

Effect of Tillage on Agro-morphological Parameters and Yield of Cassava (*Manihot esculenta crantz*) in Abongoua, East-Central Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Authors NKR and NKA designed the study, performed the statistical analysis, wrote the protocol and authors KAG and KZ managed the analyses of the study. Authors NKR and BS drafted the first version of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this work is to improve the production and yield of cassava cultivated by tillage. The experiment was conducted in the field for 13 months (June 2019-july 2020) in Abongoua in the department of Bongouanou (East-central Côte d'Ivoire). After the cleaning of a 900 m² surface of a fallow of more than 5 years, and cleared of all plant debris, soil samples were taken with an auger in the 40 cm surface in each corner and in the center of the experimental plot to constitute the composite sample for laboratory analysis. The trials were conducted in a randomized complete block design with four replicates in which four elementary plots were distributed. Three treatments T1 (tilled soil), T2 (mounded soil) and T3 (ridged soil) compared to a control treatment T0 (no-till soil) were applied in each microplot. The cuttings were directly sown at a rate of 12 cuttings per treatment. The data of the different parameters collected underwent an analysis of variance

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(ANOVA) performed with SAS software version 9.4 and the means were separated using the Newman and Keuls test at the 5% probability threshold. The results showed an acidic soil with a sandy texture and a good supply of nutrients, particularly major elements, trace elements and clay-humus complex. Good growth and development of agro-morphological parameters as well as yield were obtained with treatments T3 (ridged soil), T2 (mounded soil) and T1 (tilled soil) in decreasing order of importance compared to the control treatment (T0). In conclusion, the study clearly showed that the type of tillage, particularly the ridged tillage technique, improves the agro morphological parameters, productivity and yield of cassava. What we recommend to farmers for a good yield of cassava in the area.

Keywords: *Agro morphology; Daloa (Ivory Coast); cassava; yield; tillage.*

1. INTRODUCTION

Cassava (*Manihot esculenta Crantz*), native to the Amazon, is a plant of the Euphorbiaceae family. Today, its cultivation has been amply extended to tropical and subtropical regions [1] due to its excessive plasticity with respect to soil and climatic conditions and its cultivation period. In Côte d'Ivoire, this speculation has proven to be particularly interesting due to its diversity in products derived and consumed throughout the country. However, the Southwest and the Center remain the main cultivation areas with an average annual production of 2.41 million tons for a low yield estimated at about 6.5 tons per hectare [2]. This low yield is not only the consequence of a traditional cropping system associated with poor cultivated soils, but also the low diffusion of improved high-yielding, disease and pest resistant varieties. The growing interest in cassava has led to a search for more efficient cultivation techniques to increase yields [1,3]. To do this, various cultivation techniques have been initiated, including plowing, which aims to create a favorable environment in the soil for the development of cultivated plants. It is through these cultivation techniques to improve the structure of the soil, its physical state and consequently increase its permeability and porosity creating conditions more suitable for the development of tuberous roots. However, there is little specific scientific information on the type of tillage that can create optimal conditions for the development of tuberous roots to improve productivity. It is therefore imperative that studies be conducted to guide farmers in choosing the type of tillage that would improve the production and yield of cultivated cassava. It is in this perspective that our study entitled "Effect of tillage on agro-morphological parameters and yield of cassava (*Manihot esculenta Crantz*) in Daloa, Côte d'Ivoire" was conducted. Its

objective is to improve the production and yield of cassava cultivated by tillage.

2. MATERIALS AND METHODS

2.1 Study Area Description

The study was conducted from June 2019 to July 2020 in Abongoua in the department of Bongouanou between 6°40 North latitude and 4°26 West longitude, with an altitude of 121m (Fig.1). It is a transition zone between dense forest and wooded savannah traditionally recognized as a cassava production zone in Côte d'Ivoire. The climate is transitional humid tropical with bimodal rainfall varying between 700 and 1200 mm/year [4]. The average annual temperature varies between 25 and 30°C and the average relative humidity is around 70% [5]. The vegetation cover, very heterogeneous varies gradually from semi-deciduous dense rainforest to a cleared mesophilic forest. The soils of the region are based on vast granitic massifs, metamorphic and schistose rocks. They are represented as a complex of Distric plinthic ferralsol. These are soils that have overall good agricultural abilities and are suitable for all types of crops [6].

