EFFECTS OF GLYCINE MAX AND PHASEOLUS VULGARIS CROP RESIDUES ON MANIHOT ESCULENTA PRODUCTION IN AGRICULTURAL SOIL IN THE KARAMOKOLA AREA, CENTRAL-WESTERN COTE D IVOIRE

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EFFECTS OF *GLYCINE MAX* AND *PHASEOLUS VULGARIS* CROP RESIDUES ON *MANIHOT ESCULENTA* PRODUCTION IN AGRICULTURAL SOIL IN THE KARAMOKOLA AREA, CENTRAL-WESTERN COTE D'IVOIRE

Abstract

A comparative study of previous soybean (*Glycine max* L.) and bean (*Phaseolus vulgaris*) crops on the productivity of cassava (*Manihot esculenta* Crantz) was conducted in the department of Mankono with the aim of developing a cropping system adapted to increasing cassava yields. To this end, a trial was conducted on sandy-loam ferralitic soil, moderately desaturated, that had been left fallow for more than two years. The experimental design was based on a randomized complete block design comprising four elementary microplots corresponding to different crop precedents: (i) control ridged soil with no crop precedent, (ii) bean monoculture, (iii) soybean monoculture, and (iv) bean-soybean combination. Cassava cuttings were planted in each ridge at an angle, with two buds left above the soil. The results show that legume-based previous crops improved soil fertility, positively influencing the growth, agromorphological development, and productivity of cassava. Compared to the control (18.42 t/ha), yields were significantly higher in the three other plots previously cultivated with legumes: 35.26 t/ha in bean monoculture, 31.96 t/ha in bean-soybean combination, and 26.79 t/ha in soybean monoculture. Thus, the integration of legumes as a previous crop is an effective agronomic strategy for increasing cassava productivity. Bean monoculture and bean-soybean combination appear to be particularly favorable, confirming the value of diversifying cropping systems to optimize yields.

Keywords:-Legumes, cassava, agro-morphological parameters, yield.

Introduction :-

Approximately 1.02 billion people worldwide suffer from undernourishment (FAO, 2019). Cassava (*Manihot esculenta* Crantz), native to the Amazon and belonging to the Euphorbiaceae family, is one of the main food crops in tropical areas. Thanks to its high agro-ecological adaptability, it is a source of energy for more than 500 million people and provides livelihoods for millions of people involved in the sector (FAO, 2019). Since the late 1980s, global cassava production has been declining, accompanied by an increase in the prices of cassava products (IRAD, 2013). Today, its cultivation has spread to tropical and subtropical areas (Nouar et al., 2013). In Africa, production reached 134 million tons in 2010, making cassava the continent's leading food resource, with an estimated market value of $17.4 billion in 2011 (Von Grebmer et al., 2013). Africa remains the world's leading supplier of tuberous roots (Nouar et al., 2013). In West Africa, 90% of production is used for human consumption and 10% for animal feed (Sanni & Deppah, 2009).

In Côte d'Ivoire, cassava is produced throughout the country due to its ecological plasticity and the diversity of its derivatives. However, the southwest and center are the main production areas, with an annual average of 2.41 million tons and a yield of 6.5 t/ha (N'Zué et al., 2013). This low yield is due to the use of traditional tools, the low adoption of improved varieties, and, above all, poor soil quality. To increase productivity, several cultivation techniques are being explored, including the integration of legumes (Fabaceae) into crop rotations. These offer many advantages, such as providing protein and energy, improving fertility through symbiotic nitrogen fixation, and improving soil structure and porosity (Mohamed, 2022 ; Wang et al., 2020). However, few studies have looked at the impact of legume crop rotations on cassava grown on ridges, even though this practice could improve its development and productivity. The overall objective of this study is to restore declining agricultural soil productivity through the use of legume-based fallow systems. It aims to determine the effects of *Glycine max* and *Phaseolus vulgaris* crop rotations on *Manihot esculenta* production.

