativus* L.) is a fast-growing and widely cultivated root vegetable. Enhancing its growth and yield is crucial for food security and economic benefits. This experiment proposes to evaluate the effect of moringa leaf extract and acetyl salicylic acid on the growth and yield of radish. Radish cultivar Mino Early was treated with four levels of moringa leaf extract (M_1: 0 g L^{-1}, M_2: 30 g L^{-1}, M_3: 60 g L^{-1}, and M_4: 90 g L^{-1}), and four concentrations of acetyl salicylic acid (A_1: 0 mg L^{-1}, A_2: 100 mg L^{-1}, A_3: 200 mg L^{-1}, and A_4: 300 mg L^{-1}). The statistical analysis of data revealed that both vegetative and reproductive growth attributes were significantly affected by different levels of moringa leaf extract and acetyl salicylic acid. Maximum plant height, leaves area $plant^{-1}$, number of leaves $plant^{-1}$, root weight, root diameter, root length, and yield were observed at 90 g L^{-1} of moringa leaf extract application. Similarly, foliar application of acetyl salicylic acid at the rate of 300 mg L^{-1} gave the best results with maximum plant height, leaves area $plant^{-1}$, number of leaves $plant^{-1}$, root weight, root diameter, root length, and yield. Therefore, it was concluded that radish cv. Mino Early should be sprayed with 90 g L^{-1} of moringa leaf extract or 300 mg L^{-1} of acetyl salicylic acid for maximum productivity and yield under the environmental conditions of Peshawar.

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Introduction

Radish (*Rapahnus sativus* L.) belongs to the family Brassicaceae (Cruciferae). The radish originated in central and western China and the Indo-Pak subcontinent. The fleshy edible portion of the root develops from both the primary root and the hypocotyls. Radish is grown for its young tender tuberous root which is consumed either cooked or raw. It is a good source of Vitamin C (ascorbic acid) and minerals like calcium, potassium, and phosphorus. The leaves of radish are a good source for the extraction of protein on a commercial scale and radish seeds are a potential source of non-drying fatty oil suitable for soap making, illuminating, and edible purposes (Gamba *et al.*, 2021). Radish is predominantly a cool-season vegetable crop. But, Asiatic types can tolerate higher temperature than

European varieties. Being a cool season crop, it is sown during winter from September to January in northern plains. It is an annual or biennial crop depending upon the type for the purpose it is grown. Radish is grown in many parts of the world due to its short growing period and high nutritious value (Akram *et al.*, 2015). Radishes can be grown on all types of soil, but light, rich, moist, and friable is more suitable for it. For winter radishes, sandy or sandy loam soils are best, whereas for summer radishes cool, moist soil gives better results (Malik, 1994). In Pakistan, Radish was grown in an area of 9641 hectares with a total annual production of 157648 tons, while in KP its production was 12463 tons of the total 1051 hectares cultivated area (MINNFSR, 2019).

Moringa oleifera is the most widely cultivated genus in the family Moringaceae. It is tropical crop grown for its nutritional and medicinal purposes. The leaves of moringa are rich in zeatin, a naturally occurring cytokinin, and other growth-enhancing compounds like ascorbates, vitamin E, phenolics, and minerals (Foidl *et al.*, 2001; Nagar *et al.*, 2006). Foliar spray of crops with moringa leaf extract (MLE) accelerates plant growth, promotes resistance to stress and increases the yield of crops (Fuglie, 2000; Foidl *et al.*, 2001). Recently many scientists reported growth and yield enhancement by applying moringa leaf extract (MLE) in various horticultural crops and some field crops under normal as well as stress conditions (Shehu and Okafor, 2017). Application of MLE is a low-cost and environment-friendly technology (Nouman *et al.*, 2012), small scale and commercial farmers would benefit if they used it as a supplement or substitute to inorganic fertilizers. Since fresh moringa leaves contain lots of vitamins, zeatin, and many nutrient elements, it can be used as an effective organic fertilizer that is capable of increasing yield from 10 to 45% according to crop species (Maishanu *et al.*, 2017). The use of MLE as a possible plant growth enhancer can provide a relatively environmentally safe, easily accessible, and affordable means of improving crop production to meet the growing demand of food.

