Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

ISSN NO. 2320-5407

Article DOI:10.21474/IJAR01/17775
DOI URL: http://dx.doi.org/10.21474/IJAR01/17775

RESEARCH ARTICLE

EVALUATING THE BEHAVIOUR OF HEVEAS IN MARGINAL AREAS OF COTE D'IVOIRE: THE CASE OF MAN, TOUMODI AND PRIKRO

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Manuscript Info

Manuscript History
Received: 28 August 2023
Final Accepted: 30 September 2023
Published: October 2023

Key words:-
Behavior, Rubber Growing, Ivorian, Marginal Areas

Abstract

For a better orientation of Ivorian rubber cultivation in new areas of occupation, a study with the main objective of evaluating the behavior of rubber trees, with a view to better orientation of the extension of this culture was undertaken in the localities of Man, Toumodi and Prikro. The plant material used was rubber tree clones. During this study, the methodology consisted of evaluatingthe evolution of trees at 1.7m from the ground for mature plants and 1m from the ground for immature plants by measuring the circumference of the trees planted with a tape measure on different biotopes and soil textures previously defined. Production, dry notch rate and dry notch length of mature trees was also measured on the same parameters of the previous crop and texture. The results revealed thatthe previous cultivation of the rubber plots influences the mortality rate of the plants with a low rate observed in Man (17.30%) on the previous forest, also the trees had good growth on this previous one in Man (8.5cm.year^{-1}) and Prikro (9cm.year^{-1}). At ground level, the plants had a better level of radial growth in the localities of Man (8.30 and 9.06 cm.year^{-1}) and Prikro (8.01 cm.year^{-1}) with a more texture clayey (25% < clay < 50%). The average rubber production was also better in Man on the previous forest crop (63.85 ± 15.1 g.a^{-1}s^{-1}) similarly for the more clayey texture (25% < clay < 50%) with 63.27 ± 6 .1 g.a^{-1}s^{-1}. Rubber production from these new localities was generally good. So, through the results of this investigation, it should be noted that new rubber growing areas could be an asset for rubber production in Côte d'Ivoire. As a result, this culture can be encouraged in these areas, but with monitoring and supervision of producers on good agricultural practices.

Introduction:-

The rubbertree by itsscientificname*Heveabrasiliensis*Muell. Arg. (Euphorbiaceae) is a foresttree more than 30 meters high with a circumference of between 1 and 5 meterswhenadult (Compagnon, 1986). It has itsorigins in the

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Amazon basin of South America (Bouychou, 1963). This speciesismainlycultivated for its latex whichcontainsnaturalrubberthatiseasy to process and less productive of greenhousegasescompared to syntheticrubber (Déon, 2014). Thanks to the foreign exchange and the numerouspossibilities of use itgenerates, rubberoccupies an important place in the world economy. The quantity of rubberproducedin 2022, globally, isestimated at 14.36 millions tonnes (ANRPC, 2023). Eighty-eight percent (88%) of this production comesfrom Asia, four percent (4%) from America and six percent (8%) fromAfrica. Côte d'Ivoire is the leadingrubberproducing country in Africa and the thirdgloballywith a production of 1,39,000 tonnes of rubberin 2022 (APROMAC, 2023), To stay the course and above all to beamong the leaders in the sector, the Ivorian State, has adopted a master plan for the development of rubbergrowingwhichprovides for the production of more than 2,000,000 tonnes of dry rubber by 2025. To achievethis objective, the actors of the rubbersector are considering an increase in planted areas (APROMAC 2023). Indeed, practicedmainly in the south of the country, rubber plantations are nowspreading more and more in the central, central-eastern, central-western, western and eastern zones of Côte d'Ivoire, so-called marginal zones (Colin, 1990; Koffi et al., 2021). However, the effects of the pedoclimaticcharacteristics of these new areas on the growth and yield of rubber plants are not known. This iswhy the presentstudyaims to highlight the agronomicbehavior (growth and yield) of rubbertrees in the localities of Man, Toumodi and Prikro in order to consider a method of sustainable production of naturalrubber in theseregions. The general objective of thisstudyis to evaluate the behavior of rubbertrees in the localities of Man, Toumodi and Prikro, known as marginal zones, with a view to betterdirecting the extension of thiscrop.
More specifically it will be:

1. To evaluate the agro-physiologicalbehaviorthrough the mortality rate, the isodiametricgrowth and the production of rubbertreesaccording to previous cultivations ;
2. To determine the effects of soilparameters on the development, production and dry notching rate of rubber trees;

Study areas

This study was carried out in the departments of Man, Toumodi and Prikro-Est.The DepartmentMan is located in the west of Côte d'Ivoire, in the administrative region of Tonkpi, between 7°20' and 7°30' north latitude and between 7°30' and 7°40' west longitude (Figure 1). The department of Man is characterized by contrasting relief with average altitudes of between 300 and 1000 m. The climate is humid tropical with an annual rainfall of 1600 mm.year^{-1} and a dry season perceived from October to February and a rainy season which extends from March to September with a peak in August (Tian-Bi et al., 2018). According to Koffi et al. (2021) and WRB (2022), the soils of the locality of Man are essentially Ferralsols.

