



RESEARCH ARTICLE

Weed dynamics and soil health in coconut plantations as affected by organic weed management practices

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ABSTRACT

Eco friendly weed management is crucial in sustaining soil health and crop productivity in coconut plantations. A study on the effect of organic practices on weed dynamics and soil health was undertaken in a 20-year-old coconut plantation with a spacing of 7.5 m × 7.5 m. The organic weed management practices tested included: live mulching with *dhaincha* (*Sesbania aculeata*) or horsegram (*Macrotyloma uniflorum*) or cowpea (*Vigna unguiculata*) in the interspaces of coconut trees, intercropping with turmeric (*Curcuma longa*), mulching interspaces of coconut trees using phyto-pharmaceutical waste (byproduct of the ayurveda industry) 20 t/ha, ploughing the interspaces of coconut trees (twice per year). Unploughed interspaces of coconut trees without weeding operations served as check. Weed density and biomass were monitored. Soil samples were periodically analysed for nutrient status and microbial population changes. Grasses were the dominant weeds, followed by broad-leaved weeds. Live mulching and mulching with phyto-pharmaceutical waste resulted in more than 90 % weed control. Mulching with phyto-pharmaceutical waste was free of weeds even after one year of application. Enhanced microbial biomass carbon, dehydrogenase activity, as well as acid phosphatase activity, were observed in plots where intercropping practices or organic waste mulching was practiced. Organic weed management practices not only provided effective weed management but also enhanced soil fertility and microbial activity, making them ideal option for eco-friendly weed management in coconut plantations.

Keywords: Organic mulch, *In-situ* green manuring, Inter-cropping, Soil microbes, Live mulching, Weed shift

INTRODUCTION

Weed management remains a critical factor in sustaining productivity and ecological balance in coconut (*Cocos nucifera* L.) (Remison and Mgebeze 1987), which is the major plantation crop of Kerala. Coconut is generally planted at a spacing of 7.5m × 7.5m and the wider spacing favours greater weed infestation. Weed occurrence is influenced by factors such as crop cover, irrigation, management practices, and light availability (Surekha and Bhat 2025). Except for the initial establishment phase, the direct impact of weed competition on growth and productivity is not a major concern. However, periodic weeding and inter-cultural operations are essential to maintain health of the crop and to facilitate operations such as manuring, irrigation and harvest. There is limited scope for the use of herbicides in a plantation crop like coconut as no registered herbicides with label claim are available. However, being a perennial crop which produces plenty of recyclable plant biomass; there is large scope of adoption of organic farming practices. Coconut-based homestead farming

systems in Kerala are often organic by default. Organic weed management strategies, including green manuring and mulching, not only suppress weed proliferation but also improve soil health, nutrient cycling, and microbial activity, fostering sustainable plantation systems.

Leguminous cover crops play a vital role in sustainable weed management by providing ground cover that suppresses weed germination and growth through light exclusion and competition. Green manures such as *Stizolobium aterrimum* and *Crotalaria* spp. enhance soil fertility by reducing dependence on synthetic inputs, while their decomposition enriches soil organic matter, improves microbial activity, and strengthens soil structure, thereby supporting crop resilience (Servín Niz *et al.* 2023). Horse gram (*Macrotyloma uniflorum*), a pulse crop well adapted to arid and tropical regions, is considered ideal for perennial plantations (Bhardwaj and Yadav 2015). Cowpea (*Vigna unguiculata*) improved physicochemical and biological properties of degraded soils through root exudates that stimulated microbial activity and soil respiration (Farouq *et al.* 2022). Mulching with organic residues, optimal mulch depth, suppress weeds, conserves soil

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moisture, enhances microbial population, and contributes to slow nutrient release (Remison and Mgbeze 1987, Greenly and Rakow 1995). Sun *et al.* (2021) reported that in a 15-year-old *Ligustrum lucidum* forest, a 20-cm organic mulch layer increased bacterial diversity within six months, with community shifts linked to root traits and enzyme activity. Similarly, the use of phyto-pharmaceutical industrial by-products offered cost-effective weed suppression besides the addition of organic matter and micronutrients. Other organic mulching materials such as coffee husk, rice husk, palm leaves, and grasses reduced weeds and improved yield of cucumber (Hutabarat *et al.* 2021). However, information on the performance of such organic weed management practices in coconut plantations under tropical conditions is limited, necessitating the need for detailed evaluation to standardize long-term weed control and productivity enhancement in coconut-based organic farming systems. The objective of this study was to assess the effect of organic effective and ecological option for weed management in coconut plantations so as to sustain soil health and also to study weed flora shifts.

MATERIALS AND METHODS

Two years field study was conducted during 2022 and 2023 in a 20-year-old coconut plantation with a spacing of 7.5 m × 7.5 m. The usual practice of weed management was a single ploughing and basin opening annually during May-June months and there was severe infestation of weeds in between coconut trees rows (interspaces). The field was rainfed and organic manures 25 kg/palm were applied. A randomized block design (RBD) with seven treatments and four replications was used. The tested treatments included T1: *in-situ* green manuring with dhaincha (*Sesbania aculeata*) in the interspaces, T2: *in-situ* green manuring with cowpea (*Vigna unguiculata*) in the interspaces, T3: *in-situ* green manuring with horse gram (*Macrotyloma uniflorum*) in the interspaces, T4: mulching interspaces of coconut trees with phyto-pharmaceutical waste (by-product of the ayurveda industry) 20 t/ha with a thickness of 5-7.5 cm, T5: ploughing twice at 6 months interval in a year, and T6: intercropping with turmeric (*Curcuma longa*). The treatments were imposed after giving a single round of ploughing uniformly. Untreated control without ploughing was maintained as weedy check. All the three green manure crops were sown at a seed rate of 20 kg/ha and the fresh biomass production by the green manure crops range from 2-4 kg/m² at peak vegetative stage. However, they were incorporated

