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Growth of Two Cover Crops [*Arachis repens* (L.) and *Desmodium adscendens* (Sw.)] and Effect on Weediness in Industrial Banana Plantations in South-eastern Côte d'Ivoire

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Résumé

En culture industrielle de bananier dessert, la lutte contre les adventices fait usage des herbicides chimiques nocifs pour la santé humaine et l'environnement. Dans la présente étude, l'introduction des plantes de couverture comme alternative a été envisagée dans les bananeraies au Sud-Est de la Côte d'Ivoire. Le dispositif expérimental était un bloc de Fisher à trois répétitions de trois traitements consistant en l'utilisation des espèces *A. repens* et *D. adscendens* ainsi que deux herbicides de synthèse constituant la troisième modalité de l'étude. Les paramètres de reprise, de croissance et de résilience qui ont été évalués, ont été meilleurs chez *A. repens* que chez *D. adscendens*. De surcroit, avec les plus faibles valeurs de densité et abondance-dominances d'adventices, *A. repens* a été plus efficace à contrôler l'enherbement que *D. adscendens* et les herbicides de synthèse. Ainsi, les résultats de l'étude suggèrent l'espèce *A. repens* comme plante de couverture dans la gestion des mauvaises herbes en bananeraie, en substitution des herbicides tels que le glyphosate et le glufosinate.

Mots clés : Bananeraies, adventices, plantes de couverture, Côte d'Ivoire

Abstract

In industrial banana cultivation, the control of weeds use chemical weeders harmful to human health and environment. In this study, the introduction of cover crops was considered as an alternative in banana plantations in South-eastern Côte d'Ivoire. The experiment was designed in Fisher's block with three replications of three treatments that include use of cover crop species *A. repens* and *D. adscendens* as well as two chemical weeders constituting the third modality of the experiment. Parameters assessed on the growth recovery, development and resilience were better to *A. repens* than *D. adscendens.* In addition, with the lowest values of weed density and abundance-dominance, *A. repens* was more efficient to control the weediness than *D. adscendens* and the chemical weeders. Thus, the results of this study suggest *A. repens* as a cover crop specie for weeds management in banana plantations, instead of herbicides such as the glyphosate and glufosinate.

Keywords: Banana plantations, weeds, cover crops, Côte d'Ivoire
JEL Classification: Q01 Q10 Q15 Q16 Q56

1. Introduction

Dessert banana resulting from *Musa* spp., AAA is an important production in the economy of Côte d'Ivoire which is the leading African supplier on European Union market, with an exportation higher than 350,000 tons of fruits for the campaign 2018/19 (FIRCA, 2020). However, like all the cash crops, banana production faces several constraints, particularly those of weeds (Tournebize *et al*., 2018). The latter, in addition to being potential hosts for pests and diseases, are often in direct competition with crops for water, nutrients and space (Traore *et al.,* 2009). Caused losses of harvests are estimated at 9.7% in the world and 25% in Côte d'Ivoire (Boudjedjou, 2010; Tano *et al*., 2016). The relatively excessive use of chemical weeders to control weediness in agricultural parcels generally, and in banana plantations particularly, often generate prohibitive costs. This practice also presents several risks for health as well as on environment by various kinds of pollution (Ahmad & Danish, 2018). In order to direct crop systems and protection towards practices that reply to sustainable agriculture challenge, the use of cover crops able to suppress weeds instead of herbicides is presented as alternative (Antoir *et al*., 2016; Knezevic *et al*., 2017). In banana cultivation, several studies were carried out on use of annual and perennial cover crops to control weeds (Delone, 2014; Tardy *et al*., 2015 and 2017; Verret *et al*., 2017). Among the used plants, we distinguish those of Fabaceae's family to which *Arachis repens* and *Desmodium adscendens* objects of this study, belong.

This study focused on biological control of weediness in banana plantations by implantation of cover crops. It will be necessary to compare in banana plantations, growth recovery, development and resilience of *A. repens* and *D. adscendens*, species of local flora, then to evaluate their effects on weediness in the same conditions.

2. Material and Methods

2.1. Study Site

The experiment was carried out on the Akressi site, located in the town of Ayame, 40 km from the town of Aboisso in the forest area of Côte d'Ivoire particularly in the South Comoe region (Figure 1). The plot CA14 (05°41'04.09" North ; 003°3'53.95" West and 100 m of altitude) of the industrial dessert banana plantations owned by the Agricultural Company Kablan Joubin (SAKJ) was selected. The humid tropical climate is characterized by four seasons including two dry and two rainy (Koua, 2007). Akressi is located in the Guinean phytogeographical domain. Vegetation is diversified and includes littoral savanna, mangroves, swampy forests, riparian and sempervirentes forests (Kouame *et al*., 2009). In addition to Atlantic Ocean, Comoe, Bia and Tanoe rivers, the stream plan comprises an important system of lagoons (Ebrie, Aby, Hebe and Kodjoboue). During the study (April 2019 to July 2020), average temperature fluctuated around 27 °C and rainfall was approximately 2,915.11 mm (Figure 2).

Figure 1: Localization of the study site in the South Comoe region of Côte d'Ivoire

