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Research Article
Morphological and Chemical Characters of *Petroselinum crispum* (Mill) Subjected to Some Biostimulants

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Abstract

Background and Objectives: Parsley herb has various biological properties and used in food and pharmaceutical industries. Biostimulants represent one area of research that has the potential to increase medicinal and aromatic plants (MAP) productivity. The aim of this study was to evaluate the growth and chemical composition of parsley plant under some biostimulants treatments. **Materials and Methods:** Parsley plants were subjected to different concentrations of L-tryptophan (LTRYP, 100 and 200 mg L^{-1}), trans-cinnamic acid (TCA, 10 and 20 mg L^{-1}) and distilled water as control. Plant growth characters (PGC), plant height (cm), herb fresh weight (FW) and herb dry weight (DW)}, essential oil (EO), photosynthetic pigments (PSP), total carbohydrates (TCAR), total soluble sugars (TSS) and antioxidant enzymes [superoxide dismutase (SOD), catalase activity (CAT), peroxidase (POX)] were evaluated though various growth stages. The averages of data were statistically analyzed using two-way analysis of variance (ANOVA-2). **Results:** Obtained results reported that the treatment 200 mg L^{-1} of LTRYP produced the highest values of PGC, EO yield and main components of EO (apiol, myristicin, α-pinene, β-pinene), PSP, TCAR, TSS, SOD, CAT and POX. **Conclusion:** Generally, the highest values of growth, yield and chemical composition of parsley plants were obtained with 200 mg L^{-1} (LTRYP) treatment.

Key words: Parsley, L-tryptophan, trans-cinnamic acid, essential oil, antioxidant enzymes

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Parsley {*Petroselinum crispum* (Mill)} belongs to family Apiaceae. It is an aromatic herb used in food and drug industries. The essential oil (EO) is present in various organs of the plant such as leaves, roots and mature seeds (fruits). Parsley EO is used as a natural additive (flavouring agent) in food products and as fragrance in cosmetics or perfumes. Different biological activities such as anti-microbial, diuretic and weak antioxidants were found in parsley EO[1-4]. The major component (Myristicin) of parsley EO is a potential cancer chemo protective agent[5].

Research into different methods to improve medicinal and aromatic plants (MAP) productivity must increase as demand for food and natural pharmaceutical row material production increases. Biostimulants represent one area of research that has the potential to increase MAP productivity[6].

Amino acids (AMAs) are the main source of organic nitrogen that use for building proteins, amines, purines, pyrimidines, alkaloids, vitamins, enzymes, terpenoids and others[7]. The AMAs are necessary for cell growth, maintain pH value in plant cell and protect the plants from the toxicity of ammonia and pathogens. They are a very important source of carbon and energy[8]. L-tryptophan (LTRYP) is known as an essential AMA which acts as a precursor of auxins in plants[8,9]. Plant growth characters (PGC), EO composition, total carbohydrates (TCAR) and total soluble sugars (TSS) of *Pelargonium graveolens* were gradually increased as LTRYP dose increase[10]. The influences of LTRYP on *Catharanthus roseus* plants were investigated by Talaat *et al.*[11] and they reveled that LTRYP rates caused significant increments in PGC, photosynthetic pigments (PSP), TSS and cytokinins contents. Exogenous application of LTRYP improved PGC and pod weight of Chickpea[12]. Foliar application of LTRYP significantly increased PGC and bulb weight of onion[13]. Orabi *et al.*[14] indicated that LTRYP promoted the values of fresh weight (FW) and dry weights (DW), EO (yield and major constituents) and enzyme activities of thyme (*Thymus vulgaris*). The effects of LTRYP on PGC and chemical composition of green onion were investigated by Abd El-wahed *et al.*[15], they indicated that LTRYP resulted in significant increases of PGC, PSP and EO composition. The contents of PSP of *Philodendron erubescens* plants were significantly promoted with LTRYP doses[16]. Khattab *et al.*[17] reported that LTRYP (300 mg L^{-1}) caused a significant increment in PGC of gladiolus plant (*Gladiolus grandiflorus*).

Phenolics are low molecular secondary metabolites, they have highly significant effects on PGC, soil and water conservation, weed control, mineral nutrition, act as defense molecules against soil pests and pathogens and protect agents against biotic and abiotic stress[18-20]. The roles of trans-cinnamic acid (TCA) as phenolic compound (PHC) in plants were reported by some investigators. The TCA plays important role in plants which grow with a biotic stress factors because it has antioxidant and antibacterial properties[21]. The TCA is a fundamental phenylpropanoid involved in the restoration of damage caused by various abiotic stresses[22,23]. The TCA promoted PGC and PSP of quinoa[24]. Responses of basil to TCA were studies by Talaat and Balaa[25] and they reported that PGC, EO, major constituents of EO and TCAR were increased with TCA levels. The TCA produced highly significant increases in PGC, EO composition and TSS of sweet marjoram[26]. Various increments were found in *Lupinus termis* yield, PSP, oil content and TCAR under TCA treatments[27].

In this investigation, the possible effects of some biostimulants such as LTRYP (as AMA) and TCA (as PHC) on the PGC, EO, PSP, TCAR, TSS and antioxidant enzymes of parsley plants were studied.

MATERIALS AND METHODS

Experiments: Two pot experiments were conducted in the greenhouse of National Research Centre (NRC), Dokki, Cairo, Egypt, during two successive seasons of 2015/2016 and 2016/2017. The conditions of the greenhouse were adjusted to 31/15°C, 80/50% RH day/night and light intensity of approximately 3700 Lux. Parsley seeds were obtained from the Department of MAP, Ministry of Agriculture, Giza, Egypt. Ten seeds were sown in each pot (30 cm diameter) in the 3rd week of October during both seasons. Each pot was filled with 10 kg of air-dried soil. Physical and chemical properties of the soil used in this study were determined according to Jackson[28] and Cottenie *et al.*[29] and are presented in Table 1. Eight weeks after sowing, the seedlings were thinned and three plants/pot were left. Pots were divided into three main groups. The first group was exposed to different levels of AMA (LTRYP, 98% feed grade) at concentrations 100 and 200 mg L^{-1}. The second group was subjected to different levels of PHC (TCA, 99% HPLC grade) at concentrations 10 and 20 mg L^{-1}. The third group was subjected to distilled water (as control). The LTRYP and TCA were applied after 10 weeks from the sowing date as foliar spray. All agricultural practices were conducted according to the recommendations by the Egyptian Ministry of Agriculture. The experiments were carried out twice during two seasons because repeated the experiments lead to reduce the experimental errors and produce comprehensive results.

