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Vigna unguiculata: a productive option in the face of climate change?

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Faced with the challenges of extreme climatic events and increasing food demand, cowpea farming offers a viable option for generating grains and foliage while aiding soil preservation. This research aimed to evaluate the impact of diverse organic fertilizers and plastic mulches on cowpea yields and soil macrofauna. A completely randomized block design was employed, with a factorial arrangement of $3 \times 3 + 1$, encompassing plastic mulch (3.5 mm) color (white, black, and blue), organic fertilizer (compost of chicken manure-agricultural soil-dolomite, island guano, and cattle manure compost), as well as a control (without synthetic mulch and organic fertilization). The study evaluated soil temperature, plant height, area biomass, foliar macronutrients, yield, and soil macrofauna. The findings demonstrate that soil temperature varies based on the color of the plastic mulch. It was observed that using organic fertilizers resulted in significantly taller plants than the control group, with fresh and dry biomass weight also being significantly greater ($p<0.05$) for cattle manure compost compared to the other treatments. Furthermore, the use of plastic mulches had an impact on soil macrofauna. Cowpea displayed resistance to low soil fertility and fluctuations in soil temperature ranging from <35°C to >40°C. However, high precipitation during the fruiting and harvesting seasons significantly impacted grain yields. Organic fertilizers produced noticeable variances ($p<0.05$) in the aerial biomass weight of cowpeas, particularly cattle manure compost. The data, indicates that soil macrofauna, like the earthworm *Pontoscolex corethrurus*, improved the availability of N, P, and K to the plant during the reproductive stage. Plastic mulches and organic fertilizers were linked to an increase in earthworm weights, specifically *P. corethrurus*. Additionally, plastic mulches served as a physical barrier against ants and bugs.

1 Introduction

Cowpea (*Vigna unguiculata*) is a legume predominantly grown in warm climates within the tropics of Africa, South Asia, and Latin America (Boukar et al., 2018). Peru, in particular, produces 17,588 tonnes of cowpea mulch an area of 12,779 hectares with an average yield of 1,376 kg/ha (FAOSTAT, 2017). An annual production increase of 131.9% has been observed (INEI—Instituto Nacional de Estadística e Informática, 2020). Cowpea is predominantly cultivated in the Peruvian Amazon for grain, foliage production, and soil reclamation on sloped terrain. Its cultivation improves erosion control while enhancing physical, chemical, and biological soil characteristics.

The cowpea is a important source of calories and protein for many people worldwide, as nearly every part of the plant is consumed (Herniter et al., 2020). Due to their nutritional and nutraceutical benefits, its green and dry grains, green pods, and foliage are used in the human diet, it is also included in the diet of domestic animals, especially ruminants and poultry (Avanza et al., 2013; Herniter et al., 2020; Abebe and Alemayehu, 2022). Cowpea grains contain between 20 to 25%, and the foliage can reach up to 18.6% protein per dry weight (Boukar et al., 2018).

Although it is well known that cowpea does not require particularly fertile soil, their production is constrained by soils with low phosphorus (P) levels. (Boukar et al., 2018). Organic fertilizers enhance soil fertility and biology in cowpea production, which contains mineralized and non-mineralized organic matter. The mineralized portion of organic matter plays a crucial role in the physical, chemical, and biological fertility of the soil (Six et al., 2002; Ferreira et al., 2013; IPCC—Intergovernmental Panel on Climate Change, 2019; Murga-Orrillo et al., 2019), while the non-mineralized portion of organic matter provides energy and nutrients for soil organisms, including macrofauna, as well as for the crop (Sofo et al., 2020). As a result, studies focusing on the interaction between macrofauna and organic fertilization are especially important.

In recent decades, extreme climatic events, such as high temperatures, droughts, and heavy precipitation, have occurred (AghaKouchak et al., 2020; Fischer et al., 2021). These phenomena are frequently pronounced in tropical regions, with severe socio-economic impacts in densely populated and agricultural areas (Zhou et al., 2023). Cowpea is subjected to these extreme climatic conditions, which affect its yield due to high temperatures and intense precipitation that further erode the soil in sloped agricultural areas.

Permeable plastic mulches on the soil could mitigate these extreme climatic conditions by stabilizing soil temperature, conserving soil, and promoting cowpea biomass production. Plastic mulches improve the hydrothermal conditions of the soil, enhance nutrient mineralization rates, and facilitate the transport of N and P (Mao et al., 2020; Shah and Wu, 2020). They conserve water, suppress weeds, and increase agricultural productivity (Shah and Wu, 2020), enhancing the efficiency of N and water resource utilization, thereby increasing yields (Yu et al., 2018).

Black and silver-colored plastic mulches can reflect up to 33% of sunlight (Rumahorbo et al., 2020). Therefore, light-colored plastic mulches reflect more sunlight, causing variations in soil temperature and impacting soil micro- and macrofauna. Plastic mulches have different effects on soil macrofauna due to the complexity of interactions between species and the availability of organic substrates (Zhang et al., 2021).

Soil macrofauna represents most soil animal biomass and is considered ecosystem engineering (Gongalsky, 2021). They play a crucial role in organic matter decomposition, the formation of biogenic structures, and nutrient recycling (Lavelle and Spain, 2001; Lavelle et al., 2006; Gongalsky, 2021). However, they are susceptible to changes in land use, types of organic substrates, and climatic variations (Edwards and Bohlen, 1996; Kozlov et al., 2022).

