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*Research Article*

# Ergonomic Evaluation of the Manual Long Handle Hoes Used in Farm Work in Sandy Soil in Sri Lanka

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**ABSTRACT**

Integrating ergonomics into the manual long handle hoe design will minimize work-related musculoskeletal disorders while improving farm workers' health and safety, consequently improving the performance. To what extent ergonomic design aspects have been incorporated into the existing manual hoe types used by farmworkers in Sri Lanka for different purposes for different soil conditions are unknown. This study used farmworkers as subjects to investigate the ergonomics of five different existing hoe types under sandy soil conditions at Ampara district in Sri Lanka. It was found that the hoe type B, which has a longer handle (123 cm), smaller blade size (width-21.4 cm and length- 16.3 cm), less weight (1.8 kg) and blade to handle angle of 70°, is the most suitable among all the hoe types tested for hoeing operations in sandy soil. The study also found that farmworkers can discriminate between hoe types based on their suitability for the task. The study suggests that further research works are needed to evaluate the existing hoe types to use in different soils for different purposes that will help to improve the hoe type and farm workers' health and performance.



## Introduction

Agriculture is an important industry to feed the world, and it encompasses extremely diversified farming operations across the globe and global communities. According to the Department of Census and Statistics Sri Lanka, the workforce employed in agriculture in 2020 in Sri Lanka was 24.7% (DCS Sri Lanka, 2020). To sustain agriculture, meet the increasing demand for food, and ensure food security, it is of utmost importance to maintain the workforce's health, comfort, and safety in farming operations, mainly in food crop production and animal husbandry.

Due to the nature of farm work, farmworkers are at a higher level of risk of getting work-related Musculoskeletal Disorders (MSDs) (Walker-Bone, 2002; Rosecrance et al., 2006). This can cause severe long-term negative impacts leading to reduced physical work capacity of farmer workers, lower farm income and poor quality of life. Thus, the extreme work conditions negatively influence farmworkers' health and safety. Hence, the MSDs could negatively affect labour productivity (Kalkis, 2015), ultimately affecting farming activities, which can result in low production or a high cost of production (McPhee, 2005); in whatever case, the impact on food security would be unavoidable (Baksh et al., 2015).

Machinery and tools used in farming operations vary from automated to manual, from industrially developed countries to underdeveloped countries. On the other hand, farmworkers' manual farm tools range from advanced design, which integrates human-centered design concepts, to traditional tools across the globe. Thousands of manual tools used in farming around the world can cause musculoskeletal disorders (MSD) and

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injuries at workplaces due to their physical characteristics and design. Several research studies on farm tools indicated that farm tools lack ergonomics in their design and can affect the performance of farmworkers (Vanderwal et al., 2011; Khidiya and Bhardwaj, 2012; Patel et al., 2012; Parvez and Shahriar, 2018).

(Parvez and Shahriar, 2018), conducted a study on agricultural farm-related injuries and found that hand tools contribute 67% of total farm injuries in Bangladesh. The most significant injuries were cuts on the limbs, blisters on palm skin because of high stress in hand, tool slippage from hand, etc. According to (Vanderwal et al., 2011), farmworkers reported neck and shoulder discomfort, arm and hand discomfort, lower back discomfort, and hip and leg discomfort at 44%, 40%, 51% and 43%, respectively, after using the hand hoe for land preparation task in their experiment.

The manual long handle hoe, a widely used farm tool, is used for various farm tasks, including seedbed preparation, ridge creation, bund trimming, irrigation and drainage (Nag and Pradhan, 1992). It is also used to cut turf, remove plant roots, and harvest root crops. Integrating ergonomics into manual farm hand tool design will minimize work-related musculoskeletal disorders caused by them, improve workers' health and safety, and consequently improve farmworkers' performance. (Simcox et al., 1995), stated that ergonomic strain associated with agricultural work could be minimized or entirely prevented by redesigning the farm equipment and labour practices. According to Parvez and Shahriar, 2018, some new farm equipment and tools without ergonomic considerations and design are being introduced to the market. Our preliminary observations found that hoe blades available in the market are either manufactured locally or imported.

