Effect of integration of poultry manure and vinasse on the abundance and diversity of soil fauna, soil fertility index, and barley growth in calcareous soils

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Abstract

In Egypt, calcareous soils represent a large part of desert soils suffering from a shortage of nutrients and organic matter, which affects production and biological diversity in agroecosystems. Organic wastes, which negatively affect the environment, recycle it as a promising technology in different farming systems, and its impact on production and soil fauna is largely unknown. We investigated the effects of integrating poultry manure (P) with vinasse (V) at different rates on the diversity of soil fauna and barley growth (*Hordeum aestivm*) grown in calcareous soil. The results showed that the addition of P alone or combined with V at different rates had a significant effect on the soil fauna, soil fertility, yield of barley. The study showed a strong correlation between soil organic matter, soil fertility index, microbial biomass carbon, and soil fauna (R^2 = 0.82, P < 0.05), (R^2 = 0.86, P < 0.05), and (R^2 = 0.98, P < 0.05) when treating soil with P alone or combined with V. P2V1 mixtures have the best results in OM with 65.0% compared to control, and V contributes more than 16% of them. Total individuals of soil fauna increased by 106.3%, 243.8%, 118.8% and 43.8% in P1V1, P1V2, P2V1 and P2V2 relative to control, respectively. In pots with P addition alone or combined with V at different rates, Shannon's index and Evenness index were significantly higher than the control treatment at the mature stage of barley growth. The interaction between P and V increased the grain yield of barley plant from 5.76 to 9.52 g pot^{-1} in P2V2 and to 10.19 g pot^{-1} in P2V1. The results indicate that integration of P and V can be promising organic amendments in improving soil fauna, soil fertility, and crop yield in calcareous soils.

Introduction

In Egypt, calcareous soils are estimated at about 0.28 million hectares, which represents a large part of the desert land, especially in the northwestern coastal region and Sinai [1]. Calcareous lands are known as having a high content of calcium carbonate and high pH, which affects their chemical, biological, environmental and physical properties and thus is reflected in the cropping pattern and productivity [2]. Calcareous soil lacks organic matter (OM), whose addition in the form of compost or poultry manure, etc., improves the chemical, ecological and physical properties and increases the productivity of crops.

Sugar and Integrated Industries Company in Hawamdiya produces more than 2,000 cubic meters per day of vinasse, which is harmful to the environment, causing pollution to the waterways that drain it [3]. A liter of ethanol produces an average of 10 to 15 liters of vinasse and is a waste liquid produced during the production of ethanol from sugarcane or sugar beet or cellulosic material. Vinasse is a low-cost alternative to fertilization because it replaces fertilizers and improves crop productivity through improving the soil structure [4]. Vinasse enhances soil fauna and microbial communities [5] and increases soil fertility [4].

Poultry manure is an excellent soil amendment that provides nutrients for growing crops when used wisely, because it is high in organic matter along with nutrients available for plant growth [6]. [7] found that soil treated with poultry manure enhances soil fertility and the activity of soil organisms and increases organic matter and its water holding capacity. The decomposition of organic waste is one of the most important biochemical processes, which is due to the biological activity in the soil, which increases its fertility [8]. The use of poultry manure (30 Mg of dry matter ha^{-1}) significantly improved the stability of mounds and increased the yield of many grasses and legumes [9]. Moreover, poultry manure was the best organic waste for the reclamation of burnt soils [10]. [11] found the possibility of using poultry manure to improve burnt soil and increase rye-grass yield.

Biodiversity in agricultural systems is a promising ecological strategy for achieving sustainable production. Residue recycling is a key factor in determining soil bioactivity and the managing fauna diversity of species in agro-ecosystems [12]. Soil fauna play an important role in changing soil quality by improving soil structure, decomposing organic matter, and increasing soil fertility and the number of organisms [13]. Soil fauna, which is part of Eucaryota, are grouped into macrofauna, mesofauna, and microfauna [14]. These soil organisms contribute to the maintenance and productivity of ecosystems by affecting soil quality and health. Among the mesofauna organisms, Collembola contributes significantly to the addition of soil nutrients through the decomposition of organic matter [13]. Collembolans known to provide a healthy soil environment in the ecosystem by recycling and decomposing agricultural waste in the soil, thus they are environmentally friendly and also host many pathogens like fungi, bacteria, nematodes, protozoa, etc. [15]. Orbatid mites constitute one of the richest groups of arthropods in soil. Orbatid mites play an important role in the biogene stage of plant residues humification, and can react very sensitively to changes in natural and agricultural soils, and thus are used as bioindicators of the soil in which they live [16]. Barley is the fourth most important food crop in Egypt, with a cultivated area of about 126000 hectares in 2020 that produced 356,580 tons with an average of 2830 kg ha^{-1} [17]. Barley plants are commonly grown in newly reclaimed soils (calcareous soils) which are generally characterized by low fertility, high calcium carbonate content and high pH [18]. Organic amendments play an important role in increasing soil fertility and soil fauna for crops grown on calcareous soils. Therefore, the present study aims to explore the effects of integrating poultry manure with vinasse on the abundance and diversity of soil fauna and barley growth (*Hordeum aestivm*) grown in calcareous soil.

Material And Methods

Soil and amendments

Soil samples (0–50 cm depth) used in this experiment was collected and mixed from the Qetaa Maryout area (latitude 30.88°86°N, 29,8°54°E) Amreya 1, Alexandria Governorate, Egypt. Two types of organic amendments were used (Poultry manure (P) and vinasse (V)) in this study. The Poultry manure was collected from a poultry farm using sawdust in the litter poultry for 40 days. The vinasse, a by-product was obtained from Egyptian sugar& integrated Industries Company, El Hawamdeyia (produces more than 2,000 m^3 d^{-1} of vinasse), Cairo, Egypt. The properties of the soil, P and V were determined according to [19] and presented in (Table 1).

Table 1
Selected physicochemical properties of the soil, vinasse (V) and poultry manure (P) used in this study.

