



## Response of Broccoli Variety Matsuri to Treatment With Different Concentrations of Some Microelements (Manganese and Molybdenum)

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### ABSTRACT

To evaluate the effect of foliar application of manganese and molybdenum at various levels on the growth and yield of broccoli (*Brassica oleracea* var. *italica*) The experiment laid out over the growing season 2024–2025, the vegetables field site of the University of Mosul. Matsuri cultivar. This experiment consisted of three concentrations of manganese (0, 75, and 150 mg L<sup>-1</sup>) and three concentrations of molybdenum (0, 25, and 50 mg L<sup>-1</sup>). Periodicity of foliar spray was at three levels (1st spray: one month after germination, 2nd and 3rd spray) every 20 days interval thereafter. The experiment with nine treatment combinations was carried out in a randomized complete block design (RCBD) with three replications. All data collected were subjected to respective statistical analyses in accordance with the experimental design, and means of treatment were compared by Duncan's multiple range test at 5 % level of significance. Results showed that manganese foliar spray at 150 mg L<sup>-1</sup> had a significant positive effect on majority of the studied traits, including plant height, numbers of leaves, leaf area, total leaf area leaf, dry matter content, chlorophyll content, head diameter, No. and yield of lateral florets. Similarly, manganese at 75 mg L<sup>-1</sup> significantly improved main head weight and yield, lateral floret weight, individual plant yield, and total yield and shortened the harvest interval of both primary and secondary heads. Application of molybdenum at 50 mg L<sup>-1</sup> was highly significant for most of the parameters such as, plant height, leaves/plant, leaf area per plant, dry matter, chlorophyll content, primary head weight and primary head diameter, number of lateral florets, total yield, cumulative yield per plant and time to harvest.

**Keywords:** Broccoli, manganese, molybdenum, Growth, Yield.

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### INTRODUCTION

Broccoli (*Brassica oleracea* var. *italica*) is a high-nutritional value Brassicaceae vegetable for the winter season, with its roots commonly used as a coffee substitute or additive and a resource of inulin. This is a cool to intermediate season crop and found in much of the world, especially Mediterranean countries, Asian and parts of Europe. It is estimated that the worldwide planting area is about 25,500 thousand hectares, and its annual production is higher than 21.6 million tons [1]. Broccoli is also among the most economical crops with nutritional values, and its medicinal properties are more widely applied especially in Europe Brassicaceae Family. In it, there is a presence of bioactive compounds like glucosinolates, which are subsequently converted to sulforaphane by an enzyme, of which the role in cancer prevention has been documented repeatedly [2]. Additionally, broccoli has a high content of vitamins, namely A, B1, B2, B5, B6, B17 and E, as well as important micro-minerals like iron, zinc, calcium, and magnesium [3]. Besides its nutritional value, broccoli also has great economic value. At the moment its price in the market is almost 5 times more than that of tomato or cauliflower due to the fact that its dependence on neighbouring countries and absence in local production. Broccoli is one of the easier home garden options to grow and take care of; yet, its name

often gets the boot. This gap in domestic cultivation may be due, in part, to limited knowledge among farmers about the growth requirements of the crop. Foliar spraying of micronutrients is an important approach to accelerating plant growth in conditions where soil properties induce low nutrient uptake efficiency [4]. Sufficient levels of these micronutrients result in substantial enhancement of vegetative growth and yield quality [5]. Manganese (Mn) is an essential element in photosynthesis where it participates in water-splitting at the oxygen-evolving complex, and is also required for the activity of several enzymes in metal-trophic pathways and chlorophyll biosynthesis, is an essential component of nitrate reductase—an enzyme that catalyzes the conversion of nitrate ( $\text{NO}_3^-$ ) into nitrite ( $\text{NO}_2^-$ ), an important intermediate step in amino acid and protein biosynthesis. An inadequacy of any of these components can interfere with physiological functions and affect growth and yield adversely [6].

