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Original Research Article

The effect of the foliar application of potassium, calcium, boron and humic acid on vegetative growth, fruit set, leaf mineral content, yield and fruit quality of 'Anna' apple trees.

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 5×5 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 thatpotassium 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 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, this combination significantly improved 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: Foliar application; Humic acid; Yield and fruit quality of 'Anna' apple trees

INTRODUCTION

Anna apple (*Malus domestica* L. Borkh) is a low chilling requirement cultivar (Krisanapook *et al*., 1995) spreading in many tropic and subtropic areas including Egypt. It is considered as one of the most important commercial cultivars planted in Egypt. The adaptation of proper fertilization program is one of the important cultural techniques that greatly promote and enhance the growth and fruit quality. Most pome fruit orchards need some fertilizers to achieve and maintain optimum tree growth and fruit production. Modern pome fruit production calls for greater attention to plant nutrition because of higher density planting, the need for higher fruit production from young plantings, replanting of old orchards due to a shortage of good new land and increase the demand for better quality fruit and never-longer storage times (Bright, 2005). Foliar fertilization has advantages of low application rates, uniform distribution of fertilizer materials, easiest method of application and quick responses to applied nutrients (Khayyat *et al*., 2007).

Boron is an important micronutrient for trees, 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 (Peryea *et al*., 2003). Also, Wojcik and Wojcik (2003) mentioned that 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 and titratable acidity than those from the control trees (Wojcik and Wojcik, 2003).

Asgharzade and Babaeian (2012) studied the foliar application of calcium borate effects on some characters of apple "Sheikh Amir"variety fruits during 2010 and 2011 seasons at Shirvan region. The obtained results showed that among all measured characters high amount

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of fruits 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.

The favorable effect of calcium obtained by Siddiqui and Bangerth (1995) on "Golden Delicious" apples, they suggested that the observed effects of CaCl2 on fruits firmness are likely to be associated with the calcium content of the covalently-bound pectin fractions. Also, Benavides *et al*. (2002) on "Golden Smoothee" apple found that the fruit firmness increased when calcium was applied. Similar results were obtained by Casero *et al.* (2004) on "Golden Smoothee"apple, they indicated that fruit firmness shows a positive correlation with fruit Ca content and bitter pit incidence correlates negatively with this nutrient content ratio.Amiri *et al*. (2008) claimed that calcium plays an important role in providing stability and mechanical strength to the cell structure of the fruit.

Several studies pointed out that spraying some deciduous trees with K and Ca at different concentrations either alone or in combination has been used successfully for decreasing both fruit weight loss and decay percentages. For examble, Robertson *et al*. (1990) mentioned that fruits from trees sprayed with K or/and Ca were firmer and better quality than control during the storage duration.

El-Sherif *et al*. (2008) sprayed "Golden Japanese" plum by four potassium fertilizer sources (potassen, liquid potassium, potassium nitrate and Coda-PK) at bud burst, after fruit set and one month after fruit set. Results revealed that all treatments significantly increased fruit set, yield, fruit weight, fruit size, fruit length, fruit diameter, total sugar and potassium percentages, while they decreased fruit drop percentage in comparison with the control treatment. Moreover, Coda-PK treatment gave the highest yield when compared to other treatments in both seasons followed by liquid potassium, potassium nitrate and potassen in a descending order. In addition, the tested treatments increased total carbohydrates and leaf macro-elements content. Storage studies showed the high ability of fruits for keeping quality at 5°C for about one month without changing in aroma or taste. Abd El-Fatah *et al*. (2008) on "Costata" persimmon found that the increment in fruit weight reached about 36% due to foliar application of potassium nitrate and increased fruit firmness at harvest.

Humic acid is one of the bio-stimulants which are known as the organic materials that promote plant growth and help plants to withstand harsh environments when applied in small quantities (Chen *et al*., 1994). 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 (Chunhua *et al*., 1998). Also, it is highly beneficial for both plant and soil, it maintains proper plant growth and increases nutrient uptake, tolerance to drought and temperature extremes, activity of beneficial soil microorganisms and availability of soil nutrients particularly in alkaline soils and low organic matter (calcareous soil conditions) without excessive use of agricultural chemicals which are considered a menace to the environment (Eissa *et al.,* 2007). Furthermore, humic materials may increase root growth in a similar manner to auxins (Khattab *et al.*, 2012).

