Evaluate the effect of compost tea and some chelated micronutrients forms on black cumin productivity

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Abstract

The effects of interaction of compost tea with chelated EDTA or humic acid micronutrients on black cumin productivity were investigated. It showed that soil drenching or foliar spray of compost tea with chelated EDTA and humic acid micronutrients increased plant height, plant dry weight, weight of seeds, oil percentage and volatile oils of seeds. Interacted compost tea significantly ($p < 0.05$) increased N, P and K percentage in seeds and straw and NPK uptake when interacted with humic form or with EDTA form. The N, P and K values for interacted foliar spray compost tea with humic form were 54, 21 and 30 kg/f, and with EDTA form were 39, 13 and 20 kg/f. While values for interacted soil drenching compost tea with humic form were 39, 14 and 21 kg/f, and with EDTA form were 26, 10 and 15 kg/f. The difference between drenching and foliage application of compost tea with two chelated forms was not significant ($p > 0.05$) in the two seasons, for plant dry weight, weight of seeds and oil percentage. However it was significant ($p < 0.05$) with humic form in the second season for plant height and in the first season for volatile oils percentage. Compost tea when applying in conjunction with mineral fertilizers results in high performance in the availability, uptake and accumulation of nutrient elements and leading to increasing in black cumin productivity.

Keywords Compost tea · Black cumin · *Nigella sativa* · Micronutrients · Mineral fertilizers

1 Introduction

Black cumin, *Nigella sativa* L. plant belongs to Ranunculaceae family, common known as black cumin or black-caraway seed [36], is cultivated for seed yield and oil production. Seeds show a wide range of antibacterial, antitumor, anti-inflammatory, hypoglycemic, muscle relaxant and immune-stimulant activities [13, 28, 60]. Seeds components used in functional cosmetics and dietary supplemental products [42, 55]. The whole seeds contain 30–35% of oil which has several uses for pharmaceutical and food industries.

In newly reclaimed soils that are usually poor in their nutrients content, foliar nutrition is widely used to correct nutrition deficiency. Application of suitable foliar fertilizer rates affect growth and yield of several medicinal

plants [24] (El-Kholy et al. [19]). Foliar nutrients resulted very clear response on black cumin growth and yield components [35]. Foliar spray with Fe, Zn and Mn stimulated growth characterizes and chemical constituents on *N. sativa* plants [41, 68]. Egyptian sandy soil is characterized by poor macro- and micronutrients that negatively affect growth and productivity of medicinal plants [1]. Organic material improve soil chemical properties, decrease soil pH, increase cation exchange capacity and enhance the most nutrient, which is important for plant growth [64]. Liquid compost support metabolically dynamic process during the growth of plant and serve as a source of soluble nutrients and growth stimulants [66].

Plant nutrition is one of the most important factors that increase plant production. Micronutrients considered as a one of the most important milestones in the progress of

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agriculture crop production [56]; they are needed in small quantities for normal plant growth and development [6, 62]. Micronutrients (i.e., Cu, Mn, Zn, Fe, etc.) play an important role in crops yield and quality [57], it contribute in plants metabolic processes like, respiration, N-fixation, and photosynthesis [29]. Fe is a part of the catalytic group for many redox enzymes, several oxidases (i.e. catalase and peroxidases), and required for the synthesis of chlorophyll. Zn is an activator of a variety of enzymes including alcohol dehydrogenase, carbonic anhydrase and superoxide dismutase. Cu functions as a cofactor for oxidative enzymes including cytochrome oxidase [27]. *N. sativa* Yield responses to micronutrient application [52]. Without the use of chelates, many of these nutrients would be unavailable to plants. The word chelate comes from the Greek word “chele” which literally means “claw”, and used by researchers in the 1920s because it describes the principal of grasping and holding something, which is essentially, what occurs in the process of chelation. Chelates not absorbed by the plant and can persist environments [5], and make metal cations gradually released and absorbed by plants in complexed forms [67]. Chelating agent EDTA, Ethylenediamine tetraacetate, the most common chelating agent in synthetic fertilizers, has low biodegradability [5, 12]. Humic acid is water-soluble organic acid, naturally occurring in soil organic matter, and has many beneficial effects on soil including increase nutrients uptake [11, 37]. Application of the humic acid raised N, P, K, Ca, Mg, Na, Fe, Cu, Zn and Mn uptake, increased the dry weight of plants [32], increased seed yield and essential oil percentage [8].

