

Effect of Phosphoric Acid and Magnesium Spray on the Mineral Content, Floral and Root Characteristics of Marigold *Tagetes erecta* L. The scientific name of the plant is written in italics.

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Abstract

The experiment was conducted in the wooden canopy of the Department of Horticulture and Landscape Gardening, College of Agriculture, Tikrit University, during the 2025 agricultural season. The aim was to study the effect of phosphoric acid addition and foliar spraying with magnesium on the growth, yield, and some anatomical characteristics of the African Marigold plant (**Tagetes erecta**). The experiment was carried out using a Randomized Complete Block Design (RCBD) with three replications. The first factor involved the addition of phosphoric acid at four concentrations (0, 0.5, 1, 1.5) ml L⁻¹, and the second factor involved foliar spraying with magnesium at three concentrations (0, 0.5, 1) g L⁻¹. The results of the experiment are summarized as follows: The treatment of adding phosphoric acid at a level of (1.5) ml L⁻¹ achieved a significant superiority in mineral content, recording the highest increases in (nitrogen percentage, phosphorus percentage, potassium percentage, magnesium percentage, beta-carotene content, number of flowers, flower diameter, flower weight, mean root fresh weight, and mean root dry weight), which reached (2.842%, 0.338%, 2.145%, 0.651%, 16.938%, 4.281 flower plant⁻¹, 6.472 cm, 7.255 g, 7.991 g plant⁻¹, 1.125 g plant⁻¹), respectively, compared to the treatment without addition. Similarly, the foliar spray treatment with magnesium at a concentration of (1) g L⁻¹ was significantly superior, giving the highest increase in mineral content for the traits (nitrogen percentage, phosphorus percentage, potassium percentage, magnesium percentage, beta-carotene content, number of flowers, flower diameter, flower weight, mean root fresh weight, and mean root dry weight), which reached (3.033%, 0.386%, 2.365%, 0.855%, 18.674%, 4.835 flower plant⁻¹, 6.825 cm, 7.806 g, 9.254 g plant⁻¹, 1.247 g plant⁻¹), respectively, compared to the treatment without spraying. Significant differences were also found among the bilateral interaction treatments. The interaction treatment M₂ P₃ (spraying with magnesium sulfate at 1 g L⁻¹ + adding phosphoric acid at 1.5 ml L⁻¹) was distinguished by giving the highest significant differences in each of (nitrogen percentage, phosphorus percentage, potassium percentage, magnesium percentage, beta-carotene content, number of flowers, flower diameter, flower weight, mean root fresh weight, and mean root dry weight), which reached (3.213%, 0.456%, 2.663%, 0.970%, 20.223%, 5.250 flower plant⁻¹, 7.733 cm, 8.743 g, 11.720 g plant⁻¹, 1.670 g plant⁻¹), respectively, compared to the control treatment.

Keywords: African Marigold, *Tagetes erecta* L., Phosphoric acid, Magnesium, Foliar spraying, Mineral content, Root characteristics.

Introduction

The Marigold plant (*Tagetes erecta* L.) is one of the species belonging to the genus *Tagetes* of the Asteraceae family. Its native origin is Central America, specifically Mexico. This genus comprises about 33 species, but only two are widely used in cultivation the large-flowered American Marigold, also known as the African Marigold (*Tagetes erecta* L.), which is of Mexican origin, and the small-flowered French Marigold (*Tagetes patula* L.), which is of African origin. The Marigold is considered one of the most important commercial flower crops with high economic value, as it is widely cultivated for producing cut flowers used in garlands, ornamentation, and religious rituals, in addition to its industrial importance. Marigold is a significant source for producing carotenoid pigments, with xanthophyll being the main pigment in its flowers, and lutein is the primary carotenoid found in the petals of *Tagetes erecta* (1; 2). Mineral fertilizers aim to increase plant production and growth. Phosphorus is added as a fertilizer to meet the plant's growth requirements for phosphorus, as it is one of the essential macronutrients needed for plant growth. Plants require it in relatively large quantities because it is a core component in biological and physiological processes related to growth and flowering. Phosphorus is known as the "key to life" due to its prominent role in forming energy molecules (ATP) and (ADP), as well as coenzymes such as (NADPH₂) and (NADH₂). These are essential substances without which the plant cannot perform its vital functions, including the breakdown of carbohydrates produced by photosynthesis (3; 4). Among the studies that have examined the effect of this element on ornamental plants, an experiment conducted by (5) on the effect of phosphorus and nitrogen fertilization on the

