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Functional activities and essential oil production in Coriander plants supported with application of irradiated sodium alginate

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Abstract

Coriander is a common herbal plant belonging to the Mediterranean countries. The plant parts precisely fruits, is distinguished by its odor smell. All foliar parts of the plant are palatable, however, leaves and seeds are very useful in different type of cooking. In old-fashioned stream of medicine, coriander is explored for it curative role in various type of disorders including digestive, respiratory and urinary systems. Coriander is considered as curative agents due to its properties of diaphoretic, diuretic, carminative and stimulant. Carbohydrates that obtained from marine algae such as sodium alginate, commonly applied as plant growth stimulating substances in their oligomers form. The present study indicated that the spray of degraded sodium alginate applied on coriander plants, was successful. Application of irradiated sodium alginate as foliar spray enhanced growth features, enzymatic, yield and quality attributes. Out of seven selected concentrations, 100 ppm proved to be the significantly optimum for all studied parameters.

Keywords: Coriander, essential oil, photosynthetic parameters, irradiated polysaccharides, sodium alginate.

Introduction

Gamma-rays cut down macromolecules of polysaccharides into micromolecules, known as oligomers. Oligomers, acquired from degraded polysaccharides, have effect as plant growth supporter in the field of agriculture [1], [2]. Application of the degraded polysaccharides (in the form of oligomers) on vegetative parts of the plants enhanced biological and physiological activities, including plant growth in general [1], [2], [3], [4]. Sodium alginate is derived from marine algae and is existing in large amounts. Sodium alginate has been used as plant growth agents in their degraded form. Gamma-rays cut down macromolecules of sodium alginate into oligomers. Oligomers facilitate positively promotion of plant growth in general [1], seed germination [5], shoot elongation [6], root growth, flower production, antimicrobial activity, amelioration of heavy metal stress, phytoalexin induction, etc. [4], [7]. *Coriandrum sativum* is one of the important sources of flavonoids including pinene, terpinene, limonene and esters [8]. Linalool and geraniol are found as internal standards. Other constituents extracted from the fruits comprise flavonoids, coumarines, isocoumarines, phthalides and phenolic acids [9]. The fat content (17-29%) and protein (12-18%) in residues obtained from distilled fruits appropriate for animal fodder. Keeping the importance and increasing demand of Coriander EO in mind, this study was conducted to find out the effect of gamma-Irradiated Sodium Alginate (ISA), in order to get the best response of crop in terms of productivity, physiological activities, active constituents and production of EO.

Materials and Methods

Plant resources and growth environments

The pot trial was conducted in the natural growth environment of the net house. Prior to seed spreading, each pot was maintained with 5 kg soil and manure in ratio of 4:1. Physico-chemical properties of the soil were: texture-sandy loam, pH (1:2) 7.5, E.C. (1:2) 0.48 dSm^{-1}, available N, P and K 102.4, 7.8 and 145.9 mg kg^{-1} of soil, respectively. An even recommended dose of N, P and K (25:11:21 mg kg^{-1} soil, respectively) was applied in the form of urea, single superphosphate and muriate of potash, respectively, at the time of sowing. ISA was applied as foliar spray at 7 days interval on seedling with 2-3 true leaves to find out the agricultural response of plant. Totally, seven concentrations were applied to the crop. Each treatment was replicated five times. Un-irradiated sodium alginate was excluded it gave significantly equal effect with that of water spray control [7]. The most of the parameter studied at 60 days after planting (DAP). One healthy plant was maintained per pot. The pots were watered as and when required. The following protocols are used to study the various parameters. The detailed methodology of most parameters is already discussed in our previous publication [7].

Growth parameters

The growth parameters *viz.* length, fresh and dry weight of shoot and root were determined at 60 DAP. Potted plants from each pot were evacuated carefully to measure various growth parameters. Water content of the plant was excluded using drying oven at eighty degree celsius for one day to record dry weight.

Physiological parameters

Total chlorophyll and carotenoids contents

Total content of chlorophyll and carotenoids in the leaves was estimated using the method of Lichtenthaler and Buschmann [10].

NR activity

NR activity was estimated by the intact tissue assay method developed by Jaworski [11].

