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.

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 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 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

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. 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). Asgharzade and Babaeian (2012) studied the foliar application of calcium borate 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 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. El-Sherif *et al*. (2008) sprayed "Golden Japanese" plum by four potassium fertilizer sources 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. In addition, the tested treatments increased total carbohydrates and leaf macro-elements content. Humic acid significantly enhanced apple fruit weight, yield and soluble solids content (Li*et al*. 1999), yield, fruit quality and grower income of apple (Fathi *et al*. 2002). Applying humic fertilizers also, on "Canino" apricot (Shaddad *et al.*, 2005) and "Le-Conte" pear (Kabeel *et al.*, 2008) increased markedly the yield of these fruits.Eissa *et al*. (2007) noticed 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.

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.

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. 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*. (1982).

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 (1ml/l) as a wetting agentin 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.

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 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 calculating the percentage of fruit set according to

Westwood (1988) 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.

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

Yield per tree

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

Leaf chemical composition

Samples of twenty leaves from the middle part of the shoots (according to Chuntanaparb and 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.

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*. 1985). The digested solution was used for the determination of each of nitrogen (N) using microKjeldhal method, phosphorus (P) by vanadomolybdo method and potassium (K) was determined by flame photometer according to the methoddescribed by Chapman and Parker (1961). 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 inleaf samples was determined by dry ashing as reported earlier by Chapman and Pratt (1961), and subsequent measurement of B was done through colorimetry Azomethine-H as outlined by Bingham (1982).

Fruit quality

Twenty fruits were randomly taken at harvest time from each replicate for the 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 in fruit juice was determined according to A.O.AC., (1985), total soluble solid / total acidity ratio were calculated.

Total sugars, reducing and non-reducing sugars were estimated 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

Data in table 2, clearly showed that shoot diameter, shoot length and leaf area were increased significantly over the control by the 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 insignificant 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 increased fruit length and fruitdiameter but, they did not give a significant increase in fruit firmness in the two seasons as 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. Potasium 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 fruits as 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. 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.

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. These results are in parallel with the findings of Baligar *et al.* (2001), who stated that potassium plays a vital role as macronutrient in plant growth and sustainable crop production. Gobara (2001) also, mentioned that spraying potassium was highly effective in improving, nutritional status, yield and quality of pear and apple trees. Besides, high potassium concentration in a plant affects carbohydrate accumulation (Starck, 2003).Moreover, Martin *et al*. (2004), stated that higher potassium supply increased the total soluble solids content and decreased the total acidity of berries. Abd El-Fatah *et al*. (2008) on "Costata" persimmon found that the increment in fruit weight reached about 36% due to the foliar application of potassium nitrate and increased fruit firmness at harvest time.Taha *et al*. (2014) studied also, the effect of different potassium fertilizer forms on yield, fruit quality and leaf mineral content of "Zebda" mango trees. They stated that all different potassium forms application had a positive effect on leaf area, mineral content and yield, fruit physical and chemical characteristics as comparing with control treatment.

Additionally, our results are consistent with the findings of Casero *et al*. (2002), 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 uptake by roots decreased rapidly. Benavides *et al*. (2002), also, found that calcium application on "Golden Smoothee" apple increased the fruit firmness. 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 Wójcik and Lewandowski, (2003), who found that foliar applications of calcium chloride have been reported to delay ripening of strawberries. There is a positive correlation between the fruit firmness of "Golden Smoothee" apple and fruit Ca content (Casero *et al.*, 2004). Nachtigall and Dechen (2006) stated that the increase in leaf Ca

concentration of "Gala", "Golden Delicious" and "Fuji" apple cultivars 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. Świątkiewicz and Błaszczyk (2009) mentioned that the foliar spraying with calcium before harvesting significantly increased the Ca concentration in "Elise" apples. Moreover, fruits harvested with Ca $(NO_3)_2$ had a higher flesh firmness than the control ones. Moreover, foliar application of Calcium chloride improved the yield and quality of strawberry plants (Kazemi, 2013).

The obtained results are in the same trend with the findings of Hanson (1991), who found that spraying boron was highly effective in improving, nutritional status, yield and quality of pear and apple trees. Wojcik *et al*. (1999) also, mentioned that boron sprayed after bloom increased fruit set and yield of the apple cultivar "Elstar". The foliar application of boron to foliage of apple trees had a higher increase in fruit set, vegetative growth and yield (Peryea *et al*., 2003). 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 (Wojcik and Wojcik, 2003).

Our results could be explained in light of obtained results by Tatini *et al*. (1991) and Jianguo *et al*. (1998) 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 (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). Humic materials significantly enhanced apple fruit weight, yield and soluble solids content (Li, *et al*. 1999) increased yield, fruit quality and grower income of peach and apple (Fathi *et al*. 2002). Chen *et al*. (2004) 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 and enzyme activities. 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 (Eissa *et al*., 2007). Abd El-Razek *et al*. (2012) found that 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. Fathy *et al*. (2010) found also, that foliar application of humic acid improved vegetative growth, fruit set, yield and fruit quality of 'Canino' apricot meanwhile juice acidity decreased indicating better fruit quality.

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, it 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.

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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

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 (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**

Means not sharing the same letter(s) with in 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
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	61.83f	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

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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	1.34cde
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

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Table 5.Effect of spraying potassium, calcium, boron and humic acid on some leaf microelements Content of "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 fruit firmness 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

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

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	0.43bcde	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

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

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%)	8.46a	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	4.70bc	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

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