Turkish Journal of Field Crops
field-crops.org

DOI: 10.17557/tjfc.1480172
ISSN: 1301-1111
e-ISSN: 3023-6657
2025, 30(1), 55-66

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

Mohammad Hossein NAMAKI[1], **Mohammad Hossein ANSARI**[2*], **Hassan AKHGARI**[1]

[1]*Department of Agronomy, Rasht Branch, Islamic Azad University, Rasht, Iran.*
[2]*Department of Agronomy and Plant Breeding, Rasht branch, Islamic Azad University, Rasht, Iran*

✉ *Corresponding author: ansary330@gmail.com*

ARTICLE INFO

Research Article
Received: 7 May 2024
Accepted: 1 April 2025
Published: XX June 2025

Keywords:
Actynomycets
Organic carbon
Pruning waste
Seed yield
Soil amandments

Citation: Namaki, M. H., Ansari, M. H., & Akhgari, H. (2025). Effect of vermicompost and biochar of pruning waste on soil properties and faba bean (*Vicia faba* L.) yield under calcareous soil. *Turkish Journal of Field Crops, 30*(1), 55-66. https://doi.org/10.17557/tjfc.1480172

ABSTRACT

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 wood biochar (BIC) at two levels of 5 (BIC_5) and 10 (BIC_{10}) t ha^{-1}; wood vermicompost (VCM) at two levels of 5 (VCM_5) and 10 (VCM_{10}) t ha^{-1}; 50% (NPK_{50}) and 100% (NPK_{100}) recommended chemical fertilizer; along with a control. The results showed that the highest population of total bacteria was obtained from BIC_{10} (297.8 × 10^6 CFU/g dry soil), actinomycetes from VCM_{10} (99.5 × 10^5 CFU/g dry soil), and fungi from NPK_{50} (104.5 × 10^3 CFU/g dry soil). In both years, vermicompost treatments reduced soil pH by 1.6-9.2% compared to control, but biochars showed the highest pH and EC. Organic treatments, especially VCM_{10} 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_4^+) and nitrate (N-NO_3^-) nitrogen of soil decreased in line with increasing the use of biochar (BIC_{10}) and vermicompost (VCM_{10}), but increasing NPK, from NPK_{50} to NPK_{100}, increased soil N-NH_4^+ and N-NO_3^- 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^{-1} in first and second year, respectively) were obtained from soils treated with VCM_{10}. In addition, the highest amount of N seeds (5.579%), K (0.839%) and Fe (66.3 mg kg^{-1}) was observed in BIC_{10} and the highest amount of P seeds (0.519%) was observed in VCM_{10}. 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^{-1}) and specifically in the Tarom region (1160 kg ha^{-1}) (Ministry of Agriculture-Jihad in Iran Yearbook, 2022), remain considerably low, falling short of the global average of 8600 kg ha^{-1} (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 $CaCO_3$ 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_2S), ammonia (NH_3), 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°C and in the second year was 13.1°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^{-1}, as well 0.32 and 0.25%, respectively (Table 2).