This study aims to determine the optimal concentrations of manganese and molybdenum that maximize vegetative growth, improve yield quality, and enhance the agricultural efficiency of broccoli production—particularly in the context of sustainable agriculture practices. Several studies have demonstrated the importance of manganese in improving broccoli growth and yield due to its involvement in physiological functions such as photosynthesis [6]. In a study conducted in Bangladesh, [7] found that foliar application of molybdenum at a concentration of 0.05% significantly increased plant height, leaf number, and total yield. Another study by [8], conducted on the broccoli cultivar Pusa KTS-1, indicated that foliar application of molybdenum at 2.5% significantly enhanced vegetative traits such as plant height and number of leaves, along with improvements in head weight and total yield. [9] observed that manganese foliar spraying at  $5 \text{ mg L}^{-1}$  notably improved vegetative growth traits and yield, including plant height, number of leaves, and fresh head weight compared to the control. [10] emphasized the importance of balanced manganese levels, noting that concentrations exceeding  $7 \text{ mg L}^{-1}$  may inhibit certain metabolic activities and reduce growth. [11] found that varying manganese concentrations (2, 4, and  $6 \text{ mg L}^{-1}$ ) led to an increase in chlorophyll content in the leaves. Furthermore, [12] in Bangladesh demonstrated that foliar application of molybdenum improved marketable head yield, total yield, and head diameter. [13] reported that manganese foliar application at 10% on four broccoli cultivars resulted in increased plant height, leaf number, head weight and diameter, and total yield per plant. In another study from India, [14] found that foliar spraying of molybdenum at concentrations of 0.25%, 0.50%, 0.75%, 1.00%, and 1.25% significantly enhanced the total yield of broccoli.

## Materials and Methods

### Experimental Site, Land Preparation, Planting, and Field Management:

This research was carried out in the vegetable field of the Department of Horticulture and Landscape Engineering, College of Agriculture and Forestry, University of Mosul during the growing season of 2024–2025. To evaluate the effects of foliar application of manganese and molybdenum on vegetative, quantitative and qualitative characteristics in broccoli. Two perpendicular passes of plowing were performed with a reversible three-bottom plow with the operation complete between July 3 - 5, followed by soil leveling and smoothing with a harrow. An experimental unit comprised of two rows, measuring  $150 \text{ cm} \times 80 \text{ cm}$ . Plants were planted at 30 cm interval and an experimental unit consisted of 10 plants. Each experimental unit was  $2.4 \text{ m}^2$  in area, and the total number of plants included in the experiment was 270. On August 15, 2024, seeds planted in seedling trays. Seedlings were transplanted into the field on 20 September 2024 after reaching the appropriate transplanting stage (3–4 true leaves). All experimental units were treated uniformly in the field in relation to fertilization, weeding, pruning and preventive and curative control of pests and diseases. The insecticide Alfa was used to prevention of aphids at a dose of  $1 \text{ mL L}^{-1}$  with one application every fortnight.

### Experimental Treatments and Statistical Design:

Two “factors” were studied:

Factor 1: Manganese that was applied on the foliar surface at three concentrations: 0, 75 and  $150 \text{ mg L}^{-1}$ .

Factor 2: Molybdenum again was applied on the foliar surface at three concentrations: 0, 25 and  $50 \text{ mg L}^{-1}$ .

The plants were treated with manganese and molybdenum at different growth stages: the first application was done 20 days after transplanting, the second and the third applications also followed 20 days intervals. Spraying was done in the early morning using a 5-liter hand sprayer until full leaf wetness using the stated concentrations of each treatment. To ensure spray adhesion, a small amount of dishwashing liquid was added to the spray solution as a surfactant. As a result of factorial combination of the two factors, 3 by 3, the research developed a total of 9 treatment combinations. The experiment therefore had an overall treatment unit of 27 since it had three replications. Again the number of plants to be subjected to each treatment combination was specified earlier. The field experiment was conducted using Randomized Complete Block Design with three replicates. Appropriate statistical analysis followed thereafter [15].

