Effects of *Zaï*Pit Depth on Morphological Traits, Yield Components and Yield of Cowpea (*Vignaunguiculata*(L.)Walp) in Burkina Faso

ABSTRACT:

Cowpea is the leading food legume for many households in arid and semi-arid regions of Sub-Saharan Africa. The erratic rainfall leads to decrease in cowpea yield. The *Zaï*pit technology is an ancestral agricultural technique used for water and fertilizer management in crops production increasing productivity. A study was carried out in Burkina Faso during 2020 and 2021 dry season atKamboinsin and at Kouare with for objective of evaluating the effects of *Zaï*depth on cowpea yield and yield components. Treatments consisted of the use of three *Zaï*depths (control (tillage); 15 cm; 25 cm) and four cowpea varieties. The experimental design used was a split-plot replicated three times. Yield and yield components data were collected and subjected to an analysis of variance using JMP Pro 10 software. The results showed thatfor all the studied varieties, all the yield components and yields average values increased with the *Zaï*pit depth. *Zaï*of 25 cm and 15 cm depth increased cowpea grain yield of more than 87% and 50% respectively compared to the control (tillage). Twenty-five-centimetre *Zaï*depth substantially enhances cowpea agronomical performances and is recommendable for cowpea production in drought prone regions or of low rainfall.

Key words: *Zaï*, *Zaï*depth, cowpea, yield.

1. INTRODUCTION

Agriculture is the main backbone for food and livelihood procurement of many households in sub-Saharan African countries. In Burkina Faso, 95% of the population relies on agriculture and livestock and the economy strongly dependent on rain-fed agriculture(Food and Agriculture Organization, 2012). However, agriculture is affected by climatic variability, characterized by an irregularity and a high spatio-temporal variability of rainfall with sag trend(Food and Agriculture Organization, 2015; Ghimire *et al.*, 2023a). The erratic rainfall distribution combined with soils physical and chemical degradation and the use of inappropriate farming practices are the major causes of decline in crops yields(Ghimire *et al.*, 2023b). The affected crops include legumes such as cowpea, the fourth food crop in Burkina Faso (Ty *et al.*, 2015). Pedoclimatic stresses, the erratic rainfall and high temperatures are the major problems faced by cowpea producers (Ahmad & Ibrahim, 2013; Toudou *et al.*, 2018). These constraints affect both fodder and grain yield. Cowpea fodder and grain yield losses in drought stress conditions were estimated at 62% and 56% respectively, when sowing was done in ploughed soil (Mofokeng & Mashingaidze, 2019). This decrease in cowpea productivity affects food availability and nourishment quality. In effect, cowpea grain contains 23 to 30% of protein, making it the main source of vegetal protein for many rural populations, 50 to 67% of starch, vitamins β complex such as folic acid (vitamin B) playing animportant role in preventing malformations in the new-borns(Boukar *et al.*, 2011). Farmers are food self-sufficient when they depend on their own production. Traditional practices known to allow soil water and nutrients conservation in the cropping field are successfully used by many farmers to mitigate the negative impacts of drought on crops and increase yields. Those practices include practices such as rock-bunds and the zai pits technic(Sawadogo, 2017).

The *Zaï*is an ancestral agricultural practice used for organic manure and water management in crops production and for regenerating poorest parts of the fields if less lands are available (Partey *et al*., 2018). It consists of digging pits of 15 to 20 cm diameter and 20 to 40 cm depth, the spacing between two holes depending of the crop(Barro *et al.*, 2001). By the first rains, farmers put around 300 to 500 g of organic matter within the holes and the sowing occurs one or two weeks later (Zougmore, 2003). In Burkina Faso, the word *Zaï*comes from « *zaïégré* » in Moore language that means « to wake up early and make his ground ready ». It is also called *Tassa* technic in Tahoua in Niger (Wouterse, 2017). On the higher fields, the *Zaï*increases 4 times red sorghum and 2.5 times pearl millet yields in comparison to the control conditions(Sawadogo, 2017).Water collection by *Zaï*pit is estimated at about 25 % of run-off coming from 5 times its area(Malesu *et al*., 2006). An adequate use of the *Zaï*technique can increase production by about 500 %(Sarah *et al*., 2020).In Burkina Faso, the *Zaï*technique is mostly used by farmers for sorghum and pearl millet growing to the detriment of legumes such as cowpea. The use of *Zaï*practices can enable mitigating the erratic rainfall effects on cowpea production and help improving productivity. Therefore, the study aims at contributing to the use of appropriate agricultural system in cowpea production through *Zaï*pits technique with the following objectives are: (i) determining the impact of *Zaï*practice in cowpea agronomical performance in Burkina Faso; (ii) evaluating the effects of *Zaï*depth on cowpea yield and yield components.