The Toumodi department is located in the center of Côte d'Ivoire, in the forest-savannah transition zone, between 6°20' and 6°30' north latitude and between 4°55' and 5 °10' West longitudes. Toumodi is a transition zone between forest and savannah, with a bimodal tropical rainfall regime. The average annual rainfall is 1200 mm.year^{-1}. The rainy periods start from May to August and from October to November with a dry season interspersed in September. The long dry season concerns the period from December to April. The soils are of the Ferralsols, Cambisols type. Hydromorphic soils are also encountered in the lowlands.

Regarding the department of Prikro, it is located in the center-east of the country, in the administrative region of Iffou, between 7°40' and 7°41' north latitude and 4°9' and 4°10' West longitude. Prikro, with an average annual rainfall of 1100 mm, is characterized by two seasons: a major rainy season from March to October and a small dry season from November to February (Kouakou, 2016). Its relief is dominated by plateaus with clayey, granite and sandy soils in places (Koffi et al., 2021).

These three departments are mainly populated by natives and non-natives whose main activity is agriculture and livestock, with avegetation composed of semi-deciduous open forest, mesophilic cleared forest and mesophilic savannah (Bakayoko et al., 2016).

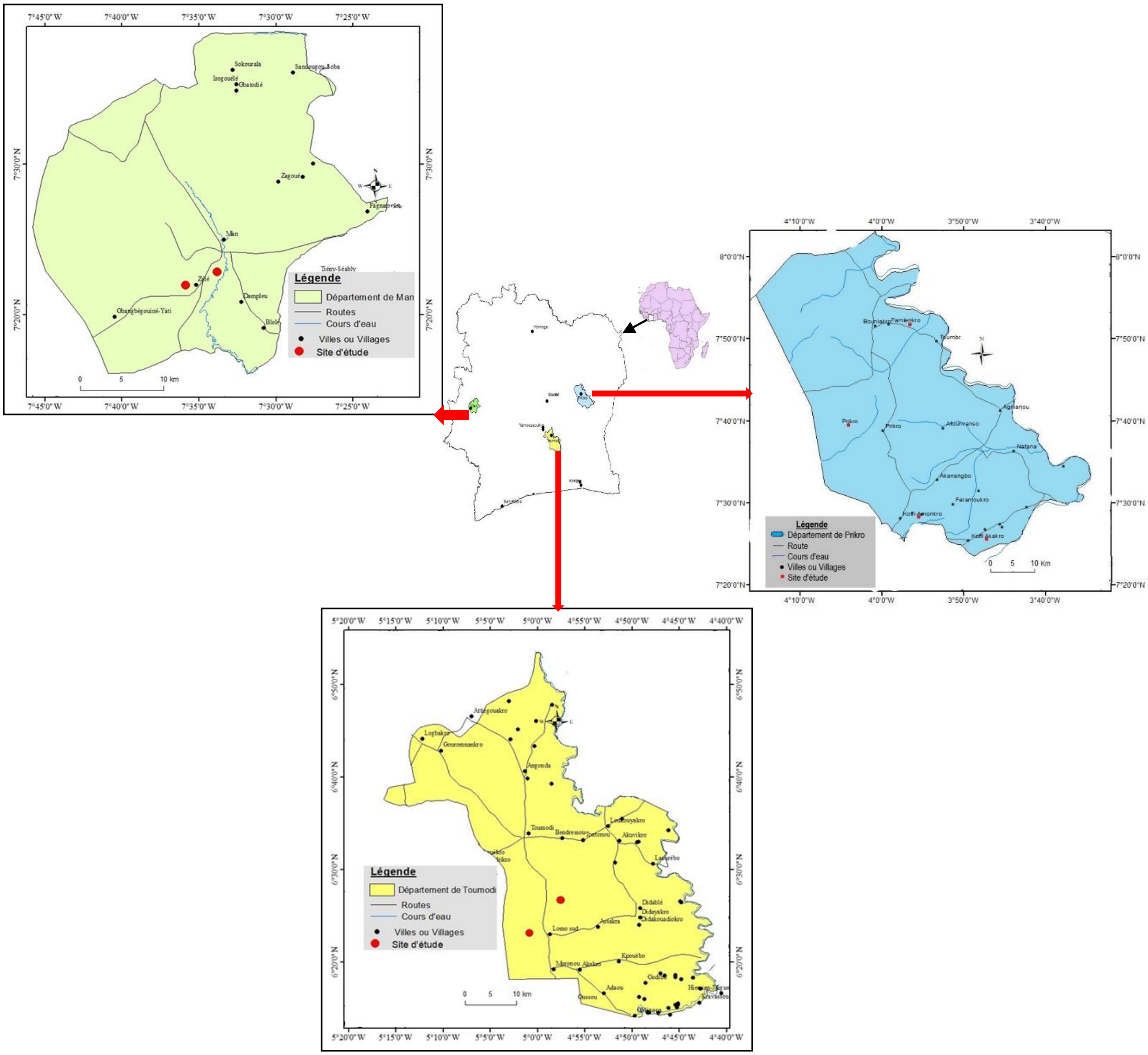


Figure 1: Location of study areas.

Study Methodology:-

Choice of behavior fields

The choice of behavioral fields focused on plantations created with good planting material, in particular bagged plants, maintenance of the plots, the clone planted, the age of the plantations, the previous cultivation and the texture of the soil. In order to minimize variables, only two clones were retained, GT1 and IRCA 41, to characterize rubber trees in the establishment phase. In practice, for young crops (immature crop), after having counted the plantations already created in a given locality, plantation visits were carried out to retain the best ones and the previous crop was noted to assess its impact on development. trees. Given the low number of mature plots (more than six years) in these regions, all those created with grafted plants were retained in the network of behavioral fields and the study of texture was retained to evaluate its influence on rubber trees.

Collection of data
Agro-physiologicalbehavior of rubbertrees
Mortality rate
The data on the mortality rate wereobtained by enumerationaccording to two criteria:
- anynecrotic, missing or easilybroken plant wasconsidereddead,
- any plant still green wasconsidered alive.

Isodiametricgrowth of rubbertrees
