Effects Of Cobalt Sulfate And Choline Chloride On Fruiting And Fruit Quality Of Mango Cv. Succary Abiad.

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ABSTRACT: The effects of foliar application of Cobalt Sulfate (Co SO4) and Choline Chloride on fruit retention; yield and quality of "Succary Abiad" mangoes were studied in two successive seasons (2007 and 2008). Cobalt Sulfate was sprayed at concentrations of 100, 200 and 300 ppm 30 days after full bloom, while Choline Chloride was sprayed at concentrations of 1000, 1500 and 2000 ppm on the same time. In general, foliar application of Cobalt Sulfate and Choline Chloride were significantly reduced fruitlets abscission, while the minimum value was recorded in Choline Chloride at 2000 ppm followed by Choline Chloride at 1500 ppm with no significant differences. All treatments increased the number of harvested fruits per tree in both seasons. Low concentrations of both Cobalt Sulfate and Choline Chloride were more effective on physical characteristics. It was increased fruit weight, volume and pulp weight. Fruit firmness was increased by spraying Cobalt Sulfate at 300 or Choline Chloride at 1500 ppm. The application of Cobalt Sulfate and Choline Chloride significantly increased SSC, SSC/TA ratio and total sugars while, ascorbic acid was decreased with almost treatments, except the treatments of Cobalt Sulfate at 200 ppm or Choline Chloride at 2000 ppm in the second season only.

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Key words: Mango, Cobalt Sulfate, Choline Chloride, fruiting, fruit quality.

1. Introduction

Mango (*Mangifera indica* L) is considered the king of fruits in many countries (Purseglove, 1972). In Egypt, mango cultivated area reached 184204 fed. (Ministry of Agriculture, 2007). More than 40% of this areas exists in Ismailia Governorate, which the main cultivar planted is "Succary Abiad". Mango yield worldwide are generally poor, ranging from 4 to 9 t/ha in the major production countries (Oosthuyse, 1993). This is attributable to wide tree spacing malformation, alternate bearing, environmental factors and fruit drop (Guzman-Estard, 1997 and Jana and Sharangi, 1998).

In spite of adequate flowering, low fruit yield in mango orchards have been experienced because of low initial fruit set and subsequently higher fruitlet abscission (Singh and Singh, 1995). Fruitlet abscission is a very complex physiological process, occurs in many cultivars of mango and at all stages of development, but it is particularly high during the first 3-4 weeks after pollination and accounts for over 90 % loss of set fruitlets (Chadha, 1993; Bains, *et al*., 1997; Guzman-Estrad, 1997 and Wahdan and Melouk, 2004).

Several factors affect on fruitlet abscission and some of the reasons suggested are the lack of pollination and failure of fertilization, ovule abortion, and embryo degeneration, hormone content, climatic factors (day length, temperature and wind), inadequate soil moisture and low photosynthetic level (Whiley, *et al*., 1986; Chadha, 1993 and Bains, *et al*., 1997).

Singh and Janes (2000) indicate the involvement of ethylene in mango fruitlet abscission. However, Malik and Singh (2003) have reported acceleration of fruitlet abscission in mango with exogenous application of ethephon. A reduction in fruit abscission with spray ethylene inhibitors such as Silver, Nickel or Cobalt (Naqvi, *et al*., 1990), 1-methylcyclopropene (1-MCP) (Kays and Paull, 2004) and cobalt sulfate (Singh and Agrez, 2002) confirmed the involvement of ethylene in mango fruit abscission.

With limited photosynthesis, the level of metabolites supply being translocated to the fruits will be less and since competition for the previously mentioned will be greater fruit abscission would increase (Kozlowski, 1992). However, Cull (1991) mentioned that, promoted photosynthetic capacity of the tree would be increase the supply of carbohydrate, with a high percentage of the photosynthetic accumulated.

The photosynthetic rate increased with Choline Chloride treatment on Manila grass (Takeuchi, *et al*., 1990) and on Fig trees (Teragishi, *et al*., 2000).

