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ORIGINAL ARTICLE

Cultivation of pink pepper in succession to cover crops and bokashi application[1]

Cultivo de pimenta rosa em sucessão a plantas de cobertura e aplicação de Bokashi

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HIGHLIGHTS:

Cover crops improve pink pepper production.
Millet and spontaneous vegetation are efficient in P and K cycling.
Pink pepper production is correlated with the application of bokashi.

ABSTRACT: Cover crops have the potential to improve economic viability while simultaneously mitigating the environmental impacts of agriculture. Pink pepper, known for its ecoplasticity and rapid growth, can be cultivated under various management systems. This study aims to assess the influence of biostimulant application on the mass production, nutrient release, and productivity of pink pepper following cover crops, focusing on carbon sequestration, soil health, and production optimization. The experimental design employed a randomized block in a 4 × 2 × 5 factorial arrangement. Three cover crops (crotalaria, stylosanthes, and millet) were compared with a control-group (spontaneous vegetation), with or without FertBokashi® application. Evaluation occurred at five periods (0, 45, 90, 135, and 180 days post-cutting). Mass production and N, P, and K release were measured for over crops. Pink pepper plants were harvested at 270 days post-transplanting to assess leaf, stem, and fruit mass productivity. The residual mass of pearl millet and spontaneous vegetation showed the highest P and K levels at cutting and 180 days later, indicating significant potential for nutrient cycling by millet and certain spontaneous vegetation species. Pink pepper plants exhibited higher fresh leaf mass (386.46 g per plant) and fruit mass (80.82 g per plant) when cultivated after spontaneous vegetation and with FertBokashi® application. Soil application of FertBokashi® positively influenced pink pepper leaf and fruit production.

Key words: *Schinus terebinthifolia*, soil cover, organic activator

RESUMO: A adubação verde pode melhorar a viabilidade econômica e reduzir os impactos ambientais da agricultura. A pimenta rosa possui ecoplasticidade e desenvolvimento rápido, podendo ser cultivada sob diferentes sistemas de manejo. O objetivo deste estudo foi avaliar como a aplicação de bioestimulante influencia a produção de massa, liberação de nutrientes e produtividade da pimenta rosa em sucessão às culturas de cobertura, com ênfase no sequestro de carbono, saúde do solo e otimização da produção. O delineamento estatístico foi o de blocos casualizados, em arranjo fatorial 4 × 2 × 5, correspondendo a três adubos verdes (crotalária, estilosantes e milheto, além da testemunha - vegetação espontânea), com ou sem aplicação de FertBokashi® sobre o solo e cinco épocas de avaliação (0, 45, 90, 135 e 180 dias após o corte). Dos adubos verdes foram avaliadas as produções de massa e liberação de N, P e K. As plantas de pimenta rosa foram cortadas aos 270 dias após o transplante para mensuração das massas de folhas, caules e frutos. Os maiores teores de P e K na massa remanescente do milheto e da vegetação espontânea no dia e aos 180 dias após o corte sugere seu elevado potencial de ciclagem desses nutrientes. As plantas da pimenta rosa produziram mais massa de folhas (386,46 g por planta) e frutos (80,82 g por planta) quando cultivadas em sucessão à vegetação espontânea e com aplicação do FertBokashi®. O uso do FertBokashi® no solo contribui para maior produção de folhas e frutos da pimenta rosa.

Palavras-chave: *Schinus terebinthifolia*, cobertura do solo, ativador orgânico

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Introduction

Cover crops offer various benefits to the soil, such as enhancing nutrients, promoting organic carbon sequestration, and improving soil health (Hu et al., 2023). Studies, including those by Dourado Neto et al. (2014), have explored biostimulants like bokashi to maximize plant genetic potential. Bokashi, a balanced blend of organic matter undergoing fermentation by beneficial microorganisms (Baldotto & Baldotto, 2016), enhances growth and production by increasing cation exchange capacity, soil pH, and nutrient availability (Sible et al., 2021).

Pink pepper (*Schinus terebinthifolia* Raddi, Anacardiaceae), a popular evergreen shrub or tree, is widely distributed in the Atlantic Forest of Brazil (Tlili et al., 2018). As a pioneer species, it exhibits high growth rates and vigorous regrowth (Velasques et al., 2021), making it essential for heterogeneous reforestation in degraded areas (Kettenhuber et al., 2023).

