

ERGONOMIC ASSESSMENT OF A SINGLE RAW MANUALLY OPERATED HAND-PUSHED WEEDER

Saleh, A.

Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, P.M.B. 1044, Zaria, Nigeria

Corresponding email: salehaminu@gmail.com

ABSTRACT

Weed control is one of the major problems in crops and vegetables production in Nigeria. Traditionally, the conventional manual weeders are the most common techniques used by small-scale farmers for controlling weeds on their farms. However, these weeders tedious in operation, time consuming and less effective. They also infringe pains and fatigue on the operator due to continuous bending posture. To address these problems, a single raw hand-pushed weeder was designed and a prototype produced in the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Zaria. Ergonomic assessment of the weeder was conducted in the experimental farm of the University, Zaria. A male operator of about 30 years was used for the study. Physiological parameters of the operator and some ergonomic parameters, such as heartbeat and energy consumption were also compared to ascertain the operator's comfort in order to reduce drudgery and fatigue. Results obtained indicated that the physiological cost of weeding was lower for the developed single raw hand-pushed weeder as compared with the conventional manual weeder. Heartbeat rate during the weeding operation 71 beat per minute for the hand-pushed weeder as against 85 beats per minute for the conventional weeder. The operating energy required for operating developed single raw hand-pushed weeders was 25.54 kJ/min against 30.27 kJ/min for conventional manual weeder. This is clear indication that the developed single raw hand-pushed weeder could be operated for longer duration at reduced stress and drudgery, and thus more effective and efficient.

Keywords: Discomfort, Ergonomic parameters, Hand-pushed, Heartbeat, Weeding Tool

1 INTRODUCTION

Weeding is one of the most significant but tedious operations process in crop production. Weed is a plant growing where it is not wanted. It competes for water, nutrient, space and sunlight thereby grows quickly and gain competitive ability on crops planted. They are tolerant to shade with no special environmental requirements for germination. Weeds are classified as crop pests and are responsible for distinct losses in crop yields. They also deteriorate the quality of crop produce and hence reduce the market value. Previous studies have documented negative effects of weed competition on crop yield. Results of such studies shows that crop losses measured under weedy conditions for maize was between 55 to 90%, 40 to 80% for sorghum, 40 to 60% for cowpea and 50 to 100% for rice [1, 2, 3, 4]. Weed infestation, therefore, constitutes a major problem in crop production. Labour requirement for weeding depends on weed intensity, weed flora, time of weeding, soil moisture and effectiveness of the farm worker. Weed control is, therefore, imperative to ensure sustained crop production, reduce drudgery for improved quality of life of the farmers and guarantee food security to the ever-increasing population. There are various types of weed control methods. These include manual, cultural, mechanical, chemical and biological. Manual weeding is done by hand or hand tools like hoes, axes and cutlasses. Operator's posture is usually by bending posture which involves a lot of drudgery. There is recent improvement where operator remains in standing position so as to reduce drudgery [5, 6, 7].

Manual weeding gives clean results with limited chances of crop damage, but process is very slow [8]. Mechanical weed control refers to any technique that involves use of farm equipment/implements to control weeds. Implements used vary from simple hand tools to more advanced drawn implements [9]. The operation of these machines that requires manual efforts to operate increases workload on the operators as well as occupational hazards which impair the performance of the operator [10]. The ergonomic aspects of the manual weeders are of great importance as working with them involves considerable physical strain to the operator. An operator has to walk behind the machine for some distance to till a specified land area [11]. Besides walking, the strains resulting from stress factors due to noise, mechanical vibration and work load also affects the performance of the operator [12]. On the other hand, due to heavy demand on the operator's biological systems, the stress and fatigue experienced by the operation results in clinical and anatomical disorders and in the long run affect the workers' health [13]. The aim of this research is to assess a single raw hand-pushed weeder developed in the Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University- Zaria in order to generate information that could be used in matching the weeding operation with the operator for optimum drudgery reduction.

2 METHODOLOGY

2.1 Materials

The materials used in this study besides the Hand-Pushed weeder to be assessed include: heartbeat sensor/oximeter (Model-SPQ2), Grass SD9 stimulator, stop watch, moisture meter, soil auger, tape rule (100m), digital weighing balance, wooden pegs.