The purpose of this study is to investigate the effect of using humic acid and foliar application of potassium, calcium and boron on vegetative growth, fruit set, leaf mineral content, yield and fruit quality of "Anna" apple trees.

Materials and Methods

This experiment was carried out during the two successive seasons, 2012 and 2013on seven years old "Anna" apple trees (*Malus domestica* L.), planted at 5×5 meters apart and grown in a sandy loam soil under drip irrigation system in a private orchard located at El-Nubaria, Beheira governorate, Egypt. Soil analysis was carried out according toCottenie *et al*.

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(1982),data shown in Table(1). Fourty trees were selected as uniformed in vigor as possible. All the trees were subjected to the same cultural practices in the two seasons.

The experiment involved ten foliage spraying treatments as follows:

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 sources of K, Ca, B and H.A. were applied as a foliar spray three times a year, before flowering, 10 days after full bloom and one month later. 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 and Misrol liquid soap (1 ml/ l) was used as a wetting agent.

All trees received the spraying solution, about five liters/ tree till run off.

Complete randomized block design was arranged where each treatment was replicated four times on one-tree/ plots.

The effect of these treatments was studied by their influence on the following parameters:

Vegetative parameters

At the end of growing seasons, the selected shoots were measured for the average of shootlength cm, shoot diameter cm and leaf area cm^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 calculation the percentage of fruit set according to Westwood (1988) equation:

$$\textbf{Fruit set \%} = \frac{\textbf{Number of set fruitlets}}{\textbf{Number of opened flowers}} \times 100$$

Pre-harvest fruit drop was calculation 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.

$$\textbf{Fruit drop \%} = \frac{\textbf{Number of dropped fruitlets}}{\textbf{Number of set fruitlets}} \times 100$$

Yield per tree

Yield was pressed in weight kgand number of fruits per tree was recorded at harvesttime (3rd week ofJune).

Leaf chemical composition

Samples at twenty leaves from the middle part of the shoots (according to Chuntanaparband Cummings,1981) 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(according to Wilde *et al*., 1985). Determinations were carried outon dry weight basis.

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Fruit quality

Fruit sample consisting of twenty fruits were randomly taken at harvest time from each replicate forthe determination of both physical and chemical characteristics.

Fruit Physical characteristics

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

Fruit chemical characteristics

Total soluble solids were determined using a hand refractometer, percentage of titratable acidity infruit juice was determined according to A.O.AC., (1985), total soluble solid / total acidity ratio werecalculated and total sugars, reducing and non-reducing sugar according to Malik and Singh (1980). Anthocyanin was determined at the stage of coloration (mg/100 g fresh weight peel) according to Rabino *et al*. (1977).

Statistical analysis

The obtained data were subjected to the proper analysis of variance (ANOVA) according to Snedecor and Cochran (1980). Least significant difference (LSD) at 0.05% level of significance was used to compare the treatment means.

Results and discussion

Data in table 2, cleary showed that the foliar application of potassium sulphate alone or combined with humic acid, humic acid alone, potassium sulphate + calcium chloride + boric acid combination, potassium sulphate + calcium chloride + boric + humic acid combination, calcium chloride + humic acid combination and the combination between boric acid + humic acid had a positive effect to cause a significant incrementinshoot diameter, shoot length and leaf area. Boric acid had a positive effect to improve 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 treatment.

Results in table 3, showed that the foliar application of potassium sulphate alone and humic acid alone or in combination with each other, had a positive effect to give great increases in the yield, fruit set percentages, average fruit weight and to decrease 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 combination, potassium sulphate + calcium chloride + boric acid combination and potassium sulphate + calcium chloride + boric acid + humic acid combination significantly increased the yield, fruit set percentages, average fruit weight and decreased the percentages of fruit drop. On the opposite side, the combination between potassium sulphate and humic acid gave a slight increase which was not enough to be significant in average fruit weight as compared to the control treatment. Also, the usage of calcium chloride did not have any significant 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 had a positive effect to give 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 had a positive significant effect to increase the percentages of K and N, but it did not have any significant effect on P and Ca percentages. Also, the combination between potassium sulphate and humic acid had a positive effect to improve 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 significant effect on N, P and K percentages in the leaves. The combination between calcium chloride and humic acid had a positive effect

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to improve N, P and K content in the leaves but it did not affect significantly Ca percentages. Boric acid had no significant effect on N, P, K and Ca percentages. The combination between humic and boric acid gave a positive effect to increase significantly P and Ca percentages, but it did not have any significant effect on the percentages of N and K. Humic acid had a positive effect to give a great increase in Ca, K and N percentages. Potassium sulphate + calcium chloride + boric acid combination positively increased N percentage, but it gave a slight increase which was not enough to be significant in Ca, K and P percentages in the leaves as compared to the control treatment in the two seasons.