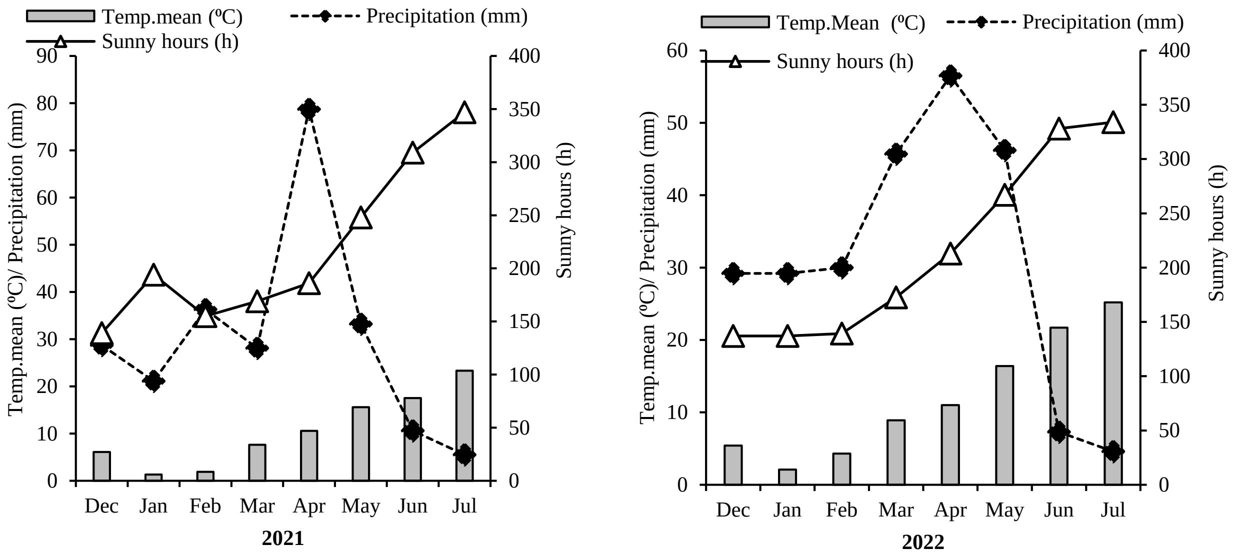

Figure 1. Mean temperature, total precipitation and sunny hours per month during plant growth (Abbar Weather Station)

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

Year	Texture	Silt	Sand	Clay	Organic Carbon	Calcium carbonate Equivalent	pH	Electrical conductivity (dS m⁻¹)	Cation exchange capacity ($cmol_c$ kg^{-1})
				(%)					
2021	Clay loam	21	52	27	0.32	23.5	8.11	1.16	19.6
2022		23	46	31	0.25	25.3	7.86	0.89	21.7

Table 2. Characteristics of organic materials used in the experiment

Chemical characteristics	**Unit**	**Biochar**	**Vermicompost**
pH	–	8.10 ± 0.02	7.37 ± 0.00
EC	(dS m^{-1})	5.23 ± 0.30	1.31 ± 0.10
Ash	(%)	32.30 ± 1.57	18.9 0 ± 1.70
C	(%)	64.10 ± 2.10	27.50 ± 0.77
N	(%)	0.86 ± 0.00	1.41 ± 0.04
C:N	–	109.40 ± 5.70	26.5 0± 1.34
P	(g kg^{-1})	1.91 ± 0.20	1.03 ± 0.30
K	(g kg^{-1})	8.66 ± 0.40	3.19 ± 0.20
Fe	(mg kg^{-1})	320.30 ± 10.60	1046.70 ± 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^{-1} (BIC_5 and BIC_{10}, respectively), vermicompost (VCM) at two levels of 5 and 10 t ha^{-1} (VCM_5 and VCM_{10}, respectively), chemical fertilizer (NPK) at two levels of half and full rate recommended by the soil analysis (NPK_{50} and NPK_{100} 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 two-year-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^3 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, inter-row spacing of 40 cm, and density of 80,000 plants ha^{-1}. 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^{-1} N as urea (in three allocations), 100 kg ha^{-1} phosphate as superphosphate triple, and 100 kg ha^{-1} 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^2 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_{10} (228, 318, and 346 × 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 × 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_{10} (76.45, 108.3, and 113.8 × 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_{10} was 60, 48, and 40 × 10^3 CFU/g dry soil on days 40, 80, and 120, respectively. They were 49, 37, and 51 × 10^3 CFU/g dry soil in BIC_{10} and 57, 72, and 36 × 10^3 CFU/g dry soil in NPK_{100}. Overall, the highest mean fungal population was obtained from the soil treated with NPK_{50} (104 × 10^3 CFU/g dry soil) and the control (101 × 10^3 CFU/g dry soil) (Table 3). The increased population of bacteria and actinomycetes can be attributed to the positive effect of vermicompost 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)

	Bacteria × 10^6 CFU/g dry soil				Actinomycetes × 10^5 CFU/g dry soil				Fungi × 10^3 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_{50}	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
$BICO_5$	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_5	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_{10}	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			
T	6764**				915**				6119**			
S × T	3512**				280**				374**			
E	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 ≤ 0.01 level; * significant at the P ≤ 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

