International Journal of Agricultural Technology 2024 Vol. 20(6):2283-2298
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

# Improving productivity, fruits physical and chemical properties of mango trees "Keitt cv." using ammonium nitrate, cobalt sulfate and vitamin $B_{12}$

**Hassan, A. M., Haggag, L. F. and Elhady, E. S.***

Pomology Department, National Research Centre (NRC), Giza, Egypt.

Hassan, A. M., Haggag, L. F. and Elhady, E. S. (2024). Improving productivity, fruits physical and chemical properties of mango trees "Keitt cv." using ammonium nitrate, cobalt sulfate and vitamin $B_{12}$. International Journal of Agricultural Technology 20(6):2283-2298.

**Abstract** Mango is one of the best fruit crops in the world due to its delicious taste and flavor as well as its content of many nutrients, but the productivity of trees sometimes suffers from a deficiency in some areas and in some growing seasons. In this experiment, the effect of foliar spraying with some nutrients and compounds beneficial to trees conducted during the 2022 and 2023 seasons on a private orchard in Al Sharkia Governorate - Egypt. The results showed that foliar spraying with ammonium nitrate at 1% + cobalt sulfate at 100 ppm + vitamin $B_{12}$ at 100 ppm together at three times during the growing season had the best significant effect on the amount of yield, physical properties of fruits, and most chemical properties of fruit juice, compared to trees that were treated the experimental materials individually.

**Keywords:** Ammonium nitrate, Cobalt sulphate, Fruit quality, Mango tree, Vitamin $B_{12}$

## Introduction

One of the most major tropical fruit trees in Egypt and the rest of the globe is the mango tree (*Mangifera indica* L.), which has been successfully cultivated in Egypt. Mangoes grown in Egypt are characterized by their delicious taste and flavor and have a high nutritional value (Elhady *et al.,* 2024). They are considered one of the most important fruits demanded locally and globally. Mango has become one of the most important crops demanded for export. The area planted with mango trees in Egypt has reached 110,337 hectares, and this area produces about 890,338 tons, according to (FAO statistics, 2022). Keitt is one of the most important mango cultivars that has been successfully cultivated in Egypt. Given that its fruits are gathered in September and October, this cultivar ripens later than others. The fruits of the Keitt cultivar are characterized by their delicious taste, excellent weight, and pale green color. The trees of this cultivar are medium-sized and have good productivity compared to other varieties.

* **Corresponding Author:** Hassan, A. M.; **Email:** Ahmed.m.hasan89@gmail.com

Ammonium nitrate is a form of nitrogen fertilizer that has proven its effectiveness when sprayed on mango trees. It is a good source of nitrogen and has a positive effect on flowering, growth and quality of fruits. Ammonium nitrate is used as a spray on trees during flower differentiation and before flowering, as it was observed that ammonium nitrate has a favorable outcomes on the percentage of flowering and fruit set. In addition, when ammonium nitrate was sprayed on mango trees in subtropical and tropical regions, it was found that the flowering process occurred early and abundantly, which contributed to the production of fruits earlier than the natural mango season, which achieved a large economic return (Morales-Martinez *et al.,* 2020). In addition**,** Abd El Migeed *et al.* (2022) found that spraying Awis mango trees with ammonium nitrate at a concentration of 2% during the month of November led to improving the productivity of the trees and additionally improved the fruits' chemical and physical qualities. In the same side, different forms of nitrogen have been used as a spray on trees, but it was found that the best form that gives the best result is ammonium nitrate at a concentration of 1% or 2%, which gave the best flowering percentage and helped in early flowering from the normal flowering dates and obtaining the best quality of fruits on some of cultivars mango trees (Salazar-Garcia *et al.,* 2000) also, on Alphonso cultivar mangoes (Sudha *et al.,* 2012).

Cobalt is considered an important nutrient for plants, as it enters into the composition of many enzymes and coenzymes, and can increase the formation of antioxidant enzymes such as catalase, oxidase, and peroxidase, they also raise the concentration of total phenols in fruits and significantly enhance plants' ability to withstand harsh climatic conditions (Hareem *et al.,* 2024). Cobalt has several roles in plant growth and in the transitions between different stages of plant life. The most important beneficial effects of cobalt are increasing plant resistance to drought, improving photosynthesis, slowing leaf aging, improving water use efficiency within the plant, and increasing levels of ethylene and abscisic acid, which play a role in reducing water loss through transpiration (Gad *et al.,* 2019). In addition to the above, cobalt is essential in improving the nutritional status of plants and also helps in the formation of vitamin $B_{12}$ within the plant (Hu *et al.,* 2021). It was also found to play a major role in improving quality of fruits, productivity and plant growth in general (Gad *et al.,* 2015). In the same side, Wahdan (2011) studied the effect of spraying with cobalt in the form of cobalt sulfate on mango trees, and discovered that it enhanced the amount of fruit produced, improved the chemical characteristics of the juice, and decreased the percentage of fruit drop. In the same respect, in a study on orange, it was observed that foliar spraying with cobalt led to an increase in the yield, fruit weight, and chemical properties of fruit juice (Mansour and Mubarak, 2014).