Foliar application of CS have been resulted in increasing fruit set and retention, fruit yield, weight, size and TSS: acid ratio and total sugars in many mango cultivars (Singh and Singh, 1993 and Singh and Agrez, 2002). Moreover, in fruit apples and peaches Choline Chloride produced oblong fruits with high SSC and low flesh firmness (Benincore, *et al*., 2000 and Kim, *et al*., 2004) as well as increased fruit weight in fig (Teragishi, *et al*,. 2000). Therefore, this study was undertaken to evaluate the effect of Cobalt Sulfate or Choline Chloride on mango, especially of the variables that determine the fruiting and fruit quality.

2. Materials and Methods

This investigation was carried out during 2007-2008 on 25-year-old Succary Abiad mango trees (*Mangifera indica* L) grafted on seedling mango rootstock, planted at 7×7 m apart, grown in sandy soil in a private orchard at Abou-Sweer region, Ismailia Governorate, Egypt. Twenty-one trees were chosen with normal growth vigor, healthy and received the same cultural practices. Selected trees were sprayed once by levels of Cobalt Sulfate (CS) (0, 100, 200 and 300 ppm) and Choline Chloride (CC) (0, 1000, 1500 and 2000 ppm) after 30 days from full bloom. The surfactant, triton B 0.1 %, was mixed individually with the different treatments and control trees were sprayed with water and surfactant. The treatments were arranged in complete randomized block design with a single tree as treatment unit and three replicates.

The following parameters were studied:

2.1. Fruitlet abscission:

In each tree, ten panicles from all directions were randomly tagged, (1st May and 28th April in both seasons, respectively) prior to treatment, by wrapping adhesive plastic around the shoots, 5 cm below the panicle. Initial fruit set was considered to have occurred when all the flowers were dried, but were still intact on the panicle. Total number of fruitlets on tagged panicle was counted biweekly interval.

Fruitlet abscission percentage (Q) was measured in terms of the fruit left on the panicle at the given time according to the formula of Vyvyan (1964).

$$Q= [(In\ X_1- In\ X_2) / (t_1- t_2) \times 100]$$

Where, In is base 10 log, X_1 is the number of fruitlets at t_1 and X_2 is the number of fruitlets at t_2, t_1 and t_2 being the different times between which the fruitlet abscission was noted.

2.2. Tree yield:

Fruits were picked when reached commercial maturity first week of July and numbers of fruits per tree were recorded. Total yield (kg) per tree was estimated by multiplying number of fruits per tree by average fruit weight.

2.3. Fruit quality:

Ten unblemished fruits were handily picked from each treated tree at early mature stage (fruit quite hard and shoulders well rounded) to study the average of fruit weight (g), skin firmness (kg/cm^2) by using Effegi Pentometer, fruit length (cm), width (cm), fruit shape index (length/width), fruit thickness (cm), pulp/fruit ratio (net ratio), soluble solids content (SSC %) by hand refractometer, fruit acidity, vitamin C, total, reducing and non-reducing sugars, and total phenols were determined as described by A.O. A. C. (1995).

4- Statistical analysis:

Data were subjected to the analysis of variance and a complete block design was used (Steel and Torrie, 1980). Analysis of variance and mean comparison (LSD, at 5%) were done by **M-**Stat program version 7 (1990).

3. Results:

3.1. Fruitlets abscission:

Fruitlets abscission were measured as the fruit retention on panicale (Table 1). Regardless treatments, data indicated that, the highest fruitlets abscission were found after 30 days from zero time in both seasons. In general, foliar application of CS and CC were significantly reduced fruitlet abscission at all the given treatments as compared with control, except at 30 or 45 days from zero time in the first and second seasons, respectively. The minimum fruitlet abscission was recorded in CC at 2000 ppm followed by CC at 1500 ppm with no significant differences at all the given time in both seasons. There was no statistically significant differences between the concentrations of CS and control. So, it was less effective than CC the total fruitlet abscission as the fruit retention was significantly affected by spraying CS and CC only in the first season, where CC at 2000 ppm gave the least fruitlet abscission.

3.2. Tree yield:

As for Cobalt Sulfate and Choline Chloride effect on total estimated mango tree yield as fruit number and weight per tree were behaved in a similar manner where it was significantly increased by all treatments in both seasons when compared with control. Except low concentration of Cobalt Sulfate (100 ppm), where it was not significantly increased in fruit number and weight per tree (141 and 126.5) compared with control (132 and 118.5 fruits/tree) in both seasons, respectively. While the highest values (238 and 214 fruits/tree) were obtained with Choline Chloride at 2000 ppm in two seasons.

