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Profitability Analysis of Zai Pits Use in Cowpea (*Vigna unguiculata* (L.) Walp) Production under Normal watering and Drought Stress Conditions

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ABSTRACT: The zai system is a traditional agricultural practice used for crops production for water and nutrients management. A study was conducted in Burkina Faso at Kamboinsin to evaluate the profitability of the zai use in cowpea cultivation. Treatments consisted of three levels of drought stress (control, drought stress at seedling and flowering stages), three zai levels (control (tillage); 15 and 25 cm zai depth) and the variety at four levels (Gorom local, Moussa local, KVx396-4-5-2D, Tiligre). The experimental design was a split-split-plot replicated three times. Grain yield and economic data were recorded and cost and returns analysis performed. 25 cm zai depth recorded the highest total variable cost and the control the least. In control conditions, the highest grain yield and net revenue were recorded in 25 cm zai depth for 50% of the varieties and in 15 cm zai depth for the others. In seedling and flowering stages drought stress conditions, the highest net revenue was recorded in 25 cm zai depth, while the lowest was recorded in the control (tillage). The highest benefit-cost ratio was consistently registered in the control (tillage) for drought-tolerant varieties. For drought-sensitive varieties, higher benefit-cost ratio was registered in zai pits in seedling-stage drought stress conditions. The use of manual zai substantial increases cowpea grain yield, but does not consistently guarantee a high economic profit. The mechanical construction of zai could reduce the cost of pits implementation and increase the financial profitability.

KEYWORDS: Zai pit, drought stress, cowpea, grain yield, profitability.

1 INTRODUCTION

Cowpea (*Vigna unguiculata* (L) Walp) is a leading food legume in tropics, mostly in sub-Saharan Africa that contributes to about 95.8% of its worldwide production (1). In west Africa, the largest cowpea producer countries are Nigeria, Niger, Ghana, Mali, Senegal and Burkina Faso (2,3). In Burkina Faso, cowpea is the third food crop after sorghum and millet (4). Cowpea production constitutes a large source of incomes for many rural households and participates to producer's economic expansion (1). Burkina Faso is one of the main cowpea grain exporters, while Ivory Coast, Gabon, Ghana, Mauritania, Togo and Nigeria are the main importers of cowpea grains (3). These exchanges are sources of devises for those countries. Though, cowpea is a resilient crop and able to adapt to some extreme conditions, but its productivity remains very low due to several biotic and abiotic constraints (5,6). The abiotic constraints encountered by farmers in cowpea production are essentially the low fertility of soils, the use of inappropriate agricultural practices and constraints related to climate, especially drought (6,7). The lack of water resources due to low and erratic rainfall leading to drought spells during production seasons is the first problem faced by cowpea producers (8). Drought negatively affects both fodder and grain yield of cowpea (9). The importance of the effects on yield attributes depends on the stage of occurrence (10). Drought stress at cowpea reproductive stage causes improper maturity of seeds leading to a huge decrease of grain yield (9). Soil and crop management practices should be adopted and promoted to mitigate the drastic effects of drought stress on cowpea production regarding its importance for rural populations. Amongst those practices we have the zai pits technology, an ancestral technic used for soil fertility restoration and water and organic manure management in cropping field (11). Farmers innovations are central to zai system in Sahelian zones of Burkina Faso (11). When well executed, this technique can increase production by about 500% (12). However, promoting an agricultural practice that enables increasing crops productivity is good but knowing the potential economics returns of it use is important, mostly when the aim of production is of gathering financial incomes. In addition, the efficiency of the zai practice could be dependent to the crop variety and the growing condition. Thus, this study has for aim of knowing the financial profitability of zai of different depths in cowpea production under normal-watering and drought stress conditions.

2 Materials And Methods

2.1 Site Of Study

The study was conducted in Burkina Faso during the dry season of 2020 and 2021 at 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' N and 01°33' W at 300 m above sea level.