Pink pepper has been extensively studied from a chemical perspective, as indicated by the literature; however, there is a dearth of detailed agronomic research focused on enhancing fruit yield and the production of secondary metabolites with medicinal value (Carnevali et al., 2020). In this context, an improved understanding of how to manage the interaction between various cover crops, pink pepper, and Bokashi can lead to enhanced crop management, resulting in increased productivity, superior product quality, and reduced environmental impact. Therefore, the aim of this study was to assess the impact of biostimulant application on biomass production, nutrient release, and the productivity of pink pepper following cover crops, with a focus on carbon sequestration, soil health, and production optimization.

Material and Methods

The research was conducted under field conditions from January 2017 to January 2018 at the Horto de Plantas Medicinais (HPM) of the Universidade Federal da Grande Dourados (UFGD) in Dourados, MS, Brazil. The experimental site is situated at 22° 11’ 43.7” S latitude and 54° 56’ 08.5” W longitude, with an elevation of 458 m. The soil in the study area is classified as Oxisols (USDA, 2014), with the following chemical characteristics at a depth of 0-0.20 m prior to sowing cover crops were: pH ($CaCl_2$) = 5.31; pH (H_2O) = 6.12; P (mg dm^{-3}) = 17.96; K ($cmol_c dm^{-3}$) = 0.47; Al^{+3} ($cmol_c dm^{-3}$) = 0; Ca($cmol_c$ dm^{-3}) = 3.21; Mg ($cmol_c$ dm^{-3}) = 2.37; H+Al ($cmol_c$ dm^{-3}) = 2.57; pH = 6.59; SB ($cmol_c$ dm^{-3}) = 6.21; CEC ($cmol_c$ dm^{-3}) = 8.97; base saturation (%) = 65.

The experimental arrangement followed a 4 × 2× 5 factorial scheme in a randomized block design with four replicates. Each plot had a useful area of 8.0 m², measuring 4.0 m in length and 2.0 m in width. The treatments included vegetation cover from three cover crops: crotalaria (*Crotalaria spectabilis*), stylosanthes (*Stylosanthes guianensis*), and millet (*Cenchrus americanus*), along with a control comprising spontaneous vegetation. These were assessed with and without the application of Bokashi (FertBokashi®) to the soil across five evaluation times (0, 45, 90, 120, and 180 days after cutting (DAC)). Plants found within the spontaneous vegetation were identified by family, genus, and species.

Crotalaria and millet were sown in continuous rows with spacings of 0.25 m and 0.40 m, respectively, using seed rates of 25 kg ha^{-1} for crotalaria and 20 kg $ha^{-1}$for millet. Stylosanthes was broadcast sown across the effective area of the plots designated for the treatment at a rate of 4 kg ha^{-1}. The cover crops were sown with the intention of synchronizing their cutting times with their respective flowering periods: stylosanthes at 100 days after sowing (DAS), crotalaria at 90 DAS, and millet at 60 DAS. The first sowing of stylosanthes occurred on January 4, 2017. Upon reaching approximately 50% flowering, the plants were cut close to the ground using a blade cutter and left on the soil surface as mulch.

Pink pepper seeds were extracted from fruits harvested at UFGD’s medicinal plant garden (SISGEN N° A9CDAAE), with a voucher specimen deposited at UFGD’s Herbarium (4602). Seedlings were propagated in nurseries under 50% shade by direct seeding and sown in 128-cell trays filled with Bioplant® vegetable substrate. At 70 DAS, seedlings were transferred to tubes and remained there until they were ready for definitive transplantation. Seedlings were transplanted into the field at an average height of 15 cm, which was achieved at 105 DAS and five DAC of the cover crops. The spacing between pink pepper plants and rows was set at 1.0 × 1.0 m. Soil water retention curves were determined using van Genuchten’s mathematical model (1980) and the Soil Water Retention Curve (SWRC) software version 2.0 (Dourado Neto et al., 2001) for irrigation management. Manual irrigation was performed to raise soil water tension to field capacity (5 kPa), with irrigation timing established when tensiometer readings indicated 70% of field capacity.

FertBokashi® activation followed the manufacturer’s recommendations. The applied dose was 100 L ha^{-1} of the activated solution. Applications occurred every 30 days, continuing until240 DAT, with the initial application immediately post-transplanting of the pink pepper.