Acetylsalicylic acid (ASA) is a commercially available form of salicylic acid. It is known that in aqueous solutions, ASA is hydrolyzed almost entirely to SA, which is an active ingredient (Mitchell and Broadhead, 1967). However, salicylic acid is an endogenous growth regulator with phenolic nature, which participates in the regulation of several physiological processes in plants, such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis and transpiration (Khan *et al.*, 2003). The effect of salicylic acid on the physiological processes is variable depending on its concentration, plant species, developmental stages and environmental conditions (El-Mergawi and Abdel-Wahed, 2004). Low SA dose enhanced growth of wheat and maize Khan *et al.* (2003). Zhang *et al.* (2022) stated that salicylic acid (SA) had great effects on the morphology and physiology of plants. Acetyl salicylic acid helps boost the plant's immune system, just like it does for us. Diluted Aspirin solution with water for plants provides accelerated germination and some resistance to disease and pests. Aspirin foliar spray in vegetable gardens has been shown to increase plant size and yield. With this background, the present investigation was designed to test the effect of moringa leaf extract and acetylsalicylic acid on the growth and yield of radish (*Raphanus sativus* L.) in agro-climatic condition of Peshawar with the objectives to find out the optimum concentration of moringa leaf extract and acetylsalicylic acid for the quality production of radish.

Materials and Methods

This study was conducted at the Horticultural Research Farm, Malakandher, The University of Agriculture Peshawar, during the year 2019-2020. The experiment was laid out in a Randomized Complete Block Design with factorial arrangement i.e. moringa leaf extracts and acetylsalicylic acid concentrations with three replications. The levels for factor A (Moringa leaf extract concentration) were: M_1= Control, M_2=30 g L^{-1}, M_3=60 g L^{-1}, and M4=90 g L^{-1} while the levels for factor B (Acetyl salicylic acid concentration) were: A_1= Control, A_2= 100 mg L^{-1}, A_3=200 mg L^{-1}, and A_4=300 mg L^{-1}. The total number of experimental units was 48 and the size of each experimental unit was 0.48 m^2. The soil was plowed with the cultivator. After plowing, undesirable plants and other extra materials were removed from the field. NPK was applied at the 120:65:100 kg ha^{-1} rate and then the field was prepared according to the experimental field layout. Seeds were sown in ridges raised to 30-40 cm. Each experimental unit consisted of one row with five seeds of radish cultivar. Radish cv. Mino Early were sown per row with a plant-to-plant distance of 20 cm and row-to-row distance of 40 cm.

Young moringa leaves were grounded for every

concentration i.e. 30 g, 60 g, and 90 g moringa leaves were ground with little water in a juicer machine. The juice was filtered through the cheesecloth by hand pressure. The solution was re-filtered using Whatman No. 2 filter paper (Fugile, 2000). The extract was diluted with one liter of distilled water. The levels were sprayed after 15, 30, and 45 days of seed emergence. The weight of the aspirin tablet (mg) was measured for acetylsalicylic acid at each level and then dissolved in one Liter of distilled water. 470 mg of aspirin tablet contains 300 mg of acetyl salicylic acid. Acetylsalicylic acid was used as a foliar spray to radish at 0, 100, 200, and 300 mg L^{-1}. The levels were sprayed at 20 and 40 days after seed emergence.

Data for plant height (cm), number of leaves $plant^{-1}$, leaves area $plant^{-1}$ (cm^2), root length (cm), root diameter (cm), root weight (g), and yield (tons ha^{-1}) were randomly selected from each experimental unit. The data collected were subjected to analysis of variance methods through the statistical software Statistix (8.1) and the mean differences were taken at ($P \leq 0.01$) by using the least significance difference test (LSD) (Steel et al., 1997).

Results

Plant height (cm)

Treatment comparisons of moringa leaf extracts showed that the maximum plant height (30.4 cm) was observed for MLE application at the rate of 90 g L^{-1} while the minimum plant height (24.4 cm) was recorded in the control treatment and the interaction of moringa leaf extract and acetylsalicylic acid was found to be non-significant. Similarly various concentrations of acetylsalicylic acid also significantly affected plant height and showed that the maximum plant height (30.54 cm) was obtained with the application of acetylsalicylic acid (300 mg L^{-1}) while the minimum plant height (24.7 cm) was achieved in the control treatment (Figure 1).