The hypothesis proposes that various colors of permeable plastic mulches influence soil temperature, consequently affecting soil macrofauna, organic matter mineralization, and nutrient availability for the crop. Similarly, organic fertilizers influence soil macrofauna, serving as a substrate that these species will mineralize, and the physiology of cowpea by providing specific nutrients such as N, P, and K, which are essential for the growth and production of this crop. This research assessed the effects of different organic fertilizers and permeable plastic mulches on cowpea production and soil macrofauna.

2 Materials and methods

2.1 Experimental area location

The experiment was carried out at "Munichis" University Campus of the School of Agronomy, National Autonomous University of Alto Amazonas (UNAAA), between December 01, 2022, and April 25, 2023. The experimental area is geolocated at a longitude of 76.2313W, latitude 5.8983S, and an altitude of 145.3 meters.

The weather data during the study period included an average temperature of 26.4°C, a relative humidity of 81.7%, and a rainfall of 1439.6 mm. The highest precipitation occurred in March, 557.0 mm, and in April, 344.2 mm (SENAMHI—Servicio Nacional de Meteorología e Hidrología del Perú, 2023) (Figure 1A). Cowpea thrives best in average temperatures ranging from 25 to 35°C, with annual rainfall between 750 and 1100 mm and various soil types (Drahansky et al., 2016).

The total area of the experiment was 255 m², with each experimental unit measuring 2.5 m × 3.4 m (8.5 m²). There were a total of 30 experimental units. On December 02, 2022, the cowpea "Chiclayo blanco," with code "PER-1005853," was planted at a plant density of 166,666.7 plants/ha. The plants were spaced at 30 cm × 20 cm, but only 30 cowpea plants were evaluated per experimental unit (1.8 m²), excluding the plants in the border area (6.7 m²).

2.2 Soil and organic fertilizer analysis

Physico-chemical properties of soil were determined using composite sample, which was collected using an auger at a depth of 0–20 cm. This sample was air-dried, ground, and sieved through a 2 mm mesh. Subsequently, organic matter was determined following the method of Walkley and Black (1934), phosphorus
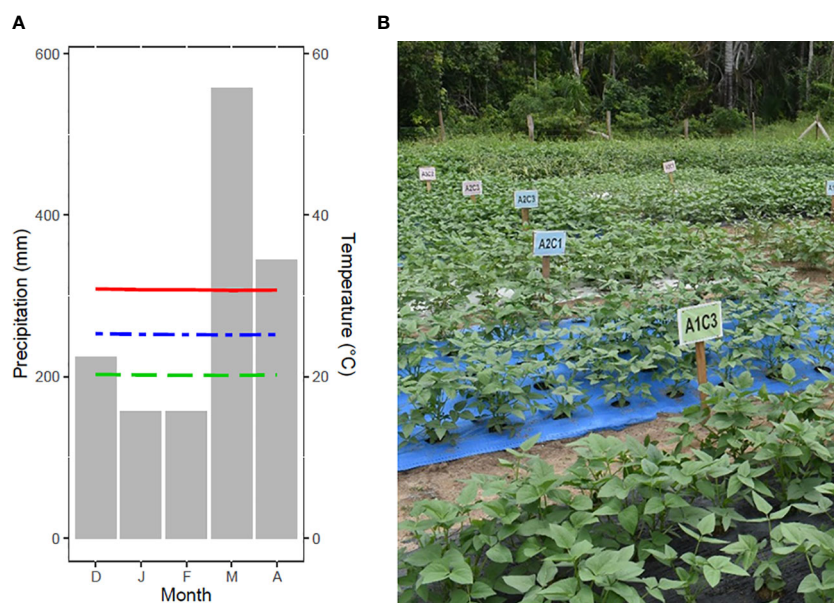
FIGURE 1
Weekly climate conditions for the study period. **(A)** Rainfall (bars), maximum temperature (red line), average temperature (blue line), and minimum temperature (green line), and **(B)** experimental cowpea plots.

(P) was determined according to Olsen et al. (1954), and exchangeable cations (K^+, Ca^{+2}, Mg^{+2}, and Na^+) were extracted using a 1N KCl solution and determined by atomic absorption spectroscopy, following the methodology proposed by Hunter (1986). Nitrogen (N) content was calculated based on the soil's organic matter content. Similarly, in the case of organic fertilizers (compost of chicken manure-agricultural soil-dolomite, island guano, and cattle manure compost), chemical analyses were carried out following the soil chemical analysis methodology. In Table 1, the physical and chemical properties of the soil are presented, corresponding to a loam-silty clay-textured soil (Sand: 65.24%, Silt: 12.84%, Clay: 21.92%) with low nutrient content and high acidity due to Al^{+3} (5.90 cmol$_c$/kg).

2.3 Soil preparation

Before plowing and neutralizing soil acidity, 7.5 t/ha of CaO was applied. The CaO was homogeneously mixed by preparing the soil at a depth of 30 cm using a disc plow attached to an agricultural tractor (Kubota, 120 HP, Model: M108S, Japan). Subsequently, plot demarcation was conducted, with each plot receiving 10 t/ha of compost of chicken manure-agricultural soil-dolomite (from wood residues, rice husk biochar, and agricultural soil), island guano (decomposed organic remains of seabirds), and cattle manure compost (decomposed cow manure). Besides the control, 3.5 mm thick black, blue, and white plastic mulches (100 g/m^2 Polypropylene Burlap Fabrics) were applied to each plot (Figure 1B).