African Marigold (*Tagetes erecta* L.) cultivar 'DOUBLE EAGLE' found that adding phosphorus at a concentration of (100) kg ha⁻¹ led to an increase in the leaf content of nitrogen and phosphorus. In a study by (6) on the effect of mineral fertilization levels on the Zinnia plant (*Zinnia elegans* L.), it was found that phosphorus fertilization at a level of (75) kg ha⁻¹ led to a significant increase in the plant's phosphorus content. (7) found that using phosphate fertilizer on the Datura plant (*Datura stramonium* L.) at a concentration of (75) kg ha⁻¹ resulted in a significant increase in the leaf content of nitrogen, phosphorus, potassium, and magnesium. (8) concluded in a study on the Petunia plant (*Petunia Hybrida Vilm.*) that using phosphorus at a concentration of (1) ml L⁻¹ led to an increase in the content of nitrogen, phosphorus, and potassium. (9) found that foliar spraying with phosphorus at a concentration of (100) mg L⁻¹ on the pot marigold plant (*Calendula officinalis*) cultivar 'Bon Bon' led to a significant increase in carotene pigment content, reaching 18.58 mg 100g⁻¹. Foliar spraying plays an effective role in the rapid delivery of nutrients, reducing the physiological stress on the plant by delivering them directly to the leaf tissues. Magnesium participates in many physiological and biochemical activities. In plants, magnesium is the central atom of the chlorophyll molecule, and it is also involved in the structure of chromosomes and polyribosomes. It also functions as a phosphorus carrier in plants, especially during the formation of oil-rich fruits. Magnesium supports the synthesis of oils and fats, aids in starch translocation, activates enzymes for protein formation, participates in the photosynthetic fixation of carbon dioxide, and facilitates many

catalytic processes within plants. Magnesium sulfate, when used as a foliar treatment, has proven effective in raising nutrient levels in crops suffering from deficiencies. Studies have indicated that its use raises chlorophyll levels, leading to improved vegetative mass (10). Among the studies that have examined the effect of this element on ornamental plants, an experiment conducted (11) involved using foliar spraying of magnesium at a concentration of (4) g L⁻¹ on the Gazania plant (*Gazania rigens* L.). This led to a significant increase

Objective of the Study:

Given the ornamental importance of the Marigold plant in gardens, as well as its economic and medicinal significance, we aimed to:

1. Investigate the use of phosphoric acid and its reflection on the mineral content
The experiment was conducted in the wooden canopy of the Department of Horticulture and Landscape Gardening, College of Agriculture, Tikrit University, from February 17 to June 17 during the 2025 agricultural season. Cleaning was carried out to remove unwanted plants in order to eliminate growing weeds, due to their negative effects in reducing production as a result of their competition with cultivated plants for water, nutrients, and light (14).

Table (1) Some physical and chemical properties of the plastic pot soil used in the experiment

Measurement unit	Concentration	Trait
	7.29	pH Soil
dS m ⁻¹	2.63)EC(
%	0.926	Organic matter
mg kg ⁻¹	20.00	Available nitrogen
mg kg ⁻¹	7.05	Available phosphorus

in nutrient content in the leaves (nitrogen 2.95%, phosphorus 0.444%, potassium 2.13%, magnesium 24.15 mg 100g⁻¹). (12) found that spraying the Gerbera plant (*Gerbera jamesonii* L.) with magnesium led to a significant increase in the content of nitrogen (1.96%), phosphorus (0.25%), and potassium (2.03%). (13) reported that using magnesium in the form of magnesium sulfate on the southernwood plant (*Artemisia abrotanum*) at a concentration of (8) g L⁻¹ led to a significant increase in carotenoid content.

