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RESEARCH ARTICLE

Response of Barhee date palm fruits to biofertilizers and vermicompost tea treatment

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Abstract

Nutrient deficiency poses a major threat to the growth and productivity of fruit crops. Applying of bio-organic fertilizers or certain bacterial strains and vermicompost tea, or bio-modified fertilizers with worm compost tea, can help to minimize this threat. Thus, it is important to develop credible and usable alternatives to overcome the limitations of chemical inputs. Many bio-organic fertilizer materials have been utilized as a source of nutrients for plant crops. The effects of nutrients can be mitigated by treating certain bacterial strains and vermicompost tea as a foliar spray. To combat nutrient deficiency and improve productivity and quality trails on Barhee date palm bunches, an experiment was conducted on a farm at Kom Ombo, Aswan Governorate, Egypt, during the two successive seasons of 2022 and 2023. The experiment included eight treatments, i.e., two bacterial strains of *Sphingomonas paucimobilis* (ECTO 30-2) and *Bacillus licheniformis* (K95), as well as vermicompost tea (VCT) (earthworm's excreta-based vermicompost) sprayed alone or in combination beside the control treatment. Results revealed that both bacterial strains, with or without VCT, achieved the highest significant increase in set and retention% of fruits as well as fruit yield and bunch weight traits during the two seasons. Bio-fertilizers with worm compost tea applications resulted in a substantial increase in both physical and chemical fruit properties. The obtained results indicated that vermicompost tea and the bacterial strain *Bacillus licheniformis* (K95) significantly increased the yield with good-quality of Barhee dates as compared to the control.

Keywords: Barhee; bacterial strains; Vermicompost tea.

1. Introduction

Date palm (*Phoenix dactylifera* L.) has great economic importance and agricultural uses throughout human history. In Egypt, the distribution of date palms covers a large area extending from Aswan to the north Delta, beside the Oases. Fruits of date palms have a high nutritional value since about 75% of the dry matter in dates is sugars (sucrose, glucose, and fructose). Dates are good sources of iron, potassium, calcium, magnesium, sulphur, zinc, and copper. They contain about sixteen kinds of free amino acids, and the seeds contain proteins, fibres, fats, ash, and about 60% carbohydrates. The major fatty acids in the seed oil are oleic and linoleic. (NAS, 1980; Ibrahiem *et al.*, 1990; Hussein *et al.*, 1993; Wrigley, 1995).

Barhee date palm cultivar has become among the most famous worldwide and in Egypt. This is due to its high productivity and high cost of production. Barhee date palm is a superior and unique date palm that is popular in both domestic and international markets (Wrigley, 1995). Unlike numerous different cultivars, dates Barhee is distributed and eaten freshly during the mature complete yellow (Khelal) stage for its crispy apple-like fruit because of its little soluble tannin ratio. (Al-Qurashi and Awad, 2011; Abd El-

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Haleem *et al.*, 2020).

Environmental protection and the need to enhance agricultural output have made research in new sustainable technologies necessary. One alternative approach to rationalize the excessive use of chemical fertilizers is the use of plant growth promoting bacteria (PGPB) to enhance plant performance in dry growth conditions. PGPB are gaining importance as sustainable agricultural tools for integration into conventional agricultural practices.

PGPB like those that (*Bacillus* spp., *Pseudomonas* spp., and others) have been indicated to confer resistance to various crops to biotic and abiotic stresses through a variety of mechanisms, including direct change of the rhizosphere microbiota and/or manipulation of key plant metabolic pathways related to plant growth and stress responses (Nadeem *et al.*, 2014; Naveed *et al.*, 2014; Vejan *et al.*, 2016; Vurukonda *et al.*, 2016; Kumar and Verma, 2018).

Recently, some PGPB have shown their capacity to protect plants against pathogens through mechanisms associated with induced systemic resistance (Corne *et al.*, 1999; Ramamoorthy *et al.*, 2001). The principal mechanisms of growth promotion are: production of growth-stimulating phytohormones (Barazani and Friedman, 1999; Gutierrez Mañero *et al.*, 1996, and 2001); mobilization of phosphate (De Freitas *et al.*, 1997; Vázquez *et al.*, 2000); siderophore production (Kloepper *et al.*, 1980; Raaska *et al.*, 1993); antibiotic production (Schnider *et al.*, 1994); ethylene production is inhibited (Glick *et al.*, 1994 and 1997); and plant systemic defense against diseases is induced. (Ramamoorthy *et al.*, 2001; Zehnder *et al.*, 2000).

The use of microbial products has certain advantages over conventional chemicals: they are considered safer than many of the chemicals now in use; they do not accumulate in the food chain; the target organisms seldom develop resistance as is the case when chemical agents are used; and properly-developed biocontrol agents are not considered harmful to ecological processes or the environment (Shen, 1997).

According to Tatiana Zapata *et al.* (2021), roots from cassava are an excellent source of Gram-negative bacteria and have tremendous potential for use in biotechnology to increase plant crops' resistance to drought in situations when there is a shortage of water.

Bacillus spores seem easy to prepare and apply, never germinate in tap water, and are unaffected by common pesticides. They also have a longevity of longer than two years. Because of these characteristics, *Bacillus* may be combined with the majority of chemical additions that seed wholesalers and farmers often use in liquid media during in-furrow treatments or as seed-coated agents for agricultural management activities.

