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Effect of *Asystasia* spp. Management on the O×G Hybrid (*Elaeis oleifera* × *Elaeis guineensis*) of Oil Palm at the Adult Stage

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Abstract

The proper management of weeds plays an important role in nutrition and health and, therefore, in the yield and sustainability of the oil palm crop. To evaluate the effect of *Asystasia* spp. management as a cover species in the interspecific hybrid O×G oil palm at the adult stage, a trial was established in the Luker Agrícola plantation (Casanare, Colombia). The treatments evaluated corresponded to four types of management of *Asystasia* spp. with different control radii concerning the stipe (drip line) (1, 3, and 4.5 m on three occasions during the year) on an O×G Coari × La Mé cultivar at the adult stage (2011 planting). The treatments were established under a randomized complete block design with four replications. The analysis of the results obtained after four years of evaluation indicated that there are no significant differences between the treatments evaluated in terms of soil chemistry, nutrition, growth, and crop yield by analysis of variance. Nonetheless, significant differences were observed in soil cover variables and biomass and nutrient accumulation according to Tukey's test at 5%. According to the results obtained, the management of *Asystasia* spp. should be focused on the conservation and efficient use of resources. It should be adapted according to the most appropriate management conditions in each case (age of the crop, weeds desired by the plantation, pests, nutrient recycling, soil moisture conservation, among others).

Keywords: weed control, soil cover, crop nutrition, soil fertility, nutrient recycling, biomass input to the soil

1. Introduction

The plant species known as weeds are plants that grow spontaneously or are introduced anthropically into production systems, are part of their agroecosystem and, due to their reproduction, propagation, and growth mechanisms, are more efficient in taking advantage of resources such as light, water, and nutrients. Due to the above, they must be properly managed, otherwise, by competing for these resources, they can have negative effects on crop productivity, profitability, and the environment (Petit et al., 2022; Salazar-Gutiérrez, 2021).

The establishment and management of crop cover species is an essential component of Integrated Weed Management (IWM), which refers to the implementation of different weed control methods promptly (Salazar-Gutiérrez, 2021). In addition, IWM in oil palm cultivation has positive effects on soil conservation, as it reduces erosion losses, reduces runoff, conserves moisture, favors nutrient recycling, and improves the physical and chemical conditions of the soil (Ruíz & Molina, 2014); this is contrary to what happens when there is widespread control of the crop's companion species and the soil remains without vegetation cover, which represents a risk to the conservation of environmental resources, mainly the soil resource.

The proper use and management of crop vegetation cover is one of the practices that generate the greatest impact on the preservation and accumulation of carbon in the soil since about 35% of the carbon accumulated in the oil palm agroecosystem is found in the soil. In addition, the carbon provided by plant cover is organic and, since it is incorporated into the soil without being exposed to constant removal, it tends to be stable and to contribute favorably to life and its regeneration (Arias, 2022).

Other benefits reported for oil palm cultivation in Colombia include the reduction of runoff from 15% in bare soils to 3% in soils with weeds of other species, that is, a reduction of 80%, which translates into a greater amount of water available for the crop and accompanying plants. In addition to the above, the implementation

and proper management of weeds also increase water infiltration, preserve humidity, and reduce soil temperature (Arias, 2022).

The species *Asystasia* spp., which belongs to the Acanthaceae family and is also known as Asystasia common or Chinese Violet (Flora & Fauna Web, 2023), is considered a weed in the oil palm crop due to its rapid growth and soil cover; therefore, it has a high potential to be considered as a cover species under proper management, since it can develop under conditions of low light and soil fertility. Added to the above, its implementation or keeping its presence in the field can promote some positive effects on the soil such as nutrient recycling, water conservation in the dry season, and reduction of soil losses due to erosion and runoff, among others (Asbur et al., 2016, 2018; Ariyanti et al., 2017).

Considering that the Eastern Oil Palm Zone of Colombia contributes 42.9% of the national production (Fedepalma, 2022) and that in this region there is a constant presence and agronomic problems regarding the management of *Asystasia* spp., the objective of this study was to evaluate the effect of *Asystasia* spp. management as a cover species in the interspecific hybrid O×G of oil palm in the adult stage on soil, nutrition, growth and crop yield variables.

2. Method

2.1 Study Site

The study was carried out in Lot G21 of the Luker Agrícola plantation, located in the municipality of Villanueva, Casanare (Figure 1) between 2019 and 2022, that is, during four years of crop production. The plantation is located at 300 m above sea level, with an average temperature of 27 °C, relative humidity of 80%, and rainfall ranging between 1500 and 2500 mm year^{-1}. The cultivar evaluated corresponded to an interspecific hybrid O×G (Coarí × La Mé) with a planting density of 128 palms ha^{-1} at the adult stage (2011 planting). The soil corresponded to the Inceptisol Order, characterized by medium-low fertility (Table 1). The average soil cover by *Asystasia* spp. in 2019 was 61.9 %, which was present mainly in the harvest and non-traffic lanes, with the area of the plate (into the drip line) remaining free.

