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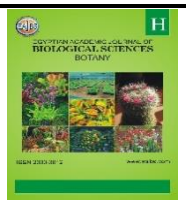

Effect of the Foliar Application with Seaweed, Moringa Extracts, Molybdenum and Boron on The Vegetative Growth and Yield of Plum Trees

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ABSTRACT

The current study was conducted during 2022 and 2023 seasons on plum (*Prunus salicina* Lindl.) cv. Kelsy was planted in sandy soil under a drip irrigation system in a private Farm located at Salah Al-Abd Village, Bostan Region, Nubaria, Behaira Governorate, Egypt to study the effect of foliar application of molybdenum 0.5 g/L, boron at 0.5 g/L, seaweed extract at 2000 ppm, moringa leaf extract at 4000 ppm, molybdenum 0.5g/L + boron 0.5g/L, molybdenum 0.5g/L + seaweed extract 2000ppm, molybedem0.5g/L + moringa extract 4000ppm, boron 0.5g/L + seaweed extract 2000ppm, boron 0.5 g/L + moringa extract 4000 ppm, seaweed extract 2000 ppm + moringa extract 4000 ppm and molybdenum 0.5g/L + boron 0.5g/L + moringa extract4000ppm + seaweed extract 2000 ppm as compared to the control treatments on vegetative growth and yield characteristics. The trees were planted at 3 x 3.5 m in sandy soil under a drip irrigation system. Sixty uniform trees of the same age, growth and size were randomly chosen. The foliar application of the twelve treatments was arranged in a randomized complete block design (RCBD) in five replicates during the two seasons. The trees were sprayed three times; before flowering, after fruit set and after one month after the second spraying. The obtained results showed that the application of the seaweed extract, moringa extract, boron and molybdenum individually or in combination effectively increased the vegetative growth attributes and fruit yield. The best results were obtained by the application of 0.5 g/L boron + 0.5 g/L molybdenum + seaweed extract + moringa extract in both seasons.

INTRODUCTION

The plum (*Prunus salicina* L.) trees are related to the Japanese group and belong to the family Rosacease. Plum fruits contain anti-inflammatory, anti-cancer agents, anti-diabetic, Antioxidant and neuroprotective so it has many positive effects that improve health (Dhalaria *et al.*, 2020). Plum fruits consider are a low source of calories, so it's characterized by their high content of fiber antioxidants, and sorbitol and low-fat content (Rozo-Romero *et al*., 2015). It is planted in warm areas around the world such as China, America, Europe and the Kaukasus. According to the Food and Agriculture Organization Corporate Statistical Database, the world's plum cultivation area in 2021 was 2.6 million ha, with an average yield was 4.6 t/ha, while in Egypt the plum cultivation area in 2021 was1440 ha with an average yield was 1.2 t/ha (FAO, 2021).

Moringa leaf extract (MLE) is considered one of the most important biostimulators and it consists of macro and micronutrients, vitamins, antioxidants, auxins, gibberellins, CKs, salicylic acid, and (Rady *et al*., 2013). MLE contains minerals, proteins, vitamins, carotene, amino acids, and zeatin so it is a high source of natural antioxidants (Jacob and Shenbagaraman 2011). Moringa leaf extract is rich in antibacterial and antioxidants (Kumar *et al*., 2012; Vongsak *et al*., 2012). However, foliar spraying moringa leaf extract increased the yield and marketable fruit and declined in number of unmarketable fruits (Sheren and El-Amary 2015; Nasira *et al*. 2016). Abbassy *et al*. (2020) reported that moringa extract is rich in (proteins, lipids, carbohydrates, minerals, vitamins, and amino acids), and improves growth and yield.

Seaweed extracts (SWE) are considered organic molecules as they appear as commercial formulations that assist in plant growth and improve tolerance to stress (Van Oosten *et al*., 2017). It was documented that the effects of seaweed extracts (SWE) exist on phytohormones and a range of organic molecules (Battacharyya *et al.,* 2015). SWE is known for its large amounts of plant growth regulators like auxins and CKs, vitamins, amino acids, organic matter, saccharides, and sterols, so it activates plant growth (Khan *et al.,* 2012). Since seaweed extract is characterized by high minerals like P, K, Ca, Mg, Cu, Fe, Mn, and Zn, it can increase the growth of the plant, and Crop yield. On the other hand, it increases the protein and leaf mineral content like N and P under desert conditions (Prasad *et al*., 2010). It plays an important role in increasing plant tolerance to abiotic and biotic stresses and improving nutrient use (Shukla *et al*. 2019; Rouphael and Colla 2020). SWE has a role in changing the characteristics of genes responsible for producing hormones such as auxins, GA and CKs. (Ali *et al*., 2019).

