The Effect of the Foliar Application of Potassium, Calcium, Boron and Humic Acid on Vegetative Growth, Fruit Set, Leaf Mineral, Yield and Fruit Quality of 'Anna' Apple Trees

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Authors’ contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

This experiment was carried out during 2012 and 2013 seasons on seven years old "Anna" apple trees (Malus domestica L.). Trees were planted at 5x5 meters on sandy loam soil under drip irrigation system in a private orchard at El-Nubaria, Behera Governorate, Egypt. The experiment involved ten foliage spraying treatments as follows: control, sprayed with water, K at 2% as potassium sulphate, Ca at 0.2% as calcium chloride, B at 0.2% as boric acid, H.A. at 5% as humic acid, potassium sulphate+ humic acid, calcium chloride+ humic acid, boric acid+ humic acid, potassium sulphate+ calcium chloride+ boric acid and potassium sulphate+ calcium chloride+ boric acid+ humic acid. The obtained results showed that potassium sulphate+ calcium chloride+ boric acid+ humic acid combination was the best treatment. This combination had the highest positive effect to improve the percentages of yield, fruit set, reducing sugar and total soluble solids. Also, it

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increased Ca, P, K, N, B, Zn, Mn and Fe in the leaves in the two seasons, as compared to the control. Moreover, this combination improved significantly anthocyanin concentration, TSS/acid ratio, shoot diameter, shoot length, leaf area, fruit diameter, fruit length, average fruit weight and fruit firmness. It decreased the percentages of fruit drop and acidity in the two seasons as compared to the control and the other treatments.

**Keywords:** Anna apple; foliar application; humic acid; yield; fruit quality.

1. **INTRODUCTION**

Anna apple (*Malus domestica* L. Borkh) is a low chilling requirement cultivar [1], spreading in many tropic and subtropic areas including Egypt. Foliar fertilization has advantages of low application rates, uniform distribution of fertilizer materials, easiest method of application and quick responses to applied nutrients [2]. Boron is an important micronutrient for trees and it may be applied to the soil or the foliage with good effect. Foliar applications of boron before full bloom or after harvest increased fruit set and fruit yield of apple trees [3]. Foliar application of calcium borate on some characters of apple fruits "Sheikh Amir" variety during 2010 and 2011 seasons at Shirvan region was studied by [4]. The obtained results showed that among all measured characters high amount of fruit yield, fruit firmness, total soluble solids and fruit concentration of B and Ca were recorded in calcium borate treatment but maximum amount of fruit acidity was obtained in control treatment. Spraying "Golden Japanese" plum by four potassium fertilizer sources at bud burst, after fruit set and one month after fruit set increased significantly fruit set, yield, fruit weight, fruit size, fruit length, fruit diameter, total sugar and potassium percentages, while decreased fruit drop percentage in comparison with the control treatment. In addition, the tested treatments increased total carbohydrates and leaf macro-elements content [5]. Humic acid enhanced significantly apple fruit yield, weight and soluble solids content [6], yield, fruit quality and grower income of apple [7]. Applying humic fertilizers on "Canino" apricot [8] and on "Le-Conte" pear [9] increased markedly the yield of these fruits. Gradual increases in shoot diameter, average shoot length, leaf area and NPK accumulation were parallel to the increase of humic acid application on "Anna" apple trees [10].

The purpose of this study was investigate the effect of foliar application of either humic acid, potassium, calcium or boron as well as their combinations on vegetative growth, fruit set, leaf mineral, yield and fruit quality of 'Anna' apple trees.

2. **MATERIALS AND METHODS**

This experiment was carried out during the two successive seasons, 2012 and 2013 on seven years old "Anna" apple trees (*Malus domestica* L. Borkh), planted at 5×5 meters apart in a sandy loam soil under drip irrigation system in a private orchard located at El-Nubaria, Beheira governorate, Egypt. The physiochemical analysis of experimental soil was indicated in Table 1 and it was carried out according to Cottenie et al. [11]. Forty uniform trees were selected for this study and all of them were subjected to the same cultural practices in the two seasons. They were sprayed three times, before flowering, 10 days after full bloom and one month later after adding misrol liquid soap (1 ml/l) as a wetting agent in the two seasons with the following treatments:

- **T1:** Control (sprayed with water)
- **T2:** K at (2%) as potassium sulphate
- **T3:** Ca at (0.2%) as calcium chloride
- **T4:** B at (0.2%) as boric acid
- **T5:** H.A.(humic acid 5%)
- **T6:** K + H.A
- **T7:** Ca + H.A.
- **T8:** B + H.A.
- **T9:** K + Ca + B
- **T10:** K + Ca + B + H.A.