Floral and root characteristics of the Marigold plant.

2. Study the effect of magnesium spraying on the mineral content Floral and root characteristics of the Marigold plant.

Materials and Methods

Planting was then carried out in cork trays, where the total number of cells used was 200 cells. Seeds of the Marigold plant (*Tagetes erecta* L.), produced by SAKATA company, were sown on 17/2/2025. After germination and the appearance of the true leaves, The seedlings were transplanted two weeks after germination into plastic pots (20 cm diameter).

mg kg⁻¹	80.07	Available potassium
mg kg⁻¹	12.04	Available magnesium
g kg⁻¹	424	Sand
g kg⁻¹	350	Silt
g kg⁻¹	226	Clay
	Silty loam	Soil texture

The study included two factors:

The first factor: Effect of phosphoric acid at four concentrations, denoted as P:

P0: Control

P1: Addition of phosphoric acid at a concentration of 0.5 ml L⁻¹

P2: Addition of phosphoric acid at a concentration of 1 ml L⁻¹

P3: Addition of phosphoric acid at a concentration of 1.5 ml L⁻¹

The second factor: Spraying with magnesium at three concentrations, denoted as M:

M0: Control

M1: Spraying with magnesium sulfate at a concentration of 0.5 g L⁻¹

M2: Spraying with magnesium sulfate at a concentration of 1 g L⁻¹

The experiment was carried out according to a Randomized Complete Block Design (RCBD) to reduce uncontrolled environmental variation and increase the accuracy of statistical results. The study

Magnesium content (Mg%): Estimated using an Atomic Absorption Spectrophotometer, according to the method indicated by (17).

Beta-carotene pigment content (β-Carotene): Estimated in the flowers using a Spectrophotometer, based on the method provided by (18).

consisted of (12) factorial treatments resulting from the interaction of the levels of the studied factors. Each experimental unit contained (4) pots, with three replications for each treatment. Thus, the total number of pots used in the experiment was (144) pots, resulting from: 4 × 3 × 3 × 4 = 144 pots. Phosphoric acid was added in two batches: the first one month after planting, and the second (15) days after the first batch. Magnesium spraying was carried out after the phosphoric acid addition, three days after each batch.

The following traits were studied:

Nitrogen content (N%): Estimated using the Micro Kjeldahl apparatus, as mentioned by (15).

Phosphorus content (P%): Estimated using a Spectrophotometer, according to the method described by (16).

Potassium content (K%): Estimated using a Flame Photometer, according to Jackson (1973).

Number of flowers: Counted upon full bloom; all flowers were manually counted per plant within each experimental unit, and then the average was calculated.

Flower diameter: Measured after the flowers were fully opened using a manual measuring tape for each flower individually, and then the average was calculated.

Flower weight: Determined by cutting the flowers after full bloom, weighing them using a sensitive balance with four decimal places, and then calculating the average per plant.

Root fresh weight: Estimated at the end of the experiment. The vegetative part was cut first, then soil and debris were removed from the roots, and the root system was extracted carefully to avoid damage.

Results and Discussion

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the nitrogen percentage

Table (1) shows that the addition of phosphoric acid led to significant differences in the mean nitrogen content in plant leaves. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) showed the highest mean nitrogen concentration, reaching 2.842%, compared to the treatment without addition, which gave the lowest mean nitrogen content of 2.445%. It is also observed from the results in the table that spraying with magnesium had a significant effect on the mean nitrogen content in plant leaves. The M2 treatment with magnesium spraying at a concentration of (1 g L⁻¹) was significantly

Afterwards, it was washed with water to remove residues, surface-dried to eliminate excess moisture, and weighed using a sensitive balance. **The average fresh root weight was calculated.**

Root dry weight percentage: Estimated using the same method used for estimating the dry matter percentage in the vegetative part, as indicated by (15).

superior, recording the highest nitrogen concentration in the leaves, reaching 3.033%, compared to the treatment without spraying, which gave the lowest mean nitrogen content of 2.322%. The results of the interaction treatments indicate clear significant differences in the mean nitrogen content of plant leaves. The M2P3 treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) showed the highest nitrogen content, reaching 3.213%, compared to the control treatment, which gave the lowest nitrogen content of 1.920%.