2.4 Experimental design and arrangement

A completely randomized block design was employed with a $3 \times 3 + 1$ factorial arrangement. The plastic mulch factor included three levels: white (C1), black (C2), and blue (C3), while the organic fertilizer factor consisted of composed of a ratio of 3:5:1 of chicken manure-agricultural soil-dolomite (A1), island guano (A2), and cattle manure compost (A3). A total of nine treatments resulted, each with an additional control represented by one plot (01) without plastic mulch (C0) and without organic fertilizer (A0). The treatments and the control were distributed in three replicates (three blocks), resulting in 30 experimental units.

TABLE 1 Physical-chemical properties of the soil in the experimental area of cowpea subjected to plastic mulches and organic fertilizers. Yurimaguas, Munichis 2023.

pH	EC	CaCO$_3$	OM	N	P	K	S	B	Cu	Fe	Mn	Zn	Ca^{+2}	Mg^{+2}	K$^+$	Na$^+$	Al^{+3}
	dS/cm	.........%...............			...............ppm....................								.........cmol$_c$/kg.............				
4.85	0.10	<0.3	2.16	0.11	2.33	52.00	8.39	0.10	0.10	84.7	3	1	3.05	0.36	0.13	0.10	5.90

pH, hydrogen ion potential; EC, electrical conductivity; CaCO$_3$, calcium carbonate; OM, organic matter; N, nitrogen; P, phosphorus; K, potassium; S, sulfur; B, boron; Cu, copper; Fe, iron; Mn, manganese; Zn, zinc; Ca, calcium; Mg^{+2}, magnesium cation; K$^+$, potassium cation; Na$^+$, sodium cation; Al^{+3}, aluminum cation.

2.5 Determination of physiological variables

Plant height was measured using a millimeter tape at 16, 30, 42, and 50 days after planting (DAP), with the final assessment conducted when more than 50% of the plants were in flower. When the pods reached physiological maturity, weekly harvests were performed during the last month to prevent moisture-related rot, as this period experienced frequent and intense rainfall (March). The pods were air-dried, and subsequently, the grains were extracted to determine crop yield (kg/ha). Following the final harvest on April 05, 2023, the above-ground biomass of the plant (FB) was collected and weighed using a 15 kg clock-type balance (Kambor Brand). Lastly, in the UNAAA Chemistry Laboratory, the above-ground biomass was oven-dried (Kert Lab Brand, Model: Heating Drying Oven Odhg-9070A, China) at 70°C for 36 hours until a constant weight was achieved. Subsequently, the dry biomass weight (DB) was determined using a precision scale (OHAUS Brand, Model V11P3T, USA).

2.6 Nitrogen, phosphorus, and potassium content in cowpea leaves

The content of N, P, and K in the physiologically active leaves of cowpea was determined as follows: 10 leaves per experimental unit were collected (from the middle third of the plant). These leaves were dried in an oven (Kert Lab Brand, Model: Heating Drying Oven Odhg-9070A, China) at 70°C for 36 hours, after which they were ground (Retsch Brand mill, Model: GRINDOMIX GM 300, Germany). Nitrogen was then determined using the Kjeldahl method (Oesper, 1934), while phosphorus (P) and potassium (K) were determined through HNO_3 digestion. For P, visible light spectrophotometry was employed, and for K, atomic absorption spectroscopy was used (Embarapa—Empresa Brasileira de Pesquisa Agropecuária, 2009).

2.7 Soil temperature with and without plastic mulches

Soil temperature was measured using soil thermometers (VIVOSUN Brand, Model B09CGLXTQ5, USA). Temperature readings were taken at 0 to 10 cm depth within each treatment. Measurements were recorded between 12:00 PM and 1:00 PM on sunny and cloudy days. Temperature data were recorded in degrees Fahrenheit and converted to degrees Celsius for analysis.

2.8 Soil macrofauna

After the cowpea harvest, monoliths measuring 30 cm in depth within a 25 cm × 25 cm were considered in the experimental plots, following the methodology adapted from Moreira et al. (2012). The macrofauna collected from each monolith was preserved in 5% formalin-dampened samples for subsequent taxonomic identification and weighing in a precision analytical balance with a 0.01 g sensitivity (Model: EHB3000, Brand: TSCALE) at the UNAAA Chemistry Laboratory.

2.9 Statistical analysis of data

The data underwent normality and homogeneity of variance tests to analyze variance using the F-test, followed by Tukey's *post hoc* test. All these analyses were conducted at a significance level of 95% and were presented using boxplots. Similarly, data without a normal distribution for soil macrofauna, soil temperature, and N, P, and K content in the leaves were analyzed and presented using boxplots. All analyses were performed using the statistical software Rstudio (R Core Team, 2023).

3 Results

In Table 2 displays the chemical properties of the organic fertilizers. Island guano has a higher availability of N, P, and K, while cattle manure compost has an alkaline pH and lower electrical conductivity than island guano and compost of chicken manure-agricultural soil-dolomite.

In Table 3, the mean squares of the ANOVA in the F-test show a significant difference (p<0.05) in the block, possibly due to the experimental area having a 9% slope. On the other hand, when analyzing the factors, they did not show a significant interaction; however, the organic fertilizer independent of the plastic mulches showed a significant difference (p<0.05) for the variables plant height, fresh biomass, and dry biomass.

The F-test (Table 3) and Tukey's mean test (Figure 2) determined that there was no initial effect of the organic fertilizer

TABLE 2 Chemical properties of three organic fertilizers used in cowpea production. Yurimaguas, Munichis 2023.