The trees were treated with actosol ® a fertilizer whose NPK ratio is 10-10-10 and humic acid concentration of 2.9%, humic acid is manufactured by ARCTECH INC. in USA.

The previous treatments were applied and arranged in a randomized complete block design. Each treatment included four replicates with one tree for each replicate.

The effect of the previous treatments was studied by evaluating their influence on the following parameters.
2.1 Vegetative Parameters

At the end of growing seasons, the selected shoots were measured for the average of shoot length cm, shoot diameter cm and leaf area cm².

2.2 Fruit Set and Fruit Drop Percentage

Two main branches from two direction (east and west) of each tree were chosen and tagged in March of the two experimental seasons, the number of flowers was recorded and those set fruits on the selected branches were counted for calculating the percentage of fruit set according to Westwood [12] equation:

\[
\text{Fruit set } \% = \frac{\text{Number of set fruitlets}}{\text{Number of opened flowers}} \times 100
\]

Pre-harvest fruit drop was calculated by counting the number of dropping fruit from the 4th week of May till the commercial harvesting time under the experimental conditions (3rd week in June), then expressed as a percent from the whole number of fruits existed on the tree at the 4th week of May.

\[
\text{Fruit drop } \% = \frac{\text{Number of dropped fruitlets}}{\text{Number of set fruitlets}} \times 100
\]

2.3 Yield per Tree

Yield was pressed in weight kg and number of fruits per tree was recorded at harvest time (3rd week of June).

2.4 Leaf Chemical Composition

Samples of twenty leaves from the middle part of the shoots according to [13] were randomly selected from each replicate (at the 2nd week of June) to determined their content from N%, P %, K %, Ca% and Fe, Zn, Mn and B at ppm.

Leaf samples were washed with tap water, then with distilled water and dried at 70°C until a constant weight, finally, ground and acid digested using H2SO4 and H2O2 until clear solution was obtained according to Wilde et al. [14].

The digested solution was used for the determination of each of nitrogen (N) using micro Kjeldhal method, phosphorus (P) by vanadomolybdo method and potassium (K) was determined by flame photometer according to the method described by [15]. Zinc, manganese, calcium and iron were determined on atomic absorption spectrophotometer (2-8200 Series Polarized Zeeman, Hitachi, Tokyo, Japan) by using specific lamp for specific nutrient. The B in leaf samples was determined by dry ashing as reported earlier by [16], and subsequent measurement of B was done through colorimetry Azomethine-H as outlined [17].

2.5 Fruit Quality

Twenty fruits were randomly taken at harvest time from each replicate for the determination of both physical and chemical characteristics.

2.6 Fruit Physical Characteristics

Fruit weight (g), fruit length (cm), fruit diameter (cm) and L/D ratio, fruit firmness (lb/ inch²) using a Magness and Taylor pressure tester with 7/18 inch plunger.

2.7 Fruit Chemical Characteristics

Total soluble solids were determined using a hand refractometer, percentage of titration acidity in fruit juice was determined according to [18], total soluble solid / total acidity ratio were calculated.

Total sugars, reducing and non-reducing sugars were estimated According to [19]. Anthocyanin was determined at the stage of coloration (mg/100 g fresh weight peel) according to Rabino et al. [20].

2.8 Statistical Analysis

The obtained data were subjected to the proper analysis of variance (ANOVA) according to [21]. Least significant difference (LSD) at 0.05% level of significance was used to compare the treatment means.

### Table 1. Physical and chemical properties of the experiment soil

| Depth (cm) | Texture     | pH  | Total CaCO₃ (mg/L) | EC.(dS/m) | O.M. (%) | Cations (meq/ 100 g soil) | DTPA-extractable (mg/kg) |
|-----------|-------------|-----|--------------------|-----------|----------|--------------------------|--------------------------|
| 0 - 40    | Sandy loam  | 8.50| 30.46              | 1.37      | 0.54     | Na⁺⁺ 2.01, K⁺ 0.07, Ca⁺⁺ 3.28, Mg⁺⁺ 2.27 | Fe 0.39, Mn 0.50, Zn 0.31 |
3. RESULTS

Data in Table 2, clearly showed that shoot diameter, shoot length and leaf area were increased significantly over the control by the foliar application of potassium sulphate alone or combined with humic acid, humic acid alone, potassium sulphate + calcium chloride + boric acid combination. Moreover, they also improved by usage, potassium sulphate + calcium chloride + boric acid + humic acid, calcium chloride + humic acid and boric acid + humic acid combinations as compared to the control in both study seasons. Boric acid improved significantly leaf area, but it did not have any significant effect on shoot length or shoot diameter. Also, the usage of calcium chloride alone did not have any significant effect on shoot length, shoot diameter or leaf area, in both seasons as compared to the control.

