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Effect of Benzyl Adenine, Indole Acetic Acid and Gibberellic Acid on Vegetative Growth, Chemical Constituents and Volatile Oil Attributes of Sweet Basil Plants

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BENZYL ADENINE, indole acetic acid and gibberellic acid at different concentrations were sprayed to study their effects on growth, chemical components and volatile oils of sweet basil in 2018 and 2019 seasons

Plant height, number of leaves/plant, average leaf area, and herb fresh and dry weights/ plant greatly improved with the applied treatments especially with IAA treatments followed by GA_3 treatments. However, the number of lateral branches/plant and stem diameter were increased with BA treatments especially with 10 ppm than 5 ppm. Generally, the second cut was superior in the studied vegetative growth parameters than the first cut.

The highest values of N, P, K, Fe, and Mn were recorded with BA at 10 ppm, whereas higher Zn values were recorded with BA at 5 ppm. Active ingredients including total phenols, total flavones, total chlorophyll, and L- ascorbic acid greatly increased with IAA at 50 or 100 than the other treatments or the control. However, volatile oil percentage and volatile oil content/plant were high in IAA at 50 or 100 ppm followed by GA3 at 200 ppm. The second cut was superior to the first cut in promoting volatile oil percentage and volatile oil content/ plant in both studied seasons. The main components in volatile oil were 1,8-cineole, linalool, á-trans-bergamotene, germacrene D and á-muurolol. The highest values of linalool, the main component in the volatile oil of sweet basil (50.90%) was recorded by IAA at 100 ppm.

Keywords: Plant growth regulators, BA, IAA, GA_3, Sweet basil, Vegetative growth, Total phenols, Volatile oil.

Introduction

There are more than a hundred and fifty basil species belonging to the *Ocimum* genus (Javanmardi et al., 2002). The two most widely grown species for producing volatile oil are holy basil (*Ocimum sanctum* L.) and sweet basil (*Ocimum basilicum* L.). Basil oil is utilized for flavor and aroma in the foods, pharmaceutical, beauty products, and aromatherapy fields. The oil is considered antimicrobial (Elgayyar et al., 2001, Suppakul et al., 2003, Kristinsson et al. 2005 and Bozin et al., 2006,) and insecticidal (Bowers & Nishida, 1980 and Aslan et al., 2004) agents. The action of sweet basil basic oil has been historically taken out from herb (stems, leaves, and flowers) by steam percolation (Trevisan et al., 2006). The ideal phase for volatile oil extraction is at blossom emergence, while the oil content material and fractions components are the highest (Zheljazkov, 2008).

Sweet basil (*Ocimum basilicum* L.) which investigated in this research is identified by high yields of raw fabric and active ingredients involved total phenols, total flavones, total chlorophyll, and L- ascorbic acid. As mentioned by Berbeć et al. (2003) who reported that the utilization of bio-stimulators can do the main function in production increasing and enhancing plant validity effect. Bio-stimulators transport essential nutrients to the plant, thereby growing its resistance to pests. In Western Europe, herb growers were use plant growth regulators on a

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large scale for over a dozen years. They promote metabolic processes within the plant, improve growth seed and fruit production as well as raise resistance to fungal and bacterial disorders (Carvajal and Alcaraz, 1998).

The quantitative and qualitative synthesis of the phytochemicals in sweet basil leaves can differ according to many factors. Chemical plant nutrition is one of the essential factors influencing plant metabolism and the level of secondary metabolites. Flavonoids are considered vital secondary metabolites regulating the growth of plants (Winkel-Shirley, 2002), and are found in leaves, flowers, fruits, and roots. They are use natural medicines and healthful food. The pathway of flavonoids in flowers starts with the shikimate pathway, and intermediate merchandise, together with chalcone and isoflavonoids, are formed through the phenylpropanoid pathway (Dixon et al., 2002 and Koes et al., 2005). These flavonoids are then conjugated to other flavonoids and glycose to form final products inclusive of anthocyanin and flavonol glycoside.

Plant growth regulators (PGRs) are natural produced with the aid of plants or synthetically through chemists and affect in plant growth cycle (Davies, 2013). PGRs include cytokinins and auxins, that at low concentrations modify plant developmental strategies (Fu et al., 2011) However, benzyl adenine (BA) and naphthalene acetic acid (NAA) have both been carried out pre- and post-cut of crops to a lot of decorative plant species. Cytokinins including BA which encourages cellular elongation and division (Krug et al., 2006). BA has additionally been used to enhance the growth and development of aromatic flowers. Treating *Lantana camara* L. flora with BA increased unstable natural compound production as volatile oil contents (Affonso et al., 2007). Similarly, Zielińska et al. (2011) indicated that the production of volatile oil contents elevated with the utility of various PGRs, such as indole-3-acetic acid (IAA), thidiazuron, kinetin, and BA, when applied to *Agastache rugosa* flowers grown *in vitro*. Auxins which include NAA coordinate many increase and behavioral procedures in vegetation cycles. Furthermore, NAA promotes cellular division and elongation, performs a key function in shoot improvement, and increases flower manufacturing (Fu et al., 2011). However, Saffari et al. (2004) in their working on *Rosa damascena* (Damask rose) indicated that the utilization of NAA at 25 mg/l to improve vase life, expanded flower longevity, plant height, flower yield, and flower oil composition. Another study by Bota and Deliu (2015) confirmed that the addition of 0.1 mg/l NAA and 1 mg/l BA to a cellular suspension culture of *Digitalis lanata* (Grecian foxglove) elevated the production of flavonoids, that are related to secondary metabolite production.

The volatile oil manufacturing does not relate only to plant genetics or developmental stage. The climate and its variations can have an impact on in a significant manner biochemical pathways and physiological approaches that alter plant metabolism and, therefore, the volatile oil biosynthesis (Sangwan et al., 2001).

Gibberellins as diterpenoids components make up a group of plant hormones which can ameliorate the plant development and improvement. GA_3 has many physiological outcomes on plant life and it has confirmed that GA_3 has an inductive effect on plant vigor and secondary metabolite biosynthesis (Taiz and Zeiger, 2010). However, Bais et al. (2001) reported that application of GA_3 leads to hastening the growth of intact common chicory plant (*Cichorium intybus* L.) and the buildup of coumarin (phenolic compound). Gibberellic acid will increase the biosynthesis of several secondary metabolites like steroids, terpenoids, flavonoids, and anthocyanins (Srivastava and Srivastava, 2007). In this respect, Davies (2013) reported that GAs growth regulators are effective in developmental strategies as seed germination, stem elongation, leaf growth, trichome improvement and flower and fruit development. It has been known that an increase in growth regulators in various agriculture practices is maximum favorable for promoting and enhancing plant-growth of different plant life (Eid and Abou-Leila, 2006.). The useful effect of gibberellic acid on different vegetative phases were recorded with the aid of Shedeed et al. (1991) on croton plant, Brooking and Cohen (2002) on Zantedeschia, Al-khassawneh et al. (2006) on black iris. They all concluded that gibberellic acid is utilized to regulating plant increase through increasing cellular department and cell elongation. GA3 sprays superior plant dry mass, leaf location, plant increase price and increased yield in *Cymbogon martini* (plamarosa) (Khan et al., 2015).

Auxins have numerous physiological results on the medicinal and aromatic plants included cellular elongation and differentiation, apical dominance phenomena, root initiation and fruit

development (Taiz and Zeiger, 2010, Khan et al., 2015). Indole-3-acetic acid (IAA) is the main detectable auxin in plants and plays many roles in plant growth (Georg et al., 2008). Moreover, the presence of indole-3-butyric acid (IBA) in plant tissues has demonstrated (Santner et al., 2009). Also, IAA inspired leaf increase in *Cymbopogon Jwarancusa* (Ansari et al., 1988).