2.1.1 Description of the Weeder

The weeder constitutes a frame, 2 wheels (pneumatic and steel types), tine cultivator, V-shape shear and rectangular weeding blade) as shown in Figure 1 while the orthographic view of the weeding hoe showing the detailed dimensions of its various parts is given in Appendix.



Figure 1. Pictorial View of the Developed Weeder

Frame - The frame is the skeleton/structural component on which all the components of the weeder were built, supported and attached. It was made from 3 mm mild steel rod. All the components mounted on it were attached with bolts and nuts for ease of transport and replacement of defective parts.

Wheel - The weeder has two different wheels; pneumatic (moulded and tubeless) and steel wheels. Both are of the same diameter (400 mm) and are not used simultaneously but one at a time depending on the type of soil.

Handle - The handle was constructed using 30 mm diameter circular (hollow) pipe. Ergonomic and anthropometric aspects were considered in such a way it suits variety of users. It was attached to the frame to control and direct the weeder on the field.

Tine cultivator - The tin cultivator was made from 10 mm diameter steel rods which were flattened at its base and supported at the top by a mild steel metal sheet. It was meant to work on stony and rooted soils. **V-shape shear blade** - The furrower was made from a 3mm mild steel metal to form a typical sweep furrow of 18 × 18 mm.

Rectangular Weeding blade - The weeding blade which forms the integral part of the weeder was made from 5 mm mild steel plate. Its dimensions are 20 × 20 mm. It has a sharp blade which is used to cut, slice and pulverize the soil for effective weeding.

2.2 Experimental site

The study was conducted in the Experimental Farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru-Zaria, Nigeria. It is located at Samaru on Latitude 11.7° 30" to 11° 120" N, Longitude 07° 36" E to 07° 42" (Figure 2) and an altitude of 686 m above sea level [14]. The climatic condition of this region is characterized by an annual mean rainfall of 1000 mm, atmospheric humidity as low as 15% during the dry season and above 60% during the wet season, minimum temperature of 22°C in January and attaining the maximum 28°C in April [14]. Mean wind velocity was 13 km/h while the soil in the site is sandy loam.