Table 1: Analysis of soil used

Items	Values
Mechanical properties (%)	
Sand	30.2
Silt	19.5
Clay	50.3
Chemical properties	
pH (1:2.5)	7.9
EC (dS m^{-1})	1.5
Organic matter (%)	1.3
$CaCO_3$ (%)	1.9
Total N (%)	67.8
Soluble cations (mg/100 g soil)	
P	14.9
K	18.6
Fe	24.6
Mn	12.1
Zn	6.9
Cu	17.8
Ca	45.8
Mg	11.2
Na	40.6
Soluble anions (mg/100 g soil)	
HCO_3	12.9
Cl	8.5
CO_3	11.4
SO_4	22.7
NO_3	6.8

PGC: Plant heights (cm), herb FW and herb DW (g $plant^{-1}$) were recorded during the vegetative stage, 120 days after sowing (120 DAS), flowering stage, 180 days after sowing (180 DAS) and fruiting stage, 225 days after sowing (225 DAS).

EO isolation: Fresh herbs (aerial part) were collected from each treatment during vegetative, flowering and fruiting stages; air dried and weighed to extract the EO, then 100 g from each replicate of all treatments was subjected to hydro-distillation (HD) for 3 h using a Clevenger-type apparatus[30]. The EO content was calculated as a relative percentage (v/w). In addition, total EO as mL/1000 plants was calculated by using the herb DW. The EOs extracted from parsley herbs were collected from each treatment and dried over anhydrous sodium sulfate to identify the chemical constituents.

Gas chromatography-mass spectrometry (GC-MS): The GC-MS analysis was carried out with an Agilent 5975 GC-MSD system. DB-5 column (60 m×0.25 mm, 0.25 mm film thickness) was used with helium as carrier gas (0.8 mL min^{-1}). GC oven temperature was kept at 60°C for 10 min and programmed to 220°C at a rate of 4°C min^{-1} that was kept constant at 220°C for 10 min and followed by elevating the temperature to 240°C at a rate of 1°C min^{-1}. Split ratio was adjusted at 40:1. The injector temperature was set at 250°C. Mass spectra was recorded at 70 eV. Mass range was m/z 35-450.

GC analysis: The GC analysis was carried out using an Agilent 6890N GC system using flame ionization detector (FID) detect temperature of 300°C. To obtain the same elution order with GC-MS, simultaneous auto injection was done on a duplicate of the same column at the same operational conditions. Relative percentage amounts of the separated compounds were calculated from FID chromatograms.

Identification of components: Identification of the EO components was carried out by comparison of their relative retention times with those of authentic samples or by comparison of their retention index (RI) to series of n-alkanes. Computer matching against commercial (Wiley GC/MS Library, Mass Finder 3 Library)[31,32] and in-house "Başer Library of EO Constituents" built up by genuine compounds and components of known oils. Additionally, MS literature data[33,34] were also used for the identification.

Determination of PSP: Chlorophyll A (Chl A), chlorophyll B (Chl B) and total carotenoids (TC) in fresh leaves collected at the vegetative and flowering stages of each treatment were determined as mg g^{-1} using the methods described by the AOAC[35].

Determination of TCAR and TSS: The TCAR and TSS contents were determined from plant material (young leaves) collected at the vegetative and flowering stages of each treatment. The method of Dubois *et al.*[36] was used.

Extraction and assaying antioxidant enzymes activities: The method adopted in enzyme extraction was that described by Mukherjee and Choudhuri[37]. Assay of catalase activity (CAT) EC 1.11.1.6 was assayed according to the method of Kar and Mishra[38]. Assay of superoxide dismutase activity (SOD) EC 1.15.1.1was determined by measuring the inhibition of the auto-oxidation of pyrogallol using a method described by Marklund and Marklund[39]. Assay of peroxidase activity (POX) EC 1.11.1.7 was assayed following the method of Kar and Mishra[38] with slight modifications.

Statistical analysis: In this experiment, 2 factors were considered; Biostimulants {LTRYP (2 levels), TCA (2 levels) and control} and 3 growth stages. For each treatment there were four replicates. The experimental design followed a randomized complete block design (RCBD). According to De Smith[40] the averages of data of both seasons were statistically analyzed using two-way analysis of variance (ANOVA-2). Significant values were determined according to p-values ($p<0.05$ = significant, $p<0.01$ = moderate significant and $p<0.001$ = highly significant). The applications of that technique were according to the STAT-ITCF program[41].

RESULTS

Effect of LTRYP and TCA on PGC: Biostimulants (LTRYP and TCA) and/or various growth stages (vegetative, flowering and fruiting) affected the all PGC {plant height (cm) herb FW and DWs (g/plant)} (Table 2). Thus, various PGC increased under the various biostimulants levels compared with control treatment. Greatest PGC were recorded at the treatment of 200 mg L^{-1} (LTRYP) during the fruiting stage (225 DAS) with values of 106.7, 42.9 and 17.7. On the other hand all various PGC were increased towards fruiting stage. The increases various PGC were highly significant ($p<0.001$) for biostimulants levels, growth stages and biostimulants×growth stages (Table 2).

Effect of LTRYP and TCA on EO contents: Different variations were found in EO contents under biostimulants rates through all growth stages (Table 2). The highest percentage (0.4) of parsley EO was obtained from aerial part at the flowering stage i.e. 180 DAS with the treatment of 20 mg L^{-1} (TCA). On the other hand, greatest EO yield (mL/1000 plants) was recorded under 200 mg L^{-1} (LTRYP) during the flowering stage (180 DAS) with the value of 120.3. The variations in EO percentage were highly significant ($p<0.001$) for different growth stages while it was insignificant for biostimulants levels or biostimulants×growth stages. Highly significant changes ($p<0.001$) were obtained with biostimulants, growth stages and their interactions for EO yield.

Effect of LTRYP and TCA on EO constituents: Sixteen components were identified by GC-MS analysis under LTRYP and TCA treatments during vegetative, flowering and fruiting stages (Table 3, 4). Apiol, myristicin, α-pinene and β-pinene were identified as the major compounds which reflected the highest amount of parsley EO (more than 70%). The major constituents were increased towards the flowering stage and

Table 2: Effect of L-tryptophan and trans-cinnamic acid on plant growth characters and essential oil contents during various growth stages

