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# Effect of Vermicompost and Biochar of Pruning Waste on Soil Properties and Faba Bean (*Vicia faba* L.) Yield under Calcareous Soil

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ARTICLE INFO	ABSTRACT
Research Article Received: 7 May 2024 Accepted: 1 April 2025 Published: 23 June 2025	A two-year field study was conducted to compare the effect of biochar and vermicompost of olive tree pruning waste together with chemical fertilizer on microbial population and soil chemical status and faba bean yield in a calcareous soil in Tarem city, Iran. The treatments included
Keywords: Actynomycets Organic carbon Pruning waste Seed yield Soil amandments	wood biochar (BIC) at two levels of 5 (BIC <sub>5</sub> ) and 10 (BIC <sub>10</sub> ) tha <sup>2</sup> ; wood vermicompost (VCM) at two levels of 5 (VCM <sub>5</sub> ) and 10 (VCM <sub>10</sub> ) t ha <sup>-1</sup> ; 50% (NPK <sub>50</sub> ) and 100% (NPK <sub>100</sub> ) recommended chemical fertilizer; along with a control. The results showed that the highest population of total bacteria was obtained from BIC <sub>10</sub> (297.8 × 10 <sup>6</sup> CFU/g dry soil), actinomycetes from VCM <sub>10</sub> (99.5 × 10 <sup>5</sup> CFU/g dry soil), and fungi from NPK <sub>50</sub> (104.5 × 10 <sup>3</sup> CFU/g dry soil). In both years, vermicompost
<b>Citation:</b> Namaki, M. H., Ansari, M. H., & Akhgari, H. (2025). Effect of vermicompost and biochar of pruning waste on soil properties and faba bean ( <i>Vicia faba</i> L.) yield under calcareous soil. <i>Turkish Journal of Field Crops</i> , <i>30</i> (1), 55- 66. <u>https://doi.org/10.17557/tjfc.1480172</u>	MFK <sub>50</sub> (104.5 × 10° CFO'g dry son). In both years, verificompose treatments reduced soil pH by 1.6-9.2% compared to control, but biochars showed the highest pH and EC. Organic treatments, especially VCM <sub>10</sub> and BIC10, increased the soil organic carbon (OC) compared to the control (by 12.9-35.4%) and NPK (by 57.2-79.1%). Ammonium (N- NH <sub>4</sub> <sup>+</sup> ) and nitrate (N-NO <sub>3</sub> <sup>-</sup> ) nitrogen of soil decreased in line with increasing the use of biochar (BIC <sub>10</sub> ) and vermicompost (VCM <sub>10</sub> ), but increasing NPK, from NPK <sub>50</sub> to NPK <sub>100</sub> , increased soil N-NH <sub>4</sub> <sup>+</sup> and N- NO <sub>3</sub> <sup>-</sup> by 21.3% and 10.7%, respectively. In both years, the highest number of pods (45.9 and 57.8 in the first and second year, respectively), number of seeds (187.3 and 240.2 in the first and second year, respectively) and seed yield (1.997 and 2.502 t ha <sup>-1</sup> in first and second year, respectively) were obtained from soils treated with VCM <sub>10</sub> . In addition, the highest amount of N seeds (5.579%), K (0.839%) and Fe (66.3 mg kg <sup>-1</sup> ) was observed in BIC <sub>10</sub> and the highest amount of P seeds (0.519%) was observed in VCM <sub>10</sub> . Totally, organic amendments were superior to chemical fertilizers in terms of improving soil fertility and seed yield.

# **1. INTRODUCTION**

Faba bean is an important leguminous crop cultivated in the northern and northwest regions of Iran. The seeds of this plant serve as edible components that can partially substitute for meat and dairy products in human nutrition, owing to their high content of complex carbohydrates, dietary fiber, and proteins, which exceed 30% on a dry weight basis (Ruisi et al., 2017). Nevertheless, the average dry seed yields in Iran (2120 kg ha<sup>-1</sup>) and specifically in the Tarom region (1160 kg ha<sup>-1</sup>) (Ministry of Agriculture-Jihad in Iran Yearbook, 2022), remain considerably low, falling short of the global average of 8600 kg ha<sup>-1</sup> (FAOSTAT, 2022). Lower yield of faba bean in Iran can be attributed to insufficient rainfall and poor soil fertility (Mesgaran et al., 2017). In the Tarom region, most of the cultivated land consists of calcareous soil (Mesgaran et al., 2017; Shiri and Farbodi, 2022). Such soils often lead to nutrient deficiencies in various plants. The elevated pH (>7) and the presence of CaCO<sub>3</sub> in calcareous soils frequently result in the limitation of essential nutrients, including N, P, S, Zn, Fe, Cu, Mn, and B, for plant uptake (Aboukila et al., 2018). Research by Bezabeh et al. (2021), El-Husseiny et al. (2021), and Gad et al. (2017) has documented the reduced yield of faba bean in calcareous soils compared to normal soils. Houassine et al. (2019) identified that the diminished yield of faba bean in calcareous soils is linked to inadequate root development and the plant's limited capacity to absorb nutrients, especially N, P, and Fe. Bezabeh et al. (2021), also concluded that the high pH in calcareous soil results in decreased solubility of micronutrients such as Cu, Mn, Fe, and Zn, adversely affecting faba bean growth.

In addition to showing soil health and quality, organic matter content is a good indicator of soil fertility, resulting from the interaction of physical, chemical, and biological processes. Organic matter improves soil porosity and permeability by enhancing the granulation conditions. However, soil organic matter content cannot be easily enhanced significantly, or its high levels cannot be easily preserved. Various methods have been suggested to increase soil organic matter content, including application of organic and biological fertilizers (Chen et al., 2018; Alan et al., 2024).