Soil macro and microelements, enhanced by organic fertilizer [44]. Integrated plant nutrient supply including organic materials, enhance efficiency of micronutrients used in fertilizers and restoring soil fertility [63]. It might be persistent for longer periods of use when compared with inorganic fertilizers [61]. Foliar spray increased yield, levels of fixed, and essential oil content in black cumin plants [26]. Foliar nutrition is helping in a specific nutrition deficiency, especially in newly reclaimed soil where it is usually poor in their nutrients content. Compost tea as an organic fertilizer contains nutrients and micronutrients that are biologically available to be consumed by soil microbes and plants [25]. Plant leaves absorb nutrients easily from foliar fertilizer resulting increase in crops production [6], so the vegetative growth of *Nigella* plants

increased significantly with foliar fertilizer comparing with soil-applied fertilizer [7]. Yield characteristic (plant height, fresh and dry weight, weight of seeds and oil percentage) of Borage plants Increased significantly with adding compost tea [18]. In addition, compost tea increased the carbohydrate content in turnip roots [20] and enhanced the percentage of Nitrogen and Phosphorus in sugar beet plant by 126 and 225%, respectively [30].

Natural extracts enhanced the efficiency of the nutrient solution and enhanced the *N. sativa* growth [48] The aim of the study was to investigate the interaction effect of compost tea with chelated forms EDTA and humic acid micronutrient solutions on black cumin productivity, in addition to some macronutrients availability and content.

2 Materials and methods

2.1 Chemical analysis of compost

Samples digested according Cottenie et al. [17], and analyzed for N, P, K and micronutrients. Organic matter content was determined according to Chapman and Pratt [15]. Total nitrogen was determined according to Chapman and Pratt [16]. pH value was measured according to Jodice et al. [31] (in 1compost:5water ratio). Phosphorus was determined according to Trough and Mayer [65] (Table 1).

2.2 Compost tea production

Aerated compost tea produced by mixing mature compost made by El-Arabeya for Organic Fertilizer Factory with distilled water in ratio of 1:5(w/v) and supplemented with 2% molasses for microbial growth stimulation. The entire contents were continuously aerated at room temperature with a fish-tank bubbling-pump for 72 h.

2.3 Microbial and chemical analysis of compost tea

Total microbial count and microbial analysis for compost tea was calculated using serial dilutions and total plate count technique. Nutrient medium used for total microbial count, King B medium used for *Pseudomonas* count, Potato Dextrose Agar medium used for fungi and yeast count, MacConkey medium used for *Enterobacteriaceae*

Table 1 Chemical analysis of compost

pH (1:5)	EC (1:5) (ds/m)	C/N	Total nutrients						
			ppm						
			N	P	K	Fe	Mn	Zn	Cu
8.1	6.8	16.8	14,600	7800	11,200	325	146	78.5	35.4

Table 2 Compost tea microbial total count

Time (h)	0	24	48	72
CFU/ml $\times 10^5$	0.51	236	383	145

Table 3 Microbiological analysis of compost tea

Total bacteria (CFU/ml)	Fungi $\times 10^2$ (CFU/ml)	Yeast (CFU/ml)	<i>Pseudomonas</i> spp. $\times 10^2$ (CFU/ml)	Enterobacteriaceae (CFU/ml)	<i>Streptococcus</i> (CFU/ml)
U.C.	115	0	21	0	0

U.C. uncountable

determination (Tables 2, 3). Chemical analysis was done according to Cottenie et al. [17] (Table 4).

2.4 Chelating forms preparation

Micronutrients solution was as sulfate form with concentration: 300 ppm for Fe, 100 ppm for Mn, 50 ppm for Zn, and 50 ppm for Cu. The chelating agents were EDTA and humic acid.

