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Responses of Cotton Crop to use of Different Conventional Tillage Tools in South Alibori Area in Benin

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Abstract: This study aims to assess the influence of the use of motorized plowing tools on cotton development in the South Alibori area in Benin. The plowing tools tested were the disc plow for plowing at 10 cm (CD10) and 20 cm depth (CD20), the moldboard plow at 10 cm (CS10) and 20 cm depth (CS20), the rotavator (Ro) and daba (Ho). A Random Complete Blocks Design constituted of six tools and three replications were implemented on Bensékou, Kokey, and Banigouré sites and were repeated over two campaigns between 2019 and 2021. The results showed that compared with daba, root and stem length increased respectively by 1.1±0.77 cm and 16±2.5 cm with CD10 and CS10 and by 2.5±0.77 cm and 34±1.84 cm with CS20 and CD20. Ramifications and diameter of root and stem were significantly increased with CD20 and CS20 treatments ($p<0.05$). Compared with daba, CD10, and CS10 on the one hand, CS20 and CD20 improved the cotton fiber yield by 1.4±0.42 q/ha and 2.7±0.42 q/ha respectively. For both campaigns, plowing at 20 cm depth is recommended for soil preparation for cotton growing.

Keywords: motorized tools; soil; plowing; cotton; South Alibori.

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1. Introduction

The economy of many French-speaking West African countries is based on cotton cultivation [13]. In Benin, its contribution to Gross Domestic Product (GDP) varies between 5 and 10 % [13], making the country the leading African cotton producer [2]. Its cultivation is mainly concentrated in the northern part of the country [3] with more than 50 % of national production since 2018 in the department of Alibori [10].

In this department, the agricultural motorization encouraged strong cotton production by initiated by the various strategies and programs of the government in the farm field since 2009. Most motorized operations have remained plowing using many tools such as the disc plow, moldboard plow, rotavator, etc. The modernization of plowing operations has probably led to the improvement of cotton production, going from 136,958 tons in 2010 to 597,986 tons in 2017 throughout the territory [24]. However, cotton production systems encouraged by increased production have been achieved at the expense of the environment [10]. Indeed, these productions cannot be carried out without the systematic supply of fertilizers and phytosanitary products requiring substantial financial means [7]. The high fertilizer application rates (250 kg ha^{-1} in the North against 200 250 kg ha^{-1} in the Center and

South zone of Benin [24]) show that there is an increased fertility decline of agricultural land in the cotton zone of the North - Benin compared with other production areas.

The purpose of motorized tillage is to provide an environment conducive to seed germination. It modifies the physicochemical and biological properties of the soil [6–11] and incidentally acts on plant growth and yield [18,25]. In precedent work in the South Alibori area, tillage equipment favored soil furnishings and reduced nutrient content and the macrobiotic density on the soil surface. By their action of mixing the layers, plowing at 20 cm has improved the water holding capacity in 10-20 cm soil layers.

This work aims to identify the plowing equipment and the plowing depth beneficial for better cotton production. This article presents the results of the study on the influence of the use of conventional tillage implements on cotton production in the Alibori department.

2. Material and Methods

2.1. Study area

This study was carried out in 2020 and 2021 on three experimental sites located in the cotton zone of North - Benin in the villages of Kokey (Banikoara), Bensékou (Kandi), and Banigouré (Gogounou). The climate is Sudanese with a unimodal regime characterized by two contrasting seasons, a rainy season extending from May to October and a dry season from November to April [15]. Rainfall fluctuates between 700mm and 1200mm per year. The soils of granitic gneiss and sandstone are most widely distributed. What's more, these soils are generally of the tropical ferruginous type [25] suitable for agriculture and cotton growing. Agriculture employs more than 92% of the working population with more than 31% of agricultural households producing cotton crops. In this cotton-growing zone, the three major cotton-producing communes are Kandi with 37.7% of households concerned, Banikoara (36.8%), and Gogounou (31.5%) [15]. The properties of 0 - 20cm soils in study sites are presented in Table 1.

Table 1. Soil characteristics of the study sites [15].