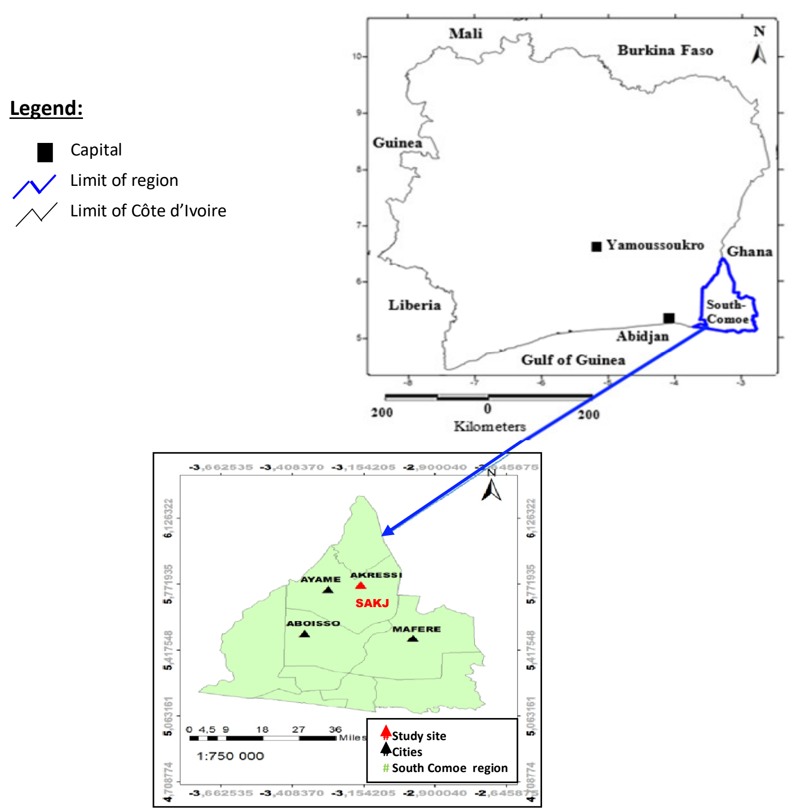
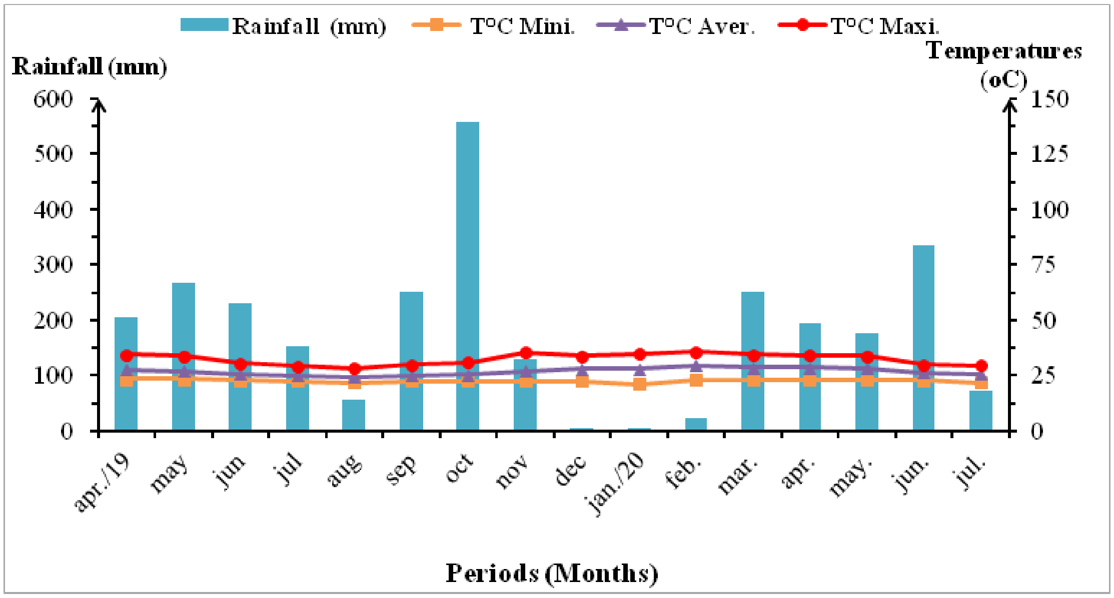
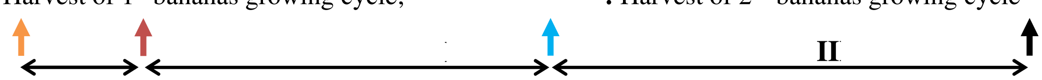


Figure 2: Rainfall and temperatures of the study site during the test period (April 2019 to July 2020)



I: Latency time before the installation of cover crops in banana plots; **II:** 1st phase or period of banana plantation trials;
III: 2nd phase or period of banana plantation trials and 2nd banana trees growing cycle; **I + II:** 1st banana trees growing cycle;
: Transplantation of banana trees in the field; **:** Transplantation of cover crops in banana plots;
: Harvest of 1st bananas growing cycle; **:** Harvest of 2nd bananas growing cycle



2.2. Plant Material

Plants of *Arachis repens* and *Desmodium adscendens* (Leguminosae) as well as banana trees (*Musa* sp., AAA, Cavendish, cv Grande Naine) were used as plant material. Plants of the first two species, old of 84 days, come from propagation by cutting on coir in a nursery. The nurseries were installed in the greenhouse of the trials station. For the third specie, plants were obtained after acclimatization of imported vitroplants (South Africa, Laboratory Du Roi) in a nursery for 77 days.

2.3. Methodology

2.3.1. Choice, Preparation of Banana Plantation Plots and Transplantation of cover Crops

For the installation of trials, banana plantation plot CA14 (3.6 ha) was selected after one year of spontaneous fallow land. This one comprised at the time of its preparation, banana trees old of 6 weeks. Inside the banana plantation plot, three successive blocks with elementary surface to 1,080 m² (108 m x 10 m) were selected. Fourteen days before the installation of cover crops, weed flora was treated with 2 l/ha of glufosinate (SL 200 g/l), using a back sprayer OSATU. Thereafter, a weeding was carried out in order to eliminate all resistant weeds. In addition, each block subdivided in three elementary plots of individual surface to 360 m² (36 m x 10 m) was identified with the aid of panels. Transplantation of cover crop plants resulting from the nursery was performed on all the elementary plots, in rainy season. Plants collected from alveolate plates were grown on the banana plots in rows, with a spacing of 30 cm x 30 cm, that is 111,111 individuals/ha. Before and after the establishment of cover crops, plants and plots were watering regularly.