only during the second round of ploughing as green manure addition was not the major objective. Data on weed growth was recorded at 2, 4 and 6 months after sowing of green manure crops/planting of turmeric/mulching with phyto-pharmaceutical waste/ploughing the interspaces. Weed density and biomass was recorded using a quadrat of 0.5m × 0.5m and expressed separately for grasses, sedges and broad-leaved weeds. Soil nutrient status was recorded initially and at the end of experiment. Sowing of green manure crops and planting of turmeric as well as organic waste mulching was done in the month of June in both years. Soil biological properties including microbial biomass carbon, dehydrogenase activity and acid phospho monoesterases, population of fungi, bacteria and actinomycetes were estimated using standard procedures.

RESULTS AND DISCUSSION

Effect on weeds

Weed flora of the experimental area constituted mainly of grasses followed by broad-leaved weeds. Broad-leaved weeds were *Celosia argentea*, *Borreria hispida*, and *Cleome* spp. *Borreria hispida* was dominant. Major grasses were *Megathyrsus maximus* and *Pennisetum pedicellatum*. By the second year, a notable shift in weed flora was observed in the legume-intercropped fields, where broad-leaved weeds gained dominance over grassy weeds. No such shift was recorded in the unweeded check, wherein the first year, at two months, grasses contributed 80% of the total weed biomass, while dicots accounted for only 20% (**Table 1**) and this trend persisted in the second year too, with grasses and dicots contributing 75% and 24%, respectively. However, under different legume intercropping practices, there was a clear ecological shift in weed composition, characterized by a drastic reduction in both the density and biomass of grass weeds. This can be attributed to the suppression of grass weeds due to reduced seed rain, thereby depleting the soil seed bank and weakening their competitive dominance in the weed community. These observations confirm the findings by Davies *et al.* (1997), who reported that annual weeds are unable to establish effectively under dense green manure canopies. The decline in seed production combined with the short seed longevity of many annual grasses accelerated this shift (Bohan *et al.* 2011). Leguminous green manures have been shown to reduce the weed seed bank by up to 65%, with residual effects persisting even up to three years (Melander *et al.* 2020). Thus, cover cropping with

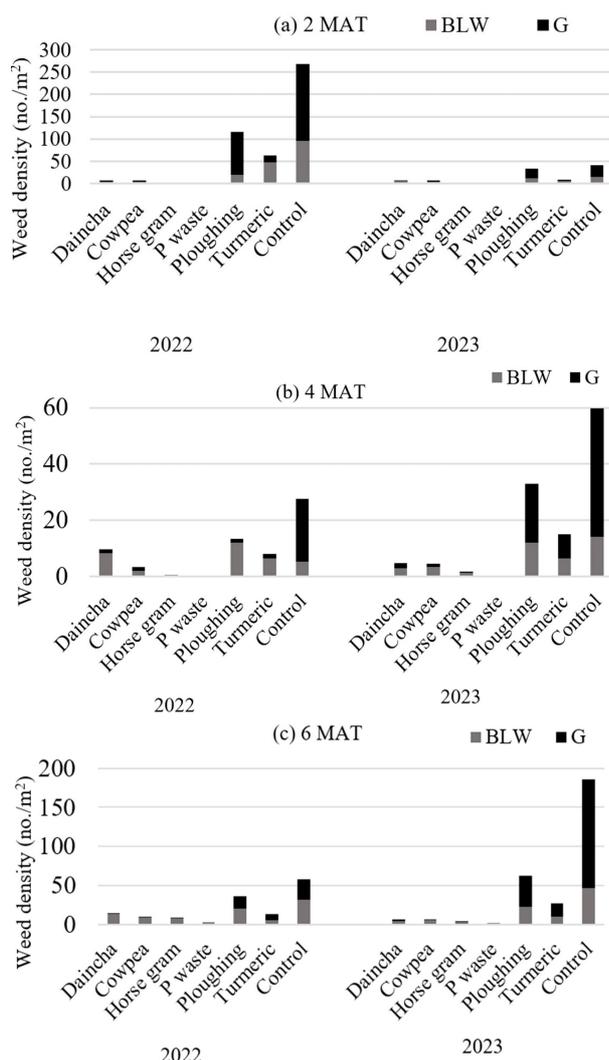


Figure 1. Weed density at (a) 2 months after treatment application (MAT), (b) 4 months after treatment application, (c) 6 months after treatment application

green manure crops play a pivotal role in both weed suppression and seed bank depletion, contributing significantly to ecological weed management in organic or natural farming systems.

A comparison of weed density in different treatments showed (Figure 1) that in the treatments *in-situ* green manuring using horse gram and mulching with phytopharmaceutical waste, no weeds were present at two months after treatment (MAT). In plots intercropped with turmeric, the weed density was very high compared to the legume intercropped plots as smothering effect was less compared to legumes (Figure 1a). The significantly highest weed density was recorded from unweeded control, followed by ploughing alone. However, ploughing could considerably reduce (by 43%) the weed density compared to weedy check. The same trend was noticed at 4 months (Figure 1b). By 6 months,

broad-leaved weeds constituted the major flora (Figure 1c). However, scarcity of rainfall caused declining trend of weed density.