		PGC			EO	
Growth stages	Treatments (mg L^{-1})	Plant height (cm)	FW (g/plant)	DW (g/plant)	%	Yield (mL/1000 plants)
120 DAS						
Control		26.0±2.0	3.6±0.3	2.4±0.4	0.2±0.1	7.2±0.2
TCA	10	31.0±1.0	7.3±0.3	3.0±0.5	0.3±0.1	21.9±0.1
	20	32.6±0.6	9.9±0.1	3.5±0.5	0.3±0.1	29.7±0.3
TRYP	100	29.8±0.4	6.7±0.2	2.4±0.1	0.3±0.1	20.1±0.1
	200	34.3±0.3	10.8±0.2	4.5±0.5	0.3±0.1	32.4±0.4
Overall 120 DAS		30.7±1.1	7.7±1.2	3.2±0.6	0.3±0.1	22.3±2.1
180 DAS						
Control		65.2±0.2	17.9±0.1	4.3±0.3	0.3±0.1	53.7±0.3
TCA	10	73.3±0.3	24.2±0.2	6.1±0.1	0.3±0.1	72.6±0.2
	20	87.7±0.2	30.6±0.6	7.6±0.4	0.4±0.1	96.8±0.1
TRYP	100	73.3±0.3	27.2±0.1	7.5±0.5	0.3±0.1	81.6±0.1
	200	88.7±0.7	40.1±0.1	9.1±0.1	0.3±0.1	120.3±0.3
Overall 180 DAS		77.6±1.4	28.0±1.6	6.9±0.9	0.3±0.1	85.0±2.3
225 DAS						
Control		79.7±0.7	19.7±0.3	8.8±0.2	0.1±0.0	17.9±0.1
TCA	10	88.3±0.3	30.8±0.1	9.1±0.1	0.1±0.0	30.8±2.0
	20	103.3±3.0	32.7±2.0	11.9±0.1	0.2±0.1	65.4±0.4
TRYP	100	98.7±0.3	33.8±0.2	10.6±0.4	0.2±0.1	67.6±0.2
	200	106.7±2.0	42.9±0.4	17.7±0.3	0.2±0.1	85.8±1.0
Overall 225 DAS		95.3±1.4	32.0±1.7	11.6±1.3	0.2±0.1	53.5±2.3
Overall treatments						
Control		57.0±2.1	13.7±1.6	5.2±1.8	0.2±0.1	26.3±2.1
TCA	10	64.2±2.1	20.8±1.5	6.1±1.1	0.2±0.1	41.8±2.5
	20	74.5±2.2	24.4±1.9	7.7±1.6	0.3±0.1	64.0±2.1
TRYP	100	67.3±1.3	22.6±1.1	6.8±1.2	0.3±0.1	56.4±2.9
	200	95.3±1.6	31.3±1.4	10.4±1.8	0.3±0.1	79.5±2.3
F-ratio						
Treatments		355.6***	775.2***	199.4***	1.5	3606.6***
Growth stages		10468.7***	5466.2***	1468.7***	12.0***	14139.2***
Treatments×growth stages		45.8***	77.9***	40.7***	0.5	383.0***

*Significant, **Moderate significant, ***Highly significant, LTRYP: L-tryptophan, TCA: Trans-cinnamic acid, DAS: Days after sowing, PGC: Plant growth characters, FW: Fresh weight, DW: Dry weight, EO: Essential oil, values are given as Mean±SD

Table 3: Effect of L-tryptophan and trans-cinnamic acid on essential oil constituents during various growth stages

		120 DAS					180 DAS					225 DAS					
		TCA			TRYP		TCA			TRYP		TCA			TRYP		
Compounds	RI	0.0	10	20	100	200	0.0	10	20	100	200	0.0	10	20	100	200	F-ratio
α-Thujene	931	0.4±0.1	0.3±0.1	0.4±0.1	0.1±0.0	0.3±0.1	0.1±0.0	0.3±0.1	0.2±0.1	0.1±0.0	0.2±0.1	0.5±0.2	1.3±0.3	2.1±0.1	0.8±0.2	0.3±0.1	28.2***
α-Pinene	939	13.0±1.0	13.4±0.4	13.5±0.5	13.8±0.2	13.9±0.1	13.2±0.2	13.6±0.6	13.9±0.1	14.1±0.1	14.4±0.4	12.7±0.2	12.9±0.5	13.1±0.1	13.3±0.3	13.7±0.3	0.1
Camphene	953	2.3±0.3	2.1±0.1	1.6±0.2	1.7±0.2	1.1±0.1	2.4±0.4	2.1±0.1	1.3±0.3	1.3±0.3	1.1±0.1	2.4±0.4	3.2±0.2	1.2±0.2	1.9±0.1	0.5±0.1	9.2***
Sabinene	976	1.4±0.4	1.1±0.1	1.3±0.3	1.1±0.1	1.1±0.1	1.3±0.3	1.7±0.2	1.2±0.2	1.2±0.2	1.0±0.0	1.5±0.5	1.2±0.2	2.4±0.4	1.4±0.4	1.4±0.2	4.1***
β-Pinene	980	9.0±1.0	9.4±0.4	9.7±0.1	9.3±0.3	9.7±0.1	9.3±0.3	9.7±0.1	9.8±0.1	9.7±0.1	9.9±0.1	8.8±0.2	9.1±0.1	9.5±0.5	9.2±0.2	9.5±0.5	1.0
Myrcene	991	1.5±0.5	1.4±0.4	1.1±0.1	1.8±0.2	1.1±0.1	1.6±0.1	1.1±0.1	1.1±0.1	1.9±0.2	1.1±0.2	1.6±0.6	1.4±0.4	1.3±0.3	1.7±0.3	0.2±0.1	2.6*
β-Phellandrene	1031	2.6±0.6	1.1±0.1	1.6±0.2	1.3±0.3	1.1±0.1	2.4±0.2	1.0±0.0	1.7±0.2	1.1±0.1	1.2±0.2	2.8±0.2	1.2±0.2	1.5±0.5	1.6±0.1	1.3±0.3	0.8
γ-Terpinene	1062	2.1±0.1	2.6±0.3	2.7±0.3	2.3±0.3	1.4±0.2	2.1±0.5	2.2±0.2	2.5±0.5	2.1±0.1	1.1±0.1	2.3±0.3	2.4±0.4	2.5±0.5	2.6±0.4	2.7±0.3	4.0***
Myrtenal	1193	3.2±0.2	2.4±0.4	2.3±0.3	1.9±0.1	1.7±0.3	3.0±0.5	2.1±0.1	2.1±0.1	1.7±0.2	1.1±0.1	3.1±0.1	2.2±0.2	2.4±0.4	1.8±0.2	1.8±0.2	0.9
β-Caryophyllene	1418	1.9±0.1	1.5±0.5	1.2±0.2	1.1±0.1	1.6±0.1	1.7±0.2	1.4±0.1	1.1±0.1	1.2±0.2	1.5±0.5	2.2±0.2	1.6±0.1	1.5±0.5	1.4±0.4	1.7±0.2	0.3
Trans-α-Bergamotene	1434	1.6±0.1	1.5±0.5	1.6±0.1	1.4±0.4	1.5±0.5	1.3±0.2	1.5±0.5	1.5±0.5	1.5±0.5	1.3±0.3	1.5±0.5	1.4±0.2	1.4±0.1	1.1±0.2	1.4±0.2	0.5
(Z)-β-Farnesene	1443	2.3±0.3	2.8±0.2	2.5±0.5	2.5±0.5	2.2±0.2	2.6±0.2	2.7±0.3	2.3±0.3	2.4±0.4	2.1±0.1	2.1±0.1	2.9±0.1	2.6±0.1	2.3±0.3	2.3±0.3	1.0
Myristicin	1520	25.0±2.0	25.8±0.8	26.4±0.4	26.7±0.2	27.1±0.4	25.2±0.2	25.9±0.5	26.8±0.8	26.9±0.3	27.2±0.2	24.7±0.7	25.1±0.1	25.9±0.1	26.2±0.2	27.0±0.1	0.2
Elemicin	1554	1.7±0.2	2.1±0. 1	1.3±0.3	1.5±0.5	1.8±0.2	1.5±0.5	2.2±0.2	1.2±0.2	1.3±0.1	1.7±0.3	1.8±0.2	2.0±0.1	1.3±0.3	1.4±0.4	2.1±0.1	0.3
Carotol	1594	2.9±0.1	2.5±1.5	2.1±0.1	1.8±0.2	2.1±0.1	2.8±0.2	2.6±0.1	2.2±0.2	1.5±0.5	2.2±0.2	2.8±0.2	2.8±0.2	2.1±0.1	1.9±0.1	2.2±0.2	0.8
Apiol	1680	29.0±1.0	29.5±0.5	30.6±0.6	31.4±0.4	31.8±0.2	29.4±0.4	29.8±0.2	30.8±0.2	31.8±0.2	32.4±0.4	28.5±0.5	28.7±0.3	29.1±0.1	30.7 0.2	31.5±0.5	0.9
MCH		32.3±0.3	31.4±0.4	31.9±0.1	31.4±0.4	29.7±0.3	32.4±0.4	31.7±0.3	31.8±0.2	31.5±0.5	30.0±1.0	32.6±0.4	32.7±0.3	33.6±0.4	32.5±0.5	29.6±0.4	1.0
MCHO		3.2±0.2	2.4±0.4	2.3±0.3	1.9±0.1	1.7±0.9	3.0±0.1	2.1±0.1	2.1±0.1	1.7±0.2	1.1±0.1	3.1±0.1	2.2±0.2	2.4±0.4	1.8±0.2	1.8±0.2	0.6
SCH		5.8±0.2	5.8±0.2	5.3±0.3	5.0±0.1	5.3±0.3	5.6±0.1	5.6±0.1	4.9±0.1	5.1±0.1	4.9±0.1	5.8±0.2	5.9±0.1	5.5±0.5	4.8±0.2	5.4±0.4	0.8
SCHO		58.6±0.4	59.9±0.1	60.4±0.4	61.4±0.4	63.1±0.1	58.9±0.2	60.5±0.5	61.0±0.1	61.5±0.5	63.5±0.5	57.8±0.2	58.6±0.4	58.4±0.4	60.2±0.2	62.9±0.1	3.0*
Total identified		99.9	99.5	99.9	99.7	99.5	99.9	99.9	99.7	99.8	99.5	99.3	99.4	99.9	99.3	99.6	