2.2 Treatments And Experimental Design

The experiment consisted of three factors: the zai depth at three levels of treatments (tillage (the control), 15 cm depth and 25 cm depth), the drought stress at three levels (control; drought at seedling stage and drought stress at flowering stage) and the variety at four levels (Gorom local, Moussa local, KVx396-4-5-2D, Tiligre). The choice of flowering stage for drought imposition is guided by the fact that drought at flowering stage of cowpea development is the most devastating compared to the other stages of development (Toudou *et al*., 2018). The experimental design was a split-plot with the zai depth in the main plot and the variety in the sub-plot. These treatments combined were replicated three times.

2.3 Soil Preparation And Sowing

The soil preparation consisted of zai pits construction for the treatments 15 and 25 cm zai depth and tillage for the control. The digging of holes was manually done in lines of 3 m with an inter-row and inter-holes spacing respectively of 80 cm and 40 cm.

2.4 Crops Management And Harvest

The crop management consisted of weeding, fertilization and pesticide application.

The weed management within each plot was done by manual hoe. The NPK (14-23-14) at the rate of 100 kg per hectare was applied as fertilizer one week after sowing to favour a good development of plants.

The plants protection against crops pests during their reproductive stage was done by applying the Delta cal insecticide at the rate of 0.02 kg active ingredient ha^{-1} at the beginning flowering and the beginning of pods formation using Knapsack sprayer.

The harvest was done at physiological maturity of pods.

2.5 DATA COLLECTION

CROP DATA

The grain yield was the only crop data collected. Harvested pods were sun-dried and threshed. The grains of each variety in each net plot were weighted and the yield calculated at hectare scale using the following formula.

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

ECONOMIC DATA

The economic data included the cost of seeds, land preparation, sowing and crops maintenance, especially cost of fertilizer, herbicides and weeding carefully recorded for each variety in each zai level.

2.6 ECONOMIC ANALYSIS

The cost of inputs and labour were noted and the economic returns calculated through the following variables and formula.

Total variable cost = cost of land preparation, seeds, sowing, herbicide application, fertilizer, weeding and harvest.

Gross revenue = Grain yield per hectare * 0.67 US$ (the prevailing market price of cowpea grains in Burkina Faso at the time of harvest)

Net revenue = Gross revenue – Total variable cost

$$\textbf{Benefit-cost ratio} = \frac{Net\ revenue}{Total\ variable\ cost}$$

3 RESULTS

3.1 VARIABLES COST AND RETURNS OF SOIL PREPARATION METHODS

The total variable cost and the economic returns depending on the soil preparation method are presented in Table 1. The highest total variable cost, including expenses incurred in holes' implementation or tillage, seed cost, sowing and plants maintenance was recorded with 25 cm zai depth (971.875 US$ ha^{-1}), followed by that of 15 cm depth (706.25 US$ ha^{-1}). The control (conventional tillage) recorded the least (234.5 US$ ha^{-1}).

In control conditions, the grain yield and subsequently the gross revenue as well as the net revenue were higher in 25 cm zai depth. 15 cm zai depth recorded intermediate average values, while the control (tillage) recorded the lowest. However, the highest benefit-cost ratio was registered in the control, while 25 cm zai depth recorded the least.

In drought stress conditions, the highest grain yield and gross revenue increased with increasing zai depth. In sedling-stage drought stress conditions, 15 cm zai depth recorded the highest net revenue, while 25 cm zai depth recorded the least. However, when drought was aapplied to plants at flowering stage, the highest net revenue was registered in 25 cm zai depth and the lowest in 15 cm zai depth. Similarly, to the unstressed control, the highest benefit-cost ratio was consistently recorded in the tilled soil (the control), while lower average values were exhibited by the zai pits.

