International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-11 Issue-1, October 2021

Comparative Analysis of Manual and Mechanised Yam Minisett Planting

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Abstract: ***Drudgery has been identified as a critical area in the cultivation of yam. The aim of the study was to compare the manual and mechanised yam minisett planting. To address this problem, heart rate (HR) of workers during mounding and ridging, and planting were measured as well as assessing economic feasibility in mechanising yam planting. Polar watch (RS 800 CX) was used to measure HR of the operations. Hoe and cutlasses were used for mounding and ridging. The HR of tractor operator during planting was determined. Descriptive statistics and analysis of variance (ANOVA) were done using GenStat software (VSN International, 2011). Statistical significance was carried out at p<0.05. The field capacity was 3.84 and 1.45 h/ha for mechanised and manual, respectively. The mean HR was 112.80 and 112.7 bpm for mounding and ridging respectively while 112.00, 132.00 bpm for mechanised and manual, respectively. Mechanised yam minisett planting reduces labour cost by 50%.***

Keywords**: Drudgery, Manual, Mechanised, Planting, Yam Minisett.***

I. INTRODUCTION

The current trend of multiplying planting material of yam (minisett production) to plant large farm size within a shortest possible time requires the change of traditional planting method. Planting is process of buried of seed or planting material into the prepared seedbed. The traditional method of planting yam is painful and affects the yield according to [1]. Traditionally, mounding is by far the greatest common practice in Ghana and throughout the West African yam agro-ecology [3]. Mound forming is difficult and labour demanding that restricts yam production output [4]. Even though mounding is difficult, but [5] reported that the higher the mound or ridge, the greater the yield. It was stated by [6] that, a ridge height of 36 cm gives a greater yield. However, the ideal height of the ridge depends on the soil type and the cultivar grown. Also, a high broad mound and ridge are less washed away by rain. Although the drudgery involved in seedbed forming and planting is noticeable to be a problem [7], but researchers are silent in estimation of drudgery and economic viability during manual and mechanised planting of yam minisett. Drudgery is difficulty in doing physical work. Drudgery could be measured through monitory of heart rate (HR) as a signal of workload. The use of HR is an active method of determining exercise oxygen agreement and energy expenditure for work done due to its solid connection with oxygen consumption [8],[9]. As [10] used HR to examine energy expenditure of oxen pulling an implement. An Individual's heart rate can also increase and drop just in response to answer, level of caffeine intake, ambient temperature, and health [11]. Several accounts on drudgery for physical activities were reported by [12],[10],[8].

The most serious restraint for growing yam production is the pain in planting procedure. Almost every stage of producing yam is labour-intensive, putting off the youth in the field of yam production which affects the scale of yam production. As [2], costs the stages involved in production such as clearing of the field, burning, and construction of seedbed to be about 49% of the labour expenditure to produce a hectare of harvested yam tubers in the rain forest agroecology of Nigeria. The manual planting rate according to [13] was 144 yam setts per hour this translated for 1152 setts for a farmer working at 8 h per day. According to [13]; [2]); about 50% of the expenditure of yam production go to the planting process against 40% of sweet potato [14]. Despite growing popularity in yam cultivation, there is no report on comparing HR in relation to seedbed forming (mounding and ridging) and planting (manual and mechanical) for yam cultivation.

The objectives of this study were to: (i) compare drudgery in seedbed forming (mounding and ridging) and planting (manual and mechanising) of yam minisett by determining the HR during these activities and (ii) to assess economic viability in mechanising yam planting. The study is hoped to estimate drudgery and cost-benefit in yam production in Ghana.

II. METHODOLOGY

A. Study site

The study site was Kwame Nkrumah University of Science and Technology (KNUST) Research Farm (Anwomaso) arable farm located ($6^0$41'56.75'N, 1^0 31'25.85'W), in the forest zone of the Ashanti Region. The map of Ghana at the study site was presented in **Fig. 1**. The study place experiences two rainy seasons (bi-modal rainfall), the main rain period starts from March to July and minor from September to November [12]. The soil classification at the study site was sandy loam and soils were predominantly Forest Ochrosols, while mean annual rainfall and relative humidity were 1200 mm and 72.8% respectively. Temperature also ranges from 20 to 32 ^{0}C [15].

