IMPROVEMENT OF GROWTH, YIELD AND VOLATILE OIL COMPOSITION IN CHILLING-STRESSED *CORIANDRUM SATIVUM* L. (CORIANDER) PLANT BY POTASSIUM SILICATE, HUMIC ACID AND GAMMA RAYS

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ABSTRACT

Temperature stress is firmly relevant to the global climatic change as one of the biggest problems that closely interferes with crop vegetative growth and productivity. In this study, acclimation to chilling stress was reinforced in coriander plant by pre-soaking of coriander (*Coriandrum sativum* L.) seeds in potassium silicate (80 mM), humic acid (50mg^{-1} l) or soaking in water after exposure to gamma rays (50 Gy) and their combination with chilling stress. Growth, metabolism, and yield-related traits were generally diminished in chilling-stressed coriander plants, whereas levels of ABA and soluble sugar were increased. Humic acid treatment has stimulated notably growth parameters and yield components in chilling-stressed coriander plants. This stimulation was accompanied by increased phytohormones, photosynthetic pigments, carbohydrates and chemical composition of volatile oils. Also, potassium silicate and gamma radiation have induced numerous ameliorative effect on coriander growth, yield, volatile oil content, and metabolic activities to a certain extent. Inflorescences, seed number, and weight, in addition to the percentage of volatile oil composition were varied under chilling stress and were all improved significantly with applied pretreatments.Generally, humic acid was the best alleviating treatment towards chilling stress impact on growth and productivity of coriander. Therefore, it might be suggested that an inclusive effect of the pretreatments on hormonal balance via increasing IAA+GA_3/ABA ratio engaged with protection of the cellular metabolic activities from chilling injury for the whole plant life cycle.

Key words: Chilling stress, *Coriandrum sativum* L., gamma radiation, humic acid, potassium silicate, volatile oil composition**.**

INTRODUCTION

Chilling impact on crop plants is as important as other abiotic stresses such as salt and drought. It occurs generally under low temperatures when there is no ice formation inside plant tissues. Subjecting tropical and subtropical plant species to low temperature is one of the serious problems happens sometimes due to sudden or instantaneous variations in temperature **(Wang *et al*. 2007)**. Chilling influences growth and production of chilling-sensitive commercial crop plants like tomato, maize, cotton, pepper, soybean, and rice. Chilling stress affects tropical fruits like banana, papaya, and mango and subtropical fruits like grapes and orange **(Sharma and Deswal 2005)**. Furthermore, low-temperature results in a physiological disturbance known as chilling injury **(Zhang *et al*. 2010)**. This injury includes crop growth, cell division, photosynthesis, water transport, lipids, metabolites, and yield **(Renaut *et al*. 2006; Lütz 2010; Hasanuzzaman *et al*. 2013)**.

Coriander (*Coriandrum sativum* L.) is a herb belongs to family Apiaceae (Umbelliferae). It is characterized by essential oils used in food industries as common spices for seasoning purpose and considered as essential ingredient in curry powder, pharmaceutical and medicinal industry, and in cosmetics. Coriander taste is ascribed to its essential oil content of linoleic and furanocoumarins (coriandrine and dihydrocoriandrine). Coriander is also well known for its antioxidant, anti-diabetic, anti-mutagenic, anti-anxiety and antimicrobial activities along with analgesic and hormone balancing effect. It helps to remove toxic mineral residues, such as mercury and lead **(Leena *et al*. 2012)**. Therefore, coriander was promoted to be supplemented in foods due to numerous health benefits and its protective effect to preserve the food for longer duration **(Sefidkan 1999)**. Furthermore, coriander is well recognized by containing many active compounds primarily monoterpenes, α-pinene, limpene, ý-terpinene, p-Cymene, borenol, citronellol, camphor, geraniol, coriandrin, dihydrocoriandrin, and coriandrons A-E, flavonoids, which are regarded as essential oil components**(Leena *et al***. **2012)**. Coriander seeds, leaves, and roots are edible possessing light and fresh distinct flavor. Fresh leaves and ripe fruits are mainly used for culinary purposes. Coriander leaves are rich source of vitamins, micronutrients, and nutritional element, while its seeds are rich in polyphenols and essential oils. The fruit contains 50% linalool composition used in the pharmaceutical industry as good source of α-tocopherol and vitamin A. All mentioned benefits of coriander prompted us to focus our study on this valuable herb particularly its productivity that is affected seriously by many environmental factors, especially chilling stress. Recently, regulation of metabolic pathways was practiced by application of biostimulants to enhance acclimation and tolerance of subjected coriander plant to chilling stress **(Pokluda *et al***. **2016)**. Seed priming using different stimulators of chemical nature like hydrogen peroxide found to acclimatize *Capsicum* sp. against chilling **(Yadav *et al***. **2011)**. Potassium silicate is valuable as significant nutritional supplement of silicon and potassium to cultured plants, stem diameter, number of lateral shoots, root length, chlorophyll content, and fresh/dry weight of plants **(Eneji *et al***. **2005)**. In addition, (Si) application was found to increase β-carotene, lutein, lycopene, and vitamin C contents in tomato fruits and enhanced fruit firmness **(Stamatakis *et al***. **2003)**. Humic acid (HA) has powerful impact on improving soil fertility, facilitating root uptake via regulating root function and structure was recently discovered, along with its impact on the physiology of growing crop plants under normal or abiotic stress **(Trevisan *et al***. **2010; Berbara and García 2014)**. The chemical structure of HA enhances chelation of soil minerals and increased nutrients acquisition by plants **(Nardi *et al***. **2009)**. Previous studies confirmed that derivatives of HA firmly attach to the root, aggregate on the cell wall, and solubilize quickly in the cell cytoplasm within few hours of treatment before moving upwards to the shoot **(Berbara and García 2014)**. However, HA action is often dependent on its concentration, pH of growth medium, and on plants species **(Muscolo *et al***. **2007)**. Facilitated uptake of HA allows its rapid effect on plant metabolism via its response on sucrose and malate dehydrogenase pathways. Effect of HA is primarily through interaction with the rhizosphere evolving IAA, and in increasing cell division via its effect on cytoskeleton proteins, growth of lateral roots and hence root total area, and increased energy via ATPase-increased activity **(Canellas *et al*. 2009; Nardi *et al*. 2009)**. Treated cereal plants by HA were improved growth, fresh/ dry weight, nitrogenous and some mineral uptake, chlorophylls, photosynthesis, respiration, sugars, proteins, flowers number, fruit yield (fertility), essential oil, and decreasing Na uptake **(Rauthan and Schnitzer 1981; Sánchez-Sánchez *et al*. 2006; Nardi *et al*. 2009; Morard *et al*. 2011; Selim *et al*. 2012; Befrozfar *et al*. 2013)**. Gamma rays fall into the category of ionizing radiation and interact with atoms or molecules to produce free radicals in cells. These radicals can damage or modify important components of plant cells and have been reported to affect the morphology, anatomy, biochemistry, and physiology of plants to different extents, depending on the irradiation level and plant species. Such effects include changes in the plant cellular structure and metabolism e.g., dilation of thylakoid membranes, alteration in photosynthesis, modulation of the antioxidative system, and accumulation of phenolic compounds **(Kim *et al*. 2004; Wi *et al*. 2005)**.Gamma irradiation of seeds improves photosynthesis by modulating pigment system **(Hegazi and Hamideldin 2010)**. Also affects proteins by causing conformational changes, oxidation of amino acids, and formation of protein free radicals. Chemical changes in the proteins caused by gamma irradiation also gamma radiation include fragmentation, cross-linking, aggregation and oxidation by oxygen radicals that are generated through the radiolysis of water **(Lee *et al*. 2005)**. Previous studies have shown that relatively low ionizing radiation dose on plants and photosynthetic microorganisms are manifested as accelerated cell proliferation, germination rate, cell growth, enzyme activity, stress resistance and crop yields **(Baek *et al*. 2005; Kim *et al*. 2005)**.

