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Comparison between Ergonomic and Conventional Hoes to determine Comfortability of Farmers when Hoeing Soil

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The use of agricultural mechanisation tools has developed rapidly at this time, but for narrow land it is not suitable to use these tools. Narrow agricultural land is more effective if processed using hoes. The purpose of this study was to compare ergonomic and traditional hoes to know comfortability of farmers when hoeing soil. The research parameters are hoe design, energy consumption, and work capacity. This study used an experimental method to test the use of hoes carried out in agricultural fields. The results showed that the energy consumption of ergonomic hoes was lower than conventional hoe use. In terms of safety and comfort, both ergonomic hoes and conventional hoes are classified as heavy work and cause complaints to workers. The work capacity of farmers using ergonomic hoes increased to 51.9% compared with the hoe P1 which only increased 32.4%. P2 and P3 increased by 26.3%.

Key words: *Hoe, Ergonomics, Comfortability Index, Work Capacity, Farmer Perception.*

Introduction

The mechanisation of agriculture has been promoted to improve work efficiency, effectiveness, and productivity in agricultural fields (McLaughlin et al., 2019). However, in its application, the mechanisation of land management has several constraints, such as the part of the corner of the land that is not possible to do using a tractor, hilly land topography that is difficult for a tractor to pass through, small plot size, low farmer capital, and strong cultural influence (Syuaib, 2015).

Due to many factors the application of agricultural mechanisation is often not possible, so it still demands the use of conventional methods using hoes (Fungo et al., 2017). Lee et al. (2013) said that the majority of agricultural cultivation, especially vegetables in Indonesia is still done conventionally with human labour. Choi and Lee (2017) say that traditional tools are still used for a long time. Therefore, in-depth studies of conventional tools still need to be done.

The hoe is one of the agricultural tools used by farmers to cultivate land around the world (Vanderwal et al., 2011). Hoes are widely used in agriculture. Hoes can be used to break, pull, and stir the soil using hand power capabilities (McLaughlin et al., 2019). The magnitude of this power capability depends on human physical capacity, soil properties, farm factors, weight and size of the hoe (Wulandary et al, 2019). Specifically, the hoe is used to turn over, break, and level the land on narrow plots of land where piracy is not possible (Choi, 2015; Fungo et al., 2017).

Based on its function, the hoe can multiply the ability of the human hand's power as a source of power in breaking down, pulling, stirring, and lifting the soil or other goods that are being worked on (Nyamangara et al., 2013). This multiplication depends on the nature of the soil and the shape, weight, and size of the hoe (Rahmawan, 2011).

Several studies have evaluated the feasibility of using hoes in preparation for crop cultivation (Baron et al., 2001; McLaughlin et al., 2019). Farmers have also collaborated with researchers to help develop and choose tools to be evaluated (Earle-Richardson et al., 2005; Rivilis et al., 2008). However, research to evaluate the use of hoes in underdeveloped areas is still very limited (Badiger et al., 2006). Some studies have not evaluated workers' discomfort in the long run (O'Neill, 2000).

In some places, farmers often complain of deteriorating physical conditions and musculoskeletal disorders after working using hoes, especially if working for long periods (Janowitz et al., 2000; Fathallah et al., 2008; Anniza et al., 2017). The size of hoe handles that have been circulating in the market vary because there are no design standards that refer to SNI (Syuaib, 2015). Hoe blades are generally box types with various specifications and brands (Khairunnisa and Mawari, D., 2015).

So far, various types of hoes have been circulating on the market, but the way of working, the shape of the blades, and the stems are not in accordance with the principles of ergonomics (Apriliani, Dervish, & Fedryansyah, 2019), so it is necessary to redesign to improve work productivity, maintain safety and comfort in working (Adiatma, Bambang, & Purnaweni, 2013). The use of hoes for future cultivation of agricultural land is still needed for various reasons such as there are parts of land that are not possible to work on by tractors, small plot size, low farmer capital, hilly land topography that is difficult for tractors to pass by, and the strong influence of local culture (Adriani, 2015).

The design and shape of hoes in each region varies, for example in North Sumatra, South Sumatra, Lampung, Bali, and Lombok the length of the hoe is 1 to 1.25 meters with a hoe angle of 70 to 80° and that weighs 1.25 kg. In Central Java, the length of the hoe is 65-80 cm, the angle of the hoe is 60 to 80 ° and it weighs 1 kg. The differences in the shape of hoes in some areas are caused by several factors, including soil type, topographical conditions and local habits (Ismy & Bahri, 2019).

