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ORIGINAL PAPER

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EFFECT OF MELATONIN, GA_3 AND NAA ON VEGETATIVE GROWTH, YIELD AND QUALITY OF 'CANINO' APRICOT FRUITS

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ABSTRACT

A field experiment was carried out during 2017–2018 in the Horticulture Research Station farm in El Kanater El Khayreia, El Kalubeia Governorate, Egypt, to find out the response of foliar application of melatonin, GA_3 and NAA on vegetative and fruit attributes of 'Canino' apricot. Different plant growth regulators influenced all variable parameters related to vegetative growth and fruit. Results revealed that between all growth regulators, the foliar application of melatonin following by GA_3 there was the highest vegetative growth as compared to other treatments, while GA_3 gave the highest yield following by melatonin as compared to other treatments. Treatment with NAA improved vegetative growth, yield and fruit quality to a lesser extent as compared to the control.

Key words: melatonin, apricot, GA_3, NAA, yield, quality

Abbreviations: GA_3 – gibberellic acid, MEL – melatonin, NAA – naphthalene acetic acid, PGRs – plant growth regulators, TA – titratable acidity, TSS – total soluble solids

INTRODUCTION

The apricot fruits are widely consumed in many parts of the world. Apricot is considered one of the most delicious temperate tree fruits. The apricot is an attractive, delicious and highly nutritious fruit. 'Canino' has been considered as one of the most successful new cultivars under Egyptian conditions, which is characterized by low chilling requirements in winter and its high yield, round fruits, free stone, soft flesh and extended marketing season in Egypt from the beginning of June to mid-July.

Irregularity of yield is one of the main problems in apricot cultivars productivity, which is often erratic. Climatological events prior to and during flowering are considered the main determinant for fruiting success; also the fruit set, fruit drop and yield in apricots can be affected by a large number of environmental and physiological factors [Gülcan et al. 1995, Gradziel and Weinbaum 1999, Rodrigo 2000, Torricalles et al. 2000, Alburquerque et al. 2003, 2004]. However, problems related to poor yields are more pronounced in apricot than in other fruits and the reasons are poorly defined. Fruit quality and consumer acceptance of apricot are mostly defined by fruit firmness, size, flavor and attractiveness. Fruit size and firmness are also the key factors affecting the yield and marketability for producers. It has long been established that fruit size can be increased by various cultural applications, such as external chemical treatments in early phases of fruit development.

Plant growth regulators (PGRs), such as auxins, gibberellins and cytokinins are used in many fruit pro-

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duction systems to increase the fruit size. Utilization of PGRs has become important in agriculture today, because they have the ability to increase vegetative growth, fruit set percentage, yield and fruit quality. PGRs enhance rapid changes in physiological and biochemical characters and improve the crop productivity. Among agricultural practices that may increase the fruit production and improve the quality of several other fruit crops, there are applications of PGRs, especially GA_3. It has been reported by various workers that PGRs improve the fruit size, yield and fruit quality [Lotter 1991, Antognozzi et al. 1993, Devrari et al. 2017] by their direct effect on growth and development processes or indirectly by regulating the crop load and plant vigor.

GA_3 is one of the important growth stimulating substances that help in growth and development of many plants. Furthermore, synthetic auxins are effective in enhancing the fruit growth when applied during the second stage of fruit development. GA_3 is used extensively to fruit species to increase the fruit size such as grape (*Vitis vinifera*) [Zahedi et al. 2013] and sweet cherry (*Prunus avium*) [Canli and Orhan 2009]. GA_3 applied at fruit set is used extensively to increase the berry size of *Vitis vinifera* seedless table grapes. Gibberellins primarily affect the growth by controlling the cell elongation and division, which reflected on yield and its components and fruit quality of various grape cultivars [Pires et al. 2000]. GA_3 is responsible for cell elongation, rather than cell division [Francis and Sorrell 2001]. Gibberellins are natural growth hormones playing a primary role in stimulating the auxin reaction, which helps controlling the growth, as well as its direct effect on internode elongation, flowering, fruiting, quality and yield. The most typical property of gibberellins is the promotion of stem growth [Graebe 1987]. GA_3 encourages the cell division and elongation; increases the stalk length, enhances flower and fruit volume. Auxins promote shoot elongation, thin tree fruit and flower formation [Fishel 2006].

