Response of Anna apples yield, quality and storage potential to boron and/or zinc foliar sprays

Kassem, H.A.*, H.A. Marzouk and A..M. El-Kobbia

Pomology Department, Faculty of Agriculture, Alexandria University, Alexandria Egypt.

*Corresponding author: hkassem60@yahoo.com

Abstract

A field study was carried out on Anna apple trees growing in calcareous loamy sandy soil. Trees were sprayed with 300 mg/L B borax (17.5% B) and 1.5 g/L zinc chelate (12 % Zn) either alone or in combinations at three foliar spraying dates; after harvest (AH), before flowering (BF) or at full bloom (FB). Zinc and boron sprays especially the combined reduced the percentage of non-opened flower buds and increased fruit set, yield and fruit quality at harvest. The FB spray was the most effective on decreasing blossom end breakdown as compared with the AH or BF spray at harvest or after storage. In the mean time, trees showed higher fruit setting and retention when sprayed at AH or BF than at FB. However, higher yield, and fruit quality at harvest and after cold storage were obtained at FB followed by BF and AH spraying dates. Zn and/or B sprays decreased the percentages of fruit weight loss, firmness loss and fruit end breakdown, and increased fruit storage life.

Keywords:

Sprays; Productivity; Flower buds; Storage; Breakdown.

Introduction

In many developing countries such as Egypt apple cultivation as a productive part of the horticulture economy is growing and tending to have a special place in horticultural programs. According to FAO (2014) the apple production in Egypt reached 541,239 tonns from a total area of 21,145 hectare, cultivated mainly with Anna apple wich is a summer maturing variety. One of the main problems that apple growers in Egypt face is the low percentage of open buds during the flowering period, which accordingly affects the final frut yield and quality. In the meantime, under the Egyptian conditions, Anna apples face another problem as its maturity and ripening occur during a hot summer which causes several types of fruit breakdown at and/or after harvest such as blossom end breakdown (Mosa et al. 2015). Such problems shorten the fruit shelf and storage life and marketing, causing a decrease in the economical outcome of this variety.

Boron and zinc poses very essential roles in apple tree growth and productivety. Boron is known to play an important role for the structure of cell wall, membranes and the integrity and functions of membranes in plants (Brown et al. 2002). Low leaf boron and zinc levels have been found to restrict the proportion of flowers pollination and fruits setting and decrease yield (Roygrong 2009). Increases in pollen germination rate (Esmé de Wet et al., 1989), fruit yield (Hanson 1991) and fruit quality (Svagzys 1995) have occurred in response to foliar B applications. This suggests that there is a specific requirements for B in the reproductive process of fruit trees. In addition, zinc is an essential trace element for the growth and development of plants, being involved in many enzymatic reactions. It is a cofactor for RNA-polmerase (Faust 1989) thus it is critical for protein synthesis and is involved in regulating the protein as well as carbohydrate metabolism (Swietlik 2002). Zinc is also involved in the formation of tryptophan, a precursor to IAA **(**Marschner 1995) which can be a limiting factor in vascular tissue differentiation. Trees suffer from zinc and boron deficiency when grown in calcareous soil, wich may cuases a delay in the opening of floral buds and a decreae of its number leading to less fruit prodcution with low quality (Roygrong 2009). Fruit trees grown in calcareous soils suffer from boron and zinc deficiency mainly because the reduction of their availability as they form insoluble complex with the calcium carbonate (Swietlik 2002). Zinc solubility in calcareous soils is reported to be decreased up to 100 fold per unit increase in pH (Swietlik 2002). Thus, because of the rapid conversion of zinc and boron to an unavailable form soil, soil application of such elements is not always effective and foliar spray is considered to be a fast and target oriented tool to cure deficiencies. Foliar absorption from liquid solutions may take place via the cuticle, cuticular cracks and imperfections, through stomata, trichomes or specialised epidermal cells (Fernández and Eichert 2009). Boron foliar sprays seem to be an optimal solution to cure their shortage in apple trees (Wojcik et al. 2008). Foliar application of boron and zinc to Fuji apple trees grown under calcareous soil was recommended by Mohammadkhany et al. (2013) in order to compensate the lack of these elements in the trees and to improve fruit set, yield, and fruit quality.