Cover crops and spontaneous vegetation were assessed using a 1.0 × 1.0 m quadrat. Plant material was collected and weighed, and 100 g of samples from each plot were placed into one of four litter bags, each measuring 0.20 × 0.20 m. These bags were then distributed across the soil surface of the corresponding plots. Additionally, 100 g of fresh biomass from each plot was set aside to determine the initial dry mass proportionally. The remaining vegetation was cut, and all material was left on the ground.

At 45, 90, 135, and 180 DAC, one “litter bag” per plot was collected to assess the remaining fresh mass of the cover crops. The dry mass was obtained by drying the samples in a forced-air circulation oven at 60 ± 5 °C until a constant mass was achieved, after which they were weighed on a scale accurate to 0.0001 g. The dried samples were then ground in a Willey-type mill and subjected to chemical analysis to determine their nitrogen, phosphorus, and potassium content, following the methods described by Malavolta et al. (1997).

From 270 to 284 DAT, the fruits from female plants, constituting 90% of the total pink pepper yield, were manually harvested bi-daily based on the reddish-pink hue, signaling the appropriate harvest time. The fresh mass of these fruits was assessed, and for dry mass determination, they were placed in a forced-air circulation oven at 60 ± 5 °C until a constant mass was achieved. Concurrently, at 270 DAT, three competitive plants per plot were harvested by cutting them at ground level. The fresh and dry masses of stems and leaves were measured using a scale accurate to 0.0001 g, and the leaf area was quantified with a LI-COR 3100 C area integrator. The specific leaf area was calculated by correlating the leaf surface area with its dry mass. To determine the dry mass of stems and leaves, 200 g of fresh mass from each plot were dried in a forced-air circulation oven at 60 ± 5 °C to a constant mass, subsequently, the dry-to-fresh mass ratio was computed.

The masses of the cover crops, the pink pepper, and the nutrient contents of the cover crops were analyzed using analysis of variance. When the F test revealed significant differences, the means were compared using Tukey's test for the cover crops and the t-test (LSD) for Bokashi. Data collected at different times were treated as split plots over time and fitted to regression equations ($p \leq 0.05$).

Results and Discussion

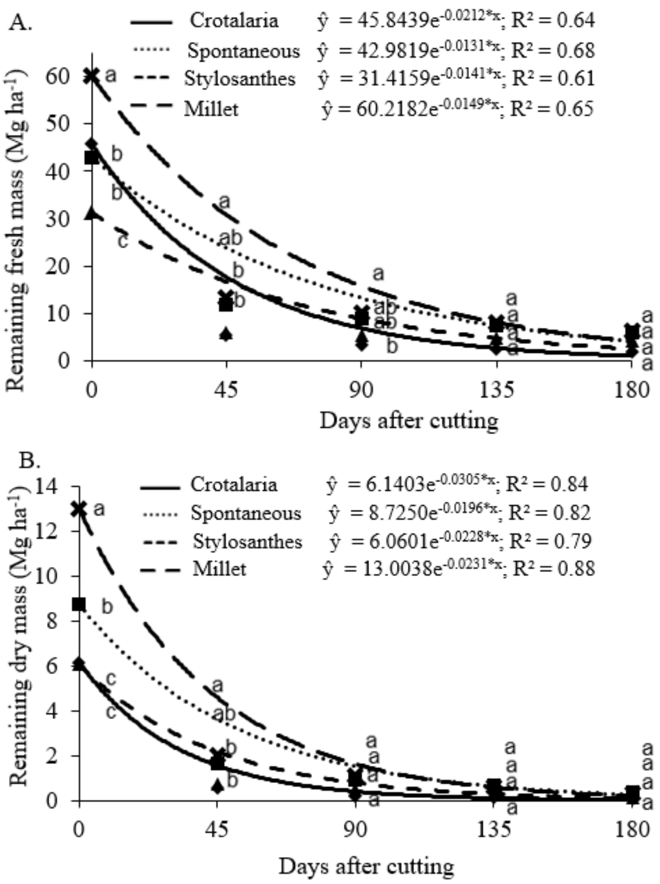
The remaining fresh and dry mass of the cover crops was influenced solely by the interaction between evaluation times and cover crops (Table 1).