Measured Parameters:

Plant height (cm plant<sup>-1</sup>): Plant height was determined at the end of the season (stature, from the base of the stem at the soil surface to the highest leaf, using a measuring tape).

Plant Leaf Number (leaves plant<sup>-1</sup>): The number of leaves was counted in five randomly selected plants per experimental unit, and numbers were averaged.

Leaf Area (cm<sup>2</sup> plant<sup>-1</sup>): From each experimental unit, five plants were randomly selected. Leaves were removed from plantlets and twenty 1 cm<sup>2</sup> leaf discs were taken using a cork borer. Plant leaf area was estimated using proportional calculation related to the fresh weight.

Total Leaf Area Plant<sup>-1</sup> (cm<sup>2</sup> plant<sup>-1</sup>) (LA-PL): This attribute was calculated as the product of leaf area and leaf number plant<sup>-1</sup>.

Leaf Dry Matter Percent: Samples were weighed (five leaves, using a high precision electronic balance. The leaves were air-dried for a week prior to oven-drying at a temperature of 75°C for 72 hours or until weight constancy (based on Silva et al. Percentage of dry matter = (Dry weight / Fresh weight) × 100

Total Chlorophyll Content of Leaves (mg 100 g<sup>-1</sup> (fw)): Total chlorophyll content was estimated as per [16] In a mortar, 1 gram of fresh mature leaves from the middlelamina region of the plant was ground with 80% acetone. The supernatant was centrifuged at 3000 rpm for 5 minutes, and absorbance at 645 nm was measured with a spectrophotometer. The calculation of Chlorophyll (mg per 100 g) using the equation, Chlorophyll (mg 100 g<sup>-1</sup>) = OD × 5.8.

Main Head Circumference (cm head<sup>-1</sup>): Measured using a measuring tape around the widest part of the main floral head.

Weight of main heads (g head<sup>-1</sup>): Total weight of the main heads in each experimental unit divided by the number of plants.

Main head yield (ton ha<sup>-1</sup>): Obtained by dividing the main head yield produced by each experimental unit by the unit area and multiplying the result by 10,000 to convert to ton ha<sup>-1</sup>.

Weight of lateral heads (g head<sup>-1</sup>): Total weight of lateral heads the experimental unit / Number of lateral heads.

Total lateral heads of all plants: the total heads of all plants in the experimental unit divided by the number of plants (heads plant<sup>-1</sup>).

Lateral head yield (g plant<sup>-1</sup>): The total lateral head yield of the unit divided by the number of plants.

Lateral Head Yield (ton ha<sup>-1</sup>) = (lateral head yield of the unit)/(unit area) × 10,000

Plant Total Yield (g plant<sup>-1</sup>): The total yield (main and lateral heads) per experimental unit.

Total yield (ton ha<sup>-1</sup>): Calculated by the sum of main and lateral head yields for each experimental unit, divided by the area of that experimental unit and multiplied by 10,000, which was done to give the same type of measure with hectares.

Days to Harvest of Principal Head: No. of days from sowing seeds until the stage of marketing maturity, when a firm head is fully developed without any indication of flowering.

Harvest Date of Lateral Head: was recorded as the number of days from sowing seeds to when lateral heads reached the marketing standard stage of maturity.

## Results and Discussion

As shown in Table (1), foliar application of manganese at a concentration of 150 mg L<sup>-1</sup> led to significant improvements in vegetative growth traits, including plant height, number of leaves, leaf area, and total leaf area per plant. These values reached 63.88 cm, 20.67 leaves plant<sup>-1</sup>, 424.11 cm<sup>2</sup> leaf<sup>-1</sup>, and 8776.6 cm<sup>2</sup> plant<sup>-1</sup>, respectively, and were significantly superior to the control treatment. Similarly, foliar spraying with molybdenum at a concentration of 50 mg L<sup>-1</sup> resulted in increased plant height (63.44 cm), number of leaves (19.55 leaves plant<sup>-1</sup>), individual leaf area (425.27 cm<sup>2</sup>), and total leaf area per plant (8320.0 cm<sup>2</sup>). This treatment showed significant differences compared to the control in all parameters except for leaf area, which only showed a significant improvement over the 25 mg L<sup>-1</sup> molybdenum treatment.