Bacillus has a high degree of variety. It has smaller genomes, averaging 4 MB, but it may create a wide range of active chemicals that are known to stimulate plant defense, have antibacterial properties, and promote plant development (Ryu *et al.*, 2004; Chen *et al.*, 2007). For a range of different plants, *Bacillus sp*. imparts resistance versus biotic and abiotic stressors (Kumar and Verma, 2018).

Vermicomposting from organic waste materials can reduce the environmental impacts of chemical fertilizers. All of the easily obtained plant nutrients found in vermicompost are recovered from waste materials and include ammonium as well as nitrates associated with nitrogen, interchangeable phosphorus, soluble magnesium, and calcium, alongside potassium (Chanda *et al.*, 2011; Ahmad *et al.*, 2022).

Vermicompost tea (VCT) can be prepared in a short period of time and can be applied directly onto the plant surface. However, the effects of VCT are short-lived and frequent, and thus repeated applications are required to replenish plant or soil surfaces with nutrients and/or beneficial microbes (Scheuerell and Mahaffee, 2002; Ingham, 2005).

Vermicompost tea has significant impact on enhancing plant vitality, nutritional quality and yield (Tara, 2003; Chen, 2006). Vermicompost tea applications have a contributable role in diminishing the unsustainable application of synthetic-based pesticides and/or fertilizers in agriculture. So, VCT are promising in sustainable horticultural crop management, it is necessary to provide further insights into their application and functionality (Zandonadi *et al.*, 2007).

The present study was performed to clarify the effects of *Sphingomonas paucimobilis* (ECTO 30-2), *B. licheniformis* (K95), and vermicompost tea (VCT) on Barhee date palm bunch yield, besides some physical and chemical properties under Aswan conditions.

2. Materials and methods

The current study was conducted on 24 identical Barhee date palms (*Phoenix dactylifera L.*) throughout the two consecutive seasons of 2022 and 2023. The chosen palms are produced in a farm at Kom Ombo, Aswan Governorate, Egypt. The soil is silty clay, and the water table is at least two meters deep. Twenty-year-old palms were chosen at random. They are uniform in vigor, healthy, had good physical conditions, free of insects, damages, and diseases. The same cultural and management procedures, including artificial pollination, trimming, watering, fertilization, and manuring, were used by them. First, the earliest, last, and smallest ones were removed from the bunches until there were 10 per palm. Regarding source, date, and technique, artificial pollination was carried out consistently (Wilde *et al.*, 1985).

This study was conducted to assess the effects of spraying with *Sphingomonas paucimobilis* (ECTO 30-2) and *Bacillus licheniformis* (K95) bacterial strains, as well as vermicompost tea, on yield and fruit quality.

2.1. Experimental work

This experiment included the following eight treatments:

T_1: Spraying bunches with water (control).

T_2: Spraying bunches twice after two and six weeks of pollination with *Sphingomonas paucimobilis* (ECTO 30-2) of 10^6 cells ml^{-1}.

T_3: Spraying bunches twice after two and six weeks of pollination with *Sphingomonas paucimobilis* (ECTO 30-2) of 10^6 cells ml^{-1} + vermicompost tea (VCT) at 10%.

T_4: Spraying bunches twice after two and six weeks of pollination with *Bacillus licheniformis* (K95) of 10^6 cells ml^{-1}.

T_5: Spraying bunches twice after two and six weeks of pollination with *Bacillus licheniformis* (K95) of 10^6 cells ml^{-1} + vermicompost tea (VCT) at 10%.

T_6: Spraying bunches twice after two and six weeks of pollination with *Sphingomonas paucimobilis* (ECTO 30-2) of 10^6 cells ml^{-1} + *Bacillus licheniformis* (K95) of 10^6 cells ml^{-1}.

T_7: Spraying bunches twice after two and six weeks of pollination with *Sphingomonas paucimobilis* (ECTO 30-2) of 10^6 cells ml^{-1} + *Bacillus licheniformis* (K95) of 10^6 cells ml^{-1} + vermicompost tea (VCT) at 10%.

T_8: Spraying bunches twice after two and six weeks of pollination with vermicompost tea (VCT) at 10%.

These treatments were administered to twenty-four identical Barhee date palms. A solution of either *Sphingomonas paucimobilis* or Bacillus licheniformis was solubilized with distilled water, while vermicompost tea was solubilized with tap water after being exposed to air for 120 minutes and then sprayed on the bunches. Bunches were treated with a small hand sprayer till the run-off stage. Other horticulture practices were carried out as usual.

The soil under test underwent physical and chemical investigations by Wilde *et al.* (1985), and the results are displayed in Table (1).

Table 1. Mechanical, physical, and chemical analysis of the tested orchard soil.