*Significant, **Moderate significant, ***Highly significant, RI: Retention index, LTRYP: L-tryptophan, TCA: Trans-cinnamic acid, DAS: Days after sowing, MCH: Monoterpenes hydrocarbons, MCHO: Oxygenated monoterpenes; SCH: Sesquiterpene hydrocarbons, SCHO: Oxygenated sesquiterpenes, values are given as Mean±SD

Table 4: Effect of L-tryptophan, trans-cinnamic acid and growth stages on essential oil constituents

		BREG (mg L^{-1})					GS			F-ratio	
		TCA			TRYP		DAS				
Compounds	RI	0.0	10	20	100	200	120	180	225	Treatments	Growth stages
α-Thujene	931	0.3±0.2	0.6±0.5	0.8±0.9	0.3±0.4	0.3±0.1	0.3±0.1	0.2±0.1	1.0±0.7	37.3***	169.7***
α-Pinene	939	13.0±0.6	13.3±0.5	13.5±0.4	13.7±0.4	14.0±0.4	13.5±0.6	13.8±0.5	13.1±0.4	8.5***	11.0***
Camphene	953	2.4±0.3	2.5±0.5	1.3±0.3	1.6±0.3	0.9±0.3	1.8±0.5	1.6±0.6	1.8±0.1	76.4***	0.1
Sabinene	976	1.4±0.4	1.3±0.3	1.6±0.6	1.2±0.3	1.2±0.2	1.2±0.2	1.3±0.3	1.6±0.5	3.9*	7.9***
β-Pinene	980	9.0±0.6	9.4±0.3	9.5±0.3	9.4±0.3	9.7±0.3	9.4±0.5	9.7±0.3	9.2±0.4	5.1***	6.6***
Myrcene	991	1.6±0.4	1.3±0.3	1.2±0.2	1.8±0.2	0.8±0.5	1.4±0.4	1.4±0.4	1.2±0.6	15.3***	1.0
β-Phellandrene	1031	2.6±0.4	1.1±0.1	1.6±0.3	1.3±0.3	1.2±0.2	1.5±0.6	1.5±0.5	1.7±0.7	46.5***	2.2
γ-Terpinene	1062	2.2±0.3	2.4±0.3	2.6±0.3	2.3±0.3	1.7±0.8	2.2±0.5	2.0±0.5	2.5±0.4	8.1***	7.2***
Myrtenal	1193	3.1±0.3	2.2±0.3	2.3±0.3	1.8±0.2	1.5±0.4	2.3±0.5	2.0±0.7	2.3±0.5	47.9***	6.0**
β-Caryophyllene	1418	1.9±0.3	1.5±0.3	1.3±0.3	1.2±0.3	1.6±0.3	1.5±0.4	1.4±0.3	1.7±0.4	9.3***	4.6
trans-α-Bergamotene	1434	1.5±0.3	1.5±0.3	1.5±0.4	1.3±0.3	1.4±0.3	1.5±0.3	1.4±0.4	1.4±0.3	0.1	0.8
(Z)-β-Farnesene	1443	2.3±0.3	2.8±0.2	2.5±0.3	2.4±0.4	2.2±0.2	2.5±0.4	2.4±0.3	2.4±0.3	5.3***	0.1
Myristicin	1520	25.0±1.0	25.6±0.6	26.4±0.6	26.6±0.4	27.2±0.3	26.3±1.2	26.4±0.9	25.8±0.9	16.1***	3.4*
Elemicin	1554	1.7±0.3	2.1±0.5	1.3±0.2	1.4±0.4	1.9±0.3	1.7±0.4	1.6±0.5	1.7±0.5	6.9***	0.5
Carotol	1594	2.8±0.2	2.6±0.3	2.1±0.1	1.7±0.3	2.2±0.2	2.3±0.5	2.3±0.5	2.4±0.4	30.6***	0.8
Apiol	1680	29.0±0.7	29.3±0.6	30.2±0.9	31.3±0.5	31.9±0.5	30.5±1.2	30.8±1.1	29.7±1.0	73.4***	26.2***
MCH		32.5±0.3	31.9±0.4	32.3±0.9	31.6±0.7	29.8±0.6	31.3±1.0	31.5±1.2	32.1±1.1	1.9	1.7
MCHO		3.1±0.5	2.2±0.3	2.3±0.3	1.8±0.2	1.5±0.6	2.3±0.6	2.0±0.7	2.3±0.2	18.2***	3.4*
SCH		5.7±0.2	5.8±0.2	5.3±0.3	4.9±0.5	5.2±0.3	5.5±0.5	5.2±0.3	5.5±0.5	9.3***	2.4
SCHO		58.5±0.5	59.6±0.9	60.0±1.1	61.0±0.7	63.2±0.4	60.8±1.5	61.1±1.1	59.6±1.3	159.9***	50.2***
Total identified		99.8	99.5	99.7	99.3	99.7	99.9	99.8	99.5		