Vitamin $B_{12}$ is a water-soluble vitamin and also known as cobalamin, Vitamin $B_{12}$ exists in four chemical forms and contains the element cobalt. Vitamin $B_{12}$ function as coenzymes in the cell. The most stable form of vitamin $B_{12}$ among the several chemical forms is cyanocobalamin (CN-Cbl), which is produced chemically by reacting cyanide with natural cobalamin (Rizzo *et al.,* 2016). Plants produce vitamin $B_{12}$ because their methioninesynthase (Met) is cobalamin-independent (Smith *et al.,* 2007). Methionine synthase (Met) is an essential methyl donor for many biological methylations, as well as the synthesis of proteins, polyamines, ethylene, and other compounds in plants (Zeh *et al.,* 2002). Because of the above, many studies were conducted on the use of vitamin $B_{12}$ to improve productivity and fruit quality. Among these studies, Al- Wasfy (2013) conducted a study on date palms, where he noted that spraying vitamin B complex led to improving the yield and fruit weight. On the same side, Faisal *et al.* (2014) found that spraying with vitamin B complex gave the highest increase in fruit weight and yield of Balady mandarin trees. In another experiment, Wassel *et al.* (2015) studied spraying with vitamin B, which led to an increase in the percentage of fruit set, yield and fruit quality. In addition, Abd El-Bary (2017) found that spraying with vitamin $B_{12}$ and $GA_3$ during flowering and after fruit set led to improving productivity, fruit quality and leaf mineral content of pear trees.

The study aimed to benefit from the beneficial effects of ammonium nitrate, cobalt sulphate and vitamin $B_{12}$ in improving the flowering rate, fruit set and yield of mango trees “Keitt cv.”, as well as studying the effect of these materials on the chemical properties of fruit juice and leaf mineral content in order to achieve the highest economic return for mango producers.

## Materials and methods

The experiment was conducted during the 2022 and 2023 seasons on mango trees “Keitt cv.” planted on a private farm of the Adliya Agricultural Association in the Belbeis area in the Sharqia Governorate - Egypt. Homogeneous trees were selected in size and shape, and the trees were about 8 years old. The trees were planted at a distance of 3 X 5 meters. Common horticultural procedures were applied to the chosen trees in addition to the treatments.

### *Analysis of irrigation water and soil*

The trees were planted in sandy soil and a soil sample was taken from three different depths, which are 0-20 cm, 20-40 cm and 40-60 cm, and a chemical analysis was done for it as shown in Table 1. As for the irrigation water, it is fresh water coming from one of the water channels from the Ismailia Canal from the Nile River. The irrigation method used is drip irrigation. The chemical analysis of the irrigation water is shown in Table c2.

**Table 1.** Analyzing the orchard soil's chemical composition

| **Depth parameters of simple (cm)** | **pH** | **EC ($dSm^{-1}$)** | **Soluble cations (meq/l)** | | | | **Soluble anions (meq/l)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **$Ca^{++}$** | **$Mg^{++}$** | **$Na^{+}$** | **$K^{+}$** | **$CO3^{=}$** | **$HCO3^{-}$** | **$Cl^{-}$** | **$SO4^{=}$** |
| **0-20 cm** | 7.97 | 0.21 | 0.6 | 0.4 | 1.0 | 0.2 | - | 0.4 | 1.2 | 0.6 |
| **20-40 cm** | 8.22 | 3.19 | 6.9 | 4.6 | 19.0 | 0.8 | - | 2.3 | 24 | 5.0 |
| **40-60 cm** | 8.25 | 0.15 | 0.4 | 0.2 | 0.7 | 0.1 | - | 0.2 | 0.9 | 0.3 |

**Table 2.** Analysis of the orchard well water

| **pH** | **EC ($dSm^{-1}$)** | **Soluble cations (meq/l)** | | | | **Soluble anions (meq/l)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **$Ca^{++}$** | **$Mg^{++}$** | **$Na^{+}$** | **$K^{+}$** | **$CO3^{=}$** | **$HCO3^{-}$** | **$Cl^{-}$** | **$SO4^{=}$** |
| **7.6** | 0.5 | 1.4 | 0.6 | 3.0 | 0.2 | - | 0.3 | 4 | 0.9 |

### *Experimental design and treatments*

The experiment was performed in Randomized Complete Block Design (RCBD). The experiment consisted of seven treatments besides the control treatment. There were three replicates for every treatment, and each replicate had one tree. The treatments included foliar spraying with ammonium nitrate, cobalt sulfate or vitamin $B_{12}$ and interactions between them. The treatments were as follows:T0- untreated (control),T1- ammonium nitrate at 1%,T2- cobalt sulfate at 100 ppm, T3- vitamin $B_{12}$ at 100 ppm, T4- ammonium nitrate at 1% + cobalt sulfate at 100 ppm, T5- ammonium nitrate at 1% + vitamin $B_{12}$ at 100 ppm, T6- cobalt sulfate at 100 ppm + vitamin $B_{12}$ at 100 ppm, T7- ammonium nitrate at 1% + cobalt sulfate at 100 ppm + vitamin $B_{12}$ at 100 ppm.

The previous treatments were added as sprays on the trees at three additional times during each of the two study seasons: the first spray in the first week of January (initiation stage), the second spray in the last week of February (before flowering), and the third spray in the first week of April (after fruit set).

### *Measurements*

In January, just before the start of the new growth season, three replicates (three trees) of each treatment were chosen at random from among the trees for the experiment, and the following measurements were made on these trees.