Characters	Values	Characters	Values
Sand %	10.60	P (ppm Olsen method)	20.00
Silt %	58.00	K (ppm ammonium acetate)	419.00
Clay %	31.40	Mg (ppm)	79.00
Texture grade	Silty clay	S (ppm)	6.90
pH (1:2.5 extract)	8.00	B (ppm hot water extractable)	0.27
EC (1:2.5 extract) mmhos/1cm/25°C	0.91	**EDTA extractable micronutrients (ppm)**	
Organic matter %	2.09	Zn	1.31
$CaCO_3$ %	1.22	Fe	11.00
Macronutrients values		Mn	10.18
Total N%	0.11	Cu	1.60

Each sample represents the mean of three replicates.

2.2. Bacterial strains

Two strains obtained via the Environmental Studies and Research Unit (ESRU), Fac. of Agri., Cairo Univ. These strains were assessed for plant growth-promoting substances (PGPR) characteristics, including acetylene-reducing activity, IAA, and solubilization of phosphate and potassium.

2.2.1. Inoculants preparation

Two associative N_2-fixing candidates; *Sphinogomonas paucimobilis* and *Bacillus licheniformis* were used for inoculating Date palm tree grown at Kom Ambo farm. Liquid cultures of associative diazotrophs were separately grown in nutrient broth with continuous shaking and/or aeration to obtain a population density of ca. 10^6 cell ml^{-1}. Each strain was 500 mL diluted with 5 L well water in a 1:9 ratio prior to spraying for bunches of palm trees.

2.2.2. Media: Nutrient agar

It contains (g l^{-1}): beef extract, 3.0; peptone, 5.0; glucose, 1.0; yeast extract, 0.5; agar, 15; pH , 7.2. N-deficient combined carbon sources medium, CCM (Hegazi *et al*., 1998) It comprises of (g l^{-1}): glucose, 2.0; malic acid, 2.0; mannitol, 2.0; sucrose, 1.0; K_2HPO_4, 0.4; KH_2PO_4, 0.6; $MgSO_4$, 0.2; NaCl, 0.1; $CuSO_4$, 0.08 mg; $ZnSO_4$, 0.25 mg; $MnSO_4$, 0.01; yeast extract, 0.2; fermentol (a local product of corn-steep liquor), 0.2; KOH, 1.5; $CaCl_2$, 0.02; $FeCl_3$, 0.015; $Na_2 MoO_4$, 0.002. Sodium lactate was included as 0.6 ml (50% v/v).

Table 2. Taxonomic position of N_2-fixing Ectorhizosphere bacteria isolates.

Strain code	Proposed position	Growth Temp. (ºC)	N2 assay nmoles/hr/culture	IAAmg^{-1}	Growth on agar with NaCl%					Functions		
					2	4	6	8	10	Solublization of		NH_3^+ Productions
										P (PSI)**	K(KSI)***	
ECTO30-2	*Sphinogomonas paucimobilis*	30	83.77	3.65	5	5	5	5	5	237	ND	Ve+
K95	*B. licheniformis*	-		2.81	5	5	5	0	0	1.60	3.36	Ve+

**ND; not detected*
***PSI; Phosphate Solubilization Index*
****KSI;Potassium Solubiliztion Index*
0, no growth ;1, scant growth; 2-3 good growth; 4-5 very good growth

2.3. Vermicompost tea extraction method

Vermicompost for the investigation was obtained from the Agriculture Research Center, Egypt's Central Laboratory for Agriculture Climate (CLAC), during two consecutive seasons in 2022 and 2023. Since vermicompost reached a stage of maturity where its organic matter levels recorded 29.70%, it was appropriate for tea extract. As seen in Table (3), vermicompost was devoid of worms, parasites, harmful bacteria, and weed seeds.

We used aerated vermicompost tea (AVCT) to prepare vermicompost liquids. Because the presence of chlorine and chloramines may inhibit the development and propagation of microorganisms, de-chlorinating water is essential for promoting their growth and multiplication. Simple methods to achieve this include aerating the tap water for 20 to 120 minutes (Allen, 1994) or putting it in a brewing tank overnight (Martin *et al.*, 2012). In a clear plastic container, vermicompost and tap water were combined in a ratio of 1:10 (w/v). A commercial VCT system made of coiled polyvinyl chloride (PVC) tubing connected to an air pump was used to aerate the mixture. To make aerated tea, well-matured compost must be given oxygen and suspended in water for a minimum of 12 to 24 hours. Just before spraying the final AVCT on trees, it was passed through a nylon membrane filter.

Table 3. Chemical and biological properties of vermicompost tea.

Type of analysis	Vermicompost tea
Chemical analysis	
pH	5.3
EC dS/m	1.901
Organic matter (%)	29.7
N-NH^{+4} (%)	<1.0
N-NO^{3} (%)	<1.0
Total-N(%)	6.9
Available-P (%)	0.71
Available-K (%)	<1.5
Biological determination (cfu/ml)	
Total coliform	Nd
Fecal coliform	Nd
Salmonella and shigella	Nd

Nd: not detected.

2.4. Experimental design

The research study was set up using a randomized complete block design (RCBD) with three replications, one tree each. Generally, the following measurements were determined during the two investigated seasons.