Materials and methods :-

Study site

The study was conducted in Karamokola, in the department of Mankono, in central-western Côte d'Ivoire. This locality, located at an average altitude of 390 m, lies between latitude 8°7'22'' N and longitude 6°10'4'' W. The climate is Sudanese, characterized by an average annual rainfall of about 1000 mm and an average temperature of 26.1 °C (Beaudou & Sayol, 1980). The rainy season, which is generally oppressive and cloudy, contrasts with the dry season, which is more humid and partially cloudy. In terms of soil, the area is dominated by Dystric Ferralsols (Lévêque, 1992). Although poor in nutrients, these soils provide an important substrate for food crops.

Furthermore, the region is a traditional cassava-producing area (ANADER, 2017), which justifies the relevance of conducting such a study there.

Biological material

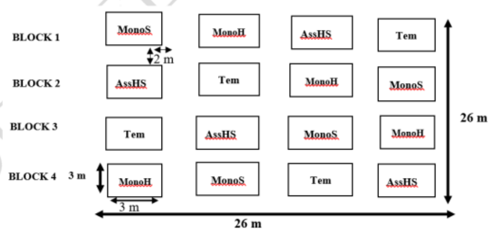
The plant material consists of *Manihot esculenta* cuttings from the Bocou 2 variety, which belongs to the collection of improved varieties at the National Agricultural Research Center (CNRA) in Bouaké. This variety, whose vegetative cycle varies between 11 and 24 months, has dense vegetation cover in rural areas and an average yield of 30 t/ha. Its dry matter content reaches 39%, making it a widely used variety in human food. In addition, two legumes have been introduced as preceding crops: green soybeans (*Glycine max* L.) and beans (*Phaseolus vulgaris*). The seeds from the collection distributed by the CNRA in Bouaké have short physiological cycles of 3 to 4 months. Average yields are estimated at between 1.2 and 2 t/ha for soybeans and between 1.5 and 2 t/ha for beans. These varieties were selected based on three main criteria: their agronomic performance, their ability to improve soil fertility, and their high taste value, which is highly appreciated by consumers.

Physicochemical characterization of the initial soil condition

Composite soil samples were taken using an auger at five points in the 0-20 cm and 20-40 cm strata of the plot for physical and chemical analysis in the laboratory. The analyses focused on texture, pH, organic matter, C, total N, assimilable P, $Ca^{(2+)}$, $Mg^{(2+)}$, $K^{(+)}$, and CEC. This step aimed to characterize the soil type and establish the initial state of the soil conditions before the experiment was set up.

Experimental setup

The trials were conducted in 2022 over two successive 90-day legume cycles, established on fallow land that was more than two years old. The first cycle ran from April to June, and the second from August to October of the same year. On each plot, a randomized complete block experimental design was set up, comprising four blocks of 26 m × 26 m each. Each block consisted of four treatments (Figure 1), namely a bean monoculture (MonoH), a soybean monoculture (MonoS), a bean-soybean combination (AssHS), and a control without legumes (Control). The elementary plots had an area of 12 m² (3 m × 3 m) and each test treatment was repeated twice per block. The legumes were grown during two cycles of 90 days each. At the end of each cycle, only the soybean and bean pods were harvested for consumption, while the above-ground biomass (stems and leaves) was buried in situ to decompose and enrich the soil for the next cycle. After the two legume cycles, all the microplots were plowed and then manually ridged using a hoe, forming ridges 50 cm high, 80 cm wide at the base, and 3 m long. Each ridge was then planted with three cassava cuttings (Figure 2), spaced 1 m × 1 m apart and planted at an angle (45°) so that 2 to 3 buds remained above the soil. Each micro-plot thus constituted a treatment unit.



MonoS: Bocou2 grown on the soybean monoculture treatment; AssHS: Bocou2 grown on the bean and soybean combination treatment; Tem: Bocou2 grown on the control; MonoH: Bocou2 grown on the bean monoculture treatment.