Carbonic anhydrase (CA) activity

The activity of carbonic anhydrase (E.C. 4.2.1.1) was measured in the fresh leaves selected randomly, using the method described by Dwivedi and Randhawa [12].

Yield and quality

Herbage yield of the crop was measured by weighing the total biomass per plant excluding the roots. The EO of coriander was extracted and determined gravimetrically according to Guenther [13]. The EO content in the leaves was extracted by distillation method for 3 h, using a Clevenger's apparatus.

Determination of specific gravity of essential oil

The specific gravity of the mint EO was determined at 25°C with a 'specific gravity bottle' according to Afaq et al. [14]

Refractive index

The refractive index of the EO was determined according to Jenkins et al. [15], employing an Abbe's Refractometer (Sipcon, New Delhi, India).

Statistical analysis

The data were analyzed statistically using SPSS-17 statistical software (SPSS Inc., Chicago, IL, USA) according to simple randomized design. Means were compared using Duncan's Multiple Range Test (DMRT) at $P<0.05$.

Results

The present study indicated that the optimized spray concentrations of ISA applied enhanced all the attributes significantly including active constituents. However, specific gravity and refractive index of the EO were not significantly increased by the treatments. The control showed the lowest effect in the present study.

Growth attributes

The influence of the ISA sprays was significant on shoot length, root length, and plant fresh and dry weights of both shoots and roots. Of the selected spray concentrations, 100 ppm of ISA proved to be the best concentration compared to other spray treatments (Table 1). It was effective in increasing the values of all the growth attributes over the control. The treatment enhanced the shoot length, root length, shoot fresh weight, root fresh weight, shoot dry weight and root dry weight by 28.1, 35.1, 38.7, 38.4, 57.4 and 56.9% respectively, when compared to the control (Table 1).

Table 1: Effect of different concentrations of ISA on growth parameters.

Parameters	DAP	Different level of Irradiated Sodium Alginate (mg/L)						
		0	20	40	60	80	100	120
Shoot length (cm)	60	80.5 ± 1.05^{e}	82 ± 1.06^{d}	84.2 ± 1.15^{cd}	86.4 ± 1.18^{c}	90.4 ± 1.21^{b}	112.2 ± 1.17^{a}	86.4 ± 1.12^{c}
Root length (cm)	60	14.8 ± 0.25^{e}	15.6 ± 0.28^{d}	17.5 ± 0.35^{c}	18.8 ± 0.28^{c}	20.3 ± 0.29^{b}	22.8 ± 0.31^{a}	17.2 ± 0.28^{c}
Shoot fresh weight (t/h)	60	19.37 ± 0.8^{f}	21.25 ± 0.9^{e}	23.43 ± 1.12^{d}	25.95 ± 1.16^{c}	27.08 ± 1.16^{b}	31.58 ± 1.18^{a}	24.61 ± 1.16^{c}
Root fresh weight (t/h)	60	8.5 ± 0.25^{e}	9.4 ± 0.22^{d}	10.2 ± 0.21^{c}	10.8 ± 0.26^{c}	11.0 ± 0.19^{b}	13.8 ± 0.24^{a}	11.0 ± 0.24^{b}
Shoot dry weight (t/h)	60	3.09 ± 0.09^{e}	4.00 ± 0.11^{d}	5.05 ± 0.15^{c}	6.15 ± 0.16^{bc}	7.08 ± 0.18^{b}	7.25 ± 0.15^{a}	5.35 ± 0.18^{c}
Root dry weight (t/h)	60	1.25 ±0.05^{e}	2.00 ± 0.06^{d}	2.05 ± 0.08^{d}	2.12 ± 0.04^{cd}	2.51 ± 0.05^{c}	2.90 ± 0.06^{a}	2.71 ± 0.04^{bc}

Physiological and biochemical attributes

All the physiological and biochemical attributes were significantly affected by the application of ISA. Exogenous application individually improved the content of chlorophyll and carotenoids significantly. However, it was noticed that spray at 100 ppm ISA caused considerable improvement, by increasing the content of total chlorophyll and carotenoid by 14.8 and 15.6% respectively than that of controls.