Based on the results of a survey of agricultural machinery and tools in Indonesia, it was found that in North Sumatra, South Sumatra, South Sulawesi, Bali and West Nusa Tenggara, hoes generally weigh in the range of 1 to 3 kg, hoe lengths are 0.65 to 1.25 meters, and the angles of hoes used are 50 to 80°(Rusadi, Hadimi, & Karyad, 2018).

Research on hoe ergonomics has been carried out by previous researchers, including Shrestha et al. (2012) who studied the effects of different hoe weights on the body's energy expenditure, capacity, and efficiency of hoeing work. Sholihah et al. (2019) studied the effect of using non-ergonomic chairs on industrial engineering students. Purwanto (1992) was concerned with the design of ergonomic hoe handles to increase the farmer's work capacity in carrying out digging. Rahmawan (2011) studied the design of hoe handles based on worker anthropometry. Choi and Lee (2017) studies farmers' anthropometry and its application in hoe design.

Based on the data mentioned above, it is important to research the design of an ergonomic hoe so as to increase farmer working productivity. Therefore, the purpose of this study was to compare ergonomic and traditional hoes to know comfortability of farmers when hoeing soil. This research is important as a reference for designing an ergonomic hoe that fits the farmer's posture in general. In addition, the hoe will be widely used in the long term.

Research Methods

Research Tools and Materials

The tools used in this study were an ergonomic hoe that had been designed, a conventional hoe, meter, balance sheet, stopwatch, and pulse meter. While the materials used are ropes and stakes.

Research Parameters

The parameters observed in this study were ergonomic hoe design, the energy consumption of hoe use, and work capacity.

Research Procedure

The study begins by designing a hoe based on the results of previous studies. The design hoe was produced in the Sinar Abadi workshop, Mataram, West Nusa Tenggara, Indonesia. A conventional hoe with different specifications was compared with 3 hoes that were obtained from the local market. There were 4 respondents in the study to test the use of hoes. Farmers are selected in the age range of 20-30 years with a posture by Indonesian anthropometry on the normal distribution.

The test site was carried out in paddy fields in Perian village, Montong Gading District, East Lombok Regency, Indonesia. The design hoe and 3 conventional hoes (Figure 1) were tested for 10 minutes in paddy fields respectively. To facilitate writing, the symbol E is used for the ergonomic hoe, P1 for the comparison hoe 1, P2 for the comparison hoe 2, and P3 for the comparison hoe 3.

Figure 1. Display of ergonomic hoe and 3 conventional hoes

The pulse of the worker before and after work is calculated to determine the level of energy consumption (Y) of the worker. The equation used is (Purba et al., 2014):

$$Y = 1.80411 - 0.0229038x - 4.71711.10^{-4} x^2 \quad (1)$$

With Y = energy (kcal/minute) and x = heart rate (pulse/minute).

Data Analysis

Analysis of research data using one-way analysis of variance (F-test) to determine differences in performance between ergonomic and conventional hoes. If the F-calculated value is greater than the F-table value, there is a significant difference in performance at the 95% significance level (Ansar et al., 2019)

Results and Discussion

Ergonomic Hoe Design

A good hoe design can optimise and harmonise the specifications of the hoe with the physical condition of the farmer so that a hoe design that is safe, comfortable, and has good performance is obtained. The making of an ergonomic hoe design is shown in Table 1. The total mass of an ergonomic hoe is 2.5 kg, P1 = 2.6 kg, P2 = 2.3 kg, and P3 = 3 kg. This mass difference affects the energy expenditure of the ground. A total mass of 2.5 kg is the optimum mass of a hoe based on the calculation of the hoe's energy and the hoe's capacity. If the mass of the hoe is less than the optimum mass as the comparative mass of P2, it requires more energy to swing so the blades can get into the ground maximally.

Table 1: Specifications of ergonomic hoe design and comparative hoe.

Specifications	Values			
	E	P1	P2	P3
The total mass of hoe stalk	2.5 kg	2.6 kg	2.3 kg	3 kg
- Mass of stalk	0.4 kg	0.6	0.4	1 kg
- The total length of the stalk	110 cm	123 cm	132 cm	135 cm
- Major diameter	3.9 cm	3.5 cm	4 cm	4 cm
- Minor diameter	3 cm	2.5 cm	2.4 cm	3 cm
- Sloping end length	10.6 cm	-	-	-
- Tilt angle	12°	-	-	-
Hoe blades:				
- Mass of blades	2.1 kg	2 kg	2 kg	2 kg
- The total length of the blade	28 cm	23 cm	23cm	23 cm
- Blade width	18 cm	17.5 cm	17cm	17 cm
- Blade thickness	0.3 cm	0.3 cm	0.3	0.3 cm
- Oval tip length	3 cm	1 cm	0,8 cm	1 cm
- The shape of the stem connection	Box	Box	Box	Box
- Curvature	10°	8 °	10 °	8 °
- The angle between the stalk and the bar	75°	80°	78°	80°

Hoes that exceed the optimum mass as compared to the mass P1 and P3 require more energy to lift the hoe. This data is relevant to the results of the researcher of Garosi et al. (2019) that the weight of different equipment greatly influences the energy expenditure of the worker's body.