Results in Table 3, showed that the foliar application of potassium sulphate alone and humic acid alone or in combination with each other gave great increases in the yield, fruit set percentages, average fruit weight and decreased the percentages of fruit drop. The similar results were obtained by the usage of boric acid alone or combined with humic acid. Furthermore, calcium chloride + humic acid, potassium sulphate + calcium chloride + boric acid or potassium sulphate + calcium chloride + boric acid + humic acid combinations increased significantly the yield, fruit set percentages, average fruit weight and decreased the fruit drop percentages with comparing to the control. On the opposite side, the combination between potassium sulphate and humic acid gave non-significant increase in average fruit weight as compared to the control. The usage of calcium chloride did not have any remarkable effect on fruit set, yield, average fruit weight or/and fruit drop as compared to the control treatment in the two seasons.

From the results in Table 4, it can be concluded that potassium sulphate + calcium chloride + boric acid + humic acid combination gave a remarkable increase in the percentages of Ca, P, K and N in the leaves as compared to the control treatment. The usage of potassium sulphate alone or combined with humic acid enhanced significantly the percentages of K and N, but it did not have any significant effect on P and Ca percentages as compared to the control. Potassium sulphate and humic acid combination improved the percentages of P, but it did not have any remarkable effect on the percentages of Ca. The usage of calcium chloride had a positive effect to increase the percentages of calcium, but it did not have any great effect on N, P and K percentages in the leaves. Calcium chloride and humic acid combination improved remarkably N, P and K percentages in the leaves but it did not affect significantly Ca percentages as compared to the control. Boric acid had no significant effect on N, P, K and Ca percentages. The combination between humic and boric acid increased significantly P and Ca percentages, but it had insignificant effect on the percentages of N and K. Humic acid gave a great increase in Ca, K and N percentages over the control. Potassium sulphate + calcium chloride + boric acid combination increased positively N percentage, but it gave non-significant increase in Ca, K and P percentages in the leaves with comparing to the control in both study seasons.

Listed data in Table 5, B, Zn, Mn and Fe content in the leaves was affected positively by the foliar application of humic acid alone, calcium chloride + humic acid, potassium sulphate + calcium chloride + boric acid or potassium sulphate + calcium chloride + boric acid + humic acid combinations as compared to the control in the two seasons. Potassium sulphate increased significantly Zn, Mn and Fe concentrations, but its effect on B content was insignificant as compared to the control in the two seasons. Potassium sulphate + humic acid combination enhanced Zn and B concentration but, it had no significant effect on Fe or Mn concentration in the leaves as compared to the control. Moreover, calcium chloride gave a considerable enhancement in Zn and Mn concentration but it did not have any significant effect on Fe or B content in the leaves in both seasons as compared to the control. Boric acid gave no remarkable increase in Fe, Mn and Zn content in the leaves. On the other side, boric and humic acid combination caused significant increments in Zn, Mn and B concentrations but it gave in significant increase in F concentration in the leaves with comparing to the control treatment in the two seasons.

From the results in Table 6, it can be noticed that potassium sulphate + calcium chloride + boric acid + humic acid combination enhanced remarkably fruit diameter, fruit length and fruit firmness in both seasons as compared to the control. Potassium sulphate, boric acid, humic acid, calcium chloride + humic acid combination or potassium sulphate + calcium chloride + boric acid combination enhanced fruit diameter, fruit length and fruit firmness in both seasons as compared to the control.
acid combination increased fruit length and fruit diameter but, they did not give a significant increase in fruit firmness in the two seasons compared to the control. Calcium chloride enhanced fruit length and fruit diameter only in the first season and fruit firmness in the second season as compared to the control. Potassium sulphate + humic acid and/or boric acid + humic acid combination gave a slight increase in fruit length or fruit diameter in the two seasons as compared to the control.