Manuscript received on August 29, 2021.
Revised Manuscript received on September 20, 2021.
Manuscript published on October 30, 2021.
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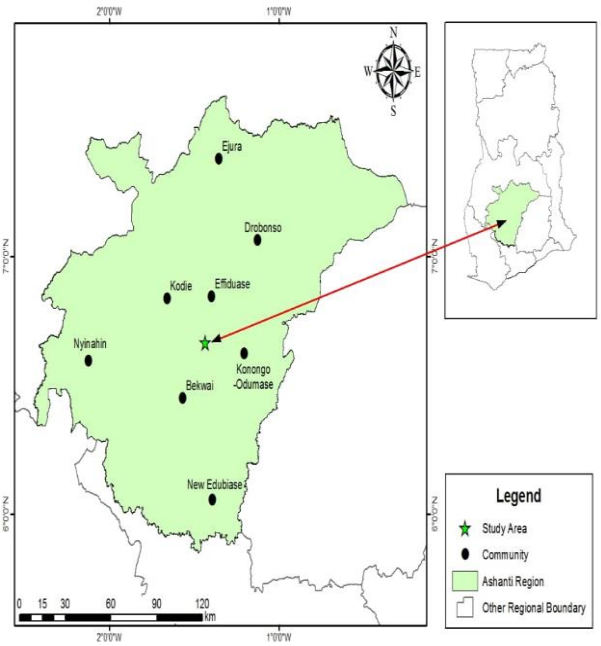

Fig. 1: Map showing the study site

B. Land Preparation

Mounding and ridging were done on 2nd March 2019 using hoes and cutlasses after the land was ploughed and harrowed by gathering topsoil to form conical (mound) heaps 45 cm high and 100 cm base. Between plants was 1 x 1 m apart from crest to crest. Ridges were constructed the same size as a mound to be 10 m long to contain the same number of plants (225) as mounds. Male workers of average age of 47, height 1.62 m and average weight (body mass) of 64 kg were hired for mound preparation and planting (minisett burying). The average weight of the workers before and after mounding and ridging were taken separately to determine weight lost during seedbed preparation and planting because Smith *et al*. (1994) related weight lost to energy spent during physical activities. The weights of the workers were taken before and after every activity. The shape and the size of the mound and ridge seedbed were presented in **Fig. 2 (a) and (b)**. The mound (45 cm height and 80 cm base was in **Fig. 2b** whereas ridge, 45 cm height and 80 cm base) was in **Fig. 2b**. The rate of mounding and ridging was obtained by dividing the number of mounds or ridges formed by the time taken. The height and weights of the workers were measured using steel tape measurement and weighing scale.

