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Influence of Spraying with Gibberellic Acid on Behaviour of Anna Apple Trees

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Abstract: This investigation was conducted during two successive seasons 2003/2004 and 2004/2005 on seven years old Anna apple trees budded on (MM. 106) rootstock and irrigated via drip system. Trees were sprayed with 250 ppm of gibberellic acid (GA_3) once at early May (6 weeks after full bloom) or twice at the previous date and at late July (l6 weeks after full bloom). The results indicated that gibberellic acid (GA_3) treatments significantly increased the vegetative growth parameters i.e., number of new growing shoot tips, shoot diameter, number of leaves developed on current shoots, total area of leaves developed on new current shoots per tree and leaf dry weight compared with the untreated trees. Although, the earlier application of GA_3 delayed bud break, gibberellic acid treatment at both times of application increased the percentage of lateral bud break of the next spring compared with the control trees. Gibberellic acid treatments had no effect on the flowering density at the next spring of the applications. However, the percentages of both fruiting spurs and fruiting lateral developed on one year old shoots of the next spring after the treatments were reduced. In general, the percentages of both initial and final fruit set at the next spring of GA_3 applications were significantly reduced for both spur bud inflorescences and mixed floral lateral buds developed on one year old shoots. Carbohydrates reserves of woody spurs were reduced for earlier application of GA_3.

Key words: Anna apple, Gibberellic acid, vegetative growth, bud break, fruit set, flowering density

INTRODUCTION

Productivity of apple trees grown in newly reclaimed area may caused a reduction in vegetative growth, which characterizes many of apple orchards. Heavy fruiting of Anna apple cultivar aggravated the problem. Management system including cultural practices affects bud break, flowering and vegetative growth are necessary to improve production system. Earlier treatments with GA_3 in the period of vegetative activity reduction, increased vegetative growth during both the treatment year and the following year[31].

Applied gibberellins inhibit apple flowering[21]. The effect of nine gibberellins (GA_1 to GA_9) on fruit set in apple was studied. A single spray of either GA_3 or GA_{4+7} at full bloom reduced the severity of biennial bearing cycle of "Braeburn" apples, measured as the proportion of flowering spurs over the two years following treatment. However, GA_3 increased rate of shoot elongation and photosynthetic capacity of Noordthiana and Treasure cultivars of Hardy Azaleas[3]. Treatments with GA_3 in July on olive induced greater photosynthetic activity. This effect does not seem to be attributed to the increased shoot growth and therefore, to the consequent increased demand for assimilates, since treatment with GA_3 in August and October increased photosynthesis but not growth[31]. The present study was undertaken to investigate the influence of gibberellic acid GA_3 application on performance of Anna apple trees, particularly vegetative growth, flowering and fruiting.

MATERIALS AND METHODS

This study was carried out during two successive seasons 2003/2004 & 2004/2005 on seven years old of Anna apple trees budded on Malling Merton (MM. 106) rootstock and located in El-Nobaria district. Trees were spaced at 3x3 meters apart. Irrigation water was supplied via a drip system. The experiment was conducted to investigate the response of vegetative growth, flowering and fruiting of Anna apple trees to gibberellic acid (GA_3) applications. So, trees were divided into three groups:

First: Untreated trees, sprayed with water only.

Second: Sprayed once in early May, (6 weeks after full bloom) with 250 ppm of Gibberellic acid (GA_3).

Third: Sprayed twice in early May, (6 weeks after full bloom) then after harvesting (16 weeks after full bloom) with 250 ppm of Gibberellic acid (GA_3).

The sprays were applied to run-off with hand sprayer. The experiment was repeated in both seasons over the same fruiting trees. Shoot growth was estimated at the

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Table l: Chilling hours and growing degree days accumulated in the field through 2003/2004 & 2004/2005 seasons.