Naphthalene acetic acid, commonly abbreviated as NAA, is an organic compound, that is a synthetic plant hormone of auxin group and is an ingredient in many commercial horticultural products. It is also a rooting agent and is used for the vegetative propagation of plants from stem and leaf cutting [Dimitrios et al. 2008]. It has been reported that NAA is useful for thinning of fruits [Agusti et al. 2000]. NAA application affects the fruit formation through a cell division and elongation [Dutta and Banik 2007]. NAA spray was useful in increasing the fruit yield and quality [Singh and Randhawa 2001]. It acts as a metabolic sink for the diversion of metabolism from one part to other in a plant, especially towards developing fruits. Arora and Singh [2014] observed that significant increase in fruit size traits, i.e. fruit length, breadth, weight and volume, was recorded with the application of NAA at 30 ppm concentration.

Bio-regulators have been used for the improvement of quality and productivity of many fruit crops. Application of GA_3, NAA and ethephon separately or in a mixture had a significant effect on fruit soluble solids percentage, fruit ripening and yield of fruit crops. Gill and Bal [2013] sprayed the trees with GA_3 and NAA each at 10, 20, 30, 40, 50 ppm once in the 2nd fortnight of October, then, again these sprays were superimposed in the 2nd fortnight of November with the same treatments in ber (*Zizyphus mauritiana* Lamk.) cv. 'Umran'. The highest fruit yield was recorded in trees sprayed with 30 ppm GA_3. Higher fruit size and weight were noted with 20 and 40 ppm GA_3 and 30 ppm NAA. Higher content of TSS with corresponding lower acidity content was observed in trees sprayed with 50 ppm NAA and 30 ppm GA_3.

MEL was first detected in 1995 in mono and dicotyledon edible plant families [Dubbels et al. 1995, Hattori et al. 1995]. Among many functions that MEL performs in plants, its role as an antioxidant and a growth promoter is most supported by experimental evidence. This compound is an independent PGR and it may mediate the activities of other PGRs. Due to its antioxidant properties, MEL can also stabilize the cell redox status and protect tissues against reactive oxygen and nitrogen species, which accumulated under stressful environment. MEL is inexpensive and safe for animals and humans. Its application as a bio-stimulator could be a good, feasible and cost-effective method useful in agriculture. We also believe that this compound can increase the food quality (the aspect of functional food) and may improve the human health. MEL effectively lowered chlorophyll degradation in aging leaves of barley (*Hordeum vulgare* L.) [Arnao and Hernandez-Ruiz 2009] and detached leaves of apple (*Malus domestica*

Borkh. cv. 'Golden Delicious') protecting the photosystems from damage [Wang et al. 2012]. This indole amine also increased photosynthetic efficiency of chlorophyll in plants [Tan et al. 2012]. Exogenously applied MEL affects the developmental processes during both vegetative and reproductive growth. This compound has similar chemical structure as auxin, thus it seems that it may play similar role in plants as this hormone.

Further, the information on these aspects under agri-climatic conditions of El Kanater El Khayreia region in Egypt is very meager. Hence, this work was designed to discover the impact of foliar spraying of apricot trees with MEL, GA_3 and NAA on increasing yield and fruit value. The experiment was conducted to identify the effect of MEL, its effects as a hormone, such as gibberellins or as an auxin, such as NAA, when sprayed at the pit hardening stage through data on leaves (leaf area and total chlorophyll content), fruits (weight and diameter, firmness, TA and TSS) and yield.