Soil properties (0-20 cm)	**Study sites**		
	Kokey	*Bensékou*	*Banigouré*
Clay (%)	12.4	14.6	11.6
Silts (%)	20.3	22.3	18.9
Sand (%)	67.1	63.1	69.2
Organic C (%)	1.323	1.177	1.342
Total nitrogen (%)	0.048	0.031	0.061
pH	7.17	6.29	5.95

2.2. Equipment and experimental design

Motorized agricultural operations consisted of soil preparation operations mainly focused on plowing. It was carried out with different plowing tools depending on the experimental set-up. For motorized plowing, a 52 HP tractor was used. The various support tools used are 3- disc plow 1.2m wide; 3- a moldboard plow 1.2m wide; rotavator with a working width of 1.3m and daba for manual plowing.

To achieve the objective, a Random Complete Blocks Design with six treatments and three replications was implemented at the three experimental sites. These treatments included the disc plow used at 10cm depth (CD10) and 20cm depth (CD20), the moldboard plow at 10cm depth (CS10) and 20cm depth (CS20), the rotavator (Ro), and the daba (Ho). Apart from the daba, this equipment was coupled to the 52-horsepower tractor. The blocks measured 30 m by 5m, each divided into six square plots of 5m per side.

2.3. Plant material

The plant material used is the ANG 956 variety, recommended by INRAB for the cotton zone of North - Benin (MAEP, 2018), and its characteristics are summarized in Table 2.

Table 2. Agronomic characteristics of the ANG 956 variety [15].

Agronomic traits	Variety ANG 956
Seed-to-maturity cycle (days)	180
Potential yield (t/ha)	4.5
Cotton yield in the field (kg/ha)	2254
Average harvest precocity (%)	81.6
Tolerance to bacteriosis	Not very sensitive

2.4. Conduct of the test

Preparation of the elementary plots began with a maintenance treatment with the total herbicide. Then followed the plowing operations following the experimental devices from June 23 to 25 of years 2020 and 2021 on the cultivation sites. The day after plowing, treatment with Cotochem Selective Herbicide followed seeding. From June 24 to 26 of each crop year, sowing was carried out at 4 - 5 seeds per pocket and 5cm deep. After installing the culture, maintenance of the culture began with the mineral fertilizer of the NPK 8th day after sowing with a dose of 250kg/ha. Application of urea is made to the 40th day at a dosage of 50kg/ha. Phytosanitary treatments after seedlings have taken the 35th day after the lifting of cotton with an interval of 14 days following the distribution of plant protection products indicated in this area [17].

2.5. Plant parameters measurements

For the study of cotton roots, the crop profile method was used by digging a 150cm × 60cm × 50cm pit. A grid of 100cm × 50cm squared every two cm was placed on the profile. Through the grid, the observation of the root system of 4 cotton plants allowed the reading and the measurement of the rooting depth, the diameter at the neck, and the number of ramifications of the main root.

The four cotton plants observed by crop profile per elementary plot were used for the study of the aerial system. Thus, the length and diameter at the neck of the main rod are measured. The count of the number of branches of the main stem was also carried out. The cotton fiber yield per elementary plot was determined using an electric scale.

2.6. Statistical analyzes

To compare the effect of the plowing tools on the development of the aerial and root system of cotton as well as on the cotton fiber yield, the linear mixed effects model was realized. The "plowing tools" factor was the fixed factor, the "site" and "campaign" were the random factors, and the "block" was nested in the factor “site”. R 3.6.3 [23] was used for statistical analysis.

3. Results

3.1. Root system of the cotton plant

The use of conventional tillage implements had an impact on the root system of the cotton plant in particular the length of the main root. Indeed, depending on the site, the main root length differed from one tool to another (Figure 2). Specifically, the linear mixed-effects model performed on the data in Figure 2 indicated a significant impact of all conventional plowing tools ($p<0.05$) except the rotavator ($p=0.125$) (Table 3).