Figure 1: Experimental setup

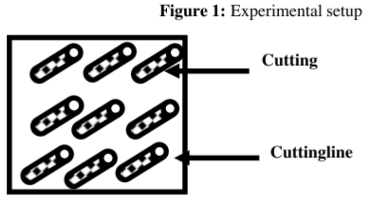


Figure 2: Diagram of a micro-plot cultivated with cassava

Collection of agro-morphological and yield data

Manual weeding was carried out whenever necessary using hoes. No chemical fertilizers or phytosanitary treatments were applied during the experiment. In each micro-plot, 12 cassava plants were selected and monitored throughout the cycle, from planting the cuttings to harvesting. During the main physiological phases (recovery, establishment, and tuberization), agromorphological and yield parameters were measured. Agromorphological parameters included stem base diameter (DBTIG), number of leaves per plant (NF), number of branching levels of the main stem (NNRAMTP), length of the main stem (LTIG), width (LAF) and length (LF) of the leaves, and plant height (HPL). The variables SBBD, MSL, LBL, LFL, and PHT are expressed in centimeters. Leaf area (LA) was calculated using the formula developed by Bonhomme et al. (1982): LA (cm^2)= (L × W) × 0.75, where L is leaf length (cm), W is leaf width (cm), and 0.75 is the adjustment coefficient.
Production parameters included the number of tuberous roots per plant (NRTP), the total weight in kilograms of tuberous roots per plant (PRTP), the weight in kilograms of the smallest (PPTRTP) and largest tuberous roots (PGRTP), and their respective lengths in centimeters (LPPTRTP, LPGRTP), measured with a tape measure. Yield (RDT) was obtained per microplot using the following formula:

$$RDT = (PF \times NP) / S$$

Where PF = total fresh weight per plant (kg), NP = number of plants per microplot, S = microplot area (m^2). The yield was then converted into tons per hectare.

Statistical data processing

Data analysis was performed using descriptive statistics and analysis of variance. The means were compared using one-way ANOVA, and in cases of significant difference, Fischer's LSD post-hoc test was applied at a 5% significance level to form homogeneou . All statistical processing was performed using R software (version 4.2.1).

Results :-

Physi chemical characterization of the initial soil condition

The results of the soil particle size analysis are presented in Table 1. The soil is dominated by a large proportion of sand (more than 54%), followed by silt. Regardless of the stratum considered, the soil has a silty-sandy texture.

Table 1 :- Soil particle size distribution

Strata	Variables	Contents (%)	Texture
0-20 cm	Clays	4,90	Sandy-lime
	Silts	38,00	
	Sands	57,10	
20-40 cm	Clays	4,34	Sandy-lime
	Silts	38,98	
	Sands	57,68	

In the 0-20 cm layer, the average pH is 5.3; organic matter is 4.3 g/kg and carbon is 2.2 g/kg (Table II). This horizon also has a nitrogen content of 0.2 $g.kg^{-1}$ and a C/N ratio of around 12.11, while assimilable phosphorus remains limited (15.96 $g.kg^{-1}$ compared to 100 $g.kg^{-1}$). For the 20-40 cm soil layer, the average pH is 5.3, organic matter is 3.8 $g.kg^{-1}$ and carbon is 2.5 $g.kg^{-1}$. Nitrogen is adequate (0.1 $g.kg^{-1}$) and the C/N ratio is high (17.28), while assimilable phosphorus remains low (15.19 $g.kg^{-1}$).

Table 2:- pH, organic matter, and available phosphorus in the soil

Strata	Variables	Contents	Reference values
0-20 cm	**pHeau**	5.30	6 -7
	C ($g.kg^{-1}$)	2.2	11.6 – 17.4
	MO ($g.kg^{-1}$)	4.3	20 - 30
	Nt ($g.kg^{-1}$)	0.2	0.015 – 0.025
	C/N	12.11	9 - 12
	Pass ($mg.kg^{-1}$)	28.41	50 - 100
20-40 cm	**pHeau**	5.35	6 -7
	C ($g.kg^{-1}$)	2.5	11.6 – 17.4
	MO ($g.kg^{-1}$)	3.8	20 - 30
	Nt ($g.kg^{-1}$)	0.1	0.015 – 0.025
	C/N	17.28	9 - 12
	Pass ($mg.kg^{-1}$)	15.19	50 - 100

OM: Organic matter, TN: Total nitrogen, P: Available phosphorus, Reference values (Doucet, 2006)

The exchangeable cation content and cation exchange capacity (CEC) compared to standard reference values are presented in Table 3. For the 0-20 cm horizon, the soil has low values for calcium (Ca^{2+} = 0.25 < 5 $cmol·kg^{-1}$), magnesium (Mg^{2+} = 0.34 < 1.5 $cmol·kg^{-1}$) and potassium (K^{+} = 0.04 < 0.25 $cmol·kg^{-1}$). The CEC remains insufficient (CEC = 2.39 < 10 $cmol^{+}·kg^{-1}$). Finally, for the 20-40 cm horizon, exchangeable bases including Ca^{2+} (0.31 < 5 $cmol·kg^{-1}$), Mg^{2+} (0.26 < 1.5 $cmol·kg^{-1}$) and K^{+} (0.09 < 0.25 $cmol·kg^{-1}$) remain low. The CEC remains low and insufficient (CEC = 1.89 < 10 $cmol^{+}·kg^{-1}$).