Listed data in table 5, showed that the spray of humic acid, calcium chloride + humic acid combination, potassium sulphate + calcium chloride + boric acid combination and potassium sulphate + calcium chloride + boric acid + humic acid combination had a positive effect to give a remarkable increase in B, Zn, Mn and Fe content in the leaves as compared to the control treatment in the two seasons. Also, potassium sulphate positively increased Zn, Mn and Fe concentrations but it gave non significant increase in B content in the leaves as compared with the control treatment in the two seasons. Potassium sulphate + humic acid combination had a positive effect to improve Zn and B concentration but it had no significant effect on Fe or Mn concentration in the leaves as compared to the control treatment. Moreover, calcium chloride had a positive effect to improve Zn and Mn concentration but it did not gave any significant effect on Fe or B content in the leaves in both seasons as compared to the control treatment. Boric acid gave no remarkable increase in Fe, Mn and Zncontent in the leaves.On the opposite side, the combination between boric and humic acid had a positive effect to cause a significant incrementinZn, Mn and B concentrations but it gave a slight increase in F concentration in the leaves which was not enough to be significant as compared to the control treatment in the two seasons.

From the results in table 6, it can be cocluded that potassium sulphate + calcium chloride + boric acid + humic acid combination had a positive increament in fruit diameter**,** fruit length and fruit firmness in both seasons as compared to the control treatment. Potassium sulphate, boric acid, humic acid, calcium chloride + humic acid combination and/or potassium sulphate + calcium chloride + boric acid combination had a positive effect to increase fruit length and fruitdiameter, but they did not give a significant increase in fruit frimness in the two seasons as compared to the control tratment. Calcium chloride increased fruit length and fruit diameter only in the first season and fruit frimness in the second season as compared to the control tratment. Potasium sulphate + humic acid and/or boric acid + humic acidcombination gave a slight increase in fruit length or fruit diameter in the two seasons as compared to the control traetment.

From the results in table 7, it can be mentioned that potassium sulphate, humic acid, boric acid, calcium chloride + humic acid combination, potassium sulphate + calcium chloride + boric acid combination, potassium sulphate + calcium chloride + boric acid + humic acid combination, had a positive effect to give a remarkable increase in the percentages of TSS/ acid ratio, TSS and to decrease the percentages of acidity in both study seasons as compared to the control tratment.The spray of potassium sulphate combined with humic acid gave a positive effect to increase TSS/ acid ratio but it had no significant effect on TSS or acidity, as compared to the control treatment. On the opposite side, calcium chloride and /or boric + humic acid combination did not have any significant effect on acidity, TSS, TSS/acid ratio in both seasons as comparing to the control treatment.

Data in table 8, showed that the combination of potassium sulphate + calcium chloride + boric acid + humic acid had a positive effect to give a remarkable increase in reducing sugar percentages and anthocyanin in the two seasons as compared to the control treatment. Potassium sulphate, boric acid, calcium chloride + humic acid, potassium sulphate + humic acid and potassium sulphate + calcium chloride + boric acid combinationshad a positive

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effect to increase anthocyanin conentration as compared to the control treatment, but they did not achieve any significant increase in reducing sugar or total sugar percentages as compared to the control tratment in the two seasons. Humic acid had a positive effect to give a great increase in reducing sugar percentage, but it gave a slight increase which was not enough to be significant in the total sugar percentage and anthocyanin concentration as compared to the control treatmentin the two seasons. On the opposite side, calcium chloride and boric acid + humic acid combination did not have any significant effect on anthocyanin concentration, total sugar and reducing sugar percentages as compared to the control treatment 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 treatment.