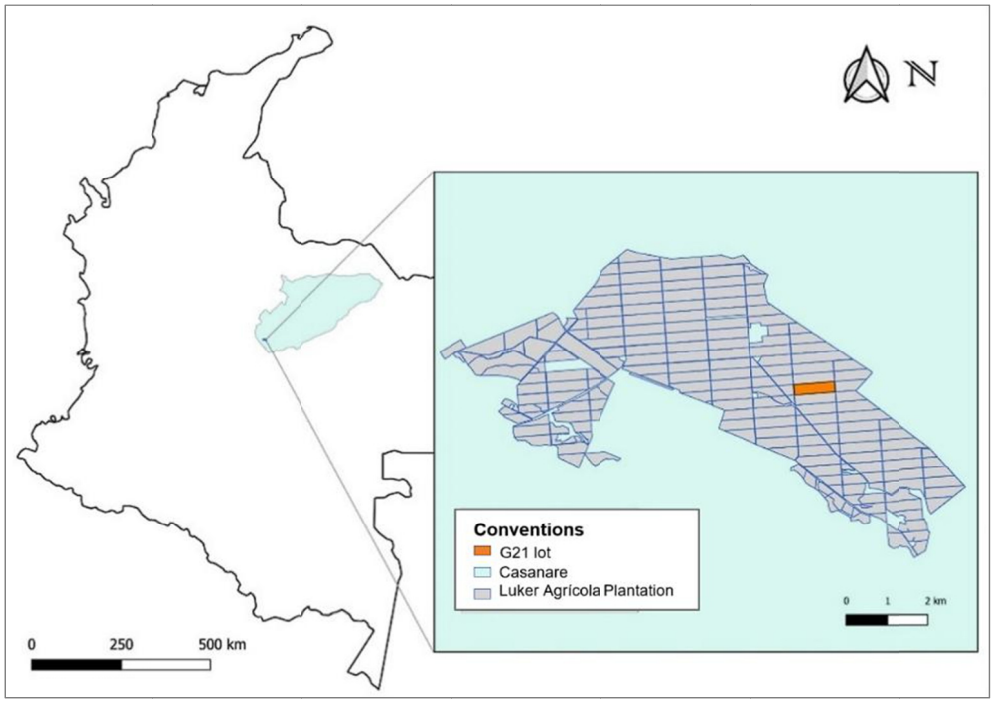


Figure 1. Map of the location of Lot G21 of the Luker Agrícola plantation (Villanueva, Casanare)

Table 1. Initial condition of the chemical properties of the evaluated soil

Property	Texture	pH	OM	P	Exchangeable cations					Al Sat.
					K	Ca	Mg	Na	Al	
Unit	-	-	%	mg kg^{-1}	---------- $cmol_c$ kg^{-1} ----------					%
Result	Loam	4.9	3.2	48	0.42	2.41	0.78	0.04	0.84	20

Note. OM: Organic Matter; P: Phosphorus; K: Potassium; Ca: Calcium; Mg: Magnesium; Na: Sodium; Al: Aluminum; Al Sat.: Aluminum saturation.

2.2 Experimental Design and Treatments

The treatments evaluated consisted of four types of management of *Asystasia* spp. with different control radii concerning the stipe of the palm (plate or into drip line) (1, 3, and 4.5 m on three occasions during the year) (Table 2), that is, from a low control to a broader and more generalized control of the weeds, which was of the chemical type equally for all treatments. For the above, environmental conditions were considered, such as adequate soil humidity and the absence of rainfall events during herbicide application, with a low probability of occurrence of the event after the work. The herbicide used for weed management was glyphosate isopropylamine salt at a concentration of 648 g L^{-1}, applied at 2 L ha^{-1}. The rest of agronomic management, such as fertilization, pruning, pest control, and other factors were equally implemented in the total area during the study duration.

Table 2. Description of the treatments evaluated

Treatment	Control radius of *Asystasia* spp. concerning the stipe (into drip line)
1	1 m (three controls per year)
2	3 m (three controls per year: plantation control)
3	3 m (two controls per year + one 4.5 m radius control)
4	4.5 m (three controls per year)

The above treatments were established under a randomized complete block design with four replications in which the slope of the terrain was considered as a blocking factor. Each experimental unit consisted of four lines of six palms each (24 palms), where the eight central palms were defined as the effective plot (n = 8).

2.3 Data Collection and Analysis

The response variables to determine the effect of the treatments corresponded to soil variables (soil chemistry, soil cover, and nutrient accumulation by *Asystasia* spp.) and crop variables (nutrition, vegetative growth, and yield). The results were analyzed under the experimental design established through the analysis of variance by the Tukey test at 5% using the Rbio software (Bhering, 2017), which uses the R software (2020) as a data analysis base.