The number of inflorescences/shoot was taken on a group of branches distributed randomly around all directions of the tree, and then the average of these numbers was calculated. Final fruit set percentage was done after 60 days of full bloom, the quantity of fruits per meter is the fruit set percentage. This figure was determined using the following formula: [Number of fruit set (60 days after full bloom) / shoot length (cm)] × 100 equals final fruit set (%).

Yield (kg/tree) was collected in mid- October, the number of fruits on each tree was counted. Next, fruit samples were taken from various parts of the tree, and the weight of each fruit was measured. Finally, the average fruit weight was computed. The tree yield was then determined by multiplying the average fruit weight by the total number of fruits on the tree.

Five fruits from each replication were supplied as a sample during harvest time in order to measure the physical properties of the fruit, such as fruit weight (g), flesh weight, seed weight, and flesh/seed ratio, according to Almutairi *et al.* (2023).

Fruit chemical characteristics was carried out using a hand refractometer to quantify the total soluble solids (T.S.S. %) in the fruit juice, and the acidity percentage, or citric acid content, was determined by titrating the fresh fruit juice against NaOH in accordance with (A.O.A.C. 1990). Next, the ratio of total soluble solids to acidity was computed (T.S.S/acidity ratio). Additionally, the method described by was used to determine the fruit juice's total sugar % (Sadasivam and Manickam 1996). Additionally, according to (A.O.A.C. 1990), the amount of vitamin C (ascorbic acid) in fruit juice was measured in milligrams of ascorbic acid per 100 g of juice. Additionally, the carotene content of apple flesh was determined colormetrically at 440 nm and reported as (mcg/g) in accordance with (Wettestien, 1957). The cobalt content of the fruit flesh was also estimated after drying the flesh in a drying oven at a temperature of 50°C. Then the cobalt was measured according to (Katami and Hayakawa, 1985).

To measure the mineral elements in the leaves, mature leaf samples were gathered in July from all four directions of each tree. After that, the samples were dried at 70ºC in an oven for drying until they attained a constant weight. The elemental content of the leaves was estimated to be as follows: N (%) was employed with Pregls (1945) modified micro-Kjeldahl method. P (%) was estimated using the method outlined in Chapman and Pratt (1961). K (%) was used a flame photometerically determined according to Brown and Lilleland (1946). Co (ppm) was analysed for the cobalt content of leaves was measured according to Katami and Hayakawa (1985).

### *Statistical analysis*

Using the Costat program, an analysis of variance (ANOVA) was performed on the data from the two seasons of the experiment (2022 and 2023) in accordance with (Snedecor and Cochran, 1980). The lowest significant domains (LSR) were used with a probability of 5% in accordance with (Duncan, 1955).

## Results

### *Number of inflorescences per shoot*

The trees sprayed with ammonium nitrate + vitamin $B_{12}$ (T5) had the highest value of number of inflorescences (4.26) in the first season, based on the findings in Table 3. While, foliar spraying with ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) recorded the largest value (3.95) during the second season. However, the lowest number of inflorescences was shown by untreated trees (T0) which was an average of 2.30, over the first season. Whilst, in the second season, the control trees (T0) and the trees sprayed with ammonium nitrate (T1) gave the lowest numbers were 3.09 and 3.13, respectively, the other treatments were in between range.

### *Final fruit set percentage and yield*

The findings showed that the applied treatments had an impact on the amount of final fruit set percentage. In this context, the highest values came from tree spraying with cobalt sulfate + vitamin $B_{12}$ (T6) and ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) was 9.83% in the first season and (13.34%) in the second season. On the other hand, untreated trees (T0) were found to have the lowest final fruit set percentage were 3.85% and 5.13% during the first and second seasons (Table 3).

Results demonstrated that in both seasons of distinct treatments were significantly varied the amount of yield of trees (Table 3). In the first season, the maximum values of yield (13.11 kg/tree) were obtained by spraying with cobalt sulfate + vitamin $B_{12}$ (T6). In the same respect, spraying with cobalt sulfate (T3) and ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) recorded the highest amounts in the second season which were 13.81 kg and 13.91 kg, respectively.

On the other side, untreated trees (control) displayed the lowest values of yield in both studied seasons; the values were 6.11 and 9.51 kg/tree, respectively, and the rest of the experimental treatments gave a greater yield than the control during the two experimental seasons.

**Table 3.** Effect of foliar spraying with ammonium nitrate, cobalt sulfate and vitamin $B_{12}$ on number of inflorescences per shoot, fruit set percentage and yield kg/tree of mango trees "Keitt cv." during 2022 and 2023 seasons

| Treat. | No. inflo./shoot | | Final fruit set% | | Yield (kg/tree) | |
|---|---|---|---|---|---|---|
| | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| T0* | 2.30 f | 3.09 d | 3.85 g | 5.13 g | 6.11 e | 9.51 e |
| T1 | 2.37 f | 3.13 d | 5.91 d | 5.29 f | 6.27 e | 9.45 e |
| T2 | 4.00 b | 3.88 a | 5.08 f | 7.07 e | 11.59 c | 13.81 a |
| T3 | 2.72 d | 3.33 c | 8.73 b | 7.93 d | 8.63 d | 9.60 e |
| T4 | 2.55 e | 3.40 bc | 6.68 c | 9.74 c | 11.40 c | 9.83 d |
| T5 | 4.26 a | 3.46 b | 6.56 c | 10.94 b | 6.23 e | 12.40 c |
| T6 | 3.90 b | 3.85 a | 9.83 a | 11.07 b | 13.11 a | 13.10 b |
| T7 | 3.48 c | 3.95 a | 5.66 e | 13.34 a | 12.86 b | 13.91 a |

At the 5% level, there is no significant difference between the means of any column containing a similar letter. *T0= untreated (control), T1= ammonium nitrate (1%), T2= cobalt sulfate (100 ppm), T3= vitamin $B_{12}$ (100 ppm), T4= ammonium nitrate (1%) + cobalt sulfate (100 ppm), T5= ammonium nitrate (1%) + vitamin $B_{12}$ (100 ppm), T6= cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm), T7= ammonium nitrate (1%) + cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm).

