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Multifunctional Cover Crops for Sustainable Intensification: Agronomic Performance, Weed Suppression and Soil Quality in Cameroon

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Abstract

Sustainable intensification in humid tropical smallholder systems requires technologies that stabilise yields, suppress weeds and regenerate soils, while reducing dependence on synthetic inputs. Against this backdrop, we evaluated the adaptability and multifunctional performance of five herbaceous cover crops—*Mucuna pruriens*, *Cajanus cajan*, *Stylosanthes guianensis*, *Crotalaria juncea* and *Crotalaria retusa*—in the Mount Cameroon Region, focusing on agronomic traits, weed suppression and soil chemical dynamics. A field experiment was established in a Randomised Complete Block Design with five cover crop treatments plus a weedy fallow control. Measurements included nodulation, canopy development, fresh and dry biomass, weed density and biomass, diversity indices, and pre- and post-season soil properties (pH, organic matter and carbon, total N, available P, exchangeable K, Ca and Mg). Results revealed that *M. pruriens* exhibited superior nodulation (9.33 ± 0.33) and rapid canopy closure (97.2% ground cover by Week 12), while *C. retusa* produced the highest dry biomass (5.76 ± 0.67 t ha^{-1}; $p < 0.05$). Across species, cover cropping increased soil pH by about 7.1% relative to baseline and raised organic matter and organic carbon by 10.7% and 16.1%, respectively. In contrast, available P declined by 25.3% ($p < 0.001$) and exchangeable Ca, Mg and K decreased significantly ($p < 0.001$), reflecting strong nutrient uptake and possible leaching in high-rainfall volcanic soils; *M. pruriens* and *C. retusa* plots retained comparatively higher cation levels, indicating superior nutrient capture. Weed suppression responses were species-specific: *M. pruriens* reduced weed biomass by up to 98% relative to the weedy fallow ($p < 0.05$), driven by dense canopy cover, whereas *S. guianensis* was consistently the least effective suppressor, and problem weeds such as *Ageratum conyzoides*, *Eleusine indica* and *Cyperus rotundus* persisted mainly in non-Mucuna plots. *C. retusa* and *M. pruriens* offered the most favourable trade-offs between biomass production, weed control and soil quality enhancement. We therefore recommend their combined integration as complementary cover crops in resilient, low-herbicide rotations for the Mount Cameroon Region and analogous humid tropical agro-ecosystems.

Keywords: Cover crops, humid tropics, soil fertility, sustainable intensification, weed suppression

Introduction

Smallholder cropping systems across the humid tropics of Cameroon face declining soil fertility, persistent weed pressure and growing dependence on synthetic herbicides, particularly on the high-rainfall volcanic soils that surround Mount Cameroon (Tening & Foba-Tendo, 2013; Kenneth et al., 2017). Herbaceous cover crops offer a low-input route to sustainable intensification because they combine biological nitrogen fixation, rapid canopy closure and residue return with the capacity to suppress weeds without herbicides (Blanco-Canqui et al., 2015). *Mucuna pruriens*, *Cajanus cajan*, *Stylosanthes guianensis*, *Crotalaria juncea* and *Crotalaria retusa* are already used across sub-Saharan Africa for soil regeneration and weed control (Ekeleme et al., 2003; Nanganoa et al., 2019; Atakoun et al., 2023), and Crotalaria-based systems have shown promising biomass and soil benefits in the western highlands of Cameroon (Beyegue Djonko et al., 2022). Comparative, multi-species evidence for agro-ecological zone IV at the foot of Mount Cameroon—where high rainfall, strongly P-fixing andosols and intense weed pressure combine—remains scarce, and wider adoption of conservation-agriculture practices in the region continues to be constrained by limited local performance data (Angwafo & Danernyuy, 2020). This study therefore evaluated the agronomic performance, weed-suppressive ability and effects on soil chemical quality of five herbaceous cover crops relative to a weedy fallow, to identify species best suited to climate-resilient, low-herbicide cropping systems for the Mount Cameroon Region and comparable humid tropical agro-ecosystems.