2.3.1 Effects on Soil

(1) Soil Chemistry

Concerning soil chemistry, sampling was carried out at 3.5 m from the stipe at a depth of 0 to 15 cm, that is, in the zone of presence of *Asystasia* spp. in the treatments where its control was not extensive and generalized. For this purpose, eight (8) crown-shaped subsamples were taken from each effective palm of each treatment at the distance and subsequently homogenized to form a composite sample. Finally, they were sent to the laboratory for chemical analysis (pH, OM, P, K, Ca, Mg, Al and Al Sat.).

(2) Ground Cover

The methodology used to measure soil cover was adapted from the Manual for Agronomic Evaluation according to the International Center for Tropical Agriculture (CIAT) (Toledo & Schultze-Kraft,1982), which consisted of randomly throwing a 1 m^2 quadrat on the ground within three effective palms of each experimental unit at three distances (1, 3 and 4.5 m distance from the stipe). The percentage (%) of vegetation cover was measured using the mobile application Canopeo® (Patrignani & Ochsner, 2015), in which a photograph was taken at the height of 1.2 m parallel to the ground for all cases and, subsequently, the ground cover was estimated.

(3) Biomass and Nutrient Accumulation by *Asystasia* spp.

To quantify the accumulation of biomass and nutrients by *Asystasia* spp., all the plant material found during the soil cover sampling was collected, *i.e.*, once the 1 m^2 quadrat was launched and the percentage of cover was estimated, the aerial plant biomass of *Asystasia* spp. was taken. Subsequently, the plant material was dried in a forced convection oven at 65 °C for 72 hours until reaching constant weight, the fresh and dry biomass was recorded and dry biomass was sent to the laboratory for analysis of macronutrients (N, P, K, Ca, Mg, and S) and micronutrients (Fe, B, Cu, Mn, and Zn) in the tissue. The estimation of nutrient accumulation and biomass contribution (fresh and dry) was calculated based on the biomass per sampling unit (1 m^2) and the concentration of nutrients in the sampled tissue and extrapolating the results to one hectare (ha). For P, K, Mg, and Ca, the extrapolated values per hectare were converted to their oxide equivalents (P_2O_5, K_2O, MgO, and CaO).

2.3.2 Effects on Crop

(4) Nutrition (Foliar Analysis)

To evaluate the effect of the treatments on crop nutrition, in an effective plot (8 palms) were taken six (6) leaflets were collected from each side of leaf 17 in the central section of the leaf, and the central portion of the leaflets was taken. Subsequently, the leaflets were cleaned with surgical cotton and distilled water and, subsequently, the veins were removed. Finally, they were dried in a forced convection oven at 65 °C for 72 hours or until a constant weight was reached and then sent to the laboratory for nutrient analysis (N, P, K, Ca, and Mg) (Munévar-Martínez et al., 2016).

(5) Vegetative Growth

The following variables were determined in the effective palms of each treatment with their respective replicates: leaf dry biomass of leaf 17 (LDB L17), total leaf dry biomass (TLDB), leaf area of leaf 17 (LA L17), and total leaf area (TLA), according to the methodology of Corley et al. (1971). For this purpose, leaf 17 of each palm (8 palms) was identified and cut, and measurements were taken of the width and thickness of the petiole, as well as the length of the leaf. Finally, the number of total leaves of each palm was counted to estimate the variables of TLDM and TLA.

(6) Fresh Fruit Bunch Yield (FFBY)

For the yield variables, the weight of bunches harvested during the four years of the evaluation was counted and recorded to obtain the average number of bunches (ANB), average bunch weight (ABW), and the yield of fresh fruit bunches per hectare (FFBY).

3. Results

3.1 Effects on Soil

(1) Soil Chemistry

Table 3 shows the results of the soil chemical analysis after four years of evaluation. In general, no statistical differences were detected using the analysis of variance in response to the management of *Asystasia* spp. It is worth highlighting that, although *Asystasia* spp. did not promote significant changes in the soil, it can be observed that, some variations were presented, mainly a decrease in pH (p = 0.15), Ca (p = 0.77), and Mg (p = 0.70) and an increase in Al and Al Sat. (p = 0.92). Other properties such as OM kept its levels in the soil (OM= 3.2% before treatment implementation and 3.3% after four years).