2.5. Yield and fruit quality

2.5.1. Yield and its components

We computed the percentages of fruit set and retained. completing a month of pollination and during harvest, five both inner and outside strands of each spathe were chosen and utilized for these measures. Applying the following formulas, the percentages of fruit set or fruit retention were determined:

$$\text{Fruit set \%} = \frac{\text{Total number of set fruit/strand}}{\text{Total nodes number per strand}} \times 100$$

$$\text{Fruit retained \%} = \frac{\text{Total number of retained fruits/strand}}{\text{Total nodes number per strand}} \times 100$$

Bunches were collected when fruits attained Khalal stage then their weights were recorded.In both experimental seasons, the yield of each palm was recorded in terms of weight per palm (kg.).

2.5.2. Fruit quality

Samples of fifteen dates from the yield of each bunch were taken randomly, and the following physical and chemical characteristics were measured:

2.5.2.1. Physical characters:

Fruit, seed, and flesh weights were calculated using a top pan balance with a sensitivity of 0.01 g. Fruit shape (length and diameter) and dimensions (length and diameter in centimeters) were noted. With dividing the weight of the flesh by the total weight of the fruit and multiplying the result by 100, the percentage of flesh was estimated.

2.5.2.2. Chemical characteristics:

2.5.2.2.1. Total soluble solids % (T.S.S. %):

The fresh fruit was well chopped with an electric blender, the past was squeezed, and the total soluble solids% was calculated by using a hand refractometer.

2.5.2.2.2. Total, reducing and non – reducing sugars:

The volumetric approach described in A.O.A.C. (2000) was used to calculate the percentages of total and reducing sugars. The percentage of non-reducing sugar was calculated by dividing the total sugar by the percentage of reducing sugar.

2.5.2.2.3. Titratable acidity %:

Using an electric blender, 25 grams of flesh were combined with 100 milliliters of distilled water; the resulting extract was filtered, and 20 milliliters were titrated against 0.1 N sodium hydroxide using phenolphthalein as an indicator (A.O.A.C. (2000). The percentage of total acidity was calculated as g. malic acid per 100 g of pulp.

2.5.2.2.4. Tannins content:

According to Balbaa (1987), the Indigo Carmen indicator was used to calculate the fruits' percentage of tannins. Solutions containing 0.1 N potassium permanganate were used for titration. The following formula was used to determine the total tannin percentage and amount of tannins in fresh weight:Tannins in 1 milliliter of potassium permanganate (0.1 N) equal 0.00416.

2.6. Statistical analysis

Data were examined to the analysis of variance (ANOVA), and the least significant differences (LSD) were calculated using MSTAT-C software (Michigan State University, MI, United States). The L.S.D. at 5% parameter was used to discriminate between treatment mean differences.

3. Results

3.1. Yield components

The set and retention percentages of fruits, as well as bunch weight, are take into an indicator for the yield on Barhee date palm. It is obvious from the data in Tables (4 and 5) that supplying Barhee date palms with bacterial strains, single or combined, as well as vermicompost tea (VCT) applied via spray on the bunches, had a significant promotion on set and retention percentages of fruits as well as bunch weight and yield/palm expressed in weights of Barhee date palms through 2022 and 2023 seasons, as compared with the control. In addition, both treatments considerably raised the fruit retention percentage and bunch weight compared to control. The increment was associated with vermicompost tea (VCT) spraying with the bacterial strains *Sphingomonas paucimobilis* (ECTO 30-2) and *B. licheniformis* (K95). The single and combined increases were better when sprayed individually.

In this respect, the best treatment (T_4) gave the highest significant effect on the previous four characteristics, followed by *B. licheniformis* (K95) (T_5) + (VCT) and (VCT) (T_8) of the two studied seasons, respectively. Control palms gave the lowest significant results on the previous four characteristics for both seasons. The highest fruit retention percentages of 40.53%, 39.73%, and 37.76% in average of both seasons were due to sprays of (K95), (K95) + (VCT), and (VCT), respectively.

On the other hand, the lowest fruit retention percentage was 29.01% in average for the control (T_1). No significant differences were observed in fruit retention percentages between spraying either with bacterial strains alone or in combination with vermicompost tea (VCT).

Results in Table (4) reveal that bacterial strains or vermicompost tea combinations had positive effects on bunch weight compared with the control. K95 and K95 + (VCT) gave the highest bunch weights (18.02 and 17.97 kg), followed by VCT (16.38 and 16.39) in average of both seasons. Control treatment recorded the lowest bunch weight of 10.73 kg in average of the two studied seasons. The other treatments were intermediate in this respect. No significant differences were found between spraying either with bacterial strains alone or in combination with vermicompost tea (VCT).

Spraying with *B. licheniformis* (K95) recorded the highest yields per palm (178.4 and 178.2 kg) in average of the two studied seasons, respectively, followed by *B. licheniformis* (K95) + VCT, which recorded 175.2 and 173.8 kg in average. Control treatment recorded the lowest value in this respect, being 105.5 kg in average. No significant differences were recorded as a result of treatment with strains K95 and K95 + VCT, whether individually or together. It is suggested to spray the bacterial strain *B. licheniformis* (K95) twice, singly or in combination, after two and six weeks of pollination to obtain a high yield of Barhee date palms.

3.2. Fruit quality

3.2.1. Physical characteristics

Tables (5 and 6) showed that treatment with bacterial strains with VCT supported the physical properties, i.e., dimensions, shape index, fruit weight, flesh, and flesh/seed percentage, as well as the weight of 100 fruits, of Barhee dates through the 2022 and 2023 seasons.

