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EFFECT OF VERMICOMPOST-TEA AND PLANT EXTRACTS ON GROWTH, PHYSIOLOGICAL, AND BIOCHEMICAL TRAITS OF LETTUCE (*LACTUCA SATIVA* L.)

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SUMMARY

The vermicompost and exogenous plant extracts as a foliar application can provide as an alternative means to enhance the growth and yield of leafy vegetable crops under low-fertility soil conditions. The objectives of the recent study sought to characterize the effect of vermicompost tea in combining some natural plant extracts to enhance the growth and yield of the lettuce plant. A study on lettuce (*Lactuca sativa* L.) took place during two successive seasons, in 2018–2019 and 2019–2020, using foliar spray— vermicompost-tea rates in combination with rosemary leaf extract (RLE) and eucalyptus buds extract (EBE). It sought to determine the effects on growth, yield, and some physiological and biochemical traits of lettuce (cv. 'Dark Green') grown on sandy soil with drip irrigation. The experiment employed the split-plot design, with four rates of vermicompost tea (0%, 5%, 10%, and 20%) as main plots and three plant extract levels (without, RLE, and EBE) as subplots. The vermicompost tea and plant extracts increased the growth characteristics, photochemical activity, photosynthetic pigments, relative water content, membrane stability index, excised leaf water retention, vitamins C and E, and total soluble solids in lettuce plants compared with the untreated control plots. The interaction and combined application of vermicompost tea (20%) and RLE proved most effective in enhancing the growth and yield traits and physio-biochemical properties in lettuce. Therefore, the integrative application of vermicompost tea (20%) with RLE comes highly recommended for growing lettuce in sandy soil conditions.

Keywords: Vermicompost tea, rosemary leaf extract, eucalyptus buds extract, chlorophyll a and b, carotenoids, vitamins C and E, total soluble solids

Key findings: The combined application of vermicompost tea (20%) and rosemary leaf extract proved the most effective treatment to enhance growth and yield traits and physio-biochemical properties in lettuce under sandy soil conditions.

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INTRODUCTION

Head lettuce (*Lactuca sativa* L.), also named iceberg, is the world's most used salad crop. It is considered one of the most important leafy vegetable crops in Egypt and many regions of the world, especially in the Mediterranean. It is eaten fresh and is chiefly and extensively grown cool-season vegetable best adapted to temperate locations (La-Bella *et al.,* 2021). Lettuce leaves contain high amounts of minerals and vitamins C and K, which human health highly needs. Lettuce is also an excellent source of fiber, folate (the natural form of vitamin B9), and carotenoids (Van-Duyn and Pivonka, 2000). Lettuce is grown commercially and as a vegetable in home gardens in many countries (Rubatzky and Yamaguchi, 1997). The excessive use of chemical fertilizers raises the cost of production, degrades the environment, and affects soil fertility; therefore, it has become fundamental to use untraditional methods of fertilizers as supplements in the lettuce crop.

Vermicompost is an organic soil amendment produced from the decomposition of organic matter, such as, food wastes and animal manure, by earthworms and microorganisms (Paymaneh *et al.,* 2023). These products are usually fine-granulated soil-like particles resulting from the grinding action of earthworms and other microorganisms. Vermicomposting earthworm is the common species raised in simple windrows and more sophisticated systems, such as, modified continuous flow bins (Edwards *et al.,* 2010a). The vermicompost manure is rich in nutrients and free of plant and human pathogens. It has excellent potential for biological, chemical, and physical characteristics and serves as a plant growth medium in crop production (Arancon and Edwards*,* 2005). Many studies mentioned the application of vermicompost as an amendment in the potting soil and determined its effects on the growth and yield of vegetable crops (Atiyeh *et al.,* 2000; Arancon *et al.,* 2003; Arancon *et al*., 2004a, b). Vermicompost suppresses several arthropod pests in horticultural crops grown conventionally in greenhouses and fields (Arancon *et al.,* 2007).

Additionally, vermicompost promotes plant growth more effectively than thermophilic composts produced from the same organic substrate due to the superior array of biochemical properties in vermicompost that can support plant growth. Recently, vermicompost has expanded its utilization as water extracts, commonly referred to as 'teas' aqueous extracts, vermi-liquid, and leachates (Agegnehu *et al.,* 2016; Raza *et al.,* 2022). Vermicompost teas refer to the same material as prepared and used interchangeably. Vermicompost teas are prepared by steeping vermicompost in water, with or without aeration, to aid in the extraction of nutrients, other metabolites, and microorganisms during vermicomposting (Paymaneh *et al.,* 2023). Similar to the original solid form, earlier studies reported the use of vermicompost teas suppressed several relevant pests and diseases in horticultural crops (Edwards *et al*., 2010b; Radovich and Arancon, 2011).

Plant extracts contain natural growth-promoting substances, such as, phytohormones, osmoprotectants, antioxidants, nutrients, and various vitamins, strengthening the plants with the highest productivity (Rady *et al*., 2018). More recently, rosemary (*Rosmarinus officinalis*) leaves extract (RLE) and eucalyptus (*Eucalyptus camaldulensis*) buds extract (EBE) were found to contribute to the sustainability of plant growth and production (Semida and Rady, 2014; Desoky *et al*., 2019). These plant extracts are vital for horticulture crops to receive a relatively larger amount of external inputs (Picchi *et al.,* 2012). Therefore, the recent research work planned to assess the influence of vermicompost tea and foliar nourishing with RLE and EBE on growth, yield, and physiological and biochemical attributes of lettuce (*Lactuca sativa* L.) plant grown on sandy soil.

MATERIALS AND METHODS

Plant material and experimental procedure

A two-year field experiment progressed during the growing seasons of 2018–2019 and 2019–2020 at a private vegetable farm in Kafr El-Sinhab, District Al-Mansoura, Dakahlia Governorate (longitude is 31.36535 and latitude is 30.04471), Egypt. The experiments aimed to study the effect of different rates (0%, 5%, 10%, and 20%) of vermicompost tea combined separately with RLE and EBE extracts on growth, yield, and physiological and biochemical processes of lettuce under sandy soil conditions with drip irrigation.

A split-plot design with three replicates took place with two factors, i.e., vermicompost tea as a soil application and plant extracts as a foliar spray. The treatment details consist, viz., a) Control - no use of vermicompost tea, b)

Table 1. Mechanical and chemical analyses of the soil used in the two-year experimentation.