Boron (B) is a necessary micronutrient for all plants, and it is a component of cell walls, its biochemical roles have been described. B is essential for the preservation of membrane function (Abdoli, 2020). B is an important element necessary for optimal plant development (Shireen *et al*.2018). Boron plays a role in germination and pollen tube growth besides to an essential nutrient for fertilization (Hegazi *et al*. 2018; Souza *et al*., 2017). Optimal B uptake improves cell wall thickness via complexes. Other advantages of balancing B uptake include increased flower quantity and retention, germination, pollen tube elongation, seed and fruit development, and seed and fruit development. B also regulates photosynthate translocation and indole acetic acid oxidation (Bibi *et al*., 2019; Jatav *et al*., 2020). Boron is linked to the anther's pollen-producing capability, pollen viability, pollen tube germination, and pollen tube development (Padasalagi *et al*., 2019).

Molybdenum (Mo) is an element that is required in trace amounts for plant development, and it is an essential component of nitrate reductase and nitrogenase and is required for nitrate absorption in soil (Cecílio-Filho *et al*., 2019). One of the specialized activities of this vital vitamin is to be a structural component of the enzyme Nitrate Reductase, which plays an important role in nitrogen absorption (Santos *et al*., 2019). Furthermore, it is an essential component of a complex organic pterin known as Mo cofactor (Moco), which binds to molybdoenzymes in most biological systems (Rana *et al*., 2020). Mo is present directly in legumes in the production of abscisic acid and the conversion of sulfite to sulfate carried out by sulfite oxidase and aldehyde oxidase, as well as being a key element of the metabolism of sulfur amino acids (Tallkvist and Oskarsson, 2015).

Therefore, the current study was performed to test the results of the foliar spraying of seaweed extract (SWE), moringa leaf extract (MLE), molybdenum (Mo), and boron (B) individually or in combination on the vegetative growth, and yield characteristics of plum cv. Kelsey.

MATERIALS AND METHODS

This field study was conducted on five-year-old "Kelsey" plum trees (*Prunus salicina* L.) budded on Mariana rootstock during two successive seasons of 2022 and 2023. The trees were planted at 3 x 3.5 m in sandy soil under drip irrigation at Salah Al-Abd Village, Bostan Region, Nubaria, Behaira Governorate, Egypt to study the impact of foliar application of 0.5 g/L molybdenum, 0.5 g/L boron, 2000 ppm seaweed extract, 4000 ppm moringa extract, 0.5g/L molybdenum + 0.5g/L boron, 0.5g/L molybdenum + 2000 ppm seaweed extract, 0.5g/L molybdenum + 4000 ppm moringa extract, 0.5g/L boron + 2000 ppm seaweed extract, 0.5 g/L boron + 4000 ppm moringa extract, 2000 ppm seaweed extract + 4000 ppm moringa extract and 0.5g/L molybdenum + 0.5g/L boron + 4000 ppm moringa extract + 2000 ppm seaweed extract as compared to control on vegetative growth parameters and yield. Sixty uniform trees of the same age, growth and size were randomly chosen.

The foliar application of the twelve treatments was arranged in a randomized complete block design (RCBD) in five replicates during the two seasons. The trees were sprayed three times; before flowering, after fruit set and after one month after the second spraying.

The effect of the above-mentioned treatments was studied by investigating their influence on the following parameters:

Vegetative Growth: At the end of growing seasons, the ten selected shoots were measured: The average shoot length (cm) and shoot diameter (cm) using hand caliber. Leaf area (cm^2). Leaf chlorophyll indication (SPAD units): by chlorophyll meter apparatus in ten leaves from each plot according to the method described by Moran (1982).

Fruit set and Fruit Drop Percentages and Fruit Yield:

Fruit set percentages, fruit drop percentages, and fruit yield: The total number of flowers at full bloom in May and then the number of set fruits were reordered for both years of study and then the fruit set percentages were calculated as the following equation 1

$$\text{Fruit set \%} = \frac{\text{No.of set fruits}}{\text{No.of flowers}} \times 100 \quad (1)$$

The fruit drop percentage was calculated by the formula 2

$$\text{Fruit drop (\%)} = \frac{\text{No.of fruitlets at initial set} - \text{No.of harvested fruits}}{\text{No.of fruitlets at initial set}} \times 100 \quad (2)$$

Fruit Yield (kg/tree): was assessed in kg for each tree/replicate.

Statistical Analysis:

The obtained data were subjected to one-way ANOVA according to (Ott and Longnecker, 2015) and the least significant difference (LSD) at 0.05% was used to compare the means of the treatments using CoSat CoHort Software (2005, Pacific Grove, CA, USA) (Snedecor and Cochran, 1990).