The research hypothesis are:

- hypothesis 1: the *Zaï*thechnique has no effects on cowpea yield;
- hypothesis 2: the *Zaï*depth variation does not influence cowpea agronomical performance.

1. MATERIALS AND METHODS

2.1 Experimental sites

The experiments were conducted in Burkina Faso during 2020 and 2021 dry seasons in Kamboinsin agricultural and environmental research and training centre (CREAF), one of the Regional Centres of the Institute of Environment and Agricultural Research (INERA). This centre is located in the northeast region of Ouagadougou, the capital city of the country at 12°28' north and 01°33' west at 300 m above sea level. The second location was Kouare located in the Eastern region of the country at 12°03’36’’N and 00°21’ 55’’ E at 400 m above level zero of sea. The climate of both locations is of north-soudanian type characterized by a long dry season from November to May and a rainy season from June to October, the rainfall varying from a year to another.

2.2 Treatments and experimental design

Treatments consisted of the use of two factors, especially the *Zaï*pit at three different depths (control (tillage); 15 cm depth and 25 cm depth) and the variety at four levels (Gorom local, Moussa local, KVx396-4-5-2D, Tiligre). The seed of the varieties was provided by the Institute of Environment and Agricultural Research (INERA), Burkina Faso. The experimental design used was a split-plot with three replications. The *Zaï*system was the main factor and the variety the sub-factor.

2.3 Cultural practices

Land preparation

The land preparation consisted of digging holes of 15 and 25 cm depth for*Zaï*and a tillage for the control. The holes' implementation was manually done in line of 3 m. The inter-row and intra-row spacing were of 80 cm and 40 cm respectively.

Sowing operation

The sowing was done in each experimental plot after the land preparation. A day before sowing, all the plots were well irrigated and the sowing occurred the morrow. For the treatments 15 cm and 25 cm *Zaï*depth, the sowing was done at the depth of the holes. For the control (tillage), sowing lines of 3 m length were laid out with the same inter-row and intra-row spacing than *Zaï*pits (80 cm and 40 cm).

2.4 Crop maintenance practices

Weeding

Weed management within each experimental field was done by manual hoe.

Fertilization

The NPK (14-23-14) at the rate of 100 kg per hectare as recommended by(Alliance for a Green Revolution in Africa, 2018), was applied as fertilizer one week after sowing to favour a good development of plants.

Pesticide application

The plants protection against crops pests during their reproductive stage was done by applying the Delta cal insecticide at the dose of 20 ml per 2 litres of water at the beginning flowering and pods formation using spraying method.

2.5 Data collection

The following growth and yield related data were collected: plant height, number of branches per plant, above ground biomass, leaf chlorophyll content, pod length, number of pods per plant, pod weight per plant, number of grains per pod, 100 grains weight, grains weight per plant, grain yield per hectare and harvest index (HI).
The grain yield was evaluated using the following formula:

$$\text{Grain yield ha}^{-1} = \frac{\text{Yield of net plot (kg)}}{\text{Harvested area per net plot (m}^2\text{)}} * 10000 \text{ m}^2$$

The harvest index (HI) was calculated as the ratio of the grain weight to the above ground dry matter including the grain and the straw weights.

$$\text{HI} = \frac{\text{Grain yield (kg } ha^{-1}\text{)}}{\text{(Biomass + Grain yields) (kg ha}^{-1}\text{)}}$$

2.6 Data analysis

Data collected were subjected to an analysis of variance using JMP Pro 16 software. Significant treatments means were separated using Student Newman Keuls' test. The Excel spreadsheet was used for graphics construction.

2. RESULTS

2.1 Effects of *Zaï*pitdepth and cowpea variety on cowpea morphologicaltraits

The effects of *Zaï*depth and variety on morphological traits were presented in Tables 1 and 2.

Plant height

*Zaï*pitdepth as well as variety had significant effect on plant height at both locations and combined. 25 cm *Zaï*depth constantly showed the tallest plant (141.43 and 120.87 cm), while the control (tillage) exhibited the shortest (101.73 and 96.69 cm). At both locations as in combined, KVx396-4-5-2D presented the tallest plant (144.50;132.88 and 138.69 cm)compared to the others.

Number of branches per plant

*Zaï*depth significantly affected the number of branches per plant only at Kamboinsin. 15 cm *Zaï*depth resulted inhigher number of branches per plant (6.29) than the other *Zaï*levels.

Cowpea varietieshad significantinfluence on number of branches per plant at both locations. Moussa local significantly and consistently exhibitedgreaternumber of branches per plant (7.88 and 5.70), while Tiligreshowed the least (4.90 and 5.12).