2.3.2. Care of Trials

Cares applied to trials consisted to manual uproot and clear out resistant weeds of the banana tree plots treated with cover crops. For control plots, weeding was performed by applications every two weeks of glufosinate for the first two months of the tests period then of glyphosate (SL 360 g/l; 3 l/ha) every eight weeks until the end of the experiment. These practices were conducted when weeds began to dominate cover crops or invade control plots. The other activities of trial care consisted of the usual cultivation methods applied in banana plantations. It is in particular about fertilization (NPK 12.5-04-28, Urea 46, KCl 50, etc.), irrigation (2 hours by intervention every two weeks in dry season), chemical and manual protection against the major pests (black leaf streak disease, nematodes, black weevils), cares to banana trees and fruits.

2.3.3. Experimental Design

The experiment was carried out following Fisher's block design with three replications of three treatments. The studied factor was weediness management methods with the modalities *A. repens, D. adscendens* and herbicides (control). Each elementary plot or experimental unit was equivalent to a replication of one treatment (factor modality). This one was composed of 60 banana trees which are planted with a density per hectare of 1,820 plants (2 x 2 quincunx rows, with spacing of 2.2 m between banana trees in the same row and 1.7 m between twinned rows). For cover crops plots, transplantation was performed with a density of 111,111 individuals/ha (spacing of 30 cm x 30 cm). The numbers of cover crop plants by experimental unit, by specie and for the total trial area were 4,000; 12,000 and 24,000, respectively. In a same block, experimental units were separated from 3 m from/to each other. Two successive blocks were separated by one drain with a width and depth of 1 m.

2.3.4. Data Collection

Evaluations were performed in 45 squares (plots) of observation, each 1 m² and delimited for the whole experimental plot, with 5 per elementary plot. The square of observation were installed on the diagonal and in the center, in middle of banana rows, with the aid of twine attached to 4 sticks in the ground. In observation plots that received cover crop plants, a sample size of 5 plants was selected per species. The latter were numbered and marked by means of stickers. Cover crop growth recovery rates and densities as well as their numbers of internodes, leaves and stem ramifications, their stem lengths, diameters and vigour index were evaluated during the 1st period of banana plantation trial. The other parameters were studied during both the phases (1st and 2nd) of banana plantations trials. These are: cover crops root length, recovering rate, resilience to be trampled and to the effects of banana trees detached organs, fresh and dry biomass as well as the density and general abundance-dominance of weeds.

2.3.4.1. Cover Crops Growth Recovery Rate and Density

The growth recovery rate (in %) of each cover crop specie was obtained by the quotient between the size of plants that have recovered growth and the number initially transplanted by square of observation, multiplied by 100. Evaluation was performed 28 days after the set up of cover crop plants in banana tree plots. At the same time, density of each specie (number of living individuals/m²) was determined.

2.3.4.2. Cover Crops Numbers of Internodes, Leaves and Stem Ramifications

Twenty-eight days after the setting up in banana plots of cover crops plants resulting from the propagation by cutting, emerged internodes, leaves and stem ramifications were counted. Observations were repeated every 28 days until the 112th day after the transplantation of plants. Values were reported by plant.

2.3.4.3. Cover Crops Stem Growth Velocity, Length, Diameter and Vigour Index

The stem mean velocity of cover crops was assessed between the 28th and 112th days after their transplantation in banana fields. At these times, length of the air axis was measured in centimetres from the collet to the apical end of main stems using a tape measure. Then, mean velocity of stem growth was expressed in cm/day. In addition, 112 days after the installation of cover crops in banana fields, vigour of each specie was appreciated by the quotient of length (cm) on the diameter (cm) taken at the stem collet. This latter was measured with an aid of a mechanic slide calliper (Mitutoyo model).

2.3.4.4. Cover Crops Recovering Rate

During the growth of plants, the recovering rate of squares of observation by the foliar biomass of cover crops was determined every 28 days. Evaluations were performed until the end of the 2nd period of banana plantation trial, from the date of cover crops set up. The obtained value represents the surface that the specie would occupy, if its shoot parts are projected vertically on the observation area. Thus, the recovering dynamic is the temporal evolution of this surface. It is expressed as a percentage.

2.3.4.5. Cover Crops Resilience

Resilience of cover crops were studied by their resistance abilities to be trampled and to the effects of organs detached from banana trees. These parameters were appreciated in visual way every 28 days during the first two phases of banana field trials. Index ranging from **1** to **5**, with **1**: very sensitive, **2**: sensitive, **3**: tolerant, **4**: resistant and **5**: very resistant were assigned. Those were depending on the ability of cover crops to grow and to occupy the plot of observation despite the trampling and the fall of banana trees leaves and organs debris due to the usual cultivation activities conducted in banana plantations. Resistance index means were determined by specie.

2.3.4.6. Cover Crops Root Length, Fresh and Dry Biomass

At the end of each period of banana plantation trials cover crops were carefully uprooted in five plots of individual surface of 0.5 m². These plots were delimited randomly within each experimental unit. For each specie and for the plots delimited, lengths of main roots were measured for five organs from the insertion node to the apex, using a tape measure. Also in the same conditions, fresh biomass of root and shoot parts and of the whole plant were determined by weighing with a Sartorius precision balance (0.01 g). Dry biomass were also obtained after dehydration during 24 H in a ventilated drying oven (Memmert model) at the temperature of 105 ^{o}C.

2.3.4.7. Weeds Density and General Abundance-Dominance

Weeds density was evaluated under the same conditions as to cover crops until the end of tests. General abundance-dominance was assessed according to the rating scale of the commission of biological tests (Table 1) every 28 days. At each evaluation, index of abundance-dominance ranging from 1 to 9 were given to the whole weed species observed in each observation plot, according to their recovering rates. Then, the mean general abundance-dominance of weeds was calculated for each treatment by the quotient between the total index and the total number of botanical inventories.

Table 1: Weeds recovering rating scale according to the commission of biological tests (Marnotte *et al*., 1998)

Index	Recovering characteristics
1	**1%** of recovering (weed rare)
2	**7%** of recovering (≤ to 1 individual/m²)
3	**15%** of recovering (**>** to 1 individual/m²**)**
4	**30%** of recovering
5	**50%** of recovering
6	**70%** of recovering
7	**85%** of recovering
8	**93%** of recovering
9	**100%** of recovering

2.3.5. Statistical Analysis of Data

Statistical tests were performed using the XLSTAT software version 2016. Data collected were subjected to analysis of variance (ANOVA) according to the studied treatments. In case of rejection of the hypothesis of equality, means of modalities were separated in homogeneous groups with the aid of the multiple comparison test of Student-Newman-Keuls at the threshold α = 5%.