*Significant, **Moderate significant, ***Highly significant, RI: Retention index, LTRYP: L-tryptophan, TCA: Trans-cinnamic acid, DAS: Days after sowing, MCH: Monoterpenes hydrocarbons, MCHO: Oxygenated monoterpenes, SCH: Sesquiterpene hydrocarbons, SCHO: Oxygenated sesquiterpenes , values are given as Mean±SD

then reduced at fruiting stage. Various constituents of parsley EO were classified to four chemical fractions. Oxygenated sesquiterpenes (SCHO) and monoterpene hydrocarbons (MCH) were the major fractions (more than 80%). Plants treated with 200 mg L^{-1} of LTRYP (during the flowering stage) produced the highest amounts of major constituents that recorded the values of 32.4, 27.2, 14.4 and 9.9%. The greatest amount of MCH (33.6%) was recorded with the 20 mg L^{-1} of TCA (during the fruiting stage) while the treatments of 10 mg L^{-1} of LTRYP and 20 mg L^{-1} of TCA produced the highest amount of MCHO (2.4%) during the vegetative and fruiting stages (Table 3). On the other hand 10 mg L^{-1} of TCA and 200 mg L^{-1} of LTRYP levels resulted in the highest amounts (5.9 and 63.5%) of SCH and SCHO at the fruiting and flowering stages (Table 3). Higher values were found in apiol, myristicin, α-pinene, β-pinene and SCHO (30.8, 26.4, 13.8, 9.7 and 61.1%) at the flowering stage than vegetative or fruiting stages (Table 4). Vegetative and flowering stages resulted in higher values of MCHO and SCH (2.3 and 5.5%) than fruiting stage. Fruiting stage obtained higher value in MCH (32.1) than both Vegetative and flowering stages. The variation in all constituents and chemical classes were insignificant for biostimulants×growth stages except the constituents of α-thujene, camphene, sabinene and γ-terpinene were highly significant ($p<0.001$) and myrcene and SCHO were significant ($p<0.05$) (Table 3). Highly significant changes ($p<0.001$) were found in all components and chemical groups for biostimulants levels except trans-α-bergamotene and MCH were insignificant and sabinene were significant ($p<0.05$) (Table 4). Through various stages, the changes in α-thujene, α-pinene, sabinene, β-pinene, γ-terpinene apiol and SCHO were highly significant ($p<0.001$) while the variations in myrtenal were moderate significant ($p<0.01$) but it was significant of myristicin and MCHO (Table 4).

Effect of LTRYP and TCA on PSP: Applying both biostimulants (LTRYP or TCA) resulted in an increase in the accumulation of PSP i.e. Chl A, Chl B and TC during vegetative and flowering stages (Table 5). The greatest amounts of all PSP were obtained during the flowering stage (180 DAS) from the treatments of 200 and 20 mg L^{-1} of LTRYP and TCA with values of 7.5, 4.6 and 1.2 mg g^{-1}. The highest of accumulation of PSP were higher during the flowering stage (6.8, 4.2 and 1.1 mg g^{-1}) than vegetative stage (4.8, 3.0 and 0.8 mg g^{-1}). The increments in various PSP were highly significant ($p<0.001$) for growth stages, biostimulants levels and their interactions.

Effect of LTRYP and TCA on TCAR and TSS: The accumulation of TCAR and TSS in parsley leaves during the vegetative and flowering stages was promoted by applying various levels of

Table 5: Effect of L-tryptophan and trans-cinnamic acid on photosynthetic pigments, total carbohydrates and total soluble sugars during various growth stages

Growth stages	Treatments (mg L^{-1})	PSP (mg g^{-1}) Chl A	Chl B	TC	TCAR	TSS
					Mg g^{-1}	
120 DAS						
Control		3.5±0.02	2.2±0.03	0.8±0.01	70.1±0.5	55.8±0.2
TCA	10	3.9±0.01	2.3±0.03	0.8±0.01	73.3±0.2	65.1±0.4
	20	5.7±0.02	3.5±0.03	0.9±0.01	84.4±0.4	67.8±0.3
TRYP	100	5.4±0.02	3.3±0.03	0.9±0.02	83.4±0.4	67.2±0.3
	200	5.7±0.02	3.5±0.04	0.9±0.02	99.7±0.6	78.5±0.2
Overall 120 DAS		4.8±0.90	3.0±0.60	0.8±0.10	82.2±0.5	66.9±0.5
180 DAS						
Control		5.7±0.10	3.5±0.10	1.0±0.02	108.1±0.3	64.1±0.3
TCA	10	6.5±0.01	4.1±0.02	1.1±0.01	130.0±0.2	69.2±0.3
	20	7.5±0.02	4.6±0.04	1.2±0.02	134.3±0.3	71.5±0.2
TRYP	100	6.9±0.02	4.2±0.02	1.1±0.01	139.3±0.3	79.3±0.3
	200	7.5±0.02	4.6±0.03	1.2±0.01	154.0±0.6	95.4±0.4
Overall 180 DAS		6.8±0.7	4.2±0.40	1.1±0.10	132.8±0.3	75.9±0.3
Overall treatments						
Control		4.6±0.20	2.9±0.30	0.9±0.10	89.1±0.2	59.9±0.4
TCA	10	5.2±0.30	3.2±0.30	0.9±0.20	101.6±0.3	67.2±0.2
	20	6.6±0.10	4.1±0.40	1.0±0.20	109.3±0.4	69.6±0.2
TRYP	100	6.1±0.40	3.8±0.40	0.9±0.10	111.4±0.6	73.2±0.6
	200	6.6±0.40	4.1±0.20	1.0±0.10	126.9±0.4	86.9±0.3
F-ratio						
Treatments		4357.9***	1321.9***	84.1***	472.3***	6727.4***
Growth stages		26352.9***	9033.4***	1572.6***	8239.5***	6860.7***
treatments×growth stages		234.2***	140.3***	73.9***	36.8***	524.0***

*Significant, **Moderate significant, ***Highly significant, LTRYP: L-tryptophan, TCA: Trans-cinnamic acid, DAS: Days after sowing, PSP: Photosynthetic pigments, TCAR: Total carbohydrates, TSS: Total soluble sugars, Chl: Chlorophyll, TC: Total carotenoides, values are given as Mean±SD

LTRYP and TCA (Table 5). The highest contents of TCAR and TSS were recorded during the treated with 200 mg L^{-1} of LTRYP at flowering stage with the values of 154.0 and 95.4 mg g^{-1}. Lower values (82.2 and 66.9) were found in TCAR and TSS during the vegetative stage than those recorded at flowering stage (132.8 and 75.9 mg g^{-1}). The increases in TCAR and TSS were highly significant ($p<0.001$) for growth stages, biostimulants levels and their interactions.