Foliar application of optimized concentration of ISA applied increased the carbonic anhydrase (CA) activity. In the present study, application of ISA at 100 ppm improved the CA activity by 31.1% compared to the control (Table 2). There was a significant improvement in nitrate reductase (NR) activity due to ISA application, compared with the control. ISA at 100 ppm recorded 22.00% higher value for NR activity the control. Leaf analysis revealed the enhanced contents of N, P and K due to ISA application. Foliar spray of ISA at 100 ppm increased the leaf-N, P and K content by 14.70, 15.10 and 14.12 respectively, over the control (Table 2).

Table 2: Effect of different concentrations of ISA on physiological parameters.

Parameters	DAP	Irradiated sodium alginate (mg/L)						
		0	20	40	60	80	100	120
Total chlorophyll content (mg g^{-1} FW)	60	1.548 ± 0.005^{e}	1.553 ± 0.005^{e}	1.625 ± 0.006^{d}	1.686 ± 0.004^{c}	1.721 ± 0.008^{b}	1.817 ± 0.05^{a}	1.702 ± 006^{c}
Total carotenoid content (mg g^{-1} FW))	60	0.460 ± 0.004^{e}	0.483 ± 0.002^{d}	0.505 ± 0.004^{c}	0.515 ± 0.006^{bc}	0.525 ± 0.005^{b}	0.545 ± 0.008^{a}	0.521 ± 0.005^{bc}
CA activity [μmol (CO_2) Kg^{-1}(FW) S^{-1}]	60	240.9 ± 1.45^{d}	253.2 ± 1.25^{cd}	260.0 ± 1.64^{c}	276.4 ± 2.05^{bc}	295.7 ± 2.15^{b}	315.7 ± 2.31^{a}	264.4 ± 1.87^{c}
NR activity (nM $NO_2^{-}g^{-1}FWh^{-1}$)	60	356.5 ± 1.85^{e}	385.6 ± 1.58^{d}	398.4 ± 1.72^{c}	415.8 ± 1.85^{bc}	436.5 ± 1.69^{b}	454.5 ± 2.04^{a}	398.8 ± 1.48^{c}
Leaf nitrogen content (%)	60	2.38 ± 0.025^{e}	2.42 ± 0.028^{c}	2.48 ± 0.031^{c}	2.58 ± 0.025^{c}	2.62 ± 0.028^{b}	2.79 ± 0.028^{a}	2.50 ± 0.027^{c}
Leaf phosphorus content (%)	60	0.231 ± 0.004^{e}	0.241 ± 0.005^{d}	0.250 ± 0.003^{c}	0.258 ± 0.002^{b}	0.260 ± 0.006^{b}	0.272 ± 0.004^{a}	0.248 ± 0.003^{c}
Leaf potassium content (%)	60	2.25 ± 0.013^{e}	2.27 ± 0.018^{d}	2.36 ± 0.0.11^{c}	2.48 ± 0.013^{bc}	2.56 ± 0.014^{b}	2.62 ± 0.013^{a}	2.40 ± 0.014^{c}

Yield and quality attributes

Application of 100 ppm of ISA was proved best for the yield and quality attributes too. The application 100 ppm of ISA enhanced the umbel number per plant, fruits per umbel, 100 seed weight and seed yield maximally, surpassing the control by 39.13, 24.00, 23.46 and 34.88% respectively (Table 3). It also resulted in the highest essential oil content surpassing the control by 15.14% (Table 4). Application of 100 ppm of ISA failed to improved significantly the specific gravity and refractive index of EO at any of the growth stages (Table 4).

Table 3: Effect of different concentrations of ISA on yield parameters.