Table (1): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the nitrogen percentage (N%) in leaves of Marigold (*Tagetes erecta* L.)

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
2.322 c	2.526 ed	2.500 e	2.343 f	1.920 g	M0
2.680 b	2.786 c	2.750 c	2.620 d	2.563 ed	M1
3.033 a	3.213 a	3.060 b	3.006 b	2.853 c	M2
	2.842 a	2.770 b	2.656 c	2.445 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the phosphorus percentage

Table (2) indicates that the addition of phosphoric acid resulted in significant differences in the mean phosphorus content in plant leaves. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) gave the highest mean phosphorus concentration, reaching 0.338%, compared to the treatment without addition, which gave the lowest mean phosphorus content of 0.254%. We also note from the table below that spraying with magnesium had a significant effect on the mean phosphorus content in the leaves, as the M2 treatment with magnesium spraying at a concentration of (1 g L⁻¹) was superior,

achieving the highest mean phosphorus concentration in the leaves, reaching 0.386%, compared to the treatment without spraying, which gave the lowest phosphorus content of 0.225%. The results of the interaction treatments show clear significant differences in the mean phosphorus content of plant leaves. The M2P3 treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) exhibited the highest phosphorus content in plant leaves, reaching 0.456%, compared to the control treatment, which recorded the lowest mean phosphorus content of 0.173%.

Table (2): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the phosphorus percentage (P%) in leaves of Marigold (*Tagetes erecta* L.).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
0.225 c	0.250 i	0.243 i	0.233 j	0.173 k	M0
0.287 b	0.310 e	0.290 f	0.280 g	0.270 h	M1
0.386 a	0.456 a	0.406 b	0.363 c	0.320 d	M2
	0.338 a	0.313 b	0.292 c	0.254 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the potassium percentage

Table (3) indicates that the addition of phosphoric acid resulted in significant differences in the mean potassium content in plant leaves. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) showed the highest mean potassium concentration, reaching 2.145%, compared to the treatment without addition, which gave the lowest mean potassium content of 1.792%. The results in the table also show that spraying with magnesium led to a significant effect on the mean potassium content in plant leaves. The M2 treatment with magnesium spraying at a concentration of (1 g L⁻¹) was significantly superior, recording the highest mean potassium

concentration in the leaves, reaching 2.365%, compared to the treatment without spraying, which gave the lowest potassium content of 1.607%. It is observed from the results of the interaction treatments that the combination of phosphoric acid addition and magnesium spraying led to a significant increase in the mean potassium content of plant leaves. The M2P3 treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) was superior, giving the highest mean potassium content in plant leaves, reaching 2.663%, compared to the control treatment, which recorded the lowest potassium content of 1.456%.

Table (3): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the potassium percentage (K%) in leaves of Marigold (*Tagetes erecta* L.).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
1.607 c	1.746 g	1.676 h	1.550 i	1.456 j	M0
1.947 b	2.026 e	2.140 d	1.850 f	1.773 g	M1
2.365 a	2.663 a	2.373 b	2.280 c	2.146 d	M2
	2.145 a	2.063 b	1.893 c	1.792 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the magnesium percentage

It is observed from the results of Table (4) that the addition of phosphoric acid resulted in significant differences in the mean magnesium concentration in plant leaves. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) showed the highest mean magnesium concentration, reaching 0.651%, compared to the treatment without addition, which gave the lowest mean magnesium concentration of 0.426%. The same table indicates that spraying with magnesium led to a significant effect on the mean magnesium concentration in plant leaves. The M2 treatment with magnesium spraying

at a concentration of (1 g L⁻¹) was significantly superior, recording the highest mean magnesium concentration, reaching 0.855%, compared to the treatment without spraying, which gave the lowest mean magnesium concentration of 0.280%. The results of the interaction treatments showed that the M2P3 treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) gave the highest significant differences in the mean magnesium concentration in plant leaves, reaching 0.970%, compared to the control treatment, which gave the lowest mean magnesium concentration of 0.066%.