3. Results

3.1. Cover Crop Growth Recovery Rate and Density

The growth recovery rate and the density of cover crops varied significantly (p=0.003) according to the specie (Table 2). For both the parameters, *A. repens* is the specie that recorded the highest values (69.58% and 11.13 plants/m²).

Table 2: Cover crops growth recovery rates and densities 28 after their transplantation in banana plantations

Cover crop species	**Growth recovery rates (%)**	**Densities (individuals/m²)**
A. repens	69.58 a	11.13 a
D. adscendens	56.67 b	9.07 b
Overall averages	63.12	10.10
CV (%)	20.20	20.20
p-value (p)	0.003	0.003
Significativities	HS	HS

In a same column, values followed by the same letter are not significantly different at the threshold α = 5% according to the Student-Newman-Keuls test. CV: coefficient of variation; HS: highly significant (p <0.01).

3.2. Cover Crop Numbers of Internodes, Leaves and Stem Ramifications

Cumulated numbers of internodes, stem ramifications and leaves per plant of each cover crops specie, according to the time after their transplantation, are compiled in tables 3, 4 and 5, respectively. The first two mentioned parameters fluctuated significantly according to the cover crop species (p=0.000) on the contrary to the emission of leaves. Number of internodes and stem ramifications of *D. adscendens* were highest and approximately the doubles than those of *A. repens,* until the 112th day after their transplantation in banana plots. Regarding the emission of leaves, means reported to the both tested were statistically the same (p>0.05) whatever the evaluation period.

Table 3: Cumulated numbers of cover crop internodes according to the time after their transplantation in banana plantations

Cover crop species	**Cumulated numbers of internodes per plant Days after transplantation in banana plantation**			
	D_{28}	**D_{56}**	**D_{84}**	**D_{112}**
A. repens	14.71 b	23.75 b	32.51 b	50.23 b
D. adscendens	29.62 a	46.05 a	65.17 a	80.88 a
Overall averages	21.05	33.24	46.40	63.26
CV (%)	64.94	66.25	67.33	61.90
p-value (p)	0.000	0.000	0.000	0.000
Significativities	VHS	VHS	VHS	VHS

In a same column, values followed by the same letter are not significantly different at the threshold α = 5% according to the Student-Newman-Keuls test. CV: coefficient of variation; VHS: very highly significant (p <0.01).

Table 4: Cumulated numbers of cover crop stem ramifications according to the time after their transplantation in banana plantations

Cover crop species	Cumulated numbers of stem ramifications per plant Days after transplantation in banana plantation			
	D_{28}	D_{56}	D_{84}	D_{112}
A. repens	7.46 b	13.12 b	17.20 b	26.57 b
D. adscendens	15.04 a	25.44 a	34.48 a	42.80 a
Overall averages	10.68	18.36	24.55	33.47
CV (%)	64.98	66.28	67.33	61.91
p-value (p)	0.000	0.000	0.000	0.000
Significativities	VHS	VHS	VHS	VHS

In a same column, values followed by the same letter are not significantly different at the threshold α = 5% according to the Student-Newman-Keuls test. CV: coefficient of variation; VHS: very highly significant (p <0.01).

Table 5: Cumulated numbers of cover crop leaves according to the time after their transplantation in banana plantations

Cover crop Species	Cumulated numbers of leaves per plant Days after transplantation in banana plantation			
	D_{28}	D_{56}	D_{84}	D_{112}
A. repens	19.26 a	38.19 a	63.45 a	87.34 a
D. adscendens	22.16 a	45.80 a	70.26 a	95.26 a
Overall averages	20.58	41.66	66.55	90.95
CV (%)	50.87	46.35	37.22	37.65
p-value (p)	0.107	0.051	0.110	0.180
Significativities	NS	NS	NS	NS

In a same column, values followed by the same letter are not significantly different at the threshold α = 5% according to the Student-Newman-Keuls test. CV: coefficient of variation; NS: nonsignificant (p>0.05)

3.3. Cover Crop Stem Growth Velocity, Length, Diameter and Vigour Index

Mean of growth velocity as well as the diameter and length of plant stems, 112 days after transplantation in banana plots, varied to a significant degree according to the cover crop species (p=0.000) on the contrary to their vigour index (Table 6). The highest values were recorded to *A. repens*, with 0.78 cm/day, 0.67 and 103.76 cm respectively that represent approximately the double to those of *D. adscendens* (0.29 cm/day; 0.36 and 56.41 cm). In addition, plant vigour index showed identical values whatever the specie (p=0.332) with an overall average around 152.01.