### ***Fruit physical properties***

It evident in both seasons that, the most varied spraying treatments considerably raised the fruits and flesh weight to the control treatment (Table 4). In the first season, the trees treated with ammonium nitrate (T1) exhibited the highest values of fruit and flesh weight which were 762.5 g and 539.2 g. Furthermore, in the second season the highest values of fruit and flesh weight were obtained from tree spraying with ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) was 728.5 g for fruit weight, and 551.0 g for flesh weight. Conversely, in the first and second seasons, the control trees provided the lowest values of 557 g and 295 g for fruit weight, and 449 g and 200 g for flesh weight in the first and second seasons, respectively.

In relation to the flesh /seed ratio, results were clearly shown that in the first season, trees sprayed with ammonium nitrate + vitamin $B_{12}$ (T5) showed the largest ratio (10.76) in Table 4. Meanwhile, In the second season, the trees treated with ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) had the largest ratio (7.31) as compared with other treatments. On the other hand, the application of cobalt sulfate alone (T2) recorded the lowest ratios of 7.53 and 5.26 in both studied seasons, respectively.

**Table 4.** Effect of foliar spraying with ammonium nitrate, cobalt sulfate and vitamin $B_{12}$ on fruit weight, flesh weight and flesh/seed ratio of mango trees "Keitt cv." during 2022 and 2023 seasons

| Treat. | Fruit weight (g) | | Flesh weight (g) | | Flesh/Seed ratio | |
|---|---|---|---|---|---|---|
| | **2022** | **2023** | **2022** | **2023** | **2022** | **2023** |
| **T0*** | 557.0 h | 295.0 g | 449.0 f | 200.0 g | 8.18 e | 5.61 e |
| **T1** | 762.5 a | 560.0 c | 539.2 a | 420.0 c | 8.08 f | 6.46 d |
| **T2** | 609.2 e | 691.0 b | 452.0 e | 447.3 b | 7.53 h | 5.26 f |
| **T3** | 596.4 f | 304.0 f | 454.3 d | 222.3 f | 8.71 d | 7.30 b |
| **T4** | 580.1 g | 339.2 e | 440.1 g | 252.1 e | 9.64 b | 7.31 b |
| **T5** | 655.0 c | 305.0 f | 527.1 b | 201.2 g | 10.76 a | 6.47 d |
| **T6** | 643.0 d | 539.0 d | 450.0 f | 389.2 d | 9.55 c | 6.82 c |
| **T7** | 716.0 b | 728.5 a | 521.2 c | 551.0 a | 7.73 g | 7.31 a |

At the 5% level, there is no significant difference between the means of any column containing a similar letter. *T0= untreated (control), T1= ammonium nitrate (1%), T2= cobalt sulfate (100 ppm), T3= vitamin $B_{12}$ (100 ppm), T4= ammonium nitrate (1%) + cobalt sulfate (100 ppm), T5= ammonium nitrate (1%) + vitamin $B_{12}$ (100 ppm), T6= cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm), T7= ammonium nitrate (1%) + cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm).

### *Fruit chemical characteristics*

It is clearly shown that all spraying treatments significantly increased the total soluble solids and total sugar percentages of fruit juice in comparison to the control treatment in both seasons of the study (Table 5). In the first season, the trees treated with ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) exhibited the highest percentages of total soluble solids and total sugar which were 19.79% and 8.76%, respectively. In this respect, in the second season, the highest percentages of total soluble solids and total sugar were obtained from tree spraying with ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) (20.70% for T.S.S. and 18.80% g for Total sugar). Conversely, in this regard, the control trees (T0) provided the lowest percentages of the values in the first and second seasons, which were 17.95% in the first season and 18.80% in the second season for total soluble solids of 8.09% and 8.17% for total sugar of juice in the first and second seasons, respectively.

**Table 5.** Effect of foliar spraying with ammonium nitrate, cobalt sulfate and vitamin $B_{12}$ on total soluble solids percentage, acidity percentage, total sugar percentage and T.S.S./acidity ratio of mango fruits juice "Keitt cv." during 2022 and 2023 seasons

| Treat. | T.S.S. (%) | | Acidity (%) | | Total sugar (%) | | T.S.S./acidity ratio | |
|---|---|---|---|---|---|---|---|---|
| | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| **T0*** | 17.95 e | 18.80 c | 0.65 a | 0.66 a | 8.04 c | 8.17 e | 27.65 d | 28.49 e |
| **T1** | 18.36 d | 19.65 abc | 0.49 b | 0.41 d | 8.12 c | 8.30 de | 37.63 c | 48.34 a |
| **T2** | 18.60 cd | 19.25 bc | 0.62 a | 0.53 c | 8.24 c | 8.50 bc | 30.17 d | 36.47 bc |
| **T3** | 18.90 c | 19.45 bc | 0.37 cd | 0.52 c | 8.54 ab | 8.43 bcd | 51.61 ab | 37.69 b |
| **T4** | 18.80 c | 19.95 ab | 0.38 c | 0.60 b | 8.65 ab | 8.40 bcd | 49.27 b | 33.25 d |
| **T5** | 19.25 b | 19.71 abc | 0.40 c | 0.59 b | 8.51 b | 8.35 cde | 47.79 b | 33.64 cd |
| **T6** | 18.90 c | 20.09 ab | 0.34 d | 0.51 c | 8.46 b | 8.57 b | 56.22 a | 38.71 b |
| **T7** | 19.76 a | 20.70 a | 0.40 c | 0.59 b | 8.76 a | 8.74 a | 49.44 b | 33.45 cd |