Effect of LTRYP and TCA on antioxidant enzymes activities: The effect of LTRYP and TCA on antioxidant enzymes such as SOD, CAT and POX were reported during vegetative and flowering stages (Table 6). Both of LTRYP and TCA levels caused an increment in all antioxidant enzymes activities at two stages. The highest accumulations of SOD, CAT and POX were obtained under the treatment of 200 mg L^{-1} of LTRYP with the values of 3.3, 33.0 and 2.4 unit g FW min^{-1}. Flowering stage recorded higher values in SOD, CAT and POX (2.6, 28.4 and 2.3 unit g FW min^{-1}) than vegetative stage (1.7, 27.8 and 1.6 unit g FW min^{-1}) the increases in various antioxidant enzymes were highly significant ($p<0.001$) for different stages, biostimulants levels and biostimulants×stages.

DISCUSSION

In this investigation, the obtained results indicated that LTRYP and TCA caused significant changes in PGC, PSP, EO composition, TCAR, TSS and antioxidant enzymes activities during various growth stages.

The AMAs such as LTRYP can promote the PGC and development through their influence on gibberellin biosynthesis[42], increase endogenous cytokinins rate which play an important role in enhancement of cell division and thereby increase branching, buds and antagonize auxin in apical dominance[43,44]. The LTRYP which is the precursor of IAA improves different vegetative growth characters and plant production. The exogenous applications of LTRYP can activate the endogenous rate of IAA, thus PGC were improved under LTRYP levels[10,11,45]. On the other hand, the increment in PGC under PHC was concomitant with high rates of endogenous growth promoting substances which increased cell division, cell enlargement, cell elongation, cell differentiation, enzymatic activities, protein synthesis and photosynthetic activity as well as increase the antioxidant capacity of plants[46-48]. It was reported that the increases in IAA and GA_3 in

Table 6: Effect of L-tryptophan and trans-cinnamic acid on antioxidant enzymes activities during various growth stages

Growth stages	Treatments (mg L^{-1})	Antioxidant enzymes (unit FW g min^{-1}) SOD	CAT	POX
120 DAS				
Control		1.4±0.0	24.6±0.2	1.0±0.0
TCA	10	1.7±0.0	26.8±0.1	1.2±0.0
	20	1.9±0.0	28.6±0.2	2.1±0.0
TRYP	100	1.7±0.0	28.0±0.1	1.5±0.0
	200	2.0±0.0	31.1±0.2	2.2±0.0
Overall 120 DAS		1.7±0.2	27.8±1.1	1.6±0.5
180 DAS				
Control		2.2±0.0	25.7±0.2	2.0±0.0
TCA	10	2.3±0.0	27.0±0.1	2.3±0.0
	20	2.8±0.0	27.9±0.1	2.4±0.0
TRYP	100	2.4±0.0	28.4±0.2	2.3±0.0
	200	3.3±0.0	33.0±0.2	2.4±0.0
Overall 180 DAS		2.6±0.4	28.4±1.6	2.3±0.2
Overall treatments				
Control		1.8±0.4	25.1±0.6	1.5±0.5
TCA	10	2.0±0.3	26.9±0.1	1.7±0.6
	20	2.4±0.4	28.2±0.4	2.2±0.1
TRYP	100	2.1±0.4	28.2±0.3	1.9±0.5
	200	2.6±0.7	32.1±1.1	2.3±0.1
F ratio				
Treatments		7242.1***	1431.1***	27079.3***
Growth stages		58389.4***	96.4***	123395.5***
Treatments×growth stages		981.5***	53.9***	8751.9***

*Significant, **Moderate significant, ***Highly significant, LTRYP: L-tryptophan, TCA: Trans-cinnamic acid, DAS: Days after sowing, SOD: Superoxide dismutase, CAT: Catalase, POX: Peroxidase, values are given as Mean±SD

sunflower herb was concomitant with an increase in growth rate due to the role of these endogenous hormones in stimulating cell division and/or the cell enlargement and subsequently growth measurements[49]. The increase in PGC under TCA rates may be due to an important role of TCA in some physiological activities such as cellular expansion, membrane permeability, nutrient uptake and Chl synthesis[25].

Different variations were obtained in EO content or composition under various levels of LTRYP and TCA through different growth stages may be due to its effects on the enzymes activity and metabolism improvements of parsley EO[50]. Similar component of parsley EO were found by Kurowska and Galazka[5] in Poland.

The increase in PSP under LTRYP treatments may be due to LTRYP (AMA) is the source of nitrogen which has a main role in the biosynthesis of PSP molecules and transpiration rates[51,52]. The increments in PSP with TCA (PHC) levels may be due its enhancing effects on Rubisco activities, content of pigments[53], CO_2 assimilation, photosynthetic rate and increased mineral uptake by the plant[54].

The high accumulation in TCAR and TSS by the application of LTRYP was concomitant with the chlorophylls rates that in turn affected TCAR content. As well as AMA are the building blocks for proteins that make as enzymes can build carbohydrates[7]. As well as PHC increase the metabolism of carbohydrates accurate the incorporation of TSS into polysaccharides and inhibit polysaccharides-hydrolyzing enzyme[55].

Plants affected by many factors in their habitats, the antioxidants are main defense. The antioxidant enzymes include CAT, SOD and POX. Reactive oxygen species (ROS), including hydrogen peroxide (H_2O_2), superoxide (O_2), hydroxyl radical (HO) and singlet oxygen, can damage the cells of the plant, loss the cell membrane integrity and that may led to senescence or aging of various plant organs[56,57]. The increase in antioxidant enzymes with AMA may be due to reduce of harmful effects of ROS during growth stages[58]. The increments in antioxidant enzymes under PHC due to its effect on capacity of the tissue to scavenging excess ROS and influence plant induction of antioxidant synthesis[59,60].

Present results in this study are confirmed with those obtained by some previous investigation. Significant increases in PGC, PSP and TSS were reported with treatments of *Catharanthus roseus*[11]. The LTRYP doses caused significant increments in PGC, EO, TC and TSS of *Pelargonium graveolens*[10]. Orabi *et al.*[14] reported that LTRYP promoted the PGC, major constituents of EO and antioxidant enzymes rates of thyme. The LTRYP levels caused higher values in PGC, PSP

and EO (contents and major constituents) on green onion than control treatments[15]. The TCA improved growth, yield, EO, major constituents of EO, PSP, TCAR and TSS of basil, sweet marjoram and *Lupinus termis* [25-27]. It may be concluded that the biostimulants such as LTRYP and TCA in the production system should be considered in the growth and chemical contents obtained from MAP.