The present study is an evaluation of the ameliorative effect of potassium silicate, humic acid and gamma radiation on acquired tolerance and acclimation of chilling-stressed coriander plant. Growth parameters and physiological traits, stress biomarkers, and volatile oil production were detected, measured, and statistically analyzed at various vegetative, flowering and harvesting stages.

MATERIALS AND METHODS

Plant Material and Treatments

Coriander (*Coriandrum sativum* L.) seeds used in this investigation were purchased from seeds suppliers' located at local market (Abd-Elhady Gayar Compony), Cairo, Egypt. Potassium silicate and humic acid were conducted from Sigma Aldrich Company. The experiments were carried out during two successive seasons 2013/2014 and 2014/2015 in the experimental farm of National Center for Radiation Research and Technology (NCRRT) at Atomic Energy Authority. Dry coriander seeds were directly soaked in solutions of potassium silicate (80 mM), HA (50 mg $^{-1}$ l) or in tap water (control). Radiation treatment was carried out in NCRRT by using Cesium-137.dose rate 0.758 rad/sec. Coriander seeds were divided into 4 groups. The first group of untreated seeds was soaked in tap water (control). While the second, third and fourth groups of seeds were soaked in potassium silicate (80mM), HA (50mg^{-1}l), and the irradiated seeds soaked in tap water. All the above mentioned treatments were preserved in room temperature (20.0 ±2° C) or in incubator at (6 ±0.5 ºC) for 16 h. The experimental design was factorial based on completely randomized design, carried out during two successive seasons of 2013/2014 and 2014/2015. Fifteen kilograms of moderately clay sandy soil (2:1w/w) were used for planting ten coriander seeds in plastic pot (40 cm) in diameter with irrigation run on regular basis. Three stages from each treatment; vegetative stage (75 days old), flowering stage (105 days old), and harvesting stage (135 days old) were analyzed for growth parameters, yield, and metabolic aspects.

Extraction, Separation and Estimation of Growth Regulating Substances

The extraction was achieved by following the method described by **(Shindy and Smith 1975)** and modified by **Hassanein *et al*. (2009)**. Plant tissues were ground in 80 % methanol, transferred to a brown flask with methanol and raised in volume up to 20 ml for every fresh weight of every sample. The methanolic-tissues left for 2 h extraction at 0˚C and then vacuum filtrated through Whatmann filter paper no. 12. Using magnetic stirrer, the residues were transferred to a flask containing methanol and stirred for 30 minutes before being filtrated again. The last step was repeated once more and the combined extracts were evaporated to the aqueous phase in a rotary flash evaporator. The 10-30 ml aqueous phase was optimized at pH 8.6 using 1 % (w/v) NaOH and partitioned with equal volumes of ethyl acetate for three times. The combined ethyl acetate fraction was evaporated to dryness. The aqueous phase was fixed at pH 2.8 with 1% HCl (v/v) and subjected to three times partition using equal volume of ethyl acetate. The remaining aqueous phase was discarded and the combined acidic ethyl acetate phase was reduced to 5 ml (fraction I) and used gas chromatography (GC) for determination of the acidic hormones IAA, ABA and GA3 **(Kelen *et al*. 2004).** Detection was performed using isocratic UV analyzer, reverse phase C18 column (RO-C18 µ Bondapak, waters). The Column included octadecylsilane (ODS) ultrasphere particle (5 µm), the mobile phases were acetonitrile-water (26:74 v/v), PH 4.00, flow rare: 0.8 ml/min, detection by UV at 208 nm, the standard solution of the individual acid was prepared in mobile phase then chromatographred. The retention times (RT) of peaks of authentic samples were used in identification and characterization of peaks of samples under investigation. Peak identification was performed by comparing the relative retention time of each peak with those of IAA, GA3, and ABA standards. Measurements of peak area were carried out by triangulation and relative properties of the individual component.

Estimation of Photosynthetic Pigments

Photosynthetic pigments (chl a, and chl b) were measured in leaves of examined control, chilled, and chilling-stress alleviated coriander plants. The Spectrocolourimeter method of **Metzner *et al*. (1965)** was followed by weighing then blending 0.5 g fresh weight of leaves using 85% aqueous acetone for 5 minutes. The homogenate was filtered and the supernatant was made up to volume with 85% aqueous acetone. The extinction was measured against a pure 85% acetone (blank) at 644, and 663 nm using Spectrocolourimeter DC Tiny 25III Model TUDC12B4. Taking into consideration the dilutions made of the pigment fraction. Chl a and chl b were determined as µg/ml using the following equations:

$$Chlorophyll\ a = 10.3\ E663 - 0.918\ E644 = \mu g/ml$$

$$Chlorophyll\ b = 19.7\ E644 - 3.87\ E663 = \mu g/ml$$

Estimation of Carbohydrates :

For determination of soluble sugars and polysaccharides, plant material was subjected to rapid oven-dry at 80˚C then ground to a fine powder using local domestic blender.

a) Extraction and estimation of soluble sugars :

A homogenized known weight, using 80% ethanol, was incubated for 15 minutes in boiling water bath with continuous shaking. After cooling, the extract was filtrated and the filtrate was oven-dried at 60˚C then dissolved in a known volume of water to be ready for determination of soluble sugars as described by **Homme *et al*. (1992)**. The anthrone sulphuric acid method described by **Whistler *et al*. (1962)** was used for determination of soluble sugars. The anthrone reagent was freshly prepared by mixing 0.2g anthrone (Merck) and 100 ml 95% H_2SO_4 in a conical flask under continuous cooling. Soluble sugar solution (0.1 ml) was mixed with 10 ml of anthrone reagent in a clear pyrex test tube, heated at 100 °C in a water bath for 7 minutes before rapid cooling using tap water. The developed blue green color was detected at 620 nm against water and anthrone reagent as a blank using Spectrocolourimeter DC Tiny 25III Model TUDC12B4. A calibration curve using pure glucose was used to assess the reading of samples concentrations. The data were calculated as mg/g dry weight.

b) Extraction and determination of polysaccharides :

The left dry residue, following soluble carbohydrate extraction, has been exploited for the determination of polysaccharides. A known weight of dried material was added to sulfuric acid (1.5 N) with air reflux and heated for 6 hours at 100 °C in a water-bath. The hydrolysate was made up to a known volume to be ready for polysaccharide determination by method of anthrone sulphuric reagent **(Whistler *et al*. 1962)**. A calibration curve using pure glucose was made, from which the data were calculated as mg/g dry weight.

C) Total carbohydrates :

Total carbohydrate content has been calculated for each sample as total sum of soluble sugars plus polysaccharides contents.

Estimation of Total Volatile Oils :

At flowering stage, volatile oils were three-hours extracted from the flowering tops of coriander using steam-distillation method as described in **British Pharmacopoeia (1968)**. Used glass apparatus was described and mentioned by **Evans (1994)**. About 50 g of fresh inflorescences and their associated leaves were mixed with 1000 ml of water in a rounded two-liter flask. The full extraction procedure was repeated for three samples representing each treatment. The oil was dried using anhydrous sodium sulfate then stored in dark at 0°C until used for analysis. The percentage of volatile oils was calculated according to the following equation:

$$Volatile\ oils\,\% = V \times 100/w$$

Where V = volume of obtained volatile oils; W = weight of extracted sample.

Estimation of Volatile Oil Components by Gas Chromatography-mass Spectrometry (GC-MS) Analysis :

Qualitative and percentage determination of the main essential oil components accumulated in *Coriandrum sativum* L. in the inflorescences and their associated leaves at the flowering stage were taken place using GC-MS at National Research Centre, Dokki, Cairo. The GC analysis was carried out using Varian 3400 GC equipped with a DB-5 fused silica capillary column (30 m X 0.25 mm i.d. 0.25 µm film thickness). The multistep temperature program was increased from 60 °C (held for 3 min) to 260 °C (held for 10 min) with rate of 5 °C min^{-1}. The carrier gas was helium at a flow rate of 1 ml min^{-1}, and the sample size was 1µl (injector temperature was 250 °C). Mass Spectrometer was a Varian- Finnigan SSQ7000 operating in ionizing potential 70 ev and the spectra were scanned in the range of 35-400 amu analysis.