Cytokinins are plant promotors which are utilized in agricultural practices for stimulation and synchronization of flowering and fruit set, promotion of rooting, reduction of vegetative growth, reduction of accommodations of agronomic crops, or defoliation (Briant,1974). Essential plant hormones that regulate numerous tactics of plant growth and development including cellular division and differentiation, enhancement of leaf enlargement and nutrient mobilization (Shudok, 1994). The reaction of plants to cytokinins have been also mentioned by Eraki (1994) on *Hibiscus sabdarijfa* L. plant referred to that utilization of BA appreciably improve plant height, number of branches as properly as fresh and dry weights of leaves than the control. However, Hassanein (1985) on *Pelargonium graveolens*, El-Sayed *et al.* (1989) on *Polianthus tuberosa*, Menesi *et al.* (1991) on *Calendula officinalis* and Mazrou *et al.* (1994) on candy basil, found that foliar utility of BA multiplied increase of various organs, active constituents production of these plant life and accelerated total carbohydrates content material on contrast to the untreated flowers. The pharmaceutical and beauty industries depend on the purity and heterogeneity of essential oils to meet the needs and necessities of the marketplace, within the aim to have a powerful organic activity (antifungal, antibacterial) or to enhance the cosmetics.

The main target of this study was to evaluate the effect of BA, IAA and GA3 on vegetative growth, macro- and micro-elements levels, chemical constituents, volatile oil production and volatile oil fractions of sweet basil plants.

Materials and Methods

The present work was carried out during 2018 and 2019 seasons in the Ornamental Nursery, Faculty of Agriculture, Ain shams Univ., Cairo, Egypt on sweet basil (*Ocimum basilicum* L.).

Seeds were sown on the mid of March 2018 and 2019 in seed bins filled with peat moss and sand (1:1). After 45 days from sowing (first of May) where the seeding reached 10-12 cm height with 8-10 leaves and 5 branches, they were transplanted to 30 cm diameter plastic pot filled with peat moss and sand (1:1). The seedlings of sweet basil were selected to be uniform in shape and exposed to all horticulture practices including irrigation, fertilization and pest managements as recommended in this respect.

Plant growth regulators were sprayed twice, on firs of June (after one month of transplanting) and again on the mid of July (the first cut) of both seasons. Seven treatments were applied as follows:

- Control as sprayed with tap water.
- Spraying benzyl adenine (BA) at 5 ppm.
- Spraying benzyl adenine (BA) at 10 ppm.
- Spraying indole acetic acid (IAA) at 50 ppm.
- Spraying indole acetic acid (IAA) at 100 ppm.
- Spraying gibberellic acid (GA_3) at 100 ppm.
- Spraying gibberellic acid (GA_3) at 200 ppm.

The experiment was designed in a randomized complete block design (RCBD) with 4 replicates for each treatment and each replicate contained 5 sweet basil plants (7 treatments x 4 replicates x 5 plants = 140 sweet basil plants) in each season. Herb of sweet basil plants was harvest twice, in the first cut when inflorescence shoots occurred (50% flowering) in mid-July in both seasons and after 45 days the second cut was done (first of September) (Taie et al., 2010). In each cut, the plants were cut at a height of 6-7 cm above the ground (Biesada and Kus, 2010).

The following data were recorded:

Vegetative growth parameters

At each cut, plant height (cm), number of lateral branches/plant, number of leaves/plant, stem diameter (cm) measured five cm above the ground, average leaf area (cm^2), herb fresh weight/plant (g) and herb dry weight/plant (g) were estimated in both seasons.

Mineral contents

At the second cut of each season, the leaves were collected, washed and dried at 70°C until constant weight and then ground for determination the nutrient elements. Nitrogen was determined according to Guebel et al. (1991). Phosphorus was determined according to Bringham (1982) and potassium was measured according to Westerman (1990). Fe, Zn, and Mn were determined according to Chapman and Pratt (1982).

Chemical constituents

At the second cut of the two studied seasons, the herb was collected and total phenols (mg/g dry weight) was determined according to Singleton and Rossi (1965), total flavones (mg/g dry weight) was determined according to Zhishen *et al.* (1999), total chlorophyll (mg/100g fresh weight) was determined according to Moran and Porath (1980) and L-ascorbic acid (mg/100g fresh weight) was determined according to A.O.A.C (2005).

Volatile oil percentage and volatile oil content/ plant

In the two cuts in both studied seasons, the essential oil was extracted by water distillation method according to Novak *et al.* (2002)**.** The amount of obtained volatile oil from three plants for each replicate was measured and both oil percentage and volatile oil content/plant were measured according to Charles and Simon (1990).

Chemical constituents of the essential oil

It was determined in the second cut of the second season only, chemical constituents of the essential oil of the herbs were analyzed using the Trace GC Ultra/Mass Spectrophotometer ISQ (Thermo Scientific) (GC/MS) apparatus to determine their main constituents (Charles and Simon, 1990).

Statistical analysis

Results were statistically analyzed using the analysis of variance (ANOVA) as described by Snedecor and Cochran (1990). The method of Duncan's multiple range tests was applied for the comparison between means according to Waller and Duncan (1969).

Results and Discussion

Vegetative growth parameters

Data in Tables 1, 2, 3 and 4 show the effect of BA, IAA and GA3 spraying on some vegetative growth parameters of sweet basil plant during 2018 and 2019 seasons.

As shown in Table 1, the highest values of plant height (73.1 and 71.4 cm) were obtained by IAA spraying at 100 ppm in the two studied seasons, respectively. However, the treatments of IAA at 50 ppm and GA_3 at 200 ppm were similar in their effect on plant height of sweet basil without significant differences between them. The least values of plant height due to the used treatments were recorded by BA at 5 or 10 ppm which were similar to the control. The second cut of sweet basil recorded the highest significant values of plant height than the first cut in both seasons. The great effect to the interaction between the applied treatments and the two cuts on plant height was recorded with 100 ppm IAA in the second cut. However, the least interaction values were recorded in the first season with unsprayed plants in the first cut and in the second season with BA 10 ppm in the first cut.

The number of lateral branches/plant illustrated in Table 1 was greatly improved with all applied treatments than the control in both seasons of the study. The superior effect was more pronounced (34.3 and 32.0 branches/plant) with 10 ppm BA in the first and second seasons, respectively, however, 5 ppm of BA came next in this respect. The treatments of GA_3 at 100 or 200 ppm recorded medium values of lateral branches/ plant without significant differences between them. However, IAA at 50 or 100 ppm recorded the least effect on the lateral branches of sweet basil. Moreover, the second cut recorded the highest significant values of lateral branches than the first cut in both seasons. Interaction values showed that the highest values of lateral branches (36.5 and 33.4 branches/plant) were recorded in the second cut due to the applied of 10 ppm BA.

Data in Table 2 show that all applied treatments, GA3 at 200 ppm in the first season and IAA at 100 ppm and GA_3 at 200 ppm in the second season, increased the number of leaves/ plant than the control.. However, BA at 5 ppm, IAA at 50 ppm and GA_3 at 100 ppm exhibited similar non-significant values of the number of leaves/plant in both studied seasons. Also, the second cut produced the great number of leaves/ plant than the first cut in the second season only. Interaction between the two studied factors did not follow a clear trend where the highest interaction value (260.5 leaves/plant) in the first season was obtained in the first cut with 10 ppm BA, whereas in the second season the highest value (254.9 leaves /plant) was recorded in the second cut with the same treatment.

TABLE 1. Effect of BA, IAA and GA3 spraying on plant height and the number of lateral branches/plant of sweet basil in 2018 and 2019 seasons.

Treatments	Plant height (cm)		Mean	No. lateral branches/plant		Mean
	1st cut	2nd cut		1st cut	2nd cut	
2018 Season						
Control	38.92 h	46.6 fg	**42.7 E**	12.6 h	15.3 gh	**14.0 F**
BA 5 ppm	44.7 g	51.4 efg	**48.1 D**	25.7 cd	30.4 bc	**28.1 B**
BA 10 ppm	45.6 g	49.7 fg	**46.2 DE**	32.1 ab	36.5 a	**34.3 A**
IAA 50 ppm	64.3 bc	68.2 ab	**66.2 B**	19.3 fg	23.1 def	**21.2 DE**
IAA 100 ppm	70.8 ab	75.3 a	**73.1 A**	16.5 gh	20.4 efg	**18.5 E**
GA_3 100 ppm	53.2 ef	57.1 de	**55.2 C**	21.5 ef	24.6 de	**23.1 CD**
GA_3 200 ppm	61.3 cd	65.8 bc	**63.6 B**	23.7 def	27.3 bcd	**25.5 BC**
Mean	**54.1 B**	**59.1 A**		**21.6 B**	**25.4 A**	
2019 Season						
Control	41.9 ef	48.4 e	**45.2 D**	14.7 f	17.9 ef	**16.2 E**
BA 5 ppm	44.7 ef	46.2 ef	**45.5 D**	24.8 cd	27.1 bc	**26.0 B**
BA 10 ppm	40.2 f	44.7 ef	**42.5 D**	30.5 ab	33.4 a	**32.0 A**
IAA 50 ppm	61.5 cd	66.5 bc	**64.0 B**	21.7 de	24.8 cd	**23.3 BC**
IAA 100 ppm	68.9 ab	73.8 a	**71.4 A**	18.2 ef	21.5 de	**19.9 D**
GA_3 100 ppm	56.9 d	60.2 cd	**58.3 C**	20.8 de	23.3 cd	**22.1 CD**
GA_3 200 ppm	63.1 bc	62.6 bcd	**62.9 BC**	24.2 cd	25.4 bcd	**24.8 BC**
Mean	**53.8 B**	**57.5 A**		**22.1 B**	**24.77 A**	

Values followed by the same letter (s) are not significantly different at 5% level.