S.O.V	Mean Square (MS)									
	pH	EC (dS m^{-1})	$N–NH_4^{+1}$	$N–NO_3^{-1}$	Olsen P (mg kg^{-1})	K	Fe	Mn	Cu	OC (%)
Y	2.11^{ns}	0.011^{ns}	50.3^{ns}	21.6^{ns}	21.5^{ns}	55510^{ns}	0.708^{ns}	4.67^{ns}	0.28^{ns}	0.26^{ns}
Y(R)	1.67	0.093	252	106	332	863381	3.44	38.4	0.157	1.37
T	0.25^{**}	0.81^{**}	58.6^{*}	128^{**}	129^{**}	934920^{**}	3.14^{**}	18.9^{**}	0.59^{**}	7.29^{**}
T × Y	0.0192^{**}	0.56^{**}	13.5^{ns}	5.6^{ns}	225^{**}	1157485^{**}	4.31^{**}	35.2^{**}	0.79^{**}	20.8^{**}
E	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

Treatments	pH			EC (dS m^{-1})			OC (%)			Olsen P (mg kg^{-1})		
	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
NPK_{50}	8.327b	7.841c	8.078c	1.307a	0.312c	0.809a	0.754c	0.662d	0.705d	42.28a	23.18bc	27.73ab
NPK_{100}	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_5	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_5	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_{10}	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 increased 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).

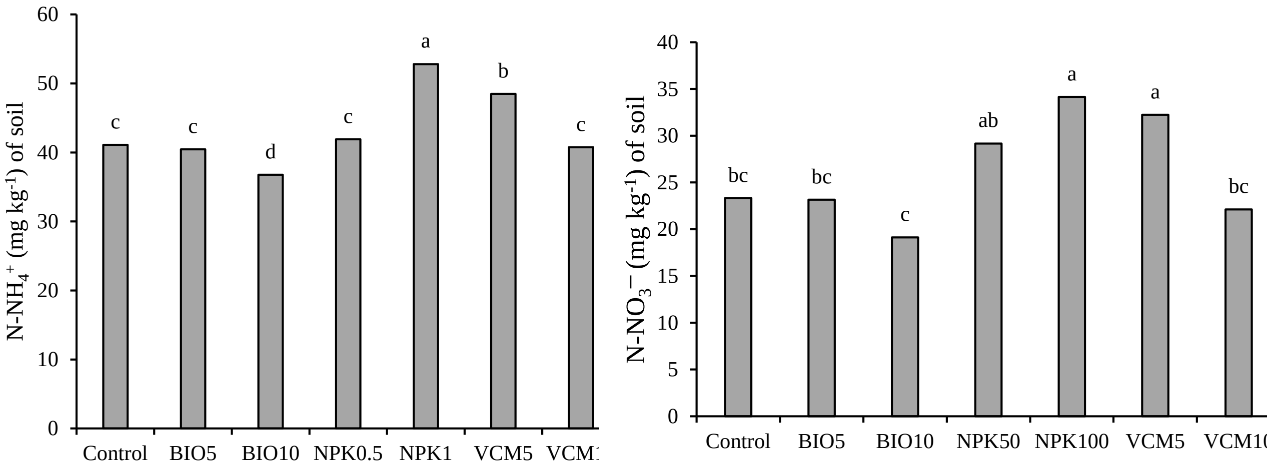

Figure 2. The means comparison for the main effect of the experimental treatments on N-NH_4^+ and N-NO_3^- of the soil

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 no-biochar 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 treatments on K, Fe, Mn, and Cu of the soil in both years