3.3. Fruit quality:

3.3.a. Fruit physical characteristics:

Data in Table (2) showed the variances in fruit characteristics throughout the two seasons of study. Fruit weight was significantly increased by almost treatments than that of control in the first season. However, in the second one, the highest value of fruit weight (233.70 g) was obtained with Cobalt Sulfate at 100 ppm compared to the lowest value (201.60 g) which obtained with Choline Chloride at 1500 ppm and other treatments came in between.

Fruit volume was increased by foliar application of CS or CC in both seasons when compared with control. These increases were more evident in the first season than the second one. Concerning concentrations, it could be seen that, maximum fruit volume was obtained by CC at 1000 ppm or CS at 100 ppm in the first season and by CS at 200 ppm in the second one.

Values of different dimensions of the whole fruit are shown in Table (2). Fruit length, width and thickness were significantly increased when CS or CC sprayed at different concentrations after 30 days from full bloom. However, in the first season, CC at 1000 ppm gave the longest fruits, while the longest widthest fruits and thickness were produced by CC at 200 ppm. In the second season, the maximum fruit dimensions was obtained by CC at 1500 ppm. Fruit shape index was not significantly affected by tested treatments in the first season, but in the second one, the treatment of CS at 300 ppm was only significantly increased fruit shape index (1.44) compared to the lowest value (1.31) which was obtained by CC either at 1500 or 2000 ppm.

Fruit firmness was not significantly affected by CS or CC in the first season. Although, there was an increment in fruit firmness when applied CS at 300 or CC at 1500 ppm. This was confirmed in the second season where the fruit firmness was significantly increased, which evidence in CS at 300 ppm or in CC at 2000 ppm.

Results on the distribution of components of whole fruit such as peel, pulp and stone are shown in Table (2). In general, CS or CC at all concentrations significantly increased the peel weight of Succary Abiad mango, except CC at 2000 ppm in the first season and CC at 1500 or 2000 ppm in the second one where they gave lower peel weight than control with no significances.

Stone weight of mango fruits was significantly affected by the applications of CS and CC. The fluctuated trend was detected in both seasons. The highest values (46.28 g and 60.75 g) were obtained with treatments of CS at 200 ppm or CC at 1000 ppm, while the lowest values (38.58 and 41.13 g) were obtained by treatments of CS at 300 ppm or CC at 1500 ppm and the other treatments came in between in both seasons.

In the first season, pulp weight was significantly increased by all the treatments where CC at 1000 ppm gave the highest values (295.0 g) when compared with control. In the second season, the all treatments failed to attain significant effects on pulp weight. Nevertheless, it could be observed that, CS at 100 ppm or CC at 1000 ppm gave higher pulp weight than control, while the other treatments slightly decreased pulp weight compared to control.

In the first season, the all concentration of CS or CC were significantly increased the net ratio, while the maximum net ratio was produced by CC at 1500 ppm followed by CC at 2000 or CS at 300 ppm in descending order. On the other hand, the net ratio behaved inverse trend in the second season, where CS at 200 ppm gave the lowest net ratio with significant difference when compared to control. This reduction may be due to decrease pulp weight in the second season.

3.3.b. Fruit chemical properties:

Data concerning fruit chemical properties as affected by CS and CC are presented in Table (3). Soluble solid contents (SSC) were significantly affected by the tested treatments. SSC was significantly increased as the concentrations of CS or CC increased (Table 3) in both seasons, except CC in the second season inverted the trend which SSC decreased with increasing the concentration of CC. Moreover, the highest SSC was obtained by CC at 2000 ppm and by CS at 200 ppm in the first and second seasons, respectively. As regard of fruit acidity, there was not significant variance among treatments, because it fluctuated within a narrow range. The lowest acidity (0.64 %) was obtained by CC at 2000 ppm, while it gave an adverse trend in the second season.

SSC/ acid ratio was significantly increased at almost treatments in the second season only. These increases may be due to the reduction in titratable acidity as shown in Table (3).