Statistical analysis :

Measurements of growth parameters were calculated as an average of ten replicates derived from the two cultivated experiments, while triple coriander samples were used in the analysis of different metabolic substances presented in this study. Data are analyzed using simple variance analysis (One way ANOVA) of SPSS ver.17, where significant difference at $p < 0.05$ is based on LSD and Duncan's multiple range tests.

RESULTS AND DISCUSSION

1.RESULTS

Growth Parameters

As compared with non-treated coriander plants, chilling stress has caused significant inhibition in all growth parameters (shoot and root lengths, fresh and dry weights of shoot and root, number of leaves per plant, number of branches per plant, leaf areas per plant and no. of inflorescences per plant) throughout the experimental duration. Generally, all growth parameters were stimulated by soaking seeds in potassium silicate, HA or exposed to γ-rays in all stages as compared with control and chilling-stressed coriander plants **(Table 1)**. The most effective treatment was HA alone in both control and stressed alleviated samples. At flowering stage **(Table 2)**, chilling stressed and alleviated coriander samples by HA treatment have recorded a significant increase of previously investigated growth parameters evaluated by 29.03%, 8.94%,91.6%, 208.5%, 216.1%, 178.8%, 132.3%, 100%, 402.9%, and 80% respectively, more than chilling stressed samples. Also, all growth parameters recorded in chilling-stressed and alleviated samples were increased over their corresponding control coriander plants by 12.5%, 15.6%, 56.5, 103.9, 218.4%, 68.3%, 34.4, 36.4%, 82.7%, 28.6% for shoot length, root length, fresh and dry weights of shoot and root, number of leaves per plant, number of branches per plant, leaf areas per plant and no. of inflorescences per plant, respectively.

Table (1): Impact of alleviation elements on growth parameters of chilling-stressed coriander plants at the vegetative stage. Coriander control plants and chilling-stressed ones were subjected to pot. silicate (80 mM), HA (50 mg. $^{-1}$ l) or gamma radiation (50 Gy). The values with the same letter are not significantly different (P<0.05).

Treatment	Shoot length (cm)	No.of leaves/ plant	No. of branches /plant	Leaves area/plant $(cm)^2$	F. wt. of shoot (g)	D. wt. of shoot (g)	Root length (Cm)	F.wt. of root (g)	D. wt. of root (g)
Control (20°C, H_2O)	11.57^{d}	16.00^{e}	5.67^{a}	30.53^{e}	0.55^{e}	0.09^{bc}	6.43^{bc}	0.046^{f}	0.012^{c}
Chilling (6 °C)	10.23^{e}	10.67^{f}	3.67^{b}	14.28^{f}	0.28^{e}	0.04^{c}	6.20^{c}	0.032^{g}	0.006^{d}
Pot. silicate (80 mM)	17.40^{a}	27.67^{cd}	6.00^{a}	94.27^{b}	0.74^{de}	0.13^{bc}	6.63^{bc}	0.064^{e}	0.016^{c}
HA (50 mg.l^{-1})	18.10^{a}	34.33^{a}	7.00^{a}	106.12^{a}	2.034^{a}	0.21^{ab}	7.73^{a}	0.131^{a}	0.024^{a}
Gamma irradiation (50 Gy)	17.57^{a}	32.67^{ab}	7.00^{a}	89.64^{b}	1.18bc	0.20^{ab}	7.37^{ab}	0.126^{a}	0.022^{a}
Chilling (6 °C) + Pot. silicate (80 mM)	14.33^{c}	23.67d	6.33^{a}	57.39^{d}	1.22^{bc}	0.12^{bc}	7.40^{ab}	0.089^{d}	0.014^{c}
Chilling (6 °C) + HA (50 mg.l^{-1})	15.77^{b}	30.00^{bc}	7.00^{a}	71.82^{c}	1.23^{b}	0.30^{a}	7.97^{a}	0.106^{b}	0.022^{a}
Chilling (6 °C) + Gamma irradiation (50 Gy)	15.50^{b}	25.00^{d}	6.00^{a}	59.34^{d}	0.97^{cd}	0.17^{abc}	6.67^{bc}	0.096^{c}	0.0164^{bc}
LSD at 0.05	**0.877**	**4.227**	**1.598**	**4.744**	**0.2597**	**0.136**	**0.994**	**0.0055**	**0.0055**

Table (2): Impact of alleviation elements on growth parameters of chilling-stressed coriander plants at the flowering stage. Coriander control plants and chilling-stressed ones were subjected to pot. silicate (80 mM), HA (50 mg. $^{-1}$ l) or gamma radiation (50 Gy). The values with the same letter are not significantly different (P<0.05).

Treatment	Shoot length (cm)	No.of leaves/ plant	No. of branches /plant	Leaves area/plant $(cm)^2$	F. wt. of shoot (g)	D. wt. of shoot (g)	Root length (Cm)	F.wt. of root (g)	D. wt. of root (g)	No. inflore scences /plant
Control(20°C, H_2O)	32^{d}	69.67^{d}	7.33^{d}	39.31^{e}	2.62^{d}	0.480^{ed}	9.17^{de}	0.136^{e}	0.082^{f}	7^{cd}
Chilling (6 °C)	27.9^{e}	40.33^{e}	5^{e}	14.28^{f}	2.14^{d}	0.314^{e}	9.73 cde	0.137^{e}	0.0495^{g}	5^{d}
Pot. silicate (80 mM)	36.67 c	103.33^{a}	9^{bcd}	94.29^{b}	4.83^{b}	0.926^{b}	12.07^{ab}	0.319^{c}	0.114^{d}	11^{ab}
HA (50 mg.l^{-1})	46^{a}	101^{a}	12^{a}	108.84^{a}	7.2^{a}	1.686^{a}	13.37^{a}	0.93^{a}	0.245^{a}	12^{a}
Gamma irradiation (50 Gy)	40.17 b	89.67^{b}	9.67^{bc}	90.31^{b}	3.87^{bc}	0.8129^{bc}	11.23 bc	0.474^{b}	0.197^{b}	8.67^{c}
Chilling (6 °C)+ Pot. silicate (80 mM)	34^{cd}	80.33^{c}	8^{cd}	57.39^{d}	2.41^{d}	0.473^{de}	10.2^{cd}	0.194^{de}	0.0823^{f}	6.33^{d}
Chilling(6 °C)+ HA (50 mg.l^{-1})	36^{c}	93.67^{b}	10^{b}	71.82^{c}	4.1^{b}	0.979^{b}	10.6^{bcd}	0.433^{b}	0.138^{c}	9^{bc}
Chilling (6 °C)+ Gamma irradiation (50 Gy)	28.33^{e}	80^{c}	8^{cd}	59.34^{d}	3.07cd	0.608^{cd}	9.57^{d}	0.285^{cd}	0.108^{e}	8^{cd}
LSD at 0.05	**3.174**	**6.77**	**1.756**	**5.609**	**0.973**	**0.207**	**1.629**	**0.111**	**0.002**	**2.071**

Yield components

In comparison with non-treated coriander plants chilling stress (6°C±0.5) induced a significant decrease in the yield components (number of fruits /plant, the number of seeds/plant, weight of fruits/plant, and weight of 1000 seeds). It was found that, number of fruits and seeds, seeds weight per plant and weight of 1000 seeds were all increased among the different treatments. HA treatment was the superior one in enhancing and improving fruits and seeds development within chilling and non-chilling conditions, followed by silicate and gamma radiation. Hereby, HA most likely has triggered the highest ameliorative effect on fruits and seeds number/plant **(Fig. 1)**.