2.2 Plant Material

The plant material used consists of cassava (*Manihot esculenta Crantz*) cuttings from the Bocou1 variety in the collection of improved varieties of the National Agricultural Research Centre of Côte d'Ivoire (Fig. 2). It is a variety with a cycle of 12 to 24 months. Bocou 1 has a good vegetation cover in rural areas and an average yield of 25 tons/ha. Its dry matter content is 39% and it is commonly used for attiéké, placali and foutou in human food [2].

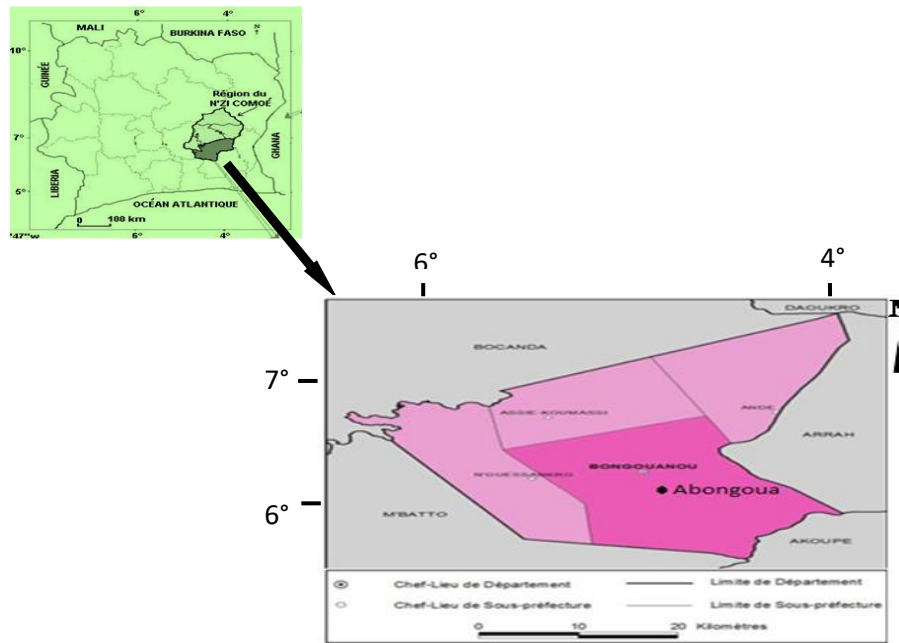


Fig. 1. Map of the study area

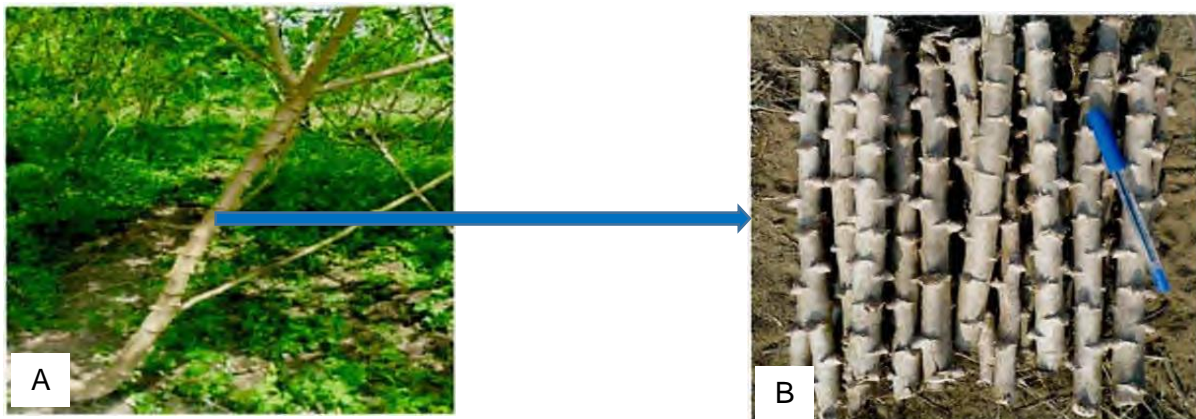


Fig. 2. Cassava variety Bocou.1 showing the foot of cassava Bocou1 (A) and cassava cuttings Bocou1 (B)

2.3 Methods

2.3.1 Site physico-chemical characterization

After cleaning an area of 900 m² of fallow land that was more than 5 years old and cleared of all plant debris, soil samples were taken with an auger from the top 40 cm in each corner and in the center of the experimental area to constitute the composite sample, 1 kg of which was taken after drying and sent to the laboratory to assess the state of soil fertility of the study site. These analyses included pH measurement (electronic glass pH meter in a soil/solution ratio of 1/2.5), determination of total carbon (Walkley & Black

method) and organic matter ($C \times 0.72$), total nitrogen (Kjeldahl method), assimilable phosphorus (Olsen-Dabin method) exchangeable bases and cationic exchange capacity-CEC (Rinse extraction of ammonium acetate solution), calcium-Ca and magnesium-Mg (Atomic absorption), potassium-K (Flame spectrophotometer), using standard laboratory methods of analysis.