Treatments	K (mg kg^{-1})			Fe (mg kg^{-1})			Mn (mg kg^{-1})			Cu (mg kg^{-1})		
	Y1	**Y2**	**Mean**	**Y1**	**Y2**	**Mean**	**Y1**	**Y2**	**Mean**	**Y1**	**Y2**	**Mean**
Control	1724b	691d	1207bc	4.049b	6.246a	5.148ab	15.67ab	9.18c	12.43bc	0.839bc	1.218a	1.029a
NPK_{50}	2530a	1090b-d	1810a	3.017c	4.836b-d	3.927c	17.11a	9.46c	13.29b	0.806c	0.8441c	0.825c
NPK_{100}	862c	1393bc	1128bc	6.128a	4.026-d	5.077ab	9.79c	13.55ab	11.67bc	1.162a	0.804cd	0.983ab
BIC_5	1018c	1632b	1325b	5.579 a	3.83de	4.706b	9.901c	14.84a	12.37bc	1.016a-c	0.795cd	0.906bc
BIC_{10}	1471b	2395a	1933a	4.253 b	2.856e	3.55c	14.31b	16.20a	15.25a	0.849bc	0.761d	0.804c
VCM_5	943c	844cd	893c	5.572a	5.34ab	5.458a	10.14c	8.052c	9.59d	1.068ab	1.021b	1.044a
VCM_{10}	1027c	1021cd	1024bc	5.453 a	5.093bc	5.273ab	11.102c	11.06bc	11.08cd	1.052ab	0.9877b	1.020ab

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

S.O.V	Mean Square (MS)								
	Pod numbers m^{-2}	Seed numbers m^{-2}	Pod yield	Seed yield	Biological yield	N	P	K	Fe
			(t ha^{-1})			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
T	217**	6558.**	72930*	250*	33969**	3.82*	0.023**	0.173**	509**
T × 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

Treatments	Pod numbers m^{-2}			Seed numbers m^{-2}			Pod yield (t ha^{-1})			Seed yield (t ha^{-1})			Biological yield (t ha^{-1})		
	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
NPK_{50}	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
NPK_{100}	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_5	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_5	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_{10}	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		
	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
NPK_{50}	3.96cd	3.446ab	3.701c	0.298b	0.426b	0.362b	0.503b	0.376b	0.440b	53.27b	41.65f	47.46bc
NPK_{100}	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_5	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_5	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 macro- and 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.

REFERENCES

Abhishek, K., Shrivastava, A., Vimal, V., Gupta, A. K., Bhujbal, S. K., Biswas, J. K., Singh, L., Ghosh, P., Pandey, A., Sharma, P., & Kumar, M. (2022). Biochar application for greenhouse gas mitigation, contaminants immobilization and soil fertility enhancement: A state-of-the-art review. Science of the Total Environment, 853, 158562. https://doi.org/10.1016/j.scitotenv.2022.158562

Abou Hussien, E., Nada, W. M., & Mahrous, H. (2021). Improving chemical and microbial properties of calcareous soil and its productivity of Faba Bean (*Vicia faba* L.) plants by using compost tea enriched with humic acid and azolla. Egyptian Journal of Soil Science, 61(1), 27-44. https://doi.org/10.1016/j.jssas.2016.09.005

Aboukila, E. F., Nassar, I. N., Rashad, M., Hafez, M., & Norton, J. B. (2018). Reclamation of calcareous soil and improvement of squash growth using brewers' spent grain and compost. Journal of the Saudi Society of Agricultural Sciences, 17(4), 390-397. https://doi.org/10.1016/j.jssas.2016.09.005

Alan, O., Budak, B., Sen, F., Gundogdu, M. (2024). Impact of integrated organomineral fertilizer application on growth, yield, quality, and health-related compounds of sweet corn. Turkish Journal Of Field Crops, 29(2), 206-217. https://doi.org/10.17557/tjfc.1558495

Allen, O. N. (1950). Experimental in soil bacteriology (2nd ed.). Burgen Pul. Co.

Aneja, K. R. (2007). Experiments in microbiology, plant pathology and biotechnology. New Age International.