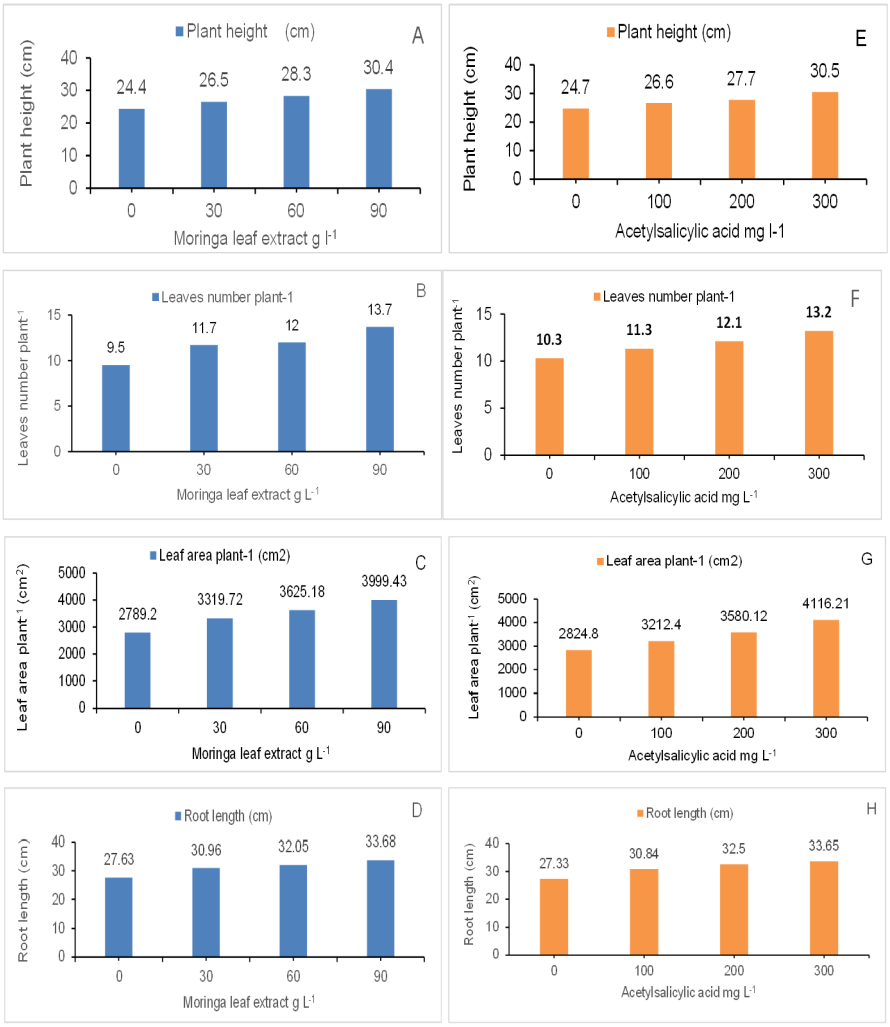

Figure 1: *Plant height (cm) (A, E), Leaves number $plant^{-1}$ (B, F), and Leaf area $plant^{-1}$ (cm^2) (C, G), Root length (cm) (D, H) of radish as affected by moringa leaf extract and acetylsalicylic acid.*