Mechanical analysis			Chemical analysis											
Coarse Sand %	Silt (%)	Clay (%)	Cations mg/100g soil				Anion mg/100g soil				E.Ca + 25c ds/m (mmhos/cm)	PH Soil Reaction	W.H.C.
			Ca++	Mg++	Na+	K+	CO3-	HCO3-	Cl-	SO4--			
52.95	27.95	19.3	3.0	1.8	2.5	0.1	0.00	0.5	1.18	5.72	2.96	7.71	34.64

vermicompost tea added at the rate of 5% (50 ml L^{-1}), c) vermicompost tea added at the rate of 10% (100 ml L^{-1}), and d) vermicompost tea added at the rate of 20% (200 ml L^{-1}) as a soil application, while plant extracts foliar sprays comprise a) control - No foliar spray, b) RLE, and c) EBE.

Lettuce (cv. 'Dark Green') seeds came from the Vegetable Research Section, Horticulture Research Institute, Agriculture Research Center (ARC), Giza, Egypt. Transplanting the seedlings ensued when two leaves fully expanded 30 days after sowing, then set up in the field on 30 October and 3 November in the first (2018-19) and second (2019-20) seasons, respectively. Seedlings planted on one side of the ridges were 25 cm apart, with the ridge measuring 80 cm in width and 4 m in length. Each subplot comprised four ridges, and the plot area measured about 12 m^2. The mechanical and chemical analyses of the used soil proceeded according to Black (1968) (Table 1).

The recommended cultural practices of growing lettuce proceeded. All plots received equal amounts of mineral nitrogen (N), phosphorus (P), and potassium (K) fertilizers, used by lettuce plants in sandy soil at 190, 110, and 170 kg ha^{-1}, in the form of ammonium sulfate (20.5% N), calcium superphosphate (15.5% P_2O_5), and potassium sulfate (48% K_2O), respectively. Mixing phosphorus with the soil occurred before planting, with N and K added into four portions every 15 days intervals, beginning 15 days from transplanting.

Vermicompost-teas preparation and application

Vermicompost-tea preparation used Compost Tea System-10 (Growing Solutions Incorporated). It is an aerated system with an air pump that produces fine bubble diffusion technology. Placing a gallon of vermicompost used a perforated plastic container suspended from the rim of the main container. Nine gallons of tap water filled the brewer and then left to brew for 24 h. The system produced a concentration of 20%, 10%, and 5% vermicompost from dilution. Preparing control (tap water only) also transpired. Vermicompost tea, with irrigation water, served as a soil application with three concentrations at a rate of 200 L ha^{-1} in three equal doses for the second, fourth, and sixth irrigations during the last 10 min of drip irrigation.

Preparation and application of RLE and EBE

The purchase of two plant samples, i.e., rosemary leaves and eucalyptus buds, took place from a local market in Zagazig, Egypt. Likewise, gallic acid, *tert*-Butylhydroquinone (TBHQ), 1,1-diphenyl 2picrylhydrazyl (DPPH˙), β-carotene, and quercetin gained purchase from Sigma (St. Louis, MO, USA). All other chemicals used were of analytical grade. The concentrations of total phenolic compounds (TPC) in the two extracts took to measure by a UV spectrophotometer (Jenway-UV-VIS Spectrophotometer) as described by Škerget *et al.* (2005). The used reagent was the Folin-Ciocalteu reagent (AOAC, 1990). Estimating the total flavonoid content proceeded according to Ordon *et al.* (2006). Performing the three foliar sprayings each of the distilled water (control), RLE, and EBE continued after 15, 30, and 45 days of transplanting, in the early morning utilizing a 20 L dorsal sprayer to run off RLE and EBE concentrations. The spray solutions received some drops of Tween-20 (0.1%, *v*/*v*) as a surfactant to optimize the penetration of the spray solution into the plant leaf tissues.

Data recorded

Growth and yield attributes

After 65 days of transplanting, plant harvest followed, recording the total yield for each plot. Three plants were randomly chosen from each experimental plot to determine plant height (cm), the number of leaves per plant, leaf area (cm^2), total yield (ton ha^{-1}), and relative increases in total yield (%).

Physiological parameters

Photochemical activity in fresh leaves of lettuce plants was determined according to Jagendorf (1956) and modified by Avron (1960) using Ferricyanide. About 0.2 g of fresh leaf tissues received grinding with 1.5 ml. phosphate buffer (pH 7.5), then transferred to conical flasks. The extraction of photosynthetic pigments (chlorophyll [Chl] a and b and carotenoids) from fresh leaf samples used pure acetone, according to Fadeels (1962). With the pigments filtered, the determination of optical density of the filtrate spectro-photo-chemically used the wavelengths of 662, 644, and 440.5 nm for Chl a, b, and carotenoids, respectively. The pigments (as mg g^{-1} fresh weight) calculation employed the method of Wettestein (1957). The method described by Barrs and Weatherley (1962) estimated the relative water content (RWC). The membrane stability index (MSI) determination followed the method described in the study of Rady (2011). Excised leaf water retention (ELWR) calculation used a formula from Farshadfar *et al*. (2001). The vitamin C was calculated based on a standard curve of L-ascorbic acid concentrations of 0, 10, 20, and 40 mg L^{-1}, according to AOAC (1990). Meanwhile, the vitamin E content estimate followed the method by Gimeno *et al.* (2000). Acquiring total soluble solids (TSS) gained through AOAC (1984).

Statistical analysis

After the analysis of variance, the comparison of significant variations among the means succeeded through Duncan's Multiple Range Test ($p \leq 0.05$). The statistical analysis followed through the CoStat computer software (CoHort Software version 6.303, Berkeley, CA, USA).

RESULTS AND DISCUSSION

Responses of plant growth characters

The effect of soil application of vermicompost tea, combined with foliar spray of two plant extracts, on plant height (cm), the number of leaves $plant^{-1}$, and leaf area (cm^2) of lettuce appears in Table 2. Compared with the untreated control, plant height, the number of leaves, and leaf area revealed significantly enhanced with increasing vermicompost-tea application rate. Application of vermicompost

Table 2. Interaction effects of vermicompost-tea soil application and foliar spray of rosemary leaf extract (RLE) and eucalyptus buds extract (EBE) on various growth traits of lettuce (cv. Dark Green) during crop seasons, 2018-2019 and 2019-2020.