Fertilizer	pH	EC	N	P	K	Ca	Mg	Na	Zn	Cu	Mn	Fe	B	OM
		µS/cm	...........................%						...........................ppm.....................					%
A1	6.09	998.0	0.93	0.26	0.07	1.14	0.12	0.02	141.1	41.3	355.1	4238.8	<0.01	7.6
A2	6.14	41.2	12.87	2.69	2.76	7.32	0.50	1.26	97.0	18.0	36.0	1048.0	46.00	45.2
A3	8.17	4.2	1.61	0.12	0.96	0.77	0.40	0.03	62.1	11.2	427.3	2885.7	4.97	26.5

A1, compost of chicken manure-agricultural soil-dolomite; A2, island guano; and A3, cattle manure compost; pH, hydrogen ion potential; EC, electrical conductivity; N, nitrogen; P, phosphorus; K, potassium; Ca, calcium; Cu, copper; Zn, zinc; Fe, iron; B, boron; and OM, organic matter.

TABLE 3 Mean squares of analysis of variance for cowpea variables. Munichis, 2023.

SV	DF	Height of cowpea plants (DAP)				FB	DB	Yd
		16	30	42	50			
		...............cm...............				...............kg/ha......................		
Block	2	56.5**	14.83*	350.3**	383.0**	38699077***	1132318***	398.1
Fertilizer (A)	2	2.80	3.48	185.8*	400.6**	15090952**	765938***	218.0
Mulch (C)	2	1.20	0.23	22.5	97.0	814046	17095	193.8
AxC	4	3.26	1.25	38.7	67.9	5437075	76966	263.8
Residuals	18	5.68	3.56	56.2	55.2	1939882	81539	133.9
CV(%)	–	17.10	7.94	17.7	18.4	38.8	41.6	21.1

SV, source of variation; DF, degrees of freedom; FB, fresh biomass; DB, dry biomass; DAP, days after planting; Yd, yield; A, fertilizer; C, mulch; *, ** and *** significance at 5%, 1%, and < 0.1% ($p < 0.05$, 0.01, and 0.001).

on plant height (Figures 2A, B). Subsequently, in evaluations when the foliage covered the entire space between plants (42 DAP) and during cowpea full flowering (50 DAP), all three organic fertilizers showed significant differences ($p < 0.05$), resulting in greater plant height compared to the control (Figures 2C, D).

Fresh biomass and dry matter of cowpea exhibited significant differences ($p < 0.05$) in Tukey's test, with better performance for cattle manure compost and moderate performance for compost of chicken manure-agricultural soil-dolomite and island guano when compared to the control (Figures 3A, B). However, the crop yield grain was very low, with no significant differences obtained (Figure 3C). Additionally, the treatment with cattle manure compost showed higher %N, %P, and %K content in cowpea leaves (Figures 4B, D, F). Simultaneously, the white plastic mulch had a higher %P content in cowpea leaves compared to the other treatments (Figures 4A, C, E).

The soil temperature in the cowpea experimental area varied depending on the color of the plastic mulch and the control (Figure 5). On sunny days, the soil temperature in the control recorded maximum values above 40°C, while on cloudy days, the soil temperature fluctuated between 35 to 36°C. On sunny and cloudy days, the white synthetic mulch maintained the soil temperature below 35°C. Conversely, on sunny and cloudy days, the black and blue synthetic mulches kept the temperature between 36 to 37°C (Figures 5A, B).

Earthworms and other arthropods including ants, termites, Glomeridae, Myriapods, Elateridae, Scarabidae, Crickets, Arachnidae, Diptera, and Bugs were recorded and identified among the soil macrofauna (Table 4). Among this macrofauna, the earthworm *P. corethrurus* had a higher live weight under white plastic mulch. It also obtained a higher live weight when treated with cattle manure compost than other treatments (Figures 6A, B). It is noteworthy that the white plastic mulch maintained the soil temperature below 35°C (Figures 5A, B), and cattle manure compost showed significant differences ($p < 0.05$) with higher fresh and dry cowpea biomass weights (Figure 3A). On the other hand, the "cuello blanco" earthworm (Figures 6C, D) exhibited higher weights across all synthetic mulches and with island guano and cattle manure compost compared to the control.