Among organic fertilizers, vermicompost has a proven superiority in maintaining soil fertility in the long run (Guridi et al., 2017). Soil amendment by vermicompost is an ecological management program and a strategy to value plant and animal residues (Baghbani-Arani et al., 2017). Vermicompost production, as an environmentally friendly technology, is a semi-aerobic process performed by a certain group of earthworms (*Eisenia fetida*) with the help of some soil-borne microorganisms, especially bacteria and actinomyces (Mahanta et al., 2012; Lim et al., 2016). This process alleviates environmental issues related to manure (the entrance of an excessive amount of heavy metals and pathogens, the loss of soil nutrients by leaching, and the emission of hydrogen sulfide (H<sub>2</sub>S), ammonia (NH<sub>3</sub>), and other toxic gases). Vermicompost has also been reported to take a shorter time for biological conversion and has high contents of minerals, hormones, enzymes, humic acid, and different available nutrients (El-Haddad et al., 2014; Lim et al., 2016). Vermicompost contains nutrients in readily accessible forms for plants, such as nitrates, exchangeable phosphorous (P), potassium (K), iron (Fe), copper (Cu), and soluble magnesium (Mg) (Soobhany et al., 2017). Guridi et al. (2017) reported that vermicompost contains biologically active compounds, such as plant growth regulators, and is highly capable of preserving soil fertility. If it is incorporated with agricultural nutrient management, crop production costs can be reduced remarkably (Martinez-Balmori et al., 2013).

One another way to increase soil organic matter using crop residues is pyrolysis (Ding et al., 2016). Pyrolysis is the process of biomass decomposition by heat which produces biochar when it happens in anaerobic or almost anaerobic conditions. Biochar is, indeed, the char produced from crop biomass and residues. In other words, biochar is a solid residue produced by the thermal analysis of biomass in a closed container under limited oxygen conditions and medium temperatures (<700 °C) (El-Naggar et al., 2021). Biochar is a porous compound with a high specific area and potential for nutrient recycling, soil ventilation, economic profit, and waste system management. It is a long-term factor in economical and reliable carbon sequestration (El-Naggar et al., 2021). Other beneficial effects of biochar application in agricultural lands are the increase in soil organic matter, the long-term carbon storage in soil, the improvement of water retention, the increase in cation exchange capacity, interaction with soil nutrient cycle by moderating soil pH, the increase in soil fertility, and the reduction of nutrient leaching (Shi et al., 2023; Senay and Tepecik, 2024). Chen et al. (2021) showed that biochar application can increase pH in tropical soils. Like its other properties, biochar pH depends on raw material type, production temperature, and production duration. So far, only a few studies have addressed the effect of biochar on the pH of calcareous soil. Van Zwieten et al. (2010) applied several types of biochar in calcareous soils and reported that only one increased soil pH (the initial pH of 7.67). Biochar effectively contributes to releasing chemical elements, including various metal ions (Baiamonte et al., 2019; Tepecik et al., 2024). It also results in the absorption of anion nutrients, like phosphate ions, although the mechanism of these processes is not fully known (Abhishek et al., 2022). However, most research on biochar and vermicompost has been conducted in acidic soils and hot areas, and research has been rare on calcareous soils. Given the high volume of waste produced by the pruning of olive shrubs in Tarom County in Zanjan, Iran, their processing into vermicompost and biochar is a chance to improve soil fertility for its long-term use. Therefore, the present research aimed to shed light on the effect of vermicompost and biochar produced from olive shrub residues on some soil properties and nutrient content, as well as faba bean yield, in calcareous soil in field conditions.

# 2. MATERIALS AND METHOD

### Study site and experimental design

The research was conducted as a field study in a research farm in Tarom County, Zanjan (Long. 48°30' E., Lat. 37°21' N., Alt. 214 m from sea level) in 2021 and 2022. The mean temperature and total annual precipitation were 17.5 °C and 379 mm. Figure 1 presents temperature, precipitation, and sunny hours during the plant growth period. During the growth period of the plant, the mean temperature in the first year was  $11.8^{\circ}$ C and in the second year was  $13.1^{\circ}$ C. Total precipitation in the first and second years was 242 and 257 mm, respectively. Also, the mean sunny hours in the first and second year were 224 and 211 h, respectively (Figure 1). Before the experiments, the soil was sampled from a 0-30 cm depth to analyze its physical and chemical characteristics. The results are reported in Table 1. The results of soil analysis showed that the soil texture is clay loam, pH in the first and second years is 8.11 and 7.86, respectively. Electrical conductivity and organic carbon in the first and second years is 1.16 and 0.89 dS m<sup>-1</sup>, as well 0.32 and 0.25%, respectively (Table 2).



Figure 1. Mean temperature, total precipitation and sunny hours per month during plant growth (Abbar Weather Station)

Year	Texture	Silt Sand		Clay Organic Carbon		Calcium carbonate Equivalent	рН	Electrical conductivity $(dS m^{-1})$	Cation exchange capacity (cmol <sub>c</sub> kg <sup>-1</sup> )	
				(%)				(us m)		
2021	Clay loom	21	52	27	0.32	23.5	8.11	1.16	19.6	
2022	Ciay Ioaiii	23	46	31	0.25	25.3	7.86	0.89	21.7	