Table (4): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the magnesium percentage (Mg%) in leaves of Marigold (*Tagetes erecta* L.).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
0.280 c	0.403 h	0.360 i	0.293 j	0.066 k	M0
0.540 b	0.580 d	0.563 e	0.546 f	0.473 g	M1
0.855 a	0.970 a	0.863 b	0.850 b	0.740 c	M2
	0.651 a	0.595 b	0.563 c	0.426 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the beta-carotene percentage

The results of Table (5) clarify that the addition of phosphoric acid led to significant

differences in the mean beta-carotene content in plant leaves. The P3 treatment

with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) gave the highest mean beta-carotene concentration, reaching 16.938%, compared to the treatment without addition, which gave the lowest mean of 14.642%. The same table shows that spraying with magnesium had a significant effect on the mean beta-carotene content in the flowers. The M2 treatment with magnesium spraying at a concentration of (1 g L⁻¹) was superior, giving the highest mean beta-carotene concentration, reaching 18.674%, compared to the treatment without

spraying, which gave the lowest mean of 12.465%. By studying the effect of the interaction between the two factors of addition and spraying, it was observed that the M2P3 interaction treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) recorded the highest significant difference in the mean beta-carotene content of plant flowers, reaching 20.223%, compared to the control treatment, which gave the lowest mean beta-carotene content of 11.286%.

Table (5): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the beta-carotene percentage (β-Carotene %) in flowers of Marigold (*Tagetes erecta* L.).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
12.465 c	13.870 i	13.313 j	11.393 k	11.286 l	M0
15.970 b	16.723 e	16.206 f	15.566 g	15.386 h	M1
18.674 a	20.223 a	18.890 b	18.330 c	17.253 d	M2
	16.938 a	16.136 b	15.096 c	14.642 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the number of flowers of Marigold

The results of Table (6) show that the addition of phosphoric acid had a significant effect on the mean number of flowers. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) was superior, recording the highest mean of

4.281 flowers plant⁻¹, compared to the treatment without addition, which recorded the lowest mean of 3.631 flowers plant⁻¹. It appears in the table below that magnesium spraying led to achieving significant differences in the mean number of flowers.

The M2 treatment with magnesium spraying at a concentration of (1 g L⁻¹) recorded the highest mean number of flowers, reaching 4.835 flowers plant⁻¹, compared to the treatment without spraying, which gave the lowest mean number of flowers of 3.291 flowers plant⁻¹. Regarding the effect of the interaction between the addition and spraying factors, the results showed that the

M2P3 interaction treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) achieved the highest significant difference in the mean number of flowers, reaching 5.250 flowers plant⁻¹, compared to the control treatment, which gave the lowest mean of 2.750 flowers plant⁻¹.

Table (6): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the number of flowers of Marigold (*Tagetes erecta* L.) (flowers plant⁻¹).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
3.291 c	3.500 g	3.500 g	3.416 g	2.750 h	M0
3.940 b	4.093 e	4.000 e	3.916 ef	3.750 f	M1
4.835 a	5.250 a	4.983 b	4.716 c	4.393 d	M2
	4.281 a	4.161 b	4.016 c	3.631 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the flower diameter of Marigold

The data in Table (7) clarify that the addition of phosphoric acid had a significant effect on the mean flower diameter. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) was superior, recording the highest mean flower diameter of 6.472 cm, compared to the treatment without addition, which gave the lowest mean flower diameter of 5.450 cm. The same table also shows that spraying with

magnesium led to a significant increase in the mean flower diameter. The M2 treatment with magnesium spraying at a concentration of (1 g L⁻¹) recorded the highest mean flower diameter of 6.825 cm, compared to the treatment without spraying, which gave the lowest mean flower diameter of 5.137 cm. Regarding the effect of the interaction between the addition and spraying factors, the results showed that the M2P3 interaction

treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) achieved the highest significant difference in the mean flower diameter,

reaching 7.733 cm, compared to the control treatment, which gave the lowest mean flower diameter of 4.366 cm.