In general, a sharp decline in total weed density was observed during the second year at two months and showed an increasing trend by 4 and 6 months due to favourable climatic factors (Figure 1). The observed decline in weed density at two months during the second year can be attributed to residual effects of earlier practices and reduced initial weed emergence. However, the increasing weed density by four and six months suggests that limited soil disturbance may allow some late-emerging weed species to establish, especially under favourable climatic conditions. In such systems, legume intercropping serve as a biologically integrated weed suppression strategy. The dense canopy and competitive nature of legumes help smother weeds and reduce their light and space resources. The population of broad-leaved weeds was higher compared to grasses. The same trend as in the first year was followed in all the treatments. Ploughing of interspaces proved less effective than intercropping, confirming that mechanical weeding alone is not sufficient to control diverse weed flora. But, mechanical weeding was statistically superior than the unweeded check. When done occasionally, it can be an effective and low-cost option in coconut plantations, where wide interspaces are available and weeds have little impact on yield if the basin area around the palms is kept weed-free. The 60% and 40% reduction in weed density by six months in 2022 and 2023 respectively, highlights the cumulative benefits of integrating tillage with cover cropping.

During both years weed biomass was recorded at two-month intervals and the same trend as that of weed density was observed. At 2 MAT, *in-situ* green manuring with horsegram and mulching with phytopharmaceutical waste were most effective with 100% weed control (Table 1). *In-situ* green manuring with cowpea and dhaincha showed a weed biomass reduction of 95%, compared to unweeded control and were statistically comparable. In intercropping with turmeric, 82% reduction in weed biomass was observed. The highest weed biomass was recorded from the unweeded control, followed by ploughing alone. At 4 and 6 MAT also, a similar trend was noticed (Table 1). By six months, weed biomass increased. In all legume intercropping treatments, weed biomass was statistically comparable, and on average, the reduction in weed biomass was 96% over the unweeded control, indicating the effectiveness of cover cropping.

From both ecological and practical farming perspectives, green manuring and mulching clearly outperformed ploughing in managing weeds in coconut plantations. Legume intercropping sustained a weed control efficiency (WCE) of over 90% up to six months (**Figure 2**), offering ecological benefits such as improved soil fertility through nitrogen

fixation, suppression of weed seed germination and reducing weed seed bank. Mulching with phyto-pharmaceutical waste provided even more immediate suppression, achieving 100% WCE at two and four months, and 98% at six months, by acting as a physical barrier to weed emergence while also conserving soil moisture and enhancing microbial