Table 3. Soil chemical properties in response to *Asystasia* spp. control radii concerning the stipe (into drip line)

Treatments	**pH**	**OM**	**P**	**K**	**Ca**	**Mg**	**Na**	**Al Sat.**
		%	mg kg^{-1}	--------- $cmol_c$ kg^{-1} ---------				%
1 m (three controls per year)	4.6	3.4	44	0.64	1.71	0.57	1.2	28
3 m (three controls per year: plantation control)	4.6	3.3	34	0.67	1.52	0.60	1.1	29
3 m (two controls per year + one 4.5 m radius control)	4.5	3.1	38	0.52	1.76	0.66	1.1	28
4.5 m (three controls per year)	4.7	3.5	22	0.59	2.05	0.66	1.1	26
Average	**4.6**	**3.3**	**35**	**0.61**	**1.76**	**0.62**	**1.1**	**28**
CV (%)	**1.8**	**12.6**	**42.7**	**19.2**	**40.2**	**20.8**	**24.3**	**28.1**
***p*-value**	**0.15**	**0.49**	**0.91**	**0.36**	**0.77**	**0.70**	**0.22**	**0.92**

(2) Ground Cover

Ground cover by *Asystasia* spp. presented statistical differences using the Tukey test at 5% for the control radius evaluated. On average, the highest ground cover at the three distances (1, 3, and 4.5 m) was observed when the species was controlled at 1 m from the stipe (61%); while the lowest ground cover was observed when the species was controlled at 4.5 m (6.6%). On the other hand, controls at 3 m three and two times a year covered the soil at 31.6% and 41.6%, respectively (Figure 2).

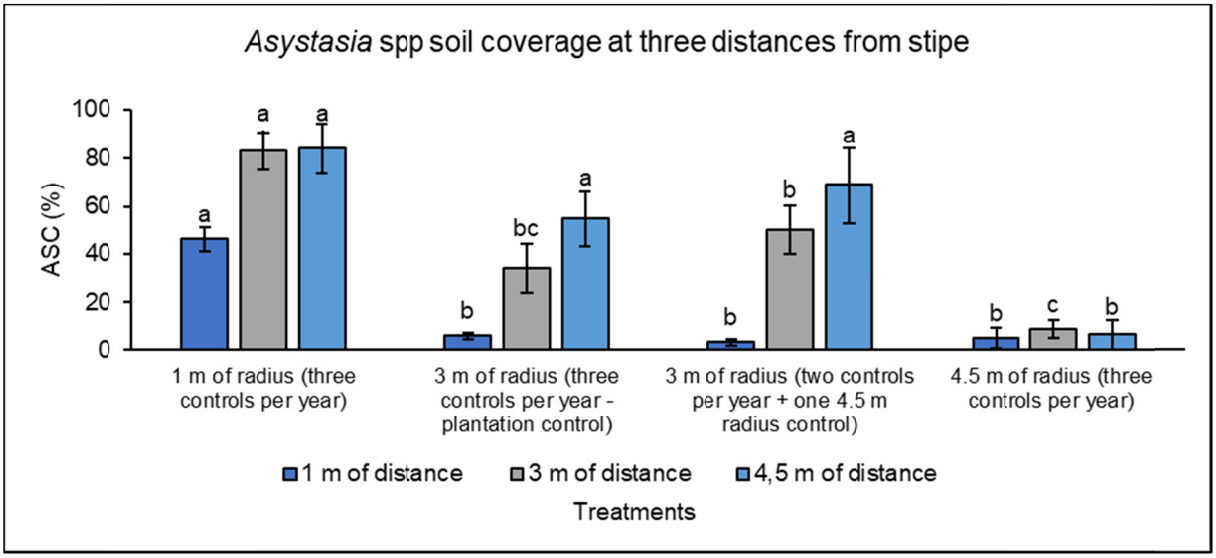


Figure 2. *Asystasia* spp. soil cover at three distances in response to the control radii of *Asystasia* spp. concerning the stipe. The error bars indicate standard deviation and different letters between bars of the same color indicate statistical difference by Tukey's test at 5%

(3) Biomass and Nutrient Accumulation by *Asystasia* spp.

As an effect of the treatments of *Asystasia* spp., significant differences (Tukey at 5%) were found in the accumulation of dry and fresh biomass (Figure 3). According to the above, the treatment in which the species was controlled at a 1 m radius concerning the stipe promoted the highest accumulation of dry and fresh biomass (1.5 and 11.7 t ha^{-1}, respectively). Nonetheless, the controls at 3 and 4.5 m did not show statistical differences between them and presented values between 0.1 and 0.5 t ha^{-1} of dry biomass and between 0.8 and 2.7 t ha^{-1} of fresh biomass, respectively, presenting themselves as management alternatives that do not promote significant biomass inputs to the soil.