Above ground biomass

At both locations, *Zaï*depth and variety significantly affected plant above ground biomass. At both sites and combined, 25 cm *Zaï*depth consistently resulted in higher above ground biomass than the control and 15 cm *Zaï*depth. At Kamboinsin, the variety Moussa local significantly presentedthe highest above ground biomass (53.77 g), while Gorom local registered the lowest (38.76). At Kouare, Gorom local consistently registered the lowest above ground biomass (34.15 g), while the highest mean value was supported by Tiligre (51.70 g).incombined, the highest above ground biomass was registered with the variety Moussa local with 52,22 g, while Gorom showed the lowest (36.45 g).

Leaf chlorophyll content

*Zaï*depth had significant influence on leaf chlorophyll content at both locations and I combined. 25 cm *Zaï*depth consistently resulted inhigher leaf chlorophyll content (51.68; 72.70 and 62.19), while the control (tillage) resulted in the lowest (39.71; 66.34 and 5.02).

Non-significant effect of variety on leaf chlorophyll content was observed at Kamboinsin. However, at Kouare and in combined locations, significant effect was registered. KVx396-4-5-2D showed the highest average value of leaf chlorophyll content (72.75 and 59.21), while Tiligre exhibited the lowest (63.61 and 54.77).

Pod length

*Zaï*depth and variety significantly affected pod length. At both locations and combined, pod length significantly increased with increasing *Zaï* depth. Longer pods were registered from

25 cm *Zaï*depth (13.51;12.94 and 13.22 cm), while shorter pods were obtained from the tilled plots (the control) (11.45; 11.97 and 11.21 cm).

At varieties scale, KVx396-4-5-2D significantlypresented longer pods (13.64 at Kamboinsin and 13.36 cm at Kouare), with a grand mean of pod length of 13.50 cm in combined. Moussa local exhibited the shortest pod length at both experimental locations and combined.

3.2 Effects of *Zaï*pit depth on yield components and yield

The yield components were variables measured at pod and grain level for individual plant (number of pods per plant, pods weight per plant, number of grains per pod and grain weight per plant, hundred grains weight); the yield was the grain yield in a hectare.

At both experimental locations and combined, the analysis of variance revealed a significant difference between *Zaï*pit depths for all the yield components and yield(Table 3), grain yield and harvest index (Table 4), except for the number of grain per pod at Kouare.

Number of pods per plant, pods weight per plant, hundred grain weight, grains weight per plant and grain yield per hectare increased with increasing *Zaï*depth. At both locations, the highest number of pods per plant, pods weight per plant, hundred grains weight and grain weight per plant were recorded from 25 cm *Zaï*depth. 15 cm *Zaï*depth exhibited intermediate average values, while the control (tillage) supported the lowest.

As regards to the number of grains per pod, the statistical analysis showed a significant difference between *Zaï*treatments only at Kamboinsin and in combined locations. The highest number of grains per pod were consistently registered in 25 cm *Zaï*depth (8.01 and 7.95), while the control (tillage)resulted in the least (7.40 and 7.43).

At both locations and combined, 25 cm *Zaï*depth consistently resulted in the highest grain yield per hectare (Table 4) (3146.78 at Kamboinsin;2234.97at Kouare and 2690.87 kg ha^{-1}incombined). Intermediate mean values of grain yield were consistently recorded from the 15 cm *Zaï*depth, while the lowest were registered in the control (tillage) (1273.95;052.70and 1163.32 kg ha^{-1}).

The effect of *Zaï*depth on harvest index was significant only at Kamboinsin. 25 cm *Zaï*depth significantly supported the highest harvest index (0.50), while the control showed the least (0.41).

3.3 Effects of cowpea variety on yield components and yield

At both experimental sites and combined, significant difference between the varieties were observed for all the yield components (Table 3),grain yield and harvest index (Table 4). The variety KVx396-4-5-2D constantly gave the highest number of pods per plant, pod weight per plant, harvest index and grain yield per hectare with a global average of 2685.27 kg ha^{-1}in combined locations.at both locations. Moussa local supported the least averages values, whileGorom local andTiligre presented intermediate means.

For the number of grains per pod, the statistical analysis significantly discriminated the varieties at both locations and combined,.KVx396-4-5-2D presented the highest number of grains per pod (9.22; 8.16 and 8.69). The lowest number of grain per pod was registered fromTiligreatKamboinsin (6.66) and from Moussa local at Kouare and in combined (7.31 and 7.01).

The highest hundred grains weight at both locations and combined was constantly exhibited by Tiligre (22.01; 22.58 and 22.34g), while Moussa local registered the lowest (18.18; 18.24 and 18.21 g).