Table 1. Weed biomass at 2, 4, and 6 months after treatment application

Treatment	2022			2023		
	BLW	G	Total	BLW	G	Total
<i>Weed biomass (g/m²) at 2 months after treatment</i>						
<i>In-situ</i> green manuring with dhaincha in the interspaces of coconut trees (interspaces)	1.85 ^d (2.94)	1.78 ^d (2.67)	2.47 ^d (5.61)	3.17 ^c (9.67)	1.93 ^d (3.33)	3.66 ^d (13.00)
<i>In-situ</i> green manuring with cowpea in the interspaces	2.02 ^d (3.60)	1.37 ^{de} (1.37)	2.34 ^d (4.97)	2.46 ^{cd} (5.67)	1.54 ^{de} (2.33)	2.91 ^d (8.00)
<i>In-situ</i> green manuring with horse gram in the interspaces	0.71 ^e (0.00)	0.71 ^e (0.00)	0.71 ^e (0.00)	1.54 ^{de} (2.33)	0.71 ^e (0.00)	1.54 ^e (2.33)
Mulching interspaces using phytopharmaceutical waste 20 t/ha	0.71 ^e (0.00)	0.71 ^e (0.00)	0.71 ^e (0.00)	0.71 ^e (0.00)	0.71 ^e (0.00)	0.71 ^e (0.00)
Ploughing twice in the interspaces	7.36 ^b (53.61)	13.96 ^b (194.62)	15.77 ^b (248.23)	6.84 ^a (46.33)	11.74 ^b (137.67)	13.57 ^b (184.00)
Inter cropping with turmeric in the interspaces	6.47 ^c (41.39)	3.93 ^c (14.98)	7.54 ^c (56.37)	5.66 ^b (32.00)	5.89 ^c (34.33)	8.17 ^c (66.33)
Unweeded control	8.55 ^a (72.61)	16.89 ^a (284.64)	18.91 ^a (357.25)	7.72 ^a (59.33)	13.52 ^a (182.67)	15.55 ^a (242.00)
LSD (p=0.05)	0.43	0.83	0.92	0.987	1.093	1.071
<i>Weed biomass (g/m²) at 4 months after treatment</i>						
<i>In-situ</i> green manuring with dhaincha in the interspaces of coconut trees (interspaces)	5.47 ^a (29.42)	1.00 ^b (0.50)	5.52 ^c (29.92)	3.76 ^c (13.67)	2.21 ^d (4.67)	4.33 ^d (18.33)
<i>In-situ</i> green manuring with cowpea in the interspaces	3.97 ^b (15.28)	1.16 ^b (0.85)	4.08 ^d (16.13)	3.69 ^c (13.33)	1.79 ^{de} (3.33)	4.14 ^d (16.67)
<i>In-situ</i> green manuring with horse gram in the interspaces	1.17 ^c (0.88)	0.71 ^b (0.00)	1.17 ^e (0.88)	2.88 ^d (8.00)	1.09 ^{ef} (1.00)	3.02 ^e (9.00)
Mulching interspaces using phytopharmaceutical waste 20 t/ha	0.71 ^c (0.00)	0.71 ^b (0.00)	0.71 ^e (0.00)	0.71 ^e (0.00)	0.71 ^f (0.00)	0.71 ^f (0.00)
Ploughing twice in the interspaces	3.56 ^b (12.17)	7.60 ^a (57.26)	8.36 ^b (69.43)	9.69 ^a (93.67)	14.19 ^b (201.00)	17.17 ^b (294.67)
Inter cropping with turmeric in the interspaces	2.06 ^c (3.73)	3.13 (12.30)	4.02 ^c (16.03)	6.46 ^b (41.33)	8.47 ^c (71.33)	10.64 ^c (112.67)
Unweeded control	3.89 ^b (14.66)	8.73 ^a (75.66)	9.53 ^a (90.33)	10.46 ^a (109.00)	18.82 ^a (354.00)	21.51 ^a (463.00)
LSD (p=0.05)	1.23	1.42	1.78	0.773	0.990	0.955
<i>Weed biomass (g/m²) at 6 months after treatment</i>						
<i>In-situ</i> green manuring with dhaincha in the interspaces of coconut trees (interspaces)	5.12 ^c (26.33)	0.95 ^d (0.43)	5.16 ^d (26.77)	4.44 ^c (20.00)	2.00 ^d (3.67)	4.83 ^d (23.67)
<i>In-situ</i> green manuring with cowpea in the interspaces	4.72 ^{cd} (22.33)	0.82 ^d (0.20)	4.74 ^d (22.53)	4.39 ^c (19.33)	1.83 ^{de} (3.67)	4.77 ^d (23.00)
<i>In-situ</i> green manuring with horse gram in the interspaces	4.28 ^d (18.33)	0.85 ^d (0.23)	4.30 ^d (18.57)	4.35 ^c (19.00)	1.54 ^{de} (2.33)	4.59 ^d (21.33)
Mulching interspaces using phytopharmaceutical waste 20 t/ha	2.49 ^e (6.33)	0.71 ^d (0.00)	2.49 ^e (6.33)	2.60 ^d (7.00)	0.71 ^e (0.00)	2.60 ^e (7.00)
Ploughing twice in the interspaces	6.42 ^b (41.33)	11.56 ^b (133.33)	13.21 ^b (174.67)	9.59 ^a (92.00)	14.77 ^b (218.33)	17.61 ^b (310.33)
Inter cropping with turmeric in the interspaces	3.21 ^e (10.33)	9.40 ^c (88.00)	9.91 ^c (98.33)	6.96 ^b (48.67)	11.03 ^c (122.00)	13.05 ^c (170.67)
Unweeded control	7.78 ^a (60.67)	14.42 ^a (208.00)	16.38 ^a (268.67)	8.99 ^a (81.00)	21.91 ^a (479.67)	23.67 ^a (560.67)
LSD (p=0.05)	0.722	0.747	0.928	0.893	1.198	1.054

$\sqrt{x+0.5}$ transformed values, original values in parenthesis. *BLW – broad-leaved weeds, G - grasses.

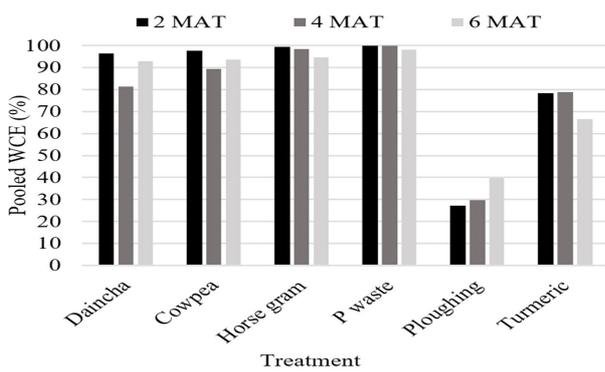


Figure 2. Effect of weed management practices on weed control efficiency (WCE)

Dhaincha - in-situ green manuring with dhaincha in the interspaces; Cowpea - in-situ green manuring with cowpea in the interspaces; Horse gram - in-situ green manuring with horse gram in the interspaces; P waste - mulching interspaces of coconut trees using phyto-pharmaceutical waste 20 t/ha; Ploughing - ploughing twice; Turmeric - intercropping with turmeric; Control - weedy check

activity. For farmers, these practices reduce the need for frequent weeding, save labour costs, and improve soil health-leading to better long-term productivity.

Soil chemical analysis

Soil samples were collected before and after the experiment. The primary nutrient status of the soil was N (86 kg/ha), P (52 kg/ha) and K (232 kg/ha). After the application of the treatments, pH of the soil varied from 5 to 5.99 and EC varied from 30 to 110 μS/m. The highest pH and EC were registered in phytopharmaceutical waste mulched field (Figure 3). The total organic matter, as well as organic carbon content, were higher in legume intercropping as well as organic waste mulching compared to ploughing alone and unweeded control. The organic matter content was higher in green manuring with horse gram and mulching with phytopharmaceutical waste with about 4% increase over unweeded check.