Character / Treatment		Plant height (cm)		No. leaves $plant^{-1}$		Leaf area (cm^2)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
Effect of soil application							
Without		24.1±1.2^{d}	25.0±1.6^{d}	27.4±1.6^{d}	26.6±1.5^{d}	198±3.3d	195±2.5^{d}
Vermicompost 5%		29.5±2.3^{c}	28.2±1.8^{c}	33.1±2.1^{c}	32.1±2.1^{c}	235±3.6c	232±3.6^{c}
Vermicompost 10%		32.2±2.2^{b}	31.2±2.3^{b}	35.9±2.4^{b}	35.0±2.4^{b}	254±3.9b	252±3.8^{b}
Vermicompost 20%		35.3±2.6^{a}	34.1±2.5^{a}	38.3±2.6^{a}	37.7±2.6^{a}	264±3.8a	262±4.2^{a}
Effect of foliar spray							
Without		27.4±2.8^{c}	26.2±1.5^{c}	30.2±2.0^{c}	29.5±2.7^{c}	208±4.2c	205±4.2c
RLE		33.1±2.9^{a}	31.8±1.4^{a}	36.1±2.4^{a}	35.2±2.1^{a}	256±4.5a	254±4.6^{a}
EBE		31.9±2.1^{b}	30.9±2.3^{b}	34.7±2.1^{b}	33.8±2.1^{b}	248±3.9b	246±4.8^{b}
Effect of interaction							
Soil application	Foliar spray						
Without	Without	24.3±1.6^{i}	23.2±1.3^{h}	25.7±1.4^{j}	25.0±1.4^{k}	188±4.5^{k}	186±4.8^{l}
	RLE	27.3±1.9^{gh}	26.4±1.6^{fg}	29.3±1.7^{h}	28.4±1.6^{i}	205±4.8^{i}	203±5.3^{j}
	EBE	25.5±1.4^{h}	25.4±1.5^{g}	27.2±1.6^{i}	26.3±1.4^{j}	199±3.6^{j}	197±3.9^{k}
Vermicompost 5%	Without	27.9±1.5^{g}	26.7±1.7^{fg}	30.6±1.9^{g}	29.8±2.6^{h}	209±3.9^{i}	206±5.4^{i}
	RLE	30.8±2.1^{d}	29.3±1.8^{d}	35.0±2.4^{e}	33.8±2.1^{e}	254±4.5^{e}	251±4.3^{e}
	EBE	29.9±2.3^{de}	28.7±1.3^{de}	33.9±2.1^{f}	32.8±2.0^{f}	241±3.6^{f}	239±4.8^{f}
Vermicompost 10%	Without	28.5±1.6^{fg}	27.2±1.6^{f}	31.6±2.1^{g}	30.9±1.9^{g}	214±5.3^{h}	212±2.6^{h}
	RLE	35.1±2.4^{b}	34.1±2.1^{b}	38.9±2.5^{c}	37.7±2.4c	277±4.8^{c}	276±3.6^{c}
	EBE	33.2±2.5^{c}	32.5±2.3^{c}	37.2±2.4^{d}	36.3±2.1^{d}	270±4.9^{d}	268±3.8^{d}
Vermicompost 20%	Without	29.1±2.5^{ef}	27.6±1.7^{ef}	33.1±2.1^{f}	32.3±2.1^{f}	219±4.2^{g}	218±3.9^{g}
	RLE	39.9±2.6^{a}	37.7±2.6^{a}	41.5±2.8^{a}	41.1±2.9^{a}	289±4.1^{a}	287±3.7^{a}
	EBE	38.1±1.9^{a}	36.9±2.5^{a}	40.6±2.9^{b}	39.8±2.4^{b}	284±4.6^{b}	282±3.9^{b}

tea at the rate of 20% provided the best performance as it increased plant height by 46.4% and 36.4%, the number of leaves by 43.9% and 41.7%, and leaf area by 33.3% and 34.3%, during the two seasons, respectively. Plant extracts (RLE and EBE) also promoted the plant height, number of leaves per plant, and leaf area of lettuce plants compared with the control treatment. Data concerning the interaction effect between vermicompost tea and the plant extracts also significantly enhanced the plant growth characteristics versus the control treatment. Among the treatments, the combined application of vermicompost tea (20%) and RLE showed the best. It increased plant height by 56.7% and 59.1%, the number of leaves by 57.9% and 59.2%, and leaf area by 50.0% and 51.6% for the two reasons, respectively.

The factors that impact plant growth could be responsible for the enhanced plant growth after substituting the medium with the pig solids vermicompost and/or the composted biosolids. Goh and Haynes (1977) reported that plant growth is generally optimized when the pH is between 5.0 and 6.5. The vermicomposted pig solids had a pH of 5.3, whereas the food waste vermicompost and all other composts had an alkaline pH between 6.8 and 8.1. The high pH of these materials may have raised the pH of the container medium to a degree proportional to the amount of vermicompost or compost incorporated (Gallardo-Lara and Nogales, 1987), resulting in reduced plant growth as compared with the vermicomposted media. The improvements in plant growth could also be due to differences in the contents of mineral element substrates, vermicomposts, and composts. Vermicompost contained large concentrations of nitrate (NO_3^--N), thus increasing plant growth significantly to a level comparable to that of fertilized soil in the raspberry study (Arancon and Edwards*,* 2005). Composted biosolids also contained high ammonium levels, resulting in a significant increase in the growth of lettuce plants. The decline in plant growth as substituted by the soil or container medium with the yard, leaf, and bark composts, could be related to the stability and maturity of these composts, rather than their mineral nutrient content (Atiyeh *et al.,* 2000). Saviozzi *et al*. (1988) reported that organic wastes, to be compatible with agricultural uses and to avoid adverse effects on plant growth, be transformed into a humus-like material and be sufficiently stabilized. The study noted taller plants and enhanced stem diameters after the treatment with vermicompost, which is also consistent with previous research showing that crop plants had increased height with the application of vermicompost (Kmet'ova and Kovacik, 2013). This boost in the growth traits might be due to the higher N content in soil caused by applying vermicompost. Singh and Varshney (2013) also found improved soil ammonium (NH^+_4-N) and NO^-_3-N significantly after applying vermicompost. Vermicompost can also enhance the growth of N-fixing microorganisms in the rhizosphere, further increasing the availability of biologically fixed N through the intimate mixing of ingested particles with soil (Mackay *et al.,* 1982). Likewise, the findings of Arancon *et al.* (2003) indicated the improvement in crop growth could also be partial to a large increase in soil microbial biomass after the application of vermicompost, leading to more hormones and humate content in the vermicompost-treated soils (Wang *et al*., 2017). The current results revealed that the application of vermicompost tea increased lettuce growth parameters compared with the control, in agreement with those found in former studies (Aslam *et al.*, 2019; Gupta *et al*., 2019; Ievinsh, 2020).