Chilling hours from Nov. till March				Growing degree days from February till mid April	
2003/2004		2004/2005		2003/2004	2004/2005
≤ 7.2 C°	≤ 10 C°	≤ 7.2 C°	≤ 10 C°		
729	860	140	620	80	660

same season of application. In the following spring flowering and fruit set data were recorded for both the spur bud inflorescences and the mixed floral lateral buds developed on one year old shoots. Samples of woody spurs were collected at the end of the second season from treated and control trees for carbohydrates analysis[10]. Each treatment was replicated three times on one tree/ plot and the randomized complete block design was arranged. Analysis of variance was done according to Snedecor and Cochran[33]. Least significant differences were used to compare between means of treatments according to Walter and Duncan[39] at probability 5%. The following determinations were recorded:

1- Vegetative growth: Shoots of each tree under investigation were randomly selected and labeled. The increment in shoot length was monthly estimated till growth cessation. New shoots and leaves which developed on these shoots were also measured. Percentages of vegetative spurs and lateral buds on one year old shoots were estimated. In addition, leaf area was determined in sample of 20 mature leaves by using leaf area meter (model ICI-203, USA). Dry weight of leaves was also calculated. Specific leaf dry weight (mg/cm^2) was calculated according to the following equation:

$$\text{Specific leaf dry weight} = \frac{\text{Leaf dry weight (gm)} \times 1000}{\text{Leaf area (cm}^2\text{)}} = mg/cm^2$$ [40].

At the end of the growing season the total number of current shoots, total length of new shoots, total number of leaves and total area of leaves developed on new current shoots were also estimated.

2- Bud Break: In both seasons, percentage of mixed floral lateral bud burst on one year old shoots was investigated in the following spring of treatments every two weeks through the period between (1/3 - 15/4). Percentage of bud break at each date for various treatments was recorded. Buds which reached the stage of "silver tip" of bud burst were considered at bud break stage. Percentage of the total number of examined buds of different treatments was estimated. Bud break date was recorded when 50% of the examined buds reached "silver tip" stage[28]. Accumulated chilling hours to which the buds were subjected in the field were computed in the two seasons in the area of study for both hour's ≤ 10 C° according to Gilreath and Buchanan[15] and accumulated chilling hours ≤ 7.2C° according to Chandler, *et al*[8]. Growing degree days, from the expected date of bud break to the date of full bloom was determined as follows:

GDD = [(Max. + Min)/2)-BT][27].

Where
Max. = Maximum Daily Temperature, Min. = Minimum Daily Temperature and BT. = Base Temperature (4.5 C°),[32].

3- Flowering Density: Flowering density represented as an average number of opened flowers for both 100 spur bud inflorescences and per 100 mixed floral lateral buds on one year old shoots was estimated for the following spring of the treatments[12]. Also the percentage of both floral spurs and floral lateral buds was determined.

4- Fruit set: Percentage of initial fruit set was calculated two weeks after full bloom of the following spring of the treatments according to the number of flowers that set fruits related to the basic number of flowers as given in the following equation:

$$\text{Percentage of initial set} = \frac{\text{No. of fruitlets}}{\text{Total No. of flowers}} \times 100$$ [41]

However, persisted fruits were counted every two weeks till harvest; the percentage of retained fruits was calculated as the number of fruits that were attached till harvest dates as given in the following equation:

$$\text{Percentage of retained fruits} = \frac{\text{No. of retained fruits}}{\text{Total number of flowers}} \times 100$$ [41]

RESULTS AND DISCUSSIONS

Vegetative growth: Table (2,3) showed that the different gibberellic acid treatments significantly increased the average shoot length, total numbers of actively growing shoot tips per tree, total area of leaves, shoot diameter and average leaf dry weight compared with the untreated trees. This was true in the two seasons of the study. It is well known that foliar application of gibberellic acid has the ability to stimulate plant growth and development in a variety of test systems. This may be due to the increment of photosynthetic rates or due to more efficient utilization of photosynthetic products. In this respect, there are many different reports on the involvement of gibberellins with photosynthetic processes, showing increases[4,13]. Foliar sprays of GA_3 have been reported to

Table 2: Effect of application time of Gibberellic acid (GA_3) on vegetative growth of Anna apple in the two seasons.

