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Short-term effect of calcined phosphate rock on soil macrofauna diversity and abundance in lixisol in a semi-arid area of Burkina Faso

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ABSTRACT: Soil fauna significantly influences soil properties. Organic and inorganic fertilization in agriculture, including the amendment with phosphate rock, may affect its presence in soils. This study evaluated the effect of calcined phosphate rock associated with organic matter on the abundance and diversity of soil macrofauna in semi-arid areas of Burkina Faso. Nine treatments were replicated four times each and applied in a complete randomized block design in sorghum and cowpea fields. These treatments were: absolute control (Control) without fertilizer, control with organic matter only (OM), Burkina Phosphate Rock (BPR) with 23 P $ha^{-1,}$ calcined phosphate rock (CPR with 23 P kg ha^{-1}), Triple super phosphate (TSP), complex fertilizer (NPK), CPR ½ +TSP ½, CPR ¾ +TSP ¼, CPR ¼ +TSP ¾ Urea provided N, and KCl supplied K in the BPR and TSP treatments. P was supplied by Triple Super Phosphate (TSP) in the TSP treatment. K and P were supplied by the complex fertilizer NPK in NPK treatment. Results showed that BPR and CPR did not significantly ($P>0.05$) improve soil fauna abundance and diversity after two years. Four orders, Coleoptera, Haplotaxida, Hymenoptera, and Isoptera, were largely dominant (more than 50 %) in all treatments, crops, and years. The population diversity of soil macrofauna rises from 0.98 (2021) to 1.49 (2022) in the sorghum field and from 1.16 (2021) to 1.63 (2022) in the cowpea field. Soil macrofauna numbers rise from 24.64 ind/m^2 (2021) to 39.59 Ind/m^2 (2022) in the cowpea field. Our findings suggest that cultivated soil fauna can be managed more appropriately with fertilizers from phosphate rock by combining organic matter application and cereal-legume associations.

KEYWORDS: Sorghum, cowpea, calcined phosphate, soil macrofauna, Burkina Faso.

1 INTRODUCTION

Most soils in Burkina Faso are of lixisol type, with more than 40% high in iron and manganese sesquioxides [1]. Soil acidity explains the unavailability of phosphorus in many sub-Saharan African croplands as soluble phosphorus, regardless of the source, reacts very strongly with iron (Fe) and aluminum (Al) to form insoluble Fe and Al phosphates in acid soils [2]. In addition to these limitations in soil properties, the smallholder farming system in sub-Sahara Africa suffers from exporting crop residues for domestic uses, which further decreases soil fertility, causes low investments, and causes weak integration between livestock and crop production. In sub-Saharan Africa in general and Burkina Faso in particular, several constraints limit the use of mineral fertilizers to increase soil productivity and crop production. Among these are soaring fertilizer prices, low availability in the market, low value-cost ratio (VCR), and low profitability [3].

Also, the high use of chemical fertilizers and pesticides is known to harm soil biodiversity [4]. Many studies demonstrated that fertilizer management without chemical pollution increases the biodiversity of beneficial organisms, restores the sustainable use of degraded lands, and ensures a healthy ecosystem and maximal crop productivity ([5]; [6]). The composition, abundance, diversity, and species richness of soil macro-fauna communities are affected by land use, agricultural activities, and fertilizer forms [7]. Management practices (e.g., crop rotation, tillage, organic resource use, and application of agrochemicals such as pesticides, herbicides, and inorganic fertilizers) can cause positive or negative changes in species composition, community structure, and population size [8]. Some of the adverse effects of management practices reported in many studies may be a decline in soil macrofauna populations' the abundance and or biomass and the elimination or reduction of species playing a pivotal role in ecosystem processes [9]. Tropical soils under annual cropping are often depleted in macrofaunal communities regarding biomass and species diversity, possibly owing to declines in soil organic matter quantity and quality [9]. To reduce the negative effect of chemical fertilizers and build a sustainable production system, using organic materials and biodegradable resources combined with chemical fertilizers, including using phosphate rocks has been suggested. However, Burkina phosphate rocks have low agronomic effectiveness, low phosphorus solubility and availability, and high silicate content [10].

Recently, some technologies, including phosphate rock acidulation, phospho-composting, association with chemical fertilizers, and calcination ([11], [12]), have suggested improving the effectiveness of Burkina phosphate rock by increasing the level of the soluble P fraction and reducing the content in silica. These fertilizer types have proven their effectiveness in increasing soil P content and improving crop yields ([11], [13]). However, only some studies have focused on their effect on the structure and composition of soil organisms, especially the soil macrofauna. It is well known that the direct application of raw Burkina phosphate rock (BPR) combined with organic matter improves soil earthworm activity, mainly due to the promotion of nutrient cycling and soil nutrients. Duponnois et al. [14] reported that the root biomass of *Acacia seyal* was significantly enhanced with *Macroterme*s + rock phosphate application. The increase was linked to the contribution of phosphate rock, which may give the plants and soil organisms more nutrients. These authors showed that soil amendment with phosphate rock and termite mounds promotes the development of some microbial communities. Maintaining a significant and diverse biological activity in ecosystems, especially in agricultural soils, is essential for sustainable crop production. Since phosphate rock positively associates with soil macrofauna, it would be interesting to study the changes in soil fauna diversity using the new fertilize types produced using Burkina phosphate rock. We conducted this study to evaluate the effect of calcined phosphate rock associated with organic matter on soil macrofauna abundance, diversity, and crop production in semi-arid soil cultivation. We hypothesize that soil fauna diversity and abundance will change in the short-term following the application of calcined phosphate rock and organic matter. We also prospect that calcined phosphate rock does not harm soil macrofauna activity in lixisols.