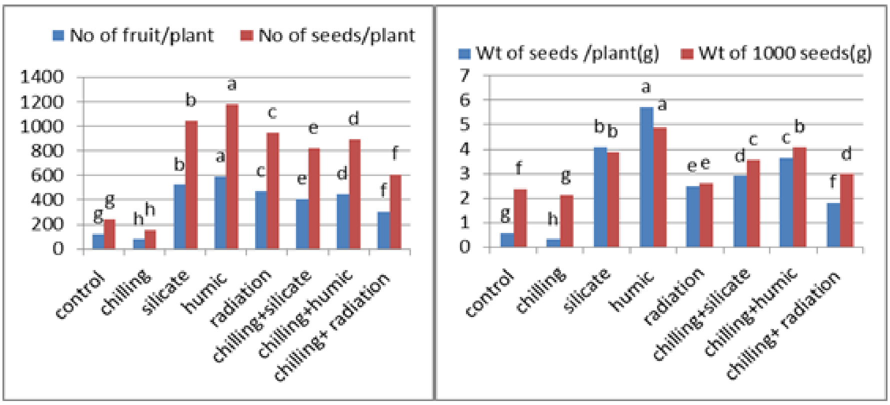

Fig. (1): Impact of alleviation elements on yield components of chilling-stressed (6 °C) coriander plants at yield stages. Coriander control seeds and chilling-stressed ones were subjected to pre-soaking in pot. silicate (80 mM), HA (50 mg. $^{-1}$l) or soaked in water after exposed to gamma radiation (50 Gy). The values with the same letter are not significantly different ($P<0.05$) using Duncan's multiple range test.

Also, pre-soaking treated coriander seeds with silicate, HA or gamma radiation has caused improvement the quality of seed index as compared with control and stressed coriander plants. The best treatment that caused the highest quality and improved seeds yield was HA alone or in combination with chilling. Moreover, seeds quality (wt of seeds/plants and No. of seeds/plant) was improved over those of the control and chilling-stressed plants, respectively upon HA application to alleviate the impact of chilling stress.

Endogenous Phytohormones

Chilling stress has induced significant decrease in the growth promoting substances (IAA and GA3) levels and significant increase in the growth inhibitor ABA level as compared with control coriander plants. All applied treatments either separately or in combination with chilling stress have induced marked increase in both IAA and GA_3contents. The maximum increases in IAA and GA3 contents were obtained in chilling-stressed samples alleviated by HA as compared by chilling-treated plants **(Fig. 2)**. On the other hand, ABA content was increased upon chilling stress and decreased particularly after HA subsequent treatment. Gamma radiation treatment has led to ABA increase in control coriander.

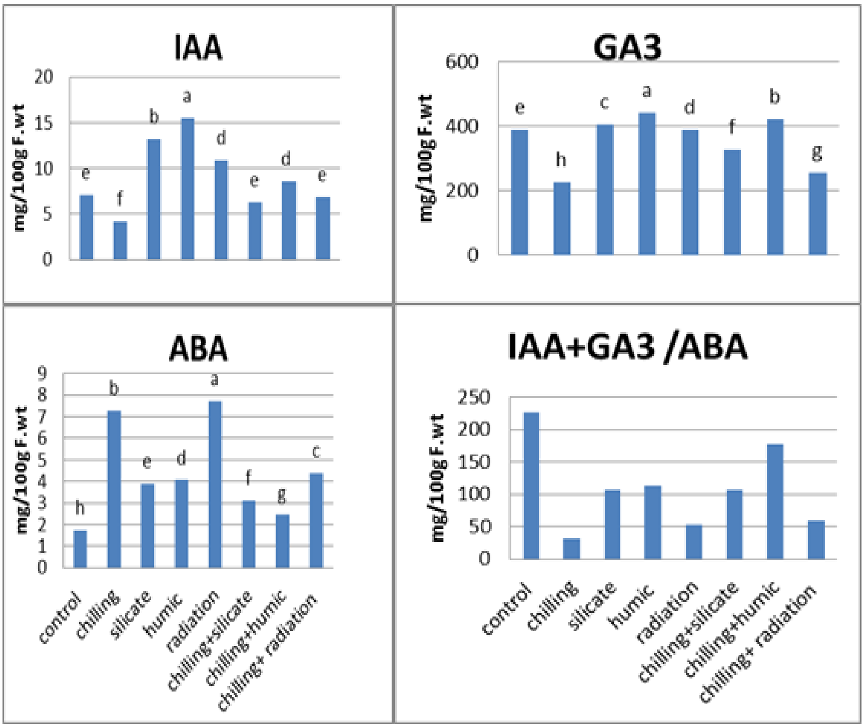

Fig. (2): Impact of alleviation elements on endogenous phytohormones of chilling-stressed (6 °C) coriander plants. Coriander control seeds and chilling-stressed ones were subjected to pre- soaking in pot. silicate (80 mM), HA (50 mg.l^{-1}) or soaked in water after exposed to gamma radiation (50 Gy). The values with the same letter are not significantly different (P<0.05) using Duncan's multiple range test.

Furthermore, chilling stress has caused marked decrease in IAA+ GA_3/ABA ratio, while soaking coriander seeds in pot. Silicate, HA or irradiated with gamma rays has induced a reverse pattern in this ratio as compared with chilling-stressed samples. It was found that the maximum peak of such response was obtained by alleviation of the chilling stress by HA application **(Fig. 2)**.

Photosynthetic Pigment Content

Chilling stress has caused a pronounced decrease in chl a, chl b, and subsequently total chlorophylls more than detected in control coriander leaves. All applied treatments have induced marked increases in chl a, chl b, and total chlorophyll content in stressed samples **(Fig. 3)**. The maximum alleviated impact was achieved by HA individual treatment or in combination with chilling as compared with those of chilling-stressed coriander plants. Chilling stress has induced the increase in (chl a/chl b) ratio more than control plants. Furthermore, all applied treatments have triggered marked increase in (chl a/chl b) ratio in relation to control.

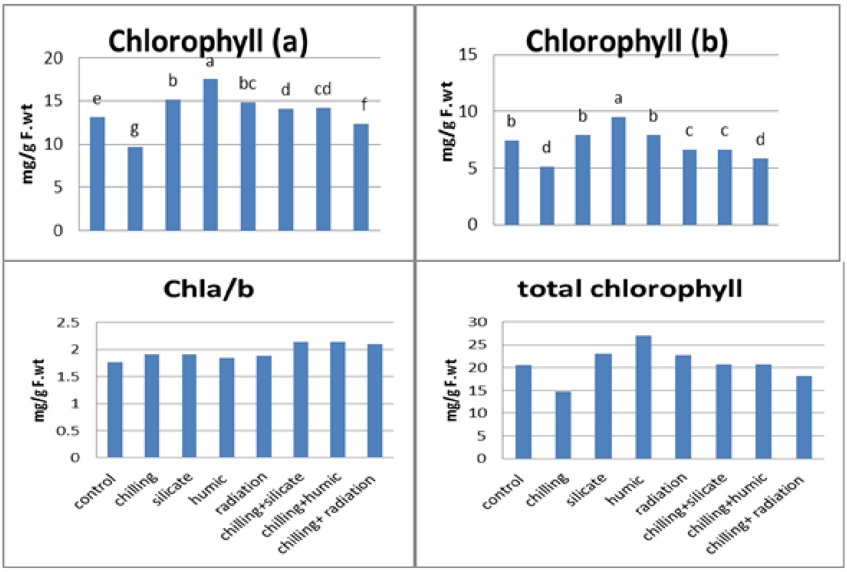

Fig. (3): Impact of alleviation elements on chl a, chl b, chl a/chl b and total chlorophyll content at flowering stage. Coriander control seeds and chilling-stressed ones were subjected to pre- soaking in pot. silicate (80 mM), HA (50 mg.l^{-1}) or soaked in water after exposed to gamma radiation (50 Gy). The values with the same letter are not significantly different (P<0.05) using Duncan's multiple range test.

Chilling stress concomitant with different alleviation elements (Pot. silicate, HA, and gamma irradiation) have recorded an increase in (chl a/chl b) ratio in control and chilling stress leaves. The maximum increased values were achieved by chilling plus silicate and chilling plus HA by 20.9% and 12.04% more than control and chilling-stressed leaves, respectively.