2.3.2 Experimental design

The trials were carried out in a randomized complete block design of four replicates maintained 2 m apart, in which four elementary

plots of 5 m × 4 m separated by a 2 m aisle are distributed. Three treatments T1, T2 and T3 consisting respectively of tilled soil, mounded soil and ridged soil compared to a control T0 (no-till soil) were applied in each microplot. Plowing was done manually with a daba. Ploughed soils were levelled to a depth of 10 cm, while mounds and ridges were levelled to a height of 30 cm and a base width of 60 cm respectively. In each microplot are sown 3 lines of 4 cuttings with 2 to 3 eyes in a 45 degree inclined position and spaced 1 m apart from each other.

2.3.3 Agro-morphological and yield data collection

In each elementary plot, the 12 cassava plants were selected and followed throughout their development cycle from the sowing of the cuttings to the harvest. During the main physiological phases, agro-morphological and yield parameters were collected. The agro-morphological parameters determined concerned:

- the measurement of the basic stem diameter (BSD), using calipers.
 - the number of leaves per plant (NL), by counting;
 - the number of the most developed main stem branches (MDSB), by counting;
 - the measurement of the height of the plant (HP) and the length of the main stem (LMS) were determined using a graduated ruler;
 - the calculation of the leaf area (LA) from the equation: $LA (cm^2) = (L \times l) \times 0.75$ [7];
Where, LA: leaf area expressed in cm^2 ; L (cm): leaf length; l (cm): leaf width; 0.75: coefficient.
- As for the yield parameters, they concerned:
- the number of tuberized roots per foot (NTRF), by counting;
 - the weight of tuberous roots per foot (WTRF), by weighing;
 - the weight of the smallest tuberous root (WSTR) and the largest tuberous root (WLTR), by weighing;
 - the length of the smallest tuberous root (LSTR) and the largest tuberous root (LLTR) were determined using a graduated ruler;

- the yield obtained first on the microplot was determined according to the following formula

$$\text{Total yield} = \text{FW (kg)} \times \text{NCP/S}$$

where: FW = Fresh weight of cassava harvested per plant; NCP = Number of cassava plants per microplot; S = Area of the microplot. This yield per microplot was then reported in tons per hectare.

2.3.4 Data statistical treatment

The data were analyzed using descriptive statistics and analysis of variance (ANOVA) methods performed with SAS software version 9.4. Means were separated using the Newman and Keuls test at the 5% probability level.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Soil granulometric composition

The results of the granulometric analysis of the soil studied are presented in Table 1. It was found that the soil of the study site consists of 15.27% clay, 11.25% fine silt and 18.30% coarse silt; or 29.55% total silt and 20.03% fine sand and 34.95% coarse sand, or 55.18% total sand. These proportions indicate that the soil texture is sandy to sandy-silty.

3.1.2 Study site soil chemical analysis

3.1.2.1 Soil acidity, organic matter content, nitrogen and available phosphorus

The values of pH, organic matter content, nitrogen and available phosphorus are presented in Table 2. It reveals an acid soil (pH = 4.8), organic matter (OM = 97.2 $g.kg^{-1}$), carbon (C = 56.5 $g.kg^{-1}$), nitrogen (N = 8.4 $g.kg^{-1}$) and available phosphorus (Pass = 500 $mg.kg^{-1}$) are high compared to the reference standards which are respectively 30 $g.kg^{-1}$ for organic matter, 17.4 $g.kg^{-1}$ for carbon, 500 $g.kg^{-1}$ for assimilable phosphorus and 0.015 to 0.025 $g.kg^{-1}$ for nitrogen. These high values are accompanied by a very low C/N ratio (6.73) compared to the normative reference value (C/N = 9).