2 MATERIALS AND METHODS

2.1 STUDY AREA

The field experiment was conducted at the Environmental and Agricultural Research and Training Center (CREAF) in Kamboinsé (latitude 12° 28N, longitude 1° 32W with an elevation of approximately 296 m from sea level) in the central region of Burkina Faso. According to Ibrahim [15], the climate of Kamboinsé is a North Sudanese type and is set between 600 mm and 900 mm isohyets. The area is characterized by a dry season of seven (7) months from November to May and a rainy season of five (5) months (June to October). The annual rainfall was 749.9 mm in 2021 and 1114.7 mm in 2022. During the cultivation periods in 2021 and 2022 (June to September), climatic data were collected and shown in Fig. 1. The soil in the study site is classified as leached tropical lixisol underlain on deep sandy materials and inherited low humus pseudogley hydromorphic soils associated with lithosol on ferruginous cuirass [16]. The soil has low contents of organic matter (< 1%), nitrogen (≈ 0.7 g kg^{-1}), and available phosphorus (≈ 15 mg kg^{-1}), with low water retention capacity [17].

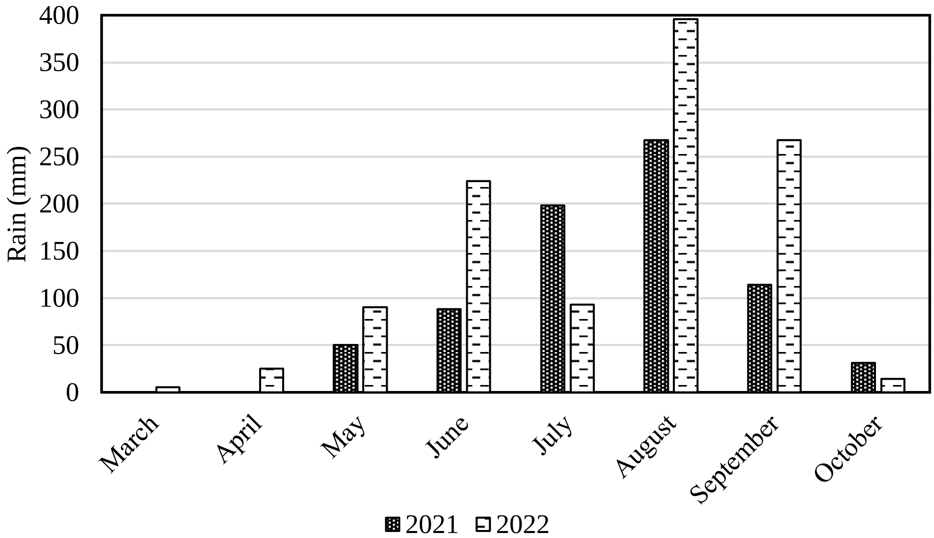

Fig. 1. Rainfall at the study site in 2021 and 2022 cropping seasons

2.2 EXPERIMENTAL DESIGN AND CROPS CULTIVATION

The experimental design was a randomized fisher block with four replications. The plot dimensions were 5 m x 4 m-. Seven (07) treatments were compared to absolute control (Control) and control with organic matter (OM) only. The seven treatments consisted of Burkina Phosphate Rock (BPR) with 23 P kg $ha^{-1,}$ calcined phosphate rock (CPR with 23 P kg ha^{-1}), Triple Super Phosphate (TSP), complex fertilizer (NPK), CPR ½ +TSP ½, CPR ¾ +TSP ¼, CPR ¼ +TSP ¾. Urea provided N, K was supplied by KCl for BPR and TSP treatments, and P was supplied by Triple Super Phosphate (TSP) in the TSP treatment and by NPK. K and P were supplied by the complex fertilizer NPK in the NPK treatment. Similar amounts of N (60 kg ha^{-1}), P (23 kg ha^{-1}), and K (14 kg ha^{-1}) were applied in all treatments, excluding the two controls. Composted cow manure provided organic matter (2.5 t ha^{-1}) in all treatments except the absolute control. Improved seed varieties of sorghum (Kapelga) and cowpea (Komcallé) were sown, and the plant spacing for both crops was 80 cm × 40 cm in all plots. During the second cultivation season, the same plots and treatments were maintained in the same place. After crop harvest, stalks were removed from the plots to retain the integrity of the applied treatments in preparation for the subsequent seasons. Soil and fertilizers used properties are shown in Table 1. The soil used for this experimentation has a low content of organic matter (<1%) and CEC (<10 meq 100 g^{-1}), according to [18].