Characteristics	Units	Soil	V	P
pH (1:10 extracts)	-	7.88 ± 0.15	4.00	8.16 ± 0.25
EC (1:10 extracts)	dSm^{-1}	11.30 ± 0.05	42.0	5.64 ± 0.07
Ca^{2+}	$meqL^{-1}$	57.40 ± 1.25	290.0	155.0 ± 1.90
Mg^{2+}	$meqL^{-1}$	51.48 ± 1.05	183.3	116.6 ± 1.63
O.M	%	0.85 ± 0.02	7.2	63.4 ± 2.05
CEC	cmol(+) kg^{-1}	10.6 ± 1.20	ND	ND
$CaCO_3$	%	28.0 ± 1.24	ND	ND
Total N	%	0.098 ± 0.05	0.36	4.20 ± 0.15
Total P	%	0.05 ± 0.01	0.40	0.68 ± 0.08
Total K	%	0.43 ± 0.05	0.68	1.12 ± 0.65
Bulk density	g cm^{-3}	1.50 ± 0.1	ND	ND

ND, not determined; EC, electrical conductivity; OM., organic matter, and; CEC, cation exchange capacity. Results are expressed as mean ± standard deviation of three replicates.

Plant material

One cultivar of cultivated barley (*Hordeum aestivm*), variety 138 (origin, Egypt (2019); *rbc*L, MW391914; *mat*K GenBank, MW336989; Kind, Naked; Pedigree, /5/Aths/lignee686/3/Deir Alla106//Sv.Asa/Attiki/4/Cen/Bglo."S". It was obtained from Barley Research Department, Field Crops Research Institute, Sakha Station, and Agricultural Research Center, Egypt. The collection of barley cultivar used in this experiment complies with institutional, national and international guidelines and legislation

Experimental design

Barley (*Hordeum aestivm*) was grown in plastic pots, each containing 10 kg of soil samples under greenhouse conditions. The soil was air -dried, then crushed and sieved with a 4 mm sieve to reflect the natural conditions of the soil. The soil used was uniformly mixed with P and V and their mixtures and filled into plastic pots of 30 cm in diameter and 23 cm in height (The height of the soil in the pots is 16 cm).

Seven treatments were used in this experiment, and randomized complete blocks with five replicates were designed. The treatments used were: C: Control; P1: poultry manure at rate 10 t ha^{-1}; P2: poultry manure at rate 15 t ha^{-1}; P1V1: poultry manure at rate 10 ha^{-1}+ vinasse at rate 3.5 t ha^{-1}; P1V2: poultry manure at rate 10 t ha^{-1} + vinasse at rate 7 t ha^{-1}; P2V1: poultry manure at rate 15 t ha^{-1} + vinasse at rate 3.5 t ha^{-1}; P2V2: poultry manure at rate 15 t ha^{-1} + vinasse at rate 7 t ha^{-1}. Seed barley (*Hordeum aestivm*) was sown on 15 November and irrigated based on water requirements (based on field capacity) with 15% added as leaching requirements. Nitrogen fertilizer was added in three equal doses in the form urea (46% N) at rate 71.4 kg fed^{-1} A basal doses P and K were added as super-phosphate (15% P_2O_5) and potassium sulfate (48% K_2O) at the rates 59.5 kg P_2 O_5 and 119 kg K_2O per ha^{-1}, respectively. All other agricultural practices on the experiment were done as recommended in the study area. The temperature during the experiment was between 17 and 20° C. Harvest was carried out 22 weeks after sowing, and yield measurements such as dry weight, 1000 grain weight, and grain weight of barley plant were recorded and soil samples were taken to measure the some soil properties.

Experimental analytical procedures

Organic matter (OM) of soil was calculated by the Walkley-Black method for the organic carbon (OC) multiplying of 1.724 [20], While, organic matter of poultry manure and vinasse was determined by combustion method [19]. Available P was determined using spectrophotometer using the ascorbic acid method after extracted by 0.5 M $NaHCO_3$ solution at pH 8.30 according to [21]. Available N (NH_4^+ and NO_3^-) was determined using the Kjeldahel method after extracted by 2M KCl solution according to [22]. Available K was determined using a flame photometer after extracted by 1.0 N ammonium acetate at pH 7 [19]. The properties of P, V and the studied soils were analyzed according to standard methods [23]. Soil bulk density of the undisturbed soil sample was measured using the core method as explained by [24].

Microbial biomass carbon (MBC) was determined with 25 g of soil samples were fumigated with ethanol-free chloroform for 24 hr at 25^0C [25]. Then the soil was extracted with K_2SO_4 and the extractable organic C was estimated using $K_2Cr_2O_7$ and H_2SO_4 for 30 minutes at 170°C and titrated against ferrous ammonium sulphate with ferroin as the indicator. Microbial biomass carbon (MBC) was calculated from:

MBC = EC fumigated soil – EC un-fumigated soil/ Kc

Where: EC = Extractable carbon

Kc = 0.379 (Kc is the K_2SO_4 extract efficiency factor [25].

Soil samples were taken to determine the soil fauna at the mature stage of barley growth. Soil fauna/microarthropods were extracted from experimental microcosms using modified Berlese's funnels. The extraction lasted 4 days. Separated organisms were preserved in 70% ethanol, and cleared with lactic acid, then identified to species level according to [27], and [28].

Species richness and Shannon–Wiener diversity index (H) and Pielou’s evenness (J) were calculated using PAST, a software package for paleontological data analysis V4.08 [29]. Shannon-Wiener index (H`) was calculated as -∑Pi In (Pi), where Pi is the proportion of species i relative to the total number of species. Evenness (J) was calculated as J= H/InS.

The fertility index was described according to [30] with following equation:

$$FI = (FN \times FP \times FK \times FOM)^{1/5}$$

Where: FI = fertility index; FN, FP, FK = available of nitrogen, phosphorus, potassium, respectively; and FOM = organic matter (%).

Statistical Analyses

All data are the means of 4 replicates. Normality of the data was tested with the Kolmogorov-Smirnov test. One–way analysis of variance (ANOVA) was applied to determine the significant differences among different treatments. If there significant differences between means, Tukey post hoc comparisons among different groups were performed. For all statistical tests P values $\leq$ 0.05 was considered to be statistically significant.