These results are in parallel with the findings of Taha *et al*. (2014), who studied the effect of different potassium fertilizer forms on yield, fruit quality and leaf mineral content of "Zebda" mango trees and the results indicated that all different potassium forms application had a positive effect on leaf area, mineral content, yield, fruit physical and chemical characteristics as comparing with control treatment. Also, our discussed results agree with the findings of Martin *et al*. (2004), who stated that higher potassium supply increased the total soluble solids content and decreased the total acidity of berries.

Calcium chloride application increased calcium content in the leaves. This effect was caused by the influence of calcium on calcium uptake, but also, was due to remaining amount of calcium on the leave area as a result of the foliar application.

The increase in apple leaf Ca concentration can be explained by Ca immobility in plant tissues and no redistribution to other plant organs along the vegetative cycle, until the end of the cycle. Leaf Ca concentrations increased faster during the first five weeks after full bloom, passing to slow and continuous increases from this period on, fitting to cubic models for "Gala", "Golden Delicious" and "Fuji" apple cultivars (Nachtigall and Dechen, 2006).

Our findings agree with the findings of Świątkiewicz and Błaszczyk (2009) who mentioned that the foliar spraying with calcium before harvesting significantly increased the Ca concentration in "Elise" apples. Moreover, fruits harvested with Ca (NO3)2 had higher flesh firmness than the control ones. Also, Wojcik *et al.* (2009) stated that calcium folir application had no effect on apple yield, mean fruit weight, concentration of soluble solids and titratable acidity of fruit at harvest time.On the opposite side, our results did not agreed with the findings of Ashour (2000) and Mohsen (1999), who reported that treated "Anna" apple fruit with calcium chloride spray decrease the acidity during storage.

The obtained results are in the same trend with the findings of Wojcik *et al*. (1999), who mentioned that boron sprays after bloom increased fruit set and yield of the apple cultivar "Elstar". Also, Peryea *et al*. (2003) showed that the foliar application of boron to foliage of apple trees had a higher increase in fruit set, vegetative growth and yield. Moreover, these results are in parallel with the findings of Chen *et al*. (2004), who stated that 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, enzyme activities.

Additionally, these results are in the same trend with those of applying humate fertilizers on "Canino"apricot (Shaddad *et al.*, 2005), "Superior seedless" and "Roomy ahmar"grapes (Abbas *et al.*, 2006), "Grand nain" banana (El-Shenawi *et al.,* 2008), "Le-Conte" pear (Kabeel *et al.,* 2008) and "Manfalouty" pomegranate trees (Khattab *et al.*, 2012), since they reported that increasing amount of humic acid markedly increased the yield. Eissa *et al.* (2007) on "Anna" apple, found a gradual increase in shoot diameter, average shoot length and leaf area parallel to the increase of humic acid application. Eyheraguibel *et al*. (2008)

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indicated the beneficial effect of humic substances which may possibly enhance the uptake of some macro, K, Ca and P, and microelements.

It cleared from our experiment results that using foliar application of humic acid improved significantly TSS % synthesis and in parallel decreased acidity % in the fruits. The same results were noticed when humic acid applied on "Canino" apricot when it enhanced TSS and decreased acidity (Fathy *et al.*, 2010). Arvind *et al*. (2012) noticed that the trees sprayed with 0.5% borax showed maximum fruit yield, fruit weight, fruit volume, TSS, reducing sugar, non reducing sugar and ascorbic acid content.

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 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 increasedCa, P, K, N, B, Zn, Mn and Fe content in the leaves in the two seasons, as compared to the control treatment. Moreover, this combination significantly improved 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.

References

Abbas E. S., Bondok S. A., Girgis V. H. 2006. Effect of foliar with some nutrients and humic acid on fruit set, yield and quality of “Roomy Ahmar" grapevines. Journal of Agricultural Science, Mansoura University 30: 6951-6961.

Abd El-Fatah D. M., Mohamed S. A., Ismail O. M. 2008. Effect of biostimulants, ethrel, boron and potassium nutrient on fruit quality of "Costata" persimmon. Australian Journal of Basic and Applied Sciences 2(4): 1432-1437.

Amiri M. E., Fallahi E., Golchin A. 2008. Influence of foliar and ground fertilization on yield, fruit quality and soil, leaf and fruit mineral nutrition in Apple. Journal of Plant Nutrition 31:515-525.