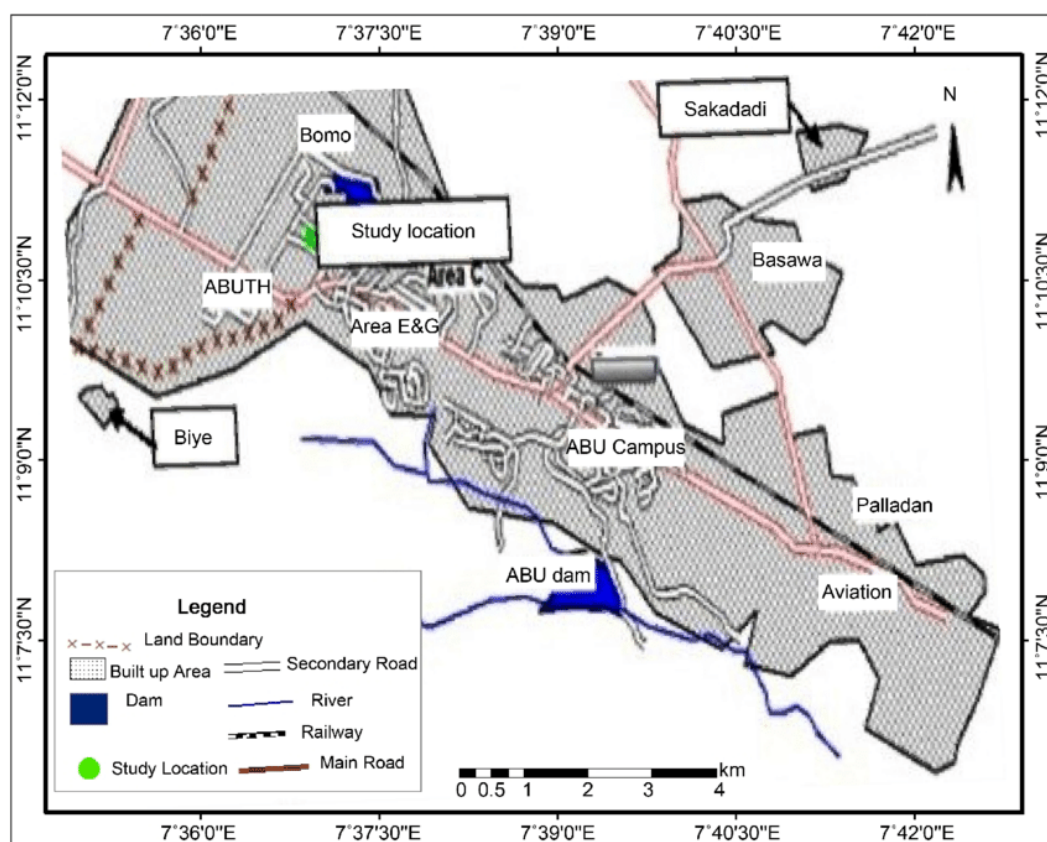


Figure 2. Map of Samaru-Zaria Showing the Study Area [15]

2.3 Experimental procedure

The Hand-Pushed weeder was put in proper condition before conducting the tests. The operator was also trained on the operation of the weeder prior to the experiment. He was asked to report at the work site at 8.00 am and has a rest for at least 30 min before the commencement of the trial experiments having tracked from his village covering a distance of about 1½km to the experimental site. He was given information about the experimental requirements so as to solicit his cooperation while the test lasts. He was also assured of having full day's payment not minding that the test may not take the whole day. Ergonomic performance evaluation of the weeder was done between the months of June and August, 2021. The tests were conducted in the morning hours of 9.00 to 11.30 am. A healthy male operator of about 30 years (based on age and medical fitness) was used for the study. The choice of the operator based on the recommendations of [16] that the maximum expected strength of a farm labourer

was determined in the age group of 25 to 35 years. The physiological data of the operator was taken before and after each trial of the weeding operation. The heartbeat rate and other parameters were measured and recorded using polar heartrate monitor for the entire work period. Each trial started with taking 5 min data for physiological responses of the operator while resting on a stool under shade. The operator was then asked to operate the weeder for duration of 15 minutes and same procedure was replicated thrice. The test conditions such as soil moisture content, soil type, bulk density of soil, root zone depth of weed, density of weed, etc. were taken into consideration. Parameters of the weeder evaluated include heartbeat rate, average oxygen consumption and rate of energy expenditure. Three types of weeding attachments/ blades were used. These are tine cultivator, V-shape shear blade and rectangular weeding blade. An average forward speed of 1.2 km/h was used in conducting the experiment as recommended by Gite and Singh [16]. The heartbeat rate was measured and recorded using polar heart rate monitor (Model - SPQ2) for the entire work period. Each trial started with taking 5 min data for physiological responses of the operator while resting on a stool under shade as suggested by Ali [17]. He was then asked to operate the weeder (already started by another person) for duration of 15 minutes and same procedure was replicate thrice for all the selected moisture levels. For the assessment of Overall discomfort rating (ODR), a 10 - point psychophysical rating scale (0 – no discomfort, 10 - extreme discomfort) was used which is an adoption of Corlett and Bishop [18] technique.

2.4 Energy expenditure rate

The energy expenditure rate indicates the level of bodily stress and in relation to heavy work it can be used to assess the level of effort to work out necessary rest periods, and to compare the efficiency of different tools and ways of arranging the work. The energy expenditure rate (EER) was determined by multiplying the oxygen consumption rate (OCR) with the calorific value of oxygen as 20.93 kJ/l [19].

$$EER = OCR \times CV_O \quad (1)$$

Where: EER = Energy Expenditure Rate (kJ/min); OCR = Oxygen Consumption Rate (l/min); CV_O = calorific value of oxygen (given as 20.93 kJ/l).