Results

Effect of poultry manure and vinasse on the abundance and diversity of soil fauna

The addition of P alone or combined with V had a significant effect on the soil fauna (Table 2). Total individuals increased by 106.3%, 243.8%, 118.8% and 43.8% in P1V1, P1V2, P2V1 and P2V2 relative to control, respectively. Prostigmata, Mesostigmata, Oribatid mites and Collembola were the dominant groups and accounted for 43.3%, 0.0%, 3.33% and 50.0%, respectively, of the total individuals at P1 and 50.0%, 16.67%, 6.67% and 20.0%, respectively, of the total individuals in P2. The highest mean numbers of soil collembola were found in P1V1 pots, followed by treatments with P1V2, P2V1 and P2V2 and the lowest abundant in the control. P1V2 mixtures gave the best results in prostigmata and Oribatid mites by 580% and 133.3%, compared to the control, respectively. The combination of P and V increased the numbers of soil prostigmata per pot from 1.25 to 5.0 in P1V1 and to 8.5 in P1V2.

Table 2
Effect of poultry manure (P), vinasse (V), and their mixtures on number of soil fauna in calcareous soils. Results are expressed as mean ± standard deviation of three replicates.

Treatments	Prostigmata	Mesostigmata	orbatid mites	Collembola	Others	Total
C	1.25 ± 0.96 [g]	0.25 ± 0.50[d]	0.75 ± 0.50[c]	1.00 ± 1.41[e]	0.75 ± 0.96[b]	4.00 ± 0.82[f]
P1	3.25 ± 2.06 [e]	0.00 ± 0.00[e]	0.25 ± 0.50[e]	3.75 ± 2.06 [a]	0.25 ± 0.5[d]	7.50 ± 3.87[d]
P2	3.75 ± 1.50[d]	1.25 ± 0.50[a]	0.50 ± 1.50[d]	1.5 ± 1.71 [c]	0.50 ± 0.50[c]	7.50 ± 3.86[d]
P1V1	5.00 ± 2.71[b]	0.75 ± 0.96[c]	0.50 ± 1.00[d]	1.75 ± 2.06 [b]	0.25 ± 0.50[d]	8.25 ± 4.04[c]
P1V2	8.5 ± 6.76[a]	1.00 ± 0.82[b]	1.75 ± 2.06[a]	1.25 ± 1.26[d]	1.25 ± 1.50[a]	13.75 ± 8.42[a]
P2V1	4.50 ± 1.73 [c]	1.25 ± 1.50[a]	1.00 ± 1.41[b]	1.25 ± 1.89[d]	0.75 ± 0.96[b]	8.75 ± 1.89 [b]
P2V2	3.00 ± 2.16[f]	0.25 ± 0.50[d]	0.75 ± 0.96[c]	1.25 ± 2.50[d]	0.50 ± 1.00[c]	5.75 ± 4.11[e]

The Evenness index increased significantly with the addition of P alone or combined with the V treatments versus the control in the mature stage of barley growth, with the largest increase in evenness index recorded in the P1V2 treatment and lowest in the control (Fig. 2). The Evenness index increased from 0.486 to 0.637 in the P1, and to 0.755 in the P2. Evenness index increased by 26.95%, 63.67%, 16.26% and 17.08% in P1V1, P1V2, P2V1 and P2V2 relative to control, respectively.

As shown in Fig. 1, in the pots with the addition of P alone or with the V treatments at different rates, Shannon's index was significantly higher than that of the control treatment at the mature stage of barley growth. Compared with the control treatment, Shannon's index increased by 19.11% and 27.94% by adding P1 and P2, respectively. The combination of P and V increased the shannon's index from 0.68 to 0.83 in P1V1 and to 0.95 in P1V2. The highest Shannon's index was found in P2V1 pots, followed by treatments with P2, P2V2 and P1V1 = P2V1 and the lowest in the control.

Effect of poultry manure and vinasse on barley productivity

The spike weight of barley was significantly increased in pots treated with P manure alone or combined with vinasse (V) addition (Table 3). The addition of P increased the spike weight by 28.8 and 31.1% in P1 and P2, respectively. The spike weight increased from 14.02 to 19.81 g in the P1V1, and to 18.52 g pot^{-1} in the P2V1. The application of P1V1 gave the highest significant increase in the spike weight of barley plants compared to other treatments. A difference in spike weight of barley plants between the P1 and P2 as well as P1V1 and P2V2 is not statistically significant.

Table 3
Effects of vinasse (V), poultry manure (P), and their mixtures on growth of barley plants grown in calcareous soils. Results are expressed as mean ± standard deviation of three replicates.

Treatments	**Spike weight, g pot^{-1}**	**1000 grain weight g**	**grain weight g pot^{-1}**	**straw weight g pot^{-1}**
C	14.02 ± 0.39 ^{c}	35.60 ± 1.00 ^{e}	5.76 ± 0.27 ^{e}	89.23 ± 0.66 ^{a}
P1	18.07 ± 0.01 ^{b}	42.40 ± 1.87 ^{d}	7.08 ± 0.34 ^{d}	73.04 ± 0.71 ^{d}
P2	18.38 ± 0.29 ^{b}	48.43 ± 1.63 ^{b}	9.90 ± 0.84 ^{ab}	82.31 ± 0.71 ^{b}
P1V1	19.81 ± 0.23 ^{a}	45.20 ± 1.35 ^{c}	6.66 ± 0.07 ^{d}	75.25 ± 0.92 ^{c}
P1V2	13.37 ± 0.33 ^{d}	54.53 ± 0.72 ^{a}	10.19 ± 0.26 ^{a}	72.38 ± 1.13 ^{de}
P2V1	18.52 ± 0.69 ^{b}	42.60 ± 0.44 ^{d}	9.52 ± 0.17 ^{b}	72.13 ± 0.26 ^{de}
P2V2	19.38 ± 0.26 ^{a}	53.30 ± 0.72 ^{a}	8.47 ± 0.14 ^{c}	71.63 ± 0.26 ^{e}

The straw weight of barley plants decreased significantly in the pots treated with P manure alone or combined with the V addition (Table 3). The straw weight decreased from 89.23 to 82.31 g pot^{-1} in the P2, and to 73.04 g pot^{-1} in the P1. Straw weight decreased as the rate of V increased. A difference in straw weight of barley plants between the P1V2, P2V1 and P2V2 as well as P1 is not statistically significant.

The application of P, V, and their mixtures had a significant effect on the 1000-grain weight of barley (Table 3). In the soil treated with P, 1000-grain weight of barley plants increased by 19.1 and 36.03% at rates 10 and 15 t ha^{-1}, respectively. The 1000-grain weight increased from 35.6 to 45.20 g in the P1V1, and to 54.53 g in the P1V2. P1V2 mixtures gave the best results in 1000-grain weight of barley plants by 53.2% relative to the control.