Treatments	Shoot length (cm)		Shoot diameter (cm)		Leaf area (cm^2)		No. of leaves shoot		Leaf dry weight (gm)	
	2003/2004	2004/2005	2003/2004	2004/2005	2003/2004	2004/2005	2003/2004	2004/2005	2003/2004	2004/2005
Control	37.00	36.50	0.41	0.46	29.16	28.00	31.00	36.50	0.33	0.28
After 6 weeks	61.33	49.70	0.71	0.62	35.10	32.70	48.33	38.30	0.38	0.37
After 6&16 weeks	36.20	45.80	0.61	0.55	31.90	35.50	31.03	38.67	0.40	0.33
L.S.D.0.05	8.65	6.87	0.10	0.09	1.31	0.24	N.S.	N.S.	0.02	0.01

Table 3: Effect of application time of Gibberellic acid (GA_3) on vegetative growth of Anna apple in the two seasons.

Treatments	Specific leaf weight (gm/cm^2)		Total no. of current Shoots		Total shoot length (m)		Total no. of leaves/shoot		Total area of leaves (m^2)		Specific leaf weight (gm/cm^2)	
	2003/ 2004	2004/ 2005	2003/ 2004	2004/ 2005	2003/ 2004	2004/ 2005	2003/ 2004	2004/ 2005	2003/ 2004	2004/ 2005	2003/ 2004	2004/ 2005
Control	11.32	9.93	10.33	15.00	3.82	5.51	348	544	348	544	100	1.53
After 6 weeks	10.82	11.21	67.33	73.70	41.27	36.30	3235	2848	3235	2848	11.32	9.40
After 6&16 weeks	12.57	9.35	31.00	37.70	11.33	17.21	984	1477	984	1477	3.13	5.22
L.S.D.0.05	0.51	0.73	9.28	15.94	4.95	7.20	448	1171	448	1171	1.82	4.27

Means having the same letters within a column are not significantly different at 5% level.

stimulate photosynthetic rates of fully expanded primary leaves of bean plants[23] and potato leaves[4]. Treatments with GA_3 (50 or l0 mg/tree) tended to stimulate shoot elongation in Shampion apple cultivar[16]. Vegetative growth of both Elstar and Golden Delicious apple cultivars was increased as a result of GA_3 application at 250 mg/liter applied at 35 days after full bloom. GA_3 caused an increase in diffusible IAA[6]. Elfving[11] reported that application of gibberellin may stimulate shoot growth and may increase leaf size. However, GA_3 increased rate of shoot elongation and photosynthetic capacity of Noordthiana and Treasure cultivars of Hardy Azaleas[3], whereas, treatments with GA_3 in July on olive induced greater photosynthetic activity. This effect does not seem to be attributed to the increased shoot growth and therefore, to the consequent increased demand for assimilates, since treatment with GA_3 in August and October increased photosynthesis but not growth[31]. The present study revealed that an increase in photosynthetic capacity was due to increase in total area of leaves in response to foliar spray of GA_3.

Bud break: It appears that the increment of bud break percentage of buds developed on one year old shoots in the following spring of the treatments was significantly affected over the two years of investigation (Table 4). Earlier application delayed bud break in both seasons and gave the highest percentage of bud break.

Apparently various external factors enhanced vigour and duration of growth, at the same time may enlarge the chilling requirement[7]. The gibberellins have been closely linked with chilling-related dormancy phenomena in seeds and a lesser extent in dormant buds[29]. The ability of exogenous gibberellins applications to replace the chilling requirements of partially chilled peach and apricot tree buds[18], has promoted speculation about a primitive role of gibberellins in bud dormancy. Gibberellic acid (GA_3) considerably advanced bud break of pistachio flower buds[38]. Likewise an application of GA_3 in autumn lowered the ABA concentration in peach flower buds, but delayed flower bud opening in spring[5]. Also, they found that a positive correlation exists between the ABA concentration in these flower buds during the dormant season may reflect a high tree vigour during the previous season. This could explain why an extended growing season due to vigorous growth may delay bud break. The effect of removing bud scales which containing high amounts of ABA could be replaced by applications of GA_3[9]. It was found that GA_3, applied 14 days after flowering or after cessation of shoot growth, resulted in increasing IAA and reduced ABA concentration in shoot tips for 3-4 weeks after treatment. Furthermore, GA_3 stimulated GA concentration in shoot tips, even growth cessation[2].