The latest findings further authenticated that foliar application of plant extracts enhanced the lettuce growth characteristics, which might be due to phenolic compounds in the extracts playing an essential role in promoting plant growth (Santosa *et al*., 2022). Plant phenolics are internal physiological regulators and chemical messengers within intact plants, found in hydroxycinnamic acids, particularly p-coumaric acid and ferulic acid, present in the insoluble or cell wall fraction. Phenolic compounds have exhibited to have both stimulatory and inhibitory effects on plant development, and therefore, play a significant role in cell wall development and lignin biosynthesis (Filippi *et al*., 2020). Some phenolic compounds work as natural auxin transport regulators in plants, and the mono-and dihydroxy flavonoids work as inhibitors of IAA transport (Ribeiro *et al*., 2019). The reported relationship between polyphenol metabolism and the seasonal development of plant tissues can influence plant growth by promoting leaf expansion (Santosa *et al*., 2022) and stimulating callus growth (Popelka *et al*., 2017). Phenolics work as a signal for growth and can directly affect the composition and activity of decomposer communities. Different types of soluble phenolics, such as, ferulic acid, gallic acid, and flavonoids, have been found to either stimulate or inhibit spore germination and hyphal growth of saprophytic fungi (Lattanzio *et al*., 2006). Phenolic acids strongly influence cell membrane potentials and support the hypothesis that affects ion uptake (Glass and Dunlop, 1974). A correlation between the seasonal growth activity and endogenous levels of specific phenolics expressed in buds of sour cherry (Szember and Wocior, 1976). However, exogenously applied naringenin did not delay bud bursts in peaches (Dennis and Edgerton, 1961).

Total yield

Lettuce plants treated with vermicompost tea (20%) showed a significant increase in fresh head and dry weight, head diameter, and total yield compared with the control treatment (Table 3). The vermicompost tea (20%) presents the best treatment, with increased lettuce total yield by 44%–45%, during both seasons. Moreover, lettuce treated with bio-stimulant plant extracts (RLE and EBE) significantly expressed a higher total yield versus the control treatment. The highest values of the previously mentioned parameters showed under RLE, followed by EBE, compared with the untreated plants. Data concerning the interaction effect between vermicompost tea and foliar application of plant extracts notably enhanced the yield characteristics compared with the control treatment. Among all the integrative treatments, the vermicompost tea 20% + RLE certifies the best, which enhanced the total lettuce yield by 66%–69% during both seasons. Vermicompost guarantees an effective type of organic fertilizer for the cultivation of lettuce (Rezaei-Chiyaneh *et al.*, 2021). Most importantly, the application of vermicompost increased the yield of plants and soil sustainability by boosting microbial activities (Mostafa, 2018). Plants receiving vermicompost demonstrated higher growth, yield, and quality parameters versus plants receiving chemical fertilizers (Uma and Malathi, 2009). Suthar (2009) reported that garlic plants with vermicompost treatment had higher values expressed in various growth and yield parameters compared with the least values obtained with chemical fertilizers.

Table 3. Interaction effects of vermicompost-tea soil application and foliar spray of rosemary leaf extract (RLE) and eucalyptus buds extract (EBE) on total yield (ton ha^{-1}), relative increases in total yield (%) and photochemical activity (micromole/mg Chl. per 10 min) of lettuce (cv. Dark Green) during crop seasons, 2018-2019 and 2019-2020.

Character / Treatment		Total yield (ton ha^{-1})		Relative increases in total yield (%)		Photochemical activity (micromole/mgchl.per10min.)	
		2018/2019	2019/2020	2018/ 2019	2019/ 2020	2018/2019	2019/2020
Effect of soil application							
Without		34.5±1.2^{d}	33.6±1.5^{d}	00.0	00.0	183±2.3^{d}	181±2.8^{d}
Vermicompost 5%		43.2±2.4^{c}	42.4±1.9 ^{c}	25.0	26.4	203±2.6^{c}	200±2.3^{c}
Vermicompost 10%		46.2±1.9	45.1±2.3^{b}	33.3	34.2	209±2.8^{b}	206±2.4^{b}
Vermicompost 20%		49.7±1.6	48.7±2.4^{a}	43.7	45.0	213±3.2^{a}	209±2.5^{a}
Effect of foliar spray							
Without		38.1±1.1^{c}	37.2±1.8^{c}	00.0	00.0	190±2.8^{c}	187±2.8^{c}
RLE		46.8±1.3^{a}	47.2±1.5^{a}	22.6	27.0	209±2.7^{a}	207±3.6^{a}
EBE		45.3±1.1^{b}	44.4±2.1^{b}	18.8	19.3	207±2.9^{b}	204±3.4^{b}
Effect of interaction							
Soil application	Foliar spray						
Without	Without	31.6±1.3^{k}	30.7±1.1^{k}	00.0	00.0	177±2.9^{j}	175±3.4^{i}
	RLE	36.2±1.5^{j}	35.5±1.4^{j}	14.3	15.6	188±3.2^{h}	186±3.5^{g}
	EBE	35.5±1.8^{j}	34.5±1.7^{j}	12.2	12.5	185±3.8^{i}	185±3.8^{g}
Vermicompost 5%	Without	38.4±1.6^{i}	37.2±1.6^{i}	21.2	21.0	189±3.7^{h}	186±3.2^{g}
	RLE	46.5±1.5^{e}	45.8±1.5^{e}	46.9	49.2	211±3.6^{d}	208±3.7^{c}
	EBE	45.1±1.9^{f}	44.1±1.4^{f}	42.4	43.7	209±3.9^{e}	206±3.5^{d}
Vermicompost 10%	Without	40.3±1.4^{h}	39.8±1.9^{h}	27.2	29.6	194±3.8^{g}	191±3.7^{f}
	RLE	49.6±2.2^{c}	48.4±2.5^{c}	56.8	57.8	217±3.5^{b}	215±3.6^{a}
	EBE	48.0±2.6^{d}	47.2±2.3^{d}	51.5	53.9	215±2.9^{c}	211±3.7^{b}
Vermicompost 20%	Without	42.2±2.2^{g}	41.1±2.^{g}	33.3	33.5	198±3.4^{f}	195±2.9^{e}
	RLE	54.2±2.6^{a}	53.5±2.5^{a}	71.2	74.2	220±3.1^{a}	217±2.4^{a}
	EBE	52.5±2.3^{b}	51.8±2.2^{b}	65.9	68.7	219±3.4^{ab}	215±2.6^{a}