The total length of the ergonomic hoe handle is 110 cm, P1 = 123 cm, P2 = 132 cm, and P3 = 135 cm. 110 cm stalk length is the optimal length for comfortable use. Because if it is too short it can cause your back to bend too much and if it is too long it can complicate the ground breaking process. The length of the major diameter of the ergonomic hoe is 3.9 cm, P1 = 3.5 cm, P2 = 4 cm, and P3 = 4 cm, while the minor diameter of the ergonomic hoe is 3 cm, P1 = 2.5 cm, P2 = 2.4 cm, and P3 = 3 cm.

A size larger than the optimum value can cause the hands to easily get sore and if it is smaller than the optimum value can cause loose grip. The sloping end of the upper end of 10.6 cm with a slope angle of 12^{o} only exists in ergonomic hoes, whereas in conventional hoe the comparator does not have a bevelled edge. The top end of 10.6 cm is based on the width of the palm with an angle of 12^{o}. The width of your palm serves to facilitate and take the back foot off the ground to feel more comfortable. The same thing has also been reported by Syuaib (2015), that the width of the palm grip can make it easier for workers to make a footing so that it feels more comfortable.

The blade design is obtained from the analysis of the hoe moments and the centre of gravity analysis on the hoe. The total length of the hoe is 28 cm, while P1, P2, and P3 are 23 cm. The total length of the blade is 28 cm based on the depth of the roots of plants that are generally planted in paddy fields. This data shows that tillage for planting with conventional hoes is still ineffective. The width of the ergonomic blade is 18 cm, P1 = 17.5 cm, P2 = 17 cm, and P3 = 17 cm. The observation shows that the width of the slats is closely related to work capacity. The greater the width of the blades, the more capacity increases. But on the other hand, the width of the blade that is too large can complicate the process of digging because it requires more energy to swing the hoe and pull the hoe from the ground.

All hoes tested to have a slightly oval tip. The ergonomic hoe has an oval tip length of 3 cm, P1 = 1 cm, P2 = 0.8 cm, and P3 1 cm. The oval-shaped tip causes the pressure to be greater making it easier for the blade to penetrate the ground. The curvature of the ergonomic hoe blades are 10^{o}, P1 = 8^{o}, P2 = 10^{o}, and P3 = 8^{o}. The curvature design is based on the hoeing track pattern which is intended to facilitate the entry of the hoe into the ground and strengthen the attachment of the soil when the hoe is pulled. If the shape of the blade is straight, it can make it difficult to insert the slats into the ground. The shape of the connection on all hoes is a box. Shaping the connection of the blade with a square handle makes the connection strong and not easily shifted when compared to the shape of a round connection.

Ergonomics of Using Hoes

Hoeing is done by standing slightly bent, the hands are then swung up and down continuously for a long time (Figure 2). Hoeing activities for a long time can cause fatigue. To avoid this fatigue, the design of the hoe must be adjusted to the farmer's posture.

Figure 2. The process of observing research data

Based on ergonomics analysis it is known that task demands and work capacity must always be balanced so that optimal performance is achieved. Thus, the demands of the work must not be too low (under load) and must not be too excessive (overload). To avoid this, it is necessary to calculate the value of workers' energy consumption.