Among the soil macrofauna, particularly noteworthy were arachnids (Order: Araneae), bugs (Order: Hemiptera), and beetles (Order: Coleoptera, Scarabidae) (Figure 7). Only spiders (Figures 7A, B) and bugs (Figures 7C, D) were found in the control; in these plots, the soil temperature varied from 40°C on
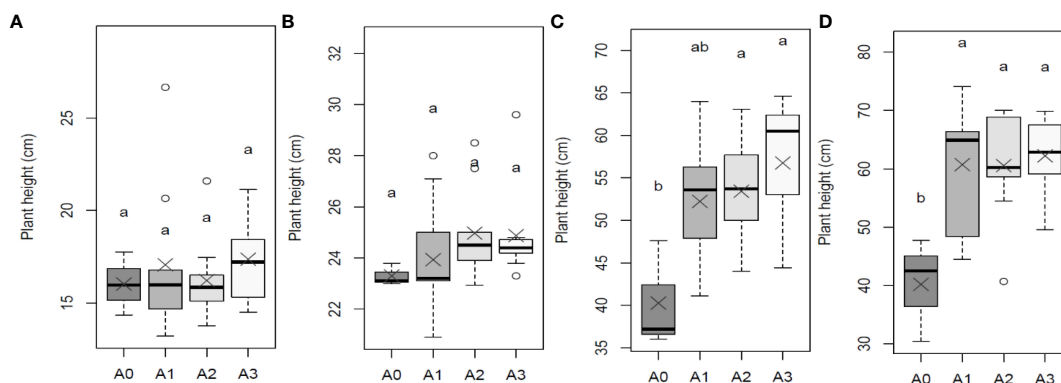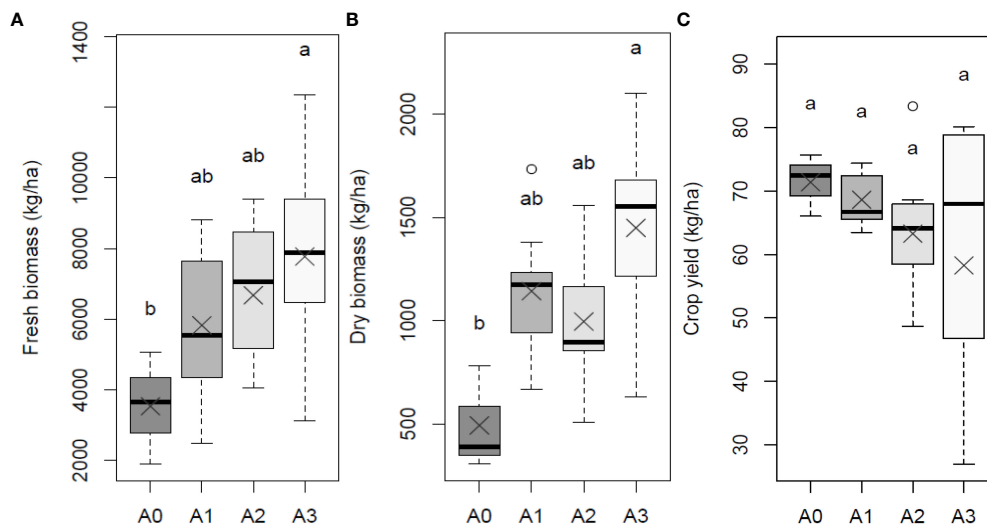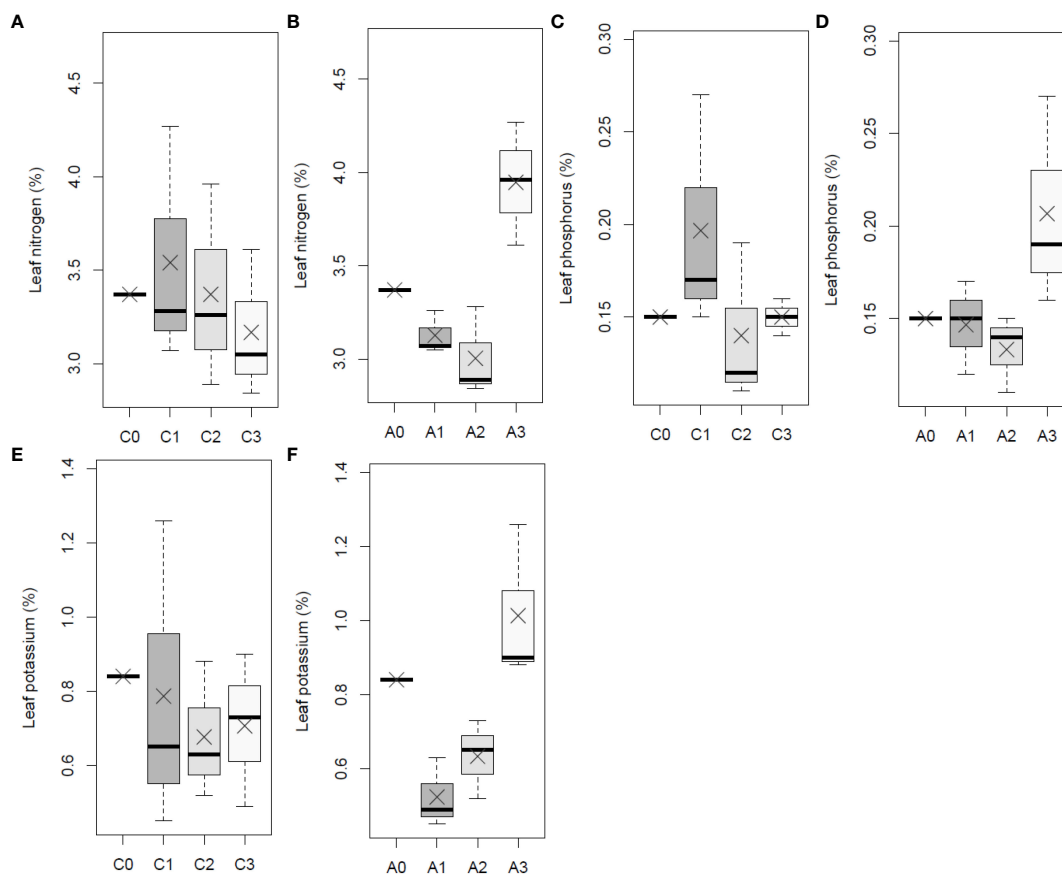

FIGURE 2
Height of cowpea plants at 16 (A), 30 (B), 42 (C), and 50 (D) days after planting, grown under four treatments (Control: A0, compost of chicken manure-agricultural soil-dolomite: A1, island guano: A2, and cattle manure compost: A3). The same lowercase letters on the boxplot indicate no significant difference in means according to Tukey's test ($p < 0.05$).