The highest fresh mass of cover crops (Figure 1A) and dry mass of cover crops (Figure 2B) were observed immediately after cutting (0 DAC), with millet plants exhibiting the greatest fresh (60.22 Mg ha^{-1}) and dry (13.00 Mg ha^{-1}) masses, which differed statistically from the other cover crops in the first two evaluations. These results suggest that millet plants are well-adapted to Cerrado soils, likely due to their deep root system that enables them to access water and nutrients from the soil's subsurface layers (Domukoski et al., 2014). Furthermore, as a C4 plant, millet exhibits superior water use and photosynthetic efficiency, which facilitates its metabolic processes and leads to greater mass accumulation (Way et al., 2014), making it an excellent choice for soil cover.

Table 1. Summary of the analysis of variance for fresh mass cover crops and dry mass cover crops cut and deposited in "litter bags" left on the soil, with application of Bokashi biofertilizer, evaluated five times

Sources of variation	DF	Mean squares: Fresh mass of cover crops	Mean squares: Dry mass of cover crops
Blocks	3	145.9979*	4.5110*
Cover crops	3	673.9155*	33.5847*
Bokashi	1	22.4294^{ns}	0.1911^{ns}
Cover crops × Bokashi	3	31.9637^{ns}	0.5668^{ns}
Error A	21	9.7254	0.4882
Times	4	9,602.8108*	399.3234*
Times ×Cover crops	12	184.0291*	14.3355*
Times × Bokashi	4	5.3568^{ns}	0.3252^{ns}
Times × Cover crops × Bokashi	12	4.3818^{ns}	0.13106^{ns}
Residue	96	5.3219	0.4219
CV (%) Error A	-	21.87	31.81
CV (%) Residue	-	16.17	29.57

* - Significant at $p \leq 0.05$ by F-test; ns - Not significant by F test; DF - Degrees of freedom; CV - Coefficient of variation



Averages were grouped according to the use of bokashi. * - Significant at $p \leq 0.05$ by the F test. Means within the same days after cutting that share the same letter do not differ according to the Tukey test ($p \leq 0.05$)

Figure 1. Remaining fresh (A) and dry mass (B) of cover crop plants as a function of days after cutting during pink pepper (*Schinus terebinthifolia*) cultivation

The dry mass of millet plants (13.00 Mg ha^{-1}) was comparable to the 14.00 Mg ha^{-1} reported by Soratto et al. (2012), who investigated the mass production of pearl millet plants in monoculture with harvesting at flowering. The reduced fresh and dry mass of Stylosanthes plants, compared to other cover crops immediately post-harvest, may be attributable to species-specific traits, including its classification as a C3 plant, which possesses lower water use efficiency and photosynthetic capacity than millet (C4) (Way et al., 2014).

At 180 DAC, the remaining fresh mass of the cover crops, in decreasing order, was 4.12 Mg ha^{-1} for millet, 4.07 Mg ha^{-1} for spontaneous vegetation, 2.48 Mg ha^{-1} for stylosanthes, and 1.01 Mg ha^{-1} for crotalaria. However, spontaneous vegetation had the highest remaining dry mass at 0.26 Mg ha^{-1} during the same period, followed by pearl millet at 0.20 Mg ha^{-1}, stylosanthes at 0.10 Mg ha^{-1}, and crotalaria at 0.03 Mg ha^{-1} (Figures 1A and B). The greater dry mass of spontaneous vegetation may be attributed to the presence of approximately 54% Poaceae plants, which typically have higher C:N ratios and thus exhibit increased persistence of plant material (Canalli et al., 2020).

Up on comparing the initial and final fresh and dry masses of the cover crops, it was observed that spontaneous vegetation exhibited the smallest reductions in fresh mass (90.53%) and dry mass (97.02%), followed by stylosanthes, millet, and crotalaria, with reductions of 92.11 and 98.35%; 93.16 and 98.46%; and 97.80 and 99.51%, respectively. Crotalaria showed the most significant reductions in fresh and dry mass, likely due to its low C:N ratio (Pereira et al., 2016). Conversely, spontaneous vegetation, despite not producing the highest initial fresh mass (42.98 Mg ha^{-1} - Figure 1A), maintained the highest remaining dry mass at 180 DAC (0.26 Mg ha^{-1} - Figure 1B). This outcome may be attributed to the higher C:N ratio of the spontaneous plants in the area (*Digitaria insularis*, *D. sanguinalis*, *Eleusine indica*, *Paspalum pumilum*, *P. virgatum*, *Urochloa humidicola*, and *U. plantaginea*), which, due to their lower N concentration, hinder the activity and growth of microorganisms responsible for the mineralization of organic carbon, thereby slowing decomposition (Tian et al., 2019).