Handles made out of local woods are mainly fixed to blades purchased from the local markets by smithery workers in most of the cases. They adjust the blade to handle angle by following their traditional knowledge of designs and materials with no ergonomic concepts. The same hoe types are used for different purposes under different soil conditions. However, to prevent human-tool conflicts, a farm tool designer must consider the human-tool relationship concerning the purpose of use.

Concerning manual long handle hoe design, hoe weight, handle form and dimensions, handle length, handle material, handle to blade angle, blade dimensions are the main elements to consider in addition to user perceptions and the tasks performed. To what extent ergonomic design aspects have been incorporated into the existing manual hoe types used by farmworkers in Sri Lanka for different purposes under different soil conditions are unknown since no research studies have been conducted so far. Further, the studies conducted on a manual hoe, for example, by (Nag and Pradhan, 1992) and (Vanderwal et al., 2011) have not considered soil conditions while tested. Hence, the present study was carried out to assess the ergonomics of long-handle manual hoe types presently used by farm workers in Sri Lanka under sandy soil conditions.

## Materials and Methods

### *Study overview*

The study was conducted using farmworkers as subjects to investigate the ergonomics of five existing hoe types under sandy soil conditions. Ampara district was selected for the study since it is one of the leading agricultural/paddy cultivation districts in Sri Lanka. After performing the given tasks separately in sandy soil, a structured questionnaire was used to solicit the farm workers' responses. Finally, the farm workers ranked all the five hoe types.

### *Description of different hoe types used in the study*

The hoe types, which were extensively used for farm works, were selected from different villages in Ampara district. They were marked as A, B, C, D and E (

Fig). The dimensions, i.e. handle length, handle diameter, blade length, blade width, blade thickness, and blade to handle angle for each hoe type were taken using a measuring tape and a Vernier caliper (Table 1). The hoe weight of each kind was obtained using a weighing balance.

Figure 1. Hoe types used in the experiment

**Table 1.** Dimensions of different hoe types selected for the experiment

| Hoe type | Handle | | | Blade | | | Weight (kg) | Blade- handle angle (˚ degrees) |
|---|---|---|---|---|---|---|---|---|
| | Length (cm) | Diameter | | Thickness (cm) | Width (cm) | Length (cm) | | |
| | | Top-end (cm) | Bottom end (cm) | | | | | |
| ***A*** | 115.0 | 3.0 | 3.8 | 0.2 | 21.5 | 19.0 | 2.3 | 67 |
| ***B*** | 123.0 | 3.1 | 4.2 | 0.2 | 21.4 | 16.3 | 1.8 | 70 |
| ***C*** | 118.0 | 3.8 | 4.4 | 0.3 | 22.0 | 21.0 | 2.5 | 65 |
| ***D*** | 115.5 | 2.5 | 4.1 | 0.3 | 22.0 | 22.0 | 2.8 | 63 |
| ***E*** | 116.0 | 3. 1 | 4.4 | 0.2 | 21.5 | 19.0 | 1.6 | 67 |

*Farmworkers participated in the study.*

For this study, ten farmworkers were selected from Oluvil village in Ampara district, and their characteristics, i.e. gender, age, body weight, height and working experience, are given in **Error! Reference source not found.**.

**Table 2. Farm workers' physical characteristics**

| Characteristics | Min. | Max. | Mean | SD |
|---|---|---|---|---|
| ***Age (year)*** | 29 | 57 | 40.6 | 6.9 |
| ***Weight (kg)*** | 58 | 92 | 71.1 | 9.7 |
| ***Height (inch)*** | 60 | 70 | 65.5 | 2.5 |
| ***Experience (year)*** | 5 | 35 | 17 | 10.8 |

*Questionnaire*

A rating questionnaire with section A comprising questions on name, address, age, weight, height and experience and with section B comprising questions to rate each hoe type, i.e. is the hoe comfortable in use, is handle grip comfortable in use and is the hoe easy to use was used.

