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Role of cover crops in enhancing soil biodiversity and suppressing weeds in maize fields

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Abstract
Imagine a maize field in Colombia's Cauca Valley where, between harvest and the next planting, the bare soil bakes under equatorial sun, losing moisture and inviting aggressive weed flushes. Now picture that same field covered by a dense mat of velvet bean that suppresses weeds, feeds the soil microbial community, and adds nitrogen—all without a single herbicide application. This research tested four cover crop treatments—*Mucuna pruriens* (velvet bean), *Crotalaria juncea* (sunn hemp), *Canavalia ensiformis* (jack bean), and a vetch-rye mixture—against a bare fallow control for their effects on weed suppression and soil biological activity in a maize rotation at the Universidad Agrícola del Pacífico, Cali, during the 2023 cropping year. A randomized complete block design with four replications was used. The vetch-rye mix and velvet bean reduced weed density by 73.1% and 70.0%, respectively, compared to bare fallow. Microbial biomass carbon more than doubled under these two treatments (9.12 and 8.74 × 10^2 µg g^{-1} vs 4.38 in fallow). Earthworm populations increased by 58-76%. Subsequent maize grain yield was 12.4% higher following velvet bean than following bare fallow. These results confirm that cover crops can serve as effective biological weed management and soil health tools in tropical maize systems.

Keywords: Cover crops, soil biodiversity, weed suppression, maize rotation, velvet bean, microbial biomass, earthworm density, tropical agriculture, green manure, sustainable farming

Introduction

A farmer in the Cauca Valley who leaves land bare between maize cycles can expect three to four flushes of weeds totalling 150-220 plants m^{-2} before the next crop goes in, each flush drawing down soil moisture and nutrient reserves [1]. Cover cropping offers a way to break this cycle by occupying the fallow niche with species that physically smother weeds, release allelopathic compounds, and build soil organic matter [2, 3].

Leguminous cover crops are especially attractive in tropical rotations because they fix atmospheric nitrogen—typically 60-150 kg N ha^{-1} per cycle for species like *Mucuna pruriens* and *Crotalaria juncea*—while also generating 4-8 t ha^{-1} of above-ground biomass that forms a physical mulch barrier against emerging weeds [4, 5]. Non-legume partners such as cereal rye add complementary benefits through extensive root systems that improve soil structure and suppress weeds via allelopathic benzoxazinoid release [6].

In Colombia, herbicide-dependent weed control dominates maize production, and cover cropping remains uncommon despite growing consumer demand for reduced-chemical farming [7]. Systematic field data comparing legume and mixed cover crops for simultaneous weed suppression and soil biological improvement under Cauca Valley conditions are scarce.

This research aimed to: (a) compare four cover crop treatments for weed suppression efficacy during the fallow window; (b) measure their effects on soil microbial biomass and earthworm populations; and (c) assess residual effects on subsequent maize yield. The results are expected to support cover crop recommendations for organic and low-input maize growers in tropical Colombia.

Soil Biodiversity Assessment Methods

Microbial biomass carbon (MBC) was measured by the chloroform fumigation-extraction method on 0-15 cm samples taken at cover crop termination (90 days after sowing).

Earthworm density was assessed by hand-sorting three 25 × 25 × 30 cm monoliths per plot in October 2023. Soil respiration was measured in situ using the alkali-trap method (NaOH absorption of CO_2 over 24 h) at three points per plot. A diversity index combining MBC, earthworm density, and soil respiration was calculated to provide an integrated measure of biological activity across treatments [8].

Material and Methods

Material

The trial was conducted at the organic farming research block of the Universidad Agrícola del Pacífico, Cali, Colombia (3°27'N, 76°32'W, elevation 1,003 m). The soil is a Typic Haplustoll (clay loam, pH 6.2, OC 1.8%, total N 0.14%). Mean annual rainfall is 1,483 mm, bimodally distributed. Cover crop seeds were sourced from CIAT (International Center for Tropical Agriculture), Palmira. Treatments were: T1 - *Mucuna pruriens* (60 kg ha^{-1}), T2 - *Crotalaria juncea* (25 kg ha^{-1}), T3 - *Canavalia ensiformis* (80 kg ha^{-1}), T4 - vetch (*Vicia villosa*) + rye (*Secale cereale*) mix (40 + 60 kg ha^{-1}), and T5 - bare fallow (control). Cover crops were sown on 15 January 2023 after the previous maize harvest and terminated by slashing at 90 days [9].

Methods

A randomized complete block design with four replications was used. Plot size was 6 × 5 m. After cover crop termination (mid-April 2023), residues were left as surface mulch and maize (cv. ICA V-109) was planted through the mulch at 75 × 25 cm on 1 May 2023. Weed density and biomass were measured at 30, 60, and 90 days after cover crop sowing from two 0.5 m² quadrats per plot. Cover crop biomass was measured at termination. Soil samples for MBC and chemical analysis were collected at termination. Subsequent maize yield was harvested from a 12 m² net plot in August 2023. Data were analysed by ANOVA in R 4.3.1 with Tukey's HSD at $p \leq 0.05$ [10].