Table 4 Nutrient contents of compost tea

Nutrients (ppm)						
N	P	K	Fe	Zn	Mn	Cu
2025	289	1725	1.36	1.95	0.86	N

N not detected

Table 5 Initial status of some chemical and physical properties of the experimental soil

Chemical properties												
Depth (cm)	pH ^a	EC (ds/m) ^b	Soluble ions in saturated soil extract (ppm)							Available nutrients (ppm)		
			Na	K	Ca	Mg	Cl	HCO ₃	SO ₄	N	P	K
0–30	8.20	1.37	5.13	0.54	3.65	4.40	3.30	3.85	6.57	35	2.66	44
30–60	8.06	1.21	2.84	3.91	4.89	0.48	3.12	3.54	5.47	27	1.74	32
Physical properties												
Depth (cm)	Particle size distribution (%)									Texture class		
	Sand			Silt			Clay					
0–30	89.12			6.34			4.54			Sandy		
30–60	90.73			5.56			3.71			Sandy		

^apH in saturated soil paste^bElectrical conductivity in saturated soil extract

2.5 Initial chemical and physical properties for soil

Soil analyses were done according to Klute [39] (Table 5).

2.6 Chemical analysis for irrigation water

Water analyses were done according to Chapman and Pratt [15, 16] (Table 6).

2.7 Field experiment

A field experiment was carried out in Baluza research station of the Desert Research Center. The experiment geographic location is coordinates: 31°3'0"N, 32°36'0"E, during two successive winter growing seasons in 2016 and 2017. Compost tea at age 48 h and two chelated micronutrients forms, previously prepared, were used. Eight treatments applied as follow: Foliar spray: compost tea (CT), EDTA, humic acid, CT + EDTA (1:1) and CT + humic acid (1:1). Soil drench: CT, CT + foliar EDTA (1:1) and CT + foliar humic acid (1:1). The eight treatments and the control applied two times, at the tillering stage (35 days from sowing) and at the booting stage (70 days from sowing), all treatments as a foliar spray or soil drench were 15 ml per each plant. The experimental field was irrigated by drip irrigation system. Black Cumin seeds were sowing during 15 November in rows spacing

Table 6 Chemical analysis for irrigation water

pH	E.C. (ppm)	S.A.R	Soluble cations (ppm)				Soluble anions (ppm)			
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ⁻	HCO ₃ ⁻	SO ₄ ⁻	Cl ⁻
7.45	1456	3.80	58	38.4	197.8	23.4	30	342.72	100.8	266.25

50 cm apart and 15 cm between seed hills (17,500 plant/fed). All treatments received 37 kg K₂O/fed as potassium sulfate, 60 kg N/fed as ammonium sulfate and K fertilizer in two equal doses with N fertilizer and Phosphorus as super phosphate (15.5% P₂O₅) at the rate of 50 kg P₂O₅ fed⁻¹ during the soil preparation. Other agricultural practices were done as recommended by Ministry of Agriculture. The experiment was arranged as randomized complete block design with three replicates. Soil samples were collected from the studied plots at two depths (0–30 cm and 30–60 cm) before initiating the experiment for physical and chemical analysis. Mature Black Cumin plants were harvested at the end of April. Crop was harvested manually. Grains were separated from straw and weighed in the field, and samples were collected for further analysis. Plant height, plant dry weight, seed weight per plant, oil content, and volatile oils were determined.

2.8 Fixed oil and volatile oils assay

Seeds fixed oil per plant was extracted by hexane and determined according to Pearson [53]. The percentage and yield of volatile oils determined in the ground seeds by water distillation using a Clevenger-type apparatus according to Pharmacopoeia [54].

2.9 Nutrients content in plants

Collected samples were dried in a hot air oven at 70 °C for 3 days and ground. The samples were wet digested in H₂SO₄–H₂O₂ mixture for N, P, K and micronutrients analysis.

2.10 Statistical analysis

The analysis of variance (ANOVA) was used to determine the effects of treatments on the generated data. Least significant difference (LSD) was used to test the differences between means at $p < 0.05$ and $p < 0.01$.