Table 1. Effects of *Zaï*depth and cowpea variety on growth parametersatKamboinsin and Kouare, averaged from two seasons

Treatments	PH (g)			NBP			AGB (g)		
	Kam	Kou	Grand Mean	Kam	Kou	Grand Mean	Kam	Kou	Grand Mean
*ZAÏ*DEPH (ZD) (cm)									
Tillage	101.73c	96.69c	99.20c	5.93b	5.02	5.47	41.84b	44.99b	43.42b
15	111.67b	111.86b	111.77b	6.29a	5.09	5.69	46.22ab	43.68b	44.95b
b 25	141.43a	120.87a	131.15a	5.98b	5.23	5.60	48.46a	50 .82a	49.64a
P-value	‹.0001	‹.0001	‹.0001	0.007	0.30	0.26	0.040	0.0002	0.001
SE±	3.214	2.761	2.747	0.120	0.097	0.094	1.857	2.527	2.106
VARIETY (V)									
Gorom local	92.89d	111.74b	102.32c	5.85b	5.22b	5.53b	38.76c	34.15c	36.45d
Moussa local	124.04b	80.40c	102.22c	7.88a	5.70a	6.79a	53.77a	50.68a	52,22a
KVx396-4-5-2D	144.50a	132.88a	138.69a	5.62b	4.42c	5.02c	44.88b	41.71bc	43.30c
Tiligre	111.68c	114.20b	112.94b	4.90c	5.12a	5.01c	44.62bc	51.70a	48.16b
P-value	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	0.0001	0.002
SE±	3.712	3.188	3.172	0.138	0.112	0.108	2.145	2.918	2.431
Interaction									
ZD*V	‹.0001	0.046	0.012	0.37	0.78	0.96	‹.0001	0.65	0.07

PH: Plant height; NBP: Number of branches per plant; AGB: Above ground biomass; ZD: *Zaï*depth; V: Variety; SE±: Standard error; Kam: Kamboinsin; Kou: Kouare.

Table 2. Effects of *Zaï*depth and cowpea variety on growth parameters at Kamboinsin and Kouare, averaged from two seasons

Treatments	LCC (SPAD value)			PL (cm)		
	Kam	Kou	Grand Mean	Kam	Kou	Grand Mean
*ZAÏ*DEPH (ZD) (cm)						
Tillage	39.71c	66.34b	53.02c	11.45c	11.97b	11.21c
15	44.94b	70.45a	57.70b	12.88b	12.59a	12.73b
25	51.68a	72.70a	62.19a	13.51a	12.94a	13.22a
P-value	‹.0001	‹.0001	.0001	‹.0001	‹.0001	‹.0001
SE±	0.871	0.994	0.646	0.139	0.129	0.125
VARIETY (V)						
Gorom local	44.42	68.78b	56.60b	11.64b	11.87b	11.74b
Moussa local	45.74	66.19b	55.96bc	11.60b	11.67b	11.63b
KVx396-4-5-2D	45.68	72.75a	59.21a	13.64a	13.36a	13.50a
Tiligre	45.94	63.61c	54.77c	13.57a	13.10a	13.33a
P-value	0.60	0.008	.0001	‹.0001	‹.0001	‹.0001
SE±	1.006	1.148	0,746	0.161	0.149	0.144
Interaction						
ZD*V	0.78	0.49	0,22	0.161	0.149	0.56

LCC: Leaf chlorophyll content; PL: Pod length; SPAD: Soil Plant AnalysisDevelopment; ZD: *Zaï*depth; V: Variety; SE±: Standard error; Kam: Kamboinsin; Kou: Kouar

Table 3.Effects of *Zaï*depth and cowpea variety on yield components at Kamboinsin and Kouare, averaged from two seasons

Treatments	NPP			WPP (g)			NGP			GWP (g)			100GW (g)		
	Kam	Kou	Grand Mean	Kam	Kou	Grand Mean	Kam	Kou	Grand Mean	Kam	Kou	Grand Mean	Kam	Kou	Grand Mean
*ZAÏ*DEPH (ZD) (cm)															
Tillage	18.37c	23.30b	20.83c	34.39c	41.17c	37.78c	7.40c	7.53	7.46c	24.77c	28.81c	26,79c	19.58b	19.60b	19.59b
15	23.73b	26.46a	25.09b	52.38b	53.38b	52.88b	7.46b	7.63	7.54b	36.52b	37.37b	36.94b	20.06ab	20.35a	20.20a
25	30.22a	28.37a	29.29a	71.92a	60.22a	66.07a	8.01a	7.90	7.95a	50.34a	42.15a	46.24a	20.27a	20.55a	20.41a
P-value	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	0.52	‹.0001	‹.0001	‹.0001	‹.0001	0.022	0.004	0.006
SE±	0.992	0.729	0.932	2.864	1.918	2.261	0.146	0.188	0.124	2.010	1.343	1.581	0.178	0.213	0.187
VARIETY (V)															
Gorom local	24.90b	25.44b	25,17b	58.31b	55.97a	57.14b	7.53b	7.72ab	7.62b	41.62b	39.18a	40.40b	21.16b	21.22b	21.19b
Moussa local	18.35d	22.03c	20.19c	32.17d	38.58b	35,37d	6.72c	7.31b	7.01d	22.52d	26.87b	24.70d	18.18c	18.24c	18.21c
KVx396-4-5-2D	31.48a	28.48a	29.96a	77.93a	58.58a	68.25a	9.22a	8.16a	8.69a	54.55a	41.01a	47.78a	18.43c	18.63c	18.53c
Tiligre	21.70c	24.09bc	22.89bc	44.73c	53.40a	49.06c	6.66c	7.70ab	7.18c	31.16c	37.38a	34.27c	22.10a	22.58a	22.34a
P-value	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	0.05	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001
SE±	1.145	0.842	1.076	3.307	2.215	2.611	0.169	0.217	0.143	2.321	1.550	1.826	0.206	0.246	0.216
Interaction															
ZD*V	0.026	0.004	0.07	‹.0001	0.033	0.017	0.50	0.21	0.29	0.006	0.033	0.018	‹.0001	‹.0001	‹.0001