Table 1. Chemical characterization of organic matter, phosphate rock, calcined phosphate, and the upper soil layers (0-10 and 10-20 cm)

Parameters	P_2O_5	K_2O	C	N	C/N	pH (H_2O)
	%					
Soil (0-10 cm)	0.05	0.12	0.57	0.02	28.50	7.23
Soil (0-20 cm)	0.02	0.11	0.49	0.02	24.50	7.16
Calcined phosphate	23.20	7.56	-	-	-	14.00
Phosphate rock	28.30	0.22	0.39	-	-	7.40
Compost	0.810	0.87	23.59	0.87	27.11	7.54

2.3 SAMPLING

Soil fauna inventory was carried out using the Tropical Soil Biology and Fertility (TSBF) method recommended by [19] at 60 days after sowing for sorghum and 30 days after sowing for cowpea during raining season in each plot. We collected one soil monolith from 7: 00 to 11: 00 am in each micro plot using a metal frame of 25 cm x 25 cm x 30 cm to assess the soil macrofauna. The metal frame was inserted to a depth of 0-20 cm, and all macroinvertebrates visible to the naked eye at this depth were removed, fixed in 70° alcohol, and brought to the laboratory for identification. Depending on the treatment, a binocular microscope with an identification key was used to identify the macrofaunal order, family, genus, and species. This identification allows for determining soil fauna parameters such as abundance and diversity.

The abundance of macrofauna was expressed by the average number of individuals collected per plot and density. Two indices were used to assess macrofauna diversity. The first index is the Shannon-Weaver index (H'), which considers the number of taxa encountered. H' value is given by the following equation [20]:

$$H' = -\sum_{i=1}^{s} \mathrm{Pi} \times \log 2\ (\mathrm{Pi})$$

where P is the probability of encountering a taxon *i* on a plot which is calculated as follows: $Pi = \frac{ni}{N}$, and *ni* is the number of individuals for species *i* and *N* is the total number of species.

H' is zero when only one of the groups is present. Its value is maximal when all have the same abundance [21]. The second index, Equitability (E) or regularity, measures the fair distribution of taxa and allows comparing stands with different numbers of taxa to observe the balance of the macrofauna population. Its value is given by the following formula [22]:

$$\mathrm{E} = \frac{\mathrm{H}'}{\log 2\ (\mathrm{s})}$$

Where (s) is the total number of taxa encountered on the plot. The Equitability (E) tends to 0 when a taxon dominates and is equal to 1 when all taxa have the same abundance [21].

2.4 DATA ANALYSIS

Soil fauna data was entered into Excel spreadsheets and subjected to analysis of variance (ANOVA) using GENSTAT statistical software (GENSTAT 11.1 2009). When the p-value was significant (p< 0,05), mean differences were compared using the Newman-Keuls comparison test. Graphs were made using GraphPad software or excel.

3 RESULTS

3.1 ABUNDANCE AND COMPOSITION OF SOIL MACROFAUNA ORDER PER TREATMENT AND CROPS

In the sorghum field, the average density was higher under phosphate rock application (63.1 ± 41.8 number/m^2) in the first year and under calcined phosphate rock in the second year (40 ± 9.07 number/m^2). The average macrofauna density in the cowpea field was abundant under the organic matter treatment (43.43 ± 14.17 number/m^2) in the first year and under calcined phosphate rock in the second year (62.86 ± 15.5 number/m^2). However, no significant difference was observed among all treatments. Generally, for some treatments, the soil macrofauna density increased in 2022 compared to 2021 for both crop fields. Significant differences were found among abundance means of 2021 and 2022 in the cowpea field ($P < 0.05$), contrasting with the sorghum field. Furthermore, the average macrofauna abundance in the cowpea plots increased from 24.64 number/m^2 in 2021 to 38.59 number/m^2 in 2022 compared to sorghum plots (Table 2).

Tables 3, 4, 5, and 6 show that the four macrofauna orders, Coleoptera, Haplotaxida, Hymenoptera, and Isoptera, dominated the two crops during the two-year survey in all treatments. The number of families and species of Coleoptera and Haplotaxida increased during the second year. The observed families of the Coleoptera order comprised the Carabidae, Scarabaedae, and Tenebrionidae in the first year and Anthicidae, Carabidae, Chrysomelidae, Pselaphidae, Scarabaeidae, Staphylinidae, Tenebrionidae, and Trogositidae in the second year in the cowpea field. In the sorghum field, the Coleoptera order was composed of the Carabidae, Coccinellidae, Elateridae, Scarabaeidae, and Tenebrionidae order in the first year, and Carabidae, Geotrupidae, Lucanidae, Scarabaeidae, Staphylinidae, and Trogidae in the second year. The macrofauna families of the Haplotaxida order found in the cowpea field were Lumbricidae, Octochaetidae for the first year, and Acanthodrilidae Lombricidae, Lumbricidae, Octochaetidae in the second year. The Hymenoptera order contained the Formicidae family only for crops and year. However, the sorghum field which also contained the Sphididae family in the first year. Termitidae was the only family of the Isoptera order present in both crops during the two years. These dominant four orders (Coleoptera, Haplotaxida, Hymenoptera, and Isoptera) represented more than 50 % of soil macrofauna n the study area. Soil macrofauna for 2021 in the sorghum field was dominated by the Isoptera, especially in the treatments it was found. However, in the same treatment (BPR, CPR, CPR ¾ +TSP ¼), Isoptera decreased or was absent in 2022. The cowpea soil in 2021 and 2022 was inhabited by a higher number of dominant orders in the NPK treatment, with 408 individuals/m^2 and 928 individuals/m^{2,} respectively. In the first year, the calcined phosphate rock treatment showed the highest macrofauna number (576 individuals/m^2) in the sorghum field. In the second year, the highest number was found in the NPK treatment (528 number/m^2). Nine (09) orders and fourteen (14) families were found in the cowpea field in 2021 (Table 3), and ten (10) orders and twenty-six (26) families were found in the same field in the second year (Table 4). Eleven (11) orders and twenty-one (21) families were found in the sorghum field in the first year (Table 5). Compared to the cowpea field, this number decreases during the second year. Indeed, eleven orders (11) and nineteen families were found in the sorghum field for the second year (Table 6).