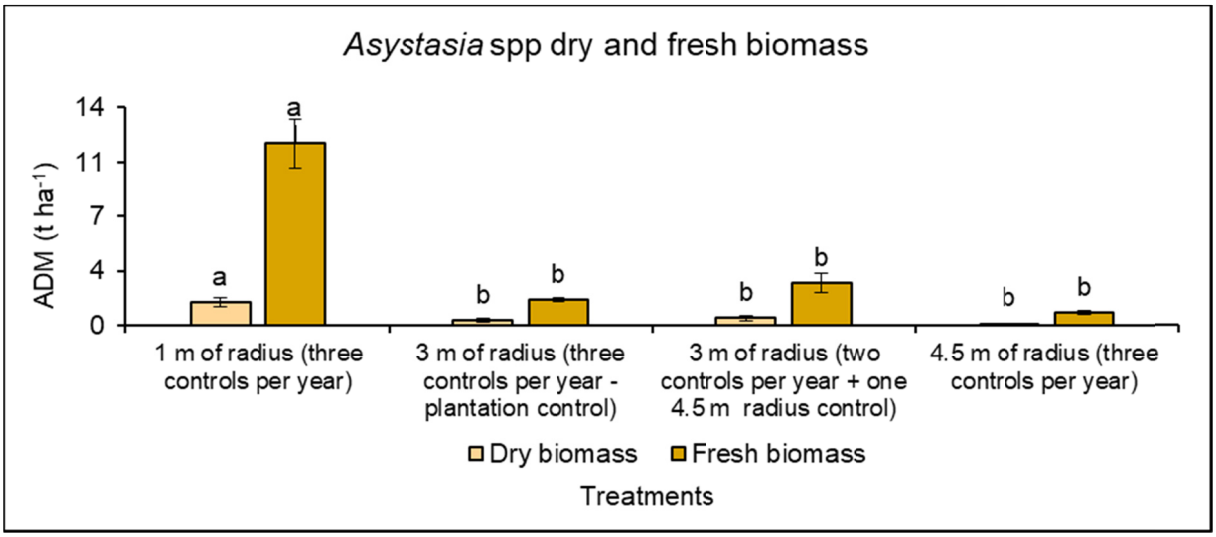


Figure 3. *Asystasia* spp. dry and fresh biomass accumulation in response to *Asystasia* spp. control radii concerning the stipe. The error bars indicate standard deviation and different letters between bars of the same color indicate statistical difference by Tukey's test at 5%

The accumulation of macronutrients (N, P, K, Ca, Mg, and S) and micronutrients (Fe, B, Cu, Mn, and Zn) by the cover species *Asystasia* spp. presented statistical differences among treatments (Figures 4 and 5). On average for all treatments, the order of accumulation of macronutrients was K > N > P > Mg > Ca > S, and for micronutrients was Fe > B > Zn > Mn > Cu. The treatment with the control radius at 1 m led to the highest accumulation of N, P_2O_5, K_2O, MgO CaO, and S (26, 18, 74, 24, 25, and 4 kg ha^{-1}, respectively) and Fe, B, Cu, Mn, and Zn (855, 194, 17, 145 and 185 g ha^{-1}, respectively); while the management with the highest weed control (Treatment 4) of *Asystasia* spp. presented the lowest accumulation values for the essential macroelements and microelements. At the same, the control treatment (Treatment 2) and its variation with a 4.5 m control (Treatment 3) behaved as intermediate.

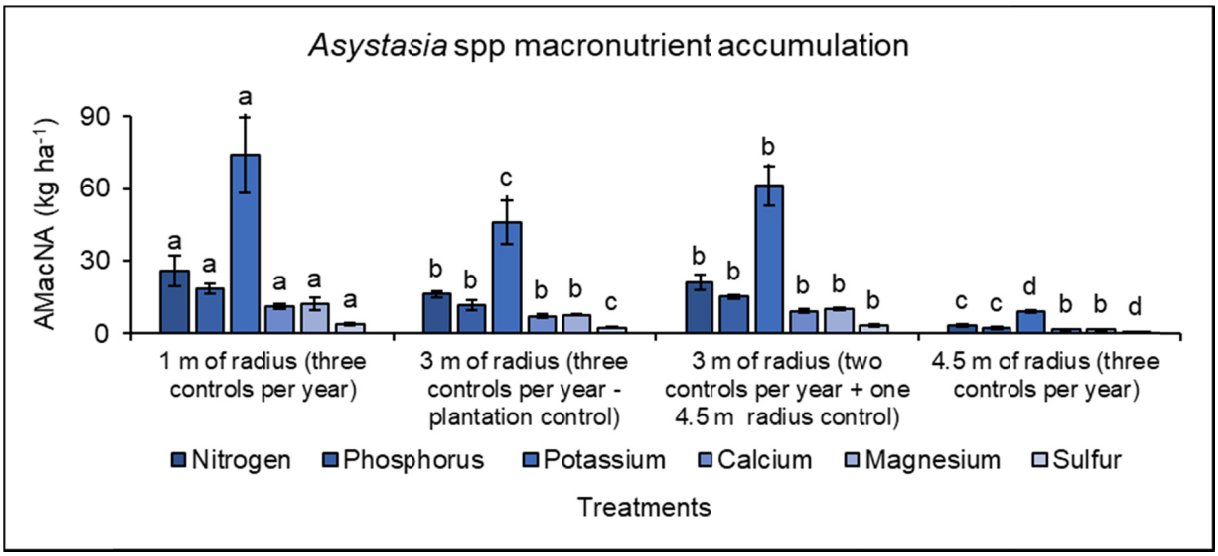


Figure 4. *Asystasia* spp. macronutrient accumulation (nitrogen-N, phosphorus-P_2O_5, potassium-K_2O, calcium-CaO, magnesium-MgO, and sulfur-S) in response to *Asystasia* spp. control radii concerning the stipe. The error bars indicate standard deviation and different letters between bars of the same color indicate statistical difference by Tukey's test at 5%