3.4. Cover Crop Recovering Rate

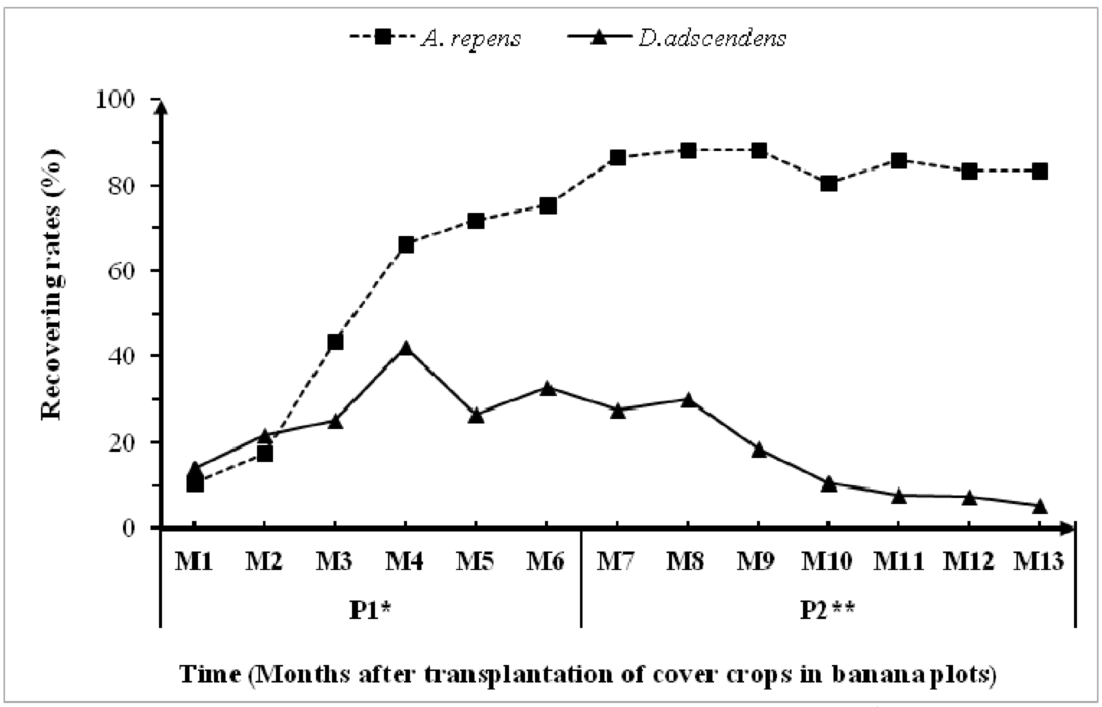
Temporal evolution of cover crops recovering rates after their transplantation in banana plots is reported in figure 3. Fast and constant increase in this parameter is observed with *A. repens* during the 1st period of banana plantation trials then stabilization around 80% for the 2nd phase. On the other hand, with *D. adscendens,* recovering rate dropped regularly during the 2nd phase of banana plantation trial after an optimum of 42.14% observed during the 1st period, 4 months after the transplantation of cover crops in banana plots. Figure 4 shows in images the evolution of soil recovering with tested plants in banana plantations.

Table 6: Cover crop stem growth velocity, lengths, diameters and vigour index 112 days after their transplantation in banana plots

Cover crop species	Stem growth velocities (cm/day)	Stem lengths (cm)	Stem diameters (cm)	Plant vigour index
A. repens	0.78 a	103.76 a	0.67 a	155.70 a
D. adscendens	0.29 b	56.41 b	0.36 b	147.11 a
Overall averages	0.57	83.41	0.54	152.01
CV (%)	61.40	46.04	33.33	32.53
p-value (p)	0.000	0.000	0.000	0.332
Significativities	VHS	VHS	VHS	NS

In a same column, values followed by the same letter are not significantly different at the threshold α = 5% according to the Student-Newman-Keuls test. CV: coefficient of variation; NS: nonsignificant (p>0.05); VHS: very highly significant (p<0.001)

Figure 3: Monthly evolution of cover crops recovering rates according to the specie