At the 5% level, there is no significant difference between the means of any column containing a similar letter. *T0= untreated (control), T1= ammonium nitrate (1%), T2= cobalt sulfate (100 ppm), T3= vitamin $B_{12}$ (100 ppm), T4= ammonium nitrate (1%) + cobalt sulfate (100 ppm), T5= ammonium nitrate (1%) + vitamin $B_{12}$ (100 ppm), T6= cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm), T7= ammonium nitrate (1%) + cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm).

In the same table, the results showed that the applied treatments had an effect on reducing the acidity percentage in the fruit juice, compared to trees not sprayed with the materials under study. The lowest percentages in this regard were obtained from tree spraying with cobalt sulfate + vitamin $B_{12}$ (T6) in the first season, and with ammonium nitrate (T1) in the second one which were 0.34% and 0.41% respectively. On the other hand, untreated trees (T0) were found to be the highest percentages of acidity for juice which were 3.85% and 5.13% in the first and second seasons, respectively.

In relation to T.S.S/acidity ratio clearly made that in the first season, trees sprayed with cobalt sulfate + vitamin $B_{12}$ (T6) and ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) showed the largest ratios (56.22 and 49.44, respectively) in Table 5. Meanwhile, in the second season, the trees treated with ammonium nitrate (T1) and cobalt sulfate + vitamin $B_{12}$ (T6) had the largest ratios of 48.34 and 38.71, respectively) as compared with other treatments. On the other hand, the control trees recorded the lowest T.S.S/acidity ratios in both studied seasons, which were 27.65 and 28.49, respectively.

In both seasons, the most varied spraying treatments considerably raised the values of vitamin C in juice of fruit compared to the control treatment (Table 6). In the first and second seasons, the trees treated with a combination of cobalt sulfate + vitamin $B_{12}$ (T6) exhibited the highest values of 40.25 and 46.80 mg/100 g juice, respectively. Conversely, in the first and second seasons, the control trees recorded the least values in this regard, where the values were 33.81 and 35.93 mg/100 g juice, respectively.

As for the content of carotene in the fruit flesh, all treatments recorded significant positive results compared to untreated trees during the two study seasons. It was found that spraying ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) had the highest values in the two study seasons, which were 22.50 and 24.37 mcg/g, respectively) according to the results in Table 6. However, untreated trees (T0) were 18.25 and 15.33 mcg/g, over the two study seasons, respectively, it showed the lowest values of carotene. The other treatments were in between ranges.

The content of cobalt in the fruit flesh was within the safe and normal range for the fruits (Table 6). The results recorded that the concentration of cobalt increased at a slight rate with the treatments that used cobalt sulfate (T2, T4, T6, and T7). The results recorded the highest values of cobalt in the fruit flesh with T6 (cobalt sulfate + vitamin $B_{12}$) in the tow study seasons, which were 14.4 and 13.2 ppm, respectively. On the other side, the trees treated with T5 (ammonium nitrate + vitamin $B_{12}$) recorded the lowest values of cobalt in both studied seasons, the values were 8.6 and 8.0 ppm, respectively.

***Leaf mineral contents***

The treatments were carried out had a significant impact on leaf mineral content of nitrogen (Table 7). In the first season, tree sprayed with ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) and ammonium nitrate + vitamin $B_{12}$ (T5) gave the maximum nitrogen of 1.54% and 1.54%. While trees sprayed with ammonium nitrate + cobalt sulfate + vitamin $B_{12}$ (T7) recorded the maximum leaf nitrogen content (1.51%) in the second season. Conversely, in both analyzed seasons, the control treatment yielded the lowest nitrogen of 1.32% and 1.09%, respectively.

**Table 6.** Effect of foliar spraying with ammonium nitrate, cobalt sulfate and vitamin $B_{12}$ on vitamin C content of juice, flesh content of carotene and cobalt of mango fruits "Keitt cv." during 2022 and 2023 seasons

| Treat. | Vit. C (mg/100 ml juice) | | Flesh content of Carotene (mcg/g flesh) | | Flesh content of cobalt (ppm) | |
|---|---|---|---|---|---|---|
| | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| **T0*** | 33.81 f | 35.93 d | 18.25 g | 15.33 g | 11.8 e | 10.4 e |
| **T1** | 37.75 b | 40.17 c | 18.50 f | 15.40 g | 12.6 d | 12.0 d |
| **T2** | 37.23 d | 39.53 c | 18.50 f | 17.00 f | 13.0 c | 12.2 c |
| **T3** | 35.97 e | 44.07 b | 19.50 e | 17.30 e | 9.8 g | 8.2 g |
| **T4** | 36.00 e | 40.77 c | 21.00 d | 22.10 b | 14.0 b | 13.0 b |
| **T5** | 40.15 a | 36.39 d | 22.00 b | 21.17 c | 8.6 h | 8.0 h |
| **T6** | 40.25 a | 46.80 a | 21.33 c | 19.13 d | 14.4 a | 13.2 a |
| **T7** | 37.50 c | 36.05 d | 22.50 a | 24.37 a | 11.0 f | 10.0 f |