FIGURE 3
Fresh biomass **(A)**, dry biomass **(B)**, and yield **(C)** of cowpea, planted with organic fertilization (control: A0, compost of chicken manure-agricultural soil-dolomite: A1, island guano: A2, and cattle manure compost: A3). The same lowercase letters on the boxplot indicate no significant difference according to Tukey's test (p<0.05).

FIGURE 4
N, P, and K (%) content in cowpea leaves: (**A, C, E**) plastic mulch (no mulch: C0, white: C1, black: C2, and blue: C3) and **(B, D, F)** organic fertilization (control: A0, compost of chicken manure-agricultural soil-dolomite: A1, island guano: A2, and cattle manure compost: A3).
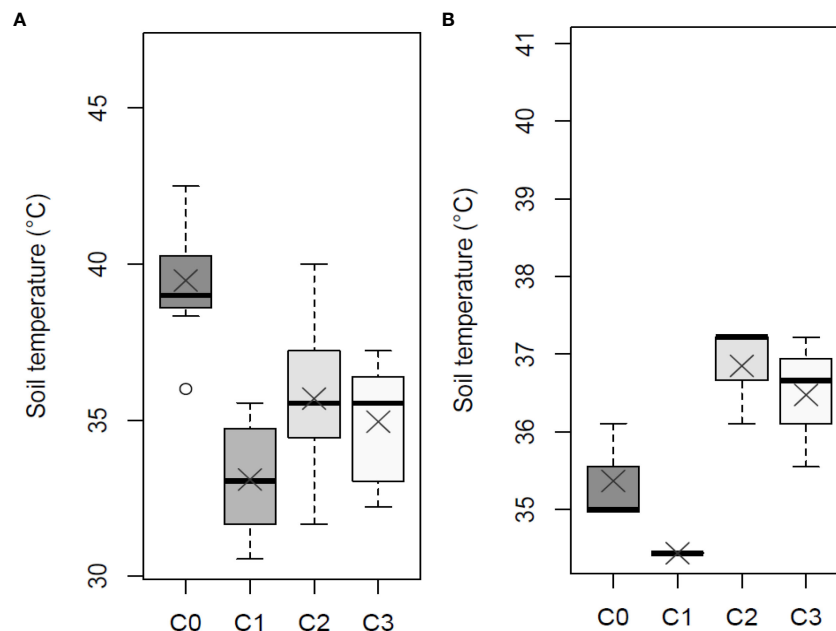
FIGURE 5
Soil temperature **(A)** at midday on sunny days, and **(B)** at midday on cloudy/rainy days in cowpea, planted with plastic mulch (no mulch: C0, white: C1, black: C2, and blue: C3).

sunny days to 35°C on cloudy days (Figures 5A, B). However, the highest body weight for beetles were found under the black mulch plastic (Figure 7E).

4 Discussion

The favorable effect of organic fertilizers became evident in cowpea growth at 42 DAP (Figures 2C, D), suggesting that cowpea thrives well on low soil fertility levels during the vegetative phase. However, at the onset of reproductive phase, nutritional demands increase, the organic treatments proved better sources for nutrient supply which resulted in greater plant height than the control. In the case of another legume, such as alfalfa (*Medicago sativa*), it was determined that treatments with organic fertilizers (compost) achieved greater plant height, fresh biomass, and yield compared to the control group (Fu et al., 2012).

On sunny and cloudy days, white plastic mulches maintained soil temperatures below 35°C, while blue and black mulches kept temperatures between 36 to 37°C. In contrast, the control exhibited temperature variations ranging from 35°C to over 40°C (Figures 5A, B). The varying soil temperatures did not significantly affect cowpea plant height, as indicated by the F-test (Table 3). In other words, cowpea exhibits resistance to soil temperature fluctuations. Other studies support cowpea's resistance to abiotic factors such as high temperatures and drought stress (Kang et al., 2023; Boukar et al., 2018).

Moreover, the intense rainfall in March (557.0 mm) (Figure 1A) did not lead to excess moisture stress in the plants, but it did result in low grain yields ranging from 50 to 80 kg/ha. The average global cowpea yield is 450 kg/ha (Kebede and Bekeko, 2020). However,

improved cowpea varieties with proper agronomic management can achieve yields of 2,200 to 3,200 kg/ha (Ashinie et al., 2020).

Organic fertilizers enhance cowpea's fresh and dry biomass production compared to the control (Figures 3A, B), with cattle manure compost standing out. Cattle manure compost, with its alkaline pH (Table 2), complements soil CaO, resulting in increased biological activity of *P. corethrurus* and "cuello blanco" earthworms (Figures 6B, D). These chemical and biological soil conditions likely promote greater availability of N, P, and K for cowpea. Indeed, cattle manure compost plots exhibited higher N, P, and K contents in the leaves (Figures 4B, D, F). It is known that soil P is more available to legumes under alkaline pH conditions (Ditta et al., 2018). Additionally, the biodegradation of organic matter by *P. corethrurus* and other earthworms increases the availability of N and P, optimizing biological nitrogen fixation and P solubilization, resulting in significant yield increase in cowpea and other crops (Padmavathiamma et al., 2008)