CONCLUSION

It is concluded that LTRYP and TCA caused a positive effects on PGC and chemical composition of parsley plants. The treatment of 200 mg L^{-1} (LTRYP) resulted in higher values in PGC, EO yield and major components of EO, PSP, TCAR, TSS and antioxidant enzymes activities (SOD, CAT and POX) than control and other treatments.

SIGNIFICANT STATEMENT

This investigation discovered that production of parsley plants under biostimulants conditions is required. LTRYP or TCA treatments resulted in various changes in the active principals (EO) extracted from parsley; so this trials help the producers, ministry of agriculture and drug companies to improve yield and active principal of parsley as a natural source of pharmaceutical and drug industries. It can be recommended that application of LTRYP or TCA is required to improve growth, yield and active principal of parsley plant.

REFERENCES

1. Karimi, F., M. Rezaei, N. Shariatifar, M. Sayadi, I. Mohammadpourfard, E. Malekabad and H. Jafari, 2014. Running head: Antimicrobial activity of parsley antimicrobial activity of essential oil of parsley (*Petroselinum crispum*) against food pathogenic bacteria. World Applied Sci. J., 31: 1147-1150.
2. Teissedre, P.L. and A.L. Waterhouse, 2000. Inhibition of oxidation of human low-density lipoproteins by phenolic substances in different essential oils varieties. J. Agric. Food Chem., 48: 3801-3805.
3. El-Zaeddi, H., J. Martinez-Tome, A. Calin-Sanchez, F. Burlo and A.A. Carbonell-Barrachina, 2016. Volatile composition of essential oils from different aromatic herbs grown in Mediterranean regions of Spain. Foods, Vol. 5, No. 2. 10.3390/foods5020041.
4. Delespaul, Q., V.G. de Billerbeck, C.G. Roques, G. Michel, C. Marquier-Vinuales and J.M. Bessiere, 2000. The antifungal activity of essential oils as determined by different screening methods. J. Essent. Oil Res., 12: 256-266.
5. Kurowska, A. and I. Galazka, 2006. Essential oil composition of the parsley seed of cultivars marketed in Poland. Flavour Fragrance J., 21: 143-147.
6. Bukar, B.B., D.W. Dayom and M.O. Uguru, 2016. The growing economic importance of medicinal plants and the need for developing countries to harness from it: A mini review. IOSR J. Pharm., 6: 42-52.
7. Bromke, M.A., 2013. Amino acid biosynthesis pathways in diatoms. Metabolites, 3: 294-311.
8. Nahed, G.A. and L.K. Balbaa, 2009. Influence of tyrosine and zinc on growth, flowering and chemical constituents of *Salvia farinacea* plants. J. Applied Sci. Res., 3: 1479-1489.
9. Khalid, A., M. Arshad and Z.A. Zahir, 2004. Screening plant growth-promoting rhizobacteria for improving growth and yield of wheat. J. Applied Microbiol., 96: 473-480.
10. Talaat, I., 2005. Physiological effect of salicylic acid and tryptophan on *Pelargonium graveolens*. Egypt. J. Applied Sci., 20: 751-760.
11. Talaat, I.M., M.A. Bekheta and M.H. Mahgoub, 2005. Physiological response of Periwinkle plants (*Catharanthus roseus* L.) to tryptophan and putrescine. Int. J. Agric. Biol., 7: 210-213.
12. Abbas, S.H., M. Sohail, M. Saleem, T. Mahmood and I. Aziz *et al*., 2013. Effect of L-tryptophan on plant weight and pod weight in chickpea under rainfed conditions. Sci. Tech. Dev., 32: 277-280.
13. Hussein, M.M., S.Y. Faham and A.K. Alva, 2014. Role of foliar application of nicotinic acid and tryptophan on onion plants response to salinity stress. J. Agric. Sci., 6: 41-51.
14. Orabi, S.A., I.M. Talaat and L.K. Balbaa, 2014. Physiological and biochemical responses of thyme plants to some antioxidants. Bioscience, 6: 118-125.
15. Abd El-Wahed, M.S.A., M.E. El Awadi, D.M. Salama and W.M. Haggag, 2016. Application of nitrogen, tryptophan and their relation on growth, yield and some chemical constituents in green onion. J. Chem. Pharm. Res., 8: 694-701.
16. Dahab, T.A. and N.G.A. El-Aziz, 2006. Physiological effect of *Diphenylamin* and *Tryptophan* on the growth and chemical constituents of *Philodendron erubescens* plants. World J. Agric. Sci., 2: 75-81.
17. Khattab, M., A. Shehata, E. Abou El-Saadate and K. Al-Hasni, 2016. Effect of glycine, methionine and tryptophan on the vegetative growth, flowering and corms production of gladiolus plant. Alex. Sci. Exch. J., 37: 647-659.
18. Li, Z.H., Q. Wang, X. Ruan, C.D. Pan and D.A. Jiang, 2010. Phenolics and plant allelopathy. Molecules, 15: 8933-8952.
19. Santana, C.M., Z.S. Ferrera, M.E.T. Padron and J.J.S. Rodriguez, 2009. Methodologies for the extraction of phenolic compounds from environmental samples: New approaches. Molecules, 14: 298-320.