In the latest study, lettuce yield increased by 43%–45% with the application of vermicompost. Together with the observed increase in plant shoot and total biomass, the increase in yield suggests that vermicompost is an efficient treatment to enhance crop yield and also confirms the results of former studies (Lazcano and Domínguez, 2011). The use of vermicompost seemed particularly useful in organic farming because vermicompost provides nutrients that would otherwise need to be brought by synthetic fertilizers that are prohibited in organic agriculture. However, to fully assess the upsides and downsides of vermicompost for agriculture require some other steps, i.e., a) Compare the increase in plant growth attributable to vermicompost to those attributable to composts produced in the absence of earthworms, b) Composting tends to stabilize organic matter so that composts have long-lasting effects on soil fertility, thus, compare the standard composting and vermicomposting, and c) Through economic analysis, compare the costs of producing vermicompost and standard compost. The present results illustrated that vermicompost significantly increased the head parameters and total yield of lettuce plants compared with the control, which confirmed the findings obtained by Ali *et al*. (2007). In addition, RLE and EBE also play an important role in increasing lettuce yield and head parameters. The composition of RLE and EBE indicates that these extracts can be used as a plant bio-stimulant as these contain a phenolic component that plays a crucial role in plant growth, reflected in total yield (Naikoo *et al.,* 2019). Phenolics influence the physiological processes related to plant growth and development, including seed germination, cell division, and synthesis of photosynthetic pigments (Tanase *et al*., 2019). Exploiting phenolic compounds for several applications include bioremediation, allelochemical, promotion of plant growth, and productivity (Bujor *et al*., 2015). In plants, phenolic accumulation is usually a consistent feature, representing a positive mechanism to increase plant yield (Naikoo *et al*., 2019).

Photochemical activity

The vermicompost-tea application increased the photochemical activity of leaf tissues compared with the untreated control (Table 3). The vermicompost-tea application at 20% gave the best results in increasing photochemical activity by about 16% in both seasons. The foliar spray with RLE and EBE also significantly increased the photochemical activity versus untreated plants. The highest values of photochemical activity exhibited under RLE treatment increased by 10%–11% in both growing seasons. Adding vermicompost tea and plant extracts also significantly enhanced the photochemical activity in treated plants versus the control. Among all treatments, the vermicompost-tea application (20%) combined with RLE proved best, enhancing the photochemical activity by 24% in both seasons. The rate determination of phosphorylation, ferricyanide, and dye reduction proceeded with chloroplasts isolated from plant leaves grown in darkness and subjected to periods of light with different durations. An increased period of illumination also increased the chlorophyll content the same as the measured three processes but showed no correlation between both factors. Moreover, no correlation occurred between the rate of any photochemical reaction and the plastoquinone content. It was concluded that some unspecified factor, possibly structural, which develops during illumination, must control the rate of the photochemical reactions.

The plants, grown in darkness, show an absence of chlorophyll and a lengthening of the internodes. Many investigators have followed the development of chlorophyll when placing such plants at night (Naikoo *et al*., 2019), and others have determined the time course of the rate of photosynthesis and its relationship to the development of chlorophyll (Abad *et al.,* 2000). In some plants, photosynthetic activity is found as and when some chlorophyll is formed, while in others the photosynthetic activity develops more slowly (Tanyolac *et al.*, 2007). The reduction in photosynthetic activity may be due to stomatal or non-stomatal mechanisms, as reported by Samarah *et al.* (2009). However, Reddy *et al*. (2004) observed decreases in photosynthetic pigments synthesis and CO_2 assimilation rates due to reduced stomatal conductance. In turn, it reduces the contents and activities of photosynthetic carbon reduction cycle enzymes, including the key enzyme, ribulose-1, 5-bisphosphate carboxylase-oxygenase. The study's present results agree with those obtained by Ose *et al.* (2021), who found that vermicompost increased photosynthetic pigments synthesis and CO_2 assimilation rates due to reduced stomatal conductance. In addition, vermicompost contains available elements causing a reduction in the activities of photosynthetic carbon reduction cycle enzymes, including the key enzyme, ribulose-1, 5- bisphosphate carboxylase-oxygenase

(Ievinsh, 2020). The study indicated that the vermicompost-tea treatment increased the photochemical activity of lettuce plants under sandy soil conditions. Aslam *et al.* (2019) demonstrated that vermicompost increased nutrients in the soil, increasing photochemical activity and CO_2 assimilation in grapefruit leaves. Gupta *et al*. (2019) also found that the photochemical activity rate was higher in those treated with vermicompost tea compared with the control.

Photosynthetic pigments

Data presented in Table 4 shows the effects of vermicompost tea, plant extracts, and their interaction on the concentration of chlorophyll a and b and carotenoids of lettuce plants. The obtained results illustrated significant variations among vermicompost-tea levels for the concentration of chlorophyll a and b and carotenoids in lettuce leaves. The highest values of chlorophyll a and b and carotenoids resulted in the application of vermicompost tea (20%), while the lowest values were in the control treatment. Foliar spray with RLE and EBE also significantly increased photosynthetic pigments compared with untreated plants. The highest values of photosynthetic pigments appeared under the RLE treatment. Vermicompost tea combined with plant extracts significantly enhanced the photosynthetic pigments compared with the control. The combined application of vermicompost tea (20%) and RLE delivered the best treatment, which increased chlorophyll a by 86.0% and 85.7%, chlorophyll b by 42.8% and 51.3%, and carotenoids by 43.1% and 43.8% in the growing seasons of 2018-2019 and 2019-2020, respectively. The maintenance of leaves per plant and green leaf area maximized leaf photosynthesis, increasing sink capacity fulfilled through the supply of photoassimilates from green leaves (Desoky *et al.,* 2021). Vermicompost-tea application maximized active photosynthetic leaves and leaf area, maintaining the chlorophyll in higher concentrations. In this respect, Ose *et al.* (2021) reported that chlorophyll concentration was positively affected by the vermicompost amendment in a concentration-dependent manner, however, this effect during a cultivation period appeared relatively late.

Table 4. Interaction effects of vermicompost-tea soil application and foliar spray of rosemary leaf extract (RLE) and eucalyptus buds extract (EBE) on photosynthetic pigments of lettuce (cv. Dark Green) during crop seasons, 2018-2019 and 2019-2020.