Spraying with bacterial strains and VCT twice gave the highest weight of 100 fruits, fruit weight, flesh percentage, and dimension of fruits compared to control. The recorded fruit weight values were 11.80, 13.99, 1585, 19.87, 18.99, 16.02, 16.36, and 17.77 g in average due to T_1 to T_8, respectively. The corresponding flesh percentages were 88.03, 88.88, 89.25, 91.31, 91.32, 90.03, 90.75, and 91.00%; fruit length or fruit height were 3.33, 3.41, 3.49, 3.92, 3.79, 3.54.3.59, and 3.71 cm; and fruit diameter were 2.44, 2.64, 2.69, 2.91, 2.88, 2.75, 2.77, and 2.78 cm in average of the two studied seasons, respectively.

The heaviest fruit weights of 19.87 and 18.99.85 g were recorded on bunches sprayed with either *B. licheniformis* (K95) or *B. licheniformis* (K95) + VCT twice against 11.80 g in unsprayed ones in average of the two studied seasons. Then the increment percentage due to these treatments over unsprayed ones was attained (40.61 and 37.86%) as an average. of the two studied seasons, respectively.

Also, the maximum values of fruit flesh% were 91.31 and 91.32%, fruit length (3.92 and 3.79 cm), and fruit diameter (2.91 and 2.88 cm) for bunches that sprayed with bacterial strains (K95) and K95 + VCT twice against 2.44 cm in unsprayed ones.

The corresponding increment percentages of fruit traits due to these treatments over control were (3.59 and 3.60%), (15.05 and 12.14%), and (16.15 and 15.28%) in average, respectively, of the two studied seasons. It could be concluded that spraying with bacterial strains and VCT twice highly improves all physical properties. Such treatment is a much more important target than total yield due to the improvement in physical fruit traits that induce an increase in packable yield.

3.2.2. Chemical characteristics

Data presented in Tables (7 and 8) show the effects of bacterial strains, single and combined, as well as vermicompost tea (VCT) spraying, on some chemical properties, i.e., total soluble solids and sugar contents, as well as total acidity and total soluble tannins percentages of Barhee date fruits through the 2022 and 2023 seasons. It is obvious from the data that the results showed a similar trend over the two studied seasons.

Spraying bunches with *Sphingomonas paucimobilis* (ECTO 30-2), *B. licheniformis* (K95), and VCT twice significantly improved the chemical constituents of the dates in terms of increasing the total soluble solids and sugar contents and decreasing the total acidity percentage and total soluble tannins percentage compared to unsprayed ones (control). Total soluble solids were equivalent to sugar content and reversed with total acidity and tannin content. In general, spraying with either bacterial strain gave the highest total soluble solids of fruits during the two studied seasons. The recorded TSS% were 35.09, 36.08, 36.39, 39.81, 39.23, 36.58, 36.83, and 38.21%, while spraying with either bacterial strains or VCT gave the highest sugar contents. The recorded total sugars% were 29.36, 30.40, 30.79, 33.04, 31.81, 30.85, 30.87, and 31.57%, reducing sugars% (20.71, 21.77, 22.26, 23.86, 23.38, 22.42, 22.46, and 23.27%) and non-reducing sugars (8.66, 8.63, 8.53, 9.18, 8.43, 8.41, and 8.29% in average of the two studied seasons due to the successive treatments from 1 to 8, respectively.

The highest values of TSS were (39.81 and 39.23%), in average of the two studied seasons, due to spraying with either bacterial strains + VCT, while total sugars (33.04 and 31.81%), reducing sugars (23.86 and 23.38%), and non-reducing sugars (9.18 and 8.53%) were due to spraying with *B. licheniformis* (K95) + VCT and *B.licheniformis* (K95), respectively.

On the other hand, the least values of TSS (35.09%), total sugars (29.36%), reducing sugars (20.71%), and non-reducing sugars (8.66%) were recorded on unsprayed bunches. The recorded titratable acidity% were 0.134, 0.128, 0.096, 0.103, 0.112, 0.116, and 0.107% in average and total soluble tannins% 0.236, 0.222, 0.221, 0.201, 0.196, 0.219, 0.215, and 0.206% due to the use of T_1 to T_8, respectively.

Also, the least values of titratable acidity percentage (0.103 and 0.113% in average for the two studied seasons) were recorded on fruits of bunches that received sprays of K95 + VCT and K95, compared to the highest ones (0.134%) of untreated fruit of bunches. The lowest values of total soluble tannins percentage (0.196 and 0.201% were recorded on fruits of bunches that were treated with T_5 and T_6, compared to the highest ones (0.236%) on fruit of untreated bunches.

Moreover, there are significant differences between K95 and K95 + VCT sprayed and unsprayed ones. Also, no significant differences were recorded due to spraying, with any K95 or K95 + VCT of them. Thus, it is economical to spray K95 and K95 + VCT in order to produce dates of the highest yield components.

It could be concluded that spraying with *B. licheniformis* K95 + VCT after 2 weeks of pollination, followed by 6 weeks of pollination, improved the tested chemical fruit properties.