Material and Methods

The trial was conducted from May to October 2024 at the Teaching and Research Farm of the Faculty of Agriculture and Veterinary Medicine, University of Buea, Fako Division, South-West Region, Cameroon (3°57′–4°28′N, 8°58′–9°24′E; agro-ecological zone IV). The site lies at the foot of Mount Cameroon on well-drained volcanic loam, receives 2500–3500 mm rainfall per year, and has a mean temperature of 25 °C and relative humidity of 75–80%. Treatments—*M. pruriens* (60 kg ha^{-1}), *C. juncea* (30 kg ha^{-1}), *C. retusa* (25 kg ha^{-1}), and *C. cajan* and *S. guianensis* (20 kg ha^{-1} each), sown at 30 cm row spacing, plus an unplanted weedy fallow control—were arranged in a Randomised Complete Block Design with four replicates (24 plots of 3 × 4 m). A pre-plant herbicide (BASNATE 200SL) was applied two weeks before sowing; cover crops were terminated by slashing at 15 WAP. Nodulation was scored on five plants per treatment at 8 weeks after planting (WAP) using a 0–9 rating (Solomon et al., 2012). Canopy cover was estimated biweekly from Week 1 to 12 using the Braun-Blanquet visual scale on five 1 m² quadrats per plot (Braun-Blanquet, 1965). Cover-crop and weed fresh and dry biomass (oven-dried at 60 °C for 48 h) and weed density were recorded at 8 and 12 WAP from four 0.5 m² quadrats per plot, following Phophi et al. (2017); weeds were identified from field photographs cross-checked against the PlantNet application and a regional field guide, and weed-community diversity was summarised with the Simpson Dominance and Shannon-Wiener indices (Nkoa et al., 2015). Composite soil samples (0–20 cm) were taken before planting (baseline) and after termination from each treatment and analysed at IRAD-Nkolbisson for pH (1:5 soil–water), organic carbon (Walkley-Black), total nitrogen (Kjeldahl), available phosphorus (Bray II) and exchangeable Ca, Mg and K (atomic absorption/flame photometry). Data were tested for normality (Shapiro-Wilk) and homogeneity of variance (Levene) in R v4.3.2, then compared among treatments by one-way ANOVA with Tukey's HSD (or Kruskal-Wallis with Dunn's test where assumptions were violated); baseline-versus-post-treatment soil values were compared by paired t-test or Wilcoxon signed-rank test, and species were additionally ranked for each functional domain using a rank summation index.

Results and Discussion

Cover crop species differed markedly in nodulation, canopy development and biomass accumulation (Figure 1). *M. pruriens* formed significantly more root nodules than all other species at 8 WAP (9.33 ± 0.33; ANOVA $F_{4,15} = 12.35$, $p < 0.001$) and also achieved the fastest canopy closure (97.2 ± 1.2% by Week 12), significantly exceeding *C. cajan*, *C. juncea* and *S. guianensis* (50.5–68.1%) but not *C. retusa* (71.8 ± 1.0%; $F_{4,10} = 15.89$, $p = 0.0001$), consistent with the rapid twining growth habit reported for *M. pruriens* in the moist savanna of Nigeria (Ekeleme et al., 2003). *C. retusa* instead produced the highest total dry biomass at 12 WAP (5.76 ± 0.67 t ha^{-1}), significantly exceeding *C. cajan* (3.11 ± 0.42), *C. juncea* (2.52 ± 0.31), *M. pruriens* (1.63 ± 0.19) and *S. guianensis* (0.36 ± 0.05 t ha^{-1}; $p < 0.05$), a biomass advantage broadly consistent with *C. retusa* performance recorded on Andic Ferralsols in the western highlands of Cameroon (Beyegue Djonko et al., 2022) and with earlier-season biomass levels reported for legume cover crops in northern Benin (Atakoun et al., 2023). Rank summation across nodulation, canopy cover and biomass placed the five species in the order *C. retusa* > *M. pruriens* > *C. cajan* > *C. juncea* > *S. guianensis*, indicating that no single species dominated every agronomic trait and that species choice should be matched to the specific function required.