Baghbani−Arani, A., Modarres−Sanavy, S. A. M., Mashhadi Akbar-Boojar, M., & Mokhtassi−Bidgoli, A. (2017). Towards improving the agronomic performance, chlorophyll fluorescence parameters and pigments in fenugreek using zeolite and vermicompost under deficit water stress. Industrial Crops and Products, 109: 346−357. https://doi.org/10.1016/j.indcrop.2017.09.026

Baiamonte, G., Crescimanno, G., Parrino, F., & De Pasquale, C. (2019). Effect of biochar on the physical and structural properties of a sandy soil. Catena, 175: 294–303. https://doi.org/10.1016/j.catena.2018.12.019

Bezabeh, M. W., Haile, M., Sogn, T. A., & Eich-Greatorex, S. (2021). Yield, nutrient uptake, and economic return of faba bean (*Vicia faba* L.) in calcareous soil as affected by compost types. Journal of Agriculture and Food Research, 6, 100237. https://doi.org/10.1016/j.jafr.2021.100237

Chen, X., Lewis, S., Heal, K. V., Lin, Q., & Sohi, S. P. (2021). Biochar engineering and ageing influence the spatiotemporal dynamics of soil pH in the charosphere. Geoderma, 386: 114919. https://doi.org/10.1016/j.geoderma.2020.114919

Chen, X., Liu, M., Kuzyakov, Y., Li, W., Liu, J., Jiang, C., & Li, Z. (2018). Incorporation of rice straw carbon into dissolved organic matter and microbial biomass along a 100−year paddy soil chronosequence. Applied Soil Ecology, 130: 84−90. https://doi.org/10.1016/j.apsoil.2018.06.010

Chintala, R., Mollinedo, J., Schumacher, T. E., Malo, D. D., & Julson, J. L. (2014). Effect of biochar on chemical properties of acidic soil. Archives of Agronomy and Soil Science, 60: 393–404. https://doi.org/10.1080/03650340.2013.789870

Chinthapalli, B., Dibar, D. T., Chitra, D. S. V., & Leta, M. B. (2015). A comparative study on the effect of organic and inorganic fertilizers on agronomic performance of faba bean (*Vicia faba* L.) and pea (*Pisum sativum* L.). Agriculture, Forestry and Fisheries, 4(6): 263–268. https://doi.org/10.11648/j.aff.20150406.14

Cukurcalıoglu, K., Takil, E., & Kayan, N. (2023). Influence of bacteria and chicken manure on yield and yield components of bean (*Phaseolus vulgaris* L.). Turkish Journal Of Field Crops, 28(2), 138-146. https://doi.org/10.17557/tjfc.1265059

Ding, Y., Liu, Y., Liu, S., Li, Z., Tan, X., Huang, X., Zeng, G., Zhou, L., & Zheng, B. (2016). Biochar to improve soil fertility. A review. Agronomy for Sustainable Development, 36: 1–18. https://doi.org/10.1007/s13593-016-0365-y

El Nahhas, N., AlKahtani, M. D. F., Abdelaal, K. A. A., Al Husnain, L., AlGwaiz, H. I. M., Hafez, Y. M., Attia, K. A., & Elkelish, A. (2021). Biochar and jasmonic acid application attenuates antioxidative systems and improves growth, physiology, nutrient uptake and productivity of faba bean (*Vicia faba* L.) irrigated with saline water. Plant Physiology and Biochemistry, 166: 807-817. https://doi.org/10.1016/j.plaphy.2021.06.021

Elad, Y., Cytryn, E., Harel, Y. M., Lew, B., & Graber, E. R. (2011). The biochar effect: plant resistance to biotic stresses. Phytopathologia Mediterranea, 50(3): 335-349. https://doi.org/10.14601/Phytopathol_Mediterr-9360

El-Haddad, M. E., Zayed, M. S., El-Sayed, G. A. M., Hassanein, M. K., & El-Satar, A. A. (2014). Evaluation of compost, vermicompost and their teas produced from rice straw as affected by addition of different supplements. Annals of Agricultural Sciences, 59(2): 243–251. https://doi.org/10.1016/j.aoas.2014.11.008

El-Naggar, A., Shaheen, S. M., Chang, S. X., Hou, D., Ok, Y. S., & Rinklebe, J. (2021). Biochar surface functionality plays a vital role in (im) mobilization and phytoavailability of soil vanadium. ACS Sustainable Chemistry and Engineering, 9(19): 6864-6874. https://doi.org/10.1021/acssuschemeng.1c01888