4. Discussion

Identifying new bacterial strains may be a critical step in the transition process towards a more sustainable agriculture by reducing the use of chemical inputs. Beneficial bacteria can help reduce reliance on chemical fertilizers, pesticides, and herbicides (Hamid, *et al.*, 2021; Orozco-Mosqueda, *et al.,* 2021).

Table 4. Effects of *Sphingomonas paucimobilis* (ECTO 30-2), *Bacillus licheniformis* (K95) and VCT on initial fruit setting%, fruit retention%, bunch weight, and yield/palm characteristics of Barhee date palms during 2022 and 2023 seasons.

Different of two strains, and VCT treatments	Initial fruit setting (%)			Fruit retention (%)			Bunch weight (kg)			Yield/palm (kg.)		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1: Control	36.22f	36.05g	36.13	28.90h	29.12o	29.01	10.77g	10.70g	10.73	105.0g	106.0g	105.5
T_2: Sprays with Strain (ECTO 30-2)	36.97f	37.03f	37.00	30.52g	30.82m	30.67	11.97f	12.10f	12.03	114.0f	115.0f	114.5
T_3: Strain (ECTO 30-2) + VCT	38.05e	38.13e	38.09	32.83f	33.07k	32.95	13.47e	13.50e	13.49	130.7e	132.5e	131.6
T_4: Sprays with Strain (K95)	44.03a	44.28a	44.16	40.42a	40.63a	40.53	18.027a	18.03a	18.02	178.4a	178.2a	178.3
T_5: Strain (K95) + VCT	43.92a	43.93a	43.93	39.62b	39.85c	39.73	17.95a	17.98a	17.97	175.2a	173.8 a	174.5
T_6: Strain (ECTO 30-2) + Strain (K95)	39.03d	39.08d	39.06	34.53e	34.83i	34.68	14.45d	14.55d	14.50	140.3d	140.8d	140.6
T_7 : Strain (ECTO 30-2) + Strain-(K95) + VCT	40.37c	40.45c	40.41	36.59d	36.83g	36.71	15.38c	15.45c	15.42	146.0c	147.0c	146.5
T_8 : VCT	41.40b	41.52b	41.46	37.58c	37.93e	37.76	16.32b	14.40b	16.36	155.0b	156.0b	155.5
L.S.D. at 0.05%	0.8	0.89		0.32	0.40		0.31	0.43		1.89	1.75	

VCT= Vermicompost tea

Table 5. Effects of *Sphingomonas paucimobilis* (ECTO 30-2), *Bacillus licheniformis* (K95) and VCT on some physical, characteristics of Barhee date palms during 2022 and 2023 seasons.

Different of two strains, and VCT treatments	Fruit height (cm.)			Fruit diameter (cm)			Fruit shape index			Fruit weight (g)		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1: Control	3.30f	3.35 f	3.33	2.37e	2.51d	2.44	1.40a	1.399a	1.39	11.78g	11.82g	11.80
T_2: Sprays with Strain (ECTO 30-2)	3.39e	3.43 e	3.41	2.63d	2.65c	2.64	1.29b	1.30c	1.29	13.97f	14.02f	13.99
T_3: Strain (ECTO 30-2) + VCT	3.45d	3.52 d	3.49	2.67cd	2.70bc	2.69	1.29b	1.31bc	1.30	15.83e	15.87e	15.85
T_4: Sprays with Strain (K95)	3.90a	3.93 a	3.92	2.91a	2.97a	2.91	1.34ab	1.35ab	1.35	19.88a	19.85a	19.87
T_5: Strain (K95) + VCT	3.69b	3.89a	3.79	2.89a	2.87a	2.88	1.34b	1.35ab	1.35	19.00b	18.98b	18.99
T_6: Strain (ECTO 30-2) + Strain (K95)	3.51c	3.57cd	3.54	2.71bcd	2.73ab	2.75	1.30b	1.31bc	1.30	16.02e	16.03e	16.02
T_7 : Strain (ECTO 30-2) + Strain-(K95) + VCT	3.57c	3.61c	3.59	2.73bc	2.75ab	2.77	1.30b	1.32bc	1.31	16.33d	16.38d	16.36
T_8 : VCT	3.69b	3.72b	3.71	2.76b	2.80ab	2.78	1.34b	1.33bc	1.33	17.75c	17.78c	17.77
L.S.D. at 0.05%	0.06	0.06		0.08	0.14		0.06	0.06		0.30	0.23	

VCT= Vermicompost tea

Table 6. Effects of *Sphingomonas paucimobilis* (ECTO 30-2), *Bacillus licheniformis* (K95) and VCT on some physical characteristics of Barhee date palms during 2022 and 2023 seasons.