Table 2. Abundance of macrofauna (number/m^2) according to treatments, crops and years

Treatments		Sorghum 2021	Sorghum 2022	Cowpea 2021	Cowpea 2022
Control		23 ± 8.86	30 ± 3.8	17.00 ± 3.53	27.64 ± 5.74
OM		18.18 ± 4.46	29.54 ± 5.9	43.43 ± 14.17	42.67 ± 12.5
BPR		63.1 ± 41.8	28.31 ± 6.81	23.43 ± 4.31	24 ± 4.13
CPR		38.4 ± 16.9	40 ± 9.07	23.00 ± 6.49	62.86 ± 15.5
CPR ¾ +TSP ¼		48 ± 22.3	34.91 ± 8.02	17.78 ± 6.9	28.80 ± 3.2
CPR ½ +TSP ½		37.7 ± 19.4	32 ± 5.56	21.14 ± 6.25	28 ± 5.9
CPR¼ +TSP ¾		17 ± 1.8	25.41 ± 5.8	19.43 ± 6.14	61.54 ± 18.55
TSP		32 ± 8.52	34.46 ± 10	18.13 ± 3.78	34.46 ± 9.03
NPK		21.33 ± 8.81	29.33 ± 5.52	40.80 ± 10.08	44.19 ± 10.05
Treatments	**Probability**	0.66	0.95	0.16	0.24
Year	**Mean**	29.27	30.83	24.64	38.59
	Probability	**0.53**		**0.002**	

OM: Organic Matter, CPR: calcinated phosphate rock, BPR: Burkina Phosphate rock, TSP and NPK are soluble fertilizers, Number/m^2: Individuals number per meter square

Table 3. Soil Macrofauna abundance (number/ m²) identified in cowpea field (2021)

Orders	Family	Control	OM	BPR	CPR	CPR ¾ +TSP ¼	CPR ½ +TSP ½	CPR¼ +TSP ¾	TSP	NPK	% Total
Araneae	Agelinidae						8	16			1
	Hahaniidae	16									1
	Nemisiidae									16	1
Coleoptera	Carabidae	80	72	56	104	8	32	48	72	8	21
	Scarabaedae	8		80		40	8	16	24	32	9
	Tenebrionidae			32		16	8		8		3
Diplopoda	Iulidae						8				0
Haplotaxida	Lumbricidae			16			8		40	48	5
	Octochaetidae	8	120	48	40		16	136	64	64	21
Hymenoptera	Formicidae	8		32	16	96	176	24	16	88	20
Isoptera	Termitidae		112		16			8	16	88	10
Orthoptera	Tetrigidae			8							0
Polidesmida	Paradoxosomatidae						8	16	24		
Webspinners	Embiidinae	16		40			24		8	64	7
Total		136	304	312	176	160	296	264	272	408	100
Total (%)		6	13	13	8	7	13	11	12	18	

OM: Organic Matter, CPR: calcinated phosphate rock, BPR: Burkina Phosphate rock, TSP and NPK are soluble fertilizers, se: standard error of mean.

Table 4. Soil Macrofauna abundance (number/m²) identified in cowpea field (2022)

Orders	Family	Control	OM	BPR	CPR	CPR ¾ +TSP ¼	CPR ½ +TSP ½	CPR¼ +TSP ¾	TSP	NPK	% Total
Acariens	Tetranychidae				32				16		1
Arachnida	Anyphaenidae			48			16			32	2
	Dysderidae						32				1
	Lycosidae					16				16	1
Coleoptera	Anthicidae		16				16				1
	Carabidae		64	64	112	64	48	32	16	16	8
	Chrysomelidae			16	16					64	2
	Pselaphidae						16		16	16	1
	Scarabaeidae	16	16		16	16	32		16	16	2
	Staphylinidae	16	80	16		16	16		32	16	4
	Tenebrionidae			16							0
	Trogositidae	80									1
Diplopoda	Iulidae							16	16		1
Haplotaxida	Acanthodrilidae			16		48			32		2
	Lombricidae					48					1
	Lumbricidae								112	112	4
	Octochaetidae	48	288	160	352	128	224	416	128	208	36
Hemiptera	Alydidae							16			0
	Aphididae	16									0
	Redriviidae				16						0
Hymenoptera	Formicidae	64	16	48	336	176	64	224	16	368	24
Isoptera	Termitidae	32	32			64	80	80	48	48	7
Lepidoptera	Lymantridae							16			0
	Noctuidae	32									1
	Papilionidae						16				0
Orthoptera	Gryllotalpidae									16	0
Total species		304	512	384	880	576	560	800	448	928	100
Total (%)		6	9	7	16	11	10	15	8	17	

OM: Organic Matter, CPR: calcinated phosphate rock, BPR: Burkina Phosphate rock, TSP and NPK are soluble fertilizers, se: standard error of mean.