In order to evaluate the annualisodiametricgrowth of rubbertrees, the measurement of the circumference of the treeswascarried out monthly. On each experimental plot, tree circumference measurements were taken at 1.70 m from the ground for mature trees and 1 m from the ground for immature trees using a tape measure, to assess the growth of trees each year. This height was chosen to avoid the tree bleeding zone 1.20 m from the ground. Themeasurements on the trees selected were made before the start of the annual defoliation, more precisely in January, to assess the growth of the trees during each tapping campaign or each year.

Production of rubbertrees
A check of fresh rubber production was carried out monthly on each experimental plot. It was recorded tree by tree, the cumulative production per monthly tapping is thus obtained during each control. Production control consists of weighing the fresh rubber produced by the plot during the month and recording its weight on a production control sheet developed for this purpose.

Dry notch rate
A complete dry notch survey was carried out on all trees in each experimental tapping plot to determine healthy and diseased trees. The rapid survey method by visual estimation made it possible to report the appearance and progress of the dry notch (Van De Sype, 1984).Trees showing normal latex flow along the entire length of the notch after tapping were considered healthy and scored zero (0). The others were considered as trees affected by dry notch and rated from 1 to 6 depending on the length of the notch which does not produce latex (Van De Sype, 1984; Okoma, 2008).

Effects of soilparameters on the development, production and dry notching rate of rubbertrees
During the experiment, one hundred and twenty (120) soil samples were taken at depths 0-20 cm and 20-40 cm across all three departments. The samples were analyzed to determine the particle size on the experimental plots, two series of samples were taken using an auger with a diameter of 6.4 cm, between 0-20 cm depth. The first sample was taken at a depth of 0-20 cm and the second at 20-40 cm. The samples were taken using the diagonal method, that is to say in each corner and in the center of the plot, to constitute a composite sample. The soil samples were dried in the open air, for 72 hours to a week, depending on the moisture status of the sample. After drying, the samples were crumbled by hand and sieved with a 2 mm square mesh sieve to obtain fine soil for laboratory analysis.

Data processing
Mortality rate
The mortality rate wascalculatedusing the formula below:

$$\text{Tm }(\%) = \frac{\text{nber of dead plants}}{\text{total nber of plants}} \text{ x } 100$$

TM: Mortality rate,
Nber of dead plants: Number of dead plants,
Total nber of plants: Total number of plants
Average annual growth
The average annual increase in trunk circumference was determined by the following relationship:

$$\text{Accmoy} = \frac{(\text{Circi} - \text{Circ0})}{\text{i}}$$

Accmoy: Average annual increase in circumference (Cm);
Circi: Circumference of trees at the end of the experiment (Cm);

Circ0: Circumference of trees at the start of the experiment (Cm);
i: Number of years of experimentation.