Table 1. Some physical and chemical properties of the studied soil

<b>Fable 2.</b> Characteristics of organic materials used in the experim
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Chemical characteristics	Unit	Biochar	Vermicompost
pH	_	$8.10\pm0.02$	$7.37\pm0.00$
EC	$(dS m^{-1})$	$5.23\pm0.30$	$1.31\pm0.10$
Ash	(%)	$32.30 \pm 1.57$	$18.9\ 0\pm1.70$
С	(%)	$64.10 \pm 2.10$	$27.50\pm0.77$
Ν	(%)	$0.86 \pm 0.00$	$1.41\pm0.04$
C:N	_	$109.40\pm5.70$	$26.5 \ 0\pm 1.34$
Р	(g kg <sup>-1</sup> )	$1.91\pm0.20$	$1.03\pm0.30$
K	$(g kg^{-1})$	$8.66 \pm 0.40$	$3.19 \pm 0.20$
Fe	$(mg kg^{-1})$	$320.30 \pm 10.60$	$1046.70 \pm 19.80$

The research was conducted in a randomized complete block design with three replications. The treatments included wood biochar (BIC) at two levels of 5 and 10 t ha<sup>-1</sup> (BIC<sub>5</sub> and BIC<sub>10</sub>, respectively), vernicompost (VCM) at two levels

of 5 and 10 t ha<sup>-1</sup> (VCM<sub>5</sub> and VCM<sub>10</sub>, respectively), chemical fertilizer (NPK) at two levels of half and full rate recommended by the soil analysis (NPK<sub>50</sub> and NPK<sub>100</sub> respectively), and a control.

## Preparation of biochar and vermicompost

A large number of pruned branches were collected from orchards in Tarom County to prepare biochar. One- and twoyear-old branches were preferred. The pruning waste of the olive shrubs was chopped into 20-30 mm pieces, washed with distilled water, and heated in an oven at 75°C for two days. Then, an electrical furnace was modified to provide anaerobic conditions for pyrolysis. To this end, two cylindrical reactors made of steel with a diameter of 20 cm and height of 40 cm were designed and fabricated by the Azarkhakab Company and were placed inside the electrical furnace for pyrolysis. The reactors had an inlet for gas and an outlet for the gas and liquid phases produced. The lid had a heat insulator to minimize heat loss. The pyrolysis process was conducted at 350°C at a rate of 3°C/min. The samples were kept at the target temperature for 180 minutes, and then the furnace was gradually cooled down to 100°C or lower through heat exchange with the environment at a rate of 2°C/min (Kim et al., 2016).

The olive pruning waste was chopped to 20-30 mm pieces and put in a 3-m<sup>3</sup> vermireactor containing a stable and very active population of *Eisenia Andrei*. Some manure was added to the waste to increase the earthworms' activity. The earthworm population density was 250 g/kg in the upper layers. The moisture in the vermireactor was kept at 75-80%. The sample was collected from the reactor's last layer (after 60 days of earthworm processing) once the manure was processed by the earthworms (Lazcano *et al.*, 2008). The vermicomposting process changed the pruning waste's physical and chemical features significantly. The vermicompost was dark in color, had a good appearance, and was converted into a homogenous compound after the earthworms' activity. The physical and chemical properties of vermicompost and biochar are reported in Table 2.

#### Agronomic operations

The experimental plots were composed of six sowing lines, each 5 m long, with an on-row spacing of 20 cm, interrow spacing of 40 cm, and density of 80,000 plants ha<sup>-1</sup>. The faba bean (cv. 'Barakat') seeds were sown by hand at a depth of nearly 5 cm on 6 December. They were then watered by sprinklers. Since the research aimed to compare organic treatments with chemical fertilization and control, only Zn was added to the soil of all treatments. In addition, 150 kg ha<sup>-1</sup> N as urea (in three allocations), 100 kg ha<sup>-1</sup> phosphate as superphosphate triple, and 100 kg ha<sup>-1</sup> K as sulfate potassium were applied in the chemical NPK treatment. The weeds were controlled mechanically (hand weeding).

After 60 days, the soil samples were air-dried and their pH, EC, organic C, mineral N, K, P and Fe that were available were measured by conventional methods. Soil organic carbon content was determined by fresh oxidation using potassium dichromate and thick sulfuric acid (Walkley & Black, 1934), mineral N (nitrate and ammonium) was determined by 2M potassium chloride (Mulvaney, 1996), absorbable P was measured by the Olsen method with 0.5N sodium bicarbonate (Olsen, 1954) using spectrophotometry. Absorbable K of ammonium acetate was estimated by flame photometry (Champam & Pratt, 1982). EC and pH were determined in a soil: water ratio of 1:5 (Hesse, 1971). The soil samples' Fe, Mn, Cu, and Zn were determined by the extraction method with DTPA and the reading of an atomic absorption device (Lehmann, 2007).

## Soil microbial populations

To count the soil microbial populations, samples were taken 40, 80, and 120 days after the planting. Two 10-g soil samples from the root area, from each plot, were separately put in 250-mL Erlenmeyer flasks containing 25 mL of sterilized distilled water (Aneja, 2007). The flasks were shaken rotationally for 20 minutes. Then, they were kept still for 15 seconds for the coarser particles to precipitate. Serial dilutions up to  $10^6$  were done by repeatedly adding 1 mL of soil suspension to 9 mL of sterilized distilled water. All determined microorganisms estimated using the optimum dilution for each group were total bacterial count ×  $1/10^6$  according to Allen et al. (1950), total actinomycetes count ×  $10^5$  according to Jensen (1930), and total fungal count ×  $10^3$  according to Martin (1950).

#### Plant sampling

To measure the fresh yield of the faba beans, after the pods reached their maximum size and weight (when the pods were green), the pods of five plants were harvested. The samples were taken from the middle rows after eliminating about 0.5 from both ends to avoid the marginal effect. At the physiological maturity stage, 2 m<sup>2</sup> were harvested and 10 plants were randomly selected to calculate biological and dry seed yields. Total dry weight was estimated on the whole plants (shoot plus pods) oven-dried at 75°C for 72 hours. The concentrations of different elements in the faba bean seeds were determined by grinding them and sampling 15 g. The N content was measured by the Kjeldahl method (Kjeldahl 2300; FOSS, Hoganas, Sweden), the P content by the vanadomolybdo–phosphoric colorimetric method (Jackson, 2005), and the Fe contents by atomic absorption spectrometry (Jones, 1972).