The addition of P alone or combined with V had a significant effect on the flag leaf area (FLA) (Fig. 2). In the pot amended with P as compared to the control, the flag leaf area increased by 60.3 and 76.6% at the rate 10 and 15 t ha^{-1}, respectively. Flag leaf area of barley plants increased with the increase of P addition. P2V1 mixtures gave the best results in FLA by 172.6% relative to the control. The combination of P and V fertilization increased leaf area from 9.06 to 24.70 cm^2 in the P2V1 and to 17.70 cm^2 in the P2V2. The difference in FLA of barley plants between the P2, P1V1, P1V2 and P2V2 treatments is not statistically significant.

The effect of adding of P, V, and their mixtures on the grain yield of barley plant was significant (Table 3). The grain yield of barley plant increased from 5.76 g pot^{-1} in the control treatment to 9.52 and to 10.19 g pot^{-1} for the P2V2 and P2V1 treatments, respectively. The grain yield of barley plant increased by about 22.9% and 71.8% in the pots treated with P1 and P2 compared with the control. The addition of P2V1 gave the highest significant increase in barley grain yield compared to the other treatments. The difference in grain yield of barley plants between P1 and P1V1 is not statistically significant.

Effect of organic amendments on soil fertility

The results of MBC and OM in soil increased significantly by adding P only or mixed with V amendment compared to unamended soil (Table 4). The OM varied from 1.20% for control to 1.98% for P2V2. When adding 15 t of P to the soil, the MBC and OM increased by 70.8% and 22.5%, respectively, compared to the control. P2V1 mixtures have the best results in OM with 65.0% compared to control, and V contributes more than 16% of them. The MBC and OM were higher in P2V1 and P2V2 than the other treatment. Organic matter and MBC increased with increasing rates of P and V addition. Additionally, differences of OM between P1V2 and P2V1 were not statistically significant. A difference in MBC between the P1, P2 and P1V1 as well as P1V2 and P2V1 is not statistically significant.

Table 4. Effect of poultry manure (P), vinasse (V), and their mixtures on organic matter, soil microbial biomass (MBC) and available of NPK.. Results are expressed as mean ± standard deviation of three replicates.

Treatment	O.M	MBC	N	P	K
	%	mg Kg^{-1}		mg Kg^{-1}	
C	1.20 ±0.02^{e}	2.16±0.10^{d}	26.46±0.13^{e}	8.62±0.03^{g}	248.19±0.03^{g}
P1	1.47 ±0.01^{d}	3.15±0.45^{bc}	31.32±0.06^{d}	11.31±0.05^{f}	255.34±0.02^{f}
P2	1.70 ±0.02^{c}	3.69±0.13^{b}	33.47±0.22^{c}	12.56±0.02^{d}	256.66±0.31^{e}
P1V1	1.53 ±0.04^{d}	3.35±0.08^{bc}	36.90±0.05^{a}	12.28±0.03^{e}	268.60±0.16^{d}
P1V2	1.77 ±0.03^{b}	5.37±0.26^{a}	35.34±0.08^{b}	13.85±0.14^{b}	280.45±0.14^{a}
P2V1	1.77 ±0.01^{b}	5.44±0.74^{a}	36.78±0.10^{a}	13.41±0.16^{c}	270.60±0.15^{c}
P2V2	1.98 0.02^{a}	2.65±0.57^{cd}	36.70±0.17^{a}	14.36±0.00^{a}	274.44±0.02^{b}
LSD	0.53	0.72	0.23	0.15	0.37

The application of P alone or combined with V had a significant effect on the available of nitrogen (N), phosphorus (P) and potassium (K) (Table 4). Available of N, P and K increased with increasing rates of P addition. High N and P available were obtained in the P2V2 and K in the P1V2 compared to other treatments. The application P1 and P2 increased N and P available by 18.37% and 26.49%, and 31.21% and 45.71%, respectively. The addition of P manure increased the K available from 248.19 to 268.60 mg kg^{-1} in P1V1 and to 280.45 mg kg^{-1} in P1V2, respectively. A difference in available P between the P1V1, P2V1 and P2V2 is not statistically significant.

Discussion

In this study, the total number of soil fauna increased significantly with the addition of organic amendments (P alone or combined with V). The higher abundance of the total number of soil fauna in the P alone or combined with V - treated soil is due to the higher OM and other nutrient contents in the P and V (Table 1). We found that soil treated with P addition alone or in combination with V had a strong significant correlation between soil organic matter, soil fertility index, microbial biomass carbon and soil fauna (R^2 = 0.82, $P < 0.05$), (R^2 = 0.86, $P < 0.05$), and (R^2 = 0.98, $P < 0.05$) (Fig. 3). [31] found that the strong positive correlation between the abundance of soil Collembola population with organic materials (r = 0.618, $P < 0.05$), phosphorus (r = 0.927, $P \leq 0.05$), potassium (r = 0.824, $P \leq 0.1$), nitrogen (r = 0.607, $P < 0.05$), sulfur (r = 0.663, $P < 0.05$). [32] found that the populations of Acari and Collembola soils increased with increasing soil content of organic matter. The addition of organic matter to the soil has an effective effect in increasing the abundance and diversity of the total collembola and oribatid mites [33]. [34] found that arthropod taxa increase with addition of organic matter as well as in organic farming systems. A significant effect of soil carbon on soil fauna has also been found in previous studies [35]; [36]; [37]. Furthermore, the carbon content of the roots greatly affected the species formation of Oribatida mites probably via rhizodeposition, as it feeds on dead roots or root-associated fungi [38]. Collembola were prevalent in this study suggesting that it benefited from organic matter coming from poultry manure and vinasse that may serve to increase microbial biomass in rhizosphere roots. The increase is due to the high rate of reproduction and the ability to adapt [39]. The high abundance of total number of soil fauna in the P1V2 pots could be explained due to the high soil microbial biomass, organic matter and improved nutrient status in P1V2 amended soil (Table 4). The presence of ethanol and phenols in vinasse can be one of the reasons for the decrease of the total number of soil fauna in pots treated with a high rate of vinasse. According to [40], vinasse and poultry manure form part of the plant's natural defense system against infection and harmful microbial invasion. Low numbers of soil fauna in the control treatment, and this may be due to the absence of an external carbon source [41]. The abundance and diversity of fauna relate to both soil fertility management and agro-ecological conditions in various fields [42].