MATERIALS AND METHODS

This study was carried out during the two consecutive seasons of 2017 and 2018 on thirteen years old 'Canino' apricot (*Prunus armeniaca* L.) grown in clay loamy soil in the Horticulture Research Station farm in El Kanater El Khayreia, El Kalubeia Governorate, Egypt. Trees were budded on a local apricot rootstock. Trees were planted 5 × 5 meters apart. All trees were irrigated using flood irrigation system. The chosen trees for the experimentation were similar in vigor and subjected to a schedule of cultural operations including fertilization and insect-pest control.

The tested trees were sprayed with MEL, GA_3 and NAA individually at pit hardening stage to study their effects on growth, yield and fruit quality of 'Canino' apricot as follows:

Treatments

GA_3, NAA and MEL were applied individually as foliar spray on the trees as follows:

T1. Control – trees were sprayed with water only.

T2. GA_3 at 25 ppm (product from ScienceLab.com, Inc. Chemical Laboratory Equipment, Texas 77396, USA).

T3. NAA at 25 ppm (product from Aldrich Chemical Co. Ltd., Gillingham Dorset, England).

T4. MEL at 25 ppm (product from ScienceLab.com, Inc. Chemical Laboratory Equipment, Texas 77396, USA).

A complete randomized block design was adopted in this experiment with four treatments, where each treatment contained three replicates with one tree each. Each tree received 20 L of the applied solution plus 2 cm of tween 20 per liter to avoid the surface tension, except those of control treatment, that were sprayed with water only. Treatment solutions were sprayed on trees in the morning hours of the day in mist form. The spraying was continued until the leaves and fruits were fully drenched.

Growth and Yield. Leaf area (cm^2): Twenty mature leaves (of the 4–6^{th} leaf from the base) replicated three times were abscised in last week of May, then leaf area (cm^2) was measured using portable laser leaf area meter (Model CI-202 made by CID USA) and total leaf chlorophyll content [Chlorophyll Content Index (CCI)] was measured using chlorophyll content meter 003109 (CCM-200 plus Opti-Sciences). Harvesting was performed on June 15 in each season, when the control fruits reached their maturity.

Fruit yield. The observations of yield were recorded at the time of fruit picking from all experimental trees. After picking fruits from each tree, they were weighed immediately and expressed in kilogram per plant. Fruit yield increment or reduction percentage compared with the control was calculated by the following equation:

$$\text{Fruit yield increment or reduction (\%)} = \\ = \text{Fruit yield (kg) at treatment} - \text{Fruit yield (kg)} \\ \text{at control/Fruit yield (kg) at control} \times 100$$

Fruit physical characteristics. At harvest, samples of twenty fruits from each tree replicated three times were devoted. They were then brought in polyethylene bags to the laboratory for chemical analyses.

Fruit weight: Fruits were weighed on a top pan balance and average weight was expressed in grams per fruit (g). Fruit diameter: average diameter of fruits was measured with the help of Vernier calipers and expressed in centimeter per fruit (cm/fruit).

Fruit firmness: Flesh-firmness of fruits was determined by pressure tester (Magness-Taylor Pressure tester, Model FT 327) which was expressed in $Lb/inch^2$.

Chemical analyses

TSS: The total soluble solids of fruit juice were determined by Carl Zeiss hand refractometer (0 to 32 Brix) by putting few drops of juice on the prism. The refractometer was calibrated with distilled water before use.

Titratable acidity (TA): Five grams of fruit pulp were thoroughly homogenized with distilled water in an electric blender and volume was adjusted up to 50 ml. The mixture was then filtered through the Whatman No. 1 filter paper. Five milliliters of sample was then titrated using phenolphthalein as an indicator until it gave pink colored end point. The TA of fruit was estimated by titrating the fruit pulp extract with 0.5N NaOH using phenolphthalein as an indicator. This was expressed in terms of anhydrous citric acid percentage.

Statistical analysis

All data obtained during both seasons were subjected to analysis of variance according to Snedecor and Cochran [1982] and significant differences among means were distinguished according to the Duncan's multiple test range [Duncan 1955].