The contents of nitrogen (N), phosphorus (P), and potassium (K) in the residual biomass of cover crop species were significantly affected solely by the interaction between evaluation times and cover crop species (Table 2).

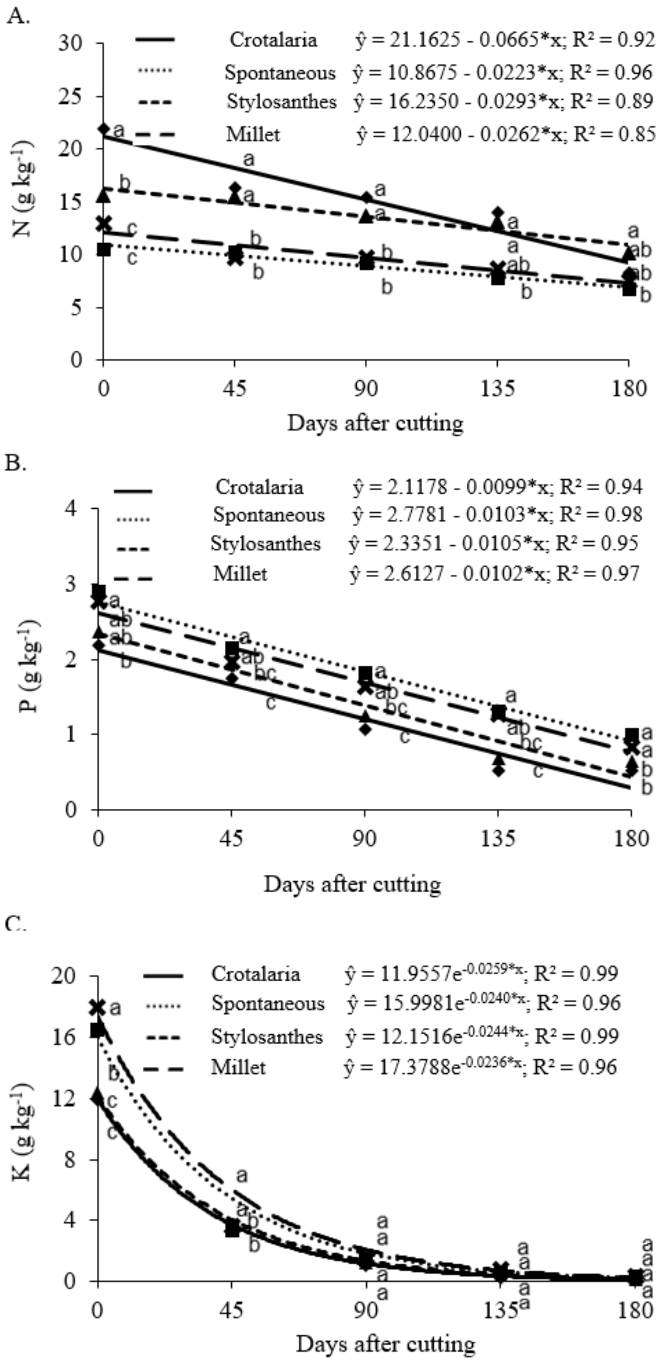
The highest contents were observed on the day of cutting (Figure 2A), with crotalaria's remaining mass exhibiting the highest N content (21.16 g kg^{-1}). It was noted that the N levels in the remaining mass of crotalaria were statistically different from those in other treatments. The elevated N content in crotalaria's residual mass may be attributed to the biological fixation of N by *Rhizobium* bacteria in the soil, facilitated by a symbiotic relationship. Conversely, the lower N content in spontaneous vegetation (10.87 g kg^{-1}) could be due to the dominance of Poaceae species, which possess a high C:N ratio in their structural composition, a higher fiber content, and the absence of bacterial symbiosis, leading to reduced N accumulation in the plant material (Foloni et al., 2016).