It is clear from data in Table 2 that stem diameter was increased with all treatments than the control except IAA at both concentrations in the first season and IAA at 100 ppm only in the second season. BA treatments were effective than the other two growth regulators in increasing the stem diameter of sweet basil plant. However, 10 ppm of BA was more effective than 5 ppm in this respect. The second cut produced thicker plants than the first cut in both seasons of study with significant differences between them. Interaction between the studied factors was significant in most cases where the highest interaction values of stem diameter (2.83 and 2.65 cm) were obtained in the second cut with the plants sprayed with 10 ppm of BA in both seasons of study.

Regarding the average leaf area, Data in Table 3 clearly show that all applied treatments with plant growth regulators increased the leaf area except the treatments of 5 ppm BA in both studied seasons. However, the highest values of leaf area (11.15 and 10.34 cm^2) were recorded by IAA at 100 ppm in both seasons. Generally, it could be noticed that IAA as promoting growth regulator was more effective than GA_3 or BA in improving the leaf area of sweet basil plant. The spraying of BA was negligible and reduced leaf area than the control and this could be attributed to that BA as a cytokinin led to branching the treated plants and produced more leaves with small areas. No significant differences were detected between the two cuts in effecting the leaf area in both studied seasons. Interaction values showed that the highest values of average leaf area (11.34 and 10.53 cm^2) were recorded with 100 ppm IAA in the second cut of both studied season.

Herb fresh weight/plant values (Table 4) were significantly increased with all spraying treatments than the control. The highest values (214.1 and 223.7 g/plant) were recorded with BA at 10 ppm in the first and second seasons, respectively. However, GA_3 at 200 ppm came next in producing high values of herb fresh weight, whereas IAA at 50 ppm recorded the least values of herb fresh weight/plant in both studied seasons. Herb fresh weight/plant was significantly affected in the second cut than the first cut in both seasons. Interaction values showed that the highest values of herb fresh weight/plant (221.8 and 230.0 g) were recorded with BA in the second cut at 10 ppm in the first and second season, respectively.

Herb dry weight/plant values (Table 4) were followed a similar trend to those found in herb fresh weight values, where the highest herb dry weight (59.0 and 62.7 g/plant) were recorded with BA at 10 ppm in the first and second season, respectively. Moreover, the least herb dry weight was gained with IAA at 50 or 100 ppm in both studied seasons. Generally, it could be noticed

that the herb dry weight of sweet basil greatly increased with BA at 10 ppm and GA_3 200 ppm and this result is important to sweet basil producers where the herb dry weight is the main product of this medicinal plant. In addition, the second cut produced the highest values of herb dry weight of sweet basil than the first cut in both studied seasons. The highest interaction values (61.3 and 63.9 g/plant) were recorded by BA at 10 ppm in the second cut in both seasons of study.

In this respect, Eraki, (1994) mentioned that benzyl adenine (BA) and naphthalene acetic acid (NAA) have both been applied pre- and post-harvest to a lot of ornamental plant species. Cytokinins such as BA are used to enhance the quality and vase life of cut flowers. Moreover, BA increases cell elongation and division, decreases flower fall and increases flower yield. Moreover, NAA stimulates cell division and elongation, affects shoot development, and improves flower yield. A study on *Rosa damascena* (Damask rose) pointed that the utilization of NAA at 25 mg/l to rose plants, improved flower longevity, plant height, flower production and flower oil yield (Hassan and El- Queni, 1989). Also, Briant (1974) extracted that cytokinins are used in the agricultural industry for stimulation and synchronization of flowering and fruit setting, promotion of rooting, reduction of vegetative growth, reduction of lodging of agronomic crops, or defoliation

Great effect of GAs was also mentioned by Khan and Chaudhry (2006) who reported that GA_3 utilization improved petiole length, leaf area and retarded petal abscission and color fading (senescence) by the hydrolysis of starch and sucrose into fructose and glucose. It has been known that growth regulators among the agriculture practices which is most favorable for enhancing and improving plant growth of different plants. The useful reaction of gibberellic acid on many plants were reported by Shedeed et al. (1991) on croton plant, Brooking and Cohen (2002) on *Zantedeschia*, Al-khassawneh et al. (2006) on black iris. They deduced that gibberellic acid is used to regulate plant growth through raising cell division and cell elongation. GA_3 utilization improved plant dry mass, leaf area, plant growth rate and crop growth rate in mustard.

TABLE 2. Effect of BA, IAA and GA3 spraying on number of leaves/plant and stem diameter of sweet basil plant in 2018 and 2019 seasons.

Treatments	Number of leaves/plant		Mean	Stem diameter (cm)		Mean
	1st cut	2nd cut		1st cut	2 nd cut	
			2018 Season			
Control	178.4 e	196.0 de	**187.2 CD**	1.46 f	1.47 f	**1.47 E**
BA 5 ppm	231.7 bc	225.1 bc	**228.4 B**	2.19 b	2.34 b	**2.27 B**
BA 10 ppm	260.5 a	248.5 ab	**254.5 A**	2.31b	2.83 a	**2.57 A**
IAA 50 ppm	218.1 cd	211.7 cd	**214.9 B**	1.58 def	1.65 def	**1.62 DE**
IAA 100 ppm	178.5 e	183.5 e	**181.0 D**	1.51 ef	1.49 ef	**1.50 E**
GA_3 100 ppm	213.2 cd	217.1 cd	**215.1 B**	1.79 de	1.74 def	**1.77 CD**
GA_3 200 ppm	194.6 de	203.8 de	**199.2 C**	1.85 cd	2.11 bc	**1.98 C**
Mean	**210.7 A**	**212.2 A**		**1.81 B**	**1.95 A**	
			2019 Season			
Control	185.6 fg	190.4 fg	**188.0 D**	1.42 g	1.40 g	**1.41 E**
BA 5 ppm	215.9 cde	230.5 abc	**223.2 B**	2.10 cd	2.41 ab	**2.25 A**
BA 10 ppm	250.2 ab	254.9 a	**252.6 A**	2.23 bc	2.65 a	**2.44 A**
IAA 50 ppm	225.4 bcd	205.7 def	**215.6 BC**	1.63 efg	1.77 ef	**1.70 CD**
IAA 100 ppm	170.4 g	195.7 ef	**183.1 D**	1.50 fg	1.56 fg	**1.53 DE**
GA_3 100 ppm	220.5 cd	204.8 def	**212.7 BC**	1.84 de	1.93 cde	**1.89 BC**
GA_3 200 ppm	190.4 fg	213.8 cde	**202.0 CD**	1.93 cde	2.15 bc	**2.04 B**
Mean	**208.4 B**	**213.7 A**		**1.81 B**	**1.99 A**	

Values followed by the same letter (s) are not significantly different at 5% level.

TABLE 3. Effect of BA, IAA and GA3 spraying on average leaf area of sweet basil plant in 2018 and 2019 seasons.