Table 1. Granulometric composition of the study site soil

	Granulométric composition of the sol (0-40 cm)						
	Clay	Fine silt	Coarse silt	Total silt	Fine sand	Coarse sand	Total sand
Teneur en sol (%)	15.27	11.25	18.30	29.55	20.03	34.95	55.18

Table 2. pH and major soil element of the study site

Parameters	Soil content	*Standards
pH	4.8	6-7
OM. (g.kg ⁻¹)	97.2	20-30
C (g.kg ⁻¹)	56.5	11.6-17.4
N total (g.kg ⁻¹)	8.4	0.015-0.025
C/N	6.73	9-12
Pass (mg.kg ⁻¹)	500	50-100

*Normative reference values [8,9]

3.1.2.2 Soil exchangeable cations and cation exchange capacity

The exchangeable cation and cation exchange capacity contents presented in Table 3 show a marked deficiency in exchangeable calcium ($\text{Ca}^{2+} = 2.05 < 5 \text{ cmol.kg}^{-1}$) and magnesium ($\text{Mg}^{2+} = 0.97 < 1.5 \text{ cmol.kg}^{-1}$) bases. On the other hand, exchangeable potassium and sodium contents show high values ($\text{K}^+ = 3.85 > 0.25 \text{ cmol.kg}^{-1}$ and $\text{Na}^+ = 1.03 > 0.7 \text{ cmol.kg}^{-1}$) respectively compared to the normative reference values. Similarly, the content of trace elements, namely, zinc ($\text{Zn}^{2+} = 25.87 > 2.8 \text{ mg.kg}^{-1}$), iron ($\text{Fe}^{2+} = 3572 > 300 \text{ mg.kg}^{-1}$) and copper ($\text{Cu} = 4.40 > 0.6 \text{ mg.kg}^{-1}$) are all high compared to normative reference values. On the other hand, a low content of manganese ($\text{Mn}^{2+} = 0.07 < 0.02 \text{ mg.kg}^{-1}$) as well as that of aluminum

($\text{Al}^{3+} = 2.05 < 2.8 \text{ cmol.kg}^{-1}$) in the soil was noted. The value of the sum of exchangeable cations is medium ($7.5 < \text{Sum} = 7.89 < 15 \text{ cmol.kg}^{-1}$) while that of the cation exchange capacity is high ($\text{CEC} = 38.5 > 15 \text{ cmol.kg}^{-1}$) in the soil for a low saturation rate (V) of exchangeable bases in the soil ($V = 20.5 < 60\%$).

3.1.2.3 Soil cation balance ratio

The Ca/Mg ratio is medium ($2 < \text{Ca/Mg} = 2.11 < 9$) and indicates a slight excess of calcium over magnesium in the soil. The Mg/K ratio is high ($\text{Mg/K} = 3.97 > 0.1$) while that of Ca+Mg/K was found to be low ($\text{Ca+Mg/K} = 0.78 < 12$). This denotes that calcium and magnesium are relatively high compared to potassium in the soil. However, the sum of calcium and magnesium is deficient relative to potassium (Table 4).

Table 3. Exchangeable cations and cation exchange capacity of soil

Parameters	Exchangeables cations and cation exchange capacity	*Standards
Ca (cmol.kg ⁻¹)	2.05	5-8
Mg (cmol.kg ⁻¹)	0.97	1.5-3
K (cmol.kg ⁻¹)	3.85	0.15-0.25
Na (cmol.kg ⁻¹)	1.03	0.3-0.7
Al (cmol. kg-1)	2.05	2.82-4.10
Mn (cmol. kg-1)	0.07	0.015-0.028
Zn (mg.kg-1)	25.87	1.9-2.8
Fer (mg.kg-1)	3572.00	200-300
Cu (mg.kg-1)	4.40	0.3-0.6
CEC (cmol.kg ⁻¹)	38.5	10-15
Sum (Ca, Mg, K, Na)	7.89	7.5-15
V = Sum*100/ CEC (%)	20.51	60-90

*Normative reference values [8,9]

Table 4. Equilibrium ratio between Ca²⁺, Mg²⁺ and K⁺ cations (cmol.kg⁻¹) in soil

Parameters	Equilibrium ratio between the cations of the horizon (0-40 cm)	*Standards
Ca ²⁺ /Mg ²⁺	2.11	2-9
Mg ²⁺ /K ⁺	3.97	0.05-0.1
Ca ²⁺ +Mg ²⁺ /K ⁺	0.78	12-15

*Normative reference values [8,9]

Table 5. Variation of average values of agronomic parameters of cassava according to treatments