Table (7): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the flower diameter of Marigold (*Tagetes erecta* L.) (cm flower⁻¹).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
5.137 c	5.583 f	5.483 f	5.116 g	4.366 h	M0
5.908 b	6.100 d	5.983 d	5.800 e	5.750 e	M1
6.825 a	7.733 a	7.066 b	6.266 c	6.233 c	M2
	6.472 a	6.177 b	5.727 c	5.450 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the flower weight of Marigold

The results of Table (8) clarify that the addition of phosphoric acid resulted in significant differences in the mean flower weight. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) gave the highest mean of 7.255 g, compared to the treatment without addition, which gave the lowest mean of 6.148 g. The data in the table below also indicate that magnesium spraying led to significant differences in the mean flower weight. The M2 treatment with magnesium spraying at a concentration of (1 g L⁻¹) recorded the

highest mean flower weight of 7.806 g, compared to the treatment without spraying, which gave the lowest mean flower weight of 5.444 g. Regarding the interaction between the addition and spraying factors, the results showed that the M2P3 interaction treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) achieved the highest significant differences in the mean flower weight, reaching 8.743 g, compared to the control treatment, which gave the lowest mean of 4.630 g.

Table (8): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the flower weight of Marigold (*Tagetes erecta* L.) (g flower⁻¹).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
5.444 c	6.026 h	5.960 h	5.160 i	4.630 j	M0
6.756 b	6.996 e	6.796 f	6.630 g	6.603 g	M1
7.806 a	8.743 a	7.800 b	7.470 c	7.213 d	M2
	7.255 a	6.852 b	6.420 c	6.148 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the mean root fresh weight of Marigold

The results of Table (9) show that the addition of phosphoric acid caused significant differences in the mean root fresh weight. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) gave the highest mean fresh weight of 7.991 g plant⁻¹, compared to the treatment without addition, which gave the lowest mean of 5.731 g plant⁻¹. The same table also shows that spraying with magnesium led to significant differences in the mean root fresh weight of the plant. The M2 treatment with magnesium spraying at a concentration of (1 g L⁻¹) gave the highest

mean fresh weight of 9.254 g plant⁻¹, compared to the treatment without spraying, which gave the lowest mean of 4.670 g plant⁻¹. Regarding the interaction between the addition and spraying factors, the results showed that the M2P3 interaction treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) achieved the highest significant difference in the mean root fresh weight, reaching 11.720 g plant⁻¹, compared to the control treatment, which gave the lowest mean of 4.303 g plant⁻¹.

Table (9): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the mean root fresh weight of Marigold (*Tagetes erecta* L.) (g plant⁻¹).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
4.670 c	5.293 g	4.720 h	4.366 i	4.303 i	M0
6.423 b	6.960 e	6.753 f	6.596 f	5.383 g	M1
9.254 a	11.720 a	9.773 b	8.016 c	7.506 d	M2
	7.991 a	7.082 b	6.326 c	5.731 d	Phosphoric acid Rate

Effect of phosphoric acid addition, magnesium spraying, and their interaction on the mean root dry weight of Marigold

The results of Table (10) clarify that the addition of phosphoric acid caused significant differences in the mean root dry weight. The P3 treatment with phosphoric acid addition at a concentration of (1.5 ml L⁻¹) gave the highest mean dry weight of 1.125 g plant⁻¹, compared to the treatment without addition, which gave the lowest mean of 0.877 g plant⁻¹. The table below indicates that spraying with magnesium led to significant differences in the mean root dry weight of the plant. The M2 treatment with magnesium spraying at a concentration

of (1 g L⁻¹) recorded the highest mean dry weight of 1.247 g plant⁻¹, compared to the treatment without spraying, which gave the lowest mean of 0.695 g plant⁻¹. The interaction treatments between addition and spraying showed that the M2P3 treatment (addition of phosphoric acid at 1.5 ml L⁻¹ + spraying with magnesium at 1 g L⁻¹) achieved the highest significant differences in the mean root dry weight, reaching 1.670 g plant⁻¹, compared to the control treatment, which gave the lowest mean of 0.686 g plant⁻¹.