Table 5. Soil Macrofauna abundance (number/m²) identified in sorghum field (2021)

Orders	Family	Control	OM	BPR	CPR	CPR ¾ +TSP ¼	CPR ½ +TSP ½	CPR¼ +TSP ¾	TSP	NPK	% Total
Araneae	Araneidae		8								0
	Segestriidae									8	0
Coleoptera	Carabidae	32			32			16		96	7
	Coccinellidae	8									0
	Elateridae			16							1
	Scarabaeidae	48	40	32	32					32	7
	Tenebrionidae			8					8		1
Dermaptera	Labiduridae				16						1
Diplopoda	Blaniulidae								16		1
	Iulidae				8						0
Haplotaxida	Acanthodrilidae	80	48	16			16			16	7
	Enchytraeidae		32								1
	Lumbricidae		16	96	8	40		8			6
	Octochaetidae	40	56		120	128	24	80	72	24	21
Hymenoptera	Formicidae	16			16	48	160	16	32		11
	Sphididae					16					1
Isoptera	Termitidae	112		80	320	248	64		64		34
Polidesmida	Polydesmidae				24						1
Salofuge	Salofugae							16			1
Trombidiformes	Trombidiidae	16									1
Webspinners	Embiidinae			8							0
Total species		352	200	256	576	480	264	136	192	176	100
Total (%)		13	8	10	22	18	10	5	7	7	

OM: Organic Matter, CPR: calcinated phosphate rock, BPR: Burkina Phosphate rock, TSP and NPK are soluble fertilizers, se: standard error of mean.

Table 6. Soil Macrofauna abundance (number/m²) identified in sorghum field (2022)

Orders	Family	Control	OM	BPR	CPR	CPR ¾ +TSP ¼	CPR ½ +TSP ½	CPR¼ +TSP ¾	TSP	NPK	% Total
Acariens	Tetranychidae			16			16				1
Arachnida	Anyphaenidae	16								32	1
Chilopoda	Geophilidae	16							16		1
Coleoptera	Carabidae	16	16				16	32	64	16	4
	Geotrupidae		16			16		16			1
	Lucanidae									16	0
	Scarabaeidae	16				32	32	48	16		4
	Staphylinidae		16	32		16		16			2
	Trogidae							16			0
Dermaptera	Forficulidae			16							0
Diplopoda	Iulidae		16	16	48			16			3
Diptera	Muscidae						16				0
	Simulidae		16								0
Haplotaxida	Acanthodrilidae	48						16	16		2
	Lumbricidae	48	48	112	80	32	144	80	16	112	18
	Octochaetidae	192	192	112	160	272	160	144	288	192	45
Hemiptera	Aphididae	16									0
Hymenoptera	Formicidae	32	64	64		16			32	16	6
Isoptera	Termitidae	80			32		64	48		144	10
Total		480	384	368	320	384	448	432	448	528	100
Total (%)		13	10	10	8	10	12	11	12	14	

OM: Organic Matter, CPR: calcinated phosphate rock, BPR: Burkina Phosphate rock, TSP and NPK are soluble fertilizers, se: standard error of mean.

3.2 Changes In Soil Macrofauna Diversity And Equitability Per Treatment, Crops And Year

Table 7 shows soil macrofauna diversity and equitability per treatment, crop, and year. We found that during the first year of experimentation, macrofauna diversity was highest under the Control treatment (1.81) in the sorghum field and with CPR ½ +TSP ½ (1.78) in the cowpea field. The highest equitability value was found under the same Control treatment for sorghum. As for cowpea, all the CPR-TSP combinations gave the highest equitability index (0.89). During the second year, the highest diversity means in the sorghum field was found under the NPK treatment (1.94) and CPR ½ +TSP ½ treatment (2.53) in the cowpea field. The highest equitability in the sorghum field was found under CPR¼+TSP ¾ (0.93) and TSP treatment (1.73) in the cowpea field. There was no difference ($P>0.05$) among equitability and diversity soil macrofauna following fertilizer treatments for both crops in the two years of experimentation. However, there was an increasing trend in the mean macrofauna diversity and equitability for both crops from 2021 to 2022. A significant difference ($P<0.05$) was also found among soil macrofauna equitability mean following the two years in both crop fields. A high mean was observed for several variables and crops in the second year. Fig. 2 also shows that the highest mean of diversity and equitability of soil macrofauna was found in the cowpea field.