From the results in Table 7, the foliar application of potassium sulphate, humic acid, boric acid or calcium chloride + humic acid combination improved TSS and TSS/acid ratio and decreased acidity percentage in the fruitsas compared to the control in the two seasons. In addition, the combination of potassium sulphate + calcium chloride + boric acid or potassium sulphate + calcium chloride + boric acid + humic acid had the same effect. Potassium sulphate combined with humic acid increased positively TSS/acid ratio but it had insignificant effect on TSS or acidity, with comparing to the control. On the opposite side, calcium chloride alone and boric + humic acid combination did not have any remarkable effect on acidity, TSS, TSS/acid ratio in both seasons as compared to the control.

Data in Table 8, showed that the combination of potassium sulphate + calcium chloride + boric acid + humic acid gave a remarkable increases in reducing sugar percentages and anthocyanin in the two seasons as compared to the control.

### Table 2. Effect of spraying potassium, calcium, boron and humic acid on some vegetative growth of "Anna" apple trees in 2012 and 2013 seasons

| Treatments          | Shoot length (cm) | Shoot diameter (cm) | Leaf area (cm²) |
|---------------------|-------------------|---------------------|-----------------|
|                     | 2012   | 2013   | 2012   | 2013   | 2012   | 2013   |
| T1: Control (sprayed with water) | 35.76e | 36.47g | 0.65g  | 0.67d  | 23.36e | 24.17d |
| T2: K at (2%) as potassium sulphate | 40.36c | 41.65c | 0.73de | 0.74c  | 27.18b | 28.53bc|
| T3: Ca at (0.2%) as calcium chloride | 36.81de | 37.27fg | 0.67fg | 0.69cd | 25.37de | 26.67c |
| T4: B at (0.2%) as boric acid | 36.92de | 37.31fg | 0.68efg | 0.70cd | 26.46d | 27.85c |
| T5: H.A. (humic acid5%) | 41.87b | 43.52bc | 0.81bc | 0.82b  | 29.24ab | 30.46ab|
| T6: K + H.A. | 37.28b | 38.52ef | 0.72def | 0.73cd | 26.85cd | 27.14c |
| T7: Ca + H.A. | 42.74b | 43.83ab | 0.77cd | 0.82b  | 28.65abc | 30.06ab|
| T8: B + H.A. | 37.65d | 39.67de | 0.71ef | 0.74c  | 26.12d | 27.23c |
| T9: K + Ca + B | 38.14d | 40.36cd | 0.84b  | 0.85b  | 27.25bcd | 28.65bc|
| T10: K + Ca + B + H.A. | 44.67a | 45.17a | 0.91a  | 0.94a  | 30.67a | 31.42a|
| L.S.D.0.05 | 1.46   | 1.57   | 0.05   | 0.06   | 2.11   | 2.17   |

**Means not sharing the same letter(s) within each column, significantly different at 0.05 level of probability**

### Table 3. Effect of spraying potassium, calcium, boron and humic acid on fruit set, fruit drop, yield and average fruit weight of "Anna" apple trees in 2012 and 2013 seasons

| Treatments          | Fruit set (%) | Fruit drop (%) | Yield (kg/ tree) | Average fruit weight (g) |
|---------------------|---------------|----------------|------------------|-------------------------|
|                     | 2012   | 2013   | 2012   | 2013   | 2012   | 2013   | 2012   | 2013   | 2012   | 2013   |
| T1: Control (sprayed with water) | 13.64e | 12.96g | 76.37a | 75.85a | 36.47f | 38.14f | 117.38f | 120.54g |
| T2: K at (2%) as potassium sulphate | 18.42cd | 18.57d | 70.25cd | 68.46cd | 43.52d | 45.27d | 134.65cd | 137.94e |
| T3: Ca at (0.2%) as calcium chloride | 13.87e | 13.72g | 75.84ab | 73.25ab | 38.56ef | 40.71ef | 119.73ef | 121.41g |
| T4: B at (0.2%) as boric acid | 19.86bc | 19.75cd | 70.86cd | 69.14c | 45.17cd | 49.63c | 132.38d | 135.46e |
| T5: H.A. (humic acid5%) | 20.36b | 20.85bc | 68.46def | 65.36de | 52.74b | 53.67b | 145.20b | 152.46b |
| T6: K + H.A. | 17.65d | 16.36e | 71.25cd | 68.56cd | 39.82e | 42.62de | 119.65ef | 122.46g |
| T7: Ca + H.A. | 20.46b | 21.74bc | 67.36ef | 65.47de | 47.85c | 49.36c | 137.81c | 146.54c |
| T8: B + H.A. | 14.67e | 15.27ef | 72.37bc | 70.85bc | 40.17e | 43.65de | 122.45e | 128.37f |
| T9: K + Ca + B | 21.37b | 22.57bc | 66.31f | 64.73ef | 50.76b | 51.36bc | 137.56c | 142.17d |
| T10: K + Ca + B + H.A. | 24.56a | 24.87a | 60.27g | 61.83f | 58.47a | 60.27a | 152.37a | 167.24a |
| L.S.D.0.05 | 1.67   | 2.05   | 3.48   | 3.29   | 2.84   | 3.04   | 4.38   | 4.14   |