3 Results and discussion

3.1 Effect of compost tea and chelated micronutrients on growth parameters of black cumin

3.1.1 Plant height

All treatments increased plant height, highly significant ($p < 0.05$) in two seasons, comparing with control (Fig. 1). The highest values of plant height came from interaction with compost tea. The values were highly significant ($p < 0.01$) in both of soil drench and foliar spray treatments comparing with chelated humic acid foliar alone. Interaction between chelated humic acid and compost tea increased plant height by 227% and 224% as a foliar spray, and by 208% and 207% as soil drench, at season one and two respectively, while foliar chelated humic acid increased plant height by 171% and 164% at season one and two respectively. The interaction between chelated EDTA and compost tea significantly ($p < 0.05$) increased plant height by 189% and 192% as foliar spray and by 175% and 167% as a soil drench, at season one and two respectively. While chelated EDTA alone increased plant height by 137% and 150% at season one and two respectively. Difference

Fig. 1 Effect of compost tea and chelated micronutrients on plant height. *Significant ($p < 0.05$); **highly significant ($p < 0.01$)

between drenching and foliage application of compost tea with two chelated forms was not significant ($p > 0.5$) in the second season.

3.2 Plant dry weight

Plant dry weight increased for all treatments comparing with control (Fig. 2). The interaction of chelates with compost tea, significantly ($p < 0.05$), revealed the highest dry weight. The values were significantly high ($p < 0.01$) in both of soil drench and foliar spray treatments comparing with chelated forms. The humic interacted with compost tea increased the dry weight by 287% and 262% with foliar apply and by 230% and 239% by soil drenching at season 1 and 2, respectively, while chelated humic alone increased it only by 73% at both seasons. The EDTA when interacted with compost tea increased the dry weight by 199% and 145% with foliar apply and by 152% and 116% by soil drenching at season 1 and 2, respectively, while chelated EDTA alone increased it only by 60% and 43% at season 1 and 2, respectively. The difference between drenching and foliage application of compost tea with two chelated forms was significant ($p > 0.05$) in the two seasons.

3.3 Weight of seeds

Weight of seeds increased for all treatments comparing with control (Fig. 3). The interaction of chelates with compost tea, significantly ($p < 0.05$), increased the seeds weight in both of soil drench and foliar spray treatments comparing with chelated forms. When humic interacted with compost tea, increased the seeds weight by 141% and 207% with foliar apply, and by 99% and 151% by soil drenching at season 1 and 2, respectively. When EDTA interacted with compost tea, increased the seeds weight by 88% and 129% with foliar apply, and by 109% and 161% by soil drenching at season 1 and 2, respectively. Chelated humic and chelated EDTA alone increased seeds weight only by 61% and 80% and 41% and 60% at season 1 and 2 respectively. The difference between drenching and foliage application of compost tea with two chelated forms was not significant ($p > 0.05$) in the two seasons.

3.4 Oil percentage

All treatments increased oil content, significantly ($p < 0.05$). Interacted humic with compost tea, affected oil percentage positively to increase by 193% and 188% with foliar apply, and by 162% by soil drenching at season 1 and 2, respectively. When EDTA interacted with compost tea, seeds weight increased by 134% and 118% with foliar

Fig. 2 Effect of compost tea and chelated micronutrients on plant dry weight. *Significant ($p < 0.05$); **highly significant ($p < 0.01$)

Fig. 3 Effect of compost tea and chelated micronutrients on weight of seeds. *Significant ($p < 0.05$); **highly significant ($p < 0.01$)

apply, and by 111% and 100% by soil drenching at season 1 and 2, respectively. Chelated humic and chelated EDTA alone increased seeds weight only by 98% and 80% and 80% and 78% for foliar spray and soil drench at season 1 and 2 respectively. There was no significant between drenching and foliage application of compost tea with two chelated forms at the two seasons. Foliar fertilizer had a significant ($p < 0.05$) effect on fixed oil percentage, it increased by 30.60% in *Nigella* plants [26] (Fig. 4).