It should be noted that treatments in the second year were used as in the first year and all the works done in the first year was repeated in the second year (Except for the soil microbial populations measured only in the second year).

#### Statistical analysis

All data were subjected to analysis of variance (ANOVA) using SAS 9.1 software. When the F-test revealed the significance of the treatments, the means were separately compared using the LSMEANS method with least significant difference (LSD) adjustment at P = 0.05.

# **3. RESULTS AND DISCUSSION**

#### Soil microbial population

Table 3 shows that the microbial populations counted in the soil (bacteria, actinomycetes, and fungi on days 40, 80, and 120) responded to the treatments, differing from the control. The difference widened over time from day 40 to day 120. Increasing the rate of organic fertilizers and applying NPK increased the number of soil bacteria compared to the control over time. The highest number of bacteria was related to the treatment of BIC<sub>10</sub> (228, 318, and  $346 \times 10^6$  CFU/g dry soil on days 40, 80, and 120, respectively). The number of actinomycetes also increased in the treated soils from day 40 to day 120, but it was 24.65, 23.29, and  $17.27 \times 10^5$  CFU/g dry soil on days 40, 80, and 120 in the untreated soils, respectively. The maximum actinomycete population was recorded in VCM<sub>10</sub> (76.45, 108.3, and  $113.8 \times 10^5$  CFU/g dry soil on days 40, 80, and 120, respectively). The second highest was related to  $BIC_{10}$  (Table 3). However, the fungal population responded to the treatments differently from the bacterial and actinomycete populations over time. The total number of fungi decreased versus the control in all treatments (except for NPK0.5). In addition, the fungal population in VCM<sub>10</sub> was 60, 48, and  $40 \times 10^3$  CFU/g dry soil on days 40, 80, and 120, respectively. They were 49, 37, and  $51 \times 10^3$ CFU/g dry soil in BIC<sub>10</sub> and 57, 72, and  $36 \times 10^3$  CFU/g dry soil in NPK<sub>100</sub>. Overall, the highest mean fungal population was obtained from the soil treated with NPK<sub>50</sub> ( $104 \times 10^3$  CFU/g dry soil) and the control ( $101 \times 10^3$  CFU/g dry soil) (Table 3). The increased population of bacteria and actinomycetes can be attributed to the positive effect of vernicompost and biochar by creating a beneficial substrate for the activity of soil microorganisms. This activity increases over time with the rise of air temperature (Elad et al., 2011; Zhang et al., 2022). It has been reported that biochar has significant effects on rhizosphere bacteria, which can be effective in improving soil fertility (Ding et al., 2016; Mohamed et al., 2017). The application of vermicompost, also, increased the soil's bacterial population, but its positive effect on the population of actinomycetes was more substantial than that of the biochar and NPK, which can be related to the highest solution nutrients in these treatments. It seems that vermicompost provides a suitable substrate for increasing the population of actinomycetes mainly by improving the physical and structural conditions of the soil, preserving soil moisture, and increasing cation exchange capacity (CEC) (Mosavi-Azandehi et al., 2023). Vermicompost is replete with microbial populations, especially bacteria and actinomycetes, which play a key role in supplying the cycle of some nutrients. In addition, organic matter undergoes peculiar biochemical interactions in earthworms' digestion system so that the waste of the earthworms can be absorbed by the plants to supply their nutrient requirements (Mosavi-Azandehi et al., 2023).

**Table 3:** Effect of experimental treatments on the microbial community of soil by (CFU/g dry soil) at different periods (40, 80, and 120 days after planting)

	Bac	teria × 106	CFU/g dr	y soil	Actino	mycetes ×	10 <sup>5</sup> CFU/g d	ry soil	Fu	ngi × 10 <sup>3</sup> C	CFU/g dry	soil
	40	80	120	mean	40	80	120	mean	40	80	120	mean
Control	33.3f	40.2d	34.3e	35.9e	24.65d	23.29f	17.27f	21.73f	108.1a	99.29b	102.5a	101.4ab
NPK <sub>50</sub>	74.1e	112.6c	169.7d	118.8d	33.17c	42.94c	52.03e	42.71e	108.7a	118.3a	86.56b	104.5a
$NPK_{100}$	93.7de	129.9c	240c	154.6c	41.46bc	52.14c	74.18d	55.89d	57.14de	72.93d	36.69d	55.58d
BICO <sub>5</sub>	170.9b	295.8a	329.6a	265.5b	54.98b	67.25c	73.16d	65.09c	98.15b	89.1c	100.4a	95.91b
$BIC_{10}$	228.7a	318.5a	346.2a	297.8a	62.82ab	76.57b	86.11c	75.09b	49.64e	37.94f	51.57c	46.38e
VCM <sub>5</sub>	99.1d	111.1c	181.9d	130.7cd	52.03b	78.61b	101.44b	77.36b	88.95c	74.86d	89.08b	84.29c
VCM <sub>10</sub>	127.8c	244.4b	284.4b	261.5b	76.45a	108.37a	113.83a	99.51a	60.89d	48.62e	40.1d	49.87de
S.O.V												
S		63318**				3244**			458.5**			
S(R)		7652				244			1405			
Т		6764**			915**					6119**		
$\mathbf{S} \times \mathbf{T}$		3512**			280**				374**			
Е		306				23.7			25.1			

Similar letter(s) in each column shows insignificance of the difference based on the LSD test at the P < 0.05 level.