Table 7. Diversity index and equitability of macrofauna according to treatments

Years	Treatments	Diversity (H')		Equitability (E)	
	Crops	Sorghum	Cowpea	Sorghum	Cowpea
2021	Control	1.81	0.84	0.91	0.69
	OM	1.12	0.62	0.66	0.49
	BPR	0.38	1.36	0.22	0.69
	CPR	1.44	0.86	0.75	0.72
	CPR ¾ +TSP ¼	0.98	1.31	0.66	0.89
	CPR ½ +TSP ½	0.92	1.78	0.58	0.89
	CPR¼+TSP ¾	0.85	1.60	0.70	0.89
	TSP	0.46	1.43	0.46	0.69
	NPK	0.94	0.86	0.68	0.65
	Probability	**0.13**	**0.42**	**0.52**	**0.89**
2022	Control	1.84	1.09	0.91	0.74
	OM	1.34	0.58	0.84	0.30
	BPR	1.88	1.49	0.89	0.74
	CPR	0.69	1.11	0.44	0.51
	CPR ¾ +TSP ¼	1.09	2.04	0.65	0.88
	CPR ½ +TSP ½	1.52	2.53	0.90	1.38
	CPR¼+TSP ¾	1.87	1.32	0.93	0.65
	TSP	1.36	2.28	0.81	1.73
	NPK	1.94	2.22	0.91	0.93
	Probability	**0.56**	**0.08**	**0.12**	**0.15**
Years	2021	0.98	1.16	0.62	0.72
	2022	1.49	1.63	0.81	0.87
	Probability	**0.003**	**0.29**	0.03	**0.03**
	Significativity	**S**	**NS**	S	**S**

OM: Organic Matter, CPR: calcinated phosphate rock, BPR: Burkina Phosphate rock, TSP and NPK are soluble fertilizers,

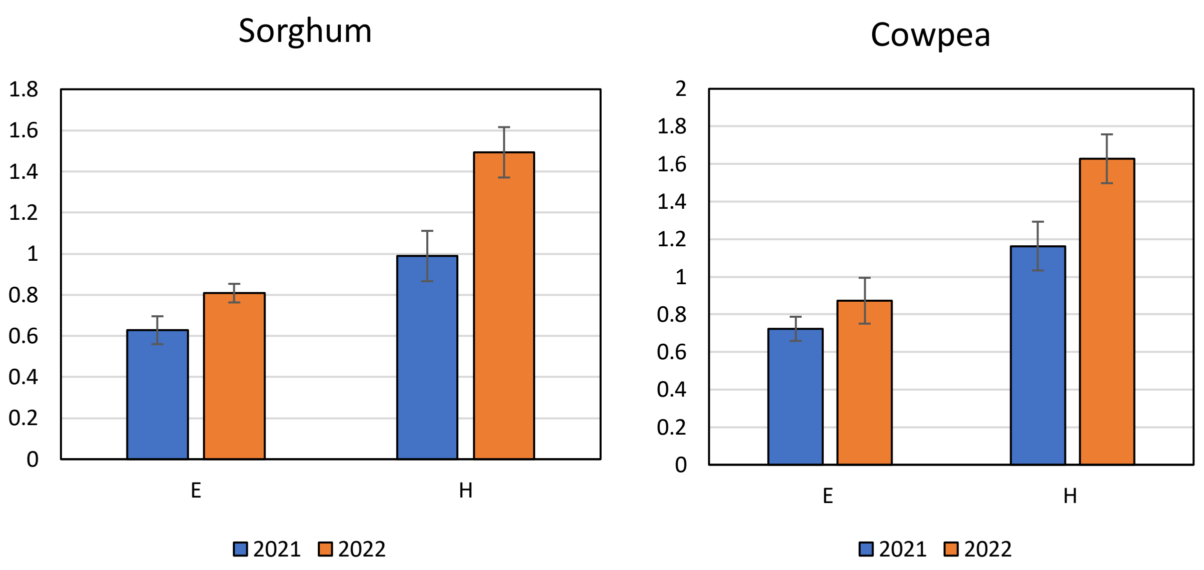

Fig. 2. Equitability (E) and diversity (H) according to crop fields

Error bars are standar error of means

3.3 Soil Organic Carbon Content As Affected By Crops, Treatments And Cropping Years

Soil total carbon content differed across treatments in the two years of experimentation. In the first year, a higher mean of total carbon was found in the cowpea field. In the second year, the total carbon was higher in the sorghum field than in the cowpea field. Nevertheless, in both fields, total carbon decreased in the cowpea field, but there was a rise in the sorghum field. A significant difference was also found (*P<0.05*) among the two fields in their total carbon content after crop harvest.