Flowering Density: It appears from (Table 5) that the flowering density represented as the number of flowers per 1.00 of both spur bud inflorescences and mixed floral buds developed on one year old shoots of the following spring of GA_3 application, was not significantly changed over the two seasons of the experiment. However, the exogenous application of gibberellic acid significantly increased the percentage of both vegetative spurs and vegetative lateral buds and decreased the percentage of

Table 4: Effect of application time of Gibberellic acid on lateral bud break percentage (B.B. %) during different periods in the two seasons.

GA_3 treatments	Period	B. B. % 2003/2004	B. B. % 2004/2005
Control	1/3	18.63	14.13
	15/3	31.83	29.54
	30/3	44.57	42.17
	15/4	47.10	45.29
After 6 weeks	1/3	0.00	0.00
	15/3	38.50	40.57
	30/3	65.20	63.36
	15/4	87.23	83.97
After 6&16 weeks	1/3	18.43	15.42
	15/3	42.10	36.73
	30/3	55.00	53.63
	15/4	72.87	63.45
L.S.D. 0.05 GA_3 Treatments Period GA_3 ×Period		1.96	2.08
		2.27	2.4
		3.93	4.16

Table 5: Flowering density as affected by application time of Gibberellic acid (GA_3) during the seasons of 2003/2004 & 2004/2005.

Time of application (after full bloom)	Flowering density			
	No. flowers/100 spurs		No. flowers/100 lateral buds	
	2003/2004	2004/2005	2003/2004	2004/2005
Control	566	553	476	459
After 6 weeks	573	558	473	455
After 6&16 weeks	570	580	443	424
L.S.D. 0.05	N.S	N.S	N.S	N.S

Table 6: Effect of application time of Gibberellic acid (GA_3) on the percentage of both fruiting and vegetative buds developed on one year old shoots and on the spur buds during (2003/2004 &2004/2005) seasons.

Treatments	Vegetative spurs %		Fruiting spurs %		Vegetative lateral buds %		Fruiting lateral buds %	
	2003/2004	2004/2005	2003/2004	2004/2005	2003/2004	2004/2005	2003/2004	2004/2005
Control	2.36	1.80	97.40	98.20	1.50	1.70	98.50	98.30
After 6 weeks	16.10	14.63	83.90	85.37	15.40	17.16	84.60	82.84
After 6&16 weeks	11.60	10.60	88.40	89.40	0.0	0.0	100.0	100.0
L.S.D. 0.05	1.70	2.42	1.50	4.81	1.19	1.80	1.23	1.71

both fruiting spurs and fruiting lateral buds (Table 6). Previous studies revealed that exogenous application of gibberellin (GA_3) at 300 ppm inhibited flower bud formation on both spurs and one year old wood of early McIntoch apple trees when applied 10 days after full bloom[22]. However, GA_3 at 500 ppm applied four weeks after full bloom on Cox's Orange and Pippin apple trees had no effect on flowering[35]. It was found that GA_3 (250 or 500 ppm) sprayed at 5 weeks after full bloom reduced the number of flowers in the following year of both Elstar and Golden Delicious apple cultivars[30]. Moreover, GA_3 (250 mg/liter) Sprayed 35 days after full bloom caused an increase in diffusible IAA during the critical period of flower induction 4-6 weeks after full bloom[6]. Inhibition

Table 7: Effect of application time of Gibberellic acid (GA_3) on fruit set of both spur buds and lateral buds percentages during different periods in the two seasons.

Treatments	Period	Fruit set % of spur buds		Fruit set % of lateral buds	
	2003/2004	2004/2005	2003/2004	2004/2005	
Control	30/3	18.54	25.56	6.41	7.64
	15/4	13.17	14.77	4.40	5.91
	5/5	11.27	11.9	3.90	4.54
	20/5	8.89	9.93	3.21	3.58
	15/6	7.71	7.87		
After 6 weeks	30/3	9.58	10.3	4.25	3.59
	15/4	6.84	7.83	2.09	2.62
	5/5	5.75	6.83	1.49	1.54
	20/5	5.32	6.07	0.7	0.76
	15/6	4.62	5.33		
After 6&16 weeks	30/3	8.48	10.27	3.14	4.43
	15/4	6.86	7.8	2.57	3.13
	5/5	6.33	6.13	2.25	2.53
	20/5	6.13	5.73	1.75	2.13
	15/6	5.94	5.67		
L.S.D 0.05					
Treatments		2.1	1.93	1.42	1.46
Period		2.71	2.49	1.63	1.69
GA_3 × Period		N.S.	N.S.	2.83	N.S.