Eo, J., & Park, K. C. (2019). Effect of vermicompost application on root growth and ginsenoside content of Panax ginseng. Journal of Environmental Management, 234: 458−463. https://doi.org/10.1016/j.jenvman.2019.01.003

FAOSTAT, Crops and Livestock Products Online Database", FAO. (2022). http://www.fao.org/faostat/en/#data/QV

Gad, N., Fekry, M. E. A., & Abou-Hussein, S. D. (2017). Improvement of Faba bean (*Vicia faba* L.) productivity by using cobalt and different levels of compost under new reclaimed lands. Middle East Journal of Applied Sciences, 7 (3), 493-500. https://doi.org/10.21608/mjas.2017.19312

Guridi, I., Calderín, G., Louro, B., Martínez, B., & Rosquete, B. (2017). The humic acids from vermicompost protect rice (*Oryza sativa* L.) plants against a posterior hidric stress. Cultivos Tropicales, 38(2): 53−60. https://doi.org/10.13140/RG.2.2.18660.78725

Hammadi, A. S., & Alwan, B. M. (2023). Studying the Effect of Biochar, Vermicompost, Potassium Silicate and Perfusion Separator on the Physical and Chemical Properties of Soil and (*Vigna radiate* L.). In IOP Conference Series: Earth and Environmental Science (IOP Publishing), 1262(8), 082036. https://doi.org/10.1088/1755-1315/1262/8/082036

Hesse, P.R. (1971). A textbook of soil chemistry analysis. John Murray Pub. Ltd. London.

Houassine, D., Latati, M., Rebouh, N. Y., & Gérard, F. (2019). Phosphorus acquisition processes in the field: study of faba bean cultivated on calcareous soils in Algeria. Archives of Agronomy and Soil Science, 66(2), 168–181. https://doi.org/10.1080/03650340.2019.1605166

Jackson, M. L. (2005). Soil chemical analysis: Advanced course. UW-Madison Libraries parallel press.

Jensen, H. L. (1930). Actinomycetes in Danish soil. Soil Science, 30(1):59-77.

Jones, J. J. (1972). Plant tissue analysis for micronutrients. In J.J. Mortvedt, P.M. Giordano, & W.L. Lindsay (Eds.), Micronutrients in agriculture (pp. 319– 346). Madison, WI: Soil Science Society of America.

Kim, H. S., Kim, K. R., Yang, J. E., Ok, Y. S., Owens, G., Nehls, T., & Kim, K. H. (2016). Effect of biochar on reclaimed tidal land soil properties and maize (*Zea mays* L.) response. Chemosphere, 142: 153-159. https://doi.org/10.1016/j.chemosphere.2015.07.068

Lazcano, C., Gómez-Brandón, M., & Domínguez, J. (2008). Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure. Chemosphere, 72(7): 1013–1019. https://doi.org/10.1016/j.chemosphere.2008.04.023

Lehmann, J. (2007). Bio-energy in the black. Frontiers in Ecology and Environment, 5:38–387. https://doi.org/10.1890/1540-9295(2007)5[381:BITB]2.0.CO;2

Lim, S. L., Lee, L. H., & Wu, T. Y. (2016). Sustainability of using composting and vermicomposting technologies for organic solid waste biotransformation: recent overview, greenhouse gases emissions and economic analysis. Journal of Cleaner Production, 111: 262−278. https://doi.org/10.1016/j.jclepro.2015.08.083

Mahanta, K., Jha, D. K., Rajkhowa, D. J., & Manoj-Kumar. (2012). Microbial enrichment of vermicompost prepared from different plant biomasses and their effect on rice (*Oryza sativa* L.) growth and soil fertility. Biological Agriculture and Horticulture, 28(4):241−250. https://doi.org/10.1080/01448765.2012.717794

Martin, J. P. (1950). Methods for estimating soil fungi. Soil Science 69: 215-233.