The organic interventions resulted in noticeable increase in soil carbon status. Both total organic matter (OM) and organic carbon (OC) were higher in the legume-intercropped and mulched plots compared to ploughed and unweeded controls (Figure 3). Green manuring with horse gram and mulching with phytopharmaceutical waste each

showed increase in organic matter from initial value of 8% to 10% and 12% respectively over the control, suggesting effective carbon input and nutrient recycling through leumes biomass incorporation and decomposition confirming the findings of Montanaro *et al.* (2017); Chahal *et al.* (2020).

Iron (Fe), the most abundant redox-active metal in the Earth’s crust, cycles between Fe(III) and Fe(II) through microbial and chemical processes. It plays an important role in deciding rhizosphere microbial communities, with previous studies showing that iron availability can influence microbial composition more than many other nutrients. Continuous cropping has been associated with a decline in bacteria involved in iron respiration—microorganisms that convert plant-unavailable Fe(III) into Fe(II), which roots can absorb (Yang *et al.* 2025). Continuous cropping or high organic matter can immobilize Fe through complexation, indirectly affecting actinomycete population by altering nutrient availability and redox conditions (Peng *et al.* 2022). The observed reduction in soil iron content (Figure 4) can be linked to a decline in actinomycete population, as these microorganisms contribute to iron cycling through the production of siderophores that mobilize Fe(III) into plant-available forms; Reduced actinomycete population under continuous cropping could therefore limit iron solubilization, accelerating the depletion of available iron in the soil. In contrast, manganese levels remained relatively stable, likely due to its higher mobility in soil compared to iron.

Soil microbiological analysis

Enhanced microbial biomass carbon, dehydrogenase activity, as well as acid phosphatase activity, were observed in plots where intercropping practices or phytopharmaceutical waste application were followed (Figure 5). Also, in the second year of treatment application, a remarkable increase in these parameters could be observed indicating improvement in soil health. A marked increase in the population of fungi and bacteria was observed in

Table 2. Soil nutrient status of coconut plantations as affected by phytopharmaceutical waste application and green manure crops cultivation in the interspaces of coconut trees

Phytopharmaceutical waste	N (%)	P (%)	K (%)	Micronutrient (ppm)		Heavy metals (ppm)				Phenol content (%)
				Cu	Fe	Ni	Cr	Cd	Pb	
Phytopharmaceutical waste (fresh)	1.66	0.151	0.331	3.7	406	84.04	54.3	BDL	276	0.083
Phytopharmaceutical waste (decomposed - 6 months after soil application)	1.05	0.162	0.149	1.9	111.6	7.70	29.8	BDL	181	0.025
Green manure crops		N (%)			P (%)					K (%)
Cowpea		3.0			0.45					1.4
Horse gram		3.0			0.42					1.4
Dhaincha		3.5			0.60					1.2