Carbohydrate Content

As compared with control readings, the soluble sugars have increased significantly in chilling stressed plants, particularly under the effect of HA treatment. All applied treatments; pot. silicate, HA, and gamma radiation either separate or in combination with chilling stress have increased the soluble sugars content of coriander leaves as compared with untreated control coriander plant **(Fig. 4)** . The most pronounced effect was recorded in HA application. The latter treatment was considered as the best enhancer of soluble sugars in chilling stressed coriander by 48.23% higher than control samples, followed by gamma radiation and pot. silicate application. Polysaccharides were decreased under chilling stress and increased in treated-coriander alleviated with silicate and HA in both stressed and control coriander. However, the increase of total carbohydrates level were taken place by HA pretreatment in the control and alleviated chilling stressed coriander with silicate and HA.

It was worthy to mention that although individual gamma radiation has increased carbohydrates over chilling stress condition, it was not the best in terms of chilling stress alleviation through carbohydrates protection and restoration compared to HA and silicate treatments. Gamma effect on carbohydrates might be described as intermediate (**Fig. 4**).

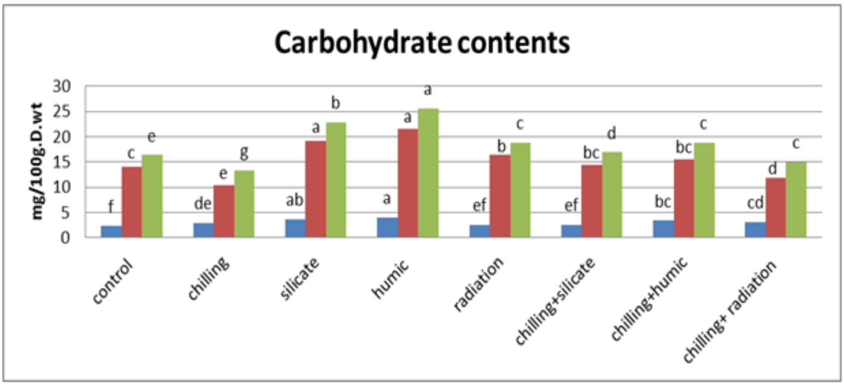

Fig. (4): Impact of alleviation elements on soluble sugars, polysaccharides, and total carbohydrate contents at flowering stage. Coriander control seeds and chilling-stressed ones were subjected to pre- soaking in pot. silicate (80 mM), HA (50 $mg.l^{-1}$) or soaked in water after exposed to gamma radiation (50 Gy). The values with the same letter are not significantly different ($P<0.05$) using Duncan's multiple range test.

Chemical Composition of Volatile Oil :

GC-MS of extracted volatile oil from coriander inflorescence and their associated leaves by steam-distillation at flowering stage (105 days old) after cultivation was performed and revealed 43 compounds. The number of detected components of volatile oil were increased in control, chilling-stressed, silicate, HA, and gamma radiation separate or in combination. The maximum number of detected compounds was 30, 29, and 29 recorded in chilling stressed plants alleviated with HA, chilling stressed samples and HA separate treatment, respectively. After data analysis of GC-MS, the main dominant components of control coriander were detected as follows; decanoic acid (19.5%), Trans-2-decenoic acid=2 E-2-Dodecnoic acid (21.37%), and dodecanoic acid=Lauric =vulvic acid (20.73%). Whereas the main components of chilling-stressed coriander were Trans-2-decenoic acid=2 E-2-Dodecnoic acid (30.08%), Palmitoleic acid=cis-hexadecenoic acid (16.72%), and Myristilalchole=tetradecylalchole=tetradecanol (9.39 %). In addition, some components were solely found in untreated control plants like nonane, octanoic acid decyl ester, and nonanoic acid undecyl ester. Also, 2-nonenal and dimethyl 6,7 dichloro2h-1-benzopyrane,4dicarboxylate were appeared only in coriander plant treated with HA alone and not detected in the other treatments. Moreover, some compounds were disappeared in control under chilling stress in related to control plant such as heptanal, octanoic acid, 1-hexadecanol, myristilmyristate, eurcic acid, and 1, docosane. Also, some compounds were newly appeared like 1-decanol, 2-undecanal, cyclododecane, dodecanal, 2-dodecanol, palmitoleic acid, palmitic acid, 2-tridecenoic acid, myristilalcohol, strearic acid, pentadecane, cyclodececane, 1-octadecanol, and nonacosane. It was worthy to note that palmitic acid was only detected in chilling and pot. silicate plus chilling samples. On the other side, 1-decanol, 2-dodecanol, palmitoleic acid, 2-tridecenoic acid, and nonacosane were appeared in all applied treatments under investigation, while the rest were flocculated. The compound heptanal was appeared in all applied treatments at room temperature and disappeared under chilling stress condition. While, octanoic acid was appeared in all applied treatments under investigation and disappeared only in chilling stressed coriander plant. On the same context, 1-hexadecanal was detected in all applied treatments under investigation except in chilling stressed coriander alleviated with silicate or gamma radiation. Myristic acid was appeared in all treatments applied either at room temperature or at incubation (6ºC±0.5) except with sole treatment by HA. In all applied treatments, except with silicate alone and radiation with chilling, 1-docosane was appeared either at room temperature or at incubation (6ºC±0.5). The proportion of the following components; nonanoic acid (pelargonic acid), trans-2-undecenoic acid, trans-2-decenoic acid=2 E-2-dodecnoic acid, oleic (9-octadecenoic acid), and 1-nonadecane have increased under chilling condition alone and/or with the treatments of chilling plants **(Table 3)**.

Table (3): GC-MS analysis of phytochemical compounds isolated from coriander leaves and inflorescence by steam distillation at the flowering stage. Prior culture, coriander seeds were treated with potassium silicate (80m M), HA (50 mg $^{-1}$ l), and gamma rays (50 Gy) before exposed to chilling stress. Rt refers to calculated retention time of sample fractionation. Tabulated data express the percentage of components of volatile oils of each treatments.

Serial No	Compound	Rt	% volatile compound							
			Control	Chilling	Pot. silicat	HA	Gamma radiation	Chilling + Pot. silicat	Chilling +HA	Chilling + gamma
1	Nonane	3.87	0.02	-----	-----	-----	-----	-----	-----	-----
2	Heptanal	4.5	0.14	-----	0.85	0.5	0.2	-----	-----	-----
3	Octanal	6.6	0.59	0.2	1.48	0.4	0.45	0.3	0.36	0.46
4	Nonanal	8.3	0.74	0.17	0.5	0.95	0.63	0.33	2.76	0.56
5	2-Decanal	10.32	4.24	0.19	6.95	8.98	18.56	4.23	5.3	10.28
6	Octanoic acid	11.1	0.9	-----	1.23	2.16	2.22	0.82	2.15	1.71
7	1-Decanol= undecyl alchole	11.96	-----	0.32	7.44	0.99	2.01	2.85	0.89	2.25
8	Nonanoic acid (Pelargonic acid)	12.59	0.31	1.56	1.18	-----	1.11	2.45	1.04	2.46
9	2-undecanal	13.513	-----	0.02	3.4	-----	0.81	-----	1.05	-----
10	1-undecanol	13.67	-----	-----	11.5	-----	0.01	-----	-----	-----
11	cyclododecane	13.68	-----	0.13	-----	-----	-----	0.32	-----	-----
12	Dodecanal	13.689	-----	0.11	-----	-----	-----	0.55	3.56	-----
13	Decanoic acid (capric acid)	14.7	19.5	13.6	14.48	12.45	7.23	20.34	11.17	16.21
14	2-Dodecanol	15.18	-----	0.11	1.72	6.36	28.02	0.55	3.56	0.94
15	Trans-2-decenoic acid=2 E-2-Dodecnoic acid	15.73	21.37	30.08	14.5	18.62	12.39	30.45	27.72	30.46
16	Undecanoic acid	16.7	1.3	2.57	0.71	3.78	2.75	2.59	3.22	2.93
17	Trans-2-undecenoic acid	17.08	0.51	5.28	3.8	6.3	5.3	5.92	5.08	5.76
18	Dodecanoic acid=Lauric =vulvic acid (C12:0)	17.71	20.73	4.66	4.1	5	2.56	6.67	5.15	5.73
19	2-nonenal	18.01	-----	-----	-----	12.01	-----	-----	-----	-----
20	Palmitoleic acid=cis-hexadecenoic acid = C16:1	18.29	-----	-----	-----	0.91	2.3	2.48	2.9	0.97
21	1,hexadecanol	18.39	2.13	-----	0.9	0.62	0.27	-----	0.96	-----