Treatments	Average leaf area (cm^2)					
	2018 Season		Mean	2019 Season		Mean
	1st cut	2nd cut		1st cut	2nd cut	
Control	7.11 de	6.75 ef	**6.93 D**	6.54 de	7.25 cd	**6.90 C**
BA 5 ppm	6.58 ef	6.26 ef	**6.42 DF**	6.11 de	6.55 de	**6.33 C**
BA 10 ppm	6.03 ef	5.49 f	**5.76 F**	5.74 e	6.17 de	**5.96 C**
IAA 50 ppm	9.72 abc	10.15 ab	**9.94 B**	9.54 ab	9.84 ab	**9.69 AB**
IAA 100 ppm	10.96 a	11.34 a	**11.15 A**	10.14 ab	10.53 a	**10.34 A**
GA_3 100 ppm	9.18 bc	9.72 abc	**9.45 BC**	9.25 ab	9.54 ab	**9.40 B**
GA_3 200 ppm	8.51 cd	8.93 bc	**8.72 C**	8.75 bc	9.07 ab	**8.91 B**
Mean	**8.30 A**	**8.38 A**		**8.02 A**	**8.43 A**	

Values followed by the same letter (s) are not significantly different at 5% level.

TABLE 4. Effect of BA, IAA and GA3 spraying on herb fresh and dry weights/plant of sweet basil in 2018 and 2019 seasons.

Treatments	Herb fresh weight/plant (g)		Mean	Herb dry weight/plant (g)		Mean
	1st cut	2nd cut		1st cut	2nd cut	
			2018 Season			
Control	129.1 g	154.6 f	**141.9 E**	35.7 g	42.8 f	**39.3 D**
BA 5 ppm	183.5 de	192.7 bcd	**188.1 C**	51.6 cde	53.4 cd	**52.5 B**
BA 10 ppm	206.3 abc	221.8 a	**214.1 A**	56.7 abc	61.3 a	**59.0 A**
IAA 50 ppm	155.9 f	174.6 ef	**165.3 D**	43.5 f	48.4 e	**46.0 C**
IAA 100 ppm	177.5 de	185.2 de	**181.4 C**	50.7 de	51.3 de	**51.0 B**
GA_3 100 ppm	187.3 cde	194.4 bcd	**190.9 C**	52.1 cde	54.0 bcd	**53.1 B**
GA_3 200 ppm	195.3 bcd	211.7 ab	**203.5 B**	54.6 bcd	58.8 ab	**56.7 A**
Mean	**176.5 B**	**190.8 A**		**49.3 B**	**52.9 A**	
			2019 Season			
Control	132.7 h	144.5 gh	**138.6 F**	37.2 h	40.1 gh	**38.7 E**
BA 5 ppm	188.1 de	201.7 bc	**194.9 B**	52.3 cd	56.5 bc	**54.4 B**
BA 10 ppm	217.3 ab	230.0 a	**223.7 A**	61.4 ab	63.9 a	**62.7 A**
IAA 50 ppm	153.7 fg	170.2 ef	**162.0 E**	40.9 gh	47.0 ef	**44.0 D**
IAA 100 ppm	162.0 fg	182.3 de	**172.2 D**	45.0 fg	50.6 de	**47.8 D**
GA_3 100 ppm	176.2 de	191.5 cd	**183.9 C**	48.8 def	52.9 cd	**50.9 C**
GA_3 200 ppm	190.8 de	204.3 b	**197.6 B**	53.0 cd	57.2 bc	**55.1 B**
Mean	**174.4 B**	**189.2 A**		**48.4 B**	**52.6 A**	

Values followed by the same letter (s) are not significantly different at 5% level.

Macro- and micro-elements

Data in Table 5 show the effect of spraying of BA, IAA, and GA_3 on the levels of N, P, K and Fe, Zn, Mn of sweet basil leaves in 2018 and 2019 seasons.

Nitrogen recorded 1.91 and 1.84% with unsprayed sweet basil plants in the first and second seasons, respectively whereas N reached 2.57% due to the application of plant growth regulators. However, the highest values of N (2.57 and 2.38%) were recorded with BA at 10 ppm in the two studied seasons. However, 5 ppm of BA and GA_3 at 200 ppm greatly increased N and came next after 10 ppm BA treatments. P and K percentages were increased with applied treatments except IAA at 100 ppm and GA_3 at 100 ppm with P in both studied seasons. However, all applied treatments increased K in sweet basil leaves than control except IAA at 50 or 100 ppm and GA_3 at 100 ppm which did not differ significantly than control in both studied seasons. Generally, it could be concluded that BA at 10 ppm treatment was effective in increasing N, P and K in sweet basil leaves and consequently improved the nutritive value of sweet basil herbs.

The effect of growth regulators spraying on Fe, Zn and Mn content of sweet basil leaves was clear during the two studied seasons. All applied treatments increased Fe content than the control, where the highest Fe content values were obtained by BA at 10 ppm and GA_3 at 100 ppm in both studied seasons. On the contrary, the treatment of IAA 100 ppm exhibited similar non-significant values to the control in both seasons. Data of Zn content were fluctuated in both seasons, where in the first season the higher values were recorded by BA at 5 ppm whereas, in the second season the highest values were recorded by BA at 10 ppm and GA_3 at 200 ppm. However, the treatment of IAA at 100 ppm recorded similar values of Zn content to the control in both seasons. Mn content data show that all treatments were negatively affected Mn content except IAA at 100 ppm or GA_3 at 100 ppm to content in both seasons. The highest values of Mn contents were recorded with BA at 10 ppm in both seasons, whereas the least values were recorded by IAA at 100 ppm in both seasons. Generally, it could be concluded that spraying of BA at 10 ppm increased Fe and Mn in sweet basil leaves, whereas BA at 5 ppm was effective in increasing Zn content.

TABLE 5. Effect of BA, IAA and GA3 spraying on some macro- and micro-elements of sweet basil leaves of the second cut in 2018 and 2019 seasons.

Treatments	Macro-elements (%)			Micro-elements (ppm)		
	N	P	K	Fe	Zn	Mn
			2018 Season			
Control	1.91 d	1.23 d	0.56 d	246.3 d	52.44 d	74.11 d
BA 5 ppm	2.34 ab	1.54 b	0.67 bc	312.4 c	78.07 a	97.24 ab
BA 10 ppm	2.57 a	1.73 a	0.78 a	381.7 a	74.21 ab	103.16 a
IAA 50 ppm	2.06 cd	1.46 bc	0.60 cd	305.8 c	58.93 c	87.15 bc
IAA 100 ppm	1.97 cd	1.31 cd	0.54 d	274.2 d	57.61 cd	78.39 cd
GA_3 100 ppm	2.13 bc	1.37 cd	0.61 cd	325.7 bc	63.45 c	83.12 cd
GA_3 200 ppm	2.28 b	1.60 ab	0.73 ab	354.8 ab	70.38 b	94.75 ab
			2019 Season			
Control	1.84 d	1.17 c	0.50 c	227.4 c	54.71 d	79.31 d
BA 5 ppm	2.29 ab	1.61 a	0.63 ab	307.5 b	66.12 b	95.46 b
BA 10 ppm	2.38 a	1.68 a	0.69 a	365.9 a	75.41 a	108.32 a
IAA 50 ppm	2.05 c	1.39 b	0.56 bc	288.3 b	62.51 bc	90.87 bc
IAA 100 ppm	1.93 cd	1.24 bc	0.52 c	253.4 c	58. 94 cd	83.88 cd
GA_3 100 ppm	2.11 bc	1.25 bc	0.52 c	310.6 b	60.63 bc	85.62 bcd
GA_3 200 ppm	2.26 ab	1.56 ab	0.64 ab	342.7 a	72.19 a	91.80 bc

Values followed by the same letter (s) are not significantly different at 5% level.

Chemical constituents

It is clear from data in Table 6 that chemical constituents of sweet basil herb which expressed as active ingredients were increased with the used growth regulators but in varied trend. However, total phenols were increased with all used treatments than the control, and the highest values were recorded by IAA at 100 ppm, IAA at 50 ppm and BA at 10 ppm in both studied seasons without significant differences between them. Total flavones were increased with all treatments than the control except the treatment of GA_3 at 100 ppm in the first season and BA at 5 ppm and GA_3 at 100 ppm in the second season. The values of total flavones increased from 10.75 mg/g d.wt in the control to 15.98 mg/g d.wt in IAA at 100 ppm (data of the first season). Total chlorophyll values were superior with both treatments of IAA in both seasons, whereas the treatments of BA at 5 ppm, GA_3 at 50 at 100 exhibited similar non-significant values to the control in both seasons.