\*\*Significant at the P  $\leq$  0.01 level; \* significant at the P  $\leq$  0.05 level; ns no significant difference.

S: Sampling time, R: Replication, T: Treatments, E: Error, CV: Coefficient of Variation.

## Soil status

The results revealed that pH, EC, and OC were influenced by the treatments in both years (Table 4). The comparison of means showed that the application of vermicompost (VCM5 and VCM10) reduced soil pH by, on average, 6.1% in the

first year and 9.25 in the second year compared to the control, whereas the biochar at both levels had the highest pH and EC in both years. The organic treatments, especially VCM10 and BIC10, increased soil OC versus the control and NPK by 12.9-35.4% and 57.2-79.1%, respectively. The highest soil OC in both years was obtained from VCM10 (4.16% in the first year and 4.28% in the second year) (Table 5).

Table 4. Variance analysis for the effect of the experimental treatments on chemical properties of the soil in both years

	Mean Square (MS)										
S.O.V		EC	N-NH4 <sup>+1</sup>	N-NO3 <sup>-1</sup>	Olsen P	K	Fe	Mn	Cu	OC	
	рп	(dS m <sup>-1</sup> )		(mg kg <sup>-1</sup> )							
Y	2.11 <sup>ns</sup>	0.011 <sup>ns</sup>	50.3 <sup>ns</sup>	21.6 <sup>ns</sup>	21.5 <sup>ns</sup>	55510 <sup>ns</sup>	0.708 <sup>ns</sup>	4.67 <sup>ns</sup>	0.28 <sup>ns</sup>	0.26 <sup>ns</sup>	
Y(R)	1.67	0.093	252	106	332	863381	3.44	38.4	0.157	1.37	
Т	0.25**	$0.81^{**}$	$58.6^{*}$	128**	129**	934920**	3.14**	$18.9^{**}$	$0.59^{**}$	$7.29^{**}$	
$T \times Y$	$0.0192^{**}$	$0.56^{**}$	13.5 <sup>ns</sup>	5.6 <sup>ns</sup>	225**	1157485**	4.31**	35.2**	$0.79^{**}$	$20.8^{**}$	
Е	0.0045	0.031	2.87	15.1	19.2	75476	0.343	2.16	0.102	0.299	
CV (%)	0.832	34.1	4.19	14.8	16.7	20.6	12.37	12.01	11.1	19.2	

\*\*Significant at the P  $\leq$  0.01 level; \* significant at the P  $\leq$  0.05 level; ns no significant difference.

Y: Year, R: Replication, T: Treatments, E: Error.

Table 5. The means comparison for the effect of the experimental treatments on pH, EC, OC, and Olsen phosphorus of the soil in both years

Traatmonto	pН			EC (dS m	EC (dS m <sup>-1</sup> )					Olsen P (1	ng kg <sup>-</sup> l)	
Treatments	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean
Control	8.284b	7.891c	8.087c	0.8144b	0.248c	0.531bc	0.536c	0.827d	0.675d	29.2b	15.53c	22.36c
NPK50	8.327b	7.841c	8.078c	1.307a	0.312c	0.809a	0.754c	0.662d	0.705d	42.28a	23.18bc	27.73ab
NPK100	8.315b	7.780d	8.053c	0.283c	0.365bc	0.324cd	0.818c	0.508d	0.655d	18.95d	20.98bc	19.97c
BIC <sub>5</sub>	8.595a	8.072b	8.333b	0.308c	0.771b	0.539b	4.610b	4.364b	4.485ab	21.94cd	27.64b	24.79bc
$BIC_{10}$	8.706a	8.304a	8.505a	0.3855c	1.237a	0.811a	6.034a	5.712a	5.37a	22.16cd	40.02a	32.99a
VCM <sub>5</sub>	8.082c	7.841c	7.941d	0.296c	0.279c	0.287d	3.570b	3.038c	3.13c	25.52bc	22.76bc	24.14bc
VCM <sub>10</sub>	8.22bc	7.659e	7.961d	0.298c	0.284c	0.291d	4.162b	4.281b	4.22b	27.97bc	27.88b	27.92ab

Similar letter(s) in each column show insignificance of the difference based on the LSD test at the P < 0.05 level.

Biochar can reduce or increase soil pH. This is related to the evolution of organic matter added to the soil and its decomposition level. Furthermore, biochar can increase soil CEC (El-Naggar et al., 2021), showing the buffer capacity of the soil. Soil CEC may increase with biochar application, so soil capacity to preserve nutrients increases. However, the effect of biochar on soil pH in calcareous soils is weaker than the effect of vermicompost, which is related to the buffer capacity of the soil due to its calcium carbon content (Abhishek et al., 2022). In both measurement years, pH was lower in both vermicompost levels, which is related to the acidic pH of the vermicompost on the one hand and the stimulation of microorganisms and the resulting increase in CO2 production and the decrease in pH on the other (Baghbani–Arani et al., 2017). These results indicate the positive effect of vermicompost in reducing pH in calcareous soils and subsequently, the improved availability of lowly mobile elements, e.g., P, in these soils (Sarma et al., 2018; Yuksel et al., 2024). The increase in EC is seemingly associated with the minerals of biochar and the effect of biochar on soil compounds and the release of dissolved nutrients. Biochar contains some nutrients, such as K, Ca, and Mg (Tepecik et al., 2022; Hammadi & Alwan, 2023). When biochar is applied to the soil, the K, Fe, and Ca ions of the soil solution may increase, which may be a reason for the increase EC of the soil (Mohamed et al., 2017; Hammadi & Alwan, 2023).