NPP: Number of pods per plant; WPP: Weight of pods per plant; NGP: Number of grains per pod; GWP: Grains weight per plant; ZD: *Zaï*depth; V: Variety; SE±: Standard error; Kam: Kamboinsin; Kou: Kouare.

Table 4.Effects of *Zaï*depth and cowpea variety on yield and harvest index at Kamboinsin and Kouare, averaged from two seasons

Treatments	GYH (kg ha^{-1})			HI		
	Kam	Kou	Grand mean	Kou	Kam	Grand mean
*ZAÏ*DEPH (ZD) (cm)						
Tillage	1273.95c	1052.70c	1163.32c	0.41c	0.39	0.40
15	2282.95b	1935.78b	2109.36b	0.44b	0.40	0.42
25	3146.78a	2234.97a	2690.87a	0.50a	0.40	0.45
P-value	‹.0001	‹.0001	‹.0001	‹.0001	0.40	0.081
SE±	123.511	79.368	52.011	0.012	0.014	0.018
VARIETY (V)						
Gorom local	2493.55b	1793.46a	2143.50b	0.51b	0.46a	0.48b
Moussa local	1314.39d	1164.76c	1239.57d	0.30d	0.33d	0.31d
KVx396-4-5-2D	3288.24a	2082.30a	2685.27a	0.55a	0.49a	0.52a
Tiligre	1842.05c	1724.07b	1783.06c	0.44c	0.43c	0.43c
P-value	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001
SE±	142.618	91.646	60.058	0.014	0.016	0.021
Interaction						
ZD*V	0.004	0.008	0.10	0.004	0.09	0.25

GYH: Grain yield per hectare; HI: Harvest index; ZD: *Zaï*depth; V: Variety; SE±: Standard error; Kam: Kamboinsin; Kou: Kouare.

3.4 Interaction between *Zaï*pit depth and cowpea variety on morphological traits, yield components (number of pods per plant, pods weight per plant, number of grains per pod and grain weight per plant, hundred grains weight) and yield (grain yield per hectare)

The interaction between *Zaï*depth and cowpea variety had significant impact on plant height, grain weight per plant at both locations, on above ground biomass at Kamboinsin (Table 5) as well as on grain yield per hectare at both experimental locations (Figure 1 and 2).

At both sites, all the varieties presented taller plants in 25 cm *Zaï*depth except for Tiligre at Kouare. The shortest plant was observed in the control for 75% of the varieties at both locations.

At Kamboinsin, plant above ground biomass of all the varieties significantly differed with change in *Zaï*depth.Moussa local showed higher biomass at 25 cm *Zaï*depth and lower biomass in the control (tillage). Similar trend was observed for the other varieties except for Tiligre that exhibited higher biomass in 15 cm *Zaï*depth.

At both locations, grains weight per plant of all the varieties increased with increasing *Zaï*pit depth. Higher grains weight per plant was registered from 25 cm *Zaï*depth, while lowergrains weight per plant was registered from the control (tillage).

Hundred per cent (100%) of the varieties registered the highest grain yield in 25 cm *Zaï*depth at Kamboinsin. Similar results were observed at Kouare; except for Moussa local that showed the highest grain yield in 15 cm *Zaï*depth. However, for all the varieties, the lowest grain yield per hectare was consistently recorded from the control (tillage).