**Means not sharing the same letter(s) within each column, significantly different at 0.05 level of probability**
Table 4. Effect of spraying potassium, calcium, boron and humic acid on some leaf macro elements content of "Anna" apple trees in 2012 and 2013 seasons

| Treatments                          | N (%)      | P (%)      | K (%)      | Ca (%)     |
|-------------------------------------|------------|------------|------------|------------|
|                                     | 2012       | 2013       | 2012       | 2013       | 2012       | 2013       | 2012       | 2013       |
| T1: Control (sprayed with water)    | 1.87e      | 1.90e      | 0.31de     | 0.30cd     | 1.83d      | 1.87e      | 1.31cd     | 1.34de     |
| T2: K at (2%) as potassium sulphate | 1.98bcd    | 2.02bcd    | 0.32cde    | 0.34abc    | 2.01c      | 2.04bcd    | 1.30cd     | 1.34de     |
| T3: Ca at (0.2%) as calcium chloride| 1.89de     | 1.91de     | 0.31de     | 0.32bcd    | 1.82d      | 1.85e      | 1.44ab     | 1.48a      |
| T4: B at (0.2%) as boric acid       | 1.96cde    | 1.98cde    | 0.29e      | 0.28d      | 1.84d      | 1.90e      | 1.28cd     | 1.29de     |
| T5: H.A. (humic acid5%)             | 2.07b      | 2.11ab     | 0.34bcd    | 0.35abc    | 2.04bc     | 2.07bc     | 1.40b      | 1.44ab     |
| T6: K + H.A.                        | 2.04bc     | 2.08bc     | 0.37ab     | 0.38a      | 2.01c      | 2.02cd     | 1.34c      | 1.37bc     |
| T7: Ca + H.A.                       | 2.07b      | 2.10b      | 0.35abc    | 0.36ab     | 2.14ab     | 2.18ab     | 1.30cd     | 1.35cd     |
| T8: B + H.A.                        | 1.91de     | 1.95de     | 0.36ab     | 0.38a      | 1.87d      | 1.90de     | 1.49a      | 1.50a      |
| T9: K + Ca + B                      | 2.05bc     | 2.07bc     | 0.34bcd    | 0.35abc    | 1.86d      | 1.94cd     | 1.28d      | 1.27e      |
| T10: K + Ca + B + H.A.              | 2.20a      | 2.22a      | 0.38a      | 0.37ab     | 2.20a      | 2.25a      | 1.46a      | 1.48a      |

Means not sharing the same letter(s) within each column, significantly different at 0.05 level of probability

Table 5. Effect of spraying potassium, calcium, boron and humic acid on some leaf microelements content of "Anna" apple trees in 2012 and 2013 seasons

| Treatments                          | Fe (ppm)   | Zn (ppm)   | Mn (ppm)   | B (ppm)    |
|-------------------------------------|------------|------------|------------|------------|
|                                     | 2012       | 2013       | 2012       | 2013       | 2012       | 2013       | 2012       | 2013       |
| T1: Control (sprayed with water)    | 119.00d    | 118.00de   | 25.00f     | 26.00g     | 45.00e     | 47.00d     | 68.00e     | 70.00e     |
| T2: K at (2%) as potassium sulphate | 123.00b    | 124.00b    | 30.00de    | 30.00e     | 50.00c     | 52.00b     | 71.00d     | 73.00de    |
| T3: Ca at (0.2%) as calcium chloride| 119.00d    | 117.00e    | 28.00e     | 29.00ef    | 49.00cd    | 49.00bcd   | 68.00e     | 71.00e     |
| T4: B at (0.2%) as boric acid       | 120.00cd   | 119.00cde  | 25.00f     | 27.00fg    | 46.00de    | 48.00cd    | 86.00bc    | 88.00b     |
| T5: H.A. (humic acid5%)             | 126.00a    | 128.00a    | 32.00cd    | 34.00c     | 56.00ab    | 58.00a     | 88.00bc    | 89.00b     |
| T6: K + H.A.                        | 121.00bcd  | 120.00cd   | 31.00d     | 33.00cd    | 48.00cde   | 49.00bcd   | 75.00d     | 78.00c     |
| T7: Ca + H.A.                       | 126.00a    | 130.00a    | 35.00b     | 37.00b     | 55.00b     | 57.00a     | 83.00c     | 89.00b     |
| T8: B + H.A.                        | 120.00cd   | 119.00cde  | 30.00de    | 31.00de    | 51.00c     | 50.00bcd   | 74.00d     | 76.00cd    |
| T9: K + Ca + B                      | 122.00bc   | 121.00c    | 34.00bc    | 38.00b     | 49.00cd    | 51.00bc    | 88.00bc    | 91.00b     |
| T10: K + Ca + B + H.A.              | 128.00a    | 129.00a    | 41.00a     | 44.00a     | 59.00a     | 60.00a     | 93.00a     | 97.00a     |