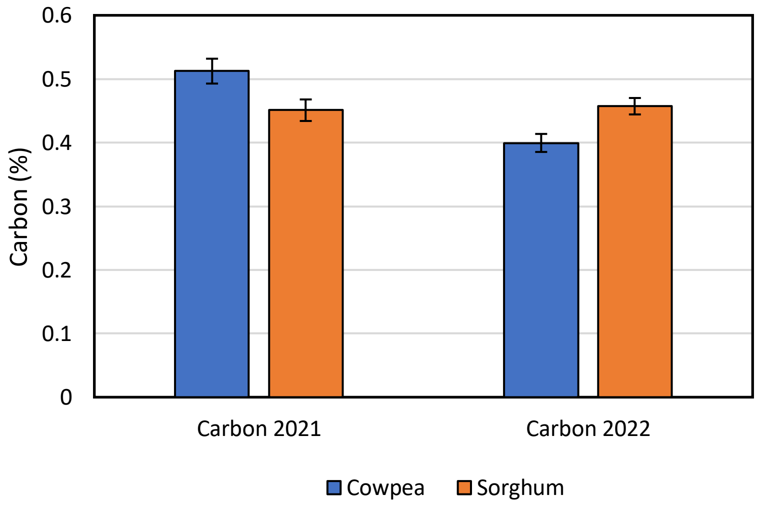

Fig. 3. Changes in soil carbon following years and crops

Error bars are standar error of means

Except for the sorghum field (Fig. 5) in the first year, the higher mean of soil carbon was observed under the organic matter (OM) and calcined phosphate rock (CPR) treatments. For both fields and crops (Fig.4 and Fig. 5), there was a significant (*P<0.05*) difference among the total carbon mean of plots after crop harvest. Also, we found a decreasing trend in the total soil carbon mean when chemical fertilizers were mixed with calcined phosphate rock in both plots.

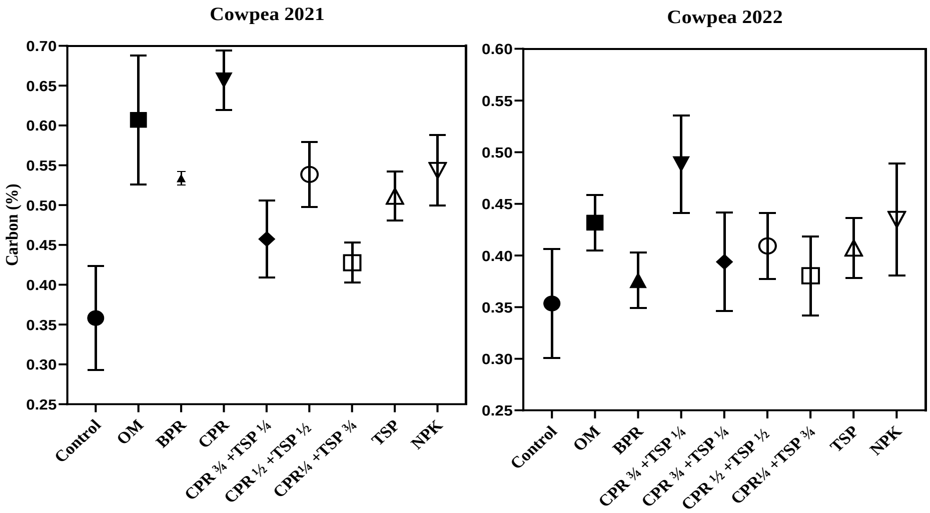

Fig. 4. Changes in total carbon among following treatments in cowpea field

Error bars are standard error of means. OM: Organic Matter, CPR: calcinated phosphate rock, BPR: Burkina Phosphate rock, TSP and NPK are soluble fertilizers.

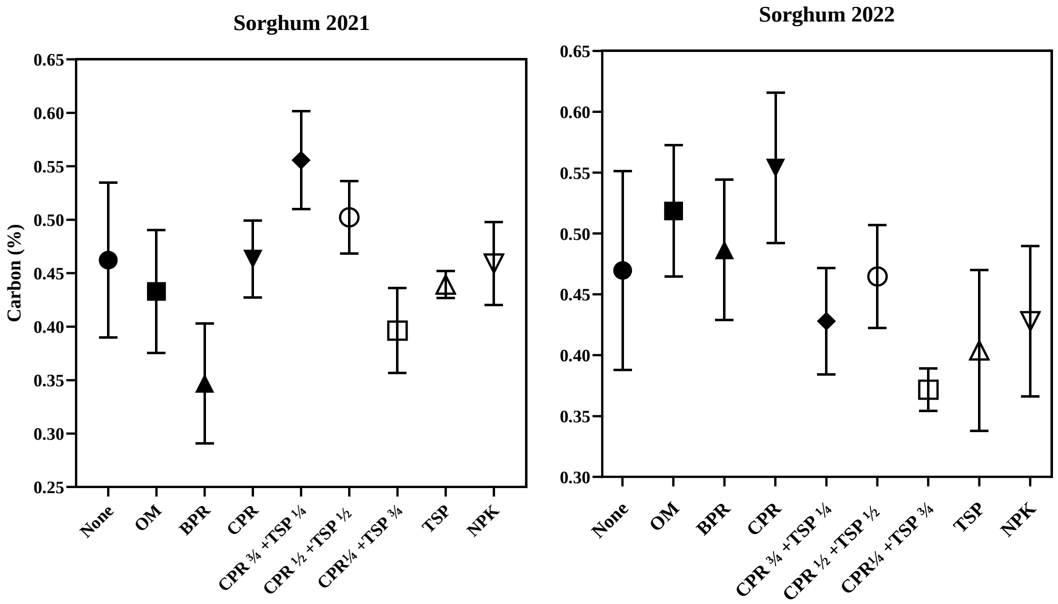

Fig. 5. Changes in total carbon among following treatments in sorghum field

OM: Organic Matter, CPR: calcinated phosphate rock, BPR: Burkina Phosphate rock, TSP and NPK are soluble fertilizers

4 DISCUSSION

4.1 CHANGES IN SOIL MACROFAUNA DENSITY FOLLOWING PHOSPHATE ROCK-BASED FERTILIZER APPLICATION ON SORGHUM AND COWPEA CULTIVATED LAND

Fertilization can increase the populations of certain organisms due to a good food supply [23]. This study evaluated the effect of calcined phosphate rock associated with organic matter on soil macrofauna abundance and diversity in cultivated semi-arid soils in Burkina Faso.