Treatments	Agro morphological parameters					
	BSD (mm)	HP (cm)	LMS (cm)	MDSB	NL	LA (cm ²)
T0	1.19±0.10c	181.87±12.29c	158.70±11.52c	0.95±0.15b	102.16±9.78 c	433.39±24.78b
T1	1.19±0.10c	176.77±12.59c	157.88±11.84c	0.81±0.14b	90.37±8.13 c	441.32±23.71b
T2	1.36±0.11b	194.40±13.59b	173.90±12.98b	0.93±0.16b	126.74±14.23b	524.68±28.22a
T3	1.67±0.12a	217.24±14.49a	197.80±14.31a	1.21±0.17a	163.78±15.98a	513.70±28.95a
CV(%)	10.85	8.74	9.82	16.04	22.01	12.88
P	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001

Values followed by the same letter in the column are not statistically different at the 5% probability level

BSD: Base stem diameter; HP: Plant height; LMS: Main stem length; MDSB: Main stem branching; NL: Number of leaves; LA: Leaf area

Table 6. Variation in mean values of cassava yield parameters across treatments

Treatments	Yield parameters						
	NTRF	WTRF (kg)	WSTR (kg)	WLTR (kg)	LSTR (cm)	LLTR (cm)	YIELD (t/ha)
T0	5.50±0.48b	2.05±0.23c	0.18±0.02a	0.77±0.07b	13.95±1.35a	35.83±2.40a	12.32±1.38c
T1	6.33±0.55ab	2.56±0.94cb	0.18±0.01a	0.95±0.09a	13.83±1.22a	38.37±2.75a	15.40±1.76c
T2	6.70±0.50ab	3.03±0.22b	0.17±0.02a	1.06±0.07a	13.16±1.48a	42.41±2.01a	18.20±1.35b
T3	7.83±0.68a	4.83±0.53a	0.22±0.03a	1.47±0.16a	16.5±1.77a	44.79±3.17a	29.00±3.18a
CV(%)	19.59	22.21	8.37	16.46	23.05	16.59	26.61
P	.036	< .0001	.49	< .0001	0.37	.089	< .0001

Values followed by the same letter in the column are not statistically different at the 5% probability level

NTRF: Number of tuberous roots per plant; WTRF: Weight of tuberous roots per plant;WSTR: Weight of smallest tuberous root per plant; WLTR: Weight of largest tuberous root per plant; LSTR: Length of smallest tuberous root per plant; LLTR: Length of largest tuberous root per plant

3.1.3 Agro-morphological parameters

The mean values of the different agro-morphological parameters of cassava determined during its growth and development according to the treatments are presented in Table 5. There was a highly significant ($P < 0.0001$) overall variability in the mean values of the different agro-morphological parameters assessed across treatments. These significant differences indicate much higher values with the T3 treatment whatever the agro morphological parameter considered. More specifically, it is worth mentioning that the base diameter of the stem (BSD), plant height (HP), length of the main stem (LMS), branching of the main stem (MDSB), number of leaves (NL) and leaf area (LA) had significant differences indicating higher values with treatments T3 and T2 respectively, in decreasing order, while T1 and T0 showed statistically identical average values for each of the agro morphological parameters studied. Overall, treatments T3 and T2 significantly affected the growth and development of cassava.

3.1.4 Yield parameters

The average values of the yield parameters reporting the productivity of cassava are noted in Table 6.

There was significant ($P = .05$) to highly significant ($P < .0001$) variability in the mean values of the yield parameters recorded, notably, for the number of tuberous roots per plant (NTRF), tuberous root weight per plant (WTRF), largest tuberous root weight (WLTR) and total yield. These yield parameters had higher average yield values with treatments T3, T2, T1 et T0 in descending order. It should also be noted that no significant differences were observed in the weight of the smallest tuberous root (WSTR), lengths of the smallest tuberous root (LSTR) and the largest root (LLTR) regardless of treatments. Specifically considering the number of tuberous roots per plant (NTRF) and their total weight per plant, the best treatment is T3. This is illustrated by the highest total yield (29 tons per hectare) with treatment T3 compared to the control treatment (T0) with 12.32 tons per hectare, a gain of more than half the yield in T3.