Table 5. Interaction between *Zaï*depth and cowpea variety on plant height (cm), grain weight per plant (g) at Kamboinsin and Kouare and above ground biomass (g) at Kamboinsin

Variables	Varieties	Kamboinsin			Kouare		
		*Zaï*depth (cm)					
		Tillage	15	25	Tillage	15	25
Plant height	Gorom local	81.98lm	81.24lm	115.48f-i	105.44h-k	102.55ijk	126.69ef
	Moussa local	93.47jkl	107.83h-k	170.81a	69.77m	79.16lm	92.27kl
	KVx396-4-5-2D	129.11def	144.67bcd	159.72ab	109.61g-j	135.33cde	151.88bc
	Tiligre	102.36ijk	112.96f-i	119.73e-h	101.94ijk	125.47efg	124.71efg
	SE±		5.233			4.985	
Grain weight per plant	Gorom local	24.22jkl	46.84bcd	50.81bc	33.25f-j	40.71d-g	43.57cde
	Moussa local	16.35l	19.99kl	31.21g-j	20.63kl	31.23g-j	28.81ijk
	KVx396-4-5-2D	34.47e-i	53.22b	75.96a	30.69hij	38.53d-h	53.80b
	Tiligre	24.04jkl	26.49ijk	43.39cde	30.68hij	39.01d-h	42.44c-f
	SE±		4.777			2.813	
Above ground biomass	Gorom local	30.93gh	32.84fgh	51.51bc			
	Moussa local	46.03b-e	51.90bc	62.37a			
	KVx396-4-5-2D	43.21cde	43.45cde	46.97b-e			
	Tiligre	45.86b-e	55.37ab	31.63fgh			
	SE±		3.416				

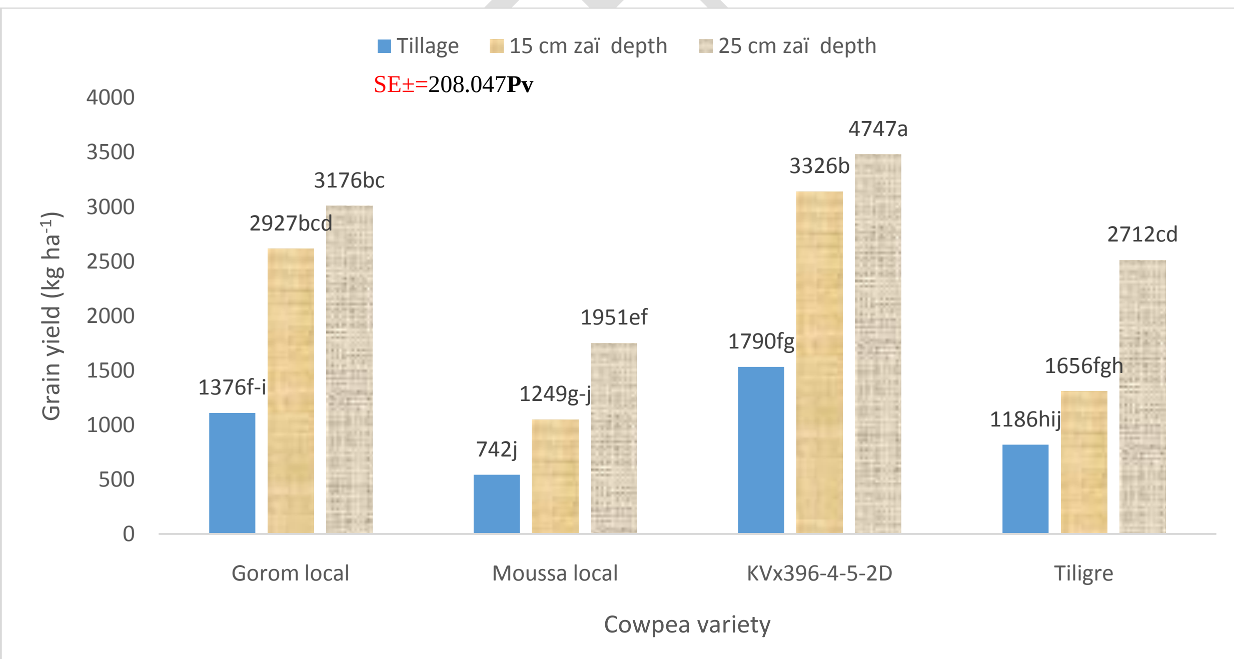

Figure 1. Interaction between *Zaï*depth and cowpea variety on grain yield per hectare at Kamboinsin