Table 1. Variable cost and economic returns depending on the soil preparation method

Variable	Soil preparation method		
	Tillage	15 cm zai depth	25 cm zai depth
COST ($/ha)			
Soil preparation	59.5	531.25	796.875
Seed	42.5	42.5	42.5
Sowing	42.5	42.5	42.5
Plant maintenance	90	90	90
Total	234.5	706.25	971.875
REURNS			
	Control conditions		
Grain yield (kg/ha)	2054.03	3034.36	3892.62
Gross revenue ($/ha)	1376.20	2033.02	3054.26
Net revenue ($/ha)	1141.70	1326.77	1636.18
Benefit-cost ratio	4.86	1.87	1.68
	Drought at seedling stage		
Grain yield (kg/ha)	1654.03	2609.36	2742.62
Gross revenue ($/ha)	1108.19	1748.27	1837.55
Net revenue ($/ha)	873.69	1042.02	865.68
Benefit-cost ratio	3.72	1.47	0.69
	Drought stress at flowering stage		
Grain yield (kg/ha)	575.97	911.11	2162.34
Gross revenue ($/ha)	385.90	610.44	1448.77
Net revenue ($/ha)	149.90	-95.81	476.89
Benefit-cost ratio	0.64	-0.14	0.49

3.2 Grain Yield, Profitability And Benefit-Cost Ratio Of The Use Of Zai Pits For Cowpea Varieties Production Under Non Limiting-Water Conditions

Table 2 presents the cost and returns depending on the variety, the zai level under unstressed conditions (control), The economic returns analysis showed that in non-limiting water conditions, 50% of the varieties (Gorom local and KVx396-4-5-2D) recorded the highest grain yield and consequently the highest gross revenue in 15 cm zai depth and 50% (Moussa local and Tiligre) in 25 cm zai depth. Lower grain yield and gross revenue were consistently recorded in the control (tillage) for all the varieties, except for Tiligre for which lower values were registered in 15 cm zai depth. The increase of yield in 15 and 25 cm zai depth were respectively of 57% and 65% compared to the tilled soil (the control). The highest net revenue was recorded in 15 cm zai depth for Gorom local and KVx396-4-5-2D, in 25 cm zai depth for Tiligre and in the control for Moussa local. The lowest net revenue was observed in the control (tillage) for Gorom local and Tiligre and in 25 cm zai depth for the others. The highest benefit-cost ratio was consistently recorded in the control zai (tillage) for all the varieties. Lower benefit-cost ratio was recorded in the deepest zai (25 cm) for 75% of the varieties; except for Tiligre that exhibited lower value in 15 cm zai depth.

Table 2. Economic values of the use of zai for four cowpea varieties in control conditions averaged from two seasons

Variety	Zai depth (cm)	Variables cost ($/ha)					Returns			
		Soil preparation	Seed	Sowing	Plant upkeep	Total	Grain yield (kg/ha)	Gross revenue ($/ha)	Net revenue ($/ha)	Benefit-cost ratio
					Control conditions					
Gorom local	Tillage	59.5	42.5	42.5	90	234.5	1400.72	938.48	703.98	3.00
	15	531.25	42.5	42.5	90	706.25	3998.87	2679.24	1972.99	2.79
	25	796.875	42.5	42.5	90	971.875	3334.90	2234.38	1262.51	1.29
	Average					637.54	2911.5	1950.7	1313.16	2.36
Moussa local	Tillage	59.5	42.5	42.5	90	234.5	1042.72	698.62	464.12	1.97
	15	531.25	42.5	42.5	90	706.25	1454.16	974.29	268.04	0.37
	25	796.875	42.5	42.5	90	971.875	1770.29	1186.09	214.22	0.22
	Average					637.54	1412.39	953	315.46	0.85
KVx396-4-5-2D	Tillage	59.5	42.5	42.5	90	234.5	2469.29	1654.42	1419.92	6.05
	15	531.25	42.5	42.5	90	706.25	3754.68	2515.64	1809.39	2.56
	25	796.875	42.5	42.5	90	971.875	2854.77	1912.69	940.82	0.97
	Average					637.54	3026.25	2027.58	1390.04	3.19
Tiligre	Tillage	59.5	42.5	42.5	90	234.5	1703.39	1141.27	906.77	3.86
	15	531.25	42.5	42.5	90	706.25	1229.75	823.93	117.68	0.16
	25	796.875	42.5	42.5	90	971.875	3010.52	2017.04	1045.17	1.07
	Average					637.54	1981.22	1327.41	689.87	1.70

3.3 Grain Yield, Profitability And Benefit-Cost Ratio Of The Use Of Zai Pits For Cowpea Varieties Production Under Seedling Stage And Flowering Stage Drought Stress Conditions

The cost and economics returns depending on the variety, the zai level under seedling and flowering stages drought stress conditions are shown in Table 3.