Moreoevr, zinc and boron were mentioned to be sprayed separately or together to the trees immediately after harvest or as fall spray + dormant spray (Westwood 1995). Maksoud and Haggag (1996**)** found that an apple fruit yield the following year was increased when B was applied between harvest and leaf fall. Never the less, Wojcik et al. (2008) indicated that after full bloom boron sprays increased fruit set and yield of apple trees. Additioally, an increase in fruit boron content and the fruit storagability of apples by summer sprays was repported by Zude et al. (1998). In the mean time, Stover et al. (1999) found that pre-bloom Zn foliar sprays increased cropping of apple trees.

In accordance to the previously discussed, the present study was undertaken to evaluate the effect of spraying Anna apples with B and/or Zn and the date of sprays on flower buds oppening, blossom end breakdown, fruit set, fruit retention, yield, and fruit quality at harvest and after cold storage.

Materials and methods

Plant material, treatments and experimental design

The present study was conducted on mature Anna apple trees (*Malus domestica*, Borkh) on Malus rootstock during the two successive seasons; 2013/2014 and 2014/2015 at a private orchard located in Abu El- Matameer region in Behera governorate, Egypt. The soil was calcareous loamy sandy with pH ranging between 7.84-7.97, $CaCO_3$ of 33% and 120-140 cm water level from the ground surface. Trees were planted at 3.0 ×3.5 m apart and irrigated with Nile water every 10-12 days.

Thirty-six Anna apple trees were selected as uniform as possible and subjected to the same cultural practices usually done in the orchard. Trees were fertilized in December, 2013 and 2014 with organic manure and calcium superphosphate (16 % P_2O_2) at a rate of 30.0 and 1.5 kg per tree, respectively. Also, 700 g of actual nitrogen from ammonium sulphate (21 % N) and 1.0 kg K_2O from potassium sulphate (48% K_2O) per tree were added in three equal doses at the beginning of February, April and May of both seasons.

Apple trees were sprayed with water only (control), 300 mg/l B in the form borax (17.5% B) and 1.5 g/l Chelate zinc (12 % Zn) either alone or in combinations at three foliar spraying dates; after harvest (AH) in mid-November of 2013 and 2014 seasons, before flowering (BF) in first February of 2014 and 2015 or at full bloom (FB) in first March of 2014 and 2015 seasons. The experiment was designed as a randomized complete block design (RCBD) with twelve spraying treatments and 3 replicate/each treatment and one tree/replicate (i.e. 3 spraying dates × 4 chemical sprays × 3 replicate = 36 trees). The surfactant Nourfilm (Alam Chemica, Egypt) was added at the rate of 40 cm^3/100 L water to all sprayed chemicals for better penetration. The chemicals were applied in the early morning directly to tree canopy with a handheld sprayer until runoff.

Growth components and fruit set and retention

Five one-year-old shoots/tree was marked in February of both seasons and tree growth was expressed as average shoot length (cm) and as leaf area (cm^2) in June. Also, the percentage of non-opened flower buds was calculated in March. Further, three individual limbs from different parts of each tree were marked in mid-February to calculate fruit set and fruit retention percent in May.

Fruit yield and weight

Fruits were harvested when they reached the red ripe stage (more than 75 - 80% of the fruit surface, in the aggregate shows red according to Kader (2002). Commercially acceptable fruits were harvested in any date and fruits weight (kg/tree) at each harvest date was recorded to estimate the total fruit yield. Also, fruit weight (g) was measured at each harvest date to estimate the total average fruit weight.

It was also estimate the the percentage of fruit blossom end breakdown at each harvest date to calculate the percentage of the unmarketable fruits.

Fruit sampling

A sample of fifty-five fruit similar in size with no physical injuries or disease infection per each replicate was harvested at the same day and transported to the Department of Pomology Research laboratory for investigations. Fifteen fruit from this sample was taken to investigate the effect of the different spraying treatments on fruit physico-chemical characteristics at harvest date.

Storage conditions

Additionally, the remaining forty fruit was surface disinfectant with 2% sodium hypo chloride for 3 min, then rinsed with water, air-dried placed in foam trays wrapped with PVC film and stored at 0°C ± 1 and 85-90% R.H. for 50 days to investigate fruits firmness, weight loss, fruit blossom end breakdown, the unmarketable fruits and storage life during 50 days of cold storage.