The soil ammonium (N-NH4+1) and nitrate (N-NO3–1) content was influenced by the organic treatments (Table 4). As the rate of biochar (BIC10) and vermicompost (VCM10) was increased, the N-NH4+1 and N-NO3–1 content of the soil decreased, but the increase in the application of the chemical fertilizers from NPK50 to NPK100 increased soil N-NH4+1 and N-NO3–1 contents by 21.3 and 10.7%, respectively. In addition, NPK100 was related to the highest N-NH4+1 content (51.4 mg kg-1) and N-NO3-1 content (33.5 mg kg-1), and BIC10 was related to the lowest ones (Figure 2). The C/N ratio plays a critical role in the N content during the decomposition of the organic matter added to the soil. The increase in soil C content often increases the C/N ratio and reduces N mineralization. The application of biochar to the farmlands in a tropical region reportedly increased N availability (Steiner et al., 2007). The decline in N availability may be related to biochar's high C/N ratio, and consequently, its higher potential for converting N to its organic form and the uptake of N-NH4+1 to biochar, which, in turn, reduces the potential of N leaching and increases its fixation for higher fertility of the surface soil over time (Steiner et al., 2007).



Figure 2. The means comparison for the main effect of the experimental treatments on N-NH4<sup>+</sup> and N-NO3<sup>-</sup> of the soil

The treatments influenced P, K, Fe, Mn, and Cu in both years (Table 4). Based on the results, the soils treated with the biochar exhibited the highest P, K, and Mn contents but the lowest Fe and Cu contents, whereas the soils treated with vermicompost had the highest Fe and Cu contents. It should be noted that the increase in the application of biochar (BIC10) and vermicompost (VCM10) reduced Fe and Cu. In addition, the variations in the nutrients of the NPK-treated soils differed from those of the soils treated with biochar or vermicompost and were closer to the control (Table 6). Nelissen et al. (2015) reported that the application of biochar in sandy and loamy soils improved available P significantly. Wu et al. (2022) stated the application of rice straw biochar increased available P significantly by 13.8% versus the nobiochar treatment. Abhishek et al. (2022) reported that biochar could increase P availability by adsorption and also through increasing soil CEC. In a study on the effect of the application of seed residue biochar on the alkaline elements of the soil, Wu et al. (2022) revealed that it increased K availability but reduced exchangeable Ca, Mn, and Na. Nelissen et al. (2015) found that the biochar of walnut shells increased soil Mn over a 67-day experimental period. Baiamonte et al. (2019) applied compost and biochar produced from it to Mediterranean (sandy and non-calcareous) soil and revealed that Zn and Cu content decreased significantly in the biochar treatment than in the compost treatment. Chintala et al. (2014) reported that applying biochar to the soil influenced the availability of nutrient ions by influencing ion exchange capacity and microbial activities. The formation of functional groups and absorption spots on the biochar surface also increases soil capacity in creating complexes with metal ions and their uptake (Zhang et al., 2022).

Table 6. The means comparison for the effect of the experimental effect of the	mental treatments on K, Fe, Mn, and Cu of the soil in both years
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K (mg kg <sup>-1</sup> )			Fe (mg kg <sup>-1</sup> )			Mn (mg kg <sup>-1</sup> )			Cu (mg kg <sup>-1</sup> )		
1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean
/24b	691d	1207bc	4.049b	6.246a	5.148ab	15.67ab	9.18c	12.43bc	0.839bc	1.218a	1.029a
530a	1090b-d	1810a	3.017c	4.836b-d	3.927c	17.11a	9.46c	13.29b	0.806c	0.8441c	0.825c
52c	1393bc	1128bc	6.128a	4.026-d	5.077ab	9.79c	13.55ab	11.67bc	1.162a	0.804cd	0.983ab
)18c	1632b	1325b	5.579 a	3.83de	4.706b	9.901c	14.84a	12.37bc	1.016a-c	0.795cd	0.906bc
71b	2395a	1933a	4.253 b	2.856e	3.55c	14.31b	16.20a	15.25a	0.849bc	0.761d	0.804c
3c	844cd	893c	5.572a	5.34ab	5.458a	10.14c	8.052c	9.59d	1.068ab	1.021b	1.044a
)27c	1021cd	1024bc	5.453 a	5.093bc	5.273ab	11.102c	11.06bc	11.08cd	1.052ab	0.9877b	1.020ab
(172) 1272 1272 1272 1272 1272 1272 1272	<u>mg kg</u> 24b 30a 2c 18c 71b 3c 27c	mg kg <sup>-1</sup> ) Y2 24b 691d 30a 1090b-d 2c 1393bc 18c 1632b 71b 2395a 3c 844cd 27c 1021cd	mg kg <sup>-1</sup> )         Y2         Mean           V4b         691d         1207bc           30a         1090b-d         1810a           2c         1393bc         1128bc           18c         1632b         1325b           71b         2395a         1933a           3c         844cd         893c           27c         1021cd         1024bc	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $

Similar letter(s) in each column show insignificance of the difference based on the LSD test at the P < 0.05 level.