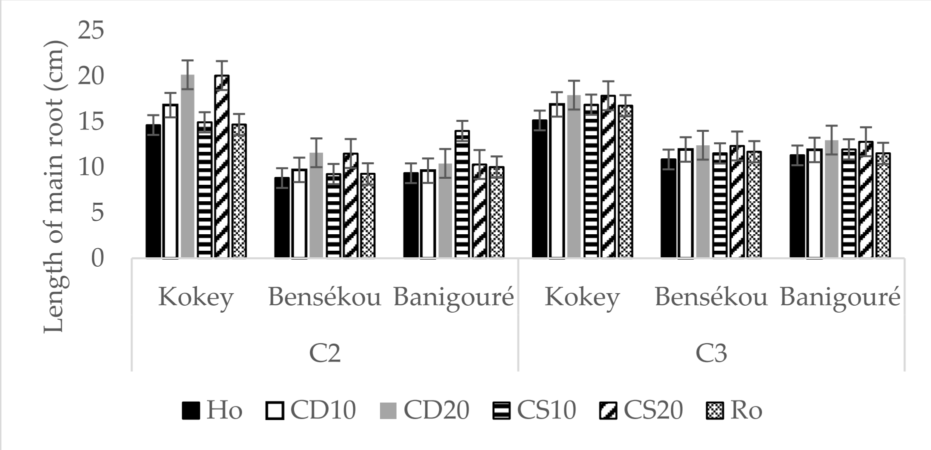

Figure 2. Length of the main root in different sites.

Table 3. Impact of tillage implements on the length of the main root.

Source of variation	Coef (SE)	t value	Prob.
Intercept	11.65 (2.29)	5.69	0.019 *
CD10	1.16 (0.77)	2.73	0.007 *
CD20	2.57 (0.77)	6.06	<0.001 *
CS10	1.30 (0.77)	3.08	0.002 *
CS20	2.48 (0.77)	5.86	<0.001 *
Ro	0.65 (0.77)	1.34	0.125
Variance due to site (Prob)	11.258 (0.0149) *		
Variance due to block (site) (Prob)	0.142 (0.165)		
Variation due to campaign (Prob)	0.654 (0.017) *		
Variance to residual	3.22		

Block (site): "block" nested in factor "site"; *: significance at the 5% level

Compared with the daba (Ho), while CD10 and CS10 increased the main root length by 1.16±0.77cm and 1.30±0.77cm respectively, CD20 and CS20 increased this parameter by 2.57±0.77cm and 2.4± 0.77cm (Table 3).

The variations induced by the use of plowing tools on the main root diameter were more visible with the CD20 and CS20 treatments in all the study sites (Figure 3). In all the sites, a significant growth of 0.9± 0.12cm and 1.0±0.12 cm of main root diameter was noted with CD20 and CS20 respectively compared with (Ho) ($p<0.001$) (Table 4).

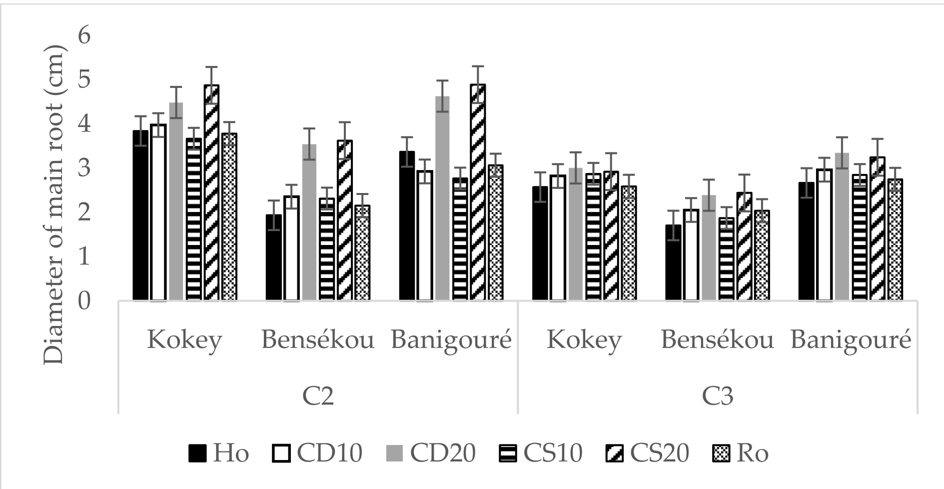

Figure 3. Diameter of the main root in different sites.

Table 4. Impact of plowing tools on the diameter of the main root.

Source of variation	Coef (SE)	t value	Prob.
Intercept	2.67 (0.55)	4.86	0.030 *
CD10	0.18 (0.12)	1.49	0.137
CD20	0.91 (0.12)	7.36	<0.001 *
CS10	0.08 (0.12)	0.64	0.524
CS20	1.01 (0.12)	8.17	<0.001 *
Ro	0.02 (0.12)	0.15	0.882
Variance due to site (Prob)	0.338 (<0.001) *		
Variance due to block (site) (Prob)	0.003 (0.639)		
Variation due to campaign (Prob)	0.362 (<0.001) *		
Variance to residual	0.273		

Block (site): "block" nested in factor "site"; *: significance at the 5% level

The development of roots had also been impacted by the use of conventional tillage tools. The main roots experienced more branching growth in plots turned with CD20, CS10, CS20, and Ro compared with the roots of plots plowed with daba. Root branches increased by at least 2 branches with CD20 and CS20 compared with CD10 and Ho (Table 5; Figure 4).