Arvind B., Mishra N. K., Mishra D. S., Singh C. P. 2012. Foliar application of potassium, calcium, zinc and boron enhanced yield, quality and shelf life of mango. Journal HortFlora Research Spectrum 4: 300-305.

Ashour N.N. 2000. Effect of environmental factors, calcium and potassium fertilization on yield and quality of apple. Ph.D. Thesis, Faculty of Agriculture, Mansoura University, Egypt.

Asgharzade A., Babaeian M. 2012. Foliar application of calcium borate and micronutrients effects on some characters of apple fruits in Shirvan region. Annals of Biological Research 3(1): 527-533.

Association of Official Agriculture Chemists, A.O.A.C. 1985. "Official methods of analysis". Benjamin Franklin Station, Washington D.C., U.S.A.: 495-510.

Benavides A., Recasens I., Casero T., Soria Y., Puy J. 2002. Multivariate analysis of quality and mineral parameters on "Golden Smoothee” apples treated before harvest with calcium and stored in controlled atmosphere. Food Science and Technology International 8:139-145.

Bright J. 2005. Apple and pear nutrition. NSW Department of Primary Industries. Primefact 85: 1-12.

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Casero T., Benavide A., Puy J., Recasens I. 2004. Relationships between leaf and fruit nutrients a fruit quality attributes in "Golden Smotthee" apples using multivariate regression techniques. Journal of Plant Nutrition 27: 313 - 324.

Chen Y., Magen H., Riov J. 1994. Humic substances originating from rapidly decomposing organic matter: properties and effects on plant growth. In Senesi N., Miano T. M (Eds): Humic substances in the global environment and implication on human health. Elsevier, Amsterdam, the Netherlands: 427- 443.

Chen Y., De Nobili M., Aviad T. 2004. Stimulatory effects of humic substances on plant growth. 103-129. In: F.R. Magdoff and R.R. Weil (Eds.) Soil Organic Matter in Sustainable Agriculture. CRC Press, New York, U.S.A.

Chunhua L., Cooper R. J., Bowman D. C .1998. Humic acid application affects photosynthesis, root development and nutrient content of creeping bentagrass. Hortscience 33(6):1023-1025.

Chuntanaparb N., Cummings C. 1981. Seasonal trends in concentration of nitrogen, phosphorus potassium, calcium, and magnesium in leaf portions of apple, blueberry, grape, and peach. Journal of the American Society for Horticultural Science 105: 933-935.

Cottenie A., Verloo M., Kickens L., Velgle G., Camerlynuck R. 1982. Chemical analysis of plant and soil: 43-51. Laboratory of Analytical and Agrochemistry, State University of Belgium, Gent.

Eissa F. M., Fathi M. A., El-Shall S. A. 2007. The humic acid and rootstock in enhancing salt tolerance of "Anna" apple seedlings. Journal of Agricultural Science Mansoura University 32: 3667-3682.

El-Shenawi M. R., Aly H. S., Mohamed B. A. F. 2008. Response of "Grandnain" banana to humic acid, potassium and magnesium fertilization. Alexandria Science Exchange Journal 29: 244-251.

El-sherif H. M., Taha N. M., El- Fahkarani F. M. 2008. Effect of potassium fertilizer source on tree fruiting, fruit quality and storability of "Golden Japanese" plum. Journal of Agricultural Science Mansoura University 33(4): 2743-2756.

Eyheraguibel B., Silvestre J., Morard P. 2008. Effects of humic substances derived from organic waste enhancement on the growth and mineral nutrition of maize, Bioresource Technology 99: 4206- 4212.

Fathy M. A., Gabr M. A., El Shall S. A. 2010. Effect of humic acid treatments on "Canino" apricot growth, yield and fruit quality. New York Science Journal 3:109-115.

Kabeel H., Abd Elatif F. M., Baza M. S. M. 2008. Growth, fruiting and nutritional status of "Le-Cont" pear trees in response to mineral and humate fertilizers. Annals of Agricultural Science Moshtohor 46(2): 139-156.

Khattab M. M., Shaban A. E., El-Shrief A. H., Mohamed A. 2012. Effect of humic acid and amino acid on pomegranate trees under deficit irrigation. I: Growth, flowering, and fruiting. Journal of Horticultural Science and Ornamental Plants 4: 253-259.