Different of two strains, and VCT treatments	Weight of 100 fruits (gm)			Fruit pulp (%)			Fruit seed weight (%)			Flesh /Seed		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1: Control	1173.67g	1172.00f	1173.00	87.98g	88.08 g	88.03	12.02a	11.92a	11.97	7.33h	7.41f	7.37
T_2: Sprays with Strain (ECTO 30-2)	1420.65f	1421.33e	1421.00	88.87f	88.90f	88.88	11.13b	11.10b	11.12	7.99g	8.01e	8.00
T_3: Strain (ECTO 30-2) + VCT	1550.33e	1551.00d	1551.00	89.20e	89.30e	89.25	10.80c	10.70c	10.75	8.27f	8.35e	8.31
T_4: Sprays with Strain (K95)	1970.00a	1751.67b	1861.00	91.15b	91.47a	91.31	8.58g	8.53g	8.56	10.65a	10.72a	10.69
T_5: Strain (K95) + VCT	1868.33b	1880.00a	1874.00	91.42a	91.22ab	91.32	8.85f	8.78fg	8.82	10.32b	10.40ab	10.36
T_6: Strain (ECTO 30-2) + Strain (K95)	1575.00d	1576.33c	1576.00	89.98d	90.07d	90.03	10.02d	9.93d	9.98	8.99e	9.07d	9.03
T_7 : Strain (ECTO 30-2) + Strain-(K95) +VCT	1586.50d	1587.33c	1587.00	90.72c	90.78c	90.75	9.28e	9.22e	9.25	9.79d	9.86c	9.83
T_8 : VCT	1740.00c	1751.67b	1746.00	91.00b	91.00bc	91.00	9.00f	8.90f	8.95	10.12c	10.25bc	10.19
L.S.D. at 0.05%	14.16	23.99		0.22	0.29		0.22	0.28		0.19	0.44	

VCT= Vermicompost tea

Table 7. Effects of *Sphingomonas paucimobilis* (ECTO 30-2), *Bacillus licheniformis* (K95) and VCT on certain physical and chemical characteristics of Barhee date palms during 2022 and 2023 seasons.

Different of two strains, and VCT treatments	Fruit size (cm^3)			Total soluble solids (%)			Total sugar (%)			Reducing sugars (%)		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1: Control	11.65f	11.70f	11.68	35.10g	35.08g	35.09	29.33d	29.40e	29.36	20.67f	20.75f	20.71
T_2: Sprays with Strain (ECTO 30-2)	13.52e	13.67e	13.59	36.06f	36.10f	36.08	30.38c	30.42d	30.40	21.78e	21.77e	21.77
T_3: Strain (ECTO 30-2) + VCT	14.48d	14.57d	14.52	36.37e	36.42e	36.39	30.77c	30.82cd	30.79	22.22d	22.30d	22.26
T_4: Sprays with Strain (K95)	19.42a	19.50a	19.46	39.18b	39.28b	39.23	31.87b	31.75b	31.81	23.35b	23.42b	23.38
T_5: Strain (K95) + VCT	18.98b	19.08b	19.03	39.75a	39.87a	39.81	33.02a	33.05a	33.04	23.88a	23.83a	23.86
T_6: Strain (ECTO 30-2) + Strain (K95)	14.57d	14.67d	14.62	36.57de	36.60e	36.58	30.82c	30.88cd	30.85	22.38c	22.45c	22.42
T_7 : Strain (ECTO 30-2) + Strain-(K95) + VCT	14.60d	14.467d	14.53	36.80d	36.85d	36.83	30.84c	30.90c	30.87	22.42c	22.50c	22.46
T_8 : VCT	15.93c	16.067c	16.00	38.20c	38.22c	38.21	31.58b	31.55b	31.57	23.25b	23.30b	23.27
L.S.D. at 0.05%	0.31	0.40		0.27	0.25		0.51	0.47		0.16	0.14	

VCT= Vermicompost tea

Table 8. Effects of *Sphingomonas paucimobilis* (ECTO 30-2), *Bacillus licheniformis* (K95) and VCT on some chemical characteristics of Barhee date palms during 2022 and 2023 seasons.

Different of two strains, and VCT treatments	Non reducing sugars (%)			Soluble tannins (%)			Total acidity (%)			Crude fiber		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1: Control	8.66b	8.65b	8.66	0.235a	0.237a	0.236	0.134a	0.133a	0.134	0.880a	0.870a	0.875
T_2: Sprays with Strain (ECTO 30-2)	8.60b	8.65b	8.63	0.222b	0.222b	0.222	0.127b	0.128b	0.128	0.850b	0.857b	0.853
T_3: Strain (ECTO 30-2) + VCT	8.55b	8.52b	8.53	0.221b	0.221b	0.221	0.097g	0.094g	0.096	0.800c	0.800c	0.800
T_4: Sprays with Strain (K95)	8.52b	8.33b	8.43	0.202e	0.200e	0.201	0.111d	0.113d	0.113	0.657g	0.650g	0.654
T_5: Strain (K95) + VCT	9.14a	9.22a	9.18	0.197e	0.195f	0.196	0.102f	0.103f	0.103	0.600h	0.590h	0.595
T_6: Strain (ECTO 30-2) + Strain (K95)	8.44b	8.42b	8.43	0.218b	0.219b	0.219	0.112d	0.112d	0.112	0.780d	0.790d	0.785
T_7 : Strain (ECTO 30-2) + Strain-(K95) + VCT	8.43b	8.40b	8.41	0.214c	0.215c	0.215	0.117c	0.116c	0.116	0.740e	0.730e	0.735
T_8 : VCT	8.33b	8.25b	8.29	0.206d	0.205d	.0206	0.107e	0.108e	0.107	0.700f	0.690f	0.695
L.S.D. at 0.05%	0.46	0.45		0.002	0.002		0.002	0.002		0.002	0.002	

VCT= Vermicompost tea

They can provide plants with the nutrients and protection they need for healthy growth and resistance to disease and environmental stresses. In addition, the use of beneficial bacterial strains can improve soil quality and biodiversity, which promote a more holistic approach to agricultural land management (Ambrosini *et al.,* 2016). Although known strains such as *Rhizobium* sp., *Pseudomonas* sp., or *Bacillus* sp. can be effective (Kumari *et al.,* 2019; Grover *et al.,* 2021), new strains should be sought, as certain strains may be more suitable for certain crops or conditions.