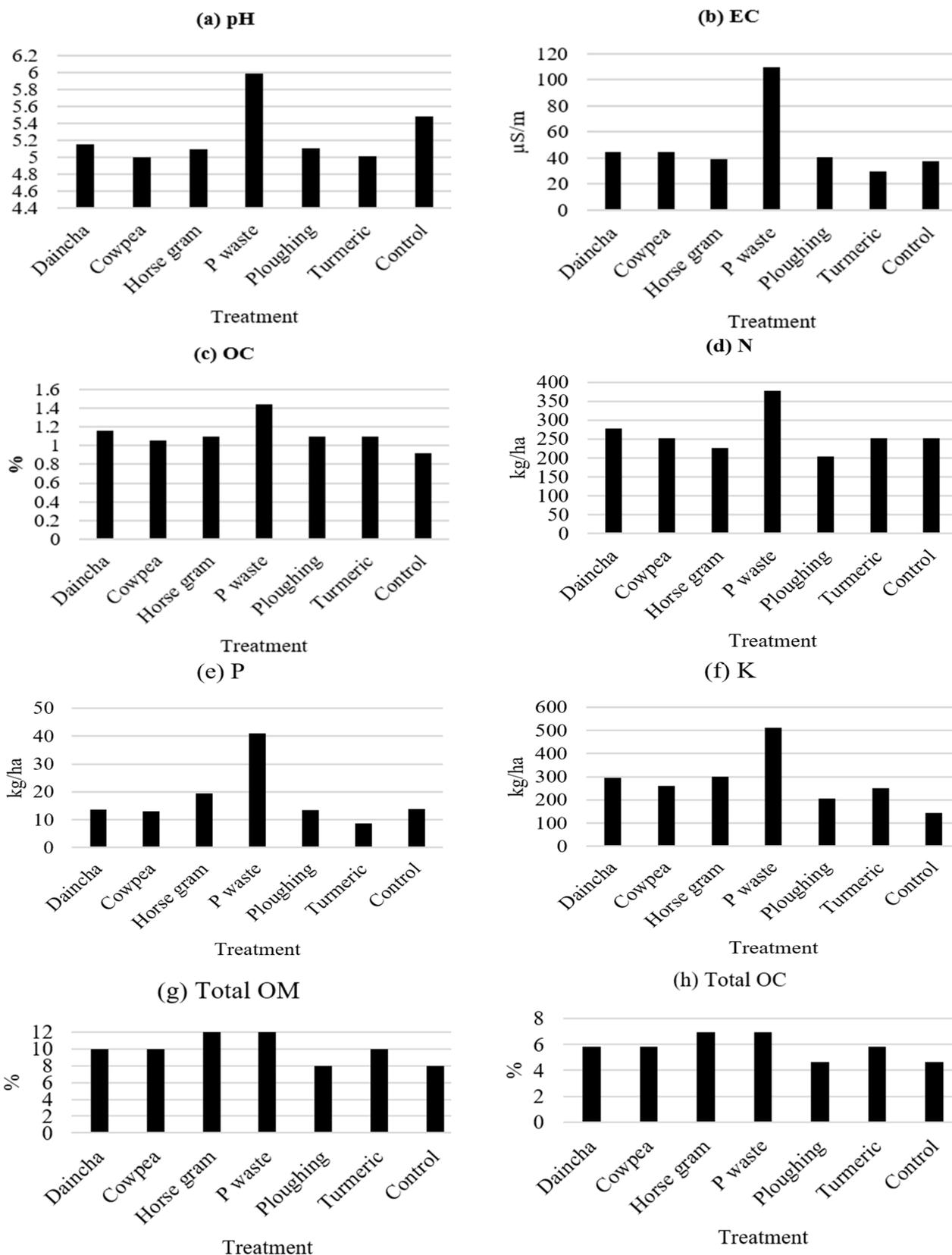


Figure 3. Soil chemical parameters (a) pH, (b) EC, (c) Organic carbon, (d) Nitrogen (N), (e), Phosphorus (P), (f) Potassium (K), (g) Total organic matter (%), (h) Total Organic carbon (%) as affected by tested treatments

Daincha - in-situ green manuring with dhaincha in the interspaces; Cowpea - in-situ green manuring with cowpea in the interspaces; Horse gram - in-situ green manuring with horse gram in the interspaces; P waste - mulching interspaces of coconut trees using phyto-pharmaceutical waste 20 t/ha; Ploughing - ploughing twice; Turmeric - intercropping with turmeric; Control – weedy check

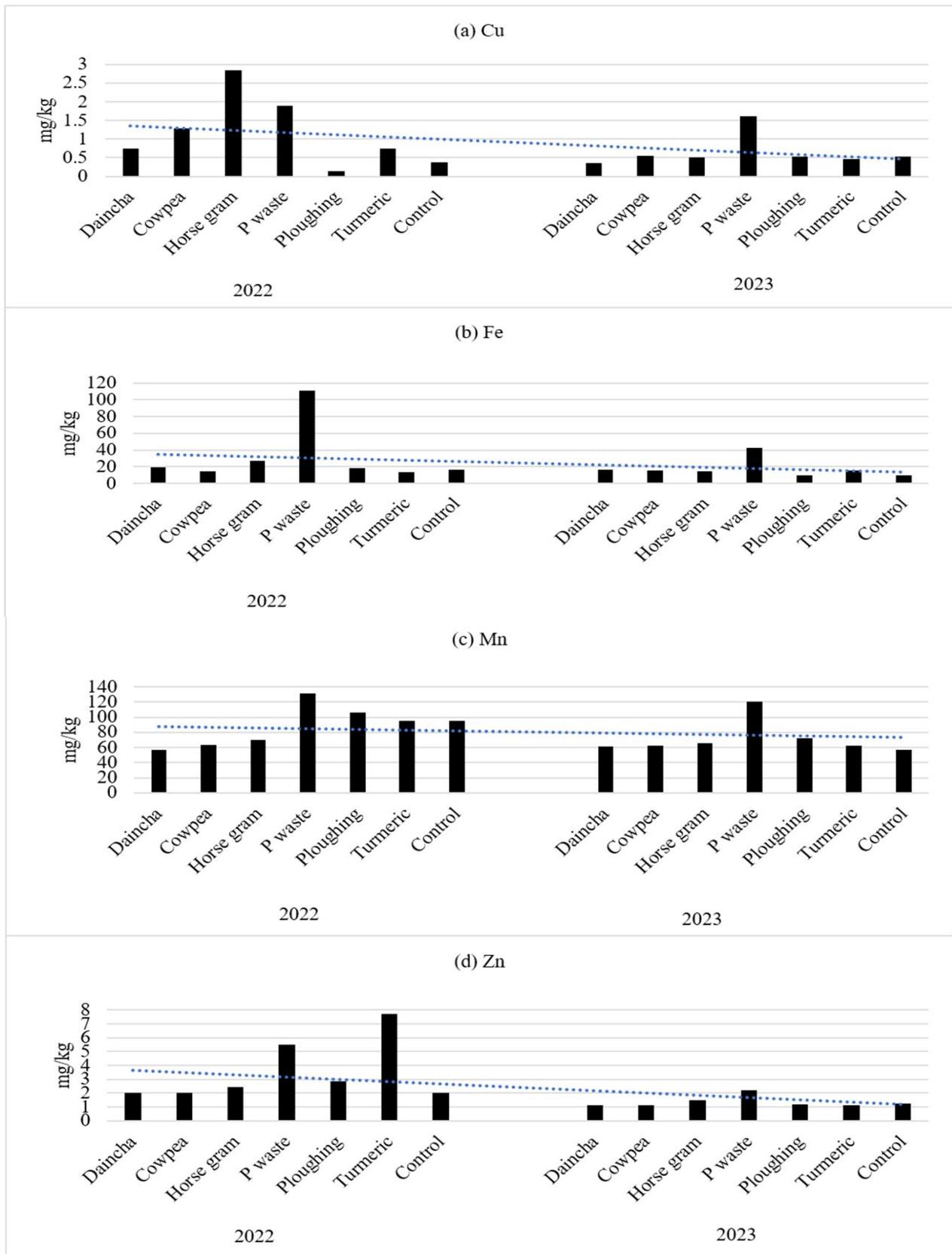


Figure 4. Soil micro-nutrient status (a) Cu, (b) Fe, (c) Mn, (d) Zn as affected by tested treatments