Khayyat M., Tafazoli E., Eshghi S., Rajaee S. 2007. Effect of nitrogen, boron, potassium and zinc sprays on yield and fruit quality of date palm. American-Eurasian Journal of Agricultural and Environmental Science 2(3): 289-296.

Krisanapook K., Subhadrabandhu S., Ogata R. 1995. Induction of budbreak in apple trees that recived insufficient chilling by hydrogen cyanamide.Kasetsart Journal (Natural Science) 29: 239- 245.

Malik C. P., Singh M. B. 1980. Extraction and estimation of amino acids and keto acids. In: Plant enzymologyand histo-enzymology. (Eds.): CP. Malik, MB. Singh, Kalyani Publishers, New Delhi-Lud Hana, India: 286.

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Martín P., Delgado R., González M. R., Gallegos J. I. 2004. Colour of "Tempranillo" grapes as affected by different nitrogen and potassium fertilization rates. Acta Horticulturae 652: 153-159.

Mohsen A.T.1999. Effect of some treatments on fruit quality and storage of 'Anna' apple. Ph.D. Thesis, Faculty of Agriculture, Cairo University, Egypt.

Nachtigall G.R., Dechen A.R. 2006. Seasonality of nutrients in leaves and fruits of apple trees. Scientia Agricola 63(5).493-501.

Peryea F.J., Neilsen D., Neilsen G. 2003. Boron maintenance sprays for apple: Early-season applications and tank-mixing with calcium chloride. HortScience 38(4): 542-546.

Rabino L., Alberto L., Monrad M. K.1977. Photocontrol of anthocyanin synthesis. Journal of Plant Physiology 59: 569- 573.

Robertson J. A., Meredith F. I., Horvat R. J., Senter S. D. 1990. Effect of cold storage and maturity on the physical and chemical characterstics and volatiale constituents of peach (cv.Cresthaven). Journal of Agricultural and Food Chemistry38(3): 620- 624.

Shaddad G., Khalil A., Fathi M. A. 2005. Improving growth, yield and fruit quality of "Canino" apricot by using bio, mineral and humate fertilizers. Minufiya Journal of Agricultural Research30: 317-328.

Siddiqui S., Bangerth F.1995. Effect of pre-harvest application of calcium on flesh firmness, cell-wall composition and fruit size of apples. Journal of Horticultural Science and Biotechnology 70(2): 263-270.

Snedecor G. W., Cochran W. G. 1980.Statistical methods, 7th edition, Ames, Iowa: Iowa State University Press: 85- 86.

Świątkiewicz D., Błaszczyk J. 2009. Effect of calcium nitrate spraying on mineral contents and storability of 'Elise' apples. Polish Journal of Environmental Studies 18(5): 971-976.

Taha R. A., Hassan H. S. A., Shaaban E. A. 2014. Effect of different potassium fertilizer forms on yield, fruit quality and leaf mineral content of "Zebda" mango trees. Middle-East Journal of Scientific Research 21 (1): 123-129.

Westwood N. M. 1988. Temperate-Zone Pomology. Timber Press. 9999 S.W. Wilshire Portland, Oregon 97225: 181.

Wilde S. A., Corey R. B., Lyer J. G., Voigt G. K. 1985. Soils and plant analysis for tree culture. 3rd Ed. Oxford, IBH, New Delhi: 1- 218.

Wojcik P., Cieslinski G. Mika A. 1999. Apple yield and fruit quality as influenced by boron applications. Journal of Plant Nutrition 22: 1365-1377.

Wójcik P., Gubbuk H., Akgül H., Gunes E., Ucgun K., Koçal H., Küçükyumuk C. 2009. Effect ofautumn calcium spray at a high rate on "Granny Smith" apple quality and storability. Journal of Plant Nutrition 33(1): 46-56.

Wojcik P., Wojcik M. 2003. Effects of boron fertilization on "Conference" pear tree vigor, nutrition and fruit yield and storability. Plant and Soil 256: 413-421.

Wojcik P., Gubbuk H., Akgl H., Gunes E., Ucgun K., Koal H., Kkyumuk C. 2010. Effect of autumn calcium spray at a high rate on "Granny Smith" apple quality and storability. Journal of Plant Nutrition 33(1): 46-56.