#### Agronomic traits

The number of pods, the number of seeds, plant weight, and seed yield were affected by the interaction of treatment and year (Table 7). Most treated plants had higher pod number (17.3-49.4% in the first and 11.6-43.8% in the second year) and seed number (26.2-53.1% in the first and 19.4-45.2% in the second year) than the control plants, although the difference was insignificant between some treatments and the control. In both years, the soils treated with VCM10 were related to the highest number of pods (45.9 and 57.8 pods m-2 in the first and second years, respectively) and seeds (187.3 and 240.2 seeds m-2 in the first and second years, respectively), and BIC10 and VCM5 were ranked lower (Table 8). According to Chinthapalli et al. (2015), organic fertilizers are eventually responsible for increasing plant biomass. Since vermicompost and biochar contain some macro and micronutrients, they increase flower buds by expanding the photosynthesizing area (Eo and Park, 2019; Alan et al., 2024). The increase in the flower number finally results in an increase in pod production, but if the plant is not capable enough to persistently mobilize materials to flowers, most flowers will fall and consequently, pod formation and number will decrease (Nafees et al., 2023). Compared to the control, the treatments increased pod yield by 4.53-20.3% in the first and 5.3-35.5% in the second year and seed yield by 10.4-

39.6% in the first and 11.7-45.1% in the second year. Furthermore, the treatment of VCM10 produced the highest seed yield in both years (1.997 and 2.502 t ha-1 in the first and second years, respectively). But, it significantly differed from VCM5 (1.607 t ha-1), BIC10 (1.823 t ha-1), and BIC5 (1.653 t ha-1) in the first and only from BIC10 (2.053 t ha-1) in the second year (Table 8).

Table 7. Variance analysis for the effect of the experimental treatments on agronomic traits in both years

	Mean Square (MS)											
S.O.V	Dod numbers m <sup>-2</sup>	Saad mumbana m <sup>-2</sup>	Pod yield	Pod yield Seed yield Biological yield		Ν	Р	K	Fe			
	Pod numbers m	Seed numbers in		(t ha <sup>-1</sup> )		In seed (%)						
Y	1.92ns	143ns	378860**	1060**	433ns	21.3**	0.154**	0.0011ns	943**			
R(Y)	10.7	13.9	658	114	235	0.194	0.00061	0.0015	85.7			
Т	217**	6558.**	72930*	250*	33969**	3.82*	0.023**	0.173**	509**			
$\mathbf{T} \times \mathbf{Y}$	52.5**	635*	95737**	209*	1326*	6.04**	0.0059ns	0.156**	398**			
E	7.88	201.9	20190	75.4	496.2	1.506	0.0054	0.0245	52.3			
CV (%)	8.29	10.12	16.3	8.7	14.81	31.6	17.4	31.7	13.3			

\*\*Significant at the P  $\leq$  0.01 level; \* significant at the P  $\leq$  0.05 level; ns no significant difference.

Y: Year, R: Replication, T: Treatments, E: Error.

**Table 8.** The mean comparison of experimental treatments effect on pod number, seed number and yield of pod, seed and biological of faba bean in both years

Traatmanta	Pod num	bers m <sup>-2</sup>		Seed nur	Seed numbers m <sup>-2</sup>		Pod yield	Pod yield (t ha <sup>-1</sup> )			Seed yield (t ha-1)			Biological yield (t ha-1)		
Treatments	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	
Control	23.0e	32.4c	13.7c	90.4e	125c	108c	9.70b	10.60c	10.15d	1.208c	1.418c	1.310d	3.56f	2.55d	2.94e	
NPK50	29.0cd	37.2bc	16.8bc	123d	144c	134b	10.02b	11.05c	10.54cd	1.345b	1.603bc	1.475cd	3.23f	3.14cd	3.08de	
NPK100	32.0c	33.6c	18.81bc	130cd	149c	139b	10.49ab	10.89c	10.70cd	1.540ab	1.667bc	1.605b-d	5.34d	3.76c	4.55cd	
BIC <sub>5</sub>	27.8d	36.3bc	17.46bc	123d	156bc	139b	10.16ab	14.35bc	12.26bc	1.653ab	1.633bc	1.64b-d	3.91e	5.63b	4.77bc	
$BIC_{10}$	40.0ab	45.4b	19.95b	167ab	183b	175a	12.01ab	15.82ab	13.92ab	1.823a	2.053ab	1.935ab	6.22b	6.11ab	6.18ab	
VCM <sub>5</sub>	38.0b	40.8bc	21.83ab	146bc	151c	148b	10.96ab	12.74bc	11.86cd	1.607ab	1.883bc	1.745bc	5.72c	6.51ab	6.11ab	
VCM <sub>10</sub>	45.9a	57.8a	27.07a	187a	240a	187a	12.20a	19.26a	15.74a	1.997a	2.502a	2.250a	7.26a	6.95a	7.106a	

Similar letter(s) in each column show insignificance of the difference based on the LSD test at the P < 0.05 level.

Although the NPK100 treatment had higher pod and seed yield than the control, it was less effective than the organic fertilizers. In addition, organic fertilizers significantly provide optimal growth and nutrition conditions for plants (Sheikh et al., 2022). Organic fertilizers improve plant growth and development, thereby increasing their yields, by supplying macro and micronutrients required by the plant, improving the soil's physical, chemical, and biological features, increasing its water retention capacity, contributing to the proper expansion of the plant's root system by improving soil structure and porosity (El Nahhas et al., 2021; Cukurcalioglu et al., 2023), synthesizing plant hormones by bacteria, and enhancing mineral uptake and translocation (Nafees et al., 2023). These are the positive effects of biochar application on the soil, leading to the plant's growth improvement by improving soil conditions, including aeration, and enhancing water and nutrient availability in the soil. The increase in N increases protoplasm and cell division, resulting in an increase in cell size and leaf area and finally the improvement of the vegetative growth by enhancing the photosynthesis activity (Saikia et al., 2010). The stem dry weight increased significantly in the culture medium containing biochar. Kim et al. (2016) stated that the highest corn dry weight was obtained from the treatment of 5% biochar.