The N contents in cover crops and spontaneous vegetation, detected at 180 DAC (Figure 2A), were as follows, in ascending order: spontaneous vegetation, 6.86; millet, 7.33; crotalaria, 9.19; and stylosanthes, 10.95 g kg^{-1}, respectively. The lowest N content in spontaneous vegetation was attributed to its lowest initial N content (0 DAC) in the remaining mass, a trend that persisted (Soratto et al., 2012). Conversely, although crotalaria had the highest initial N content in its remaining mass, it did not maintain this status at 180 DAC; stylosanthes exhibited higher values. This can be attributed to the fact that the C:N ratio of stylosanthes is greater than that of crotalaria, resulting

Table 2. Summary of the analysis of variance for nitrogen (N), phosphorus (P), and potassium (K) contents in the remaining mass of cover crops, cut and deposited in "litter bags" left on the soil, with application of Bokashi biofertilizer, evaluated in five times

Sources of variation	DF	Mean squares		
		N	P	K
Blocks	3	55.7914*	0.7438*	3.1864*
Cover crops	3	369.3121*	3.2547*	19.7511*
Bokashi	1	0.0063^{ns}	0.0043^{ns}	0.0762^{ns}
Cover crops × Bokashi	3	0.9824^{ns}	0.0012^{ns}	0.2539^{ns}
Error A	21	0.5876	0.0069	0.0667
Times	4	218.3446*	17.4423*	1,187.0061*
Times × Cover crops	12	23.1440*	0.1168*	12.9604*
Times × Bokashi	4	2.4706^{ns}	0.0108^{ns}	0.0425^{ns}
Times × Cover crops × Bokashi	12	1.3354^{ns}	0.0035^{ns}	0.0997^{ns}
Residue	96	1.2709	0.0086	0.1559
CV (%) Error A	-	6.48	5.39	6.39
CV (%) Residue	-	9.53	6.04	9.77

* - Significant at $p \leq 0.05$ according to the F-test; ns - Not significant by F test; DF - Degree of freedom; CV - Coefficient of variation



Averages were grouped according to the use of bokashi. * - Significant at $p \leq 0.05$ by the F-test. Means within the same days after cutting that share the same letter do not differ according to the Tukey test ($p \leq 0.05$)

Figure 2. Nitrogen (A), phosphorus (B), and potassium (C) contents in the remaining masses of cover crop plants as a function of days after cutting, during pink pepper (*Schinus terebinthifolia*) cultivation

in greater stability in nutrient release. Over time, however, there was a tendency for N release to stabilize across the remaining masses of all materials, as the C:N ratio increased due to the more lignified parts being the last to decompose (Soratto et al., 2012).

The highest levels of P and K in the cover crops were found in the biomass remaining on the day of cutting (Figures 2B and C), with P decreasing linearly over time and K decreasing exponentially, following the same pattern across all residual masses. The highest P levels were detected in spontaneous vegetation (2.78 g kg^{-1}), followed by millet (2.61 g kg^{-1}), stylosanthes (2.34 g kg^{-1}), and crotalaria (2.12 g kg^{-1}). The lowest P levels were recorded at 180 DAC, with crotalaria exhibiting the minimal level (0.32 g kg^{-1}), followed by stylosanthes (0.44 g kg^{-1}), millet (0.77 g kg^{-1}), and spontaneous vegetation (0.92 g kg^{-1}, Figure 2B). Regarding K, the highest concentrations were found in pearl millet (17.38 g kg^{-1}), followed by spontaneous vegetation (16.00 g kg^{-1}), stylosanthes (12.15 g kg^{-1}), and crotalaria (11.96 g kg^{-1}). Conversely, the lowest K levels at 180 DAC were in crotalaria (0.11 g kg^{-1}), followed by stylosanthes (0.15 g kg^{-1}), spontaneous vegetation (0.21 g kg^{-1}), and millet (0.25 g kg^{-1}, Figure 2C).