Martinez-Balmori, D., Olivares, F. L., Spaccini, R., Aguiar, K. P., Araújo, M. F., Aguiar, N. O., Guridi, F., & Canellas, L. P. (2013). Molecular characteristics of vermicompost and their relationship to preservation of inoculated nitrogen-fixing bacteria. Journal of Analytical and Applied Pyrolysis, 104: 540−550. https://doi.org/10.1016/j.jaap.2013.05.008

Mesgaran, M. B., Madani, K., Hashemi, H., & Azadi, P. (2017). Iran's land suitability for agriculture. Scientific Reports, 7, 7670. https://doi.org/10.1038/s41598-017-08066-4

Ministry of Agriculture-Jihad in Iran Yearbook. (2022). Available online at: https://www.maj.ir

Mohamed, I., El-Meihy, R., Ali, M., Chen, F., & Raleve, D. (2017). Interactive effects of biochar and micronutrients on faba bean growth, symbiotic performance, and soil properties. Journal of Plant Nutrition and Soil Science, 180(6): 729-738. https://doi.org/10.1002/jpln.201700293

Mosavi-Azandehi, S. M., Ansari, M. H., Sharifi, P., & Hoor, S. S. (2023). The effect of organic amendments on soil microbial activity and yield of faba bean (*Vicia faba*) inoculated with Rhizobium leguminosarum. The Indian Journal of Agricultural Sciences, 93(8): 893-898. https://doi.org/10.56093/ijas.v93i8.108630

Mulvaney, R. L. (1996). Nitrogen-Inorganic Forms. In Methods of soil analysis. Part-3- Chemical Methods. P. 1123-1184. SSSA, Inc., ASA, Inc. Madison, WI. https://doi.org/10.2136/sssabookser5.3.c36

Nafees, M., Ullah, S., & Ahmed, I. (2023). Plant growth-promoting rhizobacteria and biochar as bioeffectors and bioalleviators of drought stress in faba bean (*Vicia faba* L.). Folia Microbiologica, 1-14. Advance online publication. https://doi.org/10.1007/s12223-023-01083-7

Nelissen, V., Ruysschaert, G., Manka'Abusi, D., D'Hose, T., De Beuf, K., Al-Barri, B., & Boeckx, P. (2015). Impact of a woody biochar on properties of a sandy loam soil and spring barley during a two-year field experiment. European Journal of Agronomy, 62:65-78. https://doi.org/10.1016/j.eja.2014.09.006

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, C. A. (1954). Estimation of available phosphorous in soils by extraction with sodium bicarbonate. U. S. Department of Agricultur Circular. No. 939.

Rekha, A., Srinivasan, L., Pavithra, S., Gomathi, T., Sudha, P. N., Lavanya, G., & Vidhya, A. (2023). Biosorption efficacy studies of Sargassum wightii and its biochar on the removal of chromium from aqueous solution. Journal of the Taiwan Institute of Chemical Engineers, 105241.

Rivelli, A. R., & Libutti, A. (2022). Effect of biochar and inorganic or organic fertilizer co-application on soil properties, plant growth and nutrient content in Swiss chard. Agronomy, 12(9): 2089. https://doi.org/10.3390/agronomy12092089

Ruisi, P., Amato, G., Badagliacca, G., Frenda, A. S., Giambalvo, D., & Di Miceli, G. (2017). Agro-ecological benefits of faba bean for rainfed Mediterranean cropping systems. Italian Journal of Agronomy, 12, 865. https://doi.org/10.4081/ija.2017.865

Saikia, S. P., Dutta, S. P., Goswami, A., Bhau, B. S., & Kanjilal, P. B. (2010). Role of Azospirillum in the improvement of legumes. In D. K. Maheshwari (Ed.), Microbes for legume improvement (pp. 389-408). Springer. https://doi.org/10.1007/978-3-7091-0143-1_14

Sarma, B., Farooq, M., Gogoi, N., Borkotoki, B., Kataki, R., & Garg, A. (2018). Soil organic carbon dynamics in wheat-Green gram crop rotation amended with vermicompost and biochar in combination with inorganic fertilizers: A comparative study. Journal of Cleaner Production, 201: 471-480. https://doi.org/10.1016/j.jclepro.2018.07.012