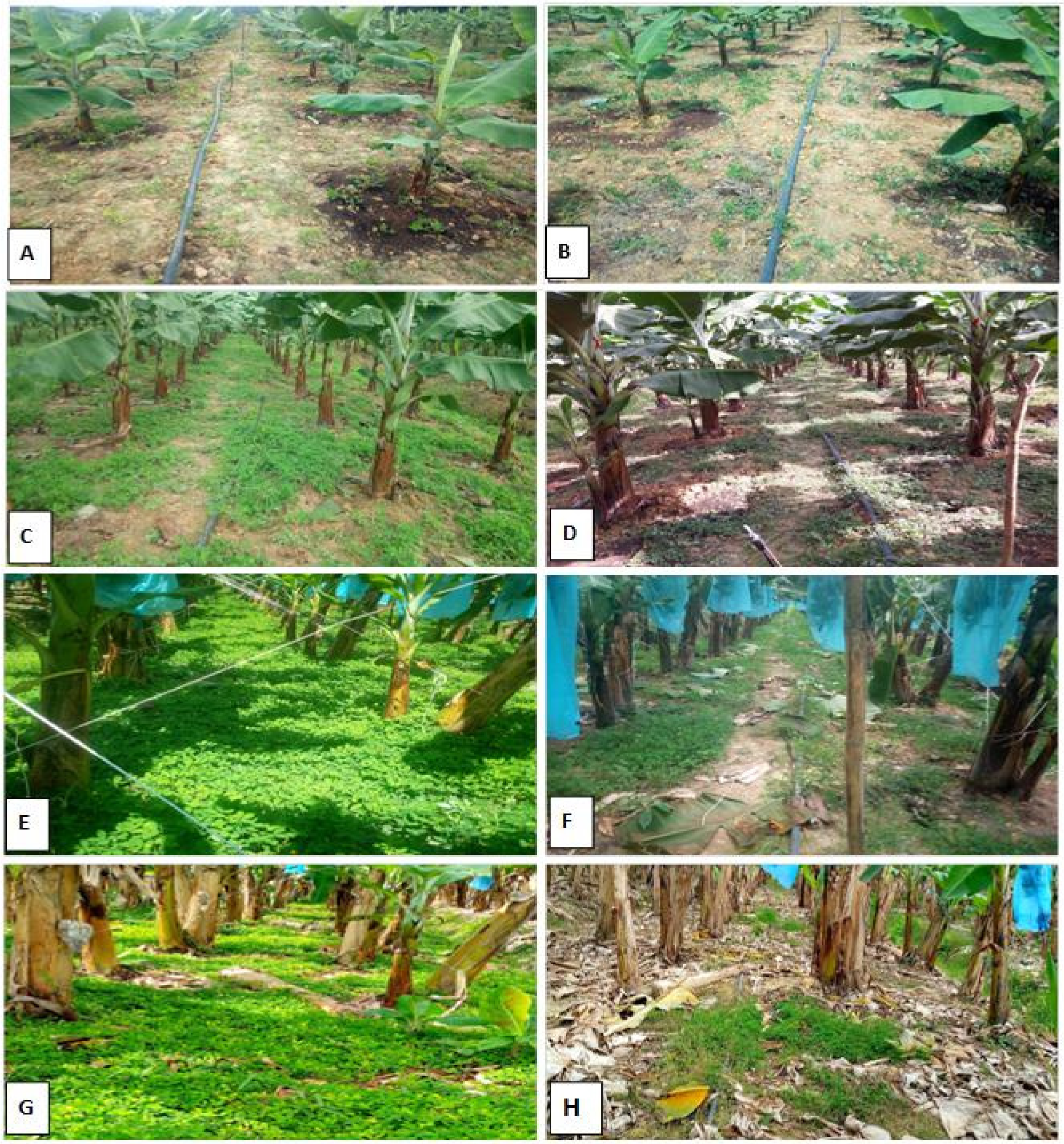


* ***P₁***: *1st period of banana plantation trials (transplantation of cover crops until harvest of 1st bananas growing cycle);*
** ***P₂*** *: 2nd period of banana plantation trials (harvest of 1st bananas growing cycle until harvest of 2nd bananas growing cycle)*

3.5. Cover Crop Resilience to be Trampled and to the Effects of Organs Detached from Banana Trees

Monthly evolution of cover crops resilience to be trampled and to the effects of organs detached from banana trees reported constant regressions with *D. adscendens* on the contrary to *A. repens* (Figure 5). With this latter, these parameters were relatively constant during all the test period. In addition, for both the respective parameters, *D. adscendens* successively evolved to state of resistant (3.87) or tolerant (3.27) to that of sensitive (1.67 or 2.07) then of very sensitive (1.06) respectively at the end of tests 1st and 2nd periods in banana plantations.

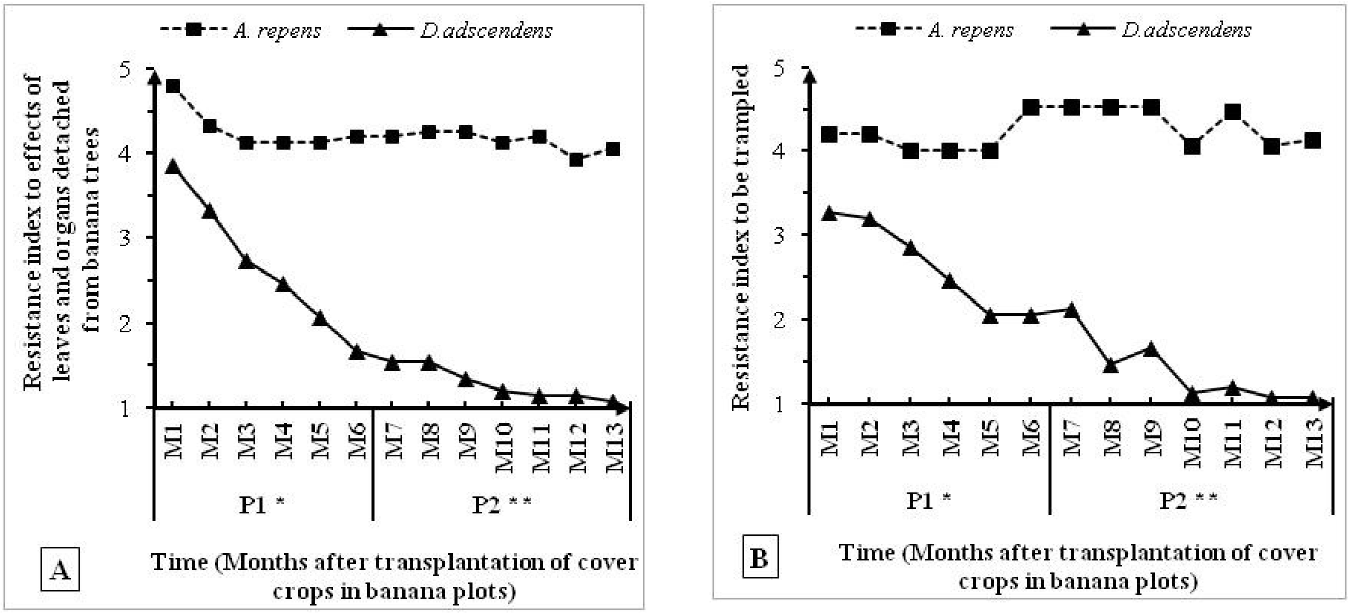
Figure 4: Banana plantation plots recovered with *A. repens* and *D. adscendens* after transplantation (A and B), 8 weeks after transplantation (C and D), at the harvest of 1st bananas growing cycle (E and F) and at the end of 2nd banana trees growing cycle (G and H)



3.6. Cover Crop Root Lengths

Root lengths at the end of both the two phases of banana plantation trials (Table 7) were depending on the cover crop species (p=0.000). Whatever the phase of banana plantation trials, the longest main roots were reported with *A. repens* (20.47 and 29.88 cm) while shortest were recorded to *D. adscendens* (9.82 and 14.43 cm).

Figure 5: Monthly evolution of resistance index to effects of leaves and organs debris detached to banana trees (A) and to trampling according the cover crop species (B)



* ***P₁*** *: 1st period of banana plantation trials (transplantation of cover crops until harvest of 1st bananas growing cycle);*
** ***P₂*** *: 2nd period of banana plantation trials (harvest of 1st bananas growing cycle until harvest of 2nd bananas growing cycle)*

Table 7: Main root lengths of cover crops at the end of banana plantation trials

Period of banana plantation trials	Cover crop species	Main root lengths (cm)
P_1*	*A. repens*	20.47 a
	D. adscendens	9.82 b
	Overall averages	15.14
	CV (%)	38.34
	p-value (p)	0.000
	Significativities	VHS
P_2**	*A. repens*	29.88 a
	D. adscendens	14.43 b
	Overall averages	22.15
	CV (%)	40.09
	p-value (p)	0.000
	Significativities	VHS

** P_1 : 1st period of banana plantation trials (transplantation of cover crops until harvest of 1st bananas growing cycle);*
*** P_2 : 2nd period of banana plantation trials (harvest of 1st bananas growing cycle until harvest of 2nd bananas growing cycle); In a same column and for a same period of tests, values followed by the same letter are not significantly different at the threshold α = 5% according to the Student-Newman-Keuls test. CV: coefficient of variation; VHS: very highly significant (p<0.001)*

3.7. Cover Crops Fresh and Dry Biomass

Biomass of root and shoot parts and of the whole plant as well fresh as dry at the end of each the two periods of banana plantation trials fluctuated significantly according to the cover crop species (p<0.05). Globally for this biomass, values recorded with *A. repens* were very higher than those reported with *D. adscendens,* particularly at the end of the 2nd phase of banana plantation trials. Moreover, from the end of the 1st period of banana plantation trials to that of the 2nd, values obtained with *D. adscendens* largely dropped, except for root parts while those recorded with *A. repens* were improved approximately of half as a whole (Table 8).