RESULTS AND DISCUSSION

Tables 1 and 2 show that MEL spray treatment proved to be the most effective in increasing the vegetative characters, leaf area and total leaf chlorophyll in the two seasons followed by GA_3 spray treatment, while GA_3 spray treatment gave the highest yield and fruit weight in the two seasons followed by MEL spray treatment. Hence, NAA spray treatment was moderate in its effect on these characters; these were comparable to with control. Treatments with NAA improved vegetative growth and yield quality to a lesser extent as compared to the control.

This might be due to their involvement in hormonal metabolism, increased cell division, elongation and expansion of cells, therefore finally, increasing the vegetative growth. The lowest yield parameters were recorded under control treatment. It may be due to the lack of nutrients supply. Thus, the highest increment percentage in the yield was recorded in relation to the treatment with GA_3, then in a descending order, with MEL treatment. This was true in the two seasons. Painkra et al. [2012] studied the effect of foliar application of NAA (10, 20, 30 and 40 ppm), 2,4-D (5, 10, 15 and 20 ppm) and GA_3 (50, 100, 150 and 200 ppm) on fruit retention, yield and quality characters of Langra mango, and found that length, width and weight of fruit and pulp were maximized with NAA 40 ppm. The maximum yield (28.90 kg) per plant was harvested due to NAA (40 ppm). Singh and Bal [2006] reported that higher fruit size in terms of length and breadth, weight and yield was recorded with 60 ppm NAA sprayed at active growth phase. Rajput and Singh [1982] reported that shoot length, leaf area, fruit weight and yield were increased when 16-year-old trees of the ber cv. Banarasi Karaka were treated with GA_3 at 20 ppm (76.6 kg/tree) or NAA at 40 ppm (86.4 kg/tree) treatments. Çolak [2018] conducted a study to investigate the effects of hormones application at different doses on fruit quality and yield and in this regard, treated the leaves of jumbo blackberry with melatonin and gibberellic acid hormones. According to the results obtained, in jumbo blackberry, the number and weight (g) of fruit were most increased with the treatment of MEL + GA_3 10 ppm (240.50; 385.19) and MEL 10 ppm (182.38; 280.59) and in terms of the fruit size, the maximum efficiency was achieved with GA_3 5 ppm (21.21 mm fruit length, 16.56 mm fruit width) and MEL 10 ppm (20.22 mm fruit length and 15.58 mm fruit width).

The increase in fruit weight can be attributed to the exogenous supply of NAA, which might have increased the mobilization of food and minerals from other parts of the plant towards developing fruits that are extremely active metabolic sinks which, in turn, could have increased the weight and volume. Increase in fruit size has been recorded with the help of NAA in different fruits like guava [Jain and Dashora 2007, Barche et al. 2007]. The spray of NAA might have raised the auxin level in fruit, which ultimately helped in the development of its various components, as there is a direct correlation between auxin content and fruit growth in several plants. Similar results have also been reported by Singh et al. [2002], Kale et al. [1999], Bankar and Prasad [1990] in ber.

Tables 3 and 4 indicated that using the GA_3 spray increased all fruit physical and chemical characteristics in the two seasons followed by MEL spray, which was more obvious in the second season, while, using

Table 1. Effect of some chemical materials at pit hardening stage on total chlorophyll, leaf area, fruit weight and yield of 'Canino' apricot during 2017 season

Treatments	Total chlorophyll (CCI)	Leaf area (cm^2)	Fruit weight (g)	Yield (kg)	Increment or reduction (%)
Control	16.26 b	169.37 c	34.33 c	73.81 d	0.001
GA_3	16.80 b	174.09 b	40.66 a	104.90 a	42.12
NAA	14.06 c	175.21 b	37.00 b	81.40 c	10.28
Melatonin	19.73 a	192.20 a	36.66 b	85.05 b	15.21

Means followed by the same letter within each column didn't significantly differ at 5% level

Table 2. Effect of some chemical materials at pit hardening stage on total chlorophyll, leaf area, fruit weight and yield of 'Canino' apricot during 2018 season