However, L-ascorbic acid values greatly improved due to the growth regulator application on sweet basil plant in both seasons. However, L-ascorbic acid increased from 18.54 mg/100 g fresh weight in the control to 27.15 mg/100 g fresh weight in IAA 100 ppm treatments (data of the first season). However, BA at 5 ppm exhibited similar non-significant values to the control in both seasons, whereas the highest values of L-ascorbic acid were recorded with both treatments of IAA and GA_3 at 200 ppm without significant differences between them in both studied seasons.

Traditionally, sweet basil has been used as a medicinal plant in the therapy of headaches, coughs, diarrhea, constipation, warts, worms, and kidney malfunction (Kaurinovic et al., 2011). However, it has been found that sweet basil leaves are rich in phenolic compounds (rosmarinic, chicoric, caeic, and caftaric), flavonol (quercetin, kaempferol) glycosides and anthocyanins (Ghasemzadeh et al., 2014).

Winkel-Shirley (2002) reported that the quantitative and qualitative components of the phytochemicals in basil leaves can vary within wide ranges and depend on both cultivation conditions and the variety of basil. Mineral plant nutrition is one of the main factors influencing plant metabolism and the level of secondary metabolites. Flavonoids, which are important secondary metabolites in plants, are involved in resist in environmental stress and regulating the growth of plants. Also, Koes et al. (2005) explained that abundant values in leaves, flowers, fruits, and roots, play important roles in herbal medicines and healthy food products. The biosynthesis of flavonoids in plants begins with the shikimate pathway, and intermediate products, such as chalcone and isoflavonoids, are formed *via* the phenylpropanoid pathway

In another study by Bota and Deliu (2015) showed that the addition of 0.1 mg/l NAA and 1 mg/l BA to a cell suspension culture of *Digitalis lanata* (Grecian foxglove) increased the production of flavonoids, which are related to secondary metabolite production. Furthermore, Sharma and Kumar (2011) claimed that gibberellic acid increased the biosynthesis of several secondary metabolites like steroids, terpenoids, and anthocyanins.

Volatile oil percentage and volatile oil content

Data in Table 7 show that volatile oil percentage in sweet basil herb greatly affected with the applied treatments than the control where it increased from 0.12% in the control to 0.38% in the used treatments. The highest values of volatile oil (0.38 and 0.44%) were recorded with IAA at 100 ppm in the first and second seasons, respectively. Generally, it could be noticed that the effect of applied plant growth regulators on volatile oil percentage of sweet basil herb was varied, where IAA was superior followed by GA_3 where BA came later in this respect. In addition, the second cut of sweet basil herbs produced high volatile oilpercentage than the first cut with significant differences between them in both seasons.

Interaction values showed that the highest values of volatile oil percentage (0.42 and 0.46%) were recorded with IAA at 100 ppm in the second cut of both seasons.

The productivity of volatile oil content per plant exhibited a similar trend to those found in volatile oil percentage. The highest values of volatile oil content/plant (0.62 and 0.59 ml/plant) were recorded with IAA at 100 ppm treatments in both first and second seasons, respectively.

Generally, it could be concluded that the application of plant growth regulators on sweet basil plants was effective in increasing volatile oil content per plant but IAA at both used concentrations was more effective than GA_3 or BA in this respect. The second cut was superior to the first one in increasing volatile oil content/ plant with significant differences between them in both studied seasons. Interaction values showed that IAA at 100 produced the highest values of volatile oil content (0.66 and 0.63 ml/plant) in the second cut of both studied seasons.

Volatile oil components

Data presented in Table 8 show the effect of plant growth promoters applied to sweet basil plant on volatile oil fractions in the second cut of the second season only.

All applied treatments exhibited high values of total components than the control. The main components, in general, were 1.8-cineole, linalool, bergameotene, germacrene, and muurolol. The highest values of 1,8 cineole (5.90%) was recorded by GA_3 at 100 ppm, whereas Linalool, the main active substance in sweet basil plant (50.90%) was superior in IAA at 100 ppm. The highest value of bergamotene (8.20%) was recorded by GA_3 at 200 ppm. Germacrzne (3.50%) was recorded by IAA at 50 ppm and the highest value of muurolol (4.60%) was recorded by both treatments of IAA. Generally, it could be concluded that linalool as main active ingredient of sweet basil was increased by all applied treatments than control.

The essential oils distilled from various basil cultivars can envolve linalool, methyl chavicol, 1,8-cineole, eugenol, methyl eugenol, methyl isoeugenol, thymol, methyl cinnamate, citral, and camphor (Zabka et al., 2014). On another study by Marotti et al. (1996) who found that the high economic value of basil oil is attributable to the existence of phenyl propanoids, like eugenol, chavicol and their derivatives or terpenoids like monoterpen alchole linalool, methyl cinnamate, and limonene.

Affonso et al. (2007) mentioned that BA has also been used to enhance the growth and expansion of aromatic plants. Utilization *Lantana camara* L. plants with BA at 0.44 and 4.4 µmol/L raised volatile organic ingredient (VOC) production, which was detected by solid phase micro-extraction. Similarly, Zielińska et al. (2011) pointed the volatile oil yield increased with the utilization of many PGRs, such as indole-3-acetic acid (IAA), thidiazuron, kinetin, and BA when applied to *Agastache rugosa.* It is regular that essential oils are the most important raw substances of the fragrance and aroma industry. They are also used in the food and pharmaceutical industries due to their therapeutic, antimicrobial and antioxidant activities. Nevertheless, they have biological activities that make them able to be used as herbicides, pesticides and anticancer compounds (Burfield and Reekie, 2005)**.** However, Taiz and Zeiger (2010) reported that the essential oils are related to plant defense and pollinator attraction among other ecological functions. As other secondary metabolites groups, these compounds play an important role in the plant's fitness under environmental variation. For this reason, a common problem that occurs in aromatic plants cultivation is the quantitative and qualitative variation in response to the environment.

The content and composition of basic oils are highly impacted by outer factors and cultural practices. In Morocco, the *Ocimum* genus and specifically *O. gratissimum L* species are widely used in traditional medicine. Basic oils of this species play a very important role in international oil marketing. The antibacterial action of basil essential oil raises by the increase in levels of methyl chavicol (Pessoa et al., 2002)**.** The heterogeneity of oils may also be obtained by the synergistic effect of the different compounds (Ngassoum et al., 2003).

Salah El-Deen (1996) studied the effect of GA, IAA, and kinetin on yield and composition of basic oils of *O. basilicum*. They showed that the GA leads to the decrease in essential oil yield while kinetin and IAA increased the yield. This change is accompanied by a decrease in levels of the main compound (methyl chavicol) for all treatments (from 75.16% in the control to 74.1%, 73.2% and 70.7% in kinetin, IAA and GA respectively). The same observation was made by Fraternale et al. (2003) who found that spraying plants *Thymus mastichina* by cytokinin caused an increase in the concentration of essential oils.

TABLE 6. Effect of BA, IAA and GA3 spraying on total phenols, total flavones, total chlorophyll and L- ascorbic acid of sweet basil plants of the second cut in 2018 and 2019 seasons.

Treatments	Total phenols (mg/g d.w.)	Total flavones (mg/g. d.w.)	Total chlorophyll (mg/100g f.w.)	L- ascorbic acid (mg/100g f.w.)
		2018 Season		
Control	16.82 e	10.75 d	7.09 cd	18.54 d
BA 5 ppm	21.48 cd	12.36 c	7.88 bc	20.17 cd
BA 10 ppm	25.11 ab	13.86 b	8.25 b	23.08 bc
IAA 50 ppm	25.94 ab	14.71 b	9.21 a	25.20 ab
IAA 100 ppm	27.62 a	15.98 a	9.77 a	27.15 a
GA_3 100 ppm	19.57 d	11.51 cd	7.13 cd	21.94 c
GA_3 200 ppm	23.75 bc	14.93 ab	6.25 d	24.84 ab
		2019 Season		
Control	18.12 e	11.23 c	6.87 d	16.29 d
BA 5 ppm	20.06 de	12.21 c	7.69 cd	17.84 cd
BA 10 ppm	24.77 ab	14.42 ab	8.45 bc	21.15 b
IAA 50 ppm	24.51 ab	14.06 ab	9.58 a	24.58 a
IAA 100 ppm	26.75 a	15.02 a	10.13 a	25.27 a
GA_3 100 ppm	21.95 cd	12.15 c	7.54 cd	20.36 bc
GA_3 200 ppm	23.35 bc	13.54 b	7.11 d	22.47 ab

Values followed by the same letter (s) are not significantly different at 5% level.