Table 1. Effect of foliar application of manganese and molybdenum on vegetative growth traits of broccoli cv. Matsuri (plant height, number of leaves, individual leaf area, and total leaf area per plant).

Manganese (mg L <sup>-1</sup> )	Molybdenum (mg L <sup>-1</sup> )	Parameters Measured			
		Plant Height (cm plant <sup>-1</sup> )	Number of Leaves (leaves plant <sup>-1</sup> )	Individual Leaf Area (cm <sup>2</sup> leaf <sup>-1</sup> )	Total Leaf Area per Plant (cm <sup>2</sup> plant <sup>-1</sup> ) <sup>1</sup>
0	0	53.33 c	14.00 c	299.17 c	4196.0 d
	25	56.66 bc	18.00 b	370.37 b	6666.6 c
	50	61.66 ab	18.33 b	422.33 a	7744.2 bc
75	0	63.66 a	19.33 ab	446.97 a	8652.4 ab
	25	61.66 ab	18.33 b	366.97 b	6715.8 c
	50	64.66 a	20.00 ab	429.50 a	8588.5 ab
150	0	62.33 ab	21.33 a	451.37 a	9633.8 a
	25	65.33 a	20.33 ab	397.00 ab	8068.9 b
	50	64.00 a	20.33 ab	423.97 a	8627.2 ab
Average Effect of Manganese	0	57.22 b	16.78 c	363.26 b	6202.3 c
	75	63.33 a	19.22 b	414.48 a	7985.5 b
	150	63.88 a	20.67 a	424.11 a	8776.6 a
Average Effect of Molybdenum	0	59.77 b	18.22 b	339.17 ab	7494.1 b
	25	61.22 ab	18.88 ab	378.11 b	7150.4 b
	50	63.44 a	19.55 a	425.27 a	8320.0 a

Means followed by the same letter within each factor or interaction are not significantly different according to Duncan's Multiple Range Test at the 5% level of probability.

The interaction between manganese and molybdenum treatments revealed that the combination of 150 mg L<sup>-1</sup> manganese with 25 mg L<sup>-1</sup> molybdenum resulted in the highest plant height (65.33 cm plant<sup>-1</sup>), which was significantly superior to the control but not significantly different from most other treatment combinations. On the other hand, the combination of 150 mg L<sup>-1</sup> manganese without molybdenum application led to the highest values for number of leaves (21.33 leaves plant<sup>-1</sup>), individual leaf area (451.37 cm<sup>2</sup>), and total leaf area per plant (9633.8 cm<sup>2</sup>). These values were significantly higher than the control treatment but did not significantly differ from most other interaction treatments.

The results indicate that manganese is involved in the composition of nitrate reductase enzymes and the photolysis of water during photosynthesis, thereby enhancing cell growth and leaf expansion [6]. Molybdenum is essential for activating nitrate reductase, which improves nitrogen utilization and protein synthesis [17]. These findings are consistent with those of [8,10], who reported that manganese enhances the uptake of major nutrients such as nitrogen.

Table 2. Effect of foliar application of manganese and molybdenum on broccoli cv. Matsuri regarding dry matter percentage in leaves, total leaf chlorophyll content (mg per 100 g fresh weight), and average main head circumference (cm).