Means not sharing the same letter(s) within each column, significantly different at 0.05 level of probability

Potassium sulphate, boric acid and calcium chloride + humic acid combination increased significantly anthocyanin concentration in the fruits. Additionally, Potassium sulphate + humic acid or potassium sulphate + calcium chloride + boric acid combination had the same effect, however all of them gave insignificant increase in reducing sugar and total sugar percentages as compared to the control in the two seasons. Humic acid achieved a great increase in reducing sugar percentage, although it gave insignificant enhancement in the total sugar percentage and anthocyanin with comparing to the control in the two seasons. On the other side, calcium chloride or boric acid + humic acid combination did not have any remarkable effect on anthocyanin concentration, total sugar or reducing sugar percentages as compared to the control in the two seasons.

All the treatments did not achieve any significant increases in the total sugar percentages in the fruits in the first season or in non-reducing sugar in both seasons as compared to the control.

4. DISCUSSION

According to our results the foliar application of potassium, calcium, boron and humic acid either alone or in combinations improved vegetative growth, fruit set, leaf mineral, yield, chemical and physical fruit characteristics of ‘Anna’ apple trees.
on "Zebda" mango trees application increased fruit firmness at harvest time [26]. To the foliar application of potassium nitrate and persimmon berries [25]. Solids content and decreased the total acidity of potassium supply increased the total carbohydrate accumulation [24]. High potassium concentration in a plant affects quality of pear and apple trees [23]. Besides, effective in improving, nutritional status, yield and crop production. As macronutrient in plant growth and sustainable [22], who stated that potassium plays a vital role in parallel with the findings of [30], who found that foliar applications of calcium chloride have been reported to delay ripening of strawberries. There are in agreement of [30], who found that foliar applications of calcium chloride increased the acidity of fruits and this explains why it delay the ripening of fruits and these results are in agreement of [28], who mentioned that foliar applications of calcium on "Golden" apple trees uptake by roots decreased rapidly. Additionally, our results are consistent with the findings of [28], who mentioned that foliar application of calcium on "Golden" apple trees was effective in the second half of vegetation period, when the delivery of Ca ions to fruits was effective in the second half of vegetation period, when the delivery of Ca ions to fruits and chemical characteristics as comparing with control treatment [27]. According to our results calcium chloride increased the acidity of fruits and this explains why it delay the ripening of fruits and these results are in agreement of [30], who found that foliar applications of calcium chloride have been reported to delay ripening of strawberries. There

| Treatments                          | Fruit length (cm) | Fruit diameter (cm) | L/ D (ratio) | Fruit firmness (lb/ inch²) |
|------------------------------------|-------------------|---------------------|--------------|---------------------------|
| T1: Control (sprayed with water)   | 5.27g             | 5.36e               | 5.21h        | 5.29f                     | 1.01b | 1.01a | 12.86b | 12.73e |
| T2: K at (2%) as potassium sulphate| 5.47d             | 5.68c               | 5.36d        | 5.58d                     | 1.02ab| 1.02a | 12.81b | 12.57e |
| T3: Ca at (0.2%) as calcium chloride| 5.35ef            | 5.48e               | 5.26fg       | 5.34f                     | 1.02ab| 1.03a | 13.37b | 13.84bc|
| T4: B at (0.2%) as boric acid      | 5.45d             | 5.57d               | 5.31e        | 5.42e                     | 1.03a | 1.03a | 12.83b | 12.69e |
| T5: H.A. (humic acid5%)            | 5.76b             | 5.89b               | 5.63b        | 5.72b                     | 1.02ab| 1.03a | 13.04b | 13.45cd|
| T6: K + H.A.                       | 5.30fg            | 5.38e               | 5.23gh       | 5.29f                     | 1.01b | 1.02a | 13.26b | 13.51cd|
| T7: Ca + H.A.                      | 5.62c             | 5.72e               | 5.54c        | 5.65c                     | 1.01b | 1.01a | 13.09b | 13.14cd|
| T8: B + H.A.                       | 5.37e             | 5.52d               | 5.27f        | 5.47e                     | 1.02ab| 1.01a | 14.64a | 14.37ab|
| T9: K + Ca + B                     | 5.60c             | 5.74c               | 5.54c        | 5.63cd                    | 1.01b | 1.02a | 13.00b | 12.96de|
| T10: K + Ca + B + H.A.             | 5.92a             | 6.03a               | 5.84a        | 5.97a                     | 1.01b | 1.01a | 14.77a | 14.63a |
| L.S.D.0.05                         | 0.05              | 0.07                | 0.03         | 0.05                      | 0.01  | 0.02  | 0.64   | 0.71   |