Dhaincha - in-situ green manuring with dhaincha in the interspaces; Cowpea - in-situ green manuring with cowpea in the interspaces; Horse gram - in-situ green manuring with horse gram in the interspaces; P waste - mulching interspaces of coconut trees using phyto-pharmaceutical waste 20 t/ha; Ploughing - ploughing twice; Turmeric - intercropping with turmeric; Control – weedy check

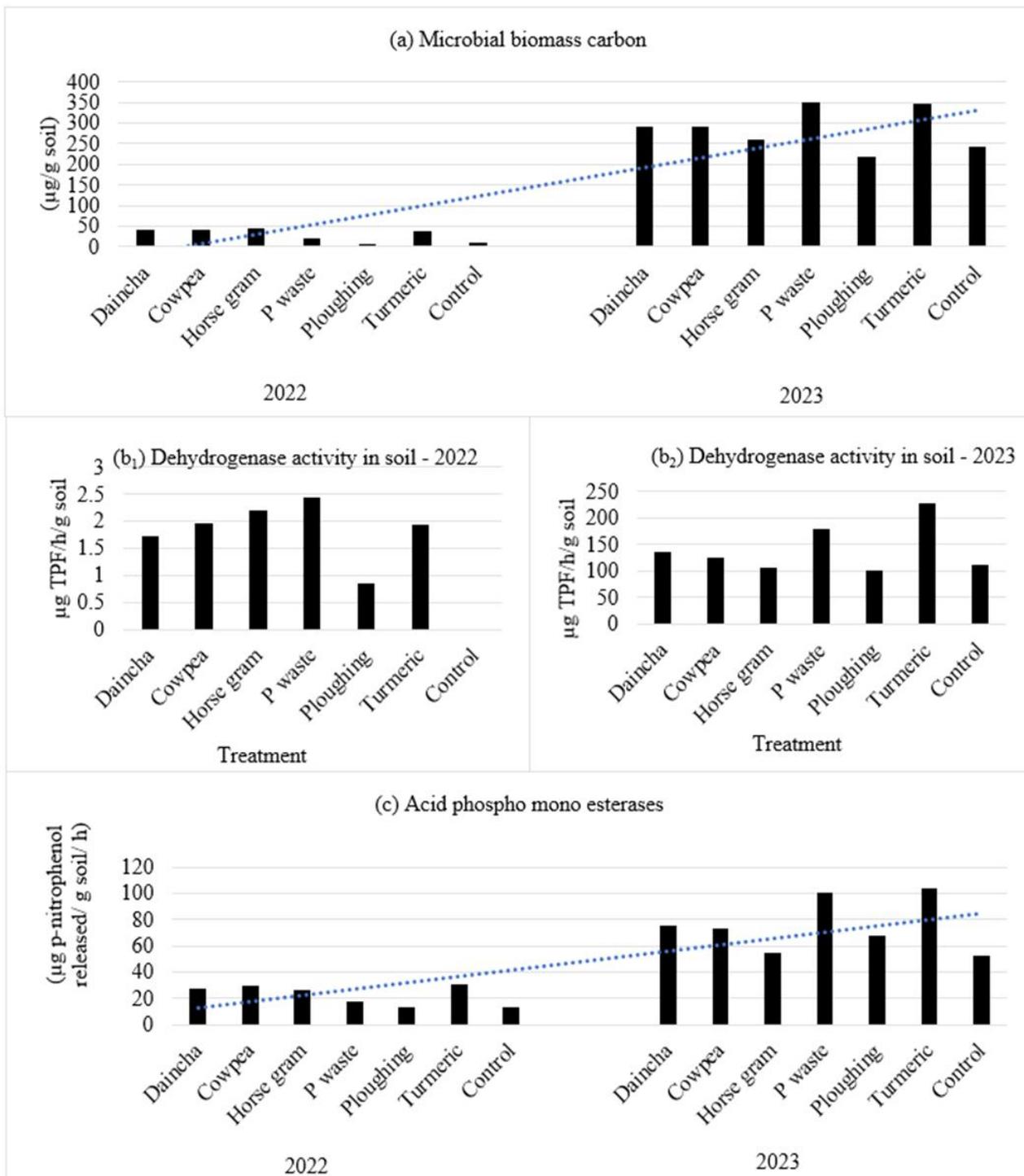


Figure 5. Soil microbiological analysis (a) Microbial biomass carbon, (b) Dehydrogenase activity, (c) Acid phospho mono esterases as affected by treatments

Dhaincha – in-situ green manuring with dhaincha in the interspaces; Cowpea – in-situ green manuring with cowpea in the interspaces; Horse gram – in-situ green manuring with horse gram in the interspaces; P waste - mulching interspaces of coconut trees using phytopharmaceutical waste 20 t/ha; Ploughing – ploughing twice, Turmeric – intercropping with turmeric; Control- weedy check

legume intercropped and organic mulched plots (Figure 6). Fungi dominated the microbial population, followed by bacteria. Actinomycetes population was lower and no definite trend could be observed with treatments. These results highlight

how legume intercropping and mulching improve soil health by creating a microbiologically active and resilient soil ecosystem, which is essential for nutrient cycling, disease suppression, and long-term soil fertility.