*Experimental procedure for evaluating hoe types*

The experimental procedure was explained to each farmworker in detail, and consent to participate voluntarily in the experiment was obtained. Plot with a size of 1m x 2m was demarcated in sandy soil. A land area was selected and plotted to have surface vegetation and soil conditions in each plot. Each farmworker was asked to do surface cleaning of one plot by a hoe type. As such, each farmworker cleaned five plots using all five hoe types. Before land clearing, the hoe types and the plots were randomized for each farmworker. After completing the clearing of each plot, the farmworker was asked to fill out the questionnaire, and it was continued until each farmworker completed land clearing using all five hoe types. The procedure was completed in a day. The subjects were allowed to participate in the experiment according to their convenience from 8.00 am to 5.00 pm on that particular day. All ten subjects participated in the investigation. After completing the clearing of five plots, each farmworker was asked to carry out a ranking of five hoe types from one to five where the "number one" represented the most comfortable hoe type and the "number five" represented the least comfortable hoe type for sandy soil surface clearing work (Fig).

**Figure 2.** Evaluation of hoe in sandy soil for land clearing

*Data analysis*

Data analysis was performed using IBM SPSS 25, a statistical software, and Excel 2013. Descriptive analysis was conducted for the general characteristics of the subjects and the features of hoe types. One-way ANOVA was performed to determine the significant differences between the mean effects of hoe types while used in sandy soil. Further, Tukey's HSD test was performed for the data set to find out which hoe type's means were different compared with each other.

## Results and Discussion

The blade size of the hoe types available in the Sri Lankan market, in general, is 22.86cm x 22.86cm as per the manufacturer's specifications. This type is typically known as a 9"x9" hoe. However, according to **Error! Reference source not found.**, all hoe types used in the experiment was smaller than the specifications because of the wearing out of hoes since we used the existing types. The same reason can be attributed to variation in blade thickness also. In the present study, for the hoe types tested, blade length varies from 16.3cm to 22cm, and blade width varies from 21.4cm to 22cm. The previous studies indicate that the long handle hoe with different blade sizes was tested for various purposes. For example, Vanderwal et al. (2011) evaluated long handle hoe with the blade length and width of 20cm

and 10cm, respectively, for land preparation tasks. (Tiwari et al., 2021), tested a long handle hoe for weeding; the blade length and width were 12.5 cm and 15 cm, respectively. (Sen and Sahu, 1996) in their study reported the blade length and width as 27.2cm and 17cm for conventional hoe, which was tested for digging. None of the studies considered the blade thickness in the ergonomic evaluation.

**Table 3.** Descriptive analysis on characteristics of hoe types used

| Parameter | Min. | Max. | Mean | SD |
|---|---|---|---|---|
| ***Handle length (cm)*** | 115 | 123 | 117.5 | 3.2 |
| ***Handle diameter top end (cm)*** | 2.5 | 3.8 | 3.1 | 0.4 |
| ***Handle diameter bottom end (cm)*** | 3.85 | 4.40 | 4.19 | 0.2 |
| ***Blade thickness (mm)*** | 2 | 3 | 2.4 | 0.5 |
| ***Blade width (cm)*** | 21.4 | 22 | 21.68 | 0.29 |
| ***Blade length (cm)*** | 16.3 | 22 | 19.46 | 2.19 |
| ***Weight (kg)*** | 1.67 | 2.8 | 2.214 | 0.47 |
| ***Blade – handle angle ( °)*** | 63 | 70 | 66 | 2.60 |

According to (Sen and Sahu, 1996), a hoe with a larger blade is less effective. With regard to blade size effects on shovel design, (Freivalds and Kim, 1990), concluded that a larger blade may increase energy expenditure beyond acceptable levels and, if a blade is too small, may reduce the efficiency of the shoveling. Further, they recommended that a shovel with a blade/weight ratio of approximately 0.0676 $m^2$/kg is suitable for the most efficient shoveling for sandy soil. However, the authors could not find similar recommendations for hoeing tasks in previous studies. During the present study, most of the subjects were of the opinion that a hoe should be less heavy for easy use. It is important to note that length, width, thickness, weight and shape with regard to the hoe blade are important for efficient hoeing operation. Hence, further studies are needed on hoe blade size for a different purpose in different soil. In addition, wearing of hoe while in use may be taken into account.