Table 5. Impact of tillage implements on main root ramifications.

Source of variation	Coef (SE)	t value	Prob.
Intercept	6.64 (0.94)	7.07	0.014 *
CD10	0.72 (0.45)	1.62	0.107
CD20	2.36 (0.45)	5.30	0.002 *
CS10	0.89 (0.45)	2.00	0.047 *
CS20	2.42 (0.45)	5.42	0.001 *
Ro	0.97 (0.45)	2.18	0.030 *
Variance due to site (Prob)	0.281 (0.689)		
Variance due to block (site) (Prob)	1.36 (<0.001) *		
Variation due to campaign (Prob)	1.077 (0.002) *		
Variance to residual	3.574		

Block (site): "block" nested in factor "site"; *: significance at the 5%

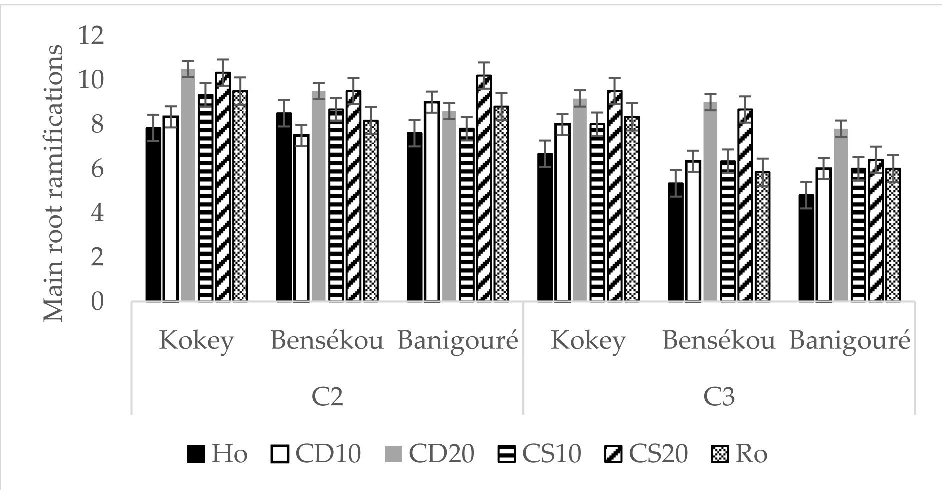

Figure 4. The number of main root branches in different sites.

3.2. Cotton aerial system

The impact of plowing on the development of the cotton plant stem was effective for all plowing tools. In fact, in Figure 5, there was a significant increase in the sizes of the main cotton stem in plots plowed by tractor compared to those in plots plowed manually.

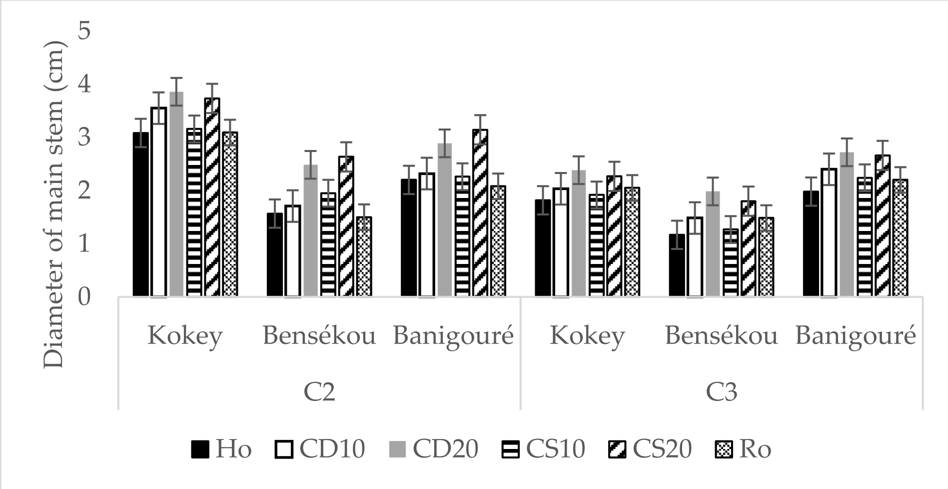

Figure 5. Length of the main cotton stem at different sites.