In the first season, vitamin C (Ascorbic acid) was fluctuated between equal to or lower than control, where the lowest ascorbic acid was obtained by CC at 1500 or 2000 ppm. While the other treatments were almost equal to control. In the second season, CS at 200 ppm or CC at 2000 ppm gave significant higher ascorbic acid than control, while the other treatments were fluctuated.

As regards of total sugars, data tabulated in the same table showed that, all application of CS and CC increased total sugars in both seasons, except the treatments of CC at 2000 ppm in the second season only which gave the lowest value of total sugars. Reducing sugars were significantly affected by various treatments in the first season only, but in the second one, no significant variances were obtained. The highest values (5.5 and 5.9 %) were obtained with treatment of CS at 200 ppm in both seasons, respectively. Concerning of non-reducing sugars, in both seasons significant increases were obtained with various treatments compared with control, except the treatment of CS at 200 ppm in the first season only.

The treatments of CS at 100 ppm and 200 ppm gave highest values (9.37 and 10.40 %) of non-reducing sugars compared with (7.61 and 6.25 %) control in both seasons, respectively.

In the first season, total phenols tended to decreased insignificantly at all treatments, except the treatment of CS at 200 ppm which gave the highest value (0.156) as compared with other treatments. But in the second season, the data of total phenols, by contraries tended to increase insignificantly at all treatments, except the treatment of CC at 1500 ppm which gave the lowest value (0.054) as compared with other treatments.

Table (1): Effect of Cobalt Sulfate (CS) and Choline Chloride (CC) on Fruitlets abscission and yield of "Succary Abiad" mango in 2007 and 2008 seasons.

Treatments	Number of initial fruit set at treatments	Fruitlets abscission as the fruit retention per panicle after			Total fruit retention (%)	Tree yield	
		15 days from treatment (%)	30 days from treatment (%)	45 days from treatment (%)		Number	Weight (kg)
	Season 2007						
Control	13.15	8.33 b	2.17 a	2.30 a	12.79 ab	132.00 e	37.25 d
C. S. at 100 ppm	11.10	10.42 ab	1.65 a	1.02 ab	13.08 ab	141.00 de	48.06 cd
C. S. at 200 ppm	5.60	6.93 b	1.48 a	0.19 b	8.59 b	170.50 cd	57.89 bc
C. S. at 300 ppm	8.35	9.38 ab	1.40 a	0.25 b	11.03 b	179.50 c	57.41 bc
C. C. at 1000 ppm	9.05	8.04 b	0.57 a	1.89 ab	10.50 b	198.50 bc	74.07 a
C. C. at 1500 ppm	10.80	9.95 ab	1.44 a	1.11 ab	12.49 ab	217.50 ab	73.36 ab
C. C. at 2000 ppm	17.60	12.93 a	2.16 a	1.85 ab	16.93 a	238.00 a	77.98 a
	Season 2008						
Control	5.50	3.97 b	4.13 ab	1.62 a	9.71 a	118.50 e	25.75 d
C. S. at 100 ppm	5.80	7.78 ab	2.31 b	0.80 a	10.88 a	126.50 de	29.47 cd
C. S. at 200 ppm	6.15	5.64 ab	3.40 ab	1.25 a	10.28 a	153.00 cd	34.83 bc
C. S. at 300 ppm	9.75	8.04 ab	4.08 ab	1.10 a	13.22 a	161.00 c	33.85 bcd
C. C. at 1000 ppm	7.90	8.68 a	2.26 b	1.45 a	12.37 a	178.50 bc	40.73 ab
C. C. at 1500 ppm	7.55	9.39 a	3.67 ab	0.00 a	13.05 a	195.50 ab	39.41 ab
C. C. at 2000 ppm	5.55	8.53 a	5.79 a	0.52 a	14.83 a	214.00 a	44.92 a

Means followed by the same letter are not significantly different at 5% level

Table (2): Effect of Cobalt Sulfate (CS) and Choline Chloride (CC) on physical characteristics of "Succary Abiad" mango fruits in 2007 and 2008 seasons.