Table 1 Physical and chemical properties of the experiment soil

Depth (cm)	Texture	pH	Total $CaCO_3$ (mg/L)	EC.(dS/m)	O.M. (%)	Cations (meq/ 100 g soil)				DTPA-extractable (mg/ kg)		
						Na^{++}	K^{+}	Ca^{++}	Mg^{++}	Fe	Mn	Zn
0 - 40	Sandy loam	8.50	30.46	1.37	0.54	2.01	0.07	3.28	2.27	0.39	0.50	0.31

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

Treatments	Shoot length (cm)		Shoot diameter (cm)		Leaf area (cm^2)	
	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	27.18bcd	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	43.52b	0.81bc	0.82b	29.24ab	30.46ab
T6:K + H.A	37.28d	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**

Table 3 Effect of spraying potassium, calcium, boron and humic acid on fruit set, fruitdrop, yieldand 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
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	70.25cde	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	22.57b	66.31f	64.73ef	50.76b	51.36bc	137.56c	142.17d
T10: K + Ca + B + H.A.	24.56a	24.87a	60.27g	61.63f	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

Table 4 Effect of spraying potassium, calcium, boron and humic acid on some leaf macroelements contentof "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	1.34cde
T2: K at (2%) as potassium sulphate	1.98bcd	2.02bcd	0.32cde	0.34abc	2.01c	2.04bcd	1.30cd	1.34cde
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	1.90de	1.28d	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	1.94cde	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
L.S.D.$_{0.05}$	0.10	0.11	0.03	0.05	0.12	0.14	0.05	0.07

Table (5) Effect of spraying potassium, calcium, boron and humic acid on some leaf microelements contentof "Anna" apple trees in2012 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	71.00de	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	88.00b	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	88.00b	91.00b
T10: K + Ca + B + H.A.	128.00a	129.00a	41.00a	44.00a	59.00a	60.00a	93.00a	97.00a
L.S.D.$_{0.05}$	2.18	2.36	2.02	2.05	3.46	3.67	4.61	4.67

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Table 6 Effect of spraying potassium, calcium, boron and humic acid on fruit length, diameter, the ratio between them and fruitfirmness of "Anna" apple trees in 2012 and 2013 seasons

Treatments	Fruit length (cm)		Fruit diameter (cm)		L/ D (ratio)		Fruit firmness (Ib/ inch^2)	
	2012	2013	2012	2013	2012	2013	2012	2013
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	5.72c	5.54c	5.65c	1.01b	1.01a	13.08b	13.14cde
T8: B + H.A.	5.37e	5.52de	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

Table 7 Effect of spraying potassium, calcium, boron and humic acid on total soluble solids, acidity and the ratio between them of "Anna" apple trees in 2012 and 2013 seasons

Treatments	TSS (%)		Acidity (%)		TSS/ acid ratio	
	2012	2013	2012	2013	2012	2013
T1: Control (sprayed with water)	12.50b	12.60c	0.48a	0.49ab	26.04d	25.71f
T2: K at (2%) as potassium sulphate	14.70a	14.90a	0.39b	0.43bcd	37.69b	34.65d
T3:Ca at (0.2%) as calcium chloride	12.60b	12.50c	0.49a	0.50a	25.71d	25.00f
T4: B at (0.2%) as boric acid	14.60a	14.80ab	0.40b	0.42cde	36.50b	35.24d
T5:H.A. (humic acid5%)	15.10a	15.40a	0.37b	0.38e	40.81a	40.53ab
T6:K + H.A	13.10b	13.40bc	0.45a	0.46abcd	29.11c	29.13e
T7: Ca + H.A.	15.20a	15.40a	0.37b	0.40de	41.08a	38.50bc
T8: B + H.A.	12.70b	12.90c	0.47a	0.48abc	27.02cd	26.88ef
T9: K + Ca + B	14.80a	14.90a	0.39b	0.41de	37.95b	36.34cd
T10: K + Ca + B + H.A.	15.80a	15.70a	0.37b	0.38e	42.70a	41.32a
L.S.D.$_{0.05}$	1.26	1.48	0.04	0.06	2.18	2.27

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)	7.82a	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%)	8.36a	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	4.70bc	4.78cd	3.22a	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

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