Table 8: Total carbohydrates of woody spurs (mg/100 gm dry weight) as affected by application time of Gibberellic acid (GA_3) during the end of the growing season of (2004/2005).

Time of application	6 weeks after full bloom	6&16 weeks after full bloom	Control
Total carbohydrate mg/100 gm dry weight	2403b	2546ab	2689a

Means separation by L.S.D at 0.05 (165.03)

of flowering of Braeburn apple cultivar was only observed on one year wood and did not occur on spurs in response to GA_3 treatments at (l00, 200 or 400 mg/liter) applied later than 6 weeks after flowering[26]. In addition, there are conflicting reports showing that they have no effect[34]. A single spray of GA_3 at (330 ppm) applied at full bloom reduced the proportion of flowering spurs of 'Braebum' apples, in the following year[25]. GA_3 at l00, 500, or 1000 mg/liter was applied at the beginning of spring growth (May) to release the trees from apical dominance and to enhance lateral growth. At the highest concentration, GA_3 reduced flower bud formation and produced the lowest yields[24]. Trees of Golden Delicious, King of the Pippin and Jonagold were treated with GA_3 (200 mg/liter) applied 14 days after flowering or after cessation of shoot growth GA_3 stimulated shoot growth and reduced flower induction. It was found that GA_3 resulted in increasing IAA and reduced ABA concentrations in shoot tips for 3-4 weeks after treatment. Furthermore, GA_3 stimulated GA concentration in shoot tips, even after growth cessation[2]. Gur *et al*[17] found that reduction in the flower bud formation has been already noted after GA application. Tromp[37] reported that the GA_3 sprays did not influence return flowering of Cox's Orange or Pippin apple. The effect gibberellin induced on flowering had been shown to be highly dependent on the type of gibberellin, concentration and date of application[35]. Treatments with GA_3 applied when the plant had reduced vegetative activity (summer autumn) did not influence flower induction. Indeed, when GA_3 moderately stimulated vegetative activity, it also promoted flowering because of a greater availability of assimilates, the results of a greater leaf area and some increase in photosynthetic activity.

Fruit set: The percentage of initial fruit set of the following spring of GA_3 treatments was significantly reduced for both spur bud inflorescence and mixed floral lateral buds on one year old shoots during the period between 30/3 and 15/6 in both seasons of investigation. However, the percentage of persistent fruits retained till harvest was decreased significantly in both seasons of the experiment for mixed floral lateral buds developed on one year old shoots. Concerning the spurs bud inflorescence, the percentage of persistent fruits of the first season was not significantly changed. However, some treatments changed significantly in the second season (Table 7). While a certain minimum level of vigour obviously essential, excessive shoot growth clearly reduces fruitfulness.

The application of gibberellin may stimulate shoot growth[11]. On the other hand,[20] reported that there is a strong competition between the developing fruitlets and rapidly growing shoot tips, and excessive shoot growth resulted in sparse cropping[14].

Treatments that stimulate vigorous shoot growth, such as earlier dormant severe pruning accompanied with hydrogen cyanamide application generally decreased fruit set in the spring and the spring of the following season[12]. During the period of intense shoot growth a minimum of the total carbohydrates may occur as a result of the strong competition among the various sinks. After shoot growth cessation, carbohydrates are accumulated in strong tissues[36]. The growth regulator TIBA has been used to increase return bloom in heavily cropping trees[19] but the failure of these flowers to set the following season may result from the depletion in nutrient reserves. Both resources and hormones play important roles, hormonal activity determining where growth takes place, while resource supply regulates the amount and duration of growth[1]. The results of the present study revealed that GA_3 resulted in lower fruit set of the following spring, this may be attributed to the more excessive vegetative growth, which makes a depletion in the nutrient reserves.

It appears from Table (8) that earlier application of GA_3 reduced carbohydrate reserves of woody spurs of the second season. The lowest percentage of fruit set achieved the earlier GA treatment may be attributed partially to the depletion in carbohydrate reserves.

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