Results showed that ten to eleven (10-11) orders were found in the field area. The four orders, Coleoptera, Haplotaxida, Hymenoptera, and Isoptera, were dominant in all treatments, crops, and years. These orders are the most frequent in arid and semi-arid soils. Many studies carried out in the arid areas of Burkina Faso and other countries showed that these orders are dominant in soil ([8], [21], [24], [25]). Reference [26] reported that these species colonize degraded lands, allowing their rehabilitation.

Soil macrofauna population density and abundance were generally higher under the following treatment: Organic Matter (OM), Burkina phosphate rock (BPR), and calcined phosphate rock (CPR). We hypothesize that the soil macrofauna populations were more likely to inhabit these plots as these inputs provided preferred food sources. [27] mentioned that phosphorus and nitrogen are the preferred food for soil macrofauna, while carbon is the primary energy source. The high macrofauna density in the treatment with organic matter application only was probably due to the absence of chemical fertilizer. Organic soils are the best habitat for macrofauna and other soil organisms [28]. Burkina phosphate rock (BPR) and calcined phosphate rock (CPR) are sustainable sources of phosphorus in the soil due to their gradual dissolution potential compared to chemical fertilizers (TSP, NPK). The progressive phosphate solubilization would explain that the plots with the highest levels of phosphate rock and calcined phosphate rock showed the highest population of macrofauna in the soil. Teles et al. [29] show that using phosphate rocks as a P source can be a better-suited alternative for overcoming the high solubility of chemical fertilizer in the soil. According to these authors, chemical fertilizers like TSP are the most effective in percolating P in the soil profile. Soil macrofauna communities were more likely to inhabit plots amended with organic input, including phosphate rock, as these inputs provided preferred food sources than those amended with chemical fertilizer. This result agreed with [30], who reported that phosphate rock mixed with other organic resources attracts termites.

On the other hand, there is an apparent rise in the population and diversity of soil macrofauna under all applied treatments after two years of cultivation in both fields. The higher rainfall and or the possible storage of soil carbon after the harvest in the first year could explain this increasing tendency during the second year. These results are similar to those of [8], who found that taxonomic abundance and distribution of termites and earthworm species were influenced by climate and soil type, as reflected in their association with rainfall and temperature, texture, and total soil carbon. According to [8], long-term application of manure in combination with fertilizer resulted in higher earthworm diversity and biomass, associated with improved soil aggregation and enhanced carbon and nitrogen stabilization. The phosphate rock and calcined phosphate rock application in this study seems to not be harmful to the soil macrofauna. Reference [31] reported that organic and inorganic fertilizers might have beneficial, neutral, or harmful effects on soil biota. However, combining chemical fertilizers with organic resources has been regarded as a good alternative to using calcined phosphate rock and is a strategy to alleviate the burden of costly fertilizers. However, these results contradict [24], who showed that land cultivation tends to decrease the abundance and diversity of soil macrofauna.

4.2 Changes In Soil Macrofauna Diversity And Equitability Under Phosphate Rock-Based Fertilizer

Results also showed that the highest means of diversity and equitability of soil macrofauna was found in the cowpea field in two years. The soil coverage through cowpea foliage could explain this result. Indeed, cowpea roots are known to release atmospheric nitrogen in the soil [32]. Such a release of nitrogen in soil improves nutrient richness, which benefits soil macrofauna activity. The abundance, diversity, composition, and activity of the soil macrofauna communities can be affected by plant species, plant diversity, and composition, as well as by animal grazing [33]. Similarly, carbon stocks appear higher in cowpea plots than in sorghum plots after the first year. This increase in soil carbon level benefits the soil organisms.

5 Conclusion

This study showed that field application of phosphate rock or calcined phosphate rock did not have a significant positive or negative impact on the abundance and diversity of soil macrofauna. Instead, the macrofauna population comprised many species, families, and orders in each land use type and each site.

Nevertheless, using this phosphate rock-based fertilizer led to an increasing trend of macrofauna abundance in the second year of cultivation for sorghum and cowpea. We also found that good rainfall is necessary to provide and maintain soil macrofauna population density in cultivated land.

Our finding confirmed that in lands cultivated with cereal or leguminous crops, Coleoptera, Haplotaxida, Hymenoptera, and Isoptera dominate macrofauna orders. We also notice that the leguminous association with cereal can lead to maintaining soil biodiversity in fertilizer used systems. Other studies are needed to investigate the relationship between the use in cropping systems of phosphate rock-based fertilizer and soil chemical and microbiological properties in the arid and semi-arid zone of Burkina Faso.

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