3 RESULTS AND DISCUSSION

3.1 Operator's physiological data

Physiological parameters of the operator were taken before and immediately after operating the developed hand-pushed weeder and presented in Tables 1 and 2, respectively. Higher working heart rate was recorded for operator as compared to prior operating the weeder. This may be due to the fact that heartrate at rest of the operator was not under stress. While the working heartrate of the operator was observed to be 71 beats/min, his heartrate was 68 beats/min when at rest. However, his heartrate rose to 85 beats /min while using the conventional manual weeding hoe that involved continues bending. Similar result was also reported by Gill and Choudhry [20]. This may be due to the fact that the aerobic power of the operator of the conventional manual weeder is higher because of the continuous bending posture than an operator that push or pull an agricultural tool as reported by Abubakar *et al.* [21].

Table 1. Physiological parameters of the operator

Operator's Variables	Physiological Data
Height (m)	1.66
Weight (kg)	64
Age (years)	30
Resting Heartbeat Rate (Beat/min)	68
Resting Blood Pressure (mm of Hg)	110/80

The factors causing the physical fatigue while operating the weeder were soil condition, operating force and energy. Hence the need for refinement of weeder based on limitations and capabilities of the developed weeder was felt [22]. The comparison of the ergonomic parameters of the operator using the developed hand-pushed and the conventional manual weeders are given in Table 2.

Table 2. Comparison of Ergonomic Parameters of developed hand-pushed and the conventional manual weeders

S/N	Parameters	Type of Weeding Tool	
		Conventional Manual Weeder	Hand-Pushed Weeder
1	Mean heart rate (Beats/min)	85	71
2	Mean oxygen consumption (l/min)	1.68	1.23
3	Mean Energy expenditure (kJ/min)	30.27	25.54
4	Oxygen consumption rate (%)	50.25	43.12
5	Overall Discomfort Rate (ODR)	5.37	4.10

The oxygen consumption rate was similarly observed to be 1.68 and 1.23 l/min for the operators of the conventional manual weeding hoe and the developed hand-pushed weeding hoe, respectively. The average oxygen consumption rate during weeding operations with the conventional manual weeding hoe was observed to be higher could be due to the fact that oxygen consumption rate has a linear relationship to the heartrate and earlier reported by McArdle *et al.* [23] and Kroemer *et al.* [24]. Similar result of oxygen consumption rate was also reported by researchers while evaluating the workers of different age groups [25]. Mean overall discomfort rating on a 10-point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 4.0 and scaled as "More than Light discomfort" during weeding. The corresponding energy expenditure of the operator for the conventional manually operated weeder and the developed hand-pushed weeder were 30.27 and 25.54 kJ/min, respectively. This indicated that the human energy expenditure was reduced to the tune of 42% with the introduction of the developed hand-pushed weeding hoe. The oxygen uptake in terms of maximum aerobic capacity was calculated and it was 43% and the value was above the acceptable limit of 35% of oxygen consumption rate (VO_2 max) indicating that the developed hand-pushed weeder could not be operated continuously for 8 hours without frequent rest-pauses. Generally, it was observed that the mean heartrate was lowest for the hand-pushed weeder compared to the conventional manual weeder indicating lower physiological demand and discomfort to the body parts. Similarly, the overall discomfort for hand-pushed weeder was lower than the conventional manual weeder. Lower energy demand and postural comfort was because of non-requirement of continuous bending posture of the operator as it was being pushed while the operator was standing. Thus, in the case of the hand-pushed weeder with lower heartbeat rate and postural comfort, the output obtained was more compared to the conventional manual weeders. Similarly, the physiological cost of weeding was higher for the conventional manually-operated weeder. This might be due to the ergonomic refinements carried out on the single raw hand-pushed weeder. It was also observed that increase in pressure, the heartbeat rate was also increased. Lesser increase of heart beat rate was observed while operating the single raw hand-pushed weeder possibly because less pressure was experienced with the elimination of the continuous pumping. Results obtained were in agreement with the findings of Gholipour [26]. Similarly, oxygen consumption was observed to be higher for the conventional manually-operated weeder since the heartbeat rate was higher. The operating energy required for operating weeders also varied. For the conventional manual weeder, the mean energy expenditure was 30.27 kJ/min. This value was 4.73 kJ/min higher than that what was obtained from the single raw hand-pushed weeder which is clear indicative of the fact that these weeders could not be operated for longer duration without adequate rest. This indicates that at high pressure rate, the energy expenditure tends to increase during the operation as suggested by Gite and Singh [16]. The results obtained also agreed with Sam [27] who observed that while performing exercise with faster movement, human muscles must contract more rapidly, consuming proportionately more energy. From the mean values of overall discomfort rate, discomfort experienced by the subject was lesser for single raw hand-pushed weeder when compared with other weeder. The less body part discomfort score was experienced by single raw hand-pushed weeder perhaps because the continuous bending posture was eliminated. The majority of discomfort experienced by the operator was in shoulders, neck and lower back for the subject operating the conventional manual weeder. Drudgery caused due to bad posture is reflected in terms of postural discomfort experienced by the worker. On the other hand, the discomfort experienced by the subject operating the single raw hand-pushed weeder was mainly due to the alternate push and pull action associated with the operation of the single raw hand-