Table 8: Biomass of organs and cover crops at the end of banana plantation trials

Period of banana plantation trials	Cover crop species	Fresh biomass per plant (g/m^2)			Dry biomass per plant (g/m^2)		
		Root Parts	Shoot Parts	Whole plants	Root parts	Shoot parts	Whole plants
P_1*	*A. repens*	100.18 a	2,019.80 a	2,119.99 a	18.05 a	429.02 a	447.07 a
	D. adscendens	40.38 b	927.23 b	967.61 b	8.74 b	201.84 b	210.58 b
	Overall averages	70.28	1,473.51	1,543.77	13.40	315.43	328.82
	CV (%)	62.17	64.05	62.73	59.71	70.15	68.45
	p-value (p)	0.001	0.009	0.006	0.005	0.024	0.020
	Significativities	HS	HS	HS	HS	S	S
P_2**	*A. repens*	149.75 a	3,096.88 a	3,246.59 a	24.98 a	758.66 a	783.64 a
	D. adscendens	51.57 b	332.19 b	383.77 b	7.36 b	90.74 b	98.10 b
	Overall averages	100.66	1,714.52	1,815.18	16.17	424.70	440.87
	CV (%)	67.97	88.06	92.92	70.93	85.93	94.36
	p-value (p)	0.000	0.000	0.000	0.000	0.000	0.000
	Significativities	VHS	VHS	VHS	VHS	VHS	VHS

** **P_1 :** 1st period of banana plantation trials (transplantation of cover crops until harvest of 1st bananas growing cycle);*
*** **P_2 :** 2nd period of banana plantation trials (harvest of 1st bananas growing cycle until harvest of 2nd bananas growing cycle); In a same column and for a same period of tests, values followed by the same letter are not significantly different at the threshold α = 5% according to the Student-Newman-Keuls test. CV: coefficient of variation; S: significant (p<0.05); HS: highly significant (p<0.01); VHS: very highly significant (p<0.001)*

3.8. Weed Density and General Abundance-Dominance

Monthly values of weed density and general abundance-dominance during their control by cover crops in banana plantation are grouped in tables 9 and 10, respectively. Globally, these two parameters varied significantly according to the weed control treatments (p<0.05). Plot treated with *A. repens* is the modality that induced the lowest values, particularly from the 12th week after transplantation in banana plantations until the end of tests. On the other hand, from this same time, weeds were more numerous per area unit and more recovering, with values statistically identical in control and *D. adscendens* plots.

Table 9: Periodic evolution of weed density in banana plantation according to their control treatments

Period of banana plantation trials	Weediness control treatments	Weed densities (individuals/m²) Weeks after transplantation of cover crops * or harvest of 1st banana trees growing cycle **					
		W4	W8	W12	W16	W20	W24
P_1*	***A. repens***	120.07 a	209.13 a	22.13 b	11.87 b	15.93 b	16.27 b
	D. adscendens	95.46 a	211.53 a	72.47 a	62.73 a	78.87 a	99.53 a
	Herbicides	148.67 a	92.87 b	7.20 b	21.80 a	96.93 a	99.13 a
	Overall averages	121.40	171.17	33.93	33.13	63.91	71.64
	CV (%)	59.69	61.93	121.94	114.82	81.11	80.82
	p-value (p)	0.132	0.001	0.000	0.000	0.000	0.000
	Significativities	NS	HS	VHS	VHS	VHS	VHS
P_2**	***A. repens***	23.13 b	13.40 b	3.60 b	11.60 b	8.60 b	4.93 b
	D. adscendens	132.53 a	87.07 a	43.47 a	110.87 a	131.40 a	165.07 a
	Herbicides	110.87 a	69.40 a	28.33 a	96.80 a	115.73 a	135.67 a
	Overall averages	88.84	56.62	25.13	73.08	85.24	101.89
	CV (%)	73.97	73.26	118.50	111.11	78.35	85.88
	p-value (p)	0.000	0.000	0.000	0.000	0.000	0.000
	Significativities	VHS	VHS	VHS	VHS	VHS	VHS

** Weeks after transplantation of cover crops for P_1 (1st period of banana plantation trials: transplantation of cover crops until harvest of 1st bananas growing cycle); ** Weeks after harvest of 1st bananas growing cycle for P_2 (2nd cycle of banana plantation trials: harvest of 1st bananas growing cycle until harvest of 2nd bananas growing cycle). In a same column and for a same period of tests, values followed by the same letter are not significantly different at the threshold α = 5% according to the Student-Newman-Keuls test. CV: coefficient of variation; NS: nonsignificant (p>0.05); HS: highly significant (p<0.01); VHS: very highly significant (p<0.001).*

Table 10: Periodic evolution of weed general abundance-dominance in banana plantation according to their control treatments