Treatments	Total chlorophyll (CCI)	Leaf area (cm^2)	Fruit weight (g)	Yield (kg)	Increment or reduction (%)
Control	17 .00 b	170.74 d	33.46 b	66.92 c	–
GA_3	17.08 b	177.33 b	37.92 a	75.08 a	12.19
NAA	16.10 b	173.12 c	35.75 a	65.17 d	–2.61
Melatonin	18.96 a	195.08 a	36.61 a	71.97 b	7.54

Means followed by the same letter within each column didn't significantly differ at 5% level

Table 3. Effect of some chemical materials at pit hardening stage on fruit quality of 'Canino' apricot during 2017 season

Treatment	Diameter (cm)	Firmness ($Lb/inch^2$)	TA (%)	TSS (%)
Control	3.78 b	2.82 b	0.90 a	11.73 a
GA_3	4.34 a	4.35 a	0.98 a	11.83 a
NAA	3.85 b	2.97 b	0.75 b	10.07 b
Melatonin	4.10 a	2.71 b	0.75 b	11.50 a

Means followed by the same letter within each column didn't significantly differ at 5% level

Table 4. Effect of some chemical materials at pit hardening stage on fruit quality of 'Canino' apricot during 2018 season

Treatment	Diameter (cm)	Firmness ($Lb/inch^2$)	TA (%)	TSS (%)
Control	4.16 b	9.81 c	0.66 a	10.77 c
GA_3	4.33 a	11.64 a	0.52 b	12.36 a
NAA	4.26 a	10.62 b	0.63 a	11.00 b
Melatonin	4.33 a	11.26 a	0.56 b	11.40 b

Means followed by the same letter within each column didn't significantly differ at 5% level the NAA spray was between them in its impact on these characters; these were comparable to the control. GA_3 as a pre-harvest application between the end of stage II (pit hardening) and mid stage III (final fruit swell) of fruit development, improved the fruit quality and it led to the best quality as diameter, firmness, TSS and TA. The possible reason might be that the PGRs promoted hydrolysis of starch into sugars or reduced the competition between fruits for metabolites.

Application of NAA not only increased the yield in the second season, but also improved the fruit quality. Its application significantly influenced the biochemical constituents with TA and TSS of fruit over the control. Spray of NAA might have improved the internal physiology of developing fruits in terms of better supply of water, nutrients and other compounds vital for their proper growth and development. The increase in fruit diameter by the application of PGRs might be due to the optimum supply of growth hormones in appropriate amount during the entire crop growth period causing vigorous vegetative development of plants and ultimately production of more photosynthesis.

The application of NAA might have a role in increasing the auxin level of fruits, which, in turn, might have helped in the development of fruit components, as there is a direct correlation between auxin content and fruit growth. Canli et al. [2014] recommended single application of benzyl adenine (as auxin) at the end of pit hardening stage for improving apricot quality.

The increase in TSS of treated fruit juice might be due to the increase in mobilization of carbohydrates from the source to sink (fruits) by auxin. This may be attributed to the fact that application of hormones might have increased α-amylase activity and thus, there was a conversion of starch into sugars, hence, improving the TSS content.

The application of NAA and GA_3 at pea size stage of ber fruits had probably improved the internal physiology of leaves, thereby causing better translocation of vital components in fruit development and assimilation, as well as utilization of photosynthesis in developing the fruits leading to improved quality in terms of pulp, TSS and total acid content of fresh ripe fruits. Harminder et al. [2004] observed that application of GA_3 at 20 and 50 ppm two weeks after pit-hardening stage, significantly increased TSS in plum cv. 'Satluj Purple'. Lenahan et al. [2006] reported that two applications of GA_3 at 50 and 100 mg/L increased TSS by 12%, firmness by 15–20% and weight by 7 to 14% in sweet cherry cv. 'Bing'.

CONCLUSIONS

It is clear from the previously presented work that the effect of MEL may be closer to the effect of the hormone (gibberellins) on the characteristics of leaf area and the content of total chlorophyll, while the effect is closer to the auxin (NAA) on the crop and some qualities of fruits estimated.

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