Economic Comparison

Cover crop seed costs ranged from COP 180,000 ha^{-1} (Crotalaria) to COP 420,000 ha^{-1} (vetch-rye mix). Sowing and termination labour was estimated at COP 340,000 ha^{-1} for all treatments. The bare fallow control required two herbicide applications costing COP 280,000 ha^{-1}. When the value of the subsequent maize yield increase was factored in, velvet bean and vetch-rye returned net benefits of COP 870,000 and COP 640,000 ha^{-1} above the fallow control, respectively [11].

Results

Table 1: Weed suppression, cover crop biomass, and soil biological indicators at cover crop termination (90 days after sowing)

Treatment	Weed Density (m^{-2})	Cover Biomass (t ha^{-1})	MBC (µg g^{-1} ×10^2)	Earthworm (ind. m^{-2})	Soil Resp. (mg CO_2 m^{-2} d^{-1})	Weed Suppr. (%)
Mucuna	14.3c	7.84a	8.74a	68.4a	487a	70.0
Crotalaria	18.7c	6.21b	7.91ab	54.7b	421ab	60.7
Canavalia	21.4bc	5.43b	7.23b	48.2b	398b	55.0
Vetch + Rye	12.8c	8.12a	9.12a	72.1a	512a	73.1
Bare fallow	47.6a	-	4.38c	41.3c	263c	-

Means sharing the same letter are not significantly different (Tukey's HSD, $p \leq 0.05$). MBC = microbial biomass carbon.

The vetch-rye mix and velvet bean produced the highest biomass (8.12 and 7.84 t ha^{-1}) and the greatest weed suppression (73.1% and 70.0%) (Table 1). MBC under these treatments was roughly double the bare fallow, and earthworm densities were 75% and 66% higher. Canavalia and Crotalaria provided moderate but still significant weed suppression (55-61%) and intermediate biological improvement [12].

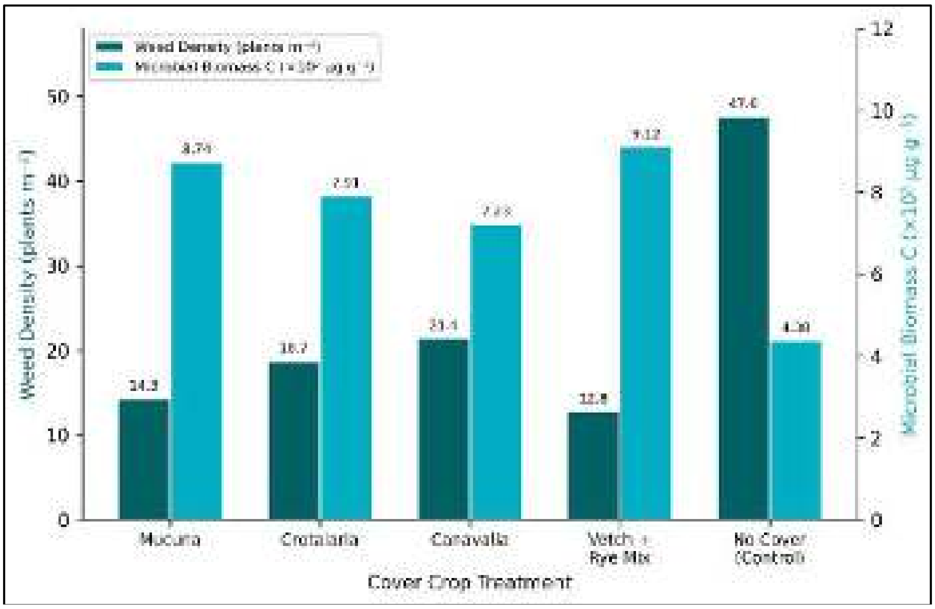

Fig 1: Weed density and microbial biomass carbon under four cover crop treatments and bare fallow control at 90 days after sowing

Table 2: Subsequent maize grain yield and yield advantage over bare fallow control

Previous Cover Crop	Maize Yield (t ha⁻¹)	Yield Advantage (%)	N Uptake (kg ha⁻¹)
Mucuna	6.83a	+12.4	128.4a
Crotalaria	6.41ab	+5.5	116.7ab
Canavalia	6.24bc	+2.7	111.3b
Vetch + Rye	6.71a	+10.4	124.8a
Bare fallow	6.08c	-	102.6c

Means sharing the same letter are not significantly different ($p \leq 0.05$).