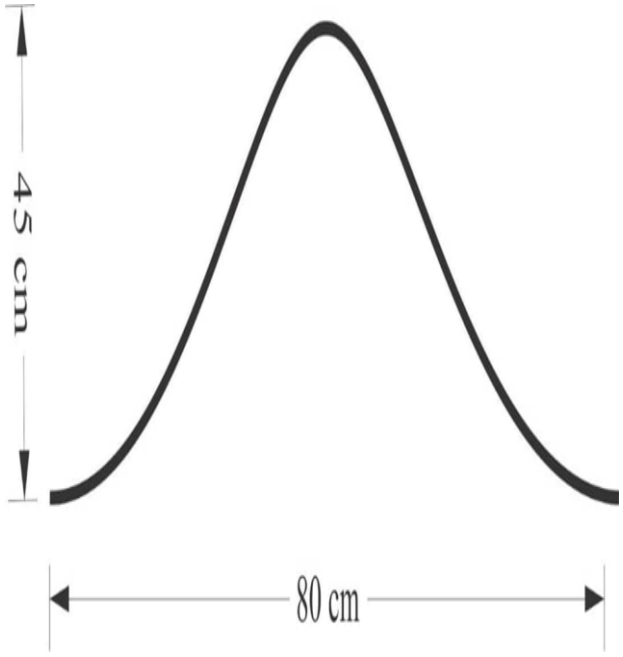

Fig. 2a. mound seedbed

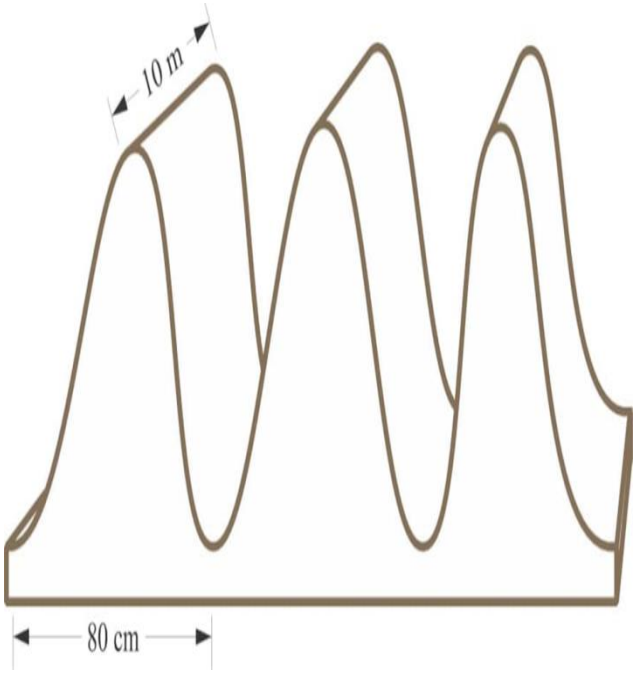

Fig. 2b. ridge seedbed

C. Heart Rate Measurement

The HR of the workers were determined to predict the energy expenditure whiles time was recorded to establish the duration for each operation to determine HR of every activity. The mean HR for respective planting operations were determined using Polar watch (RS 800 CX). The strap was worn around the chest of the workers for 20 min before seedbed forming operations started and rest 25 min after the operation ended. Because mounting of the sensor brings stress, workers were given 20 min to rest after sensor attachment. HR data were set concurrently at a sample rate of 5 s pauses [10]. The same procedure was used for planting. How polar watch with heart beat sensor attachment was worn before working activity was presented in **Fig. 3.** The rate of raising mounds and ridging was also determined by the same procedure and technology. How much energy was spent to carry out during work is important in calculate the rest period (min/h) needed by a person after working activities **equation (1)** [16].

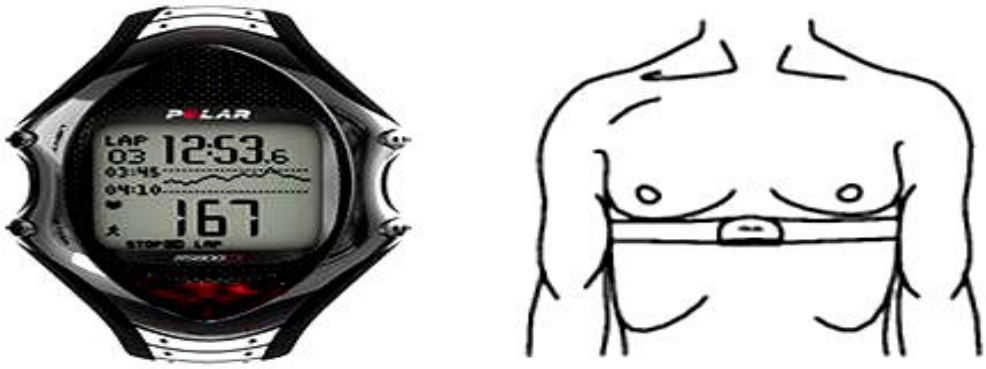

Fig. 3: Polar (RS 800 CX) watch and chest strap as worn by a person

Source: [12]; [10].

$$Tr = 60\ (1 - \frac{250}{P}) \quad (1)$$

where,
Tr = Total rest period (min/h)
P = Gross energy consumption (Watts)
Heart rate energy conversion chart was used to convert the mean heart rate attained for an activity to determined equivalent energy consumption [12].