3.5 Volatile oils %

All treatments increased volatile oils in two seasons. Interacted compost tea with humic or EDTA as a foliar spray or soil drench, significantly ($p < 0.05$), increased volatile oils Comparing with control. Volatile oils were increased by 83% and 69% when humic integrated with foliar compost tea and by 52% and 31% with soil drenching compost tea, while only by 31% and 11% with humic chelate alone at seasons 1 and 2 respectively. EDTA increased volatile oils by 21 and 14%, while when integrated with compost tea increased volatile oils by 62 and 39% and 45 and 61% for foliar application and soil drenching respectively at seasons 1 and 2. There was a significant ($p < 0.05$) difference between interacted humic with compost tea as a foliar and as soil drench in season 1 (Fig. 5).

The combination of organic and inorganic fertilizers increase the fertilizer use efficiency to a considerable extent and gave the best values for all tested parameters [49] (Mohankumar and Gowda [47]). Chelated forms of humic acid or EDTA when integrated with foliar compost tea gave the highest values, for black cumin height, dry weight, weight of seeds, oil percentage and volatile oil percentage, comparing with integration with soil drenching compost tea and comparing with the chelated micronutrients forms alone. In *Borage* plants, using compost tea significantly increased plant height, fresh and dry weight, weight of seeds and oil percentage [18]. Compost tea contains many beneficial microbes and nutrients of compost but more easily applied to plants, and could be used as an agent for promoting plant growth (Kim et al. [38]). The foliar application of mineral nutrients offers a method of supplying nutrients to plants that are more efficiently than methods involving root application [21]. Spray plants with compost tea is more effective for delivering nutrients than drenching the soil [9, 23]. Humic increased plant height [4], and mineral fertilization with compost tea increased plant dry weight by 124% comparing with the application of them individually [25]. Foliar fertilizer significantly increased fixed oil percentage in *Nigella* plants [26]. Pant et al. [51] mentioned that compost tea increased dry weight of pak choi plants (*Brassica rapa* cv Bonsai) more

Fig. 4 Effect of compost tea and chelated micronutrients on oil %. *Significant; **highly significant

Fig. 5 Effect of compost tea and chelated micronutrients on volatile oil %. *Significant ($p < 0.05$)

than mineral nutrients did, while in our results with black cumin plant, compost tea alone did not.

3.6 Nutrients content in plants

NPK percentage in black cumin seeds and straw and uptake in black cumin seeds Kilogram/fedan for season one were assayed.

3.7 N content in seeds and straw

All treatments significantly ($p < 0.05$) increased the percentage of N, in both black cumin seeds and straw (Figs. 6, 7). Compost tea when integrated with EDTA or humic acid chelated micronutrients forms, significantly high ($p < 0.1$), increased N% by 167 and 121% and 150 and 190% in seeds, and by 413 and 225% and 270 and 196% in straw, with foliar and soil drenching compost tea respectively. Chelated EDTA increased by 102 and 122%, and humic acid by 114 and 143% for seeds and straw respectively. Difference between integrated compost tea as a foliar and as a soil drenching was significant ($p < 0.05$).

Fig. 6 Effect of compost tea and chelated micronutrients on N% in black cumin seeds. **Highly significant ($p < 0.01$)

Fig. 7 Effect of compost tea and chelated micronutrients on N% in black cumin straw. **Highly significant ($p < 0.01$)

3.8 P content in seeds and straw

Figures 8 and 9 showed that, integrated treatments of compost tea, as a foliar or soil drench, increased P % in seeds highly significant ($p < 0.01$) with EDTA by 183 and 113%. Difference between EDTA and compost tea as a soil drench or as a foliar spray was non-significant. Adding compost tea to humic as foliar spray increased the P% in seeds significantly ($p < 0.05$) by 246%, while as a soil drench was non-significant. Difference between humic and compost tea as a soil drench or as a foliar spray was significant ($p < 0.05$). Integrated treatments of compost tea, as foliar increased P% in straws significantly ($p < 0.05$) with humic by 352%, while as a soil drench was non-significant. Difference between humic and compost tea as a soil drench or as a foliar spray was highly significant ($p < 0.01$).