Means not sharing the same letter(s) within each column, significantly different at 0.05 level of probability

| Treatments                          | TSS (%) | Acidity (%) | TSS/acid ratio |
|------------------------------------|---------|-------------|----------------|
| T1: Control (sprayed with water)   | 12.50b  | 12.60c      | 12.49a         |
| T2: K at (2%) as potassium sulphate| 14.70a  | 14.90a      | 14.39b         |
| T3: Ca at (0.2%) as calcium chloride| 12.60b  | 12.50c      | 12.49a         |
| T4: B at (0.2%) as boric acid      | 14.60a  | 14.80ab     | 14.48bc        |
| T5: H.A. (humic acid5%)            | 15.10a  | 15.40a      | 15.38e         |
| T6: K + H.A.                       | 13.10b  | 13.40bc     | 13.45a         |
| T7: Ca + H.A.                      | 15.20a  | 15.40a      | 15.40a         |
| T8: B + H.A.                       | 12.70b  | 12.90c      | 12.48abc       |
| T9: K + Ca + B                     | 14.80a  | 14.90a      | 14.41d         |
| T10: K + Ca + B + H.A.             | 15.80a  | 15.70a      | 15.38e         |
| L.S.D.0.05                         | 1.26    | 1.48        | 0.04           |

Means not sharing the same letter(s) within each column, significantly different at 0.05 level of probability

These results are in parallel with the findings of [22], who stated that potassium plays a vital role as macronutrient in plant growth and sustainable crop production. Spraying potassium was highly effective in improving, nutritional status, yield and quality of pear and apple trees [23]. Besides, high potassium concentration in a plant affects carbohydrate accumulation [24]. Higher potassium supply increased the total soluble solids content and decreased the total acidity of berries [25]. The increment in "Costata" persimmon fruit weight reached about 36% due to the foliar application of potassium nitrate and increased fruit firmness at harvest time [26]. The application of different potassium fertilizer forms on "Zebda" mango trees had a positive effect on leaf area, mineral content, yield and fruit physical and chemical characteristics as comparing with control treatment [27].
photosynthesis of apple trees. Moreover, humic accumulation of nutrients and enhanced humic acid substances promoted N uptake and obtained results by Our results could be explained in light of those from the control trees trees and the fruits had higher firmness than set and fruit yield of mature "Conference" pear before full bloom or after harvest increased fruit Furthermore, the foliar applications of b fruit set, vegetative growth and yield foliage of apple trees had a higher increase in "Elstar" increased fruit set and yield of the apple cultivar apple trees. [36] Boron was highly effective in improving, the findings of [33], who found that spraying boron was highly effective in improving, nutritional status, yield and quality of pear and apple trees. Boron sprayed after bloom increased fruit set and yield of the apple cultivar "Elastar" [36]. The foliar application of boron to foliage of apple trees had a higher increase in fruit set, vegetative growth and yield [3]. Furthermore, the foliar applications of boron before full bloom or after harvest increased fruit set and fruit yield of mature "Conference" pear trees and the fruits had higher firmness than those from the control trees [37]. Our results could be explained in light of obtained results by [38,39] which showed that humic acid substances promoted N uptake and accumulation of nutrients and enhanced photosynthesis of apple trees. Moreover, humic acid is one of the bio-stimulants which promote plant growth when applied in small quantities [40]. It has many effects due to their increase of cation exchange capacity which affects the retention and availability of nutrients, or due to a hormonal effect, or a combination of both [41]. Humic materials enhanced significantly apple fruit weight, yield and soluble solids content [6] and yield, fruit quality and grower income of peach and apple [7]. Humic acids had been shown to stimulate plant growth and consequently yield by acting on mechanisms involved in: cell respiration, photosynthesis, protein synthesis, water and nutrient uptake and enzyme activities [42]. Humic acid also, enhanced 'Canino' apricot plant growth, nutrient uptake, fruit yield and fruit characteristics and promoted peach, pear and apple to grow better and accumulate higher amounts of NPK and dry matter [10]. The foliar application of humic acid had a positive effect on yield, fruit quality, leaf chlorophyll as well as leaf mineral content of NPK of Florida Prince Peach [43]. Furthermore, it improved vegetative growth, fruit set, yield and fruit quality of 'Canino' apricot meanwhile juice acidity decreased indicating better fruit quality [44].