Continue Table (3)

Serial No	Compound	Rt	% volatile compound							
			Control	Chilling	Pot. silicat	HA	Gamma radiation	Chilling + Pot. silicat	Chilling +HA	Chilling + gamma
22	Palmitic acid (C16:0)	19.1	-----------	0.23	------	------	------	0.38	------	------
23	2-tridecenoic acid	19.25	------	0.73	3.19	0.82	0.31	2.3	4.83	0.17
25	Myristilalchole=tetradecylalchole =tetradecanol	20.87	------	9.39	------	8.47	------	------	5.6	1.42
26	Tridecanoic acid	20.93	------	1.36	1.64	1.08	0.78	------	1.2	0.88
27	Octanoic acid deyl ester (stearic)	22.102	2.01	------	------	------	------	------	------	------
28	Strearic(Octadecanoic acid)C18:0)	22.12	------	0.51	0.61	0.35	------	------	0.36	------
29	Nonanoic acid undecyl ester	23.25	3.69	------	------	------	------	------	------	------
30	Oleic(9-Octadecenoic acid) (C18:1)	23.49	0.36	3.43	4.99	0.38	1.13	3.08	2.19	2.23
31	Decanoic acid decyl ester	24.59	------	------	------	1.25	0.79	------	1.7	0.9
32	Pentadecene	24.61	------	0.21	------	------	------	0.93	------	------
33	Tricosane	25.67	1.3	0.14	0.4	0.44	0.96	1.31	0.61	2.33
34	Myristic acid-octylester=MyristilMyristate	26.6	4.44	------	4.5	------	2.17	1.23	0.8	2.48
35	Erucic acid(Cis-13-docosenoic acid)(C22:1)	26.61	2.2	------	------	0.65	2.08	2.7	1.65	2.29
36	Cyclodececane	27.05	------	0.13	------	0.22	------	0.74	------	------
37	1-Nonadecene	27.67	0.75	5.26	0.43	0.76	1.32	1.19	0.59	0.41
38	n-Eicosane	27.72	0.89	0.07	2.6	------	------	0.16	0.35	1.65
39	1,2benzendicarboxilic acid bis 2 ethylt ester	28.34	8.35	0.4	1.86	------	------	------	------	------
40	Dimethyl6,7-dichloro-2h-1-benzopyrane-3,4dicarboxylate	28.457	------	------	------	1.07	------	------	------	------
41	1-Octadecanol	30.05	------	0.43	------	0.39	0.07	------	0.26	------
42	Nonacosane	30.43	------	0.4	0.21	0.39	0.75	0.43	0.52	1.65
43	1-Docosane	34.75	0.93	------	------	0.39	0.29	1.15	0.75	------
	Summation		100.0	100.4	100.19	99.9	100.26	100.4	100.87	100.27

Impact of alleviation elements on detected phytochemical compounds were shown and illustrated **(Fig. 5)** where, the values show the percentage of increased, decreased, not detected, and newly appeared compounds in each physiological status as revealed by GC-MS analysis.

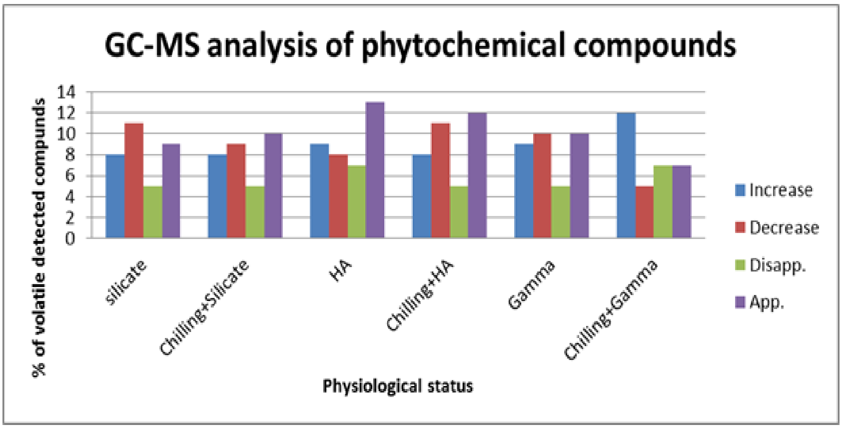

Figure (5): Impact of alleviation elements on detected phytochemical compounds. Coriander control seeds and chilling-stressed ones were subjected to pre- soaking in pot. silicate (80 mM), HA (50 mg. $^{-1}$ l) or soaked in water after exposed to gamma radiation (50 Gy). The values show the percentage of increased, decreased, not detected, and newly appeared compounds in each physiological status (separate applied biostimulant and alleviation of chilling stress by each applied biostimulant).

2-DISCUSSION:

Growth Parameters :

Generally, all growth parameters were stimulated by soaking seeds in potassium silicate, humic acids or exposed to γ-rays in both stages as compared with control and chilling (stressed) coriander plants **(Table 1).** The most effective treatment was HA alone in both control and chilling- primed samples. In the present study, chilling stress has initiated adversely inhibitory impact on investigated growth parameters of coriander plant, (shoot length, number of branches per plant, area of leaves per plant, root length, fresh and dry weights of shoot and root). The results are similar to those obtained by **(Farooq *et al*. 2008; Hasanuzzaman *et al*. 2013; Habibi 2015).** The inhibitory effect could be attributed to decrease in water absorption, altered cell division and cell elongation rates which affect the leaf sizes and weight and reduced ability to close stomata in response to subsequent water deficit **(Wilkinson *et al*. 2001; Bloom *et al*. 2004)**. Insufficient water supply provoked rapid drop of water potential of leaves during the first hours of cooling. So, decline the rate of photosynthesis due to the adverse effect in CO_2 assimilation may weaken the growth through lowering of the rates of both cell division and elongation **(Aghaee *et al*. 2011).**

Improvement of the growth parameters was initiated and triggered by using silicate, HA, and gamma rays to alleviate chilling stress. The most effective alleviative element was HA in both control and chilling-stressed samples. Stimulatory impact might be accounted for the protective role of silicate, HA, and gamma rays. Silicon was suggested to alleviate chilling stress by deposition in cell wall, increasing its rigidity, and reduction the water loss by transpiration which in turn increases internal storage water within the plant, allowing higher growth rates and consequently mitigate detrimental effects of abiotic stress **(Ashraf *et al*. 2010)**. On the same context, HA application has promoted plant growth most likely by acting as a plant growth regulator **(Rady and Osman 2011)** through interaction with the rhizosphere evolving IAA, increasing cell division via its effect on cytoskeleton proteins, growth of lateral roots, and hence root total area **(Canellas *et al*. 2009; Nardi *et al*. 2009)**. The higher rate of IAA in coriander plants treated with HA supported latter notion. HA might lead to higher rates of K+ ions uptake and therefore a corresponding increase in chlorophyll fluorescence **(Marschner 1995).** Hereby, it might be suggested that HA has improved plant tolerance to abiotic stress and promoted growth by increasing auxins, gibberellins and decreasing ABA **(Fig. 2)** , enhancing nutrient uptakes, photosynthesis, and by reduction of water loss **(Nardei *et al*. 2002; Cimrin *et al*. 2010; Saruhan *et al*. 2011)**. In addition, stimulation effect of low doses of gamma rays was speculated due to activation of cell division or cell elongation, alteration of metabolic processes that affect synthesis of phytohormones or nuclic acid , accelerated cell proliferation, germination rate, cell growth, enzyme activity, stress resistance, and crop yield (**Baek *et al*. 2005**; **Kim *et al*. 2005**) which reflected on increased growth and yield of coriander plant.