Fruit physical characteristics

Fruit firmness was measured at harvest time and after cold storage using a hand penetrometer (Fruit Pressure Tester, Make: Effegi, Model: PT 327) and the pressure required to penetrate the fruit was recorded in kg/cm^2. In addition, the number of fruits showing blossom end breakdown on each replicate was recorded at harvest time and after cold storage and the percentage of fruit blossom end breakdown was calculated.

Fruits chemical characteristics

At harvest date, fruit soluble solids content (SSC %) was determined by hand refractometer (Atago Co., Tokyo, Japan). Homogenous sample was prepared by blending the fruits in blender and direct reading was taken as described in AOAC (2000). Fruit acidity percent expressed as malic acid was determined by titrating 5-ml of juice with 0.1N sodium hydroxide, using phenolphthalein as an indicator**.** In fruit peel, anthocyanin content (mg/100g fresh weight) was measured by Photoelectric Colorimeter at 535 nm, according to the method of Fuleki and Francis (1968).

Fruit storage potential

Storage life was recorded as the number of days from the beginning of cold storage until reaching a percentage of unmarketable fruits of 20-25%, but the rest of the fruits are still acceptable for marketing. Fruit weight loss was recorded and its percentage was calculated.

Leaf mineral and chlorophyll content

For leaf mineral and chlorophyll determinations, a sample of 20 leaves from each tree was collected in July of 2014 and 2015 years from the middle part of the outer shoots. Leaves were washed with tap water, rinsed twice in distilled water and were cut into small pieces, then an amount of the fresh sample was dried to a constant weight (g) in air drying oven at 70°C. The dried leaves were grounded and digested with H_2O_2 and H_2SO_4 according to Evanhuis and DeWaard (1980). Suitable aliquots were taken for the determination of the mineral content. Fe, Zn and B contents were measured using a Model 305 atomic absorption spectrophotometer (Perkin-Elmer Corp., Norwalk, CT 06586). The concentrations were expressed ppm on dry weight basis. Also, Carotene and total chlorophyll contents were determined colorimetrically by the method of Moran (1982), as 80% acetone extract was assayed at 650 nm for total chlorophyll by using Spectrophotometer.

Statistical analysis

The data at harvest time or after cold storage were tested for the effect of the different treatments on analysed parameters by the two-way analysis of variance technique as a combined analysis by the general linear model (GLM) and analysis of variance (ANOVA) technique. Means over the two years were separated and compared using the L.S.D at 0.05 level of significance according to Snedecor and Cochran (1989). The statistical analysis was performed using Statistical Analysis System (SAS 1988).

Results

Shoot length and leaf area

Regardless of spray date, data in Table (1) showed that, spraying Zn and B either alone or in combination increased shoot length and leaf area as compared with the control trees.The best treatment was Zn + B followed by zinc alone and then boron alone.

As for the main effect of the spray dates, the full bloom (FB) spraying dates reulted in higher shoot length and leaf area than spraying after harvest (AH) and befor flowerin (BF). However, AH and BF sprays did not significantly differ in their effect on shoot length (Table 1).

The percentage of non-opened buds

The percentage of non-opened buds was significantly decreased by spraying Zn or B alone or in combination as compared with the water sprayed control. The best treatment was spraying Zn+B followed by zinc and then B.

Additionally, AH spary indicated lower percentage of non-opened buds than the BF and FB spraying dates, with no significant difference obtained between the BF and FB sprays (Table 1).

Leaf Zn, B, Fe and chlorophyll content

In accordance to the sprayed chemicals, spraying Zn either alone or combined with B significantly increased leaf Zn content when comparing with spraying B alone or water (control). Leaf zinc content did not differ significantly when spraying Zn alone or Zn combined with B. In the mean time, foliar sprays of B either alone or combined with Zn increased leaf B as compred with spraying Zn lone or water spraying. However, leaf Fe content was not affected by any of the Zn and B sprays (Table 1). The leaf total chlorophyll content increased with all spraying treatments as compared with the water sprayed control trees, with the highest increase obtained by Zn +B, followed by B alone and then Zn alone.

With regard to the sparying date, results of Table (1) showed that (FB) spray was the best spraying date followed by (MB) and then (AH) for leaf Zn, B and total chlorophyll content.