Manganese (mg L <sup>-1</sup> )	Molybdenum (mg L <sup>-1</sup> )	Parameters Measured		
		Dry Matter Percentage in Leaves	Total Leaf Chlorophyll Content (mg per 100 g fresh weight)	Average Main Head Circumference (cm)
0	0	9.66 b	3.906 c	35.66 b
	25	13.63 a	4.410 ab	43.00 a
	50	15.20 a	4.476 ab	44.00 a
75	0	14.33 a	4.183 b	48.33 a
	25	14.50 a	4.400 ab	49.00 a
	50	13.80 a	4.310 ab	46.66 a
150	0	14.10 a	4.500 a	47.66 a
	25	13.46 a	4.543 a	44.66 a
	50	14.36 a	4.380 ab	44.00 a
Average Effect of Manganese	0	12.83 b	4.264 b	40.89 b
	75	14.21 a	4.297 b	48.00 a
	150	13.97 ab	4.474 a	45.44 a
Average Effect of Molybdenum	0	12.70 b	4.197 b	43.89 a
	25	13.86 ab	4.451 a	45.56 a
	50	14.45 a	4.389 a	44.89 a

Means followed by the same letter within each factor or interaction are not significantly different according to Duncan's Multiple Range Test at the 5% level of probability.

The results presented in Table 2 indicated that 75 mg L<sup>-1</sup> of manganese applied to the leaves increased the percentage of dry matter to 14.21%, the value was significantly different from the control. For total leaf chlorophyll content, the 150 mg L<sup>-1</sup> manganese treatment was significantly higher than other treatments averaging 4.474 mg per 100 g fresh weight. The main head girth of the control treatment was 34.25 cm and this was significantly lower than the 48.00 cm and 45.44 cm obtained at the 75 mg L<sup>-1</sup> and 150 mg L<sup>-1</sup> manganese treatments, respectively. In the case of molybdenum, foliar application of 50 mg L<sup>-1</sup> of said nutrient resulted in a significant increase in dryer matter percentage in leaves up to 14.45%, which is greater than that of control. Higher concentrations of molybdenum (25 mg L<sup>-1</sup> and 50 mg L<sup>-1</sup>) also resulted in a significant increase in total chlorophyll content, 4.451 and 4.389 mg per 100 g F.W., respectively, significantly higher than the control. For the main head circumference (shown in the fig), no differences were found however. Manganese and molybdenum treatments interaction indicated that the combination of no manganese application with 50 mg L<sup>-1</sup> molybdenum resulted in the highest dry matter percentage in leaves (15.20%). This differed significantly from the control but did not differ significantly from most other interaction treatments. The maximum chlorophyll content (4.543 mg/100 g freshness weight) was given by interaction of 150 mg L<sup>-1</sup> manganese with 25 mg L<sup>-1</sup> molybdenum which was significant in comparison to control but not in comparison to other interaction treatments. The highest head circumference was also shown for 75 mg L<sup>-1</sup> manganese + 25 mg L<sup>-1</sup> molybdenum and reached to 49.00 cm and it was so higher the control and similar to most of interaction treatments. The underlying mechanisms of these effects can be explained by the function of Mn in promoting photosynthetic efficiency [11], whereas Mo promotes chlorophyll synthesis by regulating nitrogen metabolism. Similar result was reported for [18] showed that molybdenum stimulates the synthesis of enzymes involved in electron transport in chloroplasts.

Table 3. Effect of foliar application of manganese and molybdenum on broccoli cv. Matsuri in terms of: average main head weight (g), main head yield (ton ha<sup>-1</sup>), average lateral head weight (g), average number of lateral heads (heads plant<sup>-1</sup>), and lateral head yield (g).

Manganese (mg L <sup>-1</sup> )	Molybdenum (mg L <sup>-1</sup> )	Parameters Measured				
		Average Main Head Weight (g)	Average Head Yield (t ha <sup>-1</sup> )	Average Lateral Head Weight (g)	Average Number of Lateral Heads (heads plant <sup>-1</sup> )	Lateral Head Yield (g)
0	0	292.6 e	12.19 e	17.16 g	1.33 d	22.33 d
	25	335.0 de	13.96 de	42.20 d	3.66 bc	153.00 bc
	50	463.0 bc	19.29 bc	32.33 f	4.66 ab	152.00 bc
75	0	592.3 a	24.68 a	49.00 c	4.00 bc	197.67 b
	25	497.0 b	20.71 b	35.33 ef	2.33 cd	82.00 cd
	50	518.6 ab	21.61 ab	62.00 a	2.33 cd	143.67 bc
150	0	530.0 ab	22.08 ab	39.16 de	3.33 bc	129.67 bc
	25	405.3 cd	16.92 cd	41.33 d	4.66 ab	193.33 b
	50	458.3 bc	19.10 bc	54.16 b	6.00 a	326.00 a
Average Effect of Manganese	0	363.5 c	15.14 c	30.56 c	3.22 b	109.11 b
	75	536.0 a	22.33 a	48.78 a	2.88 b	141.11 b
	150	464.5 b	19.36 b	44.88 b	4.66 a	216.33 a
Average Effect of Molybdenum	0	471.6 a	19.65 a	35.11 c	2.88 b	116.56 b
	25	412.4 b	17.19 b	39.62 d	3.55 ab	142.78 b
	50	480.0 a	20.00 a	49.50 a	4.33 a	207.22 a