At the 5% level, there is no significant difference between the means of any column containing a similar letter. *T0= untreated (control), T1= ammonium nitrate (1%), T2= cobalt sulfate (100 ppm), T3= vitamin $B_{12}$ (100 ppm), T4= ammonium nitrate (1%) + cobalt sulfate (100 ppm), T5= ammonium nitrate (1%) + vitamin $B_{12}$ (100 ppm), T6= cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm), T7= ammonium nitrate (1%) + cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm).

The leaf phosphorus content did not show a clearly trend during the two seasons of the experiment (Table 7). In the first season, trees treated with cobalt sulfate (T2) recorded the maximum leaf phosphorus percentage (0.064%). However, trees sprayed with ammonium nitrate + cobalt sulfate (T4) had the highest leaf phosphorus percentage (0.074%) in the second season. On the other hand, the lowest percentage was shown by ammonium nitrate (T1) which was 0.051%, over the first season. Whilst, in the second season, trees sprayed with vitamin $B_{12}$ (T3) gave the lowest leaf phosphorus percentage (0.059%).

The data demonstrated that throughout the two seasons under investigation, treatments of spraying had a substantial impact on leaf potassium content (Table 7). Correspondingly, in the first season, trees sprayed with ammonium nitrate (T1) and vitamin $B_{12}$ (T3) showed the largest percentages which were 0.62% and 0.63%, respectively. Meanwhile, in the second season, the trees treated with vitamin $B_{12}$ (T3) had the largest percentage of potassium (0.49%) as compared with other treatments. Furthermore, in the first and second seasons, respectively, the untreated trees (control) recorded percentages of potassium in leaves of 0.33% and 0.24%, which were the lowest significant values.

**Table 7.** Effect of foliar spraying with ammonium nitrate, cobalt sulfate and vitamin B12 on leaf mineral contents of mango trees "Keitt cv." during 2022 and 2023 seasons

| Treat. | N (%) | | P (%) | | K (%) | | Co (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| **T0*** | 1.32 f | 1.09 h | 0.056 d | 0.061 d | 0.33 f | 0.24 f | 11.2 f | 9.8 g |
| **T1** | 1.40 c | 1.37 d | 0.051 f | 0.068 b | 0.62 a | 0.38 b | 12.6 e | 7.8 h |
| **T2** | 1.45 b | 1.15 g | 0.064 a | 0.067 b | 0.47 c | 0.35 c | 18.6 a | 16.8 a |
| **T3** | 1.34 e | 1.45 b | 0.058 c | 0.059 e | 0.63 a | 0.49 a | 12.6 e | 14.2 e |
| **T4** | 1.46 b | 1.40 c | 0.054 e | 0.074 a | 0.33 f | 0.39 b | 18.4 b | 16.0 c |
| **T5** | 1.54 a | 1.32 e | 0.056 d | 0.064 c | 0.44 d | 0.33 d | 10.1 g | 11.8 f |
| **T6** | 1.37 d | 1.20 f | 0.060 b | 0.063 c | 0.40 e | 0.38 b | 17.2 c | 15.4 d |
| **T7** | 1.54 a | 1.51 a | 0.061 b | 0.064 c | 0.53 b | 0.30 e | 15.6 d | 16.6 b |

At the 5% level, there is no significant difference between the means of any column containing a similar letter.*T0= untreated (control), T1= ammonium nitrate (1%), T2= cobalt sulfate (100 ppm), T3= vitamin $B_{12}$ (100 ppm), T4= ammonium nitrate (1%) + cobalt sulfate (100 ppm), T5= ammonium nitrate (1%) + vitamin $B_{12}$ (100 ppm), T6= cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm), T7= ammonium nitrate (1%) + cobalt sulfate (100 ppm) + vitamin $B_{12}$ (100 ppm).

It was noted that the cobalt content of leaves increased at a slightly rate with the treatments that used cobalt sulfate (T2, T4, T6, and T7) as compared with other treatments. The results recorded the highest values of cobalt in leaves with T2 (cobalt sulfate only) in the two study seasons, which were 18.6 and 16.8 ppm, respectively. On the other side, the trees treated with T5 (ammonium nitrate + vitamin $B_{12}$) recorded the lowest value of cobalt (10.1 ppm) in the first season.

Meanwhile, the trees treated with ammonium nitrate (T1) had the least cobalt content in the leaf (0.49%) during the second season.

## Discussion

The previous results showed that spraying mango trees with ammonium nitrate, cobalt sulfate and vitamin $B_{12}$ had a positive effect on flowering, fruit set percentage, productivity and physical and chemical fruit characteristics. It was due to the beneficial physiological roles of these materials sprayed on trees, including that ammonium nitrate plays a role in improving the nutritional status of the tree, increasing the flowering percentage, helping to push trees to flower early and improving the quality of the fruits (Martinez *et al.,* 2020). While cobalt enters into the composition of many enzymes and coenzymes that play a major role in plants' resistance to drought and adverse environmental conditions, cobalt also improves the process of photosynthesis and slows down leaf ageing (Hareem *et al.,* 2024; Gad *et al.,* 2019). Cobalt also works to form vitamin $B_{12}$, which is important for plants (Hu *et al.,* 2021). One of the beneficial roles of vitamin $B_{12}$ is that it acts as a cofactor in some biological processes in the cell, as well as helping in the synthesis of polyamines, ethylene, and types of protein in plants (Rizzo *et al.,* 2016; Smith *et al.,* 2007).