Fruit set and retention percent

Fruit set and fruit retention increased with spraying Zn and B either alone or in combinations. The highest value of fruit set and retention percent obtianed by sparying Zn+B followed by Zn and B only with no significant differences between the latest both. Additionally, as for the main effect of spraying date, the results obtained showed that, AH and BF sprays were the most effective in comparison with FB spray for fruit set with no significant differences between them (Table 2). As well as for fruit retention the AH spray was the best treatments followed by BF and then FB.

Fruit weight and yield

Spraying Zn and B either alone or in combination significantly increased fruit weight and yield with the highest values of fruit weight and yield obtained with spraying Zn+B followed by Zn and B only, with no significant differences between the latest.

Regarding the main effect of spraying date, the FB spray resulted in the most positive influence on fruit weight and yield followed by BF and then AH sprays (Table 2).

Fruit firmness and blossom end breakdown at harvest time

Spraying Zn and/or B either alone or in combination reulted in an increase in fruit firmness compared with the control fruits. The highest firmness occured with Zn+B followed by B alone and then Zn alone. In the mean time, the percentage of blossm end breakdown significantly decreased with spraying Zn and/or B either alone or in combination, with the lowest breakdown value obtained with Zn+ B treatment followed by Zn and then B spray.

Regarding the spary dates, it was obvious that the FB spray was the most effective on increasing fruit firmness and decreasing blossm end breakdown as compared with the AH or BF spray (Table 2).

Fruit chemical characteristics

Fruit SSC, anthocyanin and reducing, non-reducing and total sugars at harvest time were increased by spraying Zn and/or B either alone or in combination, with the highest values obtained with sparying Zn+ B followed by B alone and then Zn alone. Never the less, no significant difference occured between the treatments Zn + B and B lone in their influence on fruit non-reducing sugars content. In the mean time, spraying Zn and/or B either alone or in combination decreased fruit acidity with no significant differences obtaine among the spraying treatments.

As for the main effect of spraying date, the obtained results showed that spraying at fruit set (FB) indicated higher SSC, anthocyanin and reducing and total sugras content than the AH and BF sprays on. However, no significant differences occured between the three spraying dates in their effect on fruit acidity and between BF and FB sprays in their effect on fruit non-reducing sugars content (Table 3).

Fruit storage potential

Fruit weight and firmness loss decreased with Zn and/or B spraying as compared with the water sparyed control fruits. Less firmness loss was obtained by the treatment Zn+B, followed by B alone and Zn alone with no significant differences between the latest. Whereas, no significant differences among the treatments Zn+B, B alone and Zn alone in their influence on fruit weight loss. In addition, all spraying treatments decreased the fruit blossom end breakdown, with the lowest value of breakdown observed with Zn+B treatment followed by Zn alone and then B alone. In the mean time, fruit storage life increased with all spraying treatments, with the highest sotarge period obtained by sparying Zn+B followed by Zn alone and then B alone (Table 4).

With regard to the sparying dates, the obtained results indicated that the FB spray was the most effective on decreasing the percentage of fruit breakdown and increasing storage life as compared with the AH or BF sprays (Table 4).

Discussion

The above results indicated positive influences of zinc and boron foliar sprays on the different measured parameters especially spraying at fruit set (FB). These findings go in line with previously conducted investigations (Asgharzade and Babaeian 2012) working on Anna apple. Also, Mosa et al (2015) recorded similar improvement in vegetative growth, fruit set, leaf mineral content, yield and fruit quality of' Anna apple trees by boron application.

The positive influence might be refered to the good absorption and uptake of both minerals through the apple leaves. Picchioni et al (1995) stated that foliar uptake of B by the apple leaves was 88-96% complete within 24 hours of application and more than 50 % of the B retained on leaf surface was absorbed within 6 hours of treatment.

In addition, results of the present study showed a decrease in the number of unopened flower buds by the sparying treaments. These findings are in harmony with Hanson et al (1985) who reported that **b**oron accumulates in flower buds and flower parts and that its levels are higher in floral than in vegetative tissues, suggesting a specific involvement of B in the reproductive process. Also, Delgado et al (1994) suggested that B is mobilized from young leaves during anthesis to supply the requirements of flowers and young fruit. In the mean time, Spinardi and Bassi (2012) highlighted the beneficial effect of boron treatments immediately prior to anthesis, by affecting positively the fertilisation process and subsequent plant source-sink relations linked to fruitlet retention.