The higher P and K contents in the residual biomass of millet and spontaneous vegetation observed on the cutting day, compared to crotalaria and stylosanthes, may be attributed to the greater nutrient cycling potential of these species. Millet and certain species within the spontaneous vegetation (54% Poaceae) possess root systems that extend deeper and cover larger areas, enabling them to access P and K from the subsurface soil layers (Soratto et al., 2012). The elevated levels of P and K in the residual mass at 180 DAC in pearl millet and spontaneous vegetation likely stem from their higher initial concentrations (Figures 2B and C). Perin et al. (2006) also reported higher P content in spontaneous vegetation (3.75 g kg^{-1}) compared to crotalaria and millet, surpassing even the levels found in the current study. This discrepancy may be due to the diversity of plant species in spontaneous vegetation and varying soil fertility conditions. The initial mass of millet exhibited the highest K content relative to crotalaria on the day of cutting, aligning with findings by Soratto et al. (2012), who recorded values of 22.68 g kg^{-1} in millet and 15.83 g kg^{-1} in crotalaria.

The pronounced reductions in K content observed in cover crops from 0 to 45 DAC (Figure 2C) can be attributed to the nutrient's lack of integration with the structural components of plant tissue and its formation of weak, easily reversible bonds with organic complexes. Consequently, when the cover crops were cut and began to decompose, the rupture of plant tissue membranes led to the swift release of K. Additionally, irrigation may have facilitated the rapid release of K by removing its soluble fraction. Following the cutting of the cover crops, the residual plant material exhibited a marked decline in K content, indicating a rapid nutrient release.

Leaf area, fresh leaf mass, fresh fruit mass, and dry fruit mass of pink pepper plants were influenced by the interaction between cover crops and Bokashi. Fresh stem mass and dry stem mass were influenced by cover crops and Bokashi independently. Leaf dry mass was influenced solely by cover crops, while specific leaf area was not affected by the factors under study (Table 3). The greatest leaf areas, fresh leaf mass, fresh fruit mass, and dry fruit mass of pink pepper plants were observed in those cultivated in succession to spontaneous vegetation with Bokashi application (Table 4).

These results may be attributable to the biological improvements of the soil, provided by the diverse species within the spontaneous vegetation's structural arrangement. This diversity likely favored a greater variety of native soil microorganisms (Kim et al., 2020) and enhanced conditions for the proliferation of microorganisms. Microorganisms provided by Bokashi, in particular, aid in the availability of essential nutrients such as N and P, which are crucial for promoting leaf expansion and growth. Additionally, the wide array of spontaneous vegetation species contributes to the soil's physical improvement (Blanco-Canqui & Ruis, 2020). Species with long or voluminous roots can enhance aeration, porosity, water retention, and soil structure. Consequently, these improvements in soil physical attributes likely enabled pink pepper plants to extend their roots deeper, accessing nutrients from the subsurface layers. This nutrient uptake can enhance

Table 3. Summary of the analysis of variance for leaf area (LA), leaf fresh mass (LFM), leaf dry mass (LDM), stem fresh mass (SFM), stem dry mass (SDM), fruit fresh mass (FFM), and fruit dry mass (FDM) of pink pepper (*Schinus terebinthifolia*) plants at 270 days after transplanting, cultivated in succession with cover crops and with Bokashi application

Sources of variation	DF	Mean squares						
		LA	LFM	LDM	SFM	SDM	FFM	FDM
Blocks	3	38,769,977.0*	36,247.0*	3,523.0*	179,967.0*	63,711.0*	5,357.0*	1,537.0*
Cover crops	3	57,300,408.0*	59,904.0*	5,382.0*	56,534.0*	19,915.0*	3,021.0*	753.0*
Bokashi	1	142,308.0ns	228.0ns	77.0ns	24,186.0*	8,615.0*	2,434.0*	642.0*
Cover crops × Bokashi	3	6,939,979.0*	6,266.0*	511.0ns	3,237.0ns	1,398.0ns	1,503.0*	327.0*
Residue	14	1,940,384.0	1,550.0	193,22.0	4.546.0	1,400.0	252.0	70.0
CV (%)	-	20.24	17.74	21.41	27.71	25.80	36.05	40.22

* - Significant at $p \leq 0.05$ according to the F-test; ns - Not significant; DF - Degrees of freedom; CV - Coefficient of variation

Table 4. Leaf area, leaf fresh mass, fruit fresh mass and fruit dry mass of pink pepper (*Schinus terebinthifolia*) plants at 270 days after transplanting, cultivated in succession with cover crops and with Bokashi application