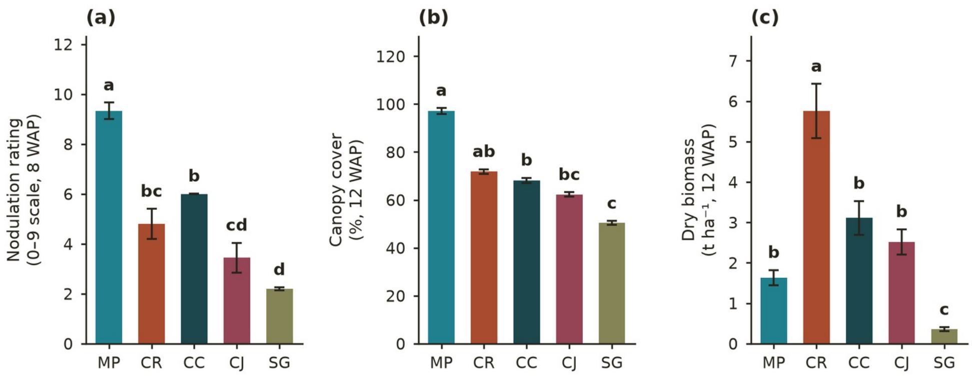

Figure 1: Mean (±SE) (a) nodulation rating at 8 weeks after planting (WAP), (b) canopy cover at 12 WAP, and (c) total dry biomass at 12 WAP for five cover crop species (MP = *M. pruriens*, CR = *C. retusa*, CC = *C. cajan*, CJ = *C. juncea*, SG = *S. guianensis*) at the University of Buea Teaching and Research Farm, 2024. Bars sharing no common lowercase letter differ significantly within each panel (Tukey's HSD, $p < 0.05$).

Relative to pre-planting baseline values, pooled post-treatment soil pH, organic matter and organic carbon all increased significantly (Table 1), consistent with residue decomposition and root turnover under cover cropping reported in reviews across temperate and tropical soils alike (Blanco-Canqui et al., 2015) and with cover-crop-driven soil carbon gains recorded elsewhere in Cameroon's humid forest zone (Nanganoa et al., 2019). Total nitrogen did not change significantly overall, whereas available phosphorus and exchangeable Ca, Mg and K all declined significantly ($p < 0.001$). This pattern is consistent with strong biological uptake by the fast-growing cover crops combined with leaching losses characteristic of high-rainfall volcanic andosols, which independently show a marked intrinsic capacity to fix and immobilise phosphorus in this landscape (Tening & Foba-Tendo, 2013; Kenneth et al., 2017). Species-level ANOVA also detected significant differences in post-treatment organic matter ($F_{4,10} = 3.33$, $p = 0.046$) and total nitrogen ($F_{4,10} = 11.06$, $p = 0.026$): Tukey's HSD confirmed *S. guianensis* exceeded *C. retusa* in organic matter (77.6 vs 60.2 g kg^{-1}; $p < 0.05$), and that *C. retusa* and *S. guianensis* exceeded *C. cajan* in total nitrogen (1.56 g kg^{-1}; $p < 0.05$); pH, organic carbon and the exchangeable cations showed no significant among-species differences ($p > 0.05$). Notably, *M. pruriens* and *C. retusa* plots retained comparatively higher residual cation levels than the other treatments, suggesting more efficient nutrient capture and banking, and a soil-based rank summation placed the species in the order *M. pruriens* > *C. juncea* > *S. guianensis* > *C. retusa* > *C. cajan*.

Table 1: Soil chemical properties before planting (baseline, n = 3 composite samples) and after cover-crop termination (pooled post-treatment mean ± SE across five cover-crop treatments, n = 15), University of Buea Teaching and Research Farm, 2024. Significance = paired baseline-vs-post-treatment test; among-species Tukey's HSD results for organic matter and total N are reported in the text above.

Soil property	Baseline	Post-treatment	Change (%)	Significance
pH (H_2O)	4.38 ± 0.00	4.69 ± 0.03	+7.1	$p < 0.001$
Organic matter (g kg^{-1})	63.73 ± 0.00	69.00 ± 2.16	+10.7	$p = 0.023$
Organic carbon (g kg^{-1})	36.39 ± 0.00	42.24 ± 1.83	+16.1	$p = 0.002$
Total N (g kg^{-1})	1.76 ± 0.00	1.75 ± 0.06	−0.6 (ns)	$p = 0.767$
Available P (mg kg^{-1})	26.97 ± 0.00	20.14 ± 0.81	−25.3	$p < 0.001$
Exch. Ca (cmol kg^{-1})	5.17 ± 0.00	3.57 ± 0.17	−31.0	$p < 0.001$
Exch. Mg (cmol kg^{-1})	1.84 ± 0.00	1.18 ± 0.06	−35.9	$p < 0.001$
Exch. K (cmol kg^{-1})	1.46 ± 0.00	0.65 ± 0.04	−55.5	$p < 0.001$