Fresh rubber production
The raw production monitoring data were analyzed to determine the monthly average production of fresh rubber in kg and $ga^{-1}.s^{-1}$ from each experimental plot. This activity consisted of collecting the rubber production contained in the cups and weighing it (fresh weight: PF). A rubber sample is then creped (Creped weight: Pc) and dried in an oven at 80°C for 24 hours, then reweighed (Dry weight: Ps). The transformation coefficient (CT) was defined according to the following formula:

$$CT\ (\%) = (Pc \times PF) \times 100$$

CT: Transformation coefficient; **P**c: Crepe weight; **PF:** Fresh weight
The determination of the dry weight (PS) is carried out from the fresh weight (PF) and the transformation coefficient (CF) according to the following relationship:

$$PS = PF \times CT$$

With **PS:** Dry rubber weight; **PF:** Weight of fresh material; **CT:** Transformation coefficient.
Rubber production is expressed in grams per tree per tapping ($ga^{-1}.s^{-1}$) and in kilograms per hectare per year ($kg.ha^{-1}.an^{-1}$). These expressions provide the quantity of rubber that a tree produces during tapping and on one hectare (ha).

Dry notch andsick notch length (LEM)
The raw dry notch survey data was used to determine the dry notch rate or diseased notch length (LEM) of each experimental plot (Okoma, 2008). For each tapped tree, a number between 0 and 6 has been assigned, the meaning of which is as follows:
- **0**, for a healthy bleeding notch,
- **1**, for a dry notch over 1 to 20% of its length (10% on average),
- **2**, for a dry notch over 21 to 40% of its length (30% on average),
- **3**, for a dry notch over 41 to 60% of its length (50% on average),
- **4**, for a dry notch over 61 to 80% of its length (70% on average),
- **5**, for a dry notch over 81 to 99% of its length (90% on average),
- **6**, for a completely dry bleed notch.

For each plot, the tree population was determined and the percentage of total diseased notch length (LEM%) was calculated as follows:

$$LEM\ (\%) = 100 \times (0.1n_1 + 0.3n_2 + 0.5n_3 + 0.7n_4 + 0.9n_5 + n_6 + ES) \times N\text{-}1$$

With :**0 ; 0.1; 0.3; 0.5; 0.7; 0.9**and 1: coefficient expressing the average percentage of diseased notches in the class considered (grade assigned);
N: Total number of trees; **ni:** Number of trees per dry notch class;
ES: Number of trees whose tapping has already stopped for total dry notching.
Also, for each plot, the percentage of completely dry trees was determined by the following relationship:

$$\text{Dry trees}\ (\%) = (n6 + ES) \times N - 1$$

With, **N:** Total number of trees; **n6:** Number of trees for dry notch class 6;
ES: Number of trees whose tapping has already stopped for total dry notching.

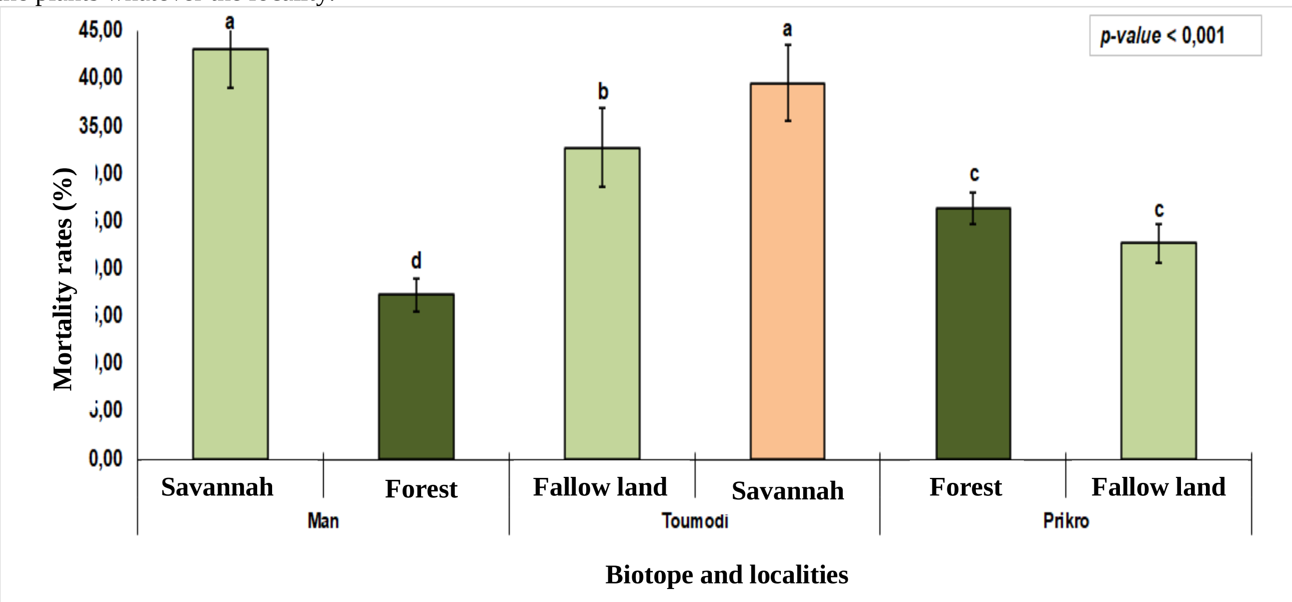
Effects of soilparameters on the development, production and dry notching rate of rubbertrees
Particle size analysis was carried out on fine earth using the Robinson-Köhn pipette method. Since the rubber tree is more sensitive to the clay content of the soil, this parameter alone was retained to assess its influence on the development and production of rubber trees.