More distinctly, the linear model carried out on the data in Figure 5 indicated that only the use of the disc or moldboard plow had a significant impact on the parameter ($p < 0.001$) (Table 6). Indeed, compared with Ho, the main stem length was increased by 16 cm with CD10 and CS10 and by 37.68 cm and 39 cm respectively with CS20 and CD20 compared with Ho (Table 6).

Table 6. Impact of plowing tools on the length of the main stem.

Source of variation	Coef (SE)	t value	Prob.
Intercept	94.81 (10.81)	8.77	0.012 *
CD10	15.38 (1.84)	8.37	<0.001 *
CD20	35.94 (1.84)	19.56	<0.001 *
CS10	14.46 (1.84)	7.87	<0.001 *
CS20	33.98 (1.84)	18.49	<0.001 *
Ro	8.37 (1.84)	4.56	0.022 *
Variance due to site (Prob)	345.31 (0.003) *		
Variance due to block (site) (Prob)	0.696 (0.667)		
Variation due to campaign (Prob)	0.00 (1)		
Variance to residual	60.78		

Block (site): "block" nested in factor "site"; *: significance at the 5%

In Figure 6, it is noted a strong development of the ramifications of the main stem with the treatments CD10, CD20 CS10, and CS20 compared with Ho.

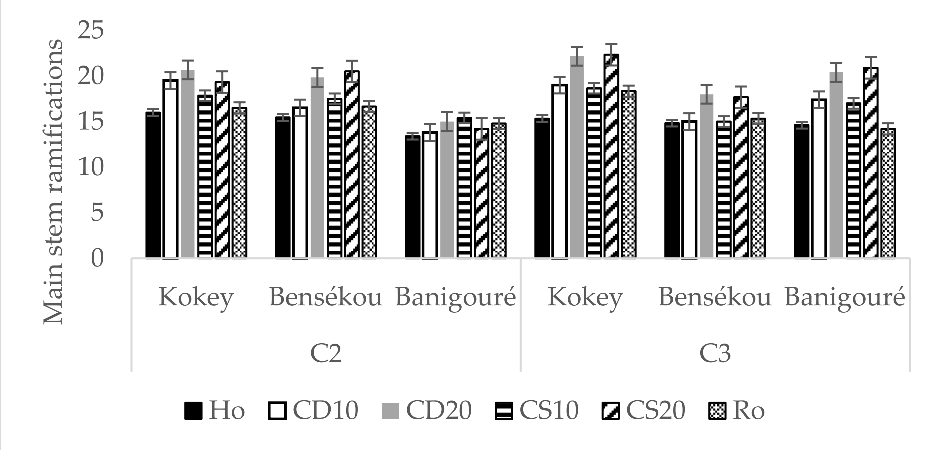

Figure 6. The number of branches of the main stem at different sites.

Indeed, table 7 showed that significantly these motorized tools had a strong growth of the stem ($p<0.05$) compared with Ho. While the number of branches increased on average over all sites from 1.87 to 1.95 with CS10 and CS20, it increased from 4.38 to 4.53 with CD20 and CS20 compared with Ho (Table 7).

Table 7. Impact of tillage implements on main stem ramifications.

Source of variation	Coef (SE)	t value	Prob.
Intercept	14.80 (1.13)	13.07	<0.001 *
CD10	1.95 (0.76)	2.57	0.011 *
CD20	4.53 (0.76)	5.98	<0.001 *
CS10	1.87 (0.76)	2.46	0.015 *
CS20	4.38 (0.76)	5.78	<0.001 *
Ro	1.09 (0.76)	1.44	0.15
Variance due to site (Prob)	2.15 (0.076)		
Variance due to block (site) (Prob)	0.75 (0.042) *		
Variation due to campaign (Prob)	0.39 (0.119)		
Variance to residual	10.35		

Block (site): "block" nested in factor "site"; *: significance at the 5%

The influence on the diameter of the main stem was not similar for all the tillage implements tested. Only CD20, CS10, and CS20 had a notable influence on this parameter of the cotton plant compared with Ho (Table 8; Figure 7). This influence, relative to Ho, was of the order of 0.28±0.11cm for CD10 ($p<0.009$), and 0.75±0.11cm and 0.78±0.11cm for CS20 and CD20 respectively ($p<0.001$).