TABLE 7. Effect of BA, IAA and GA3 spraying on volatile oil percentage and volatile oil content of sweet basil plant in 2018 and 2019 seasons.

Treatments	Volatile oil (%)		Mean	Volatile oil content (ml/ plant)		Mean
	1st cut	2nd cut		1st cut	2nd cut	
			2018 Season			
Control	0.11 g	0.13 g	**0.12 E**	0.21 g	0.22 g	**0.22 E**
BA 5 ppm	0.19 f	0.22 f	**0.21 D**	0.30 fg	0.35 ef	**0.33 D**
BA 10 ppm	0.24 ef	0.27 de	**0.23 CD**	0.38 def	0.43 de	**0.41 C**
IAA 50 ppm	0.34 bc	0.38 ab	**0.36 A**	0.54 bc	0.62 ab	**0.58 AB**
IAA 100 ppm	0.37 ab	0.42 a	**0.38 A**	0.58 ab	0.66 a	**0.62 A**
GA_3 100 ppm	0.24 ef	0.28 de	**0.26 BC**	0.37 ef	0.44 de	**0.41 C**
GA_3 200 ppm	0.30 cd	0.35 bc	**0.33 AB**	0.48 cd	0.55 bc	**0.52 B**
Mean	**0.25 B**	**0.29 A**		**0.41 B**	**0.47 A**	
			2019 Season			
Control	0.09 f	0.12 g	**0.11 E**	0.15 g	0.19 g	**0.17 E**
BA 5 ppm	0.22 e	0.27 de	**0.25 D**	0.25 fg	0.32 ef	**0.29 D**
BA 10 ppm	0.24 e	0.31 cd	**0.28 CD**	0.39 de	0.44 cd	**0.42 C**
IAA 50 ppm	0.33 cd	0.40 ab	**0.37 B**	0.45 cd	0.56 ab	**0.51 B**
IAA 100 ppm	0.42 a	0.46 a	**0.44 A**	0.55 ab	0.63 a	**0.59 A**
GA_3 100 ppm	0.27 de	0.30 cd	**0.29 CD**	0.42 cd	0.46 bc	**0.44 BC**
GA_3 200 ppm	0.28 de	0.35 bc	**0.32 BC**	0.43 cd	0.51 bc	**0.47 BC**
Mean	**0.26 B**	**0.32 A**		**0.38 B**	**0.44 A**	

Values followed by the same letter (s) are not significantly different at 5% level.

TABLE 8. Effect of BA, IAA and GA3 spraying on volatile oil fractions of sweet basil plant in the second cut in 2019 season.

No.	Component name	Area %							
		RI	Control	BA 5 ppm	BA 10 ppm	IAA 50 ppm	IAA 100 ppm	GA_3 100 ppm	GA_3 200 ppm
1.	á-pinene	936	1.04	1.02	0.90	1.13	1.21	1.08	1.03
2.	Sabinene	975	0.43	0.50	0.60	0.68	0.70	0.62	0.66
3.	β-pinene	977	1.33	1.42	1.50	1.28	1.43	1.30	1.28
4.	Myrcene	995	0.90	0.88	1.00	1.07	1.13	1.03	1.12
5.	1,8-cineole	1037	5.88	5.86	5.83	5.00	5.33	5.90	4.93
6.	Linalool	1110	48.80	48.20	49.20	49.20	50.90	49.60	50.70
7.	Camphor	1145	0.88	0.91	0.88	1.12	1.20	1.14	1.28
8.	ϭ-terpineol	1170	0.42	0.43	0.52	0.46	0.48	0.47	0.42
9.	á-terpineol	1192	1.80	1.82	1.80	1.68	1.73	1.73	1.80
10.	Bornyl acetate	1288	0.74	0.73	0.72	0.82	0.88	0.84	0.83
11.	Eugenol	1348	1.12	1.10	1.73	1.86	1.88	1.63	0.60
12.	â-elemene	1389	1.92	1.90	1.83	1.88	1.98	1.68	1.73
13.	á-trans-bergamotene	1434	7.40	7.36	7.20	6.60	6.80	7.80	8.20
14.	á-guaiene	1439	0.72	0.70	0.63	0.81	0.88	0.72	0.76
15.	á-humulene	1455	0.72	0.63	0.72	0.71	0.80	0.62	0.63
16.	â-farnesene	1462	1.30	1.40	1.30	1.21	1.33	1.42	1.43
17.	Muurola-4(14),5-diene	1465	0.83	0.82	0.80	0.92	0.93	0.88	0.89
18.	Germacrene D	1488	3.32	3.43	3.20	3.50	3.30	3.33	3.40
19.	Bicyclogermacrene	1502	0.77	0.70	0.82	0.90	0.93	0.82	0.81
20.	á-bulnesene	1510	1.30	1.40	1.20	1.32	1.23	1.41	1.42
21.	ϒ-cadinene	1512	1.62	2.41	2.10	2.33	2.50	2.20	1.80
22.	â-sesquiphellandrene	1520	0.43	0.40	0.42	0.49	0.48	0.38	0.36
23.	Spathulenol	1579	0.76	0.70	0.80	0.83	0.83	0.81	0.84
24.	1,10-di-epi-cubenol	1618	1.12	1.10	1.00	1.12	1.10	1.00	1.12
25.	á-muurolol	1644	3.40	3.80	4.30	4.60	4.60	4.30	4.20
26.	â-eudesmol	1650	0.68	0.63	0.80	0.88	0.73	0.82	0.84
	Total	89.63	90.25	91.80	92.40	91.80	95.29	93.53	93.00
Unknown		10.37	9.75	8.20	7.60	8.20	4.71	6.47	7.00

Conclusion

It could be concluded that spraying of growth regulators like BA, IAA, and GA_3 were effective in improving growth, active substances and volatile oil productivity of sweet basil plants. However, BA at 5 or 10 ppm were effective in improving vegetative growth parameters and leaf mineral contents, whereas IAA at 50 or 100 ppm were superior in increasing active substances, volatile oil percentage and volatile oil content/ plant. Additionally, IAA at 100 ppm exhibited higher values of volatile oil fractions especially linalool.

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References

A.O.A.C. (2005) *Official Methods of Analysis* of the association of official analytical chemists, 12th ed., Washengton , D.C., USA.

Affonso, V.R., Bizzo, H.R, De Lima, S.S., Esquibel, M.A. and Sato, A. (2007) Solid phase microextraction (SPME) analysis of volatile compounds produced by *in vitro* shoots of *Lantana camara* L. under the influence of auxins and cytokinins. *J. Braz. Chem. Soc.*, **18**, 1504–1508.

Al-khassawneh, N.M., Karam, N.S., and Shibli, R.A. (2006) Growth and flowering of black iris (*Iris nigricans* Dinsm) flowering treatment with plant growth regulators. *Sci. Hort.*, **107**,187–193.

Ansari, S.H., Qadry, J.S. and Jain, V.K. (1988) Effect of plant hormones on the growth and chemical composition of volatile oil of *Cymbopogon jwarancusa* (Schutt). *Indian J. Foresty*, **11**, 143-145.

Aslan, I., Özbck, H., Çalmaşur, O. and Şahin, F. (2004) Toxicity of essential oil vapours to two greenhouse pests, *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. Industrial Crops and Products, **19**,167-173.

Bais, H.P., Sudha, G., George, J. and Ravishankar, G.A. (2001) Influence of exogenous hormones on growth and secondary metabolite production in hairy root cultures of *Cichorium intybus* L. cv. Lucknow Local. *In Vitro Cell Dev.*, **37**, 101-132.

Berbeć, S., Andruszczak, S., Łusiak, J. and Sapko, A. (2003) Effect of foliar application of Atonik and Ekolist on yield and quality of common thyme. *Acta Agrophysica*, **83**, 305-311.