Statistical analysis
Raw height dataisodiametric growth of tree trunks, latex microdiagnosis and rubber productionwere analyzed with SPSS 25 software. After checking the homogeneity of variances, one-way analyzes of variance and comparison of means was carried outThe Student-Newman-Keuls (SNK) test was used to distinguish groups at the 5% threshold.

Results:-

Agro-physiologicalbehavior of rubbertrees
Mortality rate of immature rubber plants after planting following previous cultivation

The study of the mortality rate of the plants just after the establishment of the plantations revealed a highly significant difference (p-value < 0.001) in the mortality rate between the different previous cultivations (biotopes) within each locality (Figure 2). Rubber plantations established on forest plots recorded the lowest plant mortality rates, especially in Man with 15% mortality. Abandoned cocoa tree plots (Fallow-cocoa tree) follow with 20%. The highest mortality rates were observed in plantations established on coffee fallows (42%) and in wooded savannah (40%). From these results, it emerged that the previous cultivation of the rubber plots influences the mortality rate of the plants whatever the locality.

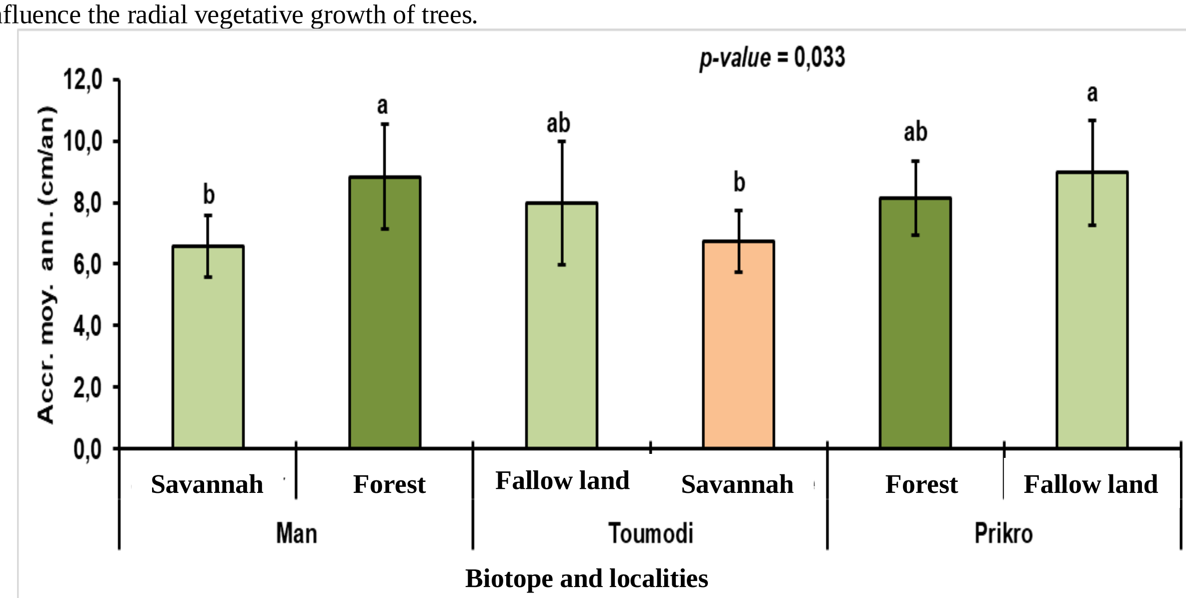


The bars represent the standard error of the mean. Means assigned to different letters indicate significant differences (Student-Newman-Keuls test, a = 0.05)

Figure 2:- Plant mortality rate depending on the biotope and localities.

Radial growth of the trunk of immature rubber trees depending on previous cultivation

The study of the radial growth of treesimmature rubber treesshowed that forest, cocoa fallow and simple fallow biotopes promote good vegetative development of plants with average annual growth of between 8.0 and 9.0 cm.year^{-1} in the investigated localities, Prikro, Man, Toumodi (Figure 3). From this study, it appears that the previous cultural a significant difference(p-value<0.05) between cultural precedents. This shows that biotopes influence the radial vegetative growth of trees.