The availability of earthworms was higher in plots with plastic mulches (Figures 6A, C), likely favored by the organic matter from the fertilizers and the reduction in soil temperature (Figures 5A, B). However, ants and bugs were found exclusively in the control, indicating that these insects are exclusive to open spaces (Figures 7A–D), where soil temperatures can exceed 40°C on sunny days and drop below 35°C on cloudy days (Figures 5A, B). Plastic mulches act as a physical control for potential pests of these insects. In contrast, beetles were generally found in soil with black synthetic mulches (Figure 7E). Plastic mulches of different colors on the ground either control certain insects or attract them (Rumahorbo et al., 2020). Therefore, it is possible that the black color of the plastic mulch has an affinity for ground beetles, possibly as a means of mimicry to evade their natural enemies. Ground
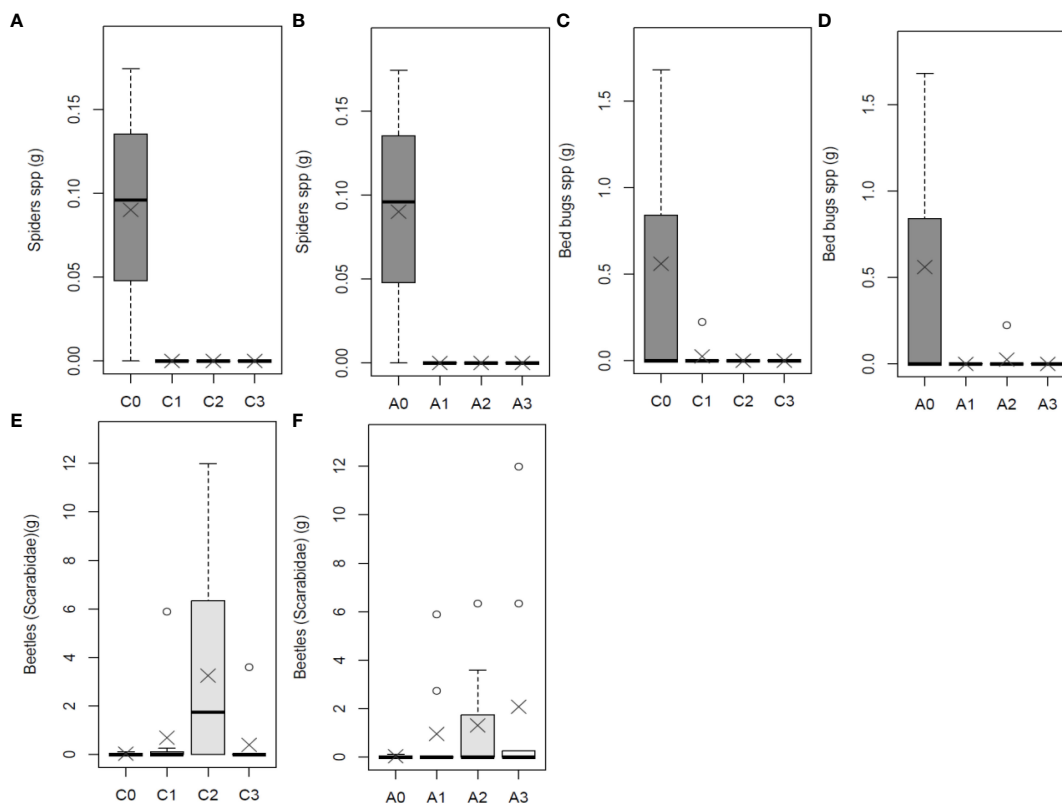
TABLE 4   Soil macrofauna under organic fertilization (control: A0, compost of chicken manure-agricultural soil-dolomite: A1, island guano: A2, and cattle manure compost: A3) and plastic mulch (no mulch: C0, white: C1, black: C2, and blue: C3) associated with cowpea.