Diversity indices for Shannon and Vennes were used to express biodiversity in soils treated with poultry manure and vinasse, which are positively correlated with improvements in soil conditions caused by nutrients and biomass through them. The increase in Shannon and Vennes indices with the addition of P alone or combined with V was significant. Similar results were reported by [43], who found that the highest value of the Shannon index in soil treated with organic manure and the lowest value in the N treatment in the maturity stage of maize.

Soil fertility is important for soil management because it reflects the production capacity of the soil to sustain growth of plants [44]. The increase in soil fertility with the addition of P alone or mixed with V coincided with their higher content of OM, P, N, K and CEC (Table 1). Barley yield increased with the addition of V, which may be related to the higher content of vinasse of OM, K, Ca, N, and P (Table 1). [45] found that the application of V improves soil fertility and physical properties, and increases sugarcane yield without adverse effects on groundwater. [46] found that the yield of durum wheat increased by 32 or 46% with the addition of sugar beet V to the soil at a rate of 3500 or 7000 kg ha $^{-1}$, respectively. [47] attributed the increase in the growth and productivity of paspalum turf-grass after the application of V to the high percentage of potassium, nitrogen, zinc and molybdenum in it, and its improvement in the characteristics of the soil. These results are consistent with those obtained by [48] on wheat, pigeon pea and maize and [49] on barley and spinach. [50] found that the addition of P increases wheat grain due to an increase in the number of tillers and grain. [51] note that the increase in collembolan species is working to higher C, P, S and N mineralization, which leads to an increase in the plant productively. [52] reported an increase in leaf area, total chlorophyll content, and grain yield of maize and sorghum with the addition of P manure. [53] reported that P contains essential nutrients needed to enhance growth and productivity of crops. The addition of P increases the soil's organic matter content and improves its water holding capacity as well as its nutrient content, which enhances crop yield. [54] reported that P applied at a rate of 10 t ha^{-1} and 20 t ha^{-1}, increased plant height, number of leaves and fruit yield of peppers. It has been observed that the nutrients provided by poultry manure have positive effects on crop yield [55]. The data showed that the addition of P in integration with V led to a significant increase in the growth and yield of barley. This increase may be due to the addition of organic fertilizers in the form of P or V, which improves soil fertility by containing macro and micro nutrients, amino acids, organic acids, sugar and organic matter. Their addition also reduces soil pH, enhances the availability of nutrients and soil fauna, and ultimately improves yield components. We found that soil treated with P addition alone or in combination with V had a strong significant correlation between soil fauna, MBC and grain yield of barley plants (R^2 = 0.91 and R^2 = 0.94, $P < 0.05$) (Fig. 3). Applying P with V to soil can reduce fertilizer input, increase crop yield, plant nutrient uptake, and increase soil fauna.

Conclusions

The results demonstrated that the addition of P alone or combined with V contributed positively to improve soil fauna, soil fertility, and barley yield. The addition of P in integration with V led to a significant increase in the OM, MBC, availability of NPK, and yield of barley at different rates. Shannon's index increased by 19.11% and 27.94% by adding P1 and P2, respectively compared to the control. In this study, the soil treated with P addition alone or in combination with V had a strong significant correlation between soil fertility, grain yield of barley plants, and soil fauna. The interaction of P and V gave the best MBC and increased SOM content and soil fertility and thus increased plant growth as compared to adding P alone. These results indicate that the interaction of P with V is one of the best waste recycling management as well as good soil health in increasing soil fauna and soil fertility, and crop productivity in calcareous soils.

Declarations

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Authors' contributions

Conceptualization: EM and RZ. Methodology and Investigation: MS and NK. Formal analysis: ME,MS and NK. Data curation: NK, RZ and MS. Writing-original draft preparation: NK and AG. Writing-review and editing: AG and EM. Supervision: EM. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests

References

1. Hassan ASA. Effect of some characteristics of calcareous soils on available phosphorus in North Africa. M.Sc. Thesis, Institute of African Research, and Studies, Cairo University, Egypt. 2012.
2. Elgabaly MM. Reclamation and management of the calcareous soils of Egypt. In: FAO Soils Bulletin 21, Calcareous soils: report of the FAO/UNDP Regional Seminar on Reclamation and Management of Calcareous Soils, Cairo, Egypt, 27 Nov - 2 Dec 1973. FAO Soils Bulletin No. 21, pp. 123–127.

3. Abd El Halim MS, Siam HS, Taalab AS, El-Ashry SM. Significant use of vinasse as a partial replacement with chemical fertilizers sources for spinach and barley production and their effect on growth and nutrients composition of plant. Plant Arch. 2019: 19: 1593-1600.
4. Silva APS, Bono JAM, Pereira FAR. Fertigation with vinasse in sugarcane crop: Effect on the soil and on productivity. Rev. Bras. Eng. Agr_ıc. Ambient. 2014:18: 38–43.
5. Pasqualin LA, Dion_ısio JA, Zawadneak MAC, Marcal CT. Macrofauna ed_afica em lavouras de cana-de-ac _ucar e mata no nor-oeste do Paran_a-Brasil. Semina Cienc. Agr_ar. 2012:.33: 7–18
6. Van Ryssen JBJ, Van Malsen S, Verbeek AA. Mineral composition of poultry manure in South Africa with reference to the farm feed act. South African J. Animal Sci. 1993:23 (2): 54-57.
7. Blay ET, Danquahe Y, Ofosu-Anim J, Ntumy JK (2002). Effect of poultry manure and/or inorganic fertilizer on the yield of shallot (*Allium cepa var. aggregatum*). Adva. *Hort. Sci. 2002:* 1: 13-16.
8. Dahlgren RA. Biogeochemical processes in soils and ecosystems: from landscape to molecular scale. J. Geochem. Explor. 2006: 88 (1–3): 186–189.
9. Vázquez FJ, Petrikova V, Villar MC, Carballas T. Use of poultry manure and plant cultivation for the reclamation of burnt soils. Biol Fertil Soils. 1996: 22:265–271
10. Villar MC, González-Prieto SJ, Carballas T. Evaluation of three organic wastes for reclaiming burnt soils: improvement in the recovery of vegetation cover and soil fertility in pot experiments. Biol Fertil Soils. 1997: 26:122–129
11. Castro A, González-Prieto SJ, Villar MC, Carballas T. Lowest effective and optimum poultry manure dose for reclaiming burnt soils: pot experiments. Biol Fertil Soils. 2000: 32(6): 494-499
12. Bhadauria T, Kumar P, Maikhuri R, Saxena **KG.** Effect of Application of Vermicompost and Conventional Compost Derived from Different Residues on Pea Crop Production and Soil Faunal Diversity in Agricultural System in Garhwal Himalayas India. Natu. Sci. 2014: 6: 433-446.
13. Ponge JF, Gillet S, Dubs F, Fedoroff E, Haese l, Sousa PJ, Lavelle PCollembola communities as bioindicators of land use intensification. Soil biol. Biochem. 2003:**35**: 813-826.
14. Giller KE, Beare GG, Lavelle P, Izaac AMM, Swift MJ. Agricultural intensification, Soil biodiversity and agro ecosystems function. In Swift, M. J. (ed.), Soil biodiversity agricultural intensification and ecosystem function. Appl. Soil Ecol. 1997: 6: 3-16
15. Abbas MJ, Parwez H. Diversity and relative abundance of Collembola in a wheat (*Triticum aestivum*) field at Aligarh. bioRxiv. 2019: 580811.
16. Behan-Pelletier VM. Oribatid mite biodiversity in gro- ecosystems and environment: role for bioindication. Agri. Ecos. Environ. 1999: 74: 411-423.
17. FAO GIEWS Country Brief on Egypt.
18. Shata SM, Mahmoud SA, Siam HS (2007) Improving Calcareous Soil Productivity by Integrated Effect of Intercropping and Fertilizer. Res. J. Agr. Bio. Sci. 2007: 3(6):733–739.
19. Page AL, Miller RH, Keeny DR. Methods of Soil Analysis (Part 2). In: Chemical and microbiological Properties. Agronomy. 1982: vol. 9. SSSA, Madison.