Table 8. Impact of plowing tools on the diameter of the main stem.

Source of variation	Coef (SE)	t value	Prob.
Intercept	1.96 (0.43)	4.59	0.024 *
CD10	0.28 (0.11)	2.61	0.009 *
CD20	0.78 (0.11)	7.12	<0.001 *
CS10	0.17 (0.11)	1.56	0.12
CS20	0.75 (0.11)	6.85	<0.001 *
Ro	0.10 (0.11)	0.95	0.34
Variance due to site (Prob)	2.556 (0.054)		
Variance due to block (site) (Prob)	0.00 (0.906)		
Variation due to campaign (Prob)	0.185 (<0.001) *		
Variance to residual	0.215		

Block (site): "block" nested in factor "site"; *: significance at the 5% level

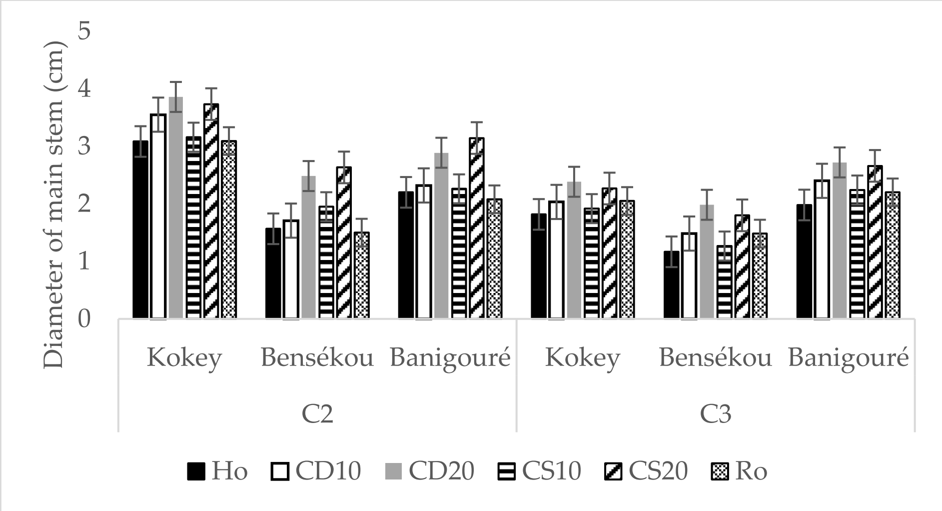

Figure 7. Diameter of the main stem in different sites.

3.3. Cotton yield

Examination of Figure 8 revealed higher cotton fiber yields in plots plowed with CD10, CD20 CS10, and CS20 than in plots plowed by hand. The plots plowed with the rotavator showed lower yields in places than those of the Ho plots, particularly during the C2 campaign in Kokey and Banigouré.

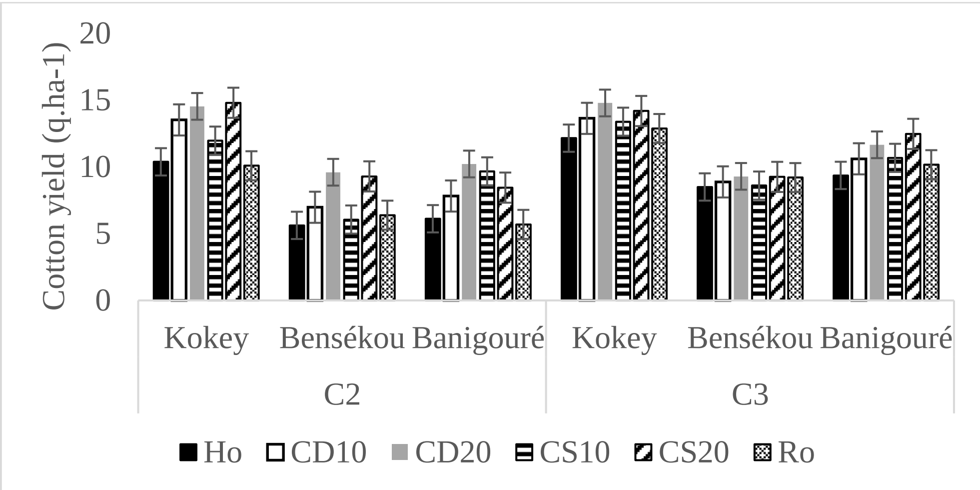

Figure 4.7. Cotton yield in different sites.