When drought was applied at seedling stage, for all the varieties, the highest gross revenue and net revenue were consistently recorded in 25 cm zai depth, while lower net revenue were exhibited in the control (tillage). Gorom local and KVx396-4-5-2D recorded higher benefit-cost ratio in the control (tillage), while lower benefit-cost ratio was recorded in 25 cm zai depth. Moussa local and Tiligre, in seedling-stage drought stress conditions recorded higher benefit-cost ratio in 25 cm and 15 cm zai depth respectively. However, for both varieties, the lowest lower benefit-cost ratio was recorded in the control (tillage).

When drought stress was imposed to plants at flowering stage, for 100% of the varieties, the highest grain yield and gross revenue were consistently recorded in 25 cm zai depth, the intermediate average values in 15 cm zai depth, while the lowest were registered in the control (tillage). The net revenue was higher in 25 cm zai depth than in the control and in 15 cm zai depth where negative net revenue (loss) was observed for 50% of the varieties. Similarly, to the unstressed conditions, the highest benefit-cost ratio was recorded in the control (tillage) for all the varieties and the lowest in 15 cm zai depth.

Table 3. Economic values of the use of zai for four cowpea varieties in seedling and flowering stage drought stress conditions averaged from two seasons

Variety	Zai depth (cm)	Variables cost ($/ha)					Returns			
		Soil preparation	Seed	Sowing	Plant upkeep	Total	Grain yield (kg/ha)	Gross revenue ($/ha)	Net revenue ($/ha)	Benefit-cost ratio
Drought stress at seedling stage										
Gorom local	Tillage	59.5	42.5	42.5	90	234.5	1158.54	776.22	541.72	2.31
	15	531.25	42.5	42.5	90	706.25	2697.43	1807.28	1101.03	1.55
	25	796.875	42.5	42.5	90	971.875	3131.62	2098.18	1126.31	1.15
	Average					637.54	2329.20	1560.56	923.02	1.67
Moussa local	Tillage	59.5	42.5	42.5	90	234.5	164.70	110.35	-124.14	-0.52
	15	531.25	42.5	42.5	90	706.25	1262.26	845.71	139.46	0.19
	25	796.875	42.5	42.5	90	971.875	1938.01	1298.46	326.59	0.33
	Average					637.54	1121.65	751.51	113.97	0.00
KVx396-4-5-2D	Tillage	59.5	42.5	42.5	90	234.5	1538.33	1030.68	796.18	3.39
	15	531.25	42.5	42.5	90	706.25	4466.34	2992.45	2286.2	3.23
	25	796.875	42.5	42.5	90	971.875	4813.70	3225.18	2253.31	2.31
	Average					637.54	3606.12	2416.10	1778.56	2.98
Tiligre	Tillage	59.5	42.5	42.5	90	234.5	227.08	152.148	-82.35	-0.35
	15	531.25	42.5	42.5	90	706.25	1833.25	1228.27	522.02	0.73
	25	796.875	42.5	42.5	90	971.875	2458.14	1646.95	675.08	0.69
	Average					637.54	1506.16	1009.12	1114.75	0.36
Drought at flowering stage										
Gorom local	Tillage	59.5	42.5	42.5	90	234.5	770.64	516.33	281.83	1.20
	15	531.25	42.5	42.5	90	706.25	1154.16	773.29	67.04	0.09
	25	796.875	42.5	42.5	90	971.875	2262.15	1515.64	543.76	0.56
	Average					637.54	1395.65	935.09	297.54	0.62
Moussa local	Tillage	59.5	42.5	42.5	90	234.5	419.64	281.16	46.66	0.20
	15	531.25	42.5	42.5	90	706.25	432.77	289.95	-416.29	-1.78
	25	796.875	42.5	42.5	90	971.875	1544.96	1035.12	63.25	0.07
	Average					637.54	799.12	535.41	-102.13	-0.50
KVx396-4-5-2D	Tillage	59.5	42.5	42.5	90	234.5	585.89	392.55	158.05	0.67
	15	531.25	42.5	42.5	90	706.25	1199.31	803.53	97.29	0.14
	25	796.875	42.5	42.5	90	971.875	2774.20	1858.71	886.83	0.91
	Average					637.54	1519.8	1018.26	380.72	0.57
Tiligre	Tillage	59.5	42.5	42.5	90	234.5	527.72	353.57	119.07	0.51
	15	531.25	42.5	42.5	90	706.25	858.18	574.98	-131.27	-0.19
	25	796.875	42.5	42.5	90	971.875	2068.06	1385.60	413.72	0.43
	Average					637.54	1151.32	771.38	133.84	0.25