Treatments	Fruit							Peel weight (g)	Stone weight (g)	Pulp Weight (g)	Net ratio (%)
	Weight (g)	Volume (cm^3)	Length (cm)	Width (cm)	Shape index	Thickness (cm)	Firmness (kg/cm^2)				
	Season 2007										
Control	282.2 c	281.5 b	10.1 d	7.5 e	1.35 a	7.15 d	1.31 a	21.55 d	44.25 ab	216.4 b	76.68 b
C. S. at 100 ppm	337.2 ab	340.0 a	10.85 ab	7.65 de	1.37 a	7.65 bc	1.44 a	28.30 bc	45.43 a	263.5 a	78.00 ab
C. S. at 200 ppm	339.6 ab	334.0 ab	10.8 b	8.35 a	1.37 a	8.05 a	1.63 a	29.43 ab	42.5 abc	267.2 a	78.60 ab
C. S. at 300 ppm	319.8 bc	314.0 ab	10.65 bc	7.85 cd	1.38 a	7.6 bc	1.84 a	26.10 c	39.45 bc	254.3 ab	79.50 a
C. C. at 1000 ppm	373.0 a	365.0 a	11.2 a	8.15 ab	1.38 a	7.85 ab	1.74 a	31.75 a	46.28 a	295.0 a	79.10 ab
C. C. at 1500 ppm	337.2 ab	335.0 ab	10.4 cd	8.05 bc	1.35 a	7.65 bc	1.84 a	26.83 bc	38.58 c	271.8 a	80.60 a
C. C. at 2000 ppm	327.8 b	325.0 ab	10.5 bc	7.85 cd	1.36 a	7.5 c	1.72 a	21.15 d	45.18 a	261.5 a	79.70 a
	Season 2008										
Control	217.2 ab	202.0 a	10.2 cd	7.65 c	1.36 b	7.0 c	0.99 c	29.05 b	43.45 b	144.7 a	66.57 a
C. S. at 100 ppm	233.7 a	211.0 a	11.75 b	8.4 b	1.36 b	8.2 b	1.02 bc	31.43 ab	49.58 ab	152.7 a	65.33 a
C. S. at 200 ppm	227.6 ab	218.0 a	11.7 b	8.75 b	1.34 b	8.25 b	1.16 a	35.85 a	60.75 a	131.0 a	57.56 b
C. S. at 300 ppm	209.4 ab	207.0 a	10 d	7.35 c	1.44 a	6.75 d	1.17 a	29.60 ab	47.10 b	132.7 a	63.41 ab
C. C. at 1000 ppm	228.1 ab	21.0 a	10.15 cd	7.55 c	1.36 b	7.2 c	1.13 ab	32.38 ab	46.28 b	149.5 a	65.61 a
C. C. at 1500 ppm	201.6 b	202.0 a	12.55 a	9.75 a	1.31 c	9.55 a	1.12 ab	28.40 b	41.13 b	132.1 a	65.52 a
C. C. at 2000 ppm	209.7 ab	211.0 a	10.3 c	7.75 c	1.31 c	7.3 c	1.21 a	28.15 b	44.00 b	137.5 a	65.80 a

Means followed by the same letter are not significantly different at 5% level

Table (3): Effect of Cobalt Sulfate (CS) and Choline Chloride (CC) on chemical properties mango fruits in 2007 and 2008 seasons.