Character / Treatment		Chl. a (mg g^{-1} FW)		Chl. b (mg g^{-1} FW)		Carotenoids (mg g^{-1} FW)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
Effect of soil application							
Without		1.76±0.12^{d}	1.73±0.14^{d}	0.728±0.02^{d}	0.686±0.01^{d}	1.06±0.09^{d}	1.01±0.02^{d}
Vermicompost 5%		2.37±0.21^{c}	2.33±0.12^{c}	0.846±0.06^{c}	0.795±0.03^{c}	1.24±0.11^{c}	1.19±0.03^{c}
Vermicompost 10%		2.49±0.16^{b}	2.45±0.16^{b}	0.890±0.08^{b}	0.855±0.04^{b}	1.28±0.12^{b}	1.24±0.04^{b}
Vermicompost 20%		2.63±0.23^{a}	2.58±0.19^{a}	0.926±0.07^{a}	0.894±0.03^{a}	1.36±0.08^{a}	1.32±0.05^{a}
Effect of foliar spray							
Without		2.07±0.16^{c}	2.03±0.18^{c}	0.772±0.03^{c}	0.735±0.05^{b}	1.13±0.06^{c}	1.09±0.02^{c}
RLE		2.47±0.15^{a}	2.43±0.17^{a}	0.896±0.02^{a}	0.847±0.06^{a}	1.31±0.07^{a}	1.25±0.04^{a}
EBE		2.40±0.17^{b}	2.36±0.16^{b}	0.875±0.04^{b}	0.840±0.06^{a}	1.28±0.09^{b}	1.22±0.06^{b}
Effect of interaction							
Soil application	Foliar spray						
Without	Without	1.50±0.11^{k}	1.47±0.11^{i}	0.690±0.02^{l}	0.623±0.02^{f}	1.02±0.04^{k}	0.98±0.01^{h}
	RLE	1.95±0.12^{i}	1.92±0.12^{g}	0.760±0.03^{j}	0.730±0.03^{de}	1.10±0.03^{j}	1.03±0.03^{g}
	EBE	1.83±0.13^{j}	1.80±0.15^{h}	0.736±0.04^{k}	0.706±0.02^{e}	1.08±0.05^{j}	1.02±0.04^{g}
Vermicompost 5%	Without	2.17±0.14^{h}	2.12±0.13^{f}	0.776±0.03^{i}	0.743±0.04^{de}	1.14±0.03^{i}	1.10±0.04^{f}
	RLE	2.50±0.16^{d}	2.48±0.14^{c}	0.893±0.06^{e}	0.826±0.06^{c}	1.30±0.05^{e}	1.26±0.05^{c}
	EBE	2.44±0.18^{e}	2.39±0.16^{d}	0.870±0.05^{f}	0.816±0.04^{c}	1.28±0.06^{f}	1.22±0.06^{d}
Vermicompost 10%	Without	2.25±0.21^{g}	2.21±0.19^{e}	0.801±0.06^{h}	0.780±0.04^{cd}	1.17±0.04^{h}	1.12±.04^{f}
	RLE	2.65±0.22^{b}	2.60±0.15^{b}	0.946±0.04^{c}	0.896±0.04^{ab}	1.35±0.06^{c}	1.32±00.07^{b}
	EBE	2.58±0.18^{c}	2.54±0.14^{bc}	0.923±0.07^{d}	0.890±0.04^{b}	1.33±0.07^{d}	1.29±0.06^{bc}
Vermicompost 20%	Without	2.36±0.19^{f}	2.32±0.13^{d}	0.823±0.06^{g}	0.796±0.05^{c}	1.20±0.03^{g}	1.16±0.08^{e}
	RLE	2.79±0.23^{a}	2.73±0.12^{a}	0.986±0.03^{a}	0.943±0.03^{a}	1.46±0.04^{a}	1.41±0.05^{a}
	EBE	2.75±0.24^{a}	2.70±0.14^{a}	0.970±0.04^{b}	0.943±0.06^{a}	1.42±0.03^{b}	1.38±0.04^{a}

Vermicompost increased the leaf chlorophyll content (Hawkins and Lewis, 1993). In most studies, the chlorophyll content of the plant increases with vermicompost addition, which leads to enhanced photosynthesis by the plant and thus, enhances the stored chemicals, like primary and secondary metabolites (Makkar *et al*., 2022). Moreover, higher chlorophyll values showed in plants treated with vermicompost and compost than control (Wang *et al.,* 2017). The correlation between the leaf chlorophyll content index and plant nitrogen content has been demonstrated to be useful for estimating plant nitrogen status (Yuan *et al*., 2016). Chlorophyll values accurately reflect the quantity of mineral N required by the plants (Van-Den-Berg and Perkins, 2004). Chlorophyll values could also demonstrate that vermicompost and compost improve the soil N status and are thus used by crop plants (Wang *et al*., 2017). In the study, the vermicompost positively affected chlorophyll concentration. Therefore, it is believed that the increased chlorophyll concentration in the leaves of lettuce plants grown in vermicompost-amended substrate reflected delayed senescence of these plants due to a prolonged supply of mineral nutrients. The present results also got support from past findings in which the effects of vermicompost and other fertilizers on the growth, yield, and nutritional values of the lettuce were studied (Meenakumari and Shehkar, 2012).

Leaf water relationship

The effect of vermicompost tea and plant extracts on leaf water relations, i.e., RWC, MSI, and ELWR in lettuce leaves reflects in Table 5. The application of vermicompost tea significantly increased the leaf-water relationship compared with untreated plants.

Table 5. Interaction effects of vermicompost-tea soil application and foliar spray of rosemary leaf extract (RLE) and eucalyptus buds extract (EBE) on relative water content (RWC), membrane stability index (MSI), and excised leaf water retention (ELWR) of lettuce (cv. Dark Green) during the crop seasons, 2018-2019 and 2019-2020.