Table (10): Effect of phosphoric acid addition, magnesium spraying, and their interaction on the mean root dry weight of Marigold (*Tagetes erecta* L.) (g plant⁻¹).

Magnesium Rate	Concentrations of phosphoric acid in ml . L ⁻¹				Magnesium concentrations (g L ⁻¹)
	P3	P2	P1	P0	
0.695 c	0.700 e	0.700 e	0.696 e	0.686 e	M0
0.922 b	1.006 c	0.913 d	0.906 d	0.863 d	M1
1.247 a	1.670 a	1,136 b	1.100 b	1.083 b	M2
	1.125 a	0.916 b	0.901 bc	0.877 c	Phosphoric acid Rate

Discussion

The results of the previous tables (1, 2, 3, 4, 5) showed that the addition of phosphoric acid led to clear significant effects on the leaf content of major nutrients, as well as on beta-carotene content. This can be physiologically explained through the multiple vital functions of phosphorus within the plant. Therefore, its availability contributes to increasing the absorption efficiency and metabolism of other elements. This explains the significant increase in the leaf content of nutrients, resulting from improved biosynthesis and protein construction processes. Furthermore, the high phosphorus content in the leaves reflects its improved availability in the root medium and ease of uptake, in addition to it being a mobile element within the plant, moving from older tissues to younger tissues to support growth and cell division. As for the increase in potassium content, it is attributed to phosphorus's role in activating

root growth and improving the efficiency of nutrient absorption, which positively reflects on the balance of elements within the plant. The increase in magnesium concentration in the leaves upon phosphorus addition is explained by the improvement in the overall nutritional status of the plant and the increase in available energy, which contribute to enhancing the efficient transport of ions, including magnesium. Also, the increase in beta-carotene content in the flowers reflects phosphorus's role in activating the metabolic pathways responsible for pigment synthesis, in addition to improving photosynthetic efficiency and the accumulation of its products. This aligns with the findings of (7) when using phosphate fertilizer on *Datura stramonium* L., (8) in their experiment on *Petunia Hybrid Vilm.*, and (9) when spraying phosphorus on pot marigold (*Calendula officinalis*)

cultivar 'Bon Bon'. The results of the same tables (1, 2, 3, 4, 5) also showed that spraying with magnesium led to a significant increase in the leaf content of nitrogen, phosphorus, potassium, and magnesium, as well as an increase in beta-carotene content in the flowers. These results can be physiologically explained by the central role of magnesium in vital processes within the plant. Magnesium is an essential element in activating a large number of enzymes related to nitrogen metabolism and protein synthesis. Therefore, its adequate availability leads to an increased efficiency of nitrogen uptake and fixation within plant tissues, explaining the significant increase in the percentage of the studied elements in the leaves. Magnesium also directly enters the structure of the chlorophyll molecule, thereby improving the efficiency of photosynthesis and increasing its output of organic matter. This is due to magnesium's role in regulating cell membrane permeability, which facilitates the transport of nutrients. Additionally, the improvement in the overall plant condition increases the efficiency of roots in absorption and transport. The significant increase in magnesium concentration in the leaves upon foliar spraying is explained by its easy absorption through the leaves and its transport to sites of activity, particularly the chloroplasts, thereby enhancing photosynthetic processes. The increase in beta-carotene content in the flowers reflects improved photosynthetic efficiency, as carotenoids are a byproduct of metabolic pathways that depend on the availability of energy and carbohydrates. This aligns with the findings of (11) in his study on *Gazania* (*Gazania rigens* L.), and (13) when using magnesium in the form of magnesium sulfate on southernwood (*Artemisia abrotanum*). The results of the previous tables (6, 7, 8) showed that phosphorus