Senay, B., & Tepecik, M. (2024). Determination of the effect of biochar applications on soil physical and chemical properties and wheat (*Triticum aestivum* L.) germination and biomass. Journal of Tekirdag Agricultural Faculty, 21(2): 297-308. https://doi.org/10.33462/jotaf.1190812

Sheikh, Q. S., Al-Jumaily, A. R. A., & Aziz, J. M. (2022). Test of the Effectiveness of Biochar and Mineral Fertilizer on The Growth and Yield of Two Broad Bean (*Vicia Faba* L.). Texas Journal of Agriculture and Biological Sciences, 4: 42-57.

Shi, Q., Wang, W., Zhang, H., Bai, H., Liu, K., Zhang, J., Li, Z., & Zhu, W. (2023). Porous biochar derived from walnut shell as an efficient adsorbent for tetracycline removal. Bioresource Technology, 383:129213. https://doi.org/10.1016/j.biortech.2023.129213

Shiri, Z. M., & Farbodi, M. (2022). Qualitative evaluation of land suitability for olive, potato and cotton cultivation in Tarom in Zanjan. agriTECH, 42(2), 102-112. https://doi.org/10.22146/agritech.58222

Song, X., Li, H., Song, J., Chen, W., & Shi, L. (2022). Biochar/vermicompost promotes Hybrid Pennisetum plant growth and soil enzyme activity in saline soils. Plant Physiology and Biochemistry, 183, 96-110. https://doi.org/10.1016/j.plaphy.2022.05.009

Soobhany, N., Mohee, R., & Garg, V. K. (2017). A comparative analysis of composts and vermicomposts derived from municipal solid waste for the growth and yield of green bean (*Phaseolus vulgaris* L.). Environmental Science and Pollution Research, 24(12):11228–11239. https://doi.org/10.1007/s11356-017-8685-3

Steiner, C., Teixeira, W. G., Lehmann, J., Nehls, T., De Macêdo, J. L. V., Blum, W. E. H., & Zech, W. (2007). Long term effects of manure, charcoal, and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. Plant and Soil, 291: 275-290. https://doi.org/10.1007/s11104-007-9193-9

Tepecik, M., Ekren, S., Ongun, A. R., & Sarikahya, N. B. (2024). Effects of biochar treatments on the elemental composition of tobacco (*Nicotiana tabacum* L.) leaves based on the priming period. Heliyon, 10; e23307. https://doi.org/10.1016/j.heliyon.2024.e23307

Tepecik, M., Kayıkcıoglu, H. H., & Kılıc, S. (2022). Effects of biochar obtained at different pyrolysis temperatures on plant nutrients of maize. Journal of Agriculture Faculty of Ege University, 59 (1):171-181.

Van Zwieten, L., Kimber, S., Morris, S., Chan, K., Downie, A., Rust, J., Joseph, S., & Cowie, A. (2010). Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. Plant Soil, 327:235-246. https://doi.org/10.1007/s11104-009-0050-x

Walkley, A., & Black, I. A. (1934). An examination of Degtjareff method for determination soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37: 29-38. https://doi.org/10.20289/zfdergi.894427

Wu, Y., Lu, S., Zhu, Y., Zhang, Y., Wu, M., & Long, X. E. (2022). Microbes in a neutral-alkaline paddy soil react differentially to intact and acid washed biochar. Journal of Soils and Sediments, 22(12), 3137-3150. https://doi.org/10.1007/s11368-022-03287-1

Yuksel, O., Balkan, A., Gocmen, D. B., Bilgin, O., & Baser, I. (2024). Effect of soil conditioners applied to seed on grain yield and yield characteristics in wheat. Turkish Journal Of Field Crops, 29(2), 121-128. https://doi.org/10.17557/tjfc.1491505

Zhang, R., Qu, Z., Liu, L., Yang, W., Wang, L., Li, J., & Zhang, D. (2022). Soil Respiration and Organic Carbon Response to Biochar and Their Influencing Factors. Atmosphere, 13(12), 2038. https://doi.org/10.3390/atmos13122038