5. CONCLUSION

The foliar application of potassium sulphate, boric acid and humic acid, singly or in combination, had a positive effect to improve the vegetative growth, fruit set, leaf mineral content, yield and fruit quality of 'Anna' apple trees. Calcium chloride alone had a positive effect to increase calcium content in the leaves. Potassium sulphate + calcium chloride + boric

Table 8. Effect of spraying potassium, calcium, boron and humic acid on some chemical fruit characteristics of "Anna" apple trees in 2012 and 2013 seasons

| Treatments                     | Total sugar (%) | Reducing sugar (%) | Non-reducing sugar (%) | Anthocyanin (mg/100 g) |
|-------------------------------|-----------------|--------------------|------------------------|------------------------|
|                               | 2012            | 2013              | 2012                   | 2013                   | 2012               | 2013               | 2012              | 2013              |
| T1: Control (sprayed with water) | 7.92a           | 7.92b              | 4.67c                  | 4.73cd                 | 3.15a             | 3.19a             | 21.37c            | 22.87d            |
| T2: K at (2%) as potassium sulphate | 8.14a           | 8.21ab             | 4.89bc                 | 4.92bcd                | 3.25a             | 3.29a             | 27.84ab           | 28.17ab           |
| T3: Ca at (0.2%) as calcium chloride | 7.81a           | 7.90b              | 4.66c                  | 4.71d                  | 3.15a             | 3.19a             | 21.40c            | 22.72d            |
| T4: B at (0.2%) as boric acid | 8.05a           | 8.12ab             | 4.86bc                 | 4.90bcd                | 3.19a             | 3.22a             | 26.35b            | 26.57bc           |
| T5: H.A. (humic acid 5%)       | 8.46a           | 8.57ab             | 5.12ab                 | 5.17ab                 | 3.34a             | 3.40a             | 22.76c            | 24.36cd           |
| T6: K + H.A.                  | 7.92a           | 7.96b              | 4.72bc                 | 4.82bcd                | 3.20a             | 3.14a             | 29.47a            | 28.95ab           |
| T7: Ca + H.A.                 | 8.24a           | 8.37ab             | 5.02abc                | 5.11abc                | 3.22a             | 3.26a             | 28.37ab           | 29.34a            |
| T8: B + H.A.                  | 7.92a           | 7.97b              | 4.78bc                 | 4.78cd                 | 3.19a             | 22.35c           | 23.47d            |                  |
| T9: K + Ca + B                | 8.21a           | 8.35ab             | 4.97abc                | 5.01bcd                | 3.24a             | 3.34a             | 27.25ab           | 28.17ab           |
| T10: K + Ca + B + H.A.        | 8.45a           | 8.72a              | 5.36a                  | 5.42a                  | 3.09a             | 3.30a             | 29.46a            | 30.18a            |
| L.S.D.0.05                    | 0.67a           | 0.74               | 0.42                   | 0.38                   | 0.27             | 0.28             | 2.52              | 2.74              |

Notes: Treatment means not sharing the same letter(s) within each column, significantly different at 0.05 level of probability.
acid+ humic acid combination was the best treatment. This combination had the highest positive effect to improve the percentages of yield, fruit set, reducing sugar and TSS. Also, it increased Ca, P, K, N, B, Zn, Mn and Fe content in the leaves in the two seasons, as compared to the control treatment. Moreover, it improved significantly anthocyanin concentration, TSS/acid ratio, shoot diameter, shoot length, leaf area, fruit diameter, fruit length, average fruit weight and fruit firmness. It decreased the percentages of fruit drop and acidity in the two seasons as compared to the control and the other treatments.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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