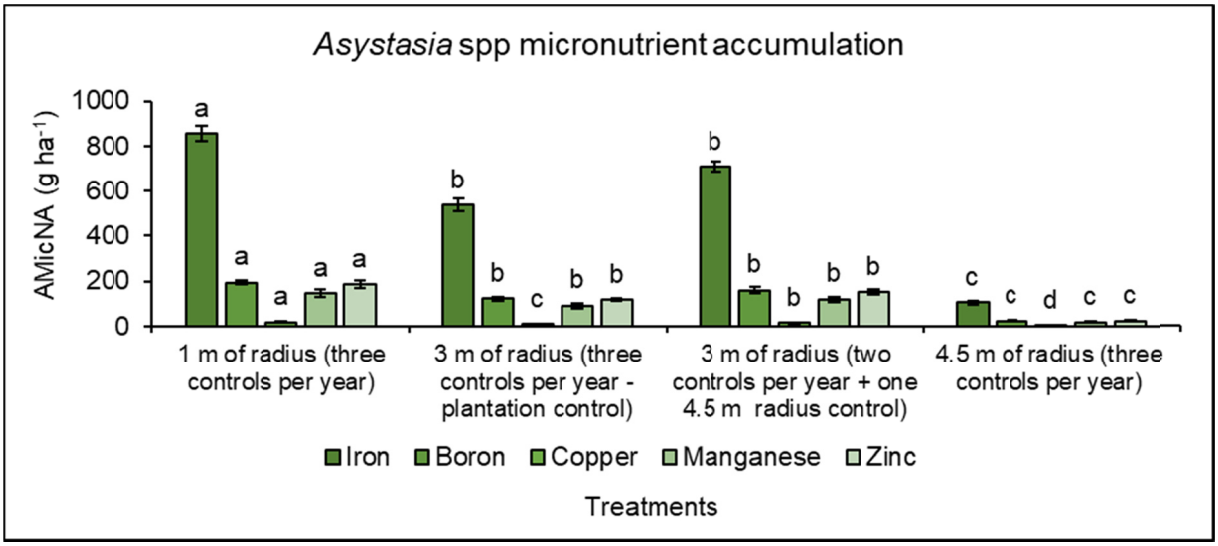


Figure 5. *Asystasia* spp. micronutrient accumulation (iron -Fe, boron-B, copper-Cu, manganese-Mn, and zinc-Zn) in response to *Asystasia* spp. control radii concerning the stipe. The error bars indicate standard deviation and different letters between bars of the same color indicate statistical difference by Tukey's test at 5%

3.2 Effects on Crop

(4) Nutrition (Foliar Analysis)

Regarding oil palm nutrition, the results of the foliar analysis did not show that the *Asystasia* spp. management treatments promoted significant statistical differences according to the analysis of variance (Table 4). In general, foliar N and K presented some descriptive effects when the *Asystasia* spp. was controlled at 1 m radii (T1) compared to the control radii at 4.5 m (T4) with 2.31 and 2.40% of N (p = 0.59), and 0.78 and 0.83% of K (p = 0.16), respectively.

Table 4. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), and boron (B) in leaf 17 in response to *Asystasia* spp. control radii concerning the stipe (into drip line)

Treatments	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**B**
	---------- % ----------						mg kg^{-1}
1 m (three controls per year)	2.31	0.15	0.78	0.82	0.27	0.16	26
3 m (three controls per year: plantation control)	2.30	0.15	0.86	0.75	0.25	0.16	19
3 m (two controls per year + one 4.5 m radius control)	2.24	0.15	0.81	0.68	0.24	0.15	23
4.5 m (three controls per year)	2.40	0.16	0.83	0.74	0.26	0.17	20
Average	**2.31**	**0.15**	**0.8**	**0.75**	**0.26**	**0.16**	**22**
CV (%)	**7.4**	**4.2**	**9.1**	**12.3**	**15.9**	**6.6**	**16.9**
***p*-value**	**0.59**	**0.21**	**0.16**	**0.24**	**0.71**	**0.31**	**0.10**

(5) Vegetative Growth

Regarding vegetative growth variables, although the wider controls (> 3 m radius) presented higher average values of TLDB, LA L17, and TLA by 3, 6 and 7% higher, respectively, when compared to the control at 1 m radii, the management of *Asystasia* spp. for the conditions evaluated did not promote significant statistical differences according to the analysis of variance (Table 5). LDB L17 and LA L17 averages (3.9 kg/leaf and 11.4 m^2/leaf, respectively) presented adequate levels concerning those related by Romero et al. (2023) by the age of evaluated palms.