Means followed by the same letter within each factor or interaction are not significantly different according to Duncan's Multiple Range Test at the 5% level of probability.

The data in Table (3) showed that treatment with manganese foliar application of 75 mg L<sup>-1</sup> produced the greatest main head weight, main head yield, and lateral head average weight per plant (536.0 g, 22.33 t ha<sup>-1</sup>, and 48.78 g, respectively). These values were much greater than the other manganese treatments. In comparison, the application of 150 mg L<sup>-1</sup> manganese per liter of water resulted in the high significant average number of lateral heads (4.66 heads plant<sup>-1</sup>), and followed by high significant average yield of all plant heads (216.33 g), above other manganese treatments. For molybdenum, foliar application at 50 mg L<sup>-1</sup> had the highest weight and yield of the main head (480.0 g and 20.00 t ha<sup>-1</sup>, respectively), which were only significantly different from the 25 mg L<sup>-1</sup> treatment. In a similar way, molybdenum application at 50 mg L<sup>-1</sup> also significantly enhanced the average weight and yield of lateral heads, with values of 49.50 g (vs. Furthermore, both 25 and 50 mg L<sup>-1</sup> molybdenum treatments significantly increased the average number of heads of lateral, with 4.33 heads plant<sup>-1</sup>).

Regarding the interaction between foliar applications of manganese and molybdenum, the results in the table indicate that spraying with 75 mg L<sup>-1</sup> manganese combined with no molybdenum application significantly increased the average main head weight and its yield, reaching 592.3 g and 24.68 t ha<sup>-1</sup>, respectively. These values differed significantly from most other interaction treatments, except the treatment with the same manganese concentration combined with 50 mg L<sup>-1</sup> molybdenum, as well as the treatment with 150 mg L<sup>-1</sup> manganese without molybdenum. For the average lateral head weight, the highest significant value (62.00 g) was obtained from the interaction between 75 mg L<sup>-1</sup> manganese and 50 mg L<sup>-1</sup> molybdenum, outperforming all other interaction treatments. Regarding the average number of lateral heads, plants sprayed with 150 mg L<sup>-1</sup> manganese and 50 mg L<sup>-1</sup> molybdenum had the highest significant value of 6.00 heads plant<sup>-1</sup>, differing significantly from other interaction treatments except for those sprayed with the same manganese concentration combined with 25 mg L<sup>-1</sup> molybdenum and the plants not sprayed with manganese but sprayed with 50 mg L<sup>-1</sup> molybdenum. The combination of 150 mg L<sup>-1</sup> manganese and 50 mg L<sup>-1</sup> molybdenum produced the highest lateral head yield, reaching 326.00 g, which was significantly higher

than all other interaction treatments. This can be explained by manganese's role in supporting carbohydrate translocation from leaves to storage organs (heads), while molybdenum improves protein synthesis [19]. These findings are consistent with [20], who reported that molybdenum increases cauliflower head weight by 25%. The synergistic effect of these elements stimulates growth hormone (auxin) synthesis and activates cell division in lateral buds [21]. These results align with [14], who found that high molybdenum concentrations (1.25%) may inhibit growth, supporting the superiority of the 50 mg L<sup>-1</sup> concentration in this study.