Exploration of bacterial diversity can lead to the discovery of unique strains with special capabilities that improve crop productivity and promote sustainable agriculture. Furthermore, revealing new bacterial strains can broaden the range of options available for crop management and enhance the ability to adapt to climate and environmental changes. Within this bacterial diversity, there are many candidates that can positively influence plant development. This is the case with *Sphingomonas* sp., which are usually identified in taxonomic inventory approaches using metabarcoding with abundance that can reach 40% of the total bacterial abundance (Peng *et al.,* 2016; Lv *et al.,* 2021)

Several species of *Sphingomonas* sp., have been described with these abilities, such as *S*. LK11, *S. paucimobilis, S. pokkalii* (Khan *et al.,* 2014; Tangaromsuk *et al.,* 2002; Menon *et al*., 2019). Stimulation of the root system by *S. sediminicola* Dae20 allows the plant to develop a more extensive root exchange zone, enabling it to take up nutrients and water more efficiently and to interact with other microorganisms to a greater extent. This enhanced root system could have significant effects on the nutrient balance of the plant, potentially leading to increased nutrient uptake and utilization. Therefore, it would be interesting to evaluate the nutrient balance of these plants to determine the extent to which *S. sediminicola* Dae20 and other *Sphingomonas* species can improve plant growth and development. Several *Sphingomonas* species have been described in the literature as being capable of producing siderophores, including *S.* LK11, *S. paucimobilis,* and *S. pokkalii* (Khan *et al.,* 2014; Yang *et al.,* 2014; Menon *et al*., 2019). Research has also shown that S. sediminicola Dae20 is able to produce siderophores, and it is consistent with the genes involved in iron absorption, storage, and transport trapping found in the genome of *S. sediminicola* Dae20 (Mazoyon *et al.,* 2023).

Several PGPR have been reported to promote plant growth under drought stress through either direct or indirect mechanisms, or a combination of both (Gururani *et al.,* 2012; Akhtar *et al.,* 2015; Ngumbi and Kloepper, 2016). In several studies, PGPR belonging to the genus *Bacillus* offered advantages over other genera of PGPR in promoting plant growth under limited water conditions (Chakraborty *et al.,* 2013; Kasim *et al.,* 2013; Radhakrishnan *et al.,* 2017). These bacteria stay as spores for their survival in water scarcity conditions, which help them to better survive under extreme conditions for longer periods compared to others. Additionally, these bacteria have been recognized as the most abundant in the root zone of drought-adapted plants.

Many recent studies stated that vermicompost tea VCT could be used to improve and regulate plant growth and to enhance stress tolerance and resilience (Nardi *et al.,* 2002; Siddiqui *et al.,* 2008). Olivares *et al.* (2015) emphasized the interest in the use of VCT as a foliar spray on tomatoes. As a result, several studies have shown that vermicompost tea can be used as a liquid fertilizer or a biocontrol agent. Crop health, yield, and nutritive quality were all improved when vermicompost tea was used (Pant *et al.,* 2009). Furthermore, it has been propagated that inert elements, carbon-based substances and soluble plant growth regulators obtained from vermi-tea have a simulative effect on initial root development and crop growth when applied foliarly or in the soil (Ahmad *et al*., 2022).

Sole application of mineral fertilizers is unable to fulfil the nutritional requirements of crops and associated cropping system due to incurring high cost associated with them and environmental pollution attributed to their large-scale application, so sustainability of system's requires a proper blend of inorganic and organic amendments (Kumar and Surendran, 2002). However, there is limited research conducted on the impact of combining the use of vermicompost, vermi-tea, and chemical fertilizer on plant growth and production.

Results regarding the promoting effect of the bacterial strains *B. licheniformis* (K95) and VCT on yield components and fruit quality are in agreement with those obtained by Gutiérrez Mañero, *et al*.,2001; Kumar, and Surendran, 2002; Pant, *et al.*, 2009; Khan, *et al.*, 2014; Ambrosini, *et al.*, 2016; Kumari, *et al.*, 2019; Aslam, and Ahmad 2020, Hamid, *et al.*, 2021; Gomaa, and Afifi, 2021; Ahmad *et al*., 2022; Ahmad, *et al*., 2023; Mazoyon *et al.*, 2023.

5. Conclusion

In light of the obtained results, it could be concluded that bunches must be sprayed with *B. licheniformis* (K95) + vermicompost tea (VCT) two times after two and six weeks of pollination to secure a high yield with good quality.

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The authors disclosed no conflict of interest.

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