Treat	Haplotaxida (Earthworms, g)					Arthropods (g)										
	P. corethrurus	Cuello blanco	Polyhumica	Epigea	Native	Ants	Termites	Glomeridae	Myriapods	Elateridae	Scarabidae	Grillidae	Cicadoidea	Arachnidae	Diptera	Bed bugs
A0	0.22 ± 0.39	4.39 ± 2.58	0.00	0.00	0.07 ± 0.12	0.16 ± 0.09	0.04 ± 0.07	0.07 ± 0.13	0.07 ± 0.13	0.00	0.04 ± 0.07	0.00	0.00	0.09 ± 0.09	0.02 ± 0.03	0.56 ± 0.97
A1	3.74 ± 5.21	6.23 ± 11.02	0.53 ± 1.33	0.18 ± 0.49	0.25 ± 0.35	0.23 ± 0.47	0.01 ± 0.02	0.11 ± 0.25	0.11 ± 0.25	0.05 ± 0.09	0.96 ± 2.06	0.02 ± 0.04	0.51 ± 1.53	0.00	0.00	0.00
A2	10.57 ± 17.11	9.71 ± 8.24	0.14 ± 0.27	0.03 ± 0.09	0.66 ± 0.94	0.03 ± 0.04	0.11 ± 0.27	0.01 ± 0.03	0.01 ± 0.03	0.02 ± 0.05	1.31 ± 2.26	0.77 ± 2.26	0.00	0.00	0.00	0.02 ± 0.07
A3	10.83 ± 12.27	13.00 ± 8.38	1.49 ± 2.68	0.00	0.92 ± 0.82	0.33 ± 0.89	0.13 ± 0.38	0.13 ± 0.23	0.13 ± 0.23	0.14 ± 0.24	2.08 ± 4.26	0.90 ± 2.71	0.00	0.00	0.03 ± 0.09	0.00
	6.34 ± 5.24	8.33 ± 3.82	0.54 ± 0.67	0.05 ± 0.08	0.48 ± 0.39	0.19 ± 0.13	0.07 ± 0.06	0.08 ± 0.05	0.08 ± 0.05	0.05 ± 0.06	1.10 ± 0.85	0.42 ± 0.48	0.13 ± 0.26	0.02 ± 0.05	0.01 ± 0.01	0.15 ± 0.28
C0	0.22 ± 0.39	4.39 ± 2.58	0.00	0.00	0.07 ± 0.12	0.16 ± 0.09	0.04 ± 0.07	0.07 ± 0.13	0.07 ± 0.13	0.00	0.04 ± 0.07	0.00	0.00	0.09 ± 0.09	0.02 ± 0.03	0.56 ± 0.97
C1	17.99 ± 17.20	7.62 ± 8.67	1.54 ± 2.54	0.01 ± 0.04	0.52 ± 0.49	0.16 ± 0.49	0.00	0.11 ± 0.25	0.11 ± 0.25	0.03 ± 0.06	0.70 ± 1.95	0.01 ± 0.02	0.51 ± 1.53	0.00	0.03 ± 0.09	0.02 ± 0.07
C2	3.72 ± 4.69	12.94 ± 11.61	0.07 ± 0.16	0.19 ± 0.49	0.64 ± 0.90	0.40 ± 0.86	0.13 ± 0.38	0.11 ± 0.23	0.11 ± 0.23	0.13 ± 0.22	3.25 ± 4.17	0.91 ± 2.71	0.00	0.00	0.00	0.00
C3	3.42 ± 5.82	8.38 ± 7.82	0.54 ± 1.54	0.00	0.67 ± 0.93	0.03 ± 0.03	0.11 ± 0.27	0.03 ± 0.06	0.03 ± 0.06	0.05 ± 0.14	0.40 ± 1.20	0.78 ± 2.26	0.00	0.00	0.00	0.00
	6.34 ± 7.43	8.33 ± 4.82	0.54 ± 0.66	0.05 ± 0.08	0.48 ± 0.32	0.19 ± 0.16	0.07 ± 0.06	0.08 ± 0.05	0.08 ± 0.05	0.05 ± 0.05	1.10 ± 1.36	0.42 ± 0.46	0.13 ± 0.23	0.02 ± 0.04	0.01 ± 0.01	0.15 ± 0.25
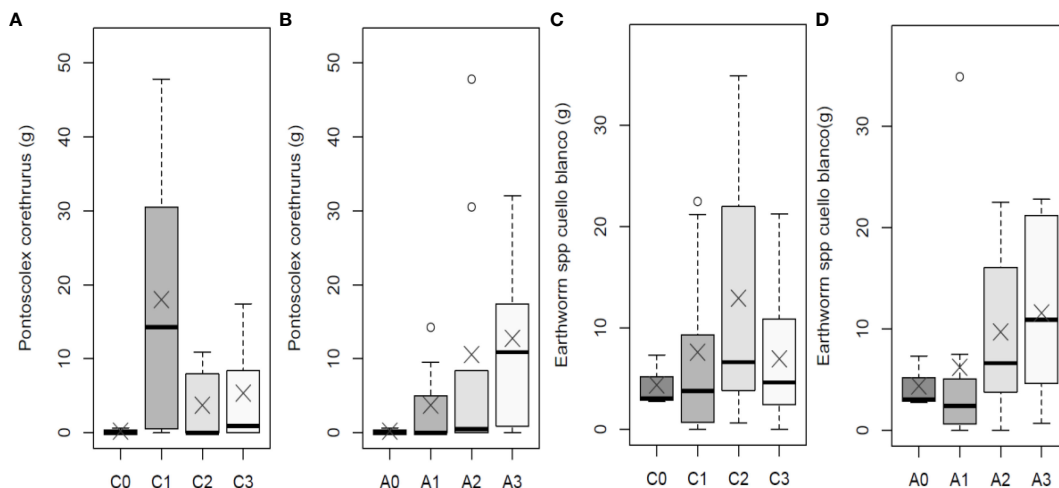
FIGURE 6
Weight of *P. corethrurus* **(A, B)** and earthworm "cuello blanco" **(C, D)** under plastic mulch conditions (no mulch: C0, white: C1, black: C2, and blue: C3) and **(A)** organic fertilization (Control: A0, compost of chicken manure-agricultural soil-dolomite: A1, guano island: A2, and cattle manure compost: A3) associated with cowpea.

FIGURE 7
Weight of spiders **(A, B)**, bed bugs **(C, D)** and beetles **(E, F)** in soil under plastic mulch conditions (no mulch: C0, white: C1, black: C2, and blue: C3) and organic fertilization (control: A0, composed of chicken manure-agricultural soil-dolomite: A1, guano island: A2, and cattle manure compost: A3) associated with cowpea.

beetles are attracted to traps of black or dark color (Cavaletto et al., 2021).

5 Conclusions

Cowpea is resilient to low soil fertility and soil temperature fluctuations between <35°C and >40°C, but high rainfall during the fruiting and harvesting period significantly impacted negative grain yields. Organic fertilizers showed significant differences (p<0.05) in cowpea biomass, especially the cattle manure compost fertilizer, suggesting that soil macrofauna such as *Pontoscolex corethrurus* and others influenced greater availability of N, P, and K for the plant during the reproductive phase. Plastic mulches and organic fertilizers were associated with higher weights of earthworms like *P. corethrurus*, and the plastic mulches also served as a physical control for ants and bugs.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Ethics statement

The manuscript presents research on animals that do not require ethical approval for their study.

Author contributions

HM-O: Conceptualization, Formal Analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JC: Data curation,

Investigation, Resources, Writing – original draft. BP: Funding acquisition, Investigation, Resources, Writing – original draft. LA: Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Writing – original draft.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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