Table 5. Leaf dry biomass of leaf 17 (LDB L17), total leaf dry biomass (TLDB), leaf area of leaf 17 (LA L17), and total leaf area (TLA) in response to *Asystasia* spp. control radii concerning the stipe (into drip line)

Treatments	**LDB L17**	**TLDB**	**LA L17**	**TLA**
	kg/leaf	kg/palm	m^2/leaf	m^2/palm
1 m (three controls per year)	3.8	140.3	10.9	402.6
3 m (three controls per year: plantation control)	3.8	140.9	11.3	426.3
3 m (two controls per year + one 4.5 m radius control)	4.0	143.7	11.6	435.4
4.5 m (three controls per year)	3.8	142.7	11.5	432.3
Average	**3.9**	**141.9**	**11.4**	**424.2**
CV (%)	**8.15**	**9.27**	**9.22**	**10.2**
***p*-value**	**0.41**	**0.30**	**0.39**	**0.19**

(6) Fresh Fruit Bunch Yield (FFBY)

The management of *Asystasia* spp. in the evaluated radius did not promote significant statistical differences between treatments according to the analysis of variance for any of the four years evaluated (Figure 6). Although there were variations among the years evaluated, which were associated with climatic factors, the average yield was 29.3, 28.8, 27.5, and 29.7 t ha^{-1} of FFB for treatments 1, 2, 3, and 4, respectively, and 28.8 t ha^{-1} of FFB on average for all the treatments evaluated, which is an adequate level of productivity for the conditions of the Eastern Zone.

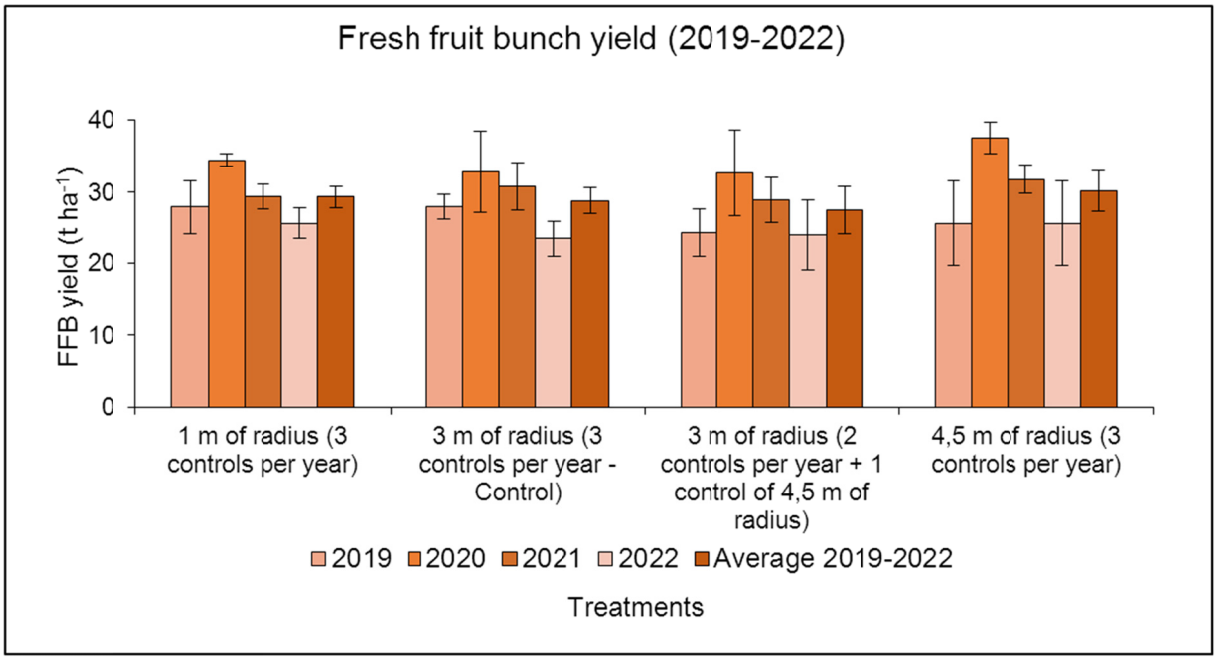


Figure 6. Fresh fruit bunch yield (FFBY) in response to *Asystasia* spp. control radii concerning stipe from 2019 to 2022. Coefficients of variation (CV) were 15.1% (2019), 13.5% (2020), 8.3% (2021) and 13.2% (2022). The error bars indicate standard deviation and different letters between bars of the same color indicate statistical difference by Tukey's test at 5%

4. Discussion

4.1 Effects on Soil

(1) Soil Chemistry

There were no statistical differences observed in soil chemistry, which indicates that regardless of the control of this species, after four years, it does not deplete soil reserves, which is reported by authors such as Satriawan et

al. (2021) and Asbur et al. (2020), who found that not only does it not deplete soil reserves, but also that the presence of *Asystasia* spp. in oil palm crops tends to improve some of its properties such as carbon (C) stock (between 39.5 and 41.2 t ha^{-1} $year^{-1}$) and the availability of N, P and K due to the contribution of biomass of 0.9 t ha^{-1} $year^{-1}$ of C by this weed. In addition to the above, Asbur et al. (2016) argue that the use of *Asystasia* spp. as a cover species reduced nutrient losses due to erosion by about 97%.