Table 3:- Exchangeable cations and cation exchange capacity of the soil

Strata	Variables	Teneurs ($cmol.kg^{-1}$)	Reference values($cmol.kg^{-1}$)
0 – 20 cm	**K^{+}**	0.04	0.15-0.25
	Ca^{2+}	0.25	5 - 8
	Mg^{2+}	0.34	1.5-3
	CEC	2.39	10 - 15
20 – 40 cm	**K^{+}**	0.09	0.15-0.25
	Ca^{2+}	0.31	5 - 8
	Mg^{2+}	0.26	1.5-3
	CEC	1.89	10 - 15

Reference values (Doucet, 2006)

Agromorphological parameters

Table 4 presents the average values of the agromorphological parameters of cassava, determined during its growth and development, according to previous crops: bean monoculture, soybean monoculture, bean-soybean intercropping, and a control. A highly significant overall variability ($P < 0.0001$) in the average values was observed for all agromorphological parameters. Parameters such as stem base diameter (DBTIG), plant height (HPL), main stem length (LTIG), number of branching levels (NNRAM), and leaf width (LAF) show high average values for the MonoH, MonoS, and AssHS treatments, while the control treatment had the lowest values. Among the three treatments, the MonoH treatment tended to have the highest values.

Cassava plants grown using the MonoH treatment have the highest number of leaves (NF), the longest leaves (LF), and the largest leaf area (SF). For these same parameters, the MonoS and AssHS treatments show statistically similar intermediate values, while the control soil supports cassava plants with the lowest values.

Table 4:- Agronomic parameters of cassava according to treatment

Variables	Treatments				CV	Pr > F
	Control	**MonoH**	**MonoS**	**AssHS**		
LTIG (cm)	171.08b	245.76a	204.95a	224.63a	18.18	<0001
NNRAM	1.56b	3.56a	2.68a	3.36a	29.60	<0001
HPL (cm)	191.55b	260.50a	226.33a	244.93a	14.75	<0001
DBTIG (cm)	1.70b	2.47a	2.13a	2.20a	9.02	<0001
LF (cm)	22.24c	25.22a	24.24ab	25.15b	10.99	<0001
LAF (cm)	17.40b	21.21a	20.59a	20.34a	11.55	<0001
NF	139.53c	247.32a	158.61b	207.75ab	17.32	<0001
SF (cm^2)	302.86c	417.38a	384.80ab	392.16b	20.96	<0001

Values followed by the same letter on the same line are not statistically different at the 5% probability threshold; MonoH: Bean monoculture; MonoS: Soybean monoculture; AssHS: Bean and soybean combination; LTIG: Stem length; NNRAM: Number of branching levels; HPL: Plant height; DBTIG: Stem diameter at base; LF: Leaf length; LAF: Leaf width; NF: Number of leaves; SF: Leaf area.

With the exception of the number of tuberous roots per plant, the other production variables and yield increased significantly (P < 0.05) in the MonoH, MonoS, and AssHS treatments (Table IV). Significant differences were noted for tuber weight per plant and yield (RDT). These parameters had the highest average values under the MonoH, MonoS, and AssHS treatments. For the weight of the smallest tuber per plant (PPTRTP), the MonoS previous crop had the highest value, while the other treatments had statistically similar values. The weights of the largest (PPGRTP) and smallest tubers (PPTRTP) for the MonoH, MonoS, and AssHS treatments were statistically identical and higher than those of the control (Control). Similarly, the length of the largest tuber (LPPGRTP) showed high and similar values for the MonoH and MonoS treatments, while AssHS and Tém showed the highest values. Analysis of the number of tuberized roots per plant (NRTP) and their total weight indicates that the MonoH previous crop is the most effective treatment. A similar trend is observed in terms of yield (RDT), reaching 35.26 t/ha for the monoH treatment compared to 18.42 t/ha for the control, representing an almost twofold increase in production.