The results presented in Table (4) indicate that foliar application of manganese at a concentration of 150 mg L<sup>-1</sup> significantly increased the yield of lateral heads, reaching 9.015 t ha<sup>-1</sup>. Regarding the total yield per plant and total yield in tons, both increased significantly with manganese application at 75 mg L<sup>-1</sup>, reaching 584.78 g and 24.366 t ha<sup>-1</sup>, respectively. Additionally, this treatment resulted in the shortest days to harvest for both main and lateral heads, with values of 122.66 and 150.22 days, respectively. For molybdenum, spraying at 50 mg L<sup>-1</sup> significantly increased the lateral head yield to 8.634 t ha<sup>-1</sup>. Moreover, this treatment enhanced the total yield per plant to 529.50 g and the total yield to 22.206 t ha<sup>-1</sup>, significantly surpassing the 25 mg L<sup>-1</sup> treatment. It also resulted in the shortest days to harvest for the main heads (125.11 days) without a significant difference compared to other treatments. The shortest days to harvest for lateral heads (149.67 days) were observed with 25 mg L<sup>-1</sup> molybdenum application.

Regarding the interaction between manganese and molybdenum applications, the combination of manganese at 150 mg L<sup>-1</sup> and molybdenum at 50 mg L<sup>-1</sup> significantly increased the lateral head yield to 13.583 t ha<sup>-1</sup>. Spraying with manganese at 75 mg L<sup>-1</sup> without molybdenum resulted in a significant increase in the total yield per plant (641.33 g) and total yield (26.722 t ha<sup>-1</sup>), differing significantly from all other interaction treatments except the manganese 75 mg L<sup>-1</sup> combined with molybdenum 50 mg L<sup>-1</sup> and manganese 150 mg L<sup>-1</sup> without molybdenum. The shortest days to harvest for the main heads (120 days) were recorded with the combination of 75 mg L<sup>-1</sup> manganese and 50 mg L<sup>-1</sup> molybdenum, differing significantly only from the control treatment. The shortest days to harvest for lateral heads (146.33 days) were observed with manganese at 75 mg L<sup>-1</sup> without molybdenum. This can be explained by the fact that micronutrients accelerate metabolic processes, thereby reducing the time required for biomass accumulation [5]. These findings are consistent with [13], who reported that molybdenum accelerates broccoli maturity in subtropical regions, and [12], who noted that balanced nutrient supply shortens the maturation period (120 days compared to 144 days in the control).

Table (4) Effect of Foliar Application of Manganese and Molybdenum on Broccoli Plants (Matsuri Cultivar) for the Traits (Lateral Head Yield (t ha<sup>-1</sup>), Total Yield per Plant (g plant<sup>-1</sup>), Total Yield (t ha<sup>-1</sup>), Main Head Harvest Date (days), Secondary Head Harvest Date (days)).

Manganese (mg L <sup>-1</sup> )	Molybdenum (mg L <sup>-1</sup> )	Parameters Measured				
		Yield of lateral inflorescences (tons ha <sup>-1</sup> )	Total yield per plant (g plant <sup>-1</sup> )	Total yield per hectare (t ha <sup>-1</sup> )	Main head harvest date (days)	Days to lateral head harvest
0	0	0.930 d	309.83 e	12.909 e	144.66 a	170.33 a
	25	6.377 bc	377.20 ed	15.717 ed	131.33 b	148.00 d
	50	6.333 bc	495.33 bc	20.639 bc	131.33 b	153.00 bcd
75	0	8.240 b	641.33 a	26.722 a	120.00 b	146.33 d
	25	3.417 cd	532.33 bc	22.180 bc	128.00 b	151.33bcd
	50	5.987 bc	580.67 ab	24.194 ab	120.00 b	153.00 bcd
150	0	5.403 bc	569.17 ab	23.710 ab	124.00 b	156.33 dc
	25	8.060 b	446.67 cd	18.611 cd	124.00 b	149.66 cd
	50	13.583 a	517.75 bc	21.573 bc	124.00 b	158.00 b
Average Effect of Manganese	0	4.546 b	394.12 c	16.422 c	135.77 a	157.11 a
	75	5.881 b	584.78 a	24.366 a	122.66 b	150.22 b
Average Effect	150	9.015 a	510.38 b	21.266 b	124.00 b	154.66 a
Average Effect	0	4.857 b	506.78 a	21.116 a	129.55 a	157.67 a