RESULTS AND DISCUSSION

The results in Table 1 showed that the mixture of Moringa + seaweed extract + boron + Molybdenum recorded the highest values of shoot length (96.50 and 99.66 cm), shoot diameter (1.33 and 1.83 cm) and leaf chlorophyll (41.06 and 42.76), while the control showed the highest results in the first and second seasons, respectively. The mixture of B + MLE extract recorded (96.15 and 96.52 cm), fruit diameter (1.32 and 1.81 cm) and chlorophyll content (39.09 and 40.48) in the first and second seasons respectively.

Table 1. Effect of the spraying of seaweed extract, moringa extract, molybdenum and boron and their combination on shoot length, shoot thickness and leaf total chlorophyll of plum tree cv. Kelsey during the 2022 and 2023 seasons.

Treatments	Shoot Length (cm)		Shoot thickness (cm)		Total chlorophyll (SPAD)	
	Seasons					
	2022	2023	2022	2023	2022	2023
Control	85.01e	82.68h	1.16de	1.35g	32.92h	35.46e-g
Boron	89.31d	87.62f	1.13e	1.50f	35.42ef	35.34fg
Molybdenum	91.35c	92.78d	1.18cd	1.61d	37.72b-d	36.66d-f
Seaweed extract	92.35bc	87.39f	1.16de	1.66bc	34.99fg	34.36gh
Moringa extract	92.62bc	86.60fg	1.16de	1.62cd	33.66gh	33.06h
Boron+ Molybdenum	91.37c	95.41bc	1.21bc	1.56e	38.25b	37.67c-e
Boron + Moringa extract	96.15a	96.52b	1.32a	1.81a	39.09b	40.48b
Boron + Moringa extract	88.44d	84.90g	1.21bc	1.55e	37.97bc	38.55b-d
Seaweed extract + Molybdenum	91.51c	90.56e	1.23b	1.65bc	36.44d-f	39.20bc
Moringa extract + Molybdenum	93.67b	93.52cd	1.29a	1.68b	38.81b	39.39bc
Seaweed extract + Moringa extract	86.23e	82.11h	1.18cd	1.53ef	36.64c-e	38.00cd
Combination	96.50a	99.66a	1.33a	1.83a	41.06a	42.76a
$LSD_{0.05}$	1.55	1.90	0.03	0.04	1.40	2.11

The effect of moringa and seaweed extract and two micronutrient applications on the number of flowers, fruit set and fruit drop percentages as well as fruit yield of plum trees during 2022 and 2023 seasons are shown in Table 2. The mixture of MLE + SWE + B + Mo recorded the highest values of fruit set (33.02 and 34.5), while the control showed the highest results fruit drop (47 and 45.26) in the first and second seasons, respectively, followed by the mixture of boron + seaweed extract and Mo + MLE in fruit drop, whereas there was no significant difference among these treatments in both seasons, while the mixture of treatments showed the lowest values of fruit drop (35.27 and 34.37%) in first and second seasons, respectively. The combination recorded the highest values of fruit weight (14.37 and 15.09 kg) and yield (13.14 and 13.8 tons), followed by a mixture of boron + seaweed extract. There was no significant difference among these treatments in both seasons, while the control treatment gave the lowest values of fruit weight (8.49 and 8.71 kg) in the first and second seasons.

Moringa leaf extract is no alternative to substitute inorganic fertilizers moreover moringa leaf extract is used to increase productivity and fruit quality (Phiri, 2010). Recently, a lot of attention has been given to moringa leaf extract because of its high content of cytokinins (Abdalla and El-Khoshiban, 2012; Abdalla, 2013). Moringa leaf extract is rich in nutrients like N, P, K, and micronutrients and helps in the absorption of them, so it could increase vegetative growth and also the root length. Besides, the same authors added that because moringa leaf extract contains high amounts of antioxidants and phytochemicals, it can increase the power of the tree (Rani *et al*. 2018; and Meireles *et al*. 2020). Semida *et al*. (2014) indicated that MLE used as a plant biostimulant to assist in growth and production when applied as foliar spray. Leaf moringa has amino acids, minerals like Calcium, magnesium phosphor, sulfur, zinc, iron, and Copper as well as vitamin E, so it has a great effect on growth and productivity) (Howladar, 2014; Rady *et al*., 2015; Nisar *et al*., 2021).