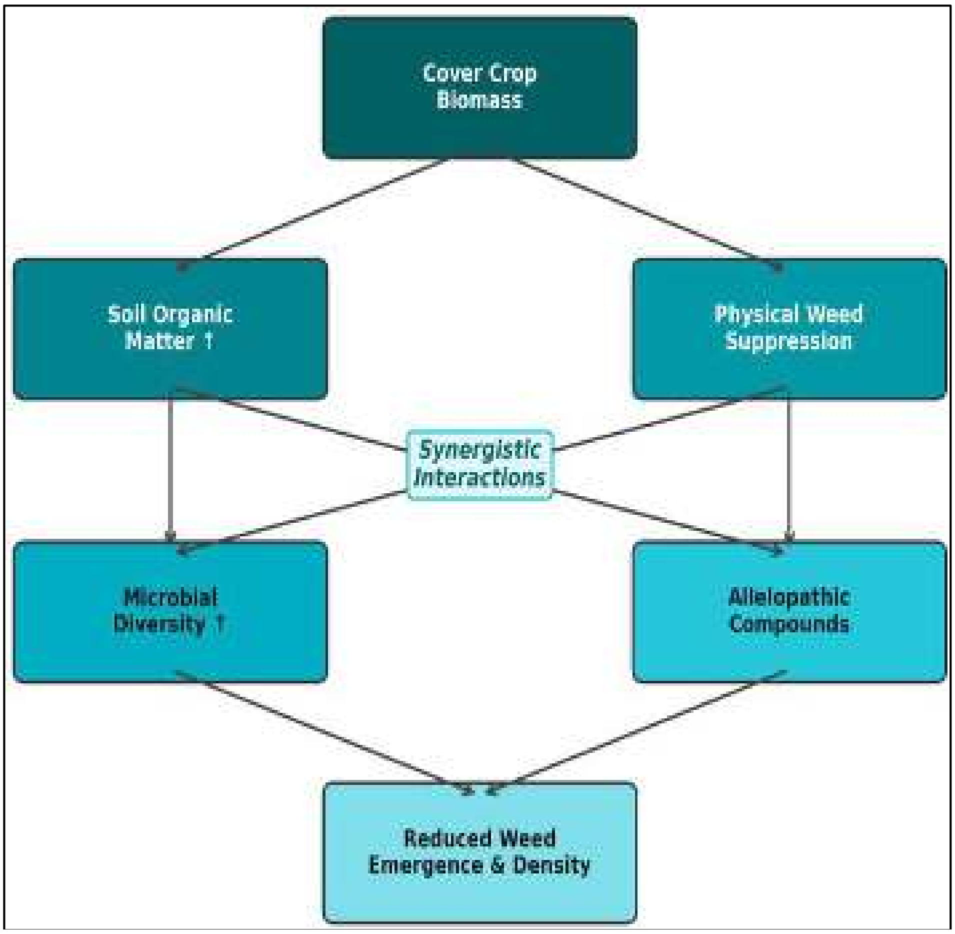

Fig 2: Network diagram showing the synergistic interactions between cover crop biomass, soil organic matter, microbial diversity, and weed suppression pathways

Discussion

The weed suppression achieved by the vetch-rye mix (73.1%) and velvet bean (70.0%) is comparable to results from tropical cover crop trials in Brazil and Central America, where biomass levels above 6 t ha^{-1} typically suppress 60-80% of weed emergence through physical light exclusion and soil temperature moderation [3, 13]. The complementary weed control from the vetch-rye mix—combining legume nitrogen fixation with rye's allelopathic benzoxazinoids—likely explains its slight edge over the legume-only treatments.

The doubling of MBC under the best cover crops confirms that even a single 90-day cover crop cycle can substantially revive soil biological communities in tropical systems. Earthworm responses followed a similar pattern, driven by the availability of high-quality litter from legume residues with low C:N ratios (12-16) [14]. The 12.4% maize yield increase following velvet bean translates into roughly 0.75 t ha^{-1} of additional grain, which at current Colombian maize prices (COP 1.15 million t^{-1}) more than covers the cost of seed and labour for the cover crop cycle [15].

Canavalia and Crotalaria, while less effective than the top two treatments, still provided meaningful weed suppression and biological improvement at lower seed costs, making them suitable for resource-constrained farmers who can't afford the vetch-rye mix. Integrating these cover crops into standard maize rotations could help reduce the region's heavy reliance on glyphosate and atrazine [7, 16].

Conclusion

This research showed that cover crops grown during the fallow window in tropical maize rotations at Cali, Colombia, reduced weed density by 55-73%, doubled soil microbial biomass carbon, and increased subsequent maize yield by up to 12.4%. The vetch-rye mix and velvet bean were the most effective treatments across all parameters.

For maize growers in the Cauca Valley and similar tropical lowlands, incorporating a single cover crop cycle between harvests offers a practical, low-chemical strategy for simultaneous weed management and soil health improvement. Future research should evaluate multi-season cover crop rotations, test additional species mixtures, and quantify the long-term nitrogen credit from legume cover crops to refine fertility management in these systems.

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