Biesiada, A. and Kuś, A. (2010) The effect of nitrogen fertilization and irrigation on yielding and nutritional status of sweet basil (*Ocimum basilicum* L.). *Acta Sci. Pol., Hortorum Cultus*, **9** (2), 3–12.

Bota, C. and Deliu, C. (2015) Effect of plant growth regulators on the production of flavonoids by cell suspension cultures of *Digitalis lanata. Farmacia*, **63**, 716–719.

Bowers, W.S. and Nishida. R. (1980) Juvocirnenes: Potent juvenile hormones mimics from sweet basil. *Science*, **209**,1030-1032

Bozin, B., Miniica-Dukic, N., Simi, N. and Anackov, G. (2006) Characterization of the volatile composition of essential oils of some lamiaceae spices and the antimicrobial and antioxidant activities of the entire oils. *J. Agr. Food Chem.*, **54**,1822-1828

Briant, R.E. (1974) An analysis of the effects of gibberellic acid on tomato leaf growth. *J. exp. Bot.*, **25**, 764–771.

Bringham, F.T. (1982) Methods of Soil Analysis, (ed.), Part 2., *Agronomy*, **9**,431-447.

Brooking, I.R. and Cohen, D. (2002) Gibberellin induced flowering in small tubers of *Zantedeschia* "Black Magic". *Sci. Hort.*, **95**, 63–73.

Burfield, T. and Reekie, S.L. (2005) Mosquitoes, malaria and essential oils. *Intern. J. Aromather*, **15**, 30-41.

Carvajal, M. and Alcaraz, C.F. (1998) Why titanium is a beneficial element for plants. *J. Plant Nutr.*, **21**,655-664.

Chapman, H.D. and Pratt, P.R. (1982) *Methods of Analysis for Soils, Plants, and Waters*, University of California,Division of Agricultural Sciences, 309 p.

Charles, D.J. and Simon, J.E. (1990) Comparison of extraction methods for the rapid determination of essential oil content and composition of basil (*Ocimum spp*.). *J. Amer. Soc. Hort. Sci.*, **115**(3), 458–462.

Coste, A., Vlase, L., Halmagyi, A., Deliu, C. and Coldea, G. (2011) Effects of plant growth regulators and elicitors on production of secondary metabolites in shoot cultures of *Hypericum hirsutum* and *Hypericum maculatum*. *Plant Cell Tissue Organ Cult.*, **106**, 279–288.

Davies, P.J. (2013) Plant Hormones: Physiology, Biochemistry and Molecular Biology, Springer Science & Business Media: Berlin, Germany, Cornell University: Ithaca, NY, USA, pp. 1–779.

Dixon, R.A., Achnine, L., Kota, P., Liu, C.J., Reddy, M. and Wang, L. (2002). The phenylpropanoid pathway and plant defense. A genomics perspective. *Mol. Plant Pathol.*, **3**, 371–390.

Eid, R.A. and Abou-Leila, B.H. (2006). Response of croton plants to gibberellic acid, benzyl adenine and ascorbic acid application. *World J. Agric. Sci.*, **2**,174–179.

Elgayyar, M., Draughon, F.A., Golden, D.A. and Mount, J.R. (2001) Antimicrobial activity of essential oils from plants against selected pathogenic and saprophytic microorganisms. *J. Food Prot.*, **64**,1019-1024.

El-Sayed, A.A., Salem, M.A. and El-Maadawy, E.I. (1989) Effect of gibberellic acid (GA_3) and benzyladenine (BA) on *Polianthus tuberosa* L. *J. Agric. Res., Tanta Univ.*, **15**,301-311.

Eraki, M.A. (1994) The effect of gibberellic application and chelated iron nutrition on the growth and flowering of Queen Elizabeth rose plants. *The first Conf. of Ornamental Hort.*, **2**,436-444.

Fraternale, D., Giamperi, L., Ricci, D., Rocchi, M.L., Guidi, L., Epifano, F. and Marcotullio, F.C. (2003). The effect of triacontanol on micropropagation and on secretory system of *Thymus mastichina. Plant Cell Tissue Organ Cult.*, 74, 87-97.

Fu, J., Sun, X., Wang, J., Chu, J. and Yan, C. (2011) Progress in quantitative analysis of plant hormones. *Chin. Sci. Bull.*, **56**, 355–366.

Georg, E.F., Hall, M.A. and De Klerk, G.J. (2008) Plant Propagation by Tissue Culture, 3rd Edition. Springer. Netherlands. pp: 175 - 204.

Gershenzon, J. (1994) Metabolic costs of terpenoid accumulation in higher plants. *J. Chem. Ecol*., **20**,1281–1328.

Ghasemzadeh, A., Nasiri, A., Jaafar, H.Z., Baghdadi, A. and Ahmad, I. (2014) Changes in phytochemical synthesis chalcone synthase activity and pharmaceutical qualities of Sabah snake grass (*Clinacanthus nutans* L.) in relation to plant age. *Molecules*, **19**, 17632–17648.

Guebel, D.V., Nudel, B.C. and Giuletti, A.M. (1991) A simple and rapid micro-Kjeldahl method for total nitrogen analysis. *Biotechnol. Tech.*, **5**(6), 427–430.

Hassan, E.A and El-Quesni, F.M. (1989) Application of growth regulators in agriculture. A cytokinin-induced new morphogenetic phenomena in carnation (*Dianthus caryophyllus* L). *Bull. Fac. Agric, Cairo Univ.*, **40**,187-196.

Hassanein, M.A.(1985) Effect of some growth regulators and potassium fertilizers on growth, yield and essential oil production of geranium plants (*Pelargonium graveolens* L). *M.Sc. Thesis*, Fac. Agric, Cairo University.

Javanmardi, J., Khalighi, A., Kashi, A., Bais, H.P. and Vivanco, J.M. (2002) Chemical characterization of basil (*Ocimum basilicum* L.) found in local accessions and used in traditional medicines in Iran. *J. Agr. Food Chem.*, **50**, 5878-5883.

Kaurinovic, B., Popovic, M., Vlaisavljevic, S. and Trivic, S. (2011) Antioxidant capacity of *Ocimum basilicum* L. and *Origanum vulgare* L. extracts. *Molecules*, **16**, 7401–7414.

Khan, A.F., Mujeeb, F., Aha, F. and Farooqui, A. (2015) Effect of plant growth regulators on growth and essential oil content in palmarosa (*Cymbopogon martinii*). *Asian J. Pharm. Clin. Res.*, **8** (2), 373-376.

Khan, A.S and Chaudhry, N.Y. (2006) GA_3 improves flower yield in some cucurbits treated with lead and mercury. *J. Biotech.*, **5**, 149-153.

Koes, R., Verweij, W. and Quattrocchio, F. (2005) Flavonoids: A colorful model for the regulation and evolution of biochemical pathways. *Trends Plant Sci.*, **10**, 236–242.

Kristinsson, K.G., Magnusdottir, A.B., Petersen, H. and Hermansson A. (2005) Effective treatment of experimental acute otitis media by application of volatile fluids into the ear canal. *J. Infect. Dis.*, **191**,1876-1880.

Krug, B.A., Whipker, B.E., McCall, I. and Dole, J.M. (2006) Narcissus response to plant growth regulators. *Hort. Technology*, **16**, 129–132.

Marotti, M., Piccaglia, R. and Giovanelli, E. (1996) Differences in essential oil composition of (*Ocimum basilicum* L.) Italian cultivars related to morphological characteristics. *J. Agr. Food Chem.*, **44**(19), 3926-3929.

Mazrou, M.M., Afify, M.M., El-Kholy, S.A. and Morsy, G.A. (1994). Physiological studies on *Ocimum bosillicum* L. plant. I. Influence of kinetin application on the growth and essential oil content. Menofiya. *J. Agric. Res.*, **19**,421-434.

Menesi, F.A., Nofal, E.M. and El-Mahrouk, E.M. (1991) Effect of some growth regulators on *Calendula officinalis* L. *Egypt. J. Appl. Sci.*, **6**,1-15.

Moran, R. and Porath, D. (1980) Chlorophyll determination in intact tissues using N,N-351 dimethyl formamide. *Plant Physiology*, **65**, 478-479.