Character / Treatment		RWC (%)		MSI (%)		ELWR (%)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
Effect of soil application							
Without		74.1±2.1^{d}	72.7±3.1^{d}	56.1±1.6^{d}	54.7±1.9^{d}	68.0±3.3^{d}	66.5±2.2^{d}
Vermicompost 5%		79.1±2.6^{c}	77.6±2.6^{c}	61.3±1.5^{c}	59.7±2.1^{c}	70.1±3.5^{c}	68.8±3.1^{c}
Vermicompost 10%		80.6±3.2^{b}	78.9±3.2^{b}	62.6±1.4^{b}	61.2±1.6^{b}	72.1±3.6^{b}	70.7±3.5^{b}
Vermicompost 20%		82.9±3.5a	81.1±3.5^{a}	64.7±1.7^{a}	63.3±2.1^{a}	75.5±3.8^{a}	71.9±3.6^{a}
Effect of foliar spray							
Without		76.2±2.9^{c}	74.9±2.4^{c}	58.8±1.2^{d}	57.3±2.2^{c}	68.2±2.6^{c}	66.5±2.8^{c}
RLE		81.2±3.4^{a}	79.3±2.9^{a}	62.9±1.6^{a}	61.5±2.3^{a}	72.5±2.9^{a}	71.2±3.6^{a}
EBE		80.1±3.6^{b}	78.5±2.7^{b}	61.9±1.5^{b}	60.4±2.7^{b}	72.0±2.4^{b}	70.6±3.1^{b}
Effect of interaction							
Soil application	Foliar spray						
Without	Without	72.1±2.2^{k}	71.1±2.3^{i}	54.3±1.7^{j}	52.9±1.9^{i}	65.4±3.3^{g}	64.0±2.5^{g}
	RLE	75.4±2.5^{i}	73.7±2.5^{h}	57.7±1.9^{h}	56.4±2.2^{g}	69.1±3.4^{e}	67.7±2.8^{e}
	EBE	74.6±2.3^{j}	73.3±2.4^{h}	56.3±1.8^{i}	54.9±2.6^{h}	67.9±3.2^{f}	66.4±2.7^{f}
Vermicompost 5%	Without	76.8±2.5^{h}	75.4±2.6^{g}	59.5±2.1^{g}	58.0±2.5^{f}	69.4±3.8^{e}	67.8±2.8^{e}
	RLE	80.4±2.9^{e}	79.2±3.1^{cd}	62.7±2.4^{d}	61.2±2.8^{c}	71.7±3.6^{d}	70.3±3.1^{d}
	EBE	79.7±2.8^{f}	78.2±2.9^{de}	61.8±2.3^{e}	59.8±2.7^{d}	70.8±2.9^{d}	69.7±3.3^{d}
Vermicompost 10%	Without	77.7±2.6^{g}	76.2±2.7^{fg}	60.6±2.6^{f}	58.8±2.3^{ef}	69.6±2.7^{e}	67.9±3.4e
	RLE	82.6±3.1^{c}	80.5±3.1^{c}	64.0±2.8^{c}	62.6±2.8^{b}	73.8±2.8^{bc}	72.5±3.6^{bc}
	EBE	81.5±3.2^{d}	80.2±3.6^{c}	63.3±2.9^{cd}	62.3±2.1^{b}	73.0±3.2^{c}	71.6±3.8^{c}
Vermicompost 20%	Without	78.4±2.7^{g}	77.1±2.8^{ef}	60.8±2.4^{f}	59.5±1.9^{de}	69.8±2.6^{e}	68.1±3.5^{e}
	RLE	86.1±3.4^{a}	84.1±3.4^{a}	67.1±2.8^{a}	65.6±2.8^{a}	75.9±2.9^{a}	74.2±3.2^{a}
	EBE	74.3±2.3^{b}	82.2±3.7^{b}	66.2±2.1^{b}	64.8±2.6^{a}	74.7±2.7^{b}	73.2±2.9^{ab}

The application of vermicompost tea (20%) enhanced the values of RWC, MSI, and ELWR. Also, foliar application of RLE and EBE significantly increased the leaf-water relations versus the control. However, the highest values of leaf-water relations existed with the treatment of RLE. Data also concerning the interaction effect between vermicompost tea and plant extracts significantly increased the leaf water relations compared with the control. Among all-integrative treatments, the combination of vermicompost tea at 20% and RLE displayed the best treatment and increased RWC by 19.4% and 18.2%, MSI by 23.5% and 24.1%, and ELWR by 16.0% and 15.8% in the crop seasons of 2018-2019 and 2019-2020, respectively. Water status proves essential to tissue health, and therefore, it is prevalent in estimating the plant responses to environmental conditions (Stępień and Kłobus, 2006). Commonly known that adverse conditions decreased the hydraulic conductivity of roots, resulting in reduced water flow from roots to shoots, even in osmotically adjusted plants (Prisco, 1980). Photosynthesis, coupled with the plant's transpiration rate and inhibition, works as a reliable and quick measure of the toxic effects of salt (Trapp *et al.,* 2008). The reduction in RWC in plants suggested that water flow from roots to shoots and caused a decrease in growth. The decrease in water flow may cause a reduction in leaf water content, which would result in the closure of stomata to preserve their water status (Prisco, 1980). In this connection, Akram's (2011) findings revealed that increased yield and yield components were associated with a high value of RWC. Progressively, the leaf size, stem extension, and root proliferation also manage the water use efficiency and plant-water relationship (Anjum *et al*., 2011). The vermicompost increased the availability of nutrients, such as potassium, which as a macro-nutrient, plays a vital role in cell expansion, closure, behavior, and movement of stomata (Elumalai *et al*., 2002) and water relation as osmotic adjustment and turgor regulation in plants (Marschner, 1995). The K-fed plants maintained higher leaf water potential, lower osmotic potential and RWC, and turgor potential compared with the untreated plants in wheat (Pier and Berkowitz, 1987). The present results indicate that the application of vermicompost tea increased the RWC, MSI, and ELWR. These results also align with Aslam *et al.* (2019), observing that the nutrient deficiency in mung bean can be treated by vermicompost, vermi-tea, and chemical fertilizers.

Vitamin C, E, and total soluble solids (TSS)

The effects of vermicompost tea, plant extracts, and their interaction on vitamins C, E, and TSS of lettuce plants occur in Table 6. The results illustrated significant variations among vermicompost-tea levels for vitamins C, E, and TSS of lettuce leaves. The recorded highest values of vitamins C, E, and TSS came under the application of vermicompost tea (20%), while the lowest values were in the control treatment. The foliar spray with RLE and EBE significantly increased vitamins C, E, and TSS compared with untreated plants. However, the highest values of vitamins C, E, and TSS resulted under RLE treatment. Also, the combined application of vermicompost tea and plant extracts significantly enhanced vitamins C, E, and TSS compared with the control treatment. The vermicompost tea (20%) and RLE confirmed the best treatment, which increased vitamin C by 80.2% and 79.5%, vitamin E by 47.3% and 46.9%, and TSS by 91.6% and 94% in both growing seasons, respectively. This vitamin is a water-soluble compound, and its content represents the overall quality of leafy vegetable products, as there is always a good correlation between its content and product quality (Souri and Hatamian, 2019). L-ascorbic acid (or vitamin C) is one of the most important quality factors in leafy vegetable crops. Adverse conditions can significantly reduce the content of this vitamin in plant tissues (Souri and Hatamian, 2019).