4 DISCUSSION

The results of the cost and economic returns analysis of the zai pits use in cowpea cultivation under non-limiting water and drought stress conditions showed that zai of 25 cm depth registered the highest total variable cost, while the control (tillage) recorded the least. The high cost observed with the two zai modalities compared to the control, could be attributed to the quantity of labour force incurred in digging the pits. The deeper the zai pit, the longer the time required for its implementation and the higher the realization financial cost. This explains the highest total variable cost registered with 25 cm zai depth than that of 15 cm depth and the control (tillage), for which shorter time was needed for its establishment in a unit area. This increase of the economic cost with increasing zai depth corroborates with the findings of (13), who reported that zai pits implementation is labour intensive and time consuming compared to conventional tillage.

In the unstressed control, 50% of the varieties (Moussa local and Tiligre) recorded the highest grain yield and gross revenue in 25 cm zai depth and 50% (Gorom local and KVx396-4-5-2D) in 15 cm zai depth, while lower values were consistently registered in the control (tillage) for all the varieties. The results show that varieties were high grain yielding in zai pits and low yielding in the tilled soil. This suggests that the zai technology increases cowpea agronomical performances. The bowls formed by zai pits increased nutrients and water availability for plants for their optimum growth and productivity comparatively to the flat soil (tillage) in which, nutrients and water are more susceptible to transport outside plant rooting zone under erosion effects (14,15). The substantial increase of grain yield observed in zai pits comparatively to the control (tillage) is in line with (16), who reported that zai practice has the potential to increase cereals yields by a factor 10. Likewise, according to the (12), the application of zai technique can increase production by about 500% if well executed.

Fifty-percent (50%) (KVx396-4-5-2D and Gorom local) and 25% (Tiligre) of the varieties recorded higher net revenue in 15 and 25 cm zai depth respectively. Only Moussa local exhibited higher net revenue in the control (tillage). Lower net revenue was recorded for 50% of the varieties in the control and in 25 cm zai depth for the others. The low net revenue observed in 25 cm zai depth suggests that the cost of the zai realization negatively affected the net profit. The zai increases cowpea grain yield but can be less profitable due to the high pits implementation cost. In effect, for all the varieties, the highest benefit-cost ratio was recorded in the control (tillage) and the lowest in 25 cm zai depth, except for Tiligre, for which lower value was observed in 15 cm zai depth. This shows that in non-limiting water conditions, the use of zai pits increases cowpea grain yield but does not guarantee a high economic profit when the pits construction cost is taken into account. The high cost incurred in pits implementation reduced the profitability comparatively to the sowing in tilled soil.