The results of the experiment were consistent with many previous studies conducted on the use of ammonium nitrate, cobalt sulfate, or vitamin $B_{12}$. The present results are consistent with those found by Abd El-Migeed *et al.* (2022), who found that spraying Awis mango trees with ammonium nitrate at a concentration of 2% during the month of November led to improve the productivity of the trees and also gave better physical characteristics to the fruits. Also the chemical properties of the fruit juice improved, such as total soluble solids, acidity, and vitamin C. Furthermore, Sudha *et al.* (2012) investigated that the best form that gives the best result is ammonium nitrate at a concentration of 1% or 2%, which gave the best flowering percentage and helped in early flowering from the normal flowering dates and obtaining the best quality of fruits on Alphonso cultivar mangoes. However, the obtained results are in agreement with those of Singh and Agrez (2002), Singh *et al.* (2008), Wahdan (2011), Mansour and Mubarak (2014) and Hareem *et al.* (2024). They stated that spraying with cobalt in the form of cobalt sulfate had a positive effect on the percentage of fruit set and reduced the percentage of fruit drop, as well as increased the yield quantity and average fruit weight, it also improved the percentage of total sugars, total soluble solids, and the amount of vitamin C, and improved TSS/acidity ratio in fruit juice.

The obtained results are in harmony with those of Al-Wasfy (2013) and Faisal *et al.* (2014), who illustrated that spraying with vitamin B complex gave the highest increase in fruit weight and yield. In addition, Wassel *et al.* (2015) and Abd El-Bary (2017) studied spraying with a mixture of vitamin B on trees led to an increase in the percentage of fruit set, yield and average fruit weight, as well as improved the chemical properties of the juice and leaf mineral content. Moreover, foliar application of cobalt sulfate + Vitamin $B_{12}$ + Vitamin C at led to increase in the yield, physical properties of fruits and chemical properties of banana fruit such as: total sugars, Vitamin C and SSC/TA, therefore, the presence of vitamin $B_{12}$ with cobalt sulfate gave the best results (El-Baz *et al.,* 2016).

In conclusion, the experiment proved that foliar spraying with ammonium nitrate, cobalt sulfate and vitamin $B_{12}$ as nutrients and without any harmful effects on the environment is the optimal approach to improve the flowering of Keitt mango trees and to increase the number of fruits on the trees and the chemical properties of the fruits. All experimental treatments had a significant positive effect on the yield, the final fruit set percentage, the average fruit weight, the chemical properties of the fruits and the mineral content of the leaves as compared to untreated trees. It was noted that spraying the experimental materials together was better than spraying them individually. Treatment T7 (ammonium nitrate at 1% + cobalt sulfate at 100 ppm + vitamin $B_{12}$ at 100 ppm) was the best results in yield, fruit weight and chemical properties of the fruit juice such as T.S.S %, total sugars and acidity percentages. Therefore, these treatments can be recommended to apply in mango trees of commercial farms under similar environmental conditions.


## Acknowledgements

The authors would like to express their sincere thanks, appreciation, respect and gratitude to Prof. Dr. Mahmoud M. Abd El-Migeed, a researcher Prof. Emeritus of Pomology at the National Research Centre in Egypt, for his contribution to the success of this work, his assistance in conducting the experiment on his private farm and his guidance in all stages of the experiment.


## References


A.O.A.C. (1990). Official Methods of Analysis. The Association of Official Analytical Chemists. 15th Ed. Arlington, West Virginia, Washington D.C., USA.

Abd El-Bary, A. A. (2017). Effect of Spraying GA3 and Cyanocobalamin (Vit. B12) on Fruit Set, Yield, and Fruit Quality of Le-Conte Pear Trees. Journal of Plant Production, Mansoura University, 8:555-558.

Abd El-Migeed, M. M. M., E. Abd El-Razek, Hassan, A. M. Ali and Abdel-Hamid, N. (2022). Efect of foliar spray of ammonium nitrate and irrigation time on vegetative growth, fruit set, yield and fruit quality of "Ewais" mango trees. Bulletin of the National Research Centre, 46:1-10.

Al- Wasfy, M. M. (2013). Response of Sakkoti date palms to foliar application of Royal Jelly, silicon and vitamins B. American Journal of Science, 9:315-321.

Almutairi, K. F., Górnik, K., Ayoub, A., Abada, H. S. and Mosa, W. F. A. (2023). Performance of Mango Trees under the Spraying of Some Biostimulants. Sustainability. 15:15543.

Brown, J. D. and Lilleland, D. (1946). Rapid determination of potassium and sodium in plant material and soil extract by flame photometer. Proceedings of the American Society for Horticultural Science, 48:331-346.

Chapman, H. D. and Pratt, P. E. (1961). Methods of analysis for soil, plant and water. University of California, Davis, Division of Agricultural Science, pp.1-309.

Duncan, D. B., (1955). Multiple ranges and multiple tests. Biometrics, 11:1- 24.