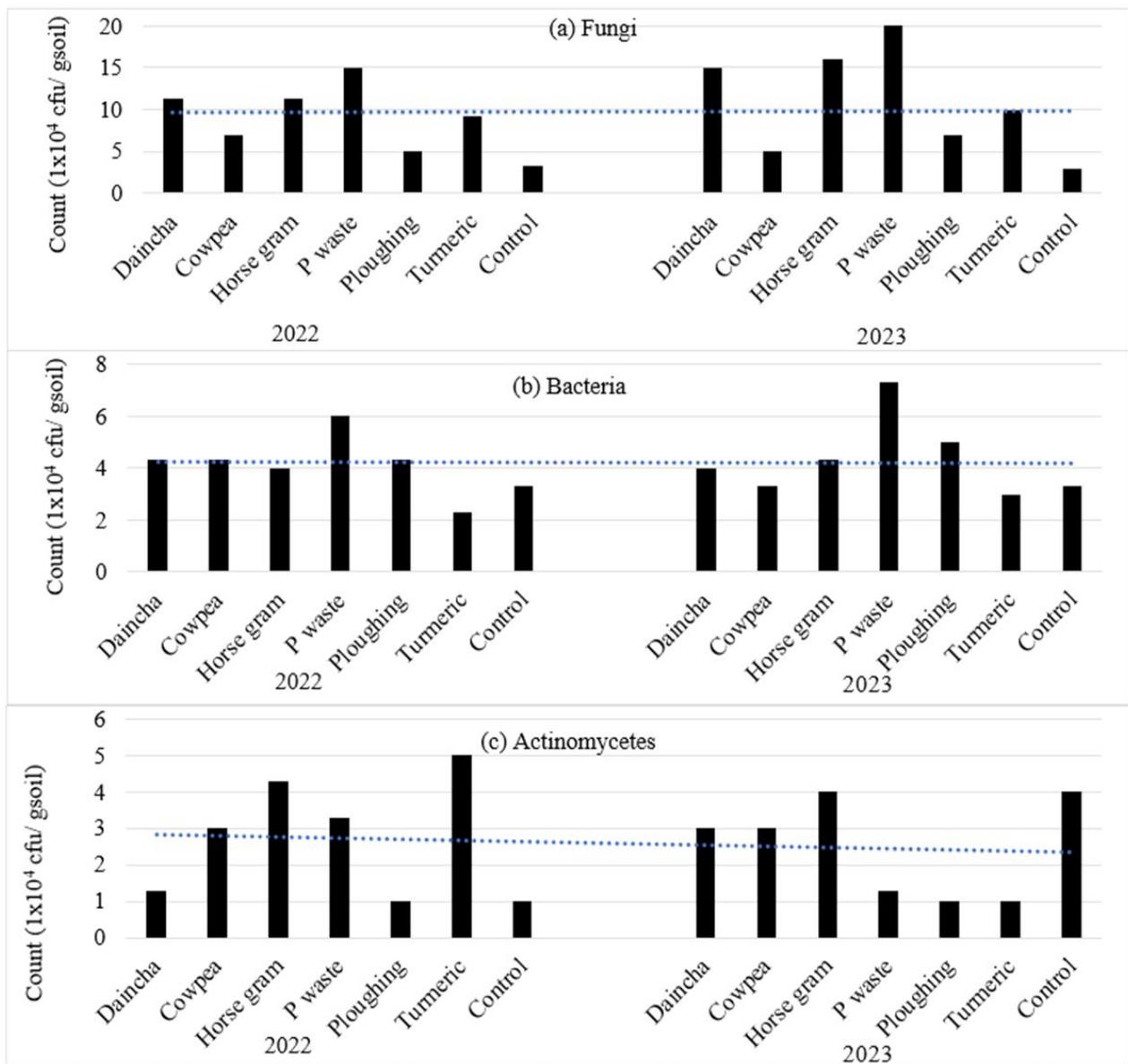


Figure 6. Soil microbial count (1x10⁴ cfu/g soil) (a) Fungi, (b) Bacteria, (c) Actinomycetes as affected by treatments Dhaincha - in-situ green manuring with dhaincha in the interspaces; Cowpea - in-situ green manuring with cowpea in the interspaces; Horse gram - in-situ green manuring with horse gram in the interspaces; P waste - mulching interspaces of coconut trees using phyto-pharmaceutical waste 20 t/ha; Ploughing - ploughing twice; Turmeric - intercropping with turmeric; Control – weedy check

The organic weed management practices—particularly *in-situ* green manuring and mulching with phyto-pharmaceutical waste offer significant agronomic and ecological benefits. Apart from effective and sustained weed suppression these substantially improved soil organic carbon, microbial activity, and overall soil health in coconut plantations. Enhanced microbial biomass and enzymatic activities, along with greater fungal and bacterial populations, indicate a more resilient and biologically active soil ecosystem.

A noticeable weed shift was observed in mulched and legume intercropped plots, where

broad-leaved weeds began to dominate over grasses, indicating a shift in weed flora composition due to reduced seed rain from grasses, altered soil conditions, and competition from leguminous cover. For natural farming conditions, legume intercropping proved particularly valuable in improving nutrient cycling and weed suppression, reinforcing the effectiveness of biodiversity-based, low-input strategies over conventional mechanical methods like ploughing. Overall, the findings of this study highlight the potential of integrated organic weed management approaches to manage weeds, promote soil health, and support long-term sustainability in perennial cropping systems of coconut.

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