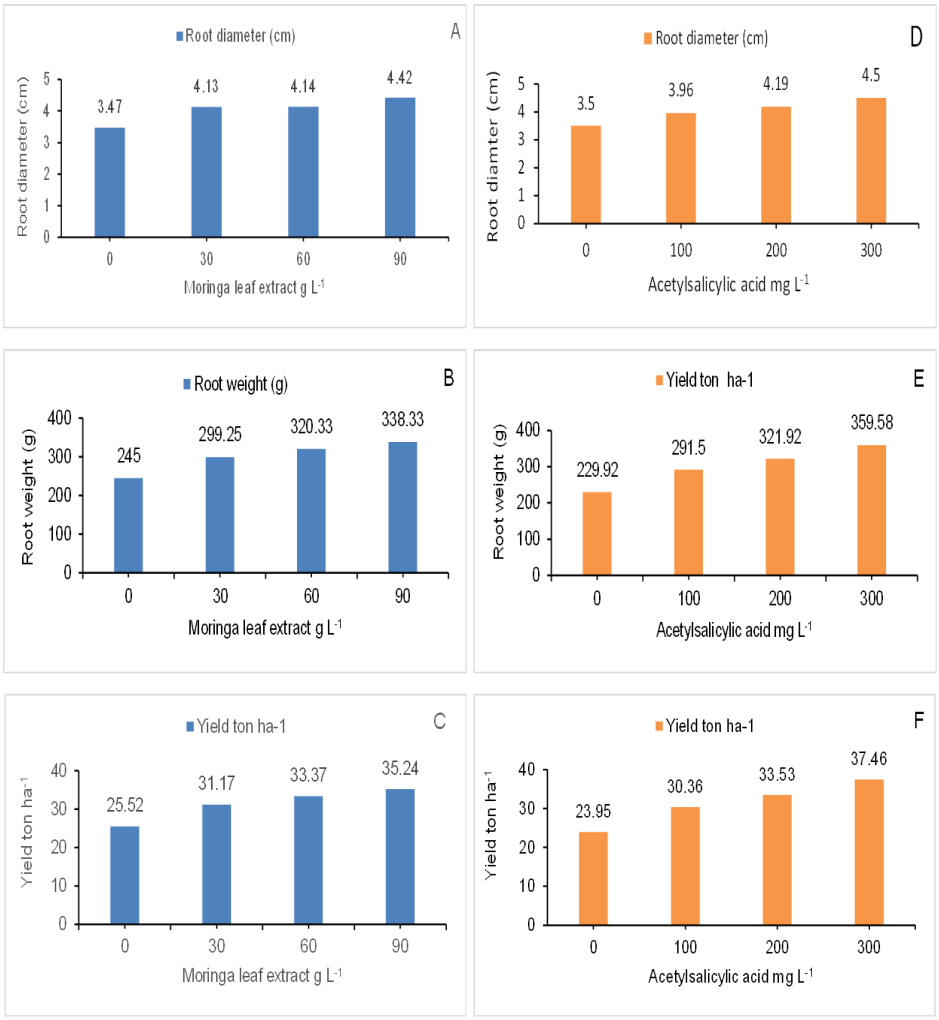

Figure 2: *Root diameter (A, D), Root weight (g) (B, E), and Yield ton ha^{-1} (C, F) of radish as affected by moringa leaf extract and acetylsalicylic acid concentrations, respectively.* Capital letters shows data significance at $p \leq 0.01$, respectively.

Number of leaves plant^{-1}

The number of leaves per plant was significantly affected by both moringa leaf extract and acetylsalicylic acid, while the interaction of moringa leaf extract and acetylsalicylic acid was found non-significant. The maximum number of leaves per plant (13.7) was recorded with the 90 g L^{-1} application of moringa leaf extract, while the lowest number of leaves plant^{-1} (9.5) was observed in the control plots. Similarly, the results obtained for acetylsalicylic acid also showed a significant difference between various concentrations for the number of leaves per plant. The highest number of leaves per plant (13.2) was recorded at 300 mg L^{-1} of acetylsalicylic acid. In the case of control plots, a lower number of leaves per plant (10.3) was recorded (Figure 1).

Leaf area plant^{-1} (cm^2)

Statistical analysis showed that among the different levels of moringa leaf extract, the highest leaf area per plant (3999.4 cm^2) for radish was recorded at 90 g L^{-1}, which was not statistically different from 3625.2 cm^2 at 60 g L^{-1} MLE. The minimum leaf area per plant^{-1} (2789.2 cm^2) was recorded for the control. Similarly, data regarding leaf area per plant with acetylsalicylic acid application revealed that the maximum leaf area plant^{-1} (4116.2 cm^2) was recorded at 300 mg L^{-1}. The leaf area per plant was found to be minimum (2824.8 cm^2) for the control treatment (Figure 1).

Root length (cm)

Different concentrations of moringa leaf extract and acetylsalicylic acid significantly affected root length, while their interaction was found to be non-significant. The maximum root length (33.68 cm) was obtained with the moringa leaf extract application at the rate of 90 g L^{-1}, while the minimum root length (27.63 cm) was recorded in the control treatment. Different concentrations of acetylsalicylic acid also significantly affected root length, such that the maximum root

length (33.65 cm) was observed at 300 mg L^{-1}, which was statistically similar to the root length (32.5 cm) at 200 mg L^{-1}. The minimum root length (24.7 cm) was recorded in the control (Figure 1).

Root diameter (cm)

Mean values of different concentrations of moringa leaf extract and acetylsalicylic acid significantly affected root diameter, while their interaction was found to be non-significant. The maximum root diameter (4.42 cm) was obtained with the moringa leaf extract concentration at the rate of 90 g L^{-1}, while the minimum root diameter (3.47 cm) was recorded in the control treatment. Similarly, for acetylsalicylic acid, a maximum root diameter (4.5 cm) was recorded with the 300 mg L^{-1} application, while control plants recorded a minimum root diameter (3.50 cm) (Figure 2).