Period of banana plantation trials	Weediness control treatments	General abundance-dominances of weeds Weeks after transplantation of cover crops * or harvest of 1st banana trees growing cycle **					
		W4	W8	W12	W16	W20	W24
P_1*	*A. repens*	3.00 ab	6.45 a	3.00 b	1.27 b	2.36 b	2.64 c
	D. adscendens	2.47 b	6.13 a	3.93 a	2.27 a	3.40 a	3.53 b
	Herbicides	3.29 a	4.43 b	2.86 b	2.43 a	3.86 a	4.14 a
	Overall averages	2.82	5.88	3.39	1.97	3.15	3.36
	CV (%)	27.30	22.45	28.32	49.75	26.35	25.29
	p-value (p)	0.036	0.002	0.008	0.010	0.000	0.000
	Significativities	S	HS	HS	S	VHS	VHS
P_2**	*A. repens*	2.82 b	2.73 b	1.45 b	2.54 a	2.27 b	2.27 b
	D. adscendens	3.87 ab	3.73 a	2.93 a	3.47 a	4.00 a	4.73 a
	Herbicides	4.71 a	3.86 a	3.14 a	4.00 a	3.71 a	4.54 a
	Overall averages	3.70	3.42	2.48	3.27	3.36	3.85
	CV (%)	41.35	27.48	49.60	46.17	31.25	38.96
	p-value (p)	0.026	0.006	0.001	0.105	0.000	0.000
	Significativities	S	HS	HS	NS	VHS	VHS

** Weeks after transplantation of cover crops for P_1 (1st period of banana plantation trials: transplantation of cover crops until harvest of 1st bananas growing cycle); ** Weeks after harvest of 1st bananas growing cycle for P_2 (2nd cycle of banana plantation trials: harvest of 1st bananas growing cycle until harvest of 2nd bananas growing cycle). In a same column and for a same period of tests, values followed by the same letter are not significantly different at the threshold $\alpha = 5\%$ according to the Student-Newman-Keuls test. CV: coefficient of variation; NS: nonsignificant ($p>0.05$); S: significant ($p<0.05$); HS : highly significant ($p<0.01$); VHS: very highly significant ($p<0.001$).*

4. Discussion

Plant growth recovery rates and densities were low with *D. adscendens* undoubtedly because this specie of shade and humid environment (Muanda, 2010) with stems of small calibre was very stressed after transplantation from greenhouse to field. This specie could not be easily adapted to the weak hydrous conditions and especially shade of banana trees in the experimental plot (Blazy, 2011; Gauthier & Kaiser, 2014). One the other hand, *A. repens,* heliophilous specie (Husson *et al*., 2012) with larger stems, would have been acclimatized better to the plantation conditions, after transplantation.

The number of stem internodes and branches were relatively high with *D. adscendens.* This observation could be the fact of a low hormonal ratio auxin/cytokinin favourable to caulogenesis in test environmental conditions (Mazinga *et al*., 2014). In spite the numbers of internodes and branches more significant with *D. adscendens* than *A. repens*, foliar size of plants remained statistically identical in both the cases. This character probably genetic, confers a denser and bulky aspect to specie *A. repens.*
Root growth of *A. repens* was also most important than that of *D. adscendens* probably as a better adaptation response to hydrous deficit which has occurred in poorly rainy periods (august and december 2019; january and february 2020) to seek in-depth water and nutrients (Toudou *et al*., 2017). This root development improves the hydrous nutrition of *A. repens* and thus its growth and production (Danjon & Reubens, 2008). Consequently, *A. repens* colonized banana plot soils more quickly and more durably than *D. adscendens* whose installation gradually regressed. Thus, *A. repens* would present a better agronomic interest because of its good capacity to recovering the banana tree plots quickly.

In addition, fresh and dry biomass of organs and whole plant were highest with *A. repens* than *D. adscendens.* This result shows a better adaptation of the perennial groundnut to weak luminosity because of the shade under banana trees during the first two growing cycles. To this property is added a better resistance to be trampled and to the effects of organs detached from banana trees on cover crops. The massive biomass of *A. repens* would represent a shelter for macrofauna which should proliferate and diversify in these conditions (Blanchart *et al.,* 2006, DuPont *et al.,* 2009). The sensitivity of *D. adscendens* would be primarily due to weak growth and fragility which limited its regeneration and potential to recover or to surmount the debris of banana trees organs. This fact would have gradually caused regression of *D. adscendens* then death of plants by absence of photosynthetic activity, particularly (Singh *et al*., 2015).

In addition, weed density and abundance dominance were, globally, weakest in banana plots treated with *A. repens* than *D. adscendens* and control plots treated with chemical weeders. *A. repens* while being established quickly and completely in banana plantations, undoubtedly, exerted suppression of weeds by smothering or inhibition of germination and dormancy breaking of their seeds which are thus rare and little recovering (Kouadio *et al*., 2009). An allelopathic effect of root exudations (benzoxazinoids, glucosinolates, flavonoids, phenolic acids, saponins) as highlighted for some Poaceae, Brassicaceae and Leguminosae, could also explain these observations (Kruidhof *et al*., 2014 ; Tournebize *et al*., 2018). Weak density and scarcity of weeds in banana plots treated with *A. repens* imply, obviously, a reduction of the number and time of weeding for each next period of the tests. While contributing to remove applications of chemical weeders, the cover crop *A. repens*, undoubtedly, maintains a good quality of banana plantation soils (Delone, 2014). Thus, we can hope that this one will make it possible to improve yields after two to three cycles comparatively to banana tree plots treated with herbicides. In addition, installation of cover crops on banana plantations in rainy season would undoubtedly have contributed to the performances mentioned in this study (FAO, 2005). This season should be preferred to plant cover crops for an optimal recovery of growth and a rapid colonization of soils of banana plantation by those. Generally, growth recovery and vegetative development, resilience to banana plantation conditions, density and abundance-dominance of weeds were better with *A. repens*. Thus, the latter would be indicated for a sustainable biological management of weeds in the banana plantations.

5. Conclusion

This study carried out in banana plantations in South-eastern Côte d'Ivoire in order to control weediness biologically by cover crops showed that, as a whole, *A. repens* is most able to growth recovery, development and biomass production than *D. adscendens*. This latter, in comparison to *A. repens,* have a high density and abundance-dominance of weeds and was less resilient to be trampled and to the effects of banana trees detached organs due to the usual practices in the field. Thus, *A. repens* can be suggested in industrial banana plantations for ecological and sustainable management of the weediness. Evaluation of effects on the main pests of this cash crop and on the production cost could lead to a good appreciation of the consequences of an adoption in large scale of this innovating practice.

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