Ngassoum, M.B., Essia-Ngang, J.J., Tatsadjieu, L.N., Jirovetz, L., Buchbauerc, G. and Adjoudji, O. (2003) Antimicrobial study of essential oils of *Ocimum gratissimum* leaves and *Zanthoxylum xanthoxyloides* fruits from Cameroon. *Fitoterapia*, **74**, 284-287.

Novak, J., Jan, L., Friedrich, P. and Chlodwig, M.F. (2002). Essential oil compounds in a historical sample of marjoram (*Origanum majorana* L., Lamiaceae). *Flavour and Fragrance Journal*, **17**, 175–180.

Pessoa, L.M., Morais, S.M., Bevilaqua, C.M. and Luciano, H.S. (2002). Anthelmintic activity of essential oil of *Ocimum gratissimum* Linn. and eugenol against *Haemonchus contortus*. *Vet. Parasitol.*, **109**, 59-63.

Saffari, V.R., Khalighi, A.D., Lesani, H.N., Babalar, M.H. and Obermaier, J.F. (2004) Effects of different plant growth regulators and time of pruning on yield components of *Rosa damascen*a Mill. *Int. J. Agric. Biol.*, **6**, 1040–1042.

Salah El-Deen, M. (1996) Response of growth and essential oil content of sweet basil *(Ocimum basilicum* L) To some naturel hormones. Proceeding int. Symp. Medicinal and Aromatics plants. Acta Hort. H26, ISHS.

Sangwan, N.S., Farooqi, A.H., Shabih, F. and Sangwan, R.S. (2001) Regulation of essential oil production in plants. *Plant Growth Regul.*, **34**, 03-21.

Santner, A., Calderon-Villalobos, L.I. and Estelle, M. (2009) Plant hormones are versatile chemical regulators of plant growth. *Nature Chemical Biology*, **5** (5), 301-308.

Sharma, H. and Kumar, A. (2011) Effect of plant growth regulators and chemical fertilizers on growth and productivity of *Chlorophytum tuberosum and Pergularia daemia*. *Journal of Medicinal Plants Res.*, **5** (13), 2647- 2651.

Shedeed, M.R., Gamassy, K.M., Hashim, M.E. and Almulla, A.M. (1991) Effect of fulifirtil fertilization and growth regulators on the vegetative growth of croton plants. *Annals Agric. Sci., Ain. Shams Univ.*, *Cairo*, **36**, 209-216.

Shudok, R. (1994) Chemistry of phenylurea cytokinins. In *Cytokinins: Chemistry, Activity and Function*, Mokk, D.V. and Mc Mok (Ed.). CRC Press, Boca Raton. pp: 35-42.

Singletary, K.W. (2018) Basil: A brief summary of potential health benefits. *Nutr. Today*, **53**, 92–97.

Singleton, V. and Rossi, J.R. (1965). Colorimetry of total phenolics with phosphomonolybdic phosphotungstic acid reagents. *Am. J. Enol. Vitic.*, **16**, 144-158.

Snedecor, G.W. and Cochran, W.G. (1990) *Statistical Methods*.11th ed., Iowa State College Press. Ames, Iowa, U.S.A. pp. 369-373.

Srivastava, N.K. and Srivastava, A.K. (2007) Influence of gibberellic acid on $^{14}CO_2$ metabolism, growth, and production of alkaloids in *Catharanthus roseus*. *Photosynthetica*, **45**, 156-160.

Suppakul, P., Miltz, J., Sonneveld, K. and Bigger, S.W. (2003) Antimicrobial properties of basil and its possible application in food packaging. *J. Agr. Food Chem.*, **51**, 3197-3207.

Taie, H.A., Salama, Z.A. and Radwan, S. (2010) Potential activity of basil plants as a source of antioxidant and anticancer agents as affected by organic and bio-organic fertilization. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **38**(1), 119-127.

Taiz, L. and Zeiger E. (2010) *Plant Physiology*, 5th ed., Sunderland, MA: Sinauer Associates., 782 p.

Trevisan, M.T., Silva, M.G., Pfundstein, B., Spiegelhalder, B. and Owen, R.W. (2006) Characterization of the volatile pattern and antioxidant capacity of essential oils from different species of the genus *Ocimum*. *J. Agr. Food Chem.*, **54**,4378-4382.

Waller, R.A. and Duncan, D.B. (1969) A Bayes rule for the symmetric multiple comparisons problem. *Journal of the American Statistical Association*, **64**(328), 1484-1503.

Westerman, R.L. (1990) Soil Testing and Plant Analysis. (3rd ed.) Soil Science Society of America, Inc. Madison Wisconsin, USA.

Winkel-Shirley, B. (2002) Biosynthesis of flavonoids and effects of stress. *Curre. Opin. Plant Biol.*, **5**, 218–223.

Zabka, M., Pavela, R. and Prokinova, E. (2014) Antifungal activity and chemical composition of twenty essential oils against significant indoor and outdoor toxigenic and aeroallergenic fungi. *Chemosphere*, **112**,443–448.

Zheljazkov, V.D., Callahan, A. and Cantrell, C.L. (2008) Yield and oil composition of thirty-eight basil (*Ocimum basilicun*, L.) accessions grown in Mississippi. *J. Agr. Food Chem.*, **56**, 241-245.

Zhishen, J., Mengcheng, T. and Jianming, W. (1999) The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chem.*, **64**, 555–559.

Zielińska, S., Piątczak, E., Kalemba, D. and Matkowski, A. (2011) Influence of plant growth regulators on volatiles produced by *in vitro* grown shoots of *Agastache rugosa* (Fischer & CA Meyer) *O. Kuntze*. *Plant Cell Tissue Organ Cult.*, **107**, 161–167.

تأثير البنزيل أدينين والأندول حمض الخليك وحمض الجبريلك على النمو الخضري والمركبات الكيميائية وخصائص الزيت الطيار لنباتات الريحان

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تم رش بنزيل الأدينين وأندول حمض الخليك وحمض الجبريليك بتركيزات مختلفة لدراسة تأثيرعلى النمو والمكونات الكيميائية والزيوت المتطايرة للريحان في موسمي ٢٠١٨ و ٢٠١٩.
تحسن بشكل كبير طول النبات، عدد الأوراق/نبات، متوسط مساحة الورقة، والوزن الطازج والجاف للعشب/نبات مع المعاملات وخاصة معاملات وأندول حمض الخليك ويليها معاملات حمض الجبريليك. ومع ذلك، زادت عدد الفروع الجانبية/نبات، قطر الساق بمعاملات بنزيل الأدينين خاصة بتركيز ١٠ جزء في المليون عنه بتركيز ٥ جزء في المليون. بشكل عام، كان الحشة الثانية متفوقة في صفات النمو الخضري المدروسة عن الحشة الأولى. وسجلت أعلي القيم من النيتروجين، الفوسفور، البوتاسيوم، الحديد والمنجنيز عند المعاملة بالبنزيل أدينين بتركيز ١٠ جزء في المليون في حين سجلت أعلي قيم من الزنك عند المعاملة بالبنزيل أدينين بتركيز ٥ جزء في المليون. زادت بشكل كبير المواد الفعالة مثل الفينولات الكلية، الفلافونات الكلية، الكلوروفيل الكلي، وحمض الأسكوربيك بالمعاملة بأندول حمض الخليك بتركيز ٥٠ أو ١٠٠ جزء في المليون عن باقي المعاملات الأخرى أو معاملة المقارنة. و مع ذلك، فإن النسبة المئوية للزيت الطيار ومحتوى الزيت الطيار لكل نبات قد زادت زيادة واضحة عند المعاملة بأندول حمض الخليك بتركيز ٥٠ أو ١٠٠ جزء في المليون يليها المعاملة بحمض الجبريليك بتركيز ٢٠٠ جزء في المليون. و كانت أعلي القيم في الحشة الثانية عنها في الحشة الأولى في النسبة المئوية ومكونات الزيت الطيار لكلا الموسمين تحت الدراسة.

وكانت المكونات الرئيسية الموجودة في الزيت الطيار مثل ١,٨ سينيول، الليناليول، ألفا ترانس برجاموتين، جيرماسيرين و ألفا مورلول. و كانت أعلي القيم لليناليول (المركب الاساسي) في الزيت الطيار في الريحان (٥٠,٩٠ ٪) عند المعاملة مع الاندول حمض الخليك بتركيز ١٠٠ جزء في المليون.