D. Manual Planting Capacity

Yam *(pona)* tubers that have broken dormancy were acquired from Crop Research Institute (CRI) Kumasi, Ghana. The tuber was sliced into minisett weighing an average of 50 g with moisture content of 82%. The sliced setts surfaces were spread out in open space and then allowed to dry for an hour. Ashes were applied on the surfaces before planting to avoid rotten [17]. The same male workers who constructed the seedbed were tasked after two weeks to plant 225 yam minisett on mound, ridge, and flat, *while time used* during planting was recorded for the individual workers. Planting started at the beginning of rain on 20th April 2016 in order to moist the seedbed. The setts were buried to an average depth of 12.5 cm from the apex of mound or ridge using hoes and cutlasses. Planting capacity (sett/h) was determined using **equation (2)** adopted from [18]. Timing of seedbed forming and planting activities were taken using a stopwatch, meanwhile, the height and weights of the workers were measured using 30 m steel tape measure and weighing scale.

$$Planting\ capacity = \frac{minisett\ planted\ X\ 36}{10000\ X\ time\ taken\ (s)} \quad (2)$$

E. Planter Economic Feasibility Assessment

The costs of planting with a double row mechanised yam minisett planter were calculated using the assumptions in **Table 1** according to [12],[19].

Table 1. Assumptions and recommendations for cost calculations

Cost Parameter	Assumptions
Salvage value	0.0
Insurance	0.5% of the purchasing price
Shelter	0.5% of the purchasing price
Interest	0.5% of the purchasing price
Taxes	0% of purchasing price*
Lubricant cost	15% of fuel cost
Hectare planted/year	100

**Though, agricultural inputs are tax-free by law but subject to current law. If the law is changed, that may also change.*

Depreciation and interest on planter ownership were determined using **equation (3) and (4)** respectively [20].

$$Depreciation = \frac{Purchase\ price - Salvage\ value}{Economic\ life} \quad (3)$$

$$Interest = Rate\ \frac{(Purchase + Salvage\ value}{2} \quad (4)$$

The expected revenue, profit, and breakeven cost were determined for each planting method adopted by [2] using **equation 5**.

$$Breakeven = \frac{Total\ fixed\ cost}{Hiring\ cost - total\ variable\ cost} \quad (5)$$

F. Data Analysis

Descriptive statistics and analysis of variance (ANOVA) were done using GenStat software (VSN International, 2011). Means were obtained using the least significant difference (LSD) when the treatment effect is significant at p ≤. 0.05. Tukey and Fisher's approach was used to determine differences in treatment mean.

III. RESULTS AND DISCUSSION

A. Land Preparation and Planting

Table 1 presents seedbed preparation and manual planting capacity, time taken for seedbed preparation and planting as well. A worker took an hour to construct 35 mounds and 1 h for 6 ridges of 6.2 m long. On the basis of seedbed preparation rate, 284 and 258 man-hours were required for mounding and ridging respectively. The seedbed type could contribute to the differences in mounding and ridging time. Again, 2.5, 2.5, and 3.2 h were used for planting (sett burying) 225 setts on mound, ridge, and flat, respectively. The planting rate was 90, 90, and 71 sett/h for mound, ridge, and flat, respectively. The average time per hectare for sett burying alone were 142, 111, and 111 h/ha for flat, ridge, and mound, respectively. Time taken for seedbed preparation and burying of sett for hectare were 142, 396 and 369 h/ha (man-hour) for flat, mound and ridge, respectively. More time was used for flat planting.

Published By:
Blue Eyes Intelligence Engineering
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Meanwhile, additional time for mounding and ridging together with burying could also play a role in the difference in planting capacity per hectare. Again, seedbed type played a role in the difference in planting rate. The result showed that as result of pegging before planting on flat seedbed, planting on flat seedbed would plant fewer plants than planting on mound and ridge. This result disagrees with the study by [2] that ridging as seedbed for yam cultivation costs higher than planting on flat if time is quantified into money. This means that, additional time for pegging made costs of cultivating on the flat seedbed more than that of ridging. Average planting rate would mean that a worker would need 8 man-hours to plant an average of 669 setts, translating 0.066 ha/day.