20. Nelson DW, Sommers LE. Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis, Part 2, 2nd ed., A.L. Page et al., Ed. Agronomy 9:961-1010. Amer. Soc. Agron. 1996, Inc. https://doi.org/10.2136/sssabookser5.3.c34
21. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of Available Phosphorus in Soils by Extracting with Sodium Bicarbonate. USDA Circular 939, Washing Mg DC. 1954.
22. Soil Survey Staff. Kellogg Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42, Version 5.0. Lincoln, NE: U.S. Department of Agriculture, Natural Resources Conservation Service. 2014.
23. Sparks DL.Methods of soil analysis. Part 3 – Chemical methods. SSSA Book Series No. 5. SSSA and ASA, Madison, WI. 1996.
24. Grossman RB, Reinsch TG. Bulk Density and Linear Extensibility. In: Dane, J.H. and Topp, G.C., Eds., Methods of Soil Analysis: Physical Methods, Part 4, Soil Science Society of America, Madison. 2002: 201-228.
25. Wu J, Joergensen RG, Pommerening B. Measurement of soil microbial biomass C by fumigation-extraction an automated procedure. Soil Biol. Biochem. 1990: 22 (8): 1167-1169.
26. Haynes RJ. Size and activity of the soil microbial biomass under grass and arable management. Biol. Fert. Soils. 1999: 30: 210-216.
27. Balogh J, Balogh P. The oribatid mites genera of the world (Hungarian National Museum Press), Budapest I 1992: 263(2): 375 vol. 1, 2).
28. Al-Assiuty AIM, Bayoumi BM, Khalil MA, Van Straalen NM. The influence of vegetational type on seasonal abundance and species composition of soil fauna at different localities in Egypt. Pedobiologia. 1993: 37: 210–222.
29. Hammer O, Harper DA, Ryan PD. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia electronica. 2001: 4(1): 9.
30. Abdellatif MA, El Baroudy AA, Arshad M, Mahmoud EK, Saleh AM, Moghanm FS, Shaltout KH, Eid EM, Shokr MS. A GIS-Based Approach for the Quantitative Assessment of Soil Quality and Sustainable Agriculture. Sustainability. 2021: 13(23): 13438.
31. Islam MS, Hossain M, Yasmin M. Impact of climatic factors and soil quality on the abundance and population density of Collembola in the Rajshahi University Campus, Bangladesh. J. Entom. Zoolo. Studies. 2018: 6(1):1119-1125
32. Rosilda MM, Silvana de Paula QS, Sandra V, Valdirene RS. Study of Acari and Collembola Populations in Four Cultivation systems in Dourados-MS. Brazilian Arc. Biol. Techn. 2002: 45 : 257-264.
33. Muturi JJ, Mbugi JP, Mueke JM, Lagerlóf J, Mungatu JK, Nyamasyo D, Gikungu M. Collembola density and diversity along a gradient of land-use types in Embu district, Eastern Kenya. Trop. Subtro Agroeco. 2009: 11: 361-369
34. Wardle DA, Nicholson KS, Bonner KI, Yeates GW. Effects of agricultural intensification on soil-associated arthropod population dynamics, community structure, diversity and temporal variability

over a seven-year period. Soil Biol. Biochem. 1999: 31: 1691-170. https://doi.org/10.1016/S0038-0717 (99)00089-9