3.9 K content in seeds and straw

Foliar compost tea integrated with EDTA increased the K% highly significant ($p < 0.01$) in black cumin seeds by 608%, while integrated drenching compost

tea increased it significantly ($p < 0.05$) by 531%, and the difference between foliar and soil drenching integrated compost tea was non-significant. In addition, Foliar compost tea integrated with humic increased the K% highly significant ($p < 0.01$) in black cumin seeds by 704%, while integrated drenching compost tea increased it significantly by 556%, and the difference between foliar and soil drenching integrated compost tea was significant ($p < 0.05$). In Straw, foliar compost tea integrated with EDTA or with humic increased the K percentage significantly high ($p < 0.01$) by 266% and 283% respectively, while with drenching compost tea the increment was non-significant (Figs. 10, 11).

3.10 Nutrients uptake in black cumin seeds

NPK uptake increased in all treatments comparing with control, the highest values came when compost tea integrated with humic or EDTA as a foliar spray, and then when integrated as a soil drenching (Fig. 12). The NPK uptake values were 54, 21 and 30 kg/f, 39, 13 and 20 kg/f, for integrated foliar compost tea with humic and EDTA respectively. And were 39, 14 and 21 kg/f and 26, 10 and 15 kg/f for integrated drenching compost tea with humic and EDTA respectively.

Availability of nutrients of organic fertilizers depends on the dynamics of the mineralization process [45]. Compost tea enhancing the uptake and accumulation of nutrient elements in the plant [58]. It is a primary nutrient source, and when applying in conjunction with mineral fertilizers

Fig. 8 Effect of compost tea and chelated micronutrients on P% in black cumin seeds. **Highly significant ($p < 0.01$)

Fig. 9 Effect of compost tea and chelated micronutrients on P% in black cumin straw. **Highly significant ($p < 0.01$)

Fig. 10 Effect of compost tea and chelated micronutrients on K% in black cumin seeds

Fig. 11 Effect of compost tea and chelated micronutrients on K% in black cumin straw.
**Highly significant ($p < 0.01$)

Fig. 12 Effect of compost tea and chelated micronutrients on nutrients uptake in black cumin seeds

results in high performance. For Basil [34], Borage [18], Sugar Beet [30] and Peppers, Cucumbers and Sweet Onions [55].

Foliar nutrition is helping in a specific nutrition deficiency. Compost tea contains nutrients and micronutrients in easily available form to be consumed by plants and soil microorganisms besides supporting the metabolism of plant growth [25, 66].

Biologically active metabolites such as humic acids and plant growth regulators, as well as water extractable mineral nutrients present in compost would be extracted during the brewing process of compost tea production [10, 50]. These compounds increasing soils microbial contents, enhance root development, extend nutrient supplying capacity, reduce mineral nutrient loss, and improve plant growth (Carpenter-Boggs [14]), [40]. Compost tea increasing N, P and K concentration and its uptake by plants because as a role of organic extracts which develop the root system of plant and improved nutrient uptake [3, 46]. Compost tea increased permeability of cellular membranes in plants to minerals [33]; promote root absorption of nutrients [22]. Foliar fertilization with compost tea allows nutrients to be absorbed by the plants directly through stomata on their leaf surfaces resulting increase in nutrients uptake by plants and crops production [6]. Foliar application

of compost tea increased the time stomata stay open, reducing loss from the leaf surface, so the availability of mineral nutrients is higher for foliar than drench application [43]. Highly nutrients concentrated compost tea when combined with mineral fertilization increased N, P and K concentrations and their uptake [2].

4 Conclusion

Conjunction of compost tea, as a foliar spray or soil drenching with chelates forms EDTA and humic acid micronutrient solutions increased plant height, dry weight and weight of seeds, oil percentage and volatile oils in black cumin. High performance in the availability, uptake and accumulation of nutrients occurred. NPK percentage increased in seeds and straw of black cumin. Compost tea enhanced the effect of micronutrients on black cumin productivity and oil contents beside the uptake of NPK, when applied in a combination.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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