The bars represent the standard error of the mean. The means assigned different letters indicate significant differences (Student-Newman-Keuls test, a = 0.05), ***Accr.moy.ann****: Average increase per year*

Figure2:- Average annual growth of immature plants depending on the biotope and localities.

Production of rubbertreesdepending on previous cultivation

The average production of rubber at the tree and at the tapping ($g.a^{-1}s^{-1}$) varied from41.94±8.15 to63.85±15.1$g.a^{-1}s^{-1}$ (Table I). Production per tree was highly influenced by the biotope (P-value = 0.001), unlike production per hectare which was weakly (P-value < 0.05) influenced. This variation was marked by locality with the greatest productions observed in Man with respectively the previous forest (63.85 ± 15.1 $g.a^{-1}s^{-1}$) andFallow-Coffee(62.69 ± 12.5 $g.a^{-1}s^{-1}$). Furthermore, the lowest production was observed on the Toumodi plantation (41.94±8.15$g.a^{-1}s^{-1}$) having a cultural precedent of wooded savannah.As for the average annual production of rubber per hectare, it varied from1396.6± 37 to3007.34±79$kg.ha^{-1}yr^{-1}$, with the best production observed in Man.

Table I:- Average rubber production based on previous crops.

		Average production	
Localities	**Biotope**	**$g.a^{-1}s^{-1}$**	**$kg.ha^{-1}yr^{-1}$**
Man	Fallow-Coffee	**62.69 ± 12.5a**	**2018.62 ± 79.1 b**
	Forest	**63.85 ± 15.1 a**	**3007.34 ± 42.3 a**
Toumodi	Fallow	**52.03 ± 9.5 b**	**2023.97 ± 45.2 b**
	Tree savannah	41.94 ± 8.15c	1396.6 ± 37.7 c
Prikro	Forest	**54.2 ± 13.4 b**	**2254.72 ± 59.4 b**
	Fallow-Cocoa	52.3 ± 11.2 b	2322.1 ± 43.8 b
P-value		0.001	0.022

*Means assigned different letters in the same column indicate significant differences (Student-Newman-Keuls test, a = 0.05).**$g.a^{-1}s^{-1}$**: Gram per tree per tapping;**$kg.ha^{-1}yr^{-1}$**:Kilogram per hectare per year*

Effects of soilparameters on the development, production and dry notching rate of rubbertrees

Effect of soil texture on radial vegetative growth of trees

The evaluation of the average annual radial vegetative growth of mature and immature rubber trees measured as a function of soil texture was significant (P-value < 0.05) in each department (Table II). The study showed that the radial vegetative growth of trees is greater on soils with a clay-loam texture (25% < clay < 50%) in the three localities. It varies from 7.06 to 9.06 $cm.year^{-1}$ respectively in Toumodi and Man for immature trees and from 2.30 to 3.15 cm.year-1 for mature trees.

The texture with a good clay content (25% < clay < 50%) of the soil allowed good development of the rubber plants.

Table II:- Radial vegetative growth of rubber trees as a function of texture.

		Radial vegetative growth ($cm.year^{-1}$)		
Localities	**Texture**	**Immature period**	**Mature period**	***p-value***
Man	Sandy-clayey (10% < clay < 25%)	**7.50 b**	**2.80a**	**0.031**
	Clay-loamy (25% < clay < 50%)	**9.06a**	**3.15a**	
Toumodi	Sandy-clayey (10% < clay < 25%)	6.00 b	2.47 b	**0.042**
	Clay-loamy (25% < clay < 50%)	**7.06a**	**2.65a**	
Prikro	Sandy-clayey (10% < clay < 25%)	6.96b	2.30b	**0.022**
	Clay-loamy (25% < clay < 50%)	**8.01a**	**2.75a**	

Means assigned different letters in the same column indicate significant differences (Student-Newman-Keuls test, a = 0.05). ***$Cm.year^{-1}$****: Centimeter per year*

Effect of soil texture on rubber production

The average production of rubber was greater on silty-clay soils with more than 25% clay, mainly in Man with 63.27±6.1 $g.a^{-1}s^{-1}$against53 ± 5.09 $g.a^{-1}s^{-1}$hasPrikroand 46.99±7.1$g.a^{-1}s^{-1}$ in Toumodi (Table III). Low production was recorded on sandy-clayey soils (10% < clay < 25%), especially in Toumodi (42.03 ± 4.2 $g.a^{-1}s^{-1}$). In terms of production in $kg.ha^{-1}yr^{-1}$, plantations established on soilsclay-silty (25% < clay < 50%)also recorded the best productions, ranging from1736.45 ± 237.2 $Kg.ha^{-1}yr^{-1}$(Toumodi) to2984.8 ± 442.6$Kg.ha^{-1}yr^{-1}$(Man).

Table III:- Average rubber production depending on soil grain size.