35. Minor MA, Norton RA (2004). Effects of soil amendments on assemblages of soil mites (Acari: Oribatida, Mesostigmata) in short_rotation willow plantings in central New York. Canadian J. Forest Res. 2004:34: 1417–1425.
36. Wissuwa J, Salamon JA, Frank T. Oribatida (Acari) in grassy arable fallows are more affected by soil properties than habitat age and plant species. Eur. J. Soil Bio. 2013: 59: 8–14.
37. Meyer S, Kundel D, Birkhofer K, Fliessbach A, Scheu S. Soil microarthropods respond differently to simulated drought in organic and conventional farming systems. Ecol. Evolu. 2021: 2: 1–12.
38. Pollierer MM, Langel R, Körner C, Maraun M, Scheu S. The underestimated importance of belowground carbon input for forest soil animal food webs. Ecol. Letters. 2007:10: 729–736.
39. Muturi JJ, Mbugi JP, Mueke JM, Lagerlóf J, Mungatu JK, Nyamasyo D, Gikungu M. Collembola density and diversity along a gradient of land-use types in Embu district, Eastern Kenya. Trop. Subtrop. Agroeco. 2009: 11: 361-369
40. Wardle DA. Communities and Ecosystems: Linking the Aboveground and Belowground Components. Princeton University Press, Princeton. 2002.
41. Dijkstra FA, Bader NE, Johnson DW, Cheng W. Does accelerated soil organic matter decomposition in the presence of plants increase plant N availability? Soil Biol. Biochem. 2009: 41: 1080–1087.
42. Lisa C, Bradford MA, Peter JAS, Bardgett RD (2006) The abundance, richness and functional role of soil meso- and macrofauna in temperate grassland—A Case Study. J. Appl. Soil Ecol. 2006: 33, 186-198.
43. Zhen Z, Liu H, Wang N, Guo L, Meng J, Ding, N, Wu G, Jiang G. Effects of Manure Compost Application on Soil Microbial Community Diversity and Soil Microenvironments in a Temperate Cropland in China. PLoS ONE. 2014: 9(10): e108555.
44. Wasli ME, Tanaka S, Kendawang J, Abdu A, Lat J. Soils and vegetation condition of natural forests and secondary fallow forests within Batang Ai national park boundary, Sarawak, Malaysia. Kuroshio Sci. 2011: 5-1: 67-76
45. You, Q., T.M. Su, and Y. Zhong. 2009. Effects of vinasse on sugarcane field. Guangxi Agri. Sci.. 2009: 40(6): 677—680.
46. Gemtos TA, Chouliaras N, Marakis S. Vinasse rate, time of application and compaction on soil properties and durum wheat crop. J Agric Eng Res. 1999: 73:283–296
47. Taha AM. Effect of yeast vinasse on the growth of paspalum turf-grass under compost application in sandy soils. Scientific J. Agri.Sci. 2020: 2 (2): 19-28. sjas.2020.48568.105/10.21608: DOI
48. Komdorfer GH, Anderson DL (1993). Use and impact ofsugar-alcohol residues vinasse And filter on sugarcane production in Brazil, In Proc. of Inter American Seminor 122. Miami, USA, 15-17

49. Mahmoud E, Ibrahim M, Ali N, Ali H. Effect of biochar and compost amendments on soil biochemical properties and dry weight of canola plant grown in soil contaminated with heavy metals. Comm. Soil Sci. Plant Analysis.2020: 51(12): 1561-1571.
50. Pedro A, Savin R, Habash DZ, Slafer GA. Physiological attributes associated with yield and stability in selected lines of a durum wheat population. Euphytica. 2011: 180: 195-208.
51. Winck BR, Chauvat M, Coulibaly SF, Santonja M, Saccol de Sá EL, Forey E. Functional collembolan assemblages induce different plant responses in Lolium perenne. Plant and Soil. 2020: 452(1):347-358.
52. Amujoyegbe BA, Opabode JT, Olayinka A. Effect of organic and inorganic fertilizer on yield and chlorophyll content of maize (*Zea mays L*) and Sorghum (*Sorghum bicolour L Moench*). African J. Biotechnical. 2007: 6 (16):1869 – 1873.
53. Jackson H. Land disposal of broiler litter changes in soil potassium, calcium and magnesium. J.Environ. Quality 1999: 4:202-206.
54. Fagimi AA, Odebode CA. Effect of poultry manure on pepper veinal mottle virus (PVMV), yield and agronomic parameters of pepper (*Capsicum annum*) in Nigeria. East Africa J. Sci. 2007: 1(2), 104-111.
55. Adekiya AO, Agbede TM, Ojeniyi SO. The effect of three years of tillage and poultry manure application on soil and plant nutrient composition, growth and yield of cocoyam. Exp. Agric. 2016: 52 (3) (2016), pp. 466-476

Figures

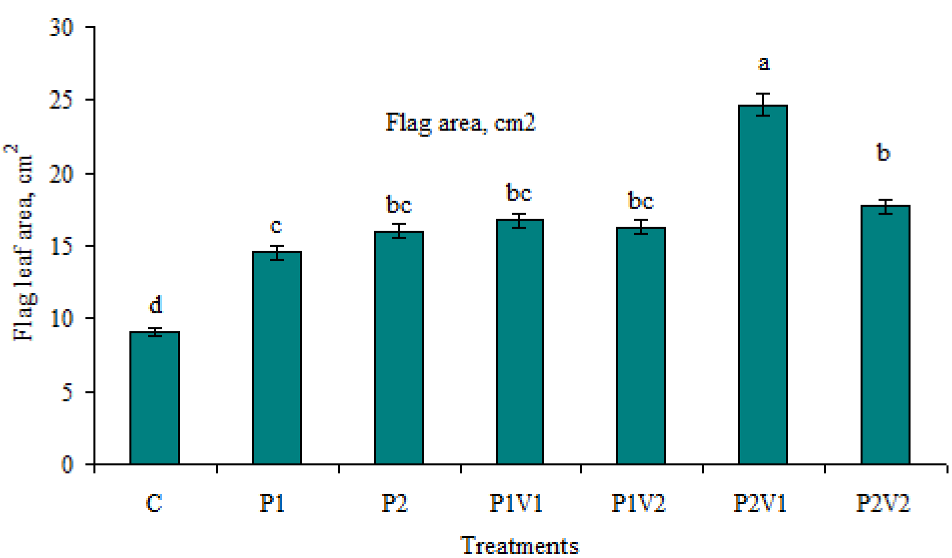

Figure 1

Effect of poultry manure (P), vinasse (V), and their mixtures on flag leaf area of barley plant