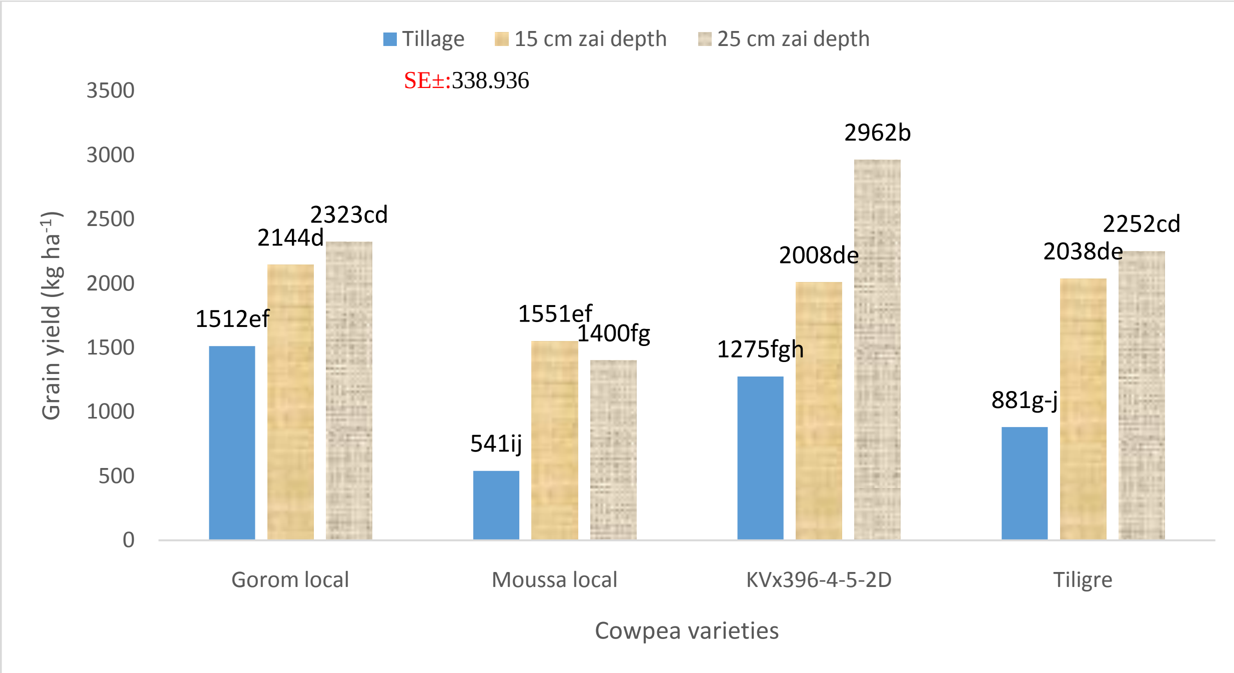

Figure 2. Interaction between *Zaï*depth and cowpea variety on grain yield per hectare at Kouare

1. DISCUSSION

4.1 Effects of *Zaï*pitdepth on morphological traits, yield components (number of pods per plant, pods weight per plant, number of grains per pod and grain weight per plant)and grain yield of cowpea

The analysis of the variance showed a significant difference between *Zaï*depths for most of the morphological traits, yield components and yield at both experimental locations. *Zaï*of 25 cm depth presented the tallest plants and resulted in the highest above ground biomass, pod length, number of pods per plant, pods weight per plant, number of grains per pod, hundred grains weight, grains weight per plant and grain yield per hectare. Intermediate average values were recorded from 15 cm *Zaï*depth, while the lowest, at both locations, were registered from the control, (tillage). This ascertainment suggests that the use of *Zaï*system as well as the *Zaï*pit depth enhanced cowpea varieties performance. The bowls formed by *Zaï*pits increased nutrients and water availability for plantsfor their optimum growth leading to a good productivity comparatively to the flat soil (tillage), in which,nutrients and water at the soil surface are more susceptible to transport outside plant growing area under erosion effects. The *Zaï*pits allow nutrients accumulation and water collection at the plant rooting zone necessary to a good pod formation and filling (Lenhardt *et al*., 2014; Schuler *et al*., 2016). According to (Evett & Tolk, 2009), the *Zaï*technique successfully reduces runoff, evaporation and improves rain water capture leading to improved crops productivity.This explains the increase of the average values of the plant height, above ground biomass, pod length, number of pods per plant, pods weight per plant, number of grains per pod, hundred grains weight, grains weight per plant and grain yield per hectare in the 25 cm *Zaï*depth, followed by that of 15 cm depth and their decrease in the control (tillage). These advantages of *Zaï*technique use in crop production compared with the tillage have been underlined by several authors. According to Jägermeyr *et al.*(2016), integrating water harvesting technologies such as *Zaï*system with soil fertility management techniques can create synergies that can further increase water use efficiency and hence, the final yield. Sawadogo (2017)suggested that *Zaï*system increases respectively by 4- and 2-times red sorghum and pearl millet yield comparatively to the control. In regions of low rainfall of Burkina Faso (Sahel, Nord, and Centre-Nord) , the *Zaï*SystemScan triple sorghumyields(Jaime *et al*., 2023).In Niger, the IntegratedSoilFertility Management (ISFM) such as *Zaï*can increasesorghum grain yieldsbetween 2- and 69-times (Fatondji & Bielders, 2011).The obtained results also corroborate the findings of(Paracchini *et al*., 2020) who globally suggested that zai improves farmers productions and those of(Amede *et al*., 2011), who resulted in increase of potato yield of 380%in Ethiopia.Billaz (2012) highlighted that under *Zaï*system,the sorhum yield increases from 70 kg/ha to 300 kg/hacompared to without*Zaï*.Wildemeersch *et al*. (2015)reported that *Zaï*practice not only increases production of cereals grains (150 to 1700 kg/ha) and straw (500 to 5300 kg/ha) but also reintroduces a large diversity of useful plants that may help during the fallow period and the process of degraded soils restoration. In this study, in both experimental sites, 25 and 15 cm *Zaï*depths respectively allowed an increase in cowpea grain yield of more than 87% and 50% compared to the control, the tilled soil. This not only testifies the *Zaï*impact in improving cowpea yield but also the importance of varying the *Zaï*depth for obtaining better yield. 25 cm *Zaï*depth collects and stocks more efficiently water and nutrients near plant root system, ensuring a better development of plants compared to 15 cm *Zaï*depth. Thus, the deeper the *Zaï*depth, the higher the grain yield. The substantial increase in grain yield is in line withSerah *et al*. (2021)that reported that *Zaï*practice has the potential to substantially crops productivity and biomass production.Sarah *et al*. (2020) suggested that the application of *Zaï*technique can increase production by about 500% if well executed. The highest average grain yield having been registered from 25 cm *Zaï*depth, this means that at both locations, Kamboinsin and Kouare, with the same thickness of 30 cm, 25 cm *Zaï*depth would be more suitable for cowpea production than that of 15 cm depth and the tillage that resulted in the lowest grain yield. However, the increase of grain yield with the *Zaï*pit depth could be site-specific and dependent on the soil chemical and physical properties, which need to be taken into account according to the agro ecological zone of production. The low fertility or the encrusted nature of some soils at deeper horizons can negatively affect the efficiency of the *Zaï*depth in increasing the yield.