The N, P, K, and Fe contents were affected by the interaction of the treatment and year (Table 7). The comparison of the seed N content of different treatments revealed that although the seeds of the plants treated with biochar contained the highest amount of N in both years (6.74 and 4.40% in the first and second years, respectively), the seeds of the plants treated with vermicompost and NPK100 had lower N than the control (Table 9). Unlike the seed N content, its P content was the highest in the vermicompost treatments. The biochar treatments were superior to the control in this respect, but not significantly (Table 9). The application of biochar positively influenced plant growth, maybe due to the supply of N and other nutrients required by the plant at balanced levels. However, biochar had a more positive effect on the plant traits at higher levels (Hammadi et al., 2023), which can be ascribed to the increased stability of water in soil particulates and the higher level of P in the soils mixed with biochar. The positive effect of biochar mainly depends on the capability of biochar to retain soil nutrients owing to its high specific area. This, in turn, increases soil EC (El Nahhas et al., 2021).

Table 9. The mean comparison of experimental treatments effect on N, P, K and Fe content of seed of faba bean in both years

Treatment		Seed N		_	Seed P			Seed K			Seed Fe			
1 reatment	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean	Y1	Y2	Mean		
Control	5.35a-c	3.666ab	4.514b	0.3206b	0.4936ab	0.407ab	0.476b	0.573b	0.525b	71.67ab	44.55e	58.11ab		
NPK50	3.96cd	3.446ab	3.701c	0.298b	0.426b	0.362b	0.503b	0.376b	0.440b	53.27b	41.65f	47.46bc		
NPK100	2.78d	2.64b	2.71de	0.339b	0.404b	0.372b	0.510b	0.46b	0.485b	55.21b	41.65f	48.43bc		
BIC <sub>5</sub>	6.30ab	3.95a	5.133ab	0.317b	0.5096ab	0.413ab	0.453b	0.356b	0.405b	75.06a	54.24b	64.65a		
$BIC_{10}$	6.74a	4.40a	5.579a	0.3783ab	0.403b	0.391ab	0.796a	0.881a	0.839a	67.8ab	64.89a	66.35a		
VCM <sub>5</sub>	2.56d	2.56b	2.513e	0.455a	0.49ab	0.473ab	0.363b	0.476b	0.422b	30.02c	53.27c	41.65c		
$VCM_{10}$	4.47b-d	2.05b	3.264cd	0.4036ab	0.634a	0.519a	0.316b	0.34b	0.328b	60.0ab	46.49d	53.25a-c		

Similar letter(s) in each column show insignificance of the difference based on the LSD test at the P < 0.05 level.

In terms of the seed K content, too, the biochar treatments significantly outperformed the control (0.796 and 0.505% higher in the first and 0.881 and 0.573% higher in the second year), but other treatments did not differ from the control significantly. In addition, except for the biochar treatments, the chemical fertilizer treatments had higher K content than the control, but not significantly (Table 9). Other researchers have also supported the increase in soil K in the presence of biochar. Since the soils treated with biochar had the highest P content, it was expected that the seeds of the plants in these soils had the highest P content, but the seeds of those treated with VCM10 had higher P content in both years (Table 9). On the contrary, the highest Fe content in the soil and seeds was recorded by the treatments of vermicompost and biochar, respectively. In this regard, BIC10 had the highest N and K content in both seeds and soil. This can be attributed to a set of intricate factors influencing nutrient uptake from the soil by the plant, including soil pH and EC, as well as the method and volume of nutrient uptake and plant root secretions (Sheikh et al., 2022; Alan et al., 2024). Of course, the amount of seed N and K and soil in BIC10 was higher than the other treatments. This finding can be attributed to a set of complex factors influencing the absorption of elements in the soil by the plant, so that the value of soil pH and EC, as well as the method and volume of element absorption and plant root secretions have always been discussed (Rekha et al., 2023; Yuksel et al., 2024). Finally, we conclude that the concentration of N, P, K and Fe in faba bean seeds indicates their content in soils under different treatments. These results are consistent with Rivelli and Libutti (2023) who demonstrated that the application of organic amendments such as biochar and vermicompost from hardwood chips increased plant nutrient availability. Song et al. (2022) reported that applying biochar and vermicompost significantly contributed to the increase of plant nutrients in poor soils. This can be explained by the ability of these organic amendments to increase the availability of soil nutrients and their content in faba bean plants.

# **4. CONCLUSION**

The obtained results showed that the conversion of the shoots obtained from pruning olive trees into biochar and vermicompost can lead to the production of environmentally friendly organic fertilizers, which had a positive effect on the fertility of poor limestone soil, as it significantly increased the population of bacteria and actinomycetes in the soil and caused changes in some soil characteristics such as OC, pH, and EC, and also increased the usability of some macroand micro-elements, compared to NPKs and control. Of course, soils treated with biochars showed the highest amount of P, K, and Mn and the lowest amount of Fe and Cu, while vermicompost soils showed the highest amount of Fe and Cu. In addition, the application of 10 t ha-1 was better than 5 t ha-1, so that in most of the measured traits, the application of 10 t/ha of biochar and vermicompost was superior to 5 t ha-1. The amount of nitrate and ammonium nitrogen in the soil also decreased significantly in line with the increase in the amount of biochar and vermicompost. In both years, the highest number of pods, number of seeds and seed yield were obtained from soils treated with VCM10, and BIO10 and VCM5 were ranked lower. In addition, the highest amount of N, K and Fe seeds was obtained from BIO10, but the highest amount of P seeds was observed in VCM10. Based on the obtained results, organic amendments were superior to chemical fertilizers in improving soil fertility and seed yield. To obtain higher seed yield in similar calcareous soils, the use of vermicompost, especially 10 t ha-1, is superior to biochar. These results showed that organic fertilizers have the potential to produce healthier and safer plants with higher yields than chemical fertilizers. The use of organic fertilizers in the sustainable production of agricultural products and the management of soil nutrients has gained attention and popularity. The present study revealed that using biochar and vermicompost is a better option for the sustainability of faba bean production, which can guarantee food security and safety.

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