When drought was imposed at seedling stage, 100% of the varieties exhibited higher gross revenue and net revenue in 25 cm zai depth and lower average values in the control (tillage). These results show that the varieties were high grain yielding in the zai pits (25 cm and 15 cm depth) than in the tilled soil (control). The ability of zai pits in gathering water and nutrients in the plant rooting zone enabled to reduce drought stress effects and increase plants productivity leading to consequent economic net revenue. Therefore, in seedling stage drought stress conditions, the zai pits is the most adapted agricultural practice for cowpea production for increasing substantially harvest yields compared to the tillage. However, in the seedling stage drought stress conditions, 50% of the varieties (Groom local and KVx396-4-5-2D), consistently exhibited higher benefit-cost ratio in the control zai (tillage), while 50% (Moussa local and Tiligre) had higher benefit-cost ratio in zai of 25 cm. These results suggest that zai pits increased the gross and net revenues but did not imply a guarantee in increase of benefit-cost ratio. This could be due to the high total variable cost incurred in zai construction. In addition the genetic status of the varieties (tolerance or sensitivity) to drought would have also played a major role. According to (5), Groom local is a drought-tolerant variety; KVx396-4-5-2D is drought-sensitive but nevertheless gives acceptable grain yields under drought stress. The tolerance status of these varieties could have allowed seedlings to withstanding to the negative effects of drought even in the flat soil (tillage), making the gap of yield between the zai pits and the control not enough significant. This could explain the highest benefit-cost ratio recorded in the control (tillage) for these varieties when drought was imposed at seedling stage. However, Moussa local and Tiligre are drought-sensitive. Thus, drought at early stage of development could have caused seedlings collapse more in the tilled soil (the control) than in the zai pockets, reducing plant density in field and impacting negatively the final yield and therefore the net revenue. This could explain the lowest benefit-cost ratio registered in the control (tillage) and the highest in zai pits. This ascertainment shows that in early stage drought stress conditions, the genetic status of the cowpea variety is determinant in the choice of the agricultural system of production when the purpose is of getting high economic returns. For drought-tolerant cowpea varieties, using ploughing would be the most economically suitable agricultural practice for production than using zai technology as it leads to high benefit-cost ratio. However, for drought-sensitive varieties, the use of zai pits technology (15 cm or 25 cm depth) is economically recommendable.

When drought was imposed to plants at flowering stage, 100% of the varieties recorded higher grain yield and gross revenue in 25 cm zai depth, the intermediate in 15 cm zai depth and the lowest in the control (tillage). The net revenues were higher in 25 cm zai depth, while lower values were recorded in 15 cm zai depth. The increase of grain yield with increasing zai depth and the low yields observed in the control (tilled soil) show that zai pits had positive impact on plants productivity, especially in drought stress effects mitigation. The deep of the pits could have allowed plants to escape or to better withstand to drought spell effects. The highest net revenue registered in 25 cm zai depth despite the high cost incurred during its realization suggests that this modality of zai was of great agronomic to plants and economically the most appropriate for cowpea production under drought stress conditions. The lowest net revenue observed with 15 cm zai depth shows that increase of grain in that modality of zai holes compared to the tillage and regarding the implementation cost tillage was not enough to generate better incomes than the control. However, similarly to the control conditions, the highest benefit-cost ratio was recorded in the control (tillage) in flowering stage drought stress conditions. This testifies that either in non-limiting water conditions or in drought stress conditions, the tillage remains the most profitable considering the benefit-cost ratio generated.

However, the low profitability of the use of zai pockets observed in this study in control and in drought stress conditions could be attributed to the fact that pits were manually dug, which made the implementation time consuming and more expensive, reducing the net revenue. The mechanically realization of zai pits might be more profitable and is therefore to be explored. Constructing mechanically the zai holes could considerably reduce the required time and the labour force and consequently the cost compared to manual implementation of pits. This could contribute to simultaneously increasing the grain yield and the economic profit.

5 Conclusion

The zai pits use in cowpea production leads to substantial increases of cowpea grain yield and mitigates drought stress effects on plants productivity. The increase of yield does not guarantee a high economic profit when pits implementation cost is taken into account. Using tillage is economically recommendable for production of drought-tolerant cowpea varieties than the zai system as it leads to higher benefit-cost ratios. However, for drought-sensitive varieties, in seedling stage drought stress conditions, the use of zai pits leads to higher benefit-cost ratios. The mechanical construction of the zai pits is to be explored; it could reduce the cost of digging the pits and contribute to increasing the profitability of the use of zai technology and the benefit-cost ratio.

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