Furthermore, boron is known to play an important role for the structure of cell wall membranes and its integrity and function in plants **(**Brown et al 2002). Its role in activating both cell division and elongation in the meristematic tissues as well as the biosynthesis of organic assymelates could explain its positive action on increasing leaf area (Ahmed and Morsy 2001). It is also known to stimulate carbohydrate, RNA and hormonal metabolism, as well as the rapid mobilization of water and sugars in the fruit tissues (Kato et al 2009).

Never the less, zinc is an important micronutrient associated especially with several enzymatic activities and growth regulators biosynthesis in all photosynthetic plants (Ved et al 2002). It is considered a functional, structural or regulatory factor of a large number of enzymes (Bowler et al 1994). It has been identified as component of almost 60 enzymes and it has a role in synthesis of growth promoting hormone (auxin), which would be directly associated with inducing pollen tube growth (Chaplin and Westwood 1980), delaying the formation of abscission layer during early stages of fruit development and thus enhancing fruit set and retention (Yadav et al 2013).

The previous roles of boron and zinc might accredit their enhancement of the Anna apple fruit physiochemical properties and tree yield in the present study as previously mentioned in several fruit species (Gaya 2008).

In commercial plant production, providing a sufficient B and Zn supply is particularly important for stress tolerance and fruit storability (Wojcik et al 2008). Low B results in short storage life with the fruit having a higher susceptibly to storage breakdown and fruit deformities, whereas, high B results in a higher incidence of internal disorders such as water core and internal breakdown (Asgharzade et al 2012). Results of the present study revealed that zinc and boron sprays improved fruit storagability. Previous findings on boron and zinc effects on decreasing fruit weight loss and decay during cold storage are reported (Bhatt et al 2012). Slowing down firmness loss and decreasing fruit breakdown might be related to the increase of fruit Ca content after boron sprays (Wojcik et al 2008). Also, boron is reported to be located in the cell wall and associated with pectin (Moraes et al 2002) thus influencing firmness.

Never the less, the application timing is a very important factor influencing tree response to boron and zinc application. Zinc and boron were mentioned to be sprayed separately or together to dormant trees immediately after harvest or as fall spray + dormant spray (Westwood 1995). Delgado et al (1994) found that applying B at anthesis time increased the leaf and fruit B concentrations. Boron sprays after full bloom increased apple fruit set and yield (Wojcik et al 2008). Also, Peryea et al (2003) found that foliar applications of boron before full bloom or after harvest increased fruit set and fruit yield of apple trees. In the mean time, Stover et al (1999) reported that the pre-bloom Zn foliar sprays increased apple trees yield. Hanson (1991) working on cherries and Nyomora et al (2000) working on almonds stated that tree crops responded well to foliar boron sprays at pre-bloom, bloom and/or fall.

The previous discussion is in harmony with the application dates stated in the present study: after harvest (AH), at before flowering (BF) and at full bloom (FB) with the best results concerning fruit set and retention when trees were sprayed after harvest (AH) or at before flowering (BF), and best fruit physicochemical characters and storagability obtained when trees were sprayed at (FB) or at (BF) followed by after harvest (AH).

Conclusion

From the obtained results it may be concluded that Anna apple trees which received any preharvest application of Zn and/or B indicated a low non-opened buds percentage with high yield and fruit quality and developed less fruit blossom end breakdown, weight and firmness loss and had longer storage life than the untreated ones. Thus, foliar application of Zn and/or B prior to and/or at flowering or at full bloom would be recommended for increasing yield and fruit marketability of Anna apples putting in considerations the growing conditions as the responses are related to species, cultivar, and tree nutrient status.

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Tables:

Table (1): Main effect of boron and/or zinc foliar application and spraying dates on growth components, non-opened buds, leaf mineral and total chlorophyll content of Anna apple trees.