Parameters	DAP	Different level of ISA (mg/L)						
		0	20	40	60	80	100	120
Umbel number per plant	60	7.0 ± 0.33^{e}	7.5 ± 0.36^{d}	8.0 ± 0.34^{cd}	8.5 ± 0.38^{c}	9.5 ± 0.39^{b}	11.5 ± 0.38^{a}	7.5 ± 0.38^{d}
Fruits per umbel	60	17.5 ± 0.25^{d}	17.0 ± 0.28^{d}	18.5 ± 0.35^{c}	19.0 ± 0.28^{c}	20.5 ± 0.29^{b}	23.0 ± 0.31^{a}	17.5 ± 0.28^{d}
100 seed weight (g)	60	0.685 ± 0.004^{g}	0.715 ± 0.005^{f}	0.745 ± 0.006^{e}	0.795 ± 0.004^{d}	0.825 ± 0.005^{b}	0.895 ± 0.005^{a}	0.800 ± 0.005^{c}
Seed yield (g/plant)	60	0.941 ± 0.25^{g}	0.985 ± 0.22^{f}	1.015 ± 0.21^{e}	1.225 ± 0.26^{d}	1.368± 0.19^{b}	1.445 ± 0.24^{a}	1.241 ± 0.24^{c}

Table 4: Effect of different concentrations of ISA on growth parameters.

Parameters	DAP	Different level of ISA (mg/L)						
		0	20	40	60	80	100	120
Essential oil content (%)	60	0.157 ± 0.005^{d}	0.159 ± 0.004^{d}	0.168 ± 0.006^{cd}	0.171 ± 0.004^{c}	0.168 ± 0.004^{c}	0.185 ± 0.005^{a}	0.179 ± 0.006^{b}
Specific gravity of essential oil (g/cm^3)	60	0.785 ± 0.001^{a}	0.784 ± 0.002^{a}	0.783 ± 0.003^{a}	0.786 ± 0.004^{a}	0.784 ± 0.004^{a}	0.789 ± 0.003^{a}	0.785 ± 0.004^{a}
Refractive index of essential oil	60	1.351 ± 0.001^{a}	1.353 ± 0.002^{a}	1.353 ± 0.001^{a}	1.355 ± 0.002^{a}	1.359 ± 0.002^{a}	1.362 ± 0.003^{a}	1.358 ± 0.001^{b}

Discussion

Oligosaccharides might be analogous with endogenous growth elicitors that possibly could work as a signal to prompt the production of various type of proteins and other metabolites that can activate various plant responses by influencing the gene expression [16]. The present study showed significant enhancement in different attributes related to plant development by treatment of ISA. There are various reports that indicate irradiated sodium alginate has capability to promote plant processes [17]. Some reports suggested that plants can recognize the oligomers or oligosaccharides with low molecular weight which may be regulate physiological activities, development and defense responses of plants [17], [18] [2]. According to El-Rehim [18], ISA resulted in development of root growth and enlarged shoot elongation. It might have improved output due to improvement in growth and other parameters. ISA raised the value of chlorophyll and carotenoid contents than that of control (Table 2). Several reports indicate that ISA induce cell signaling, leading to stimulation of physiological processes in various plants, including ISA-mediated amended photosynthetic pigments [3], [4]. Carbonic anhydrase activity increase with addition of ISA. The enzyme activity amplified to the maximum extent (Table 2). Findings related to carbonic anhydrase are similar to those that claim ISA can facilitate the synthesis of certain enzymes in tissue culture [19]. The increment in yield parameters by ISA treatment might probably terminate in enlargement of herbage-yield (Tables 1 and 2). Presumably, the improved content and yield of EO in ISA treated plants could be due to the improved rates of photosynthesis and amended translocation of photosynthates and other metabolites to the reproductive organs as indicated by the photosynthetic model for oil production in *Mentha piperita* [20]. The effect of ISA on EO yield might also be mediated through the ISA-improved growth and metabolism as reported in this study (Table 1 and 2). Expectedly, ISA-improved secondary metabolism which contributed to elevate the levels of EO in mint crop. The promotion of essential oil production of medicinal and aromatic plants, as affected by several plant growth regulators, has been reported by various Scientist [21] [22]. Naeem et al [2], [3] suggested that ISA, like other plant hormones might activate enzymes or alter the permeability of a membrane, which could trigger a cascading effect resulting in increased metabolism and the enhanced accumulation of various critical intermediate compounds. The increase in the EO content in lavender, spearmint, Japanese mint, geranium and coriander as a result of application of EBL, ethrel, gibberellic acid and tria contanol might support our studies in this context [23], [24], [25]. The phenomenon by which the degraded oligomers of sodium alginate and other natural polysaccharides stimulate the physiological processes related to the promotion of plant growth still needs further investigations.

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