4.2 Interaction between *Zaï*pitdepth and cowpea variety on yield

The interaction between *Zaï*treatments and cowpea varieties had significant effects on grain yield. Seventy-five (75%) of the varieties showed the highest grain yield in 25 cm *Zaï*depth at both locations; except Moussa local that exhibited the highest grain yield in 15 cm *Zaï*depthat Kouare. However, without exception,the lowest grain yield per hectare was recorded from the control (tillage). Similarly, the tallest plant for all the studied varieties was recorded from 25 cm *Zaï*depth, whereas the shortest was registered from the tillage (control). The same trend was observed for the variables grain weight per plant at both locations and for above ground biomass at Kamboinsin. These results show the importance of *Zaï*pits positive impact in enhancing cowpea varieties agronomical performance. *Zaï*system use for cowpea cultivation enables plants to produce more and effective pods and subsequently increases the grain yield, comparatively to sowing in flat soil. This great performance under *Zaï*,presented by all the varieties involved in this study could be attributed to the ability of *Zaï*pits in collecting rain or irrigation water and nutrients near plants rooting zone. The concentration of water and nutrients thanks to the bowls formed by the pits positively affects plants growth and therefore their final yield. The results are in line with findings of Jägermeyr *et al.*(2016) and who suggested that agricultural practices such as *Zaï*system have ability to substantially increasing crops yield. The gap in grain yield observed between 25 cm and 15 cm *Zaï*depth at both experimental locations shows that the use of bowls of 25 cm depth for cowpea production is more advantageous in reinforcing cowpea varieties production potentialities compared to that of 15 cm depth. The exceptional high grain yield observed in 15 cm *Zaï*depth at Kouare for the variety Moussa local compared to the others, could be explained by intrinsic characteristics to this variety or by plants diseases which were not noted in this study. The *Zaï*of 25 cm depth can therefore be advised to be used by cowpea growers for getting higher yield instead of using pits of 15 cm or tillage that substantially leads to lower grain yield.

2. CONCLUSION

The *Zaï*technique has significant positive impact on cowpea production. 25 cm and 15 cm*Zaï* depth substantially increase cowpea agronomical performance.The*Zaï* depth variation has effects on cowpea performance. The deeper the *Zaï*, the higher the yield attributes average values and yield.Comparatively to the control, the tilled soil, sowing in 25 cm and 15 cm*Zaï* depth can increase cowpea grain yield of more than 87% and 50% respectively. KVx396-4-5-2D and Moussa local are respectively the high and the low grain yieldingvarieties. Cowpea varieties differently interact with the *Zaï*treatments. 25 cm *Zaï*depth result in higher grain yield in cowpea production, while sowing in tilled soil results in lower yield.The hypothesis 1 and 2 of this research are infirmed. Even though, the physical and chemical properties of the soil are to be considered, this study carried out in two locations shows that 25 cm*Zaï*depth appears the most advantageous agricultural practice in cowpea production rather than to that of 15 cm depth. Sowing cowpea in tilled soil gives lower grain yield compared to using *Zaï*technique.

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