Main effect	Shoot length (cm)	Leaf area (cm^2)	Non-opened buds (%)	Zn (ppm)	B (ppm)	Fe (ppm)	Total chlorophyll (mg/l)
Water	34.2^d	36.8^d	38.9^a	20^b	14^b	120^a	157^d
Zn	48.9^b	49.3^b	11.1^c	37^a	14^b	128^a	176^c
B	44.7^c	46.6^c	18.2^b	22^b	30^a	128^a	182^b
Zn + B	58.2^a	55.9^a	8.3^d	39^a	32^a	123^a	193^a
L.S.D. 0.05	3.8	2.3	3.6	3.2	2.2	NS	6.0
AH	43.4^b	45.1^c	14.9^b	27^b	20^c	122^a	169^c
BF	45.3^b	47.1^b	19.1^a	29^b	24^b	126^a	176^b
FB	50.8^a	49.3^a	23.4^a	33^a	26^a	127^a	185^a
L.S.D 0.05	3.2	1.9	3.0	2.6	1.7	7.4	5.0

Means followed by similar letters in each column are not significantly different at 5% level of probability.

Table (2): Main effect of boron and/or zinc foliar application and spraying dates on fruit set, fruit retention, weight, yield, firmness and blossom end breakdown at harvest time of Anna apple trees.

Main effect	Set (%)	Retention (%)	Weight (g)	Yield (kg/tree)	Firmness (kg/cm^2)	Blossom end breakdown (%)
Water	20^c	59^c	123^c	35^c	9.0^d	27^a
Zn	29^b	76^b	132^b	42^b	10.1^c	14^c
B	31^b	78^b	135^b	41^b	11.0^b	21^b
Zn + B	34^a	81^a	146^a	54^a	11.9^a	8^d
L.S.D. 0.05	2.4	2.7	4.3	4.6	0.89	3.1
AH	30^a	78^a	130^c	39^c	9.9^b	22^a
BF	29^a	74^b	134^b	43^b	10.8^a	17^b
FB	27^b	70^c	138^a	47^a	11.0^a	14^c
L.S.D 0.05	2.0	2.3	3.5	3.8	0.67	2.7

Means followed by similar letters in each column are not significantly different at 5% level of probability.

Table (3): Main effect of boron and/or zinc foliar application and spraying dates on fruit chemical characteristics at harvest time of Anna apple.

Main effect	Acidity (%)	SSC (%)	Anthocyanin (mg/100g)	Reducing sugars (%)	Non-reducing sugars (%)	Total sugars (%)
Water	1.17^a	10.8^d	7.6^d	7.38^d	2.02^c	9.40^d

Zn	0.94[b]	11.9[c]	9.0[c]	7.85[c]	2.37[b]	10.22[c]
B	0.94[b]	12.3[b]	10.3[b]	8.55[b]	2.87[a]	11.42[b]
Zn + B	0.90[b]	13.1[a]	13.4[a]	9.12[a]	3.12[a]	12.24[a]
L.S.D. 0.05	0.15	0.32	1.10	0.44	0.31	0.73
AH	1.00[a]	11.5[c]	8.8[c]	7.89[b]	2.33[b]	10.22[c]
BF	0.99[a]	12.1[b]	9.9[b]	8.23[b]	2.58[ab]	10.81[b]
FB	0.97[a]	12.5[a]	11.5[a]	8.68[a]	2.75[a]	11.43[a]
L.S.D 0.05	NS	0.27	0.92	0.37	0.26	0.58

Means followed by similar letters in each column are not significantly different at 5% level of probability.

Table (4): Main effect of boron and/or zinc foliar application and spraying dates on storage potential of Anna apple.

Main effect	Firmness loss (%)	Weight loss (%)	Blossom end breakdown (%)	Storage life (day)
Water	45.9[a]	5.74[a]	40.0[a]	26[d]
Zinc	36.7[b]	4.68[bc]	23.3[c]	38[b]
Boron	35.9[b]	4.54[b]	30.0[b]	35[c]
Zn + B	30.2[c]	4.18[c]	15.0[d]	41[a]
L.S.D. 0.05	5.1	0.54	6.3	3.0
AH	44.7[a]	5.87[a]	30.8[a]	31[c]
BF	33.2[b]	4.96[b]	27.5[ab]	35[b]

FB	33.1[b]	3.53[c]	22.9[b]	39[a]
L.S.D 0.05	4.3	0.43	5.2	2.4

Means followed by similar letters in each column are not significantly different at the 5% level of probability.