Table 9. Impact of plowing tools on cotton yield.

Source of variation	Coef (SE)	t value	Prob.
Intercept	8.81 (1.67)	5.27	0.013 *
CD10	1.51 (0.42)	3.57	<0.001 *
CD20	2.94 (0.42)	6.96	<0.001 *
CS10	1.31 (0.42)	3.10	0.002 *
CS20	2.65 (0.42)	6.27	<0.001 *
Ro	0.36 (0.42)	0.85	0.398
Variance due to site (Prob)	6.02 (0.002) *		
Variance due to block (site) (Prob)	0.611 (0.015) *		
Variation due to campaign (Prob)	1.253 (<0.001) *		
Variance to residual	3.216		

Block (site): "block" nested in factor "site"; *: significance at the 5% level

According to the linear mixed-effects model summarized in table 9, only Ro showed similar returns to Ho (p=0.398). CD10 and CS10 increased the Ho yield by 1.51±0.42 q ha^{-1} and 1.31±0.42 q ha^{-1}, respectively. CD20 and CS20 increased the Ho yield by 2.94±0.42 q ha^{-1} and 2.65±0.42 q ha^{-1} respectively.

4. Discussion

4.1. Impact of conventional tillage on the cotton root system

The roots play a fundamental role in the functioning and production of plants [29]. It is thanks to them that the water and mineral elements are supplied to it. They also perform the roles of anchoring to the ground, accumulating reserves, etc. [19]. It is therefore important for the production of the crop to have a well-developed root system, especially in-depth. One of the essential roles of plowing is to promote root growth in a restrictive environment. It often enables us to reduce the mechanical resistance of the soil to penetration of the roots through an improvement of the aeration of the soil and the facilitation of gas exchange at the root level [9]. The results of this work indicated, contrasting to the impact of manual labor, a significant positive difference in the impact of motorized plowing equipment on the length, diameter, and ramifications of the main root. The impact is more pronounced with plowing implements used 20 cm into the ground. Plowing allowed a greater reduction in the bulk density and soil moisture in 0 - 10 cm layers. But with plowing at 20 cm depth, the furnishings concern 10-20cm layers. However, root development is strongly affected by exogenous factors, main structure, bulk density, etc. [17–23]. Therefore, for better root development, it is more necessary to plow at 20cm.

4.2. Impact of conventional tillage on cotton aerial system

The impact of the use of motorized tools on the development of the stem of cultivated plants is strongly correlated with their incidence on the underground system of the plant. Poor development of the underground system sends a negative signal from the root to the aerial apparatus of the plant. In response to this signal, a drop in aerial growth is observed [18,12]. A reduction in water and mineral absorption by the root system due to an increase in the bulk density of the soil or a low useful water reserve in the soil acts directly on the growth of the vegetative system [28] in reducing plant height [20] and above ground biomass [11,27]. The influence of tillage implements on cotton stem development has shown a positive impact of power tools compared to manual labor. The length of the rod was important with the motorized plowing tools and even more with the tools used 20 cm deep. In this study, the relationship between the root system and cotton stem development was thus more pronounced.

4.3. Impact of conventional tillage on cotton fiber yield

The use of the motorized tools tested, namely the disc plow and the moldboard plow, allowed a better yield of cotton fibers than manual tillage. Therefore, the motorization of farming operations increases the yield of cotton cultivation. Yields were greater with plowing at 20 cm than plowing at 10 cm. These results were observed by [30] on two varieties of maize. The change of soil conditions in the 0-20 cm layer was beneficial to the better development of cotton. On tropical ferruginous soils in other cotton-growing areas of Africa, producers recommend deep cultivation for crops [21].

5. Conclusion

This study reports the influence of several tillage tools on cotton development and its yield. The results indicated that any power tool had an impact on the main root components but only those used 20cm depth had a pronounced impact on the length, diameter, and branching of the main root. The development of the cotton plant root system is therefore correlated with the intensity of conventional tillage. It was the same for the development of the cotton plant. Power tools affected the main stem components, but only tools used to plow 20cm in depth had a big impact on stem length, diameter, and branching. The impact on the yield was effectual for the plows compared with the use of the Daba with high yields in plots plowed at 20 cm with the disc plow and the moldboard plow.

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