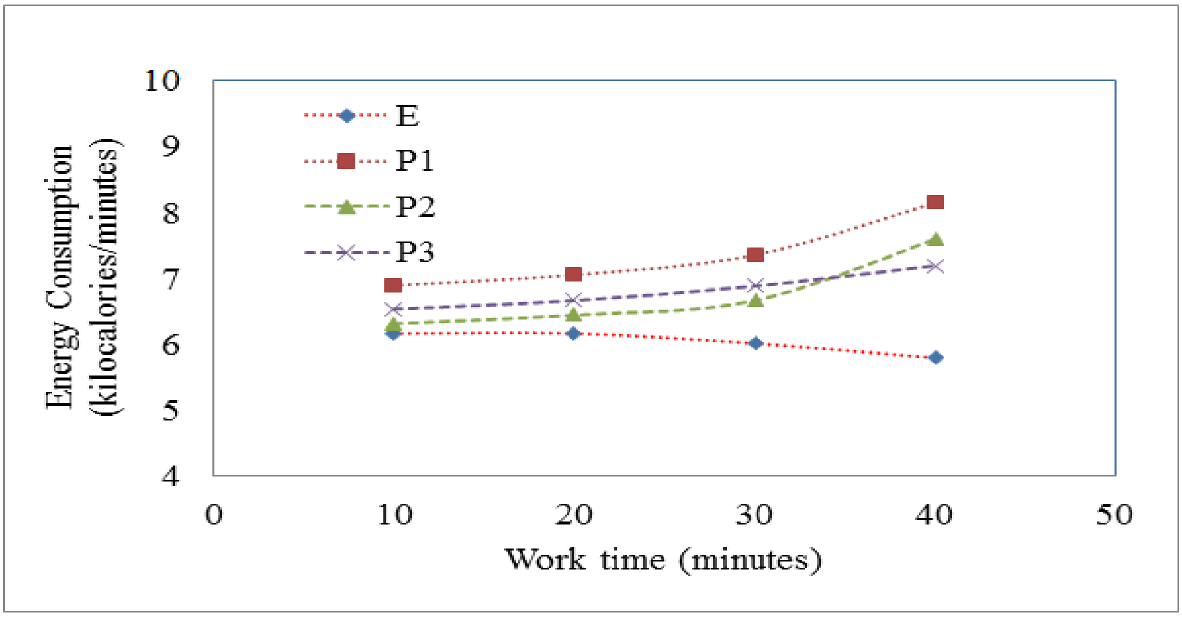
Worker energy consumption is obtained through the measurement of heart rate (Garosi et al., 2019). Heart rate is an important variable in determining energy consumption. Normally an index parameter for an increase in heart rate is used (Busyairi et al., 2014). The following data are the results of observations of farmers' heart rate after hoeing for 8 days with 4 observations (Table 2).

Table 2: Observation data of farmers' pulses after hoeing (pulse/minutes)

Hoe variation	Observation			
	1st	2nd	3rd	4th
E	108	108	114	105
P1	105	115	131	123
P2	108	95	112	119
P3	118	108	105	116

Based on equation 1, data on the value of workers' energy consumption is presented in Figure 3. The data in Figure 3 shows the different values of energy consumption depending on the type of hoe used. The biggest value of energy consumption is in comparison hoe 1 (P1) which is 8.15 kcal/minute, then comparator hoe 2 (P2) is 7.60 kcal/minute, comparator hoe 3 (P3) is 7.20 kcal/minute, and the lowest is ergonomic hoe (E) with value of 5.80 kcal/minute. This data shows that the energy consumption of using ergonomic hoes is lower than conventional hoes. This is due to differences in the shape and mass of the hoe. The same data has been reported by Syuaib (2015) that differences in the shape of a hoe can affect the process of hoeing on shear forces and the insertion of a hoe into the soil.

Figure 3. Calculation results of ground energy consumption (kilocalories/minutes)



The results of statistical data analysis using a one-way analysis of variance (F test) shows that the F-calculated value is 6.278 greater than the F-table which is 3.490 (Table 3). This data indicates that there are significant differences between ergonomic and conventional hoes on farmer's performance.

Table 3: Analysis of variants of one farmer's performance path using hoes

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.564	3	1.188	6.278	0.008	3.490
Within Groups	2.270	12	0.189			
Total	5.835	15				

The mass of the hoe is closely related to the power needed to hoe. The strength of body muscles also affect the comfort of hoeing. The use of the ergonomic hoe is not too heavy, so it can reduce the energy that must be expended by farmers. When swinging up it is not too light, making it easier for the blade to enter the ground without expending great energy.

When hoeing, the body receives a burden from the outside, it can be a physical or mental burden. The severity of the workload received by the worker can be used to determine how long a person can carry out work activities by the relevant work capabilities. The heavier the workload, the shorter one's work time to work.

Hoeing is categorised as heavy work, although improvements have been made with the use of ergonomic hoes. The same result has been stated by Bodin (2020) that farmers working using hoes are classified as heavy workloads. Therefore, to reduce the level of loading that is too heavy and the risk of shoulder pain (musculoskeletal), it requires adequate rest time. Westgaard et al. (2011) also said that adequate rest periods for workers ranged from 20-30% of optimal working hours. So, it takes a break of about 12-18 minutes for every hour of work.

Conclusion

The lowest energy consumption of workers is obtained from the use of ergonomic hoe because it has been adjusted to the worker's posture. Complaints about the use of hoes occur in all types of hoes because the hoeing movements are done in a standing position while bending with the movement of the hand swinging continuously for a long time. Increased productivity of hoeing using ergonomic hoes reached 51.9% compared to other types of hoes which are widely circulating in the market today. The results of this study are very important information for the hoe making industry.

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Conflict of Interest

All authors declare that there was no conflict interest between authors and the founder.

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