Yield

The results obviously has shown that pre-sowing coriander seeds in HA was the most effective treatment in mitigation the adverse effect of chilling on seeds yield of coriander plant, this result was in agreement with earlier studies(**Ayas and Gulser 2005)**. Improvement of yield and yield components by HA may be attributed to increasing of nutrients uptake, especially nitrogen content, phosphorus and hormone-like effect of HA or by maintained photosynthetic tissues and yield increase by positive effect on cellular metabolism and leaf chlorophyll increase **(Naderi *et al*. 2002)**. Also, HA effect on endogenous hormones stimulating cell division and/or the cell enlargement was reported in turn to improve plant growth by maintenance of IAA level by decreasing IAA oxidase activity and consequently promoting metabolic activities which accelerate growth and yield of crops **(Kalaichelvi *et al*. 2006)**. In addition, gamma irradiation has induced improvement of seed yield in chilling coriander plant. Similar results were obtained by **(El- shafie *et al*. 1993; Moussa 2011).** This could be ascribed to growth stimulation by changing the hormonal signaling network or by increasing antioxidative capacity of the cell to easily overcome daily stress **(Kim *et al*. 2004)** or by promoting the enzymatic activation resulting in stimulation of cell division rate which affects not only in germination, but also vegetative growth and flowering. Also, previous studies have concluded that irradiation activates the growth and yield due to promotion of stomatal conductance, transpiration, and photosynthetic rate, which enhanced plant and grain nutritional quality **(Singh and Datta 2010)**.

Endogenous phytohormones

Chilling stress has caused decrease in both IAA and GA3 contents in coriander leaves **(Fig 2)**. On the other hand, the amount of ABA detected in coriander leaves was increased in response to chilling stress. ABA was accumulated in response to different environmental stresses such as salinity, cold and drought, which plays a critical role in alleviating stress. ABA regulates important cellular processes such as stomatal closure by guard cells, mediated by solute efflux, and regulates expression of many genes that may function in tolerance against chilling stress **(Himmelbach *et al* . 2003; Mahajan and Tuteja 2005).** It is noticeable that, pre-soaking coriander seeds in silicate, HA, and gamma rays have induced higher contents of growth promoting substances (IAA and GA3) and lowered ABA level. The most effective treatment which increased (IAA and GA3) to alleviate chilling stress was HA. In this respect, latter findings were in agreement with **Abdel-Mawgoud *et al*. (2007)** who has demonstrated that HA treatment was the causal agent of increased auxins, cytokinins, and GA3 contents in tomato. On the same context, ***El-Bassiouny et al*. (2014)** has found that growth promoter (IAA) was increased in wheat grown under newly reclaimed soil supplemented with HA. It might be suggested that HA could be functioned as growth regulator to regulate hormonal levels, improve plant growth, and enhance stress tolerance **(Cimrin *et al*. 2010)** to a lesser extent than HA, low dose of γ-rays was found to increase Kinetin and GA3 hormones of *Eruca vesicaria* L. through triggering changes in hormonal signal network followed by stimulation of growth **(Moussa 2006)**. It might be concluded that improvement of coriander tolerance to chilling stress was achieved to a higher extent in response to applied HA treatment, followed by silicate one. This is depended on their role in decreasing IAA oxidase activity, synthesis adequate level of endogenous phytohormones, promote metabolic activity, and consequently acceleration of growth.

Photosynthetic pigments

Regarding to the effect of chilling stress on photosynthetic pigments of coriander plant (**Fig.3**) significant decreases in chlorophyll a, chlorophyll b, and subsequently the total pigments in coriander leaves were shown. The results were consistent with earlier experiments conducted on *phaseolus* spp. grown at low temperature (10 °C) **(Tsonev *et al*. 2003)**. The marked reduction in photosynthetic pigments in leaves of chilling-stressed coriander plant might be ascribed to mechanical forces generated by formation of extracellular ice crystals as well as cellular dehydration and increase concentration of intracellular salts (**Levitt 1980**) which resulted in membrane damage and alter the membrane structure that affected on photosynthetic electron transport , CO_2 fixation, Rubisco activity and stomatal conductance which consider the major target impaired by chilling stress in plant. In the present study, application of silicate, HA, and gamma radiation on chilling-stressed plant could alleviate the adverse effect of chilling **(Fig. 3)** by increasing in Chl a, Chl b, and the total chlorophylls levels. These results were in harmony with **Zhu *et al*. (2006) Sivanesan *et al*. (2010)**, and **Habibi (2015)**. This may be attributed to silicon increased the level of chl a, chl b which, indicating synthesis of new pigment and maintenance of previously existing chl a and chl b. Furthermore, HA was the most effective treatment in mitigation chilling stress. The present data has manifested that HA generates chilling tolerance in coriander to the level found in control plants through hormonal balance which mediated root growth enhancement, maintenance of photosynthetic pigments and carbohydrates metabolism, through declining ABA levels **(Mahajan and Tuteja, 2005; Mora *et al*. 2012).**

Carbohydrate content

Carbohydrates are considered one of the main organic constituents of the dry matter and affected by chilling stress. In the present investigation **(Fig. 4)**, soluble sugars were increased in leaves of chilling-stressed coriander plant, while polysaccharides and total carbohydrate contents were decreased as compared with the corresponding control plant. The accumulation of total soluble sugars in response to chilling stress were reported in many plant species **(Sasaki *et al*. 1998; Farooq *et al*. 2008; Azymi *et al*. 2012)** Soluble sugars might be acted as compatible solutes under chilling stress **(Azymi *et al*. 2012)**. **Bartels and Sunkar 2005** have suggested that soluble sugars act for osmotic adjustment and/or protect specific macromolecules and contribute to the stabilization of membrane structures, where sugars are thought to interact with polar head groups of phospholipids in membranes so that membrane fusion is prevented. In addition, Sucrose and other sugars play a central role as signaling molecules that regulate the physiology, metabolism and development of plants **(Arroyo *et al*. 2003)**. The reduction in polysaccharides and total carbohydrates of leaves of chilling coriander plant **(Fig. 3)** were concomitant with arrested growth rate **(Table 1,2)** and leaf photosynthetic pigments **(Fig. 2)** led to the conclusion that cold stress might inhibit the photosynthetic activity and/or increase partial utilization of carbohydrates into the soluble sugars and metabolic products **(Arroyo *et al*. 2003)**. On the other hand, pre- soaking seed of coriander plants in silicate, HA or exposed to gamma radiation have induced significant increase in soluble sugar, polysaccharides and total carbohydrates in coriander plants. These effects much more pronounced by HA alone or in combination with chilling treatment. Similar effect of low dose of gamma radiation (20 Gray) on increasing the carbohydrate contents was reported on onion and potatoes (**Nouri and Toofanian 2001)** and Lupine **(Khodary and Moussa 2003)**. **El-Bassiouny *et al.* (2014)** has found that HA has caused the accumulation of soluble sugars concomitantly with increased content of polysaccharides and total carbohydrates in wheat plants grown in newly reclaimed soil. Also, silicon has promoted photosynthetic pigments and hence total carbohydrates were increased. In contrast, silicon has induced reduction in total soluble carbohydrate in drought-stressed *Sorghum bicolor* L. (**Harter and Barros 2011)**. It could be concluded that silicate, HA, and gamma radiation alone or in combination have played prominent role in alleviating the water dehydration caused by chilling stress in coriander plant either via osmotic adjustment by increasing soluble sugars or by stabilizing the chloroplast membrane and enhancing the photosynthetic rate resulting in increased content of carbohydrate biosynthesis.