Treatments	SSC (%)	T A (%)	SSC/TA ratio	V C (mg/100g)	Total Sugars (%)	Reducing Sugars (%)	Non-Reducing Sugars (%)	Total Phenols (%)
	Season 2007							
Control	14.70 c	0.73 a	20.18 a	36.80 a	12.40 d	4.80 ab	7.61 ab	0.12 ab
C. S. at 100 ppm	15.80 abc	0.66 a	24.28 a	33.60 abc	13.60 abc	4.25 ab	9.37 a	0.11 ab
C. S. at 200 ppm	15.20 bc	0.87 a	17.65 a	36.80 a	13.00 bcd	5.50 a	7.50 b	0.16 a
C. S. at 300 ppm	16.10 ab	0.88 a	18.69 a	36.40 ab	13.70 ab	4.65 ab	9.09 ab	0.09 b
C. C. at 1000 ppm	15.00 bc	0.94 a	16.17 a	36.80 a	12.80 cd	4.20 ab	8.66 ab	0.07 b
C. C. at 1500 ppm	15.65 abc	0.84 a	20.01 a	30.80 c	12.45 d	3.65 b	8.85 ab	0.08 b
C. C. at 2000 ppm	16.60 a	0.64 a	27.09 a	32.80 bc	14.20 a	5.05 ab	9.05 ab	0.10 b
	Season 2008							
Control	13.50 d	0.47 bc	28.95 bc	28.80 b	11.55 d	5.30 a	6.25 c	0.08 ab
C. S. at 100 ppm	14.25 cd	0.52 b	27.13 c	28.80 b	12.05 cd	5.70 a	6.35 c	0.08 ab
C. S. at 200 ppm	18.35 a	0.49 bc	37.94 a	30.80 a	16.30 a	5.90 a	10.40 a	0.09 a
C. S. at 300 ppm	16.70 abc	0.42 c	40.20 a	25.60 d	14.55 ab	5.10 a	9.45 a	0.10 a
C. C. at 1000 ppm	17.85 ab	0.49 bc	36.27 ab	27.60 bc	15.00 ab	4.30 a	10.70 a	0.10 a
C. C. at 1500 ppm	16.60 abc	0.41 c	40.79 a	26.00 cd	14.05 bc	5.20 a	8.90 ab	0.05 b
C. C. at 2000 ppm	15.50 bcd	0.66 a	23.74 c	30.80 a	11.50 d	5.05 a	6.50 bc	0.08 ab

Means followed by the same letter are not significantly different at 5% level

4. Discussion:

Concerning fruitlets abscission, Singh and Agrez, (2002) on mango trees found that, exogenous spray application of Co SO_4 to fully-grown panicles before anthesis was the most effective inhibitor of ethylene biosynthesis to improve initial and final fruit set. The substantial increase in initial and final fruit set of mango with the exogenous application of inhibitor of ethylene biosynthesis may be attributed to the inhibition of biosynthesis of endogenous ethylene. Cobalt ions (Co^{+2}) have also been shown to inhibit the ethylene biosynthesis pathway, by blocking the conversion of 1-Amino-Cyclopropan-1-Carboxilic acid (ACC) to ethylene (Yang and Hoffman, 1984).

Regarding yield, similar results were mentioned by Teragishi, *et al*., (2000) they reported that the total fruit weight were increased when Fig trees sprayed with Choline Chloride at 1500 ppm. Also, Singh and Singh (1993) found that, the single foliar spray of cobalt sulfate prior to flower bud differentiation in the first week of October was more effective in increasing fruit yield in all years. A single exogenous spray applications of Co SO_4 (200 mg/L) on mango trees onto fully-grown panicles before anthesis improve yield. The increased fruit yield may be attributed to the increase in fruit retention with this treatment (Singh and Agrez, 2002).

Concerning fruit quality, In this respect, Singh and Singh (1993) found that, foliar application of CS improved fruit weight and size of mango. Recently, Kim *et al*., (2004) pointed out that, lower levels of CC (600 and 1000 ppm) increased fruit weight, size, diameter and firmness of peach fruits.

Regarding the results of the effect of CC on chemical properties it is in harmony with those Benincore *et al*., (2002) on apple and Teragishi *et al*., (2000) on fig all of them found that application of CC increased SSC in fruit. On the other hand, Kim *et al*., (2004) reported that, foliar application of CC on "Mibeek" peaches decreased SSC while increased (TA). Concerning the effect of Co SO_4, Singh and Singh (1993) found that, the foliar application of Co SO_4 improved TSS/acid ratio and total sugars in the fruits of "Dusheri" mango.

5. Conclusion

In general, foliar application of Cobalt Sulfate and Choline Chloride were significantly reduced fruitlets abscission, while the minimum value was recorded in Choline Chloride at 2000 ppm followed by Choline

Chloride at 1500 ppm with no significant differences. All treatments increased the number of harvested fruits per tree in both seasons. Low concentrations of both Cobalt Sulfate and Choline Chloride were more effective on physical characteristics. It was increased fruit weight, volume and pulp weight. Fruit firmness was increased by spraying Cobalt Sulfate at 300 or Choline Chloride at 1500 ppm. The application of Cobalt Sulfate and Choline Chloride significantly increased SSC, SSC/TA ratio and total sugars while, ascorbic acid was decreased with almost treatments, except the treatments of Cobalt Sulfate at 200 ppm or Choline Chloride at 2000 ppm.

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