Elhady, E. S., Haggag, L. F., Hassan, A. M. and Belopukhov, S. L. (2024). Effect of rock phosphate and bacteria solubilizing nutrients soil application on yield and fruit quality of olive trees cv. "Picual" under the arid zones. BIO Web of Conferences, 82:1-8.

El-Baz, E. E. T., Lo'ay, A. A., Ibrahium, E. G. and El-Deeb, M. R. I. (2016). Effect of Cobalt and some Vitamins as Foliar Application Treatments on Productivity and Quality of Williams Banana Cultivar. Journal of Plant Production, 7:777-786.

FAOSTAT (2022). Food and Agriculture Organization of the United Nation (FAO). Retrieved from http://www.fao.org.

Gad, N., Abdel-Moez, M. R. and Ali, M. E. F. (2019). Maximization of drought tolerance of bean plants using cobalt supplementation: B-physiological and chemical contents in plants. Plant Archives, 19:2282-2287.

Gad, N., Moez, A. and Kandil, H. (2015). Response of Okra (Hibiscus esculentus) growth and productivity to cobalt and humic acid rates. International Journal of ChemTech Research, 8:1782-1791.

Hareem, M., Danish, S., Obaid, S. A., Ansari, M. J. and Datta, R. (2024). Mitigation of drought stress in chili plants (*Capsicum annuum* L.) using mango fruit waste biochar, fulvic acid and cobalt. Scientific Reports, 14:14270.

Hu, X., Wei, X., Ling, J. and Chen, J. (2021). Cobalt: An essential micronutrient for plant growth? Frontiers in Plant Science, 12:768523.

Katami, T. and Hayakawa, T. (1985). Spectrophotometric Determination of Cobalt in Pepperbush Leaves and Coal Fly Ashes Using 2-(2-Benzothiazolylazo)-5- di methylam ino benzoic Acid. ANALYST, 110:399-401.

Mansour, N. and Mubarak, M. (2014). Improving yield, fruit quality and leaf mineral content of navel orange trees with natural elements compound (NEC) and cobalt applications. American-Eurasian Journal of Agricultural & Environmental, 14:303-313.

Morales-Martinez, M., Moscoso-Ramirez, P. A., Castelan-Estrada, M. and Contreras-Oliva, A. (2020). Effect of nitrates alone or with paclobutrazol on flowering induction and production in mango cv. Tommy Atkins. Biotecnia, 22:20-27.

Pregl, F. (1945). Quantitative Organic Micro Analysis. 4th, Ed. J. Churchill Ltd. London.

Rizzo, G., Laganà, A. S., Rapisarda, A. M., La Ferrera, G. M., Buscema, M., Rossetti, P., Nigro, A., Muscia, V., Valenti, G., Sapia, F., Sarpietro, G., Zigarelli, M. and Vitale, S. G. (2016). Vitamin $B_{12}$ among vegetarians: status, assessment and supplementation. Nutrients, 8:767.

Sadasivam, S. and A. Manickam, (1996). "Biochemical Methods," New Age International (P) Limited, New Delhi, 2:124-126.

Salazar-Garcia, S., Pérez-Barraza, M. H. and Vázquez-Valdivia, V. (2000) Effect of ammonium nitrate sprays on flowering and harvest time of 'Manila', 'Ataulfo', and 'Tommy Atkins' mango in Nayarit. México Acta Horticulturae, 509:573-580.

Singh, Z. and Agrez, V. (2002). Fruit set, retention and yield of mango in relation to ethylene. Acta Horticulturae, 575: 805-811.

Singh, Z., Singh, L., Arora, C. L. and Dhillon, B. S. (2008). Effect of cobalt, cadmium, and nickel as inhibitors of ethylene biosynthesis on floral malformation, yield, and fruit quality of mango. Journal of Plant Nutrition, 17:1659-1670.

Smith, A. G., Croft, M. T., Moulin, M. and Webb, M. E. (2007). Plants need their vitamins too. Current Opinion in Plant Biology, 10:266-275.

Snedecor, G. W. and Cochran, W. D. (1980). Statistical methods. $7^{th}$Ed. Iowa State University Press, Ames, Iowa., U.S.A., 491p.

Sudha, R., Balamohan, T. N. and Soorianathasundaram, K. (2012). Effect of foliar spray of nitrogenous chemicals on flowering, fruit set and yield in mango (*Mangifera indica* L.) cv. Alphonso. Journal of Horticultural Sciences, 7:190-193.

Wahdan, M. T. (2011). Effects of cobalt sulfate and choline chloride on fruiting and fruit quality of mango Cv. Succary Abiad. Life sciences journal, 8:337-343.

Wassel, A. H. M., Gobara, A. A., Ibrahiem, H. I. M. and Shaaban. M. M. (2015). Response of wonderful pomegranate trees to foliar application of amino acids, vitamins B and silicon. World Rural Observations, 7:91-95.

Wettestien, V. D. (1957). Chlorophyll lethal unjjer sub mink roskpische for minvechoeljerplastijen. Experimental Cell Research, 12:427 - 433.

Zeh, M., Leggewie, G., Hoefgen, R. and Hesse, H. (2002). Cloning and characterization of a cDNA encoding a cobalamin-independent methionine synthase from potato (*Solanum tuberosum* L.). Plant Molecular Biology, 48:255-265.

(Received: 20 August 2024, Revised: 7 November 2024, Accepted: 10 November 2024)