Table 2: Seedbed preparation and manual planting rate

Location	Seedbed Type	No. of seedbed	Duration for land forming (h)	Seedbed forming rate/h	No. sett planted	Planting time (h)	Planting capacity (sett/h)
UCCRF	Mound	225	6.4	35	225	2.5	90.0
	Ridge	36	5.8	6(6.2 m)	225	2.5	90.0
	Flat	1	-	-	225	3.2	71.0

B. Heart Rate Measurement

Table 2 illustrates the mean HR with matching gross energy consumed and rest period during seedbed-forming (mounding, ridging) and planting activities. The mean heart rates during mounding and ridging were 112.80 and 112.70 bpm, respectively. Similarly, the energy expenditure needed for mounding was 665.15 W and ridging 664.56 W. There was no significant difference ($p>0.05$) in mean heart rate for mounding and ridging. Similarly, the mean heart rate at manual and mechanical planting was 132.00 and 112.00 bpm, respectively. Again, the energy needed for manual and mechanical was 886.26 and 660.04 W, respectively. There were significant ($p\geq0.05$) differences between the mean heart rate for manual and mechanised planting. It was observed that the mean heart rate, gross energy consumption, and rest periods could mean that the longer period of rest was needed to compensate for used energy. The association among energy consumption and the rest period were in line with findings by [12]; [10] that, physical work requires more rest periods.

Table 3: Mean heart rate (bpm), gross energy consumption (W) and total rest period (min/h) for seedbed-forming and manual planting

	Evaluation parameter		
Activities	Mean Heart Rate (bpm)	Estimated Energy (W)	Rest Period (min/h)
Manual Planting	132.00_a	886.26	43.07
Mechanised planting	112.00_b	660.04	37.27
LSD	11.36		
Ridging	112.70	664.56	37.43
Mounding	112.80	665.15	37.45
LSD	Ns	-	-

Within each column, means followed by the same subscript letter are significantly different at $p\leq0.05$

Heart rate profiles during manual and mechanised yam minisett planting were presented in **Fig. (4a) and (b)**. The HR profile during manual was **Fig. 4a**, whereas HR profile during mechanised planting was in **Fig. 4b.** The profile describes rest before work, planting and recovery after work.

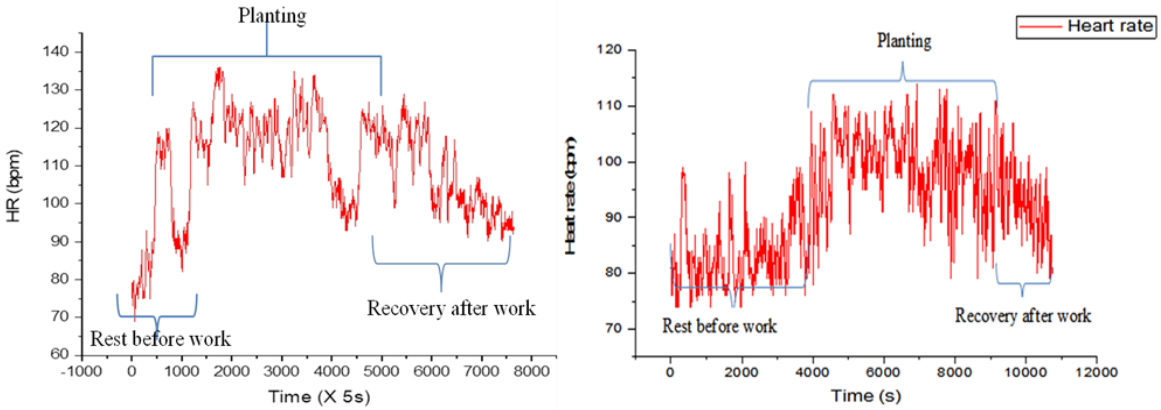

Fig. 4a. Heart rate profile during manual, 4b); mechanised yam minisett planting

C. Economic Analysis of the Planter

Table 3 and 4 presents the cost per hector for using manual and mechanised planting, respectively. It could be observed from the table that planting with the DRYM planter allows a reduction of 50% labour cost for planting and increasing timeliness in planting of 75%. This is similar to findings by [13] that the use of a mechanical planter reduces the total cost of yam production. Again, investing in the DRYM planter of Gh₵3400.00, the mechanised yam planting offered a total annual cost of Gh₵ 5411.00.