3.2 Discussion

3.2.1 Soil physico-chemical parameters

The results of the analysis of the physico-chemical parameters of the soil showed an acid

soil with a sandy texture presenting a good disposition in major nutrients and in clay-humic complex suitable for the cultivation of cassava. These results corroborate with the findings of several recent studies showing that sandy texture, acidic pH and acceptable mineral content of the soil are excellent conditions for the growth and development of most tuberous root crops including cassava for good yield [10,11,12]. This physico-chemical fertility of the soil could be explained by a strong accumulation of organic matter on the surface of the soil due to the fact that the exploited plot is set aside over a long period of 10 years [13]. This results in a slow decomposition of organic matter which, associated with the biological activity of plants justifies the increase in the content of assimilable phosphorus, the low C/N ratio and the naturally acidity of the soil [14,15,16]. Exchangeable bases showed a marked deficiency in calcium and magnesium. However, the exchangeable potassium and sodium contents were respectively high. This shows that increasing potassium concentration in the soil nutrient solution decreases calcium and magnesium uptake. On the other hand, the relatively high values of the sum of exchangeable cations and cation exchange capacity in the soil would be explained by the fact that the soil is moderately endowed with cations, thus justifying the average saturation ratio [17,8]. The respectively satisfactory equilibrium ratios could improve cassava yield [8,11].

3.2.2 Cassava agro-morphological parameters

The study revealed an acceptable physico-chemical fertility of the soil that is likely to favor good growth and development of the cassava plant, if we refer to the results of analyses. In addition to this particular physico-chemical disposition of the soil, the improved cassava variety (Bocou 1) has an interesting agronomic performance character, characterized by a very good plant cover [2,18]. In addition to these edaphic and agronomic factors, the cultivation technique applied, ranging from plowing to sowing of cuttings, allowed a good lifting of dormancy of cuttings. This favored a good recovery of the planted cuttings and a good development of the agronomic parameters evaluated. However, compared to the control treatment (T0), corresponding to the no-till-soil, treatments T3 (ridged soil), T2 (mounded soil) and T1 (till-soil) had a good growth and development of agro-morphological parameters in decreasing order of importance. This result

could be explained by the type of soil tillage. Indeed, plowing creates an environment in the soil that is favorable to the development of cassava cuttings by improving its physical properties (porosity, permeability, water and air retention capacity) as well as by allowing good incorporation of green manure (grasses and plant debris from the clearing) into the soil, whose decomposition would contribute to improving organic matter and carbon in the soil. On this basis, the study clearly indicates that ridged soil is more conducive to cassava cultivation than ridged and ploughed soils in decreasing order. This confirms the importance of the key role played by tillage in improving soil structure and agricultural suitability [19,20].

3.2.3 Cassava yield parameters

In this study, cassava yield in fresh weight of tubers per hectare ranged from 12.32 t.ha⁻¹ for the no-tillage control treatment (T0) to 29 t.ha⁻¹ for the ridge treatment (T3). These values obtained in this study are of the same order of magnitude as those reported in other similar research with an average fresh weight yield of tubers ranging from 18.01 t.ha⁻¹ to 20 t.ha⁻¹ [21,22].

This result would be due to the simultaneous influence of tillage and the development of agromorphological parameters on cassava yield. Indeed, a higher leaf development is a necessary condition to obtain high tuber yields [23]. The positive influence of tillage on tuberization is also related to a rapid and high leaf development, which would allow the best use of the light radiation levels of the active phase of photosynthesis. Differences in fresh tuberous root yield parameters at harvest are thought to be the result of different rates of nutrient transport from the leaves to the roots depending on the type of tillage. Another factor that could explain the tuberization of cassava is the plasticity of the soil structure, resulting in water availability and nutrient enrichment. This offers not only a good elongation of the tuberous roots in the soil, but also a better extraction of these elements from the soil. These results are similar to those of other researchers who explain that soil moisture would be the consequence of adequate tillage and high organic matter accumulation [24]. Also, it has been shown that good tillage facilitates better rooting of tuberous plants and that good cassava yields at harvest are also a result of high extraction of nutrients, including N, P, K, Ca, Mg and Zn from the soil [25,26,27].

4. CONCLUSION

The aim of the study was to evaluate the effect of the type of tillage on the agro-morphological parameters and on the productivity of an improved variety of cassava named "Bocou 1" distributed in the Bongouanou region. This study also aimed at identifying the type of tillage adapted to obtain a good cassava yield. The study site, which was a fallow land, allowed a natural fertility of the soils that affected not only the growth and the development of the agromorphological parameters of cassava, but also influenced its productivity. The study of cassava production functions also showed that the contents of organic matter, nitrogen, phosphorus, potassium, zinc and calcium, as well as the sum of cations are likely to promote good growth of cassava plants and good tuberization of cassava. However, based on the cultivation technique adopted, which consisted of tilling the soil, cassava cultivation on ridges and mounds proved to be very conducive to improving cassava productivity, with 29 tons and 18.20 tons per hectare, respectively, compared to 12.32 tons per hectare on unplowed soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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