Root weight (g)

Among the different levels of moringa leaf extract, the maximum root weight (338.33 g) was obtained with the moringa leaf extract application at the rate of 90 g L^{-1}, while the minimum root weight (245.0 g) was obtained in the control and the interaction of moringa leaf extract and acetylsalicylic acid was found to be non-significant. Similarly, the various acetylsalicylic acid levels also significantly affected the radish root weight. The maximum root weight (359.58 g) was recorded with the application of acetylsalicylic acid at the rate of 300 mg L^{-1}. In the control treatment, a minimum root weight of (229.92 g) was obtained (Figure 2).

Yield (tons ha^{-1})

The statistical analysis of the data showed that both moringa leaf extract and acetylsalicylic acid applications significantly affected yield, whereas their interaction was found to be non-significant. Among the different concentrations of moringa leaf extract, the highest yield (35.24 tons ha^{-1}) was obtained with the moringa leaf extract application at the rate of 90 g L^{-1}, while the lowest yield (25.52 tons ha^{-1}) was noted in the control treatment. Similarly, the various levels of acetylsalicylic acid also significantly affected the yield of radish. The maximum yield (37.46 tons ha^{-1}) was recorded by applying acetylsalicylic acid at the rate of 300 mg L^{-1}, while the minimum yield (23.95 tons ha^{-1}) was obtained in the control treatment (Figure 2).

Discussion

Plant height (cm)

The application of MLE as a growth-promoting substance appeared to significantly enhance plant growth as maximum plant height was obtained with the 90 g L^{-1} of moringa leaf extract application. This aligns with the findings of Kato *et al.* (2002), who attributed the growth-promoting effects of moringa leaf extract to its diverse nutrient content, including potassium, calcium, phenols, and ascorbates. Afzal and Muhammad (2015) similarly observed up to a 40% increase in plant height with moringa leaf extract application compared to controls. Yasmeen (2011) also reported enhanced growth attributes and greater plant height in wheat following foliar application of moringa leaf extract. Furthermore, Mady (2009) showed that acetylsalicylic acid application induced hormonal changes in plants, resulting in increased plant height.

Number of leaves $plant^{-1}$

The highest number of leaves per plant was observed with the 90 g L^{-1} application of moringa leaf extract. These results align with Azra's (2011) findings, who reported a greater number of leaves in tomato with foliar application of moringa leaf extract compared to controls. This increase was attributed to the presence of zeatin, a cytokinin-derived, nutrient-rich compound that positively influences vegetative growth. Similarly, Kamel (2015) observed a greater number of leaves in pomegranate following foliar spraying of moringa leaf extract. These findings are also consistent with those of Gharieb (2007), who stated that acetylsalicylic acid application promoted vegetative growth in cucumber, likely because acetylsalicylic acid plays a key role in auxin synthesis within meristematic tissues, leading to increased leaf development.

Leaf area $plant^{-1}$ (cm^2)

The highest leaf area per plant (3999.4 cm^2) for radish was recorded at 90 g L^{-1} MLE. This supports the findings of Thomas and Howarth (2000), who suggested that moringa leaf extract, being rich in zeatin, plays a vital role in cytokinin biosynthesis, thereby increasing photosynthetic activity, chlorophyll production, and consequently, leaf number and area. These results also align with those of Nouman *et al.* (2012), who observed improvements in plant vegetative attributes, such as emergence, shoot vigor, and chlorophyll b content, after hydro-priming in moringa leaf extracts. Furthermore, Martin-Mex *et al.* (2003) found that acetylsalicylic acid application in ornamental plants like violet and gloxinia led to a 10% increase in leaf area and number of leaves, resulting

in greater biomass production. Similarly, Jamali *et al.* (2011) observed increased leaf area in strawberries with increasing acetylsalicylic acid concentrations.

Root length (cm)

The maximum root length was observed with the 90 g L^{-1} application of moringa leaf extract. Our results are in line with Rady *et al.* (2013), who suggested that seed soaking in plant extracts, particularly moringa, promotes uniform and maximized growth, likely due to increased chlorophyll content, leading to greater leaf area and, consequently, root length. Similar findings were reported by Ozobia *et al.* (2014), who observed maximum plant height, weight, and yield (both root and shoot) in eggplants treated with moringa leaf extracts. Increased root length in faba bean with moringa leaf extract application (up to 2.5%) was also reported by Mona *et al.* (2017). Furthermore, salicylic acid's role in increasing plant tolerance to salt stress and maximizing yield has been established. Baghaei *et al.* (2014) proposed that acetylsalicylic acid plays a vital role in improving plant physiological efficiency, specifically by increasing root proline content, which contributes to greater root length.