		Average production		
Localities	**Texture**	**g.a^{-1}s^{-1}**	**Kg.ha^{-1}yr^{-1}**	***p-value***
Man	Sandy-clayey (10% < clay < 25%)	**52 ± 5.4b**	**2164.5 ± 266b**	**0.001**
	Clay-loamy (25% < clay < 50%)	**63.27 ± 6.1 a**	**2984.8 ± 442.6 a**	
Toumodi	Sandy-clayey (10% < clay < 25%)	42.03 ± 4.2b	1636 ± 125.1 a	**0.042**
	Clay-loamy (25% < clay < 50%)	46.99 ± 7.1 a	1736.45 ± 237.2 a	
Prikro	Sandy-clayey (10% < clay < 25%)	**49.75 ± 3.7 b**	**1834.06 ± 143.5 b**	**0.019**
	Clay-loamy (25% < clay < 50%)	**53 ± 5.09a**	**2353.2 ± 190 a**	

*Means assigned different letters in the same column indicate significant differences (Student-Newman-Keuls test, a = 0.05).**g.a^{-1}s^{-1}**: Gram per tree per tapping;**kg.ha^{-1}an^{-1}**: Kilogram per hectare per year*

Effect of soil texture on dry notch susceptibility of rubber trees

The evaluation ofdry tree rate and diseased tree notch lengthdepending on the texture of the soil showed significant diseased notch length (LEM) in the plantations of Man and Prikro, established on soils with a sandy-clay texture (10% < clay < 25%) with respectively9.68% and15.59%. On the other hand, the high proportions of LEM in Toumodi were observed in plantations on soilsClay-loamy (25% < clay < 50%)with21.8% LEM.It is the same for theTotal dry notch (ES), where the lowest rates were recorded on soilsClay-loamy (25% < clay < 50%)localities of Prikro (ES = 1) and Man (ES = 5).According to these results, the Toumodi plots present a high level of total dry notch and diseased notch length regardless of soil texture. However, in Man and Prikro, the loam-clay texture soils with more than 25% clay minimize the dry notch syndrome in the plantations.

Table III:- Dry notch rate of experimental plots of crops in production.

Localities	Texture	LEM (%)	ES Total	*p-value*
Man	Sandy-clayey (10% < clay < 25%)	9.68a	9 a	0.0001
	Clay-loamy (25% < clay < 50%)	6.38 b	5b	
Toumodi	Sandy-clayey (10% < clay < 25%)	12.17b	30b	0.0001
	Clay-loamy (25% < clay < 50%)	21.8a	42 a	
Prikro	Sandy-clayey (10% < clay < 25%)	15.59a	30 a	0.0001
	Clay-loamy (25% < clay < 50%)	6.88b	1 b	

*Means assigned different letters in the same column indicate significant differences (Student-Newman-Keuls test, a = 0.05). **LEM**: Sick Notch Length; **ES**: Total dry notch;**cm:** centimeter; **%** : percentage.*

Discussion:-

The study of the mortality rate of the plants just after the establishment of the plantations showed that the previous crop influences the success of the plants despite the use of the same plant material. The plots with abandoned coffee trees (coffee fallows) and wooded savannahs as a previous crop had the highest mortality rates, unlike the plots with a forest crop precedent. Indeed, this high mortality rate could be linked to climatic variations: drought, too strong temperature variations, particularly in Toumodi which is a savannah zone with a high level of temperature (Mahyao et al., 2022). In addition, this high mortality rate in the field after transplantation could be due to the deformation of the root system and the insufficient number of rootlets caused by the long stay in the bags. Indeed, the establishment of a plant after transplantation depends on its hydromineral nutrition which is a function of the rootlets equipped with absorbent hairs. The spiralization and orthotropy of plagiotropic lateral roots caused by these deformations reduce the capacity for root development after planting by limiting the use of water and soil fertilizer resources. They also harm the stable and lasting anchoring of plants which could be uprooted by the winds (Assi et al., 2018). The high mortality rate of plants under previous coffee fallow in Man could be due to “white root rot” whose causal agent is a soil fungus called Leptoporuslignosus or Rigidoporuslignosus or Fomes lignosus commonly called Fomes (Wahounou et al., 2017). Root rot can decimate 10 to 30% or even 50% of a plantation's rubber stand (Obouayeba, 2005). Indeed, it is capable of remaining in a saprophytic state within woody debris for several years after clearing (Wahounou et al., 2017). These mortality rates are different from those observed in traditional areas under the same growing conditions (Elabo et al., 2022).