Table 5:- Cassava production parameters and yield according to treatments

Variables	Treatments				CV	Pr > F
	Control	**MonoH**	**MonoS**	**Ass HS**		
PRTP (g)	3.07d	5.87a	4.46c	5.35b	8.69	<0001
PPTRTP (g)	0.20b	0.20b	0.37a	0.19b	35.45	0,0003
PPGRTP (g)	1.07b	1.52a	1.64a	1.12b	20.45	0,0004
NRTP	6.86a	7.31a	7.07a	7.80a	9.54	0,0645
LPPTRTP (cm)	22.17b	28.75a	27.07a	30.00a	14.88	0,0031
LPGRTP (cm)	56.42b	80.96a	72.04a	72.90a	10.90	<0001
RDT (t/ha)	18.42d	35.26a	26.79c	31.96b	8.59	<0001

Values followed by the same letter in the column are not statistically different at the 5% probability threshold. MonoH: Bean monoculture; MonoS: Soybean monoculture; AssHS: Bean and soybean combination; PRTP: Weight of tuberous roots per plant; PPTRTP: Weight of the smallest tuberous root per plant; PPGRTP: Weight of the largest tuberous root per plant; NRTP: Number of tuberous roots per plant; LPPTRTP: Length of the smallest tuberous root per plant; Length of the largest tuberous root per plant; RDT: Yield.

Discussion :-

The granulometric analysis of the soil in the study area revealed a silty-sandy texture, favorable for cassava cultivation. This result corroborates the work of Buol et al. (2011), indicating that such a texture is suitable for tuberous root crops, including cassava, for good yields. However, the mineral content of the soil in its initial state indicates a deficiency in organic matter, carbon, and assimilable phosphorus, although the nitrogen content and

C/N ratio are higher than the normative reference values. The low assimilable phosphorus content could result from a low organic matter content, which promotes its immobilization, in accordance with the observations of Bertrand & Gigou (2000). The exchangeable bases reveal a marked deficiency in calcium, magnesium, and potassium, all of which are limiting factors. FAO (2024). Exchangeable bases reveal a marked deficiency in calcium, magnesium, and potassium, all of which are potential limiting factors for cassava productivity. This situation fully justifies the exploration of strategies to improve fertility through the introduction of cover legumes.

The comparative evaluation of previous crops demonstrates the significant advantage of treatments including legumes compared to the control. The descending order of performance (MonoH > AssHS > MonoS) suggests a differential influence of legume species and their planting methods. The superiority of the MonoH treatment (bean monoculture) is evident in both vegetative development and final yield, with a production of 35.26 t/ha compared to 18.42 t/ha for the control. This exceptional performance could be explained by several synergistic factors. The dense plant cover generated by the beans, with more than sixty leaves per square meter, creates a microclimate conducive to maintaining soil moisture and biological activity. The decomposition of this abundant biomass gradually enriches the soil with organic matter and nutrients, as observed by FAO (2024). Legumes affect soil fertility through complex and complementary mechanisms. The process of rhizodeposition, defined as the emission of compounds by roots (Mohamed, 2022), plays a fundamental role in soil nitrogen enrichment. Beyond nitrogen compounds, rhizodeposition influences phosphorus availability and stimulates soil microbial communities, as documented by Lupwayi & Kennedy (2007). The effect of legumes on soil physical properties is equally remarkable. Improved porosity, permeability, and water retention capacity create a root environment conducive to cassava tuber development (Mohamed, 2022; Stagnari et al., 2017; Veloso et al., 2019). These physical improvements facilitate the exploration of the soil profile by the root system and optimize nutrient use efficiency.

Conclusion :-

The results of this study support the systematic integration of cover legumes into cassava-based cropping systems. Bean monoculture appears to be the most promising option, offering the best compromise between soil improvement and agronomic performance. The yield obtained was 35.26 tons per hectare, compared to 18.42 tons per hectare for the control. This practice is in line with sustainable agriculture, reducing dependence on external inputs while maintaining the productivity of the system.

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