The response related to soil acidification (pH decrease and Al Sat. increase) is caused by an intrinsic characteristic of natural fertility with time due to climatic factors such as rainfall (Havlin et al., 2017; Sadeghian, 2022) and also to management factors such as the addition of fertilizers especially in the area of the plate (into drip line).

(2) Ground Cover

When analyzing the behavior at the distances evaluated, soil coverage at 1 m from the stipe differed statistically from the other treatments, covering 46% of the soil, while the other treatments did not exceed 6% coverage. The above behavior was also observed for the distance of 3 m, in which the control of *Asystasia* spp. at a 1 m radius, that is, having performed less extensive and generalized controls of this weed allowed promoting the presence of the same, which covered the soil with statistically higher percentages concerning the other treatments, showing values of 83% on average, followed by 34, 50 and 9%, respectively for treatments 2, 3 and 4. On the other hand, at a 4.5 m distance from the stipe, all the controls were statistically equal except for the widest control (4.5 m three times a year), in which an average value of 6% soil cover was found.

It was noticed that the *Asystasia* spp. plant tends to increase soil cover as the distance from the stipe increases. This can be explained by the herbicide's control effect at the distances where it was applied and the crop management.

(3) Biomass and Nutrient Accumulation by *Asystasia* spp.

Asystasia spp. promoted significant differences in the accumulation of dry and fresh biomass and in the macro and micronutrient accumulation, too. In this regard, the presence of ground covers in oil palm cultivation promotes the preservation and accumulation of carbon in the soil through the decomposition of plant material (Chaparro-Triana et al., 2020). In turn, the carbon provided by the vegetative cover is organic and, being incorporated into the soil, can be used as a source of carbon in the soil. is organic and, since it is incorporated into the soil without being exposed to constant removal, it tends to be stable and to contribute favorably to life and its regeneration (Arias, 2022). In addition to the above, they improve the soil structure on the surface, because they can minimize the impact of raindrops, in addition, they improve the water infiltration capacity (facilitate water mobility in the soil), reduce the dragging of soil particles, and favor the recycling of nutrients (Ruiz & Molina, 2014). Regarding nutrient recycling, the residues generated by *Asystasia* spp. can contribute about 93, 91 and 97% of the N, P, and K contained in the tissues for 30 days, indicating rapid decomposition and recycling of nutrients to the soil (Asbur et al., 2015; Asbur & Purwaningrum, 2018).

In this sense and considering that weed control should be oriented towards the conservation and improvement of natural resources such as soil, a greater presence of soil cover using plant species such as *Asystasia* spp. is, in general, more appropriate than wider and generalized controls.

4.2 Effects on Crop

(4) Nutrition (Foliar Analysis)

As in the case of the effect observed in the soil, this shows that, after four years, the presence of *Asystasia* spp. in the management evaluated does not deplete soil reserves, and does not negatively affect the absorption of nutrients by the palm; therefore, there is no competition for these elements by the weed in question. These results are related by other authors like Satriawan et al. (2021) and Asbur et al. (2020) who report that *Asystasia* spp. doesn´t have negative effects on the nutritional or soil status of oil palm crops.

(5) Vegetative Growth

The above may be related to the fact that the presence of *Asystasia* spp. did not negatively affect the nutritional status of the oil palm (especially for those nutrients intimately related to growth such as N and K) (Arias & Beltrán, 2014) and, consequently, there were no nutritional limitations between treatments, so that the palm maintained its growth without significant alterations.

(6) Fresh Fruit Bunch Yield (FFBY)

The absence of effect on FFB yield due to the presence of the weed in question is related to the fact that, under the management and conditions evaluated, *Asystasia* spp. did not negatively affect soil chemistry, nutrition, and

growth of the oil palm; therefore, since there were no adverse conditions for the adequate development of the crop, there were no limitations for adequate yields.

The analysis of the results obtained after four years of evaluation indicated that there were no significant differences between the treatments evaluated in terms of soil chemistry, nutrition, crop growth, and yield using the analysis of variance. Regardless, significant differences were observed in soil cover variables and biomass and nutrient accumulation according to Tukey's test at 5%. According to the above, the management of *Asystasia* spp. should be focused on the conservation and efficient use of resources. It should be adapted according to the most appropriate management conditions in each case (age of the crop, weeds desired by the plantation, pests, nutrient recycling, soil moisture conservation, among others).

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