The evaluation of the average growth of plants also showed that biotopes influence tree growth. The cocoa fallow, forest and simple fallow allowed a good level of plant growth. This situation would probably be linked to the aftereffect of the biomass left on the soil after weeding. It is generally recognized that crop residues allow the recycling of nutrients, notably nitrogen, phosphorus and potassium (Bado, 2002; Kambiré et al., 2007), which would promote the growth of future crops, hence good productivity as was observed in this study. This could also be explained by the fact that forest trees had a beneficial effect on the soil by making it more loose, deep and airy. Likewise, root rot, a dreaded root disease caused by the genus Fomes on Hevea brasiliensis trees, could be an obstacle to the success and growth of plants that have recorded a low growth rate (Wahounou et al., 2017). At the same time, given the high rainfall recorded in Man, this locality could be more favorable for the growth of plants (Camara, 2019). However, for Lines et al., (2010); Hurst et al., (2011), plant growth increases due to greater vulnerability to external factors such as drought, fungi or insect outbreaks.

It should also be noted in this study that rubber plants developed better in Man and Prikro than in Toumodi depending on the clay content of the soils. Indeed, clay is an important constituent of the soil which can affect its structure, its water retention and its capacity to provide nutrients to plants (Rezaei & Gilkes, 2005) which would justify the good growth of rubber plants on these types of soil. Also, the potential of a soil for growing crops is largely determined by the environment that the soil provides for root growth. Roots need air, water, nutrients and adequate space to grow. Soil physical properties and, in turn, plant growth are significantly controlled by variation in landscape attributes, which influence energy distribution, plant nutrients and vegetation (Rezaei & Gilkes, 2005). This reflects the divergent levels of plant development in the study localities. According to Soltner (1992), reported by N'guessan et al., (2015), when coarse sands dominate in a soil, they promote the penetration of water and air, retain little water and facilitate the temperature exchanges. The soil heats up quickly in the dry season, and its constituents cannot clump together. Which would justify the low level of development of the plants in the locality of Toumodi. However, it should be noted that the cultivation of rubber trees would be beneficial to the environment of these regions. Indeed, rubber tree cultivation improves the physical, hydrodynamic, chemical and biological properties of degraded soils (Chandrakala et al., 2019; Andriyana et al., 2020), because of the very abundant root hair and its large capacity. of CO2 sequestration and the secondary forest environment it creates. It also rebuilds forest cover from the fifth year of cultivation (Obouayeba et al., 2016).

The average production of natural rubber at the tree and at the tapping ($g.a^{-1}.s^{-1}$) and relatively that in kilogram per hectare per year (kg.ha-1.an-1) were influenced by the environmental parameters and soil parameters studied. The results showed more increased rubber productivity in Man and Prikro than in Toumodi. These results could be attributable to environmental conditions. Indeed, the locality of Man has a rainfall of over 1600 $mm.year^{-1}$ which is well distributed throughout the year (Brou, 2017) and the soils were more clayey. This level of clay could retain water in order to make it available to the plant during dry periods. Devakumar et al. (1988) reported that during a period of soil water stress the flow rate of latex is reduced. Chandrasekhar, (1994) argued that soil moisture was significantly and positively related to latex yield. It is therefore certain that the increase in coarse fragments reduces the available soil moisture and thus reduces growth as well as rubber yield, when other conditions are kept constant. Apart from the direct impact of soil physical parameters including clay content of soil on growth and rubber yield, Rao &Vijayakumar. (2006) showed the significant effect of soil nutrients on rubber yield.

The average rates of diseased notch length (LEM) and dry extract were higher in Toumodi and Prikro than in Man. Several studies have indicated that dry notch syndrome is caused by exogenous stresses and/or physiological dysfunction of trees (Okoma et al., 2011; Okoma et al., 2016; Obouayeba et al., 2016). Exogenous stress can be due to over-stimulation (Chrestin, 1985) or to multiple stresses including strong seasonal variations in climate (Okoma et al., 2016), soil type (Jobbe-Duval et al. al., 1988) in particular, its level of compaction which may be linked to the passage of bulldozers (IRD, 2005), etc. The high sensitivity to dry notching observed at Toumodi and Prikro could lead us to put forward the hypothesis of a soil problem.

Conclusion:-

The evaluation of the behavior of rubber trees in the new areas made it possible to monitor and understand the impact of the biotope and soil texture on the development and production of natural rubber. Thus, rubber plants flourish well on plots with previous forest and fallow. As a result, the plants developed better in Man and Prikro where the previous cultivation allowed good adaptation of the plants and the clay textures of the soil also allowed good development as well as good production. The diseased notch length and dry notch rate of trees is also influenced by soil texture. It is higher on soils containing less clay. Overall, it should be noted that the rubber trees are performing well in these new areas, particularly in Man and Prikro unlike in Toumodi where the environmental conditions have a little more impact on the proper functioning of the plants.Given the development potential of the rubber tree in these regions, it would be desirable to deepen the studies by combining climatic and agropedological parameters in order toto make these departments another hub for the development of rubber growing in Côte d'Ivoire.

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