In this study, the most pronounced effect of vermicompost-tea application resulted from the leaf vitamin C concentration. An increase in the leaf vitamin C and improvement in its quality has also existed with the application of vermicompost tea (Junxi *et al*., 2010; Arın *et al*., 2021). Wang *et al.* (2010) investigated the effects of vermicompost on the plant growth of Chinese cabbage and noted that the application of vermicompost significantly increased the nutritional values and vitamin C contents. Arancon and Edwards (2005) reported that vermicompost is critical in the ripening of various plants, even if used in low doses. On the other hand, vermicompost-tea soil application also increased vitamin E, and Hanc and Vasak (2015) reported the same findings. The total soluble solids percentage increased significantly with the

Table 6. Interaction effects of vermicompost-tea soil application and foliar spray of rosemary leaf extract (RLE) and eucalyptus buds extract (EBE) on vitamins C, E, and total soluble solids (TSS) of lettuce (cv. Dark Green) during crop seasons, 2018-2019 and 2019-2020.

Character / Treatment		Vitamin C (mg/ 100g FW)		Vitamin E (mg/ 100g FW)		TSS (%)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
Effect of soil application							
Without		15.5±1.1^{d}	15.1±1.4^{d}	0.137±0.00^{d}	0.134±0.00^{d}	3.46±0.12^{d}	3.38±0.11^{c}
Vermicompost 5%		20.1±1.3^{c}	19.2±1.7^{c}	0.161±0.01^{c}	0.156±0.00^{c}	4.55±0.15^{c}	4.48±.013^{b}
Vermicompost 10%		21.7±1.5^{b}	20.9±1.9^{b}	0.170±0.01^{b}	0.165±0.00^{b}	2.08±0.16^{b}	4.80±0.18^{b}
Vermicompost 20%		23.3±1.4^{a}	22.1±2.1^{a}	0.180±0.01^{a}	0.175±0.00^{a}	5.33±.019^{a}	5.27±0.15^{a}
Effect of foliar spray							
Without		17.5±1.2^{c}	16.7±1.5^{c}	0.147±0.00^{c}	0.143±0.00^{c}	3.87±0.11^{c}	3.81±0.12^{c}
RLE		21.9±1.6^{a}	21.1±1.9^{a}	0.171±0.01^{a}	0.168±0.00^{a}	5.06±00.13^{a}	4.90±0.16^{a}
EBE		21.1±1.8^{b}	20.3±1.8^{b}	0.167±0.01^{b}	0.162±0.00^{b}	4.88±0.28^{b}	4.74±0.22^{b}
Effect of interaction							
Soil application	Foliar spray						
Without	Without	14.2±1.2^{k}	13.7±1.1^{h}	0.133±0.00^{k}	0.130±0.00^{j}	3.10±0.15^{l}	3.03±0.12^{g}
	RLE	16.5±1.4^{j}	16.1±1.4^{g}	0.140±0.00^{j}	0.137±0.00^{i}	3.73±0.18^{j}	3.61±0.21^{ef}
	EBE	16.0±1.4^{j}	15.6±1.3^{g}	0.137±0.00^{j}	0.134±0.00^{i}	3.57±0.12^{k}	3.46±0.24^{f}
Vermicompost 5%	Without	17.5±1.5^{i}	17.1±1.5^{f}	0.147±0.00^{i}	0.144±0.00^{h}	4.02±0.13^{i}	3.94±0.21^{de}
	RLE	21.7±1.9^{e}	20.5±1.8^{d}	0.170±0.01^{e}	0.166±0.00^{e}	4.94±0.14^{e}	4.87±0.23^{bc}
	EBE	21.1±1.8^{f}	20.0±1.7^{d}	0.165±0.00^{f}	0.159±0.00^{f}	4.69±0.14^{f}	4.64±0.25^{c}
Vermicompost 10%	Without	18.7±1.6^{h}	17.6±1.5^{f}	0.152±0.00^{h}	0.147±0.00^{h}	4.13±0.25^{h}	4.10±0.26^{d}
	RLE	23.8±1.1^{c}	23.1±2.1^{b}	0.180±0.01^{c}	0.177±0.00^{c}	5.65±0.23^{c}	5.25±0.28^{b}
	EBE	22.6±1.1^{d}	22.1±2.0^{c}	0.177±0.01^{d}	0.173±0.00^{d}	5.45±0.25^{d}	5.07±0.24^{bc}
Vermicompost 20%	Without	19.7±1.3^{g}	18.6±1.6^{e}	0.157±0.00^{g}	0.153±0.00^{g}	4.22±0.24^{g}	4.15±0.23^{d}
	RLE	25.6±1.4^{a}	24.6±2.2^{a}	0.196±0.01^{a}	0.191±0.01^{a}	5.94±0.25^{a}	5.88±0.24^{a}
	EBE	24.7±1.2^{b}	23.3±2.1^{b}	0.187±0.01^{b}	0.182±0.00^{b}	5.84±0.23^{b}	5.79±0.26^{a}

application of vermicompost tea, and in this respect, Blouin *et al*. (2019) also declared that vermicompost has a positive effect on mineral element uptakes, such as K and P. When exposing the nutrient solution in the field, the plant's roots get stimulated, allowing for higher nutrient absorption and improved plant characteristics, such as, TSS. Also, Zohair (2016) found a significant increase in TSS in lettuce leaves due to raising the availability of N in the soil, which might be due to the improved soil microbial biomass and activity (Ali *et al*., 2007; Edwards *et al*., 2010a).

CONCLUSIONS

The application of vermicompost tea and foliar spray of plant extracts (RLE and EBE) succeeded as an efficient strategy to alleviate the growth and yield of lettuce plants grown under sandy soil conditions. The application of vermicompost and plant extracts, separately and in combination, enhanced photochemical activity and photosynthetic pigments, which led to increased growth and yield. Therefore, the conclusion that these materials positively impact the physiological, biochemical, yield, and quality traits of lettuce plants proves fit.

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