Volatile oils

Previous studies have recorded volatile oil induction under the effect of different abiotic stresses like chilling stress **(Lianopoulou *et al*. 2014)**. The volatile oil is a part of plant's natural products which know by varied chemical composition due to environmental factors and applications **(Zheljazkov *et al*. 2008)**. Volatile oil encloses multiple antioxidative stress compounds that participate under stress conditions with defense mechanism. The composition of the essential oil was dependent on biological and geographical variability **(Bhuiyan *et al*. 2009)**. Limit information about essential oil composition inflorescence with associated leaves of coriander plants was reported. In the present work, GC–MS **(Table 3)** revealed that the essential oil extracted from the coriander inflorescence is marked by a significant percentage of aliphatic aldehydes, alkenals, alkanals and alchols, saturated and unsaturated fatty acid, among which heptanal, nonanal, 1-decanol, 2-dodecanol and 2-decenal**.**

Major changes of detected phytochemicals were shown and denoted downwards. HA followed by Gamma radiation were the most effective alleviation elements that affected the phytochemical profile of coriander plants. These and the other aldehydes of coriander volatile oil should be considered to be important biologically active substances due to their possible toxic activity against tropical transmitting dangerous illnesses **(Nurzyńska-Wierdak 2013)**.Number of alkenals, alkanals where were found to possess antibacterial activity against *Salmonlla choleraesuis* spp. 2E- Dodecanal most effective against food-borne bacterium followed by 2E-undecanal **(Bhat *et al*.**

2014). Also, in control coriander plant the oil were detected unsaturated fatty acids, especially an omega-9- monounsaturated fatty acid (oleic) and cis-13-monounsaturated fatty acid (erucic) applied. whereas, the saturated acids were octanoic acid nonanoic acid capric acid , trand,2-decanoic acid ,undecanoic acid dodecanoic acid(Lauric acid) palmitic, myristic, and stearic acid. The Unsaturated fatty acids present in vegetable oils (coriander) are characterized by high absorbability, anti-allergic properties, and most important in cosmetology and medicine include **(Bojarowicz and Woźniak 2008**).

It has been found in present work the number of detected compound in control coriander was 23 compound and the main dominant components were decanoic acid (19.5%), Trans-2-decenoic acid (21.37%), and Dodecanoic acid (20.73%).While application of chilling, pot. silicate, HA, gamma radiation separately or in combination with chilling were increased the number of detected components of volatile oil. The maximum number was recorded in chilling-stressed plants treated with HA followed by chilling alone and HA alone (30, 29, and 29). Those treatments considers most effective in increase health benefited of coriander plant. Coriander essential oil was considered as a source of bioactive compounds with many health benefits **(Burt. 2004)**. The increase in oil content may be attributed to decline in primary metabolites due to effect of chilling, causing intermediately product to become available for secondary metabolites where essential oil considered important secondary metabolites **(Aghaei and Kamatsu 2013)**. Chilling stress has increased Trans-2-decenoic acid by 30.08 % over control plant and triggered appearance of new compounds, especially omega-7-monounsaturated fatty acid Palmitoleic acid (C16:1; 16.72%) here and in all applied treatment. Also chilling and all applied treatments induced increases in value of an omega-9-fatty acid oleic acid (C18:1). Latter Fatty acids (C16:1 and C18:1) are regarded as an alternative source of natural antioxidants **(Singh *et al*. 2006)**. So, coriander have protective effects of antioxidants against oxidative stress-induced diseases have received increasing attention in recent times, especially within biological, medical and nutritional areas. Application of pot. silicate, HA ,and gamma radiation individually or in combination with chilling stress can be safe methods to improving and stimulating bioactive and healthy components in coriander plant such asnonanoic acid (pelargonic acid), trans-2-undecenoic acid, trans-2-decenoic acid=2 E-2-dodecnoic acid, oleic (9-octadecenoic acid) and 1-nonadecane , decanal, 2-dodecanol ,*E*-2-decenal ,2E-Dodecanal, 2E-undecanal ,2-tridecenoic acid, erucic acid and Palmitoleic acid. This may attributed to different irradiation doses produced different kinds as well as different amounts of compounds of fatty acid**.** Application of pot. silicate, HA, and gamma radiation on chilling-stressed coriander were increased characteristic property of coriander is its use as antioxidant due to multifunction use and protective and preventing action against various chronic diseases. Also, contains various bioactive compounds and may be recommended as a plant of phytopharmaceutical importance: eicosane, used in the petrochemical industry and found in paraffin wax used to form candles; palmitic acid, used to produce soaps and cosmetics; oleic acid, used in soap as an emulsifying agent for testing new drugs to treat lung diseases; palmeitolic acid, insulin resistance, atherogenesis, and cardio-vascular disease (CVD) **(Schauer *et al*. 2011**). To conclude, coriander is used in preparation of many of household medicines to cure bed cold, seasonal flavor, vomiting, and stomach disorders and also used in drug for, indigestion, against worms, rheumatism and pain in the joint. Many of healing properties may be ascribed to its exceptional phytonutrients. Hence, it is considered as store house for bioactive compounds **(Ullagaddi and Bondada 2011)**.

Conclusion

The present study has focused on treating coriander seeds/plants using potassium silicate, HA, and gamma radiation and on anticipating the physiological effect of these treatments for increasing the plant's whole life tolerance against chilling stress. Derived coriander from chilling stress was characterized by improved vegetative growth and decreased ABA level. Photosynthetic pigments and carbohydrates content (c.a. soluble sugars) were positively promoted concomitantly after alleviation of chilling stress using applied biostimulants. Moreover, some volatile components undergo either induction or significant increase upon the pretreatments. Therefore, it could be suggested that effectiveness of used biostimulants in this study (especially, HA) and their potential stimulatory effect in inducing stress tolerance in cultivated coriander under low temperature. Provided, makes up and resembles a pronounced step to enhance acclimation and tolerance of coriander plant to chilling stress by safe methods improving and stimulating bioactive hormones, pigments, and healthy components.

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تحسين نمو وانتاجيه وتركيب الزيوت الطيارة فى نبات الكزبرة المعرض لإجهاد البرودة باستخدام سيليكات البوتاسيوم وحمض الهيوميك واشعه جاما

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إن للإجهاد الحراري علاقة وثيقة بالتغير المناخي العالمي كأحد المشكلات الكبري التي تتداخل بشكل وثيق مع نمو المحاصيل النباتية وإنتاجيتها. تم في هذه الدراسة تعزيز التأقلم مع إجهاد البروده نبات الكزبرة من خلال نقع البذور في 80 ملى مول سيليكات البوتاسيوم ، أو 50ملى جرام لكل لترحمض الهيوميك أو في الماء بعد تعرضها 50 جراى لأشعة جاما والتداخل بين المعاملات . لقد تم حفظ البذور المعامله بالمعاملات المختلفه في درجة حرارة الغرفة (20 ± 2 درجة مئوية) أو في (6.0 ± 0.5 درجة مئوية) لمدة 16 ساعة قبل الزراعة ثم نثرها للنمو حتى مرحلة الحصاد (135 يوم) .

أدى التعرض لإجهاد البرودة الى نقص النمو بشكل عام ، و كذلك التمثيل الغذائي وإنتاجيه النبات، بينما ارتفعت مستويات حمض الابسيسيك والسكر الذائب . حفز حمض الهيوميك النمو و الانتاجيه في نبات الكزبرة المعرض لإجهاد البروة. وقد رافق هذا التحفيز زيادة الهرمونات النباتيه ، أصباغ البناء الضوئي ، الكربوهيدرات ومحتوى الزيوت الطيارة. أيضا ، تسببت سيليكات البوتاسيوم وأشعة جاما في تأثير تحفيزي عديد وذلك على نمو النبات ، والمحصول ، ومحتوى الزيوت الطيارة وأنشطة التمثيل الغذائي. وقد تغير النورات وعدد البذور ووزن البذور ، بالإضافة إلى النسبة المئوية من تركيبة الزيوت الطيارة في ظل إجهاد البروده ، وكلها تحسنت بشكل كبير مع المعاملات السالف ذكرها.عموما لقد وجد أن حمض الهيوميك هو أفضل معامله في التخفيف من الآثار السلبية للبرودة على نمو وإنتاجية نبات الكزبرة. تبرز النتائج أن للمعاملات المستخدمه دورا هاما فى مقاومه الإجهاد وذلك من خلال التوازن الهرموني عن طريق زيادة نسبه اندول حمض الخليك وحمض الجبريليك إلى الابسيسيك ، التي تعمل أيضًا على حماية أنشطة التمثيل الغذائي الخلوي من تأثير إجهاد البروده طوال دورة حياة النبات.

كلمات البحث

إجهاد بالبروده، الكزبرة، سيليكات البوتاسيوم، حمض الهيوميك و أشعة جاما و الزيوت الطيارة.