Weed suppression was strongly species-specific and closely tracked canopy development (Figure 2). *M. pruriens* reduced weed fresh biomass at 12 WAP to 0.32 ± 0.32 t ha^{-1}, about 98% below the weedy fallow (14.47 ± 1.24 t ha^{-1}; $F_{5,12} = 14.72$, $p < 0.0001$, Tukey's HSD), and weed density fell to 5.3 ± 1.3 plants m^{-2} versus 130 ± 39.5 in the fallow, consistent with reports of allelopathic root exudates contributing to weed suppression in Cameroonian cropping systems (Ndam et al., 2021, 2025). *M. pruriens* was the only treatment that differed significantly from the fallow; *C. retusa* (4.79 ± 0.40), *C. juncea* (6.41 ± 1.76), *C. cajan* (7.26 ± 2.46) and *S. guianensis* (13.50 ± 1.76 t ha^{-1}) did not differ significantly from one another or from the fallow ($p > 0.05$), reflecting *S. guianensis*'s slower establishment and more open canopy relative to the other species (Phophi et al., 2017). Weed species richness rose from 14 taxa at 8 WAP to 20 at 12 WAP, with *Ageratum conyzoides*, *Eleusine indica* and *Cyperus rotundus* most abundant, persisting mainly in non-Mucuna plots (Nkoa et al., 2015). The weed-suppression rank summation followed *M. pruriens* > *C. retusa* > *C. cajan* > *C. juncea* > *S. guianensis*.

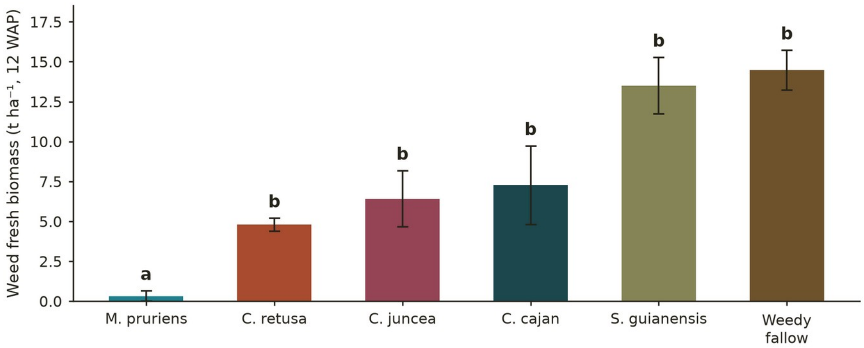

Figure 2: Mean (±SE) weed fresh biomass at 12 weeks after planting under five cover crop treatments and a weedy fallow control, University of Buea Teaching and Research Farm, 2024. Bars sharing no common lowercase letter differ significantly (Tukey's HSD, $p < 0.05$).

Conclusions and Outlook

The five cover crops evaluated differed substantially in agronomic performance, weed-suppressive ability and effects on soil chemical properties under Mount Cameroon Region conditions, and no single species was best across all three functions. *M. pruriens* and *C. retusa* emerged as the most multifunctional options: *M. pruriens* combined the fastest canopy closure and by far the strongest weed suppression with favourable nutrient retention, while *C. retusa* delivered the highest biomass and the second-best soil ranking. *S. guianensis* consistently under-performed as a single-species stand and may be better deployed in mixtures. We recommend prioritising *M. pruriens* and *C. retusa*, ideally in combination, for low-herbicide, climate-resilient rotations with banana, plantain or maize in the region, alongside targeted management of the post-season decline in available P and exchangeable cations—for example through rock phosphate or organic amendments—given the inherently strong P-fixing capacity of Mount Cameroon's volcanic soils (Tening & Foba-Tendo, 2013). Multi-year, multi-site trials that test cover-crop mixtures, a wider range of species and residual soil seedbank effects are needed before these recommendations are extended more broadly.

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