Variables	Bokashi	Cover crops				CV (%)
		Millet	Stylosanthes	Crotalaria	Spontaneous	
Leaf area (cm^2 per plant)	With	4,709.6 bA	5,482.1 bA	4,818.0 bA	11,975.0 aA	20.2
	Without	6,766.0 bA	6,504.0 bA	5,098.1 bA	9,710.2 aB	
Leaf fresh mass (g per plant)	With	152.5 bA	166.3 bA	171.7 bA	386.5 aA	17.2
	Without	166.6 bA	207.2 bA	209.3 bA	315.5 aB	
Fruit fresh mass (g per plant)	With	33.7 bA	21.1 bA	75.6 aA	80.8 aA	36.1
	Without	34.4 bA	23.6 bA	22.8 bB	55.5 aB	
Fruit dry mass (g per plant)	With	18.1 bA	9.7 bA	34.9 aA	40.3 aA	40.2
	Without	19.9 aA	10.3 aA	11.3 aB	22.8 aB	

Averages followed by the same uppercase letter in the columns for each characteristic, and by the same lowercase letter in the rows, do not differ significantly from each other according to the t-test and Tukey's test, respectively, at $p \leq 0.05$. CV - Coefficient of variation

Table 5. Stem fresh mass, stem dry mass and leaf dry mass of pink pepper (*Schinus terebinthifolia*) plants at 270 days after transplanting, cultivated in succession to cover crops

Variables (g per plant)	Cover crops				CV (%)
	Millet	Stylosanthes	Crotalaria	Spontaneous	
Stem fresh mass	202.55 b	196.32 b	202.12 b	369.29 a	27.71
Stem dry mass	122.65 b	114.58 b	123.34 b	219.66 a	25.80
Leaf dry mass	52.49 b	54.78 b	48.78 b	103.66 a	21.41

Means grouped according to the use of Bokashi, followed by the same letter within rows, do not differ significantly according to the Tukey test ($p \leq 0.05$); CV - Coefficient of variation

the plants' physiological processes and support increased leaf area growth (Ludewig & Flügge, 2013).

The increased production of fruit dry mass in pink pepper plants, when grown following spontaneous vegetation and with Bokashi application, may also result from the plants' larger leaf area in the presence of the biofertilizer. A larger leaf area can lead to a higher photosynthetic rate, which promotes the accumulation and translocation of photo assimilates to the fruits, thereby enhancing productivity (Ludewig & Flügge, 2013). Pink pepper plants grown after spontaneous vegetation, with or without Bokashi, exhibited higher fruit dry mass (Table 1) than those reported by Moreira et al. (2016), who recorded an average of 13.5 g per plant when grown following *Stizolobium aterrimum*. The specific leaf area was not affected by the treatments, averaging 93.27 $cm^2 g^{-1}$. The greatest fresh stem mass, dry stem mass, and dry leaf mass in pink pepper plants were observed in those grown after spontaneous vegetation (Table 5).

This phenomenon could be associated with enhancements in soil physical properties; plants with high biodiversity may have promoted soil aeration, porosity, and structure through their more extensive root systems (Tahat et al., 2020). Consequently, these improvements aid in the water and nutrient uptake of pink pepper. Both fresh and dry stem mass were greater in the absence of Bokashi application, irrespective of the cover crop succession (Table 6).

This finding diverges from other data on plant growth using Bokashi, potentially due to the increased energy expenditure for producing leaf fresh mass, fruit fresh mass, and fruit dry mass at the expense of reduced stem mass (Ludewig & Flügge, 2013).

Table 6. Stem fresh mass and stem dry mass of pink pepper (*Schinus terebinthifolia*) plants at 270 days after transplanting, cultivated with Bokashi biofertilizer application

Variables (g per plant)	Bokashi		CV (%)
	With	Without	
Stem fresh mass	215.83 b	270.81 a	27.71
Stem dry mass	128.65 b	161.46 a	25.80

Cover crop averages were grouped, with means followed by the same letter within rows not differing significantly according to the t-test at $p \leq 0.05$. CV - Coefficient of variation

Conclusions

1. Elevated levels of P and K were observed in the residual mass of millet and in spontaneous vegetation.

2. Pink pepper plants exhibited increased leaf and fruit fresh mass when cultivated in successively with spontaneous vegetation and with Bokashi application.

3. Incorporating organic Bokashi activator into the soil promotes higher yields of pink pepper leaves and fruits.

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