SWE has auxins, gibberellins, cytokinins, and amino acids at low concentrations, so it can activate the physiological side of the plant, increase plant growth, improve blooming and production, and harvest, so it has become a biostimulant for a variety of fruits and vegetables (Arioli *et al*., 2021). Spraying pomegranate seedlings with seaweed extract at 4 ml/L remarkably increased the seedling height, average main stem diameter and leaf area

(Athbib *et al*., 2018). Besides that, the foliar application of SWE Increases growth and productivity, and Characteristics of fruit quality (Harhash *et al*., 2021). SWE is a high and good source of nutrients, organic matter, and plant growth; therefore, a foliar application of a seaweed extract is an efficient method to increase vegetative growth, photosynthetic rate, proline content and TSS, and abiotic stress tolerance, yield, fruit quality and fruit shelf life in fruit crops (Stirk *et al*., 2020). Mohamed *et al*. (2020) found that plum trees sprayed with 6% moringa extract had an increased fruit set, and fruit yield in the plum cv "Hollywood", while they had reduced fruit drop compared to the use of 0%, 4%, or 5% MLAE.

The foliar application of boron (B) improved the fruit set because it plays in the growth of the pollen tube (Williams *et al*., 2019). Karlidag *et al*. (2017) demonstrated that combining 1000 ppm boron with 3% urea resulted in a higher yield in apricot plants (Aftab *et al*., 2010). In the same trend, Larbi *et al*. (2011) stated that B sprays improved blooming rate and olive yield. Boron plays a role in germination and pollen tube growth besides to an essential nutrient for fertilization, improving cell wall thickness, increasing flower quantity and retention, pollen tube elongation, and seed and fruit development (Sharafi and Raina 2021).

Several investigations have demonstrated that a lack of molybdenum (Mo) lowers the activity of molybdoenzymes, which has a detrimental impact on primary nitrogen absorption and activity in legume nodules (Lucasynski *et al*., 2019). As a result, the role of Molybdenum is strongly related to nitrogen metabolism, and its absence leads to Nitrogen deficit in plants (Pollock *et al*., 2002). Mo is an essential microelement for plants, and its lack may limit their growth. Different plant enzymes, such as nitrate reductase in N metabolism, consume Molybdenum, therefore deficient plants display lower growth and poor chlorophyll content (Hille *et al*., 2011; Rana *et al*., 2020). Mo and B are involved in various enzymatic processes regulating plant growth and physiological processes (Ilyas *et al*., 2015).

Table 2. Effect of the spraying of seaweed extract, moringa extract, molybdenum and boron and their combination on fruit set and drop percentages and fruit yield of plum tree cv. Kelsey during the 2022 and 2023 seasons.

Treatments	Fruit Set %		Fruit drop %		Yield (kg/tree)	
	Seasons					
	2022	2023	2022	2023	2022	2023
Control	25.70f	26.50e	47.00a	45.26bc	8.49g	8.71 h
Boron	30.56 b-d	29.65d	40.19e-g	40.66c-e	11.58de	11.80de
Molybdenum	30.98 a-d	31.90b-d	42.16c-e	41.29b-e	11.92cde	10.72fg
Seaweed extract	30.05b-e	30.63cd	43.14bcd	43.12a-c	12.03cd	11.26cd
Moringa extract	28.96de	27.07e	44.79a-c	45.36 a	11.25e	10.22g
Boron+ Molybdenum	30.55b-d	31.58b-d	43.25b-d	42.99a-d	11.27e	12.46cd
Boron + Moringa extract	32.35 ab	33.22ab	38.06g	39.19e	13.72b	14.05b
Boron + Moringa extract	29.59cde	31.50 b-d	41.30d-f	40.38de	10.49f	11.39ef
Seaweed extract + Molybdenum	30.71a-d	31.22b-d	39.12fg	38.91e	12.43c	13.02c
Moringa extract + Molybdenum	28.13e	31.24 b-d	45.34ab	43.75ab	11.60de	12.84c
Seaweed extract + Moringa	31.69a-c	32.55a-c	40.13e-g	40.68c-e	11.52de	12.26cd
Combination	33.02a	34.50a	35.27h	34.37 f	14.37a	15.09 a
$LSD_{0.05}$	2.10	2.07	2.54	2.41	0.59	0.78

Conclusion

Based on the previous results, it was concluded that foliar application of the mixture of 0.5g/L molybdenum + 0.5g/L boron + 4000 ppm moringa extract + 2000 ppm seaweed extract recorded the highest values of shoot length and thickness, leaf area, leaf total chlorophyll, fruit weight, fruit set percentage and fruit yield. On the other side, this treatment

recorded the lowest values for the fruit drop percentages in the two seasons. Also, the Boron + Moringa extract also had a good effect on these parameters in the two seasons.

Declarations:

Ethical Approval: Ethical Approval is not applicable.

Competing interests: The authors declare no conflict of interest.

Authors Contributions: I hereby verify that all authors mentioned on the title page have made substantial contributions to the conception and design of the study, have thoroughly reviewed the manuscript, confirm the accuracy and authenticity of the data and its interpretation, and consent to its submission.

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