pushed weeder. It has been observed by Gite [25] that muscular discomfort of body is comparatively more important than heartbeat rate and oxygen consumption rate in agricultural operations as limiting factors. Ghugare *et al.* [28] also discovered that maximum discomfort in the body parts was experienced in the conventional manual weeder in the left clavicle region, followed by lower back, neck, left thigh and right clavicle. The above results confirmed that developed hand-pushed weeder performed better than the conventional manual weeder.

3.2 Relationship between heart beat rate and work done

The relationship between heart beat rate and work done using the three attachments (tine cultivator, V-shape shear blade and rectangular weeding blade) of the developed single raw hand-pushed manual weeder was conducted as shown in Figures 2 to 4.

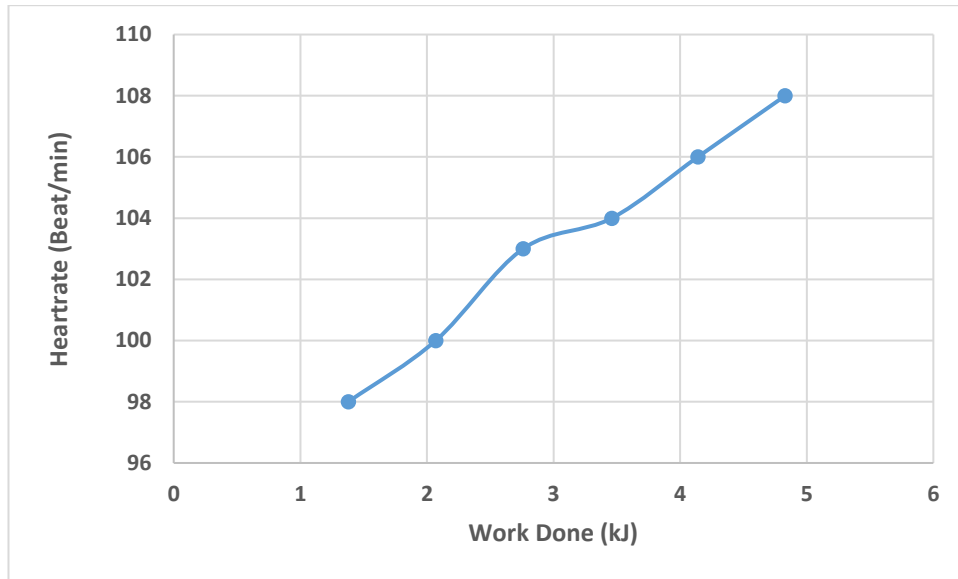


Figure 2. The relationship between heart beat rate and work done using tine cultivator