20. Makoi, J.H. and P.A. Ndakidemi, 2007. Biological, ecological and agronomic significance of plant phenolic compounds in rhizosphere of the symbiotic legumes. Afr. J. Biotechnol., 6: 1358-1368.
21. Korkina, L.G., 2007. Phenylpropanoids as naturally occurring antioxidants: From plant defense to human health. Cell Mol. Biol., 53: 15-25.
22. Wang, D., K. Pajerowska-Mukhtar, A.H. Culler and X. Dong, 2007. Salicylic acid inhibits pathogen growth in plants through repression of the auxin signaling pathway. Curr. Biol., 17: 1784-1790.
23. Singh, P.K., R. Singh and S. Singh, 2013. Cinnamic acid induced changes in reactive oxygen species scavenging enzymes and protein profile in maize (*Zea mays* L.) plants grown under salt stress. Physiol. Mol. Biol. Plants, 19: 53-59.
24. Allah, M.M.S.A., H.M.S. El-Bassiouny, T.A.E. Elewa and T.N. El-Sebai, 2015. Effect of salicylic acid and benzoic acid on growth, yield and some biochemical aspects of quinoa plant grown in sandy soil. Int. J. ChemTech. Res., 8: 216-225.
25. Talaat, I.M. and L. Balbaa, 2010. Physiological response of sweet basil plants (*Ocimum basilicum* L.) to putrescine and trans-cinnamic acid. Am.-Eurasian J. Agric. Environ. Sci., 8: 438-445.
26. El-Moursi, A., I.M. Talaat and L.K. Balbaa, 2012. Physiological effect of some antioxidant polyphenols on sweet marjoram (*Majorana hortensis*) plants. Nusant. Biosci., 4: 11-15.
27. El-Awadi, M.E., Y.R. Abdel-Baky, M.S. Sadak, A.A.B.A. Amin and M.G. Dawood,2016 2016. Physiological response of *Lupinus termis* to trans-cinammic acid and benzoic acid treatments under sandy soil conditions. Res. J. Pharm. Biol. Chem. Sci., 7: 120-129.
28. Jackson, M.L., 1973. Soil Chemical Analysis. 1st Edn., Prentice Hall Ltd., New Delhi, India, Pages: 498.
29. Cottenie, A., M. Verloo, L. Kiekens, G. Velgh and R. Camcrlynck, 1982. Chemical analysis of plant and soil. Laboratory Analytical Agrochemistry, State University Ghent, Belbium.
30. Clevenger, J.F., 1928. Apparatus for the determination of volatile oil. J. Am. Pharm. Assoc., 17: 345-349.
31. Adams, R.P., 2007. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry. 4th Edn., Allured Publishing Co., Carol Stream, IL., USA., ISBN-13: 9781932633214, Pages: 804.
32. Kumari, S., S. Pundhir, P. Priya, G. Jeena and A. Punetha *et al*., 2014. EssOilDB: A database of essential oils reflecting terpene composition and variability in the plant kingdom. Database. 10.1093/database/bau120.
33. Cincotta, F., A. Verzera, G. Tripodi and C. Condurso, 2015. Determination of sesquiterpenes in wines by HS-SPME coupled with GC-MS. Chromatography, 2: 410-421.
34. ESO., 2006. The complete database of essential oils. Boelens Aroma Chemical Information Service, Leffingwell and Associates, USA.
35. AOAC., 2016. Official Methods of Analysis of AOAC International. 20th Edn., AOAC International, Washington, DC., USA., ISBN-13: 9780935584875, Pages: 3172.
36. Dubois, M., K.A. Gilles, J.K. Hamilton, P.A. Roberts and F. Smith, 1956. Phenol sulphuric acid method for carbohydrate determination. Ann. Chem., 28: 350-359.
37. Mukherjee, S.P. and M.A. Choudhuri, 1983. Implications of water stress-induced changes in the levels of endogenous ascorbic acid and hydrogen peroxide in *Vigna* seedlings. Plant Physiol., 58: 166-170.
38. Kar, M. and D. Mishra, 1976. Catalase, peroxidase and polyphenoloxidase activities during rice leaf senescence. Plant Physiol., 57: 315-319.
39. Marklund, S. and G. Marklund, 1974. Involvement of the superoxide anion radical in the autoxidation of pyrogallol and a convenient assay for superoxide dismutase. Eur. J. Biochem., 47: 469-474.
40. De Smith, M.J., 2015. STATSREF: Statistical Analysis Handbook-A Web-Based Statistics Resource. The Winchelsea Press, Winchelsea, UK.
41. Statsoft, 2007. Statistica version 7.1. Statsoft Inc., Tulsa, Oklahoma.
42. Ahmed, A.M.A., I.M. Talaat and A.K. Khalid, 2017. Soil moisture and glutamic acid affect yield, volatile oil and proline contents of oregano herb (*Origanum vulgare* L.). Int. J. Bot., 13: 43-51.
43. Gashaw, A., 2014. Manipulation of endogenous cytokinin with IPT gene confers tolerance to multiple abiotic stresses. Int. J. Agron. Plant Prod., 5: 44-51.
44. El-Showk, S., R. Ruonala and Y. Helariutta, 2013. Crossing paths: Cytokinin signalling and crosstalk. Development, 140: 1373-1383.
45. Parvez, M.A., F. Muhammad and M. Ahmad, 2000. Effect of auxin precursor (L-Tryptophan) on the growth and yield of tomato (*Lycopersicon esculentum*). Pak. J. Biol. Sci., 3: 1154-1155.
46. Dempsey, D.A. and D.F. Klessig, 2017. How does the multifaceted plant hormone salicylic acid combat disease in plants and are similar mechanisms utilized in humans. BMC Biol., Vol. 15, No. 1. 10.1186/s12915-017-0364-8.
47. Blokhina, O., E. Virolainen and K.V. Fagerstedt, 2003. Antioxidants, oxidative damage and oxygen deprivation stress: A review. Ann. Bot., 91: 179-194.
48. El-Tayeb, M.A., 2005. Response of barley grains to the interactive e.ect of salinity and salicylic acid. Plant Growth Regul., 45: 215-224.
49. Taiz, L. and E. Zeiger, 2012. Plant Physiology. 5th Edn., Sinaur Associates Inc., Sunderland, Massachetts, USA.
50. Khalid, A.K. and M.R. Shedeed, 2014. Influence of kinetin on growth and biochemical accumulation in *Nigella sativa* L. plants grow under salinity stress conditions. Thai J. Agric. Sci., 47: 195-203.

51. Spinelli, F., G. Fiori, M. Noferini, M. Sprocatti and G. Costa, 2009. Perspectives on the use of a seaweed extract to moderate the negative effects of alternate bearing in apple trees. J. Hortic. Sci. Biotechnol., 84: 131-137.
52. Talaat, I.M., H.I. Khattab and A.M. Ahmed, 2014. Changes in growth, hormones levels and essential oil content of Ammi visnaga L. plants treated with some bioregulators. Saudi J. Biol. Sci., 21: 355-365.
53. Khodary, S.E.A., 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt stressed maize plants. Int. J. Agric. Biol., 6: 5-8.
54. Szepesi, A., J. Csiszar, S. Bajkan, K. Gemes and F. Horvath *et al*., 2005. Role of salicylic acid pre-treatment on the acclimation of tomato plants to salt- and osmotic stress. Acta Biol. Szegediensis, 49: 123-125.
55. Kaveh, S.H., F. Bernard and K. Samiee, 2004. Growth stimulation and enhanced invertase activity induced by salicylic acid in tea cuttings (*Camellia sinensis* L.). Proceedings of the 4th International Iran and Russia Conference, September 8-10, 2004, Shahrekord, Iran, pp: 113-116.
56. Thannickal, V.J. and B.L. Fanburg, 2000. Reactive oxygen species in cell signaling. Am. J. Physiol.-Lung Cell. Mol. Physiol., 279: L1005-L1028.
57. Fu, J. and B. Huang, 2001. Involvement of antioxidants and lipid peroxidation in the adaptation of two cool-season grasses to localized drought stress. Environ. Exp. Bot., 45: 105-114.
58. Bahari, A., H. Pirdashti and M. Yaghubi, 2013. The effects of amino acid fertilizers spraying on photosynthetic pigments and antioxidant enzymes of wheat (*Triticum aestivum* L.) under salinity stress. Int. J. Agron. Plant Prod., 4: 787-793.
59. Yordanova, R. and L. Popova, 2007. Effect of exogenous treatment with salicylic acid on photosynthetic activity and antioxidant capacity of chilled wheat plants. Gen. Applied Plant Physiol., 33: 155-170.
60. Ghasemzadeh, A. and H.Z.E. Jaafar, 2012. Effect of salicylic acid application on biochemical changes in ginger (*Zingiber officinale* Roscoe). J. Med. Plants Res., 6: 790-795.