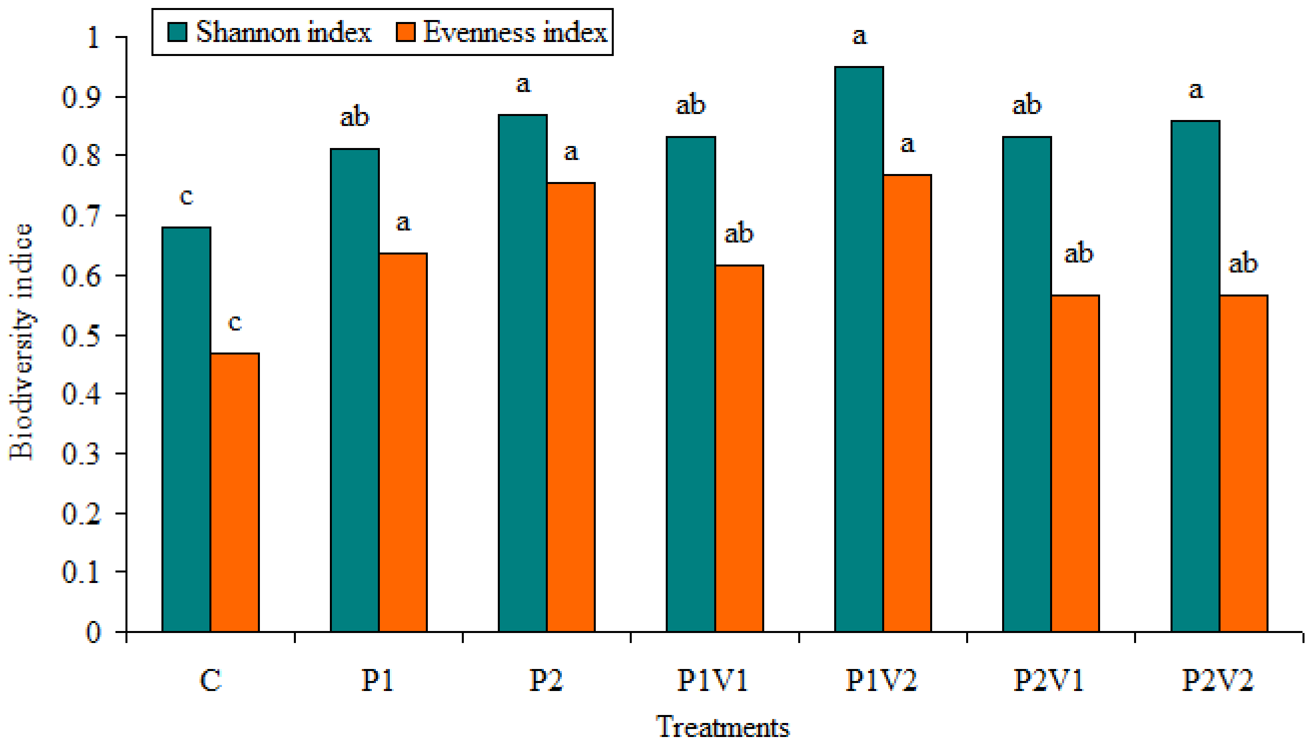

Figure 2

Effect of poultry manure (P), vinasse (V), and their mixtures on biodiversity indices

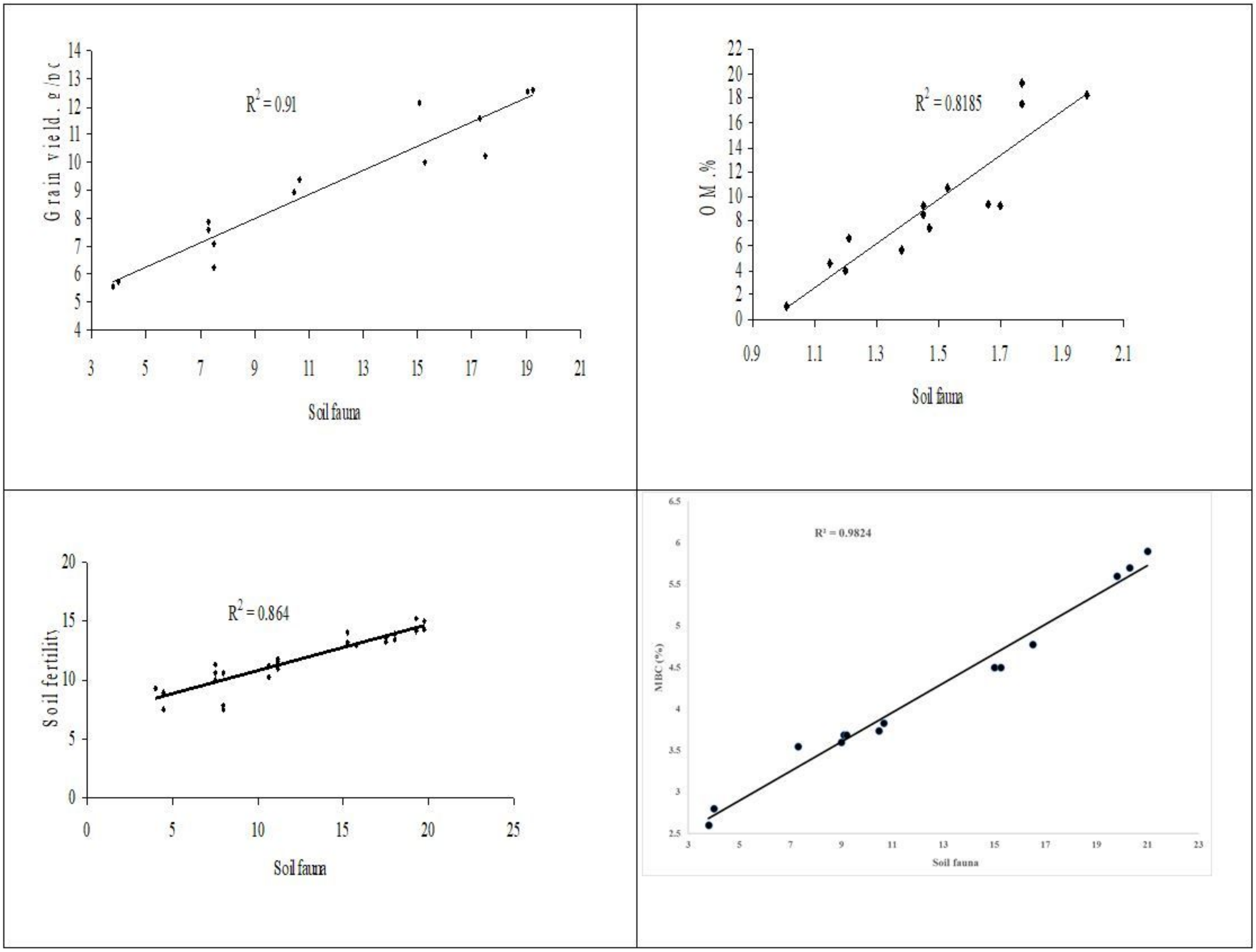

Figure 3

Correlation between soil organic matter, soil fertility index, microbial biomass carbon, grain yield of barley plants and soil fauna after the P addition alone or in combination with G.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Data1.xls