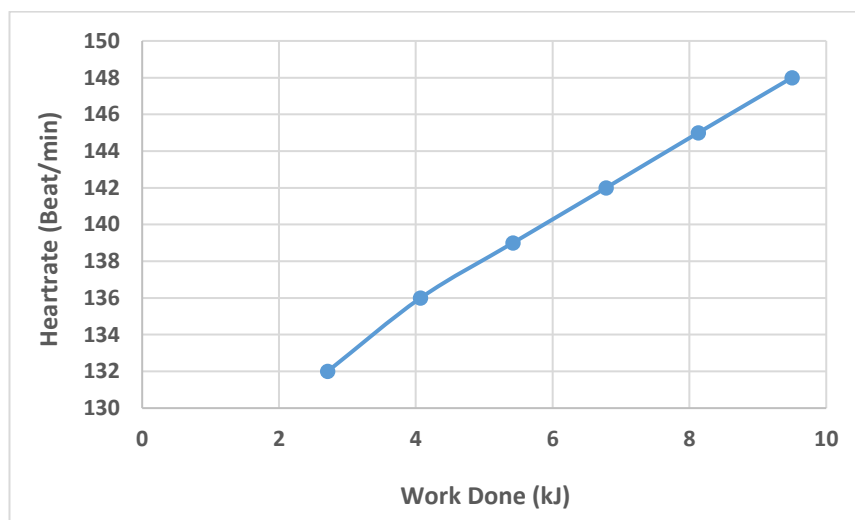


Figure 3. The relationship between heart beat rate and work done using V-shape shear blade

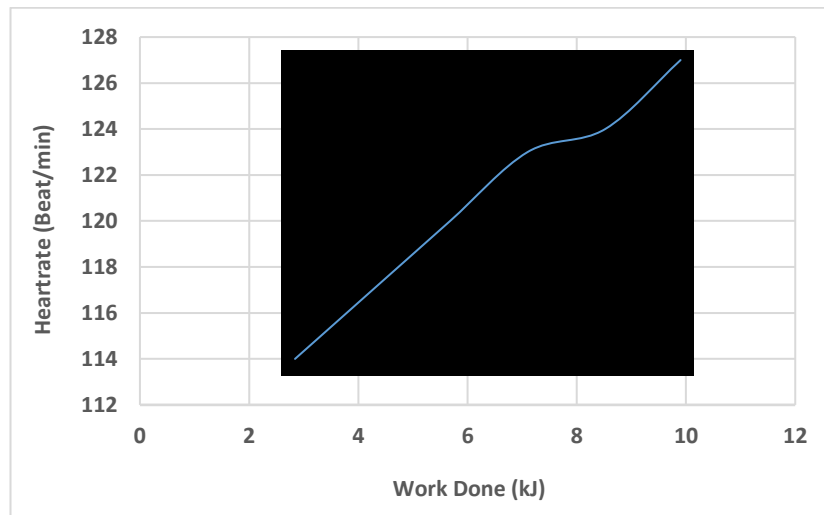


Figure 4. The relationship between heart beat rate and work done using rectangular weeding blade

Results of the study show that the heart rate of operator was varied from 108.0 to 148.63 beats/min (Figures 2 to 4). The highest heart rate of 148.63 beats/min, 127.27 beats/min and 108.0 beats/min were observed for V-shape shear blade, rectangular weeding blade and tine cultivator, respectively at forward speed of 1.2 km/h. Increasing the rate of weeder was observed to increase the heart rate by 3.1, 5.11 and 4.76 % for tine cultivator, the V-shape shear blade and rectangular blade, respectively. These results to increase in the fatigue and stress being encounter by the respective operators thereby having significant effect on the comfort of operator and his ability to perform the desired task. The result of this study was in total agreement with the earlier finding of Kumar [7] while investigating the effect of increasing the rate of work done for cono-weeder.

4 CONCLUSIONS

This study conducted the ergonomic assessment of the developed hand-pushed weeding tool. It was observed that the heartrate beat of the operator was reduced as compared with conventional weeders whose operations involved continuous bending. Higher cardiac cost was reported while weeding with conventional manual weeder whose range was between 140.2 and 136.3 beats per minute while using the three attachments of the hand-pushed weeder (tine cultivator, V-Shape and the rectangular shape blade). The oxygen consumption rate and energy expenditure rate followed the same trend. The designed hand-pushed weeder could not only increase the productivity of the workers but also it helps in reducing the drudgery and fatigue of the workers. If one worker is engaged for the weeding operation with the developed weeder, 5 min rest is recommended to be provided after 30 minutes of working.

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APPENDIX
ORTHOGRAPHIC VIEW OF THE HAND-PUSHED WEEDING HOE

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