Table 4: Manual planting cost

Seedbed-form type	Seedbed-form unit	Unit cost (GH)	Total cost (Gh)	Number of plants	Unit cost	Total cost	Cost per hectare (Gh/ha)
Mound	224	0.5	112	224	0.2	44.8	14,000
Ridges	36	4	108	224	0.2	44.8	13,650
Flat	-	-	-	228	0.4	91.2	8,000

The total costs of manual yam planting per hectare on a different seed-form (mound, ridges, and flat) were Gh₵14,000.00, Gh₵13,650.00, and Gh₵8,000.00, respectively as shown in **Table 4** for the study site. Apart from several benefits in using mechanical yam planter, so far as the work is completed at an appreciable reduction labour cost and within a shorter time as compared to manual planting makes it easier for the farmer to cultivation at the right time. This increases the timeliness of fieldwork. Furthermore, using yam planter helps to reduce deficiencies in planting processes such as uniformity of plant spacing, plant depth, covering procedure, etc. Meanwhile, the total cost of yam planting under ridges was higher, followed by mound and flat, which was contrary to estimation by [19] that, yam production on ridge cost less than using mound.

Table 5: Planter cost estimation

Cost Parameter	**Costs (Gh₵)**
Purchase price	3400.00
Salvage value	0
Economic life (year)	10
Fixed Costs	**(Gh₵/y)**
Depreciation	340.00
Interest	17.00
Insurance	17.00
Tax	0.00
Shelter	17.00
Total Fixed Cost	**391.00**
Fuel (diesel) cost (Gh₵/L)	4.80
Fuel Consumption (average) (L/ha)	9.2
Field Capacity (average)	0.26
Hectare cultivated (ha/y)	100
Labour Cost (Gh₵/ha)	20.00
Number of labourers	1
Variable Cost	**(Gh₵/h)**
Fuel	11.48
Lubricant	1.72
Repair and Maintenance (Gh₵/ha)	17.00
Labour	20.00
Total cost (Gh₵/h)	50.20
Total Variable Cost	**5020.00**
Total Cost (Gh₵/y)	**5411.00**

The breakeven analysis chart for using the DRYM planter was presented in **Fig. 5**. The breakeven point for the yam minisett planter was 4.5 y of machine use, equivalent to approximately 117 ha of yam field planted. This result shows that using a double row mechanical yam sett planter seasonally, the investment would be better with the substantial profit made through routine hiring of the planter.

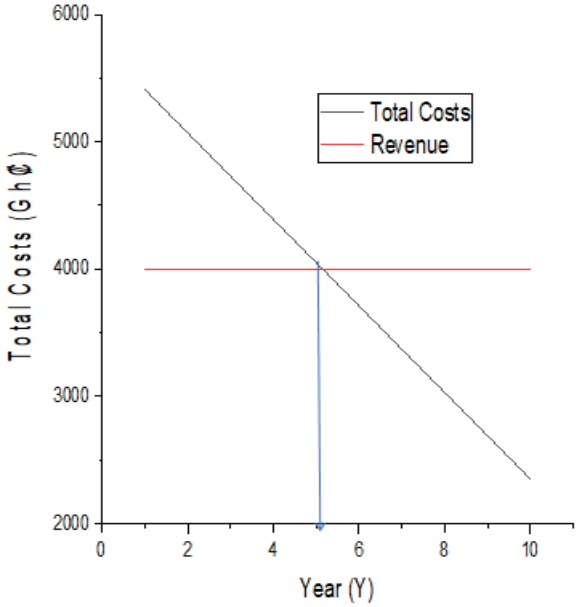

Fig. 5. Breakeven analysis of using a mechanical planter

IV. CONCLUSION

1. Deploying mechanical yam minisett planter had demonstrated much better reduction in total planting cost by about 50%, and 75% timeliness increase over manual planting option
2. The heart rates for manual and mechanised planting were 132.00 and 112.00 bpm, respectively. There was significant ($p<0.05$) difference between the mean heart rate for manual and mechanised planting and the same translated into rest period of 43.07 m/h for manual and 37.32 m/h for mechanised planting.

ACKNOWLEDGMENT

The authors wish to express their profound gratitude to Mr. Benjamin Assaga of KNUST and the entire staff of Takoradi Technical University, Department of Auto and Ref. Engineering.

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