Root diameter (cm)

The maximum root diameter was observed with the moringa leaf extract concentration at 90 g L^{-1}. These results are consistent with Siddhuraju and Becker (2003), who reported that moringa leaf extract contains zeatin, which plays a vital role in cell division and elongation, thus enhancing plant growth attributes. Bashir *et al.* (2014) also found that moringa leaf extract improved yield parameters in tomatoes. Similarly, acetylsalicylic acid has been shown to induce salinity tolerance in plants. Parvin *et al.* (2017) stated that the addition of salicylic acid and silica-containing compounds promotes plant growth, enhances protective systems, and results in greater root production and increased tolerance in cabbage.

Root weight (g)

The maximum root weight was observed with the moringa leaf extract application at 90 g L^{-1}. The present study suggests that both factors contributed to increased production of both vegetative and reproductive attributes in radish plants. These results are consistent with Saleem *et al.* (2014), who reported enhanced biomass and yield in bitter gourd with seed soaking in plant extracts. Aluko (2016) similarly concluded that plant growth and fruiting parameters were significantly improved with moringa leaf extract application. This also agrees with Culver *et al.* (2012), who found improved yield and related components in tomatoes treated with moringa leaf extract. These findings are related to the work of Sabongari and Aliero (2004), who showed improved germination and biomass accumulation in tomato plants with seeds soaked in moringa leaf extract. Likewise, Raza *et al.* (2013) found that foliar application of salicylic acid promoted root growth parameters in cadmium-contaminated soils, likely because the phytohormone increased the impermeability of root endoderms, blocking heavy metal uptake and leading to higher plant productivity. This is further supported by Metwally et al. (2003), who reported that salicylic acid application increased root and shoot length, as well as fresh and dry root weight, in barley.

Yield (tons ha^{-1})

The highest yield was obtained with the moringa leaf extract application at the rate of 90 g L^{-1}. The remarkable increase was recorded in plots receiving various levels of moringa leaf extract because of the significant role being contributed by extract in cell division and elongation leading to higher yield as reported by Taiz and Zeigar (2006). These findings are also correlated with Foidle *et al.* (2001) who stated that the growth of young plants increases the resistance of plants to pests and disease, thereby producing more fruits and increased yield up to 20-30% in radish and beans. Similar results were also shown by Iqbal, 2014 who studied that different crop like soybeans, tomato, and sorghum recorded maximum yield when applied with moringa leaf extracts. Furthermore, these results follow the findings of Nagar *et al.* (2006) who reported that the application of moringa leaf extract recorded a remarkable increase in the yield of many crops when compared with the control. Acetyl salicylic acid recorded an increase in total yield and enhanced quality of tomato as found by Kazemi (2014). Similarly, the yield was also found to be maximum in squash when acetyl salicylic acid was applied in the foliar form which altered the sex ratio in favor of female flowers thereby increasing fruit production and total yield as observed by Al-Rubaye and Abd-Atia (2016).

Conclusions and Recommendations

From the current results, it has been concluded that among different concentrations of moringa leaf

extract, the level proved to be the superior one was 90 g L^{-1} in terms of enhancing the vegetative and yield-related traits. Similarly foliar application of acetyl salicylic acid at the rate of 300 mg L^{-1} also promoted the growth and performance of radish in terms of all growth attributes resulting in achieving maximum yield. So, for achieving maximum yield and productivity of radish, it is recommended to apply moringa leaf extract at the rate of 90 g L^{-1} after 15, 30, and 45 days of seed germination under agro-climatic conditions of Peshawar. Foliar application of acetyl salicylic acid is recommended to be done after 20 and 40 days of germination at the rate of 300 mg L^{-1}, for achieving high production and yield of radish under the Peshawar locality. Further experiments are needed to explore the acetyl salicylic acid and moringa leaf extract application on other crops of this family and also must check their effects in different locations.

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Novelty Statement

This study investigated the effects of moringa leaf extract and acetyl salicylic acid on radish growth and yield. It highlights their potential as effective, low-cost biostimulants under Peshawar's environmental conditions.

Author's Contribution

I. Khan: Conducted the research, performed experiments, analyzed data, and wrote the original draft of the manuscript.
N. Ara: Supervised the research, reviewed and edited the manuscript.
F. Fatima: Assisted in experiments and contributed to manuscript revisions.
F. Aman: Supported laboratory work and reviewed the manuscript.
M. Atta: Assisted in data collection, contributed to data analysis.

Generative AI and AI-assisted technology statement
The authors declare that no Genrative AI was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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