addition led to a significant increase in the number of flowers, flower diameter, and flower weight. This is because phosphorus works to regulate the metabolic processes associated with energy transfer within the plant. Phosphorus is also involved in stimulating the growth of the root system and increasing its absorption efficiency, leading to enhanced uptake of nutrients and water, thus providing the necessary growth requirements for the formation of a greater number of flower buds. The improvement in flower diameter and weight is attributed to phosphorus's role in supporting the transport of photosynthesis products from leaves to flowers, increasing the accumulation of carbohydrates and structural materials within floral tissues, which is reflected in increased flower size and fresh and dry weight. This aligns with the findings of (19) when using phosphorus on chrysanthemum. The results of the same tables (6, 7, 8) also indicate that foliar spraying with magnesium led to a significant increase in the number, diameter, and weight of flowers. This is explained by magnesium being the central component of the chlorophyll molecule; magnesium contributes to increasing the efficiency of photosynthesis, leading to increased production of carbohydrates, which are the primary source of energy and building materials necessary for flower formation and growth. Magnesium activates many enzymes responsible for the synthesis of proteins and sugars, as well as playing a role in facilitating the transport of photosynthesis products through the phloem from leaves to floral organs. This improves the nutrition of flowers during their various developmental stages, reflected in an increased number of flowers and improved morphological traits, especially flower diameter and weight. This aligns with the findings of (20) in their study on rose (*Rosa damascena* Mill.), and (21) in her study on

China aster (*Callistephus chinensis*). The results of the previous tables (9, 10) showed that phosphorus addition led to a significant increase in the fresh and dry weight of the root system of the Marigold plant. Phosphorus is involved in cell division and elongation, particularly in the meristematic regions of roots. Phosphorus also contributes to stimulating the growth of lateral roots and increasing the density of root hairs. The increased availability of phosphorus improves the roots' ability to absorb and grow. The increase in root dry weight is attributed to the increased accumulation of organic and structural materials within root tissues as a result of improved metabolic activity and the transport of photosynthesis products towards the roots. This aligns with the findings of (22) in their study on white and purple stock (*Matthiola incana* L.). The results of the same tables (9, 10) indicate

Conclusions

1. The addition of phosphoric acid at a concentration of 1.5 ml L^{-1} resulted in significant differences in most vegetative, flowering and root growth characteristics, as well as in the mineral content of the plant.
2. Foliar spraying of Magnesium at a concentration of 1 g L^{-1} achieved significant differences in most vegetative, flowering and root growth characteristics, as well as in the mineral content of the plant.

Recommendations

that spraying with magnesium led to a significant improvement in the fresh and dry weight of the root system. Magnesium is the central element in the structure of the chlorophyll molecule, leading to increased photosynthetic efficiency and higher carbohydrate production. These carbohydrates are the primary source of energy and building materials necessary for root growth, as they are transported from the leaves to the roots via the phloem to be used in building new root tissues. Magnesium also contributes to the activation of a large number of enzymes responsible for protein synthesis and regulation of metabolic processes, which is reflected in the increased accumulation of dry matter in the roots. This aligns with the findings of (23) in their study on seashore paspalum (*Paspalum vaginatum*).

3. The interaction treatments had a significant effect, with the M2P3 treatment (addition of phosphoric acid at 1.5 ml L^{-1} + spraying with magnesium at 1 g L^{-1}) being distinguished by giving the highest significant differences in most of the studied traits.

Based on the results shown by this study, the following recommendations can be made:

1. Expand the use of higher concentrations of phosphoric acid and magnesium spraying on the Marigold plant, as well as on other plants and varieties, given the positive effects these treatments showed on the studied traits.
2. Conduct future studies on the same plant or other plants from the same family to estimate some active compounds in the flowers, in addition to studying physical traits.
3. It is advisable to expand the cultivation of the Marigold plant on a large scale in public and home gardens, due to its nutritional, medicinal, and aesthetic importance

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