of	25	5.951 b	452.07 b	18.836 b	127.78 a	149.67 b
Molybdenum	50	8.634 a	532.94 a	22.206 a	125.11 a	154.67 a

Means followed by the same letter within each factor or interaction are not significantly different according to Duncan's Multiple Range Test at the 5% level of probability.

### Conclusions

It can be concluded that foliar application of manganese and molybdenum had a positive effect on enhancing the vegetative growth and productivity traits of broccoli plants, including plant height, leaf number and area, dry matter, and chlorophyll content. It also improved the weight of the main head and lateral florets, individual and total yield, and reduced the harvesting period. These results highlight the vital role of these two micronutrients in improving growth, productivity, and crop quality, supporting their inclusion in foliar nutrition programs to promote sustainable agricultural efficiency.

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## استجابة صنف البروكولي Matsuri للمعاملة بتراكيز مختلفة لبعض العناصر الغذائية الصغرى (المنغنيز والمولبيديوم)

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### الخلاصة

لتقييم تأثير الرش الورقي بالمنغنيز والمولبيديوم بمستويات مختلفة في نمو وإنتاجية البروكولي (*Brassica oleracea* var. *italica*)، نُفذت التجربة خلال الموسم الزراعي 2024–2025 في حقل الخضر التابع لجامعة الموصل، باستخدام صنف *Matsuri*. تضمنت التجربة ثلاث تراكيز من المنغنيز (0، 75، 150 ملغم لتر<sup>-1</sup>) وثلاث تراكيز من المولبيديوم (0، 25، 50 ملغم لتر<sup>-1</sup>). تم إجراء الرش الورقي ثلاث مرات: الرشة الأولى بعد شهر من الإنبات، أما الرشة الثانية والثالثة فتمت بفواصل 20 يوماً بين كل رشة وأخرى.

نُفذت التجربة بتسعة معاملات وفق تصميم القطاعات العشوائية الكاملة (RCBD) وبثلاث مكررات. وتمت مقارنة المتوسطات باستخدام اختبار دنكن متعدد الحدود عند مستوى معنوية 5%.

أظهرت النتائج أن الرش الورقي بالمنغنيز بتركيز 150 ملغم لتر<sup>-1</sup> كان له تأثير معنوي إيجابي على معظم الصفات المدروسة، بما في ذلك: ارتفاع النبات، عدد الأوراق، مساحة الورقة، المساحة الورقية الكلية، محتوى المادة الجافة، محتوى الكلوروفيل، قطر الرأس، عدد الأفراس الزهرية الجانبية وإنتاجيتها. كما أن المنغنيز بتركيز 75 ملغم لتر<sup>-1</sup> حسن معنوياً وزن وإنتاج الرأس الرئيسي، ووزن الأفراس الزهرية الجانبية، وإنتاجية النبات الواحد، والإنتاجية الكلية، وقلل من المدة اللازمة للحصاد للرأسين الرئيسي والثانوي. في حين أدى الرش بالمولبيديوم بتركيز 50 ملغم لتر<sup>-1</sup> تأثير معنوي لمعظم الصفات مثل: ارتفاع النبات، عدد الأوراق/نبات، المساحة الورقية للنبات، المادة الجافة، محتوى الكلوروفيل، وزن وقطر الرأس الرئيسي، عدد الأفراس الزهرية الجانبية، الإنتاجية الكلية، ومدة الحصاد.

الكلمات المفتاحية: البروكولي، المنغنيز، المولبيديوم، النمو، الإنتاجية.