As per **Error! Reference source not found.** and **Error! Reference source not found.**, the hoe handles are different in diameter, and also, the handle diameter varies from bottom-end to top-end with a tapering towards top-end. In the bottom-end, the handle is fixed to the blade by tightly inserting the handle into the blade head where no nails or any other assembling materials are used. To enable the proper gripping while in use, the handle is tapered, which blacksmith workshop operators determine based on their experience since there are no recommended dimensions locally available for hoe handles. According to **Error! Reference source not found.**, handle length varies from 115cm to 123cm for all the five hoe types used in the study. The handle diameter at top-ends varies from 2.5cm to 3.8cm and at bottom-ends from 3.85cm to 4.4cm, and the handle material was wood.

According to previous studies (Kumar et al., 2008), important tool design factors are improper handle diameter and handle length, inappropriate material and texture of handle, improper clearance for hand in handles, which affect the performance of the persons and cause injuries. (Vanderwal et al., 2011), found that the new long handle hoe significantly reduced the reporting discomfort in all body regions, as well as injury near misses compared to the use of the new short handle hoe. Further, they found that the new long handle hoe enabled subjects to work with an upright posture. Several studies (Nag and Pradhan, 1992; Vanderwal et al., 2011) recommended long handle for hoeing operations.

The length of the model long handle hoe used by (Vanderwal et al., 2011) was 145cm, while the handle length recommended by (Nag and Pradhan, 1992) was 70 cm to 75cm. To an open question paused to farmworkers for suggestions to improve, a few farm workers suggested increasing handle length for hoe type A, C, D and E except for hoe type B, which is found with the handle length of 123cm. The study shows that experienced farmworkers can report the suitable hoe handle length for a particular task. From the observations of researchers and subjects' suggestions, it is understood that for land clearing work in the sandy soil, handle length needs to be longer enough since subjects move hoe away from the working point for clearing around them without bending and maintaining an upright posture. Furthermore, when briefly pause work, they rest the palm on the top-end of the handle while standing. Hence, the long handle hoe with sufficient handle length is required to maintain upright posture (Vanderwal et al., 2011) and also reduce work related injuries (Kumar et al., 2008) while facilitating work and short breaks.

Mean effects of hoe types on comfortable use, grip comfort and easiness to use were significantly different at $P<0.001$ in sandy soil hoeing work (Table 4) where P values were below 0.000 for all three afore mentioned

factors rated. Further, multiple comparisons using Tukey's HSD test resulted in several significant differences between hoe types for comfortable in use, grip comfortable and easy to use. The subjective evaluation is not well received due to the subjectivity in its nature (Kamat et al., 2010). However, user comfort of hand hoe is considered necessary in the design process since several research studies evaluated comfort subjectively to determine ergonomics of hoeing operation (Chang et al, 1999; Vanderwal et al., 2011: Norhidayah et al, 2015). The exciting finding of this study is that the farmworkers could discriminate between hoe types through user evaluation. According to (Kuijt-Evers et al., 2007), comfort and discomfort of hand tools use is determined by physical interaction also, which may indicate that physical characteristics of the hoe type influence the evaluation of hoe types by farmworkers.

**Table 4.** Mean effects of hoe types on-farm workers' ratings in sandy soil hoeing work

| Factors rated by farmworkers | df | F |
|---|---|---|
| ***Comfortable in use*** | 4 | 6.732 |
| ***Grip comfortable*** | 4 | 8.993 |
| ***Easy to use*** | 4 | 6.753 |

Referring to **Error! Reference source not found.**, all of the farmworkers who participated in the study rated the hoe type B as the most comfortable one to use in sandy soil. Likewise, all farmworkers, except one, rated hoe type B as the type with the most grip comfortable (Fig) and again, hoe type B was ranked as the easiest one to use (

Fig). In contrast, poor ratings were given to hoe type D in terms of comfortable use, grip, and ease of use. The results may indicate that hoe type B is the most acceptable type for hoeing operation in sandy soil owing to its physical characteristics and design.

According to

, farm workers ranked hoe type B as the most preferred one with a mean rank of 1.6; the lower the value, the higher the rank order (higher level of preference). Hoe type D was given the lowest preference with a mean rank of 4.4. The overall results indicate that hoe type B is the most suitable one among all hoe types tested for hoeing operation in sandy soil. The physical features of hoe type B (**Error! Reference source not found.**) are longer handle length, smaller blade size, higher blade to handle angle and second-lowest weight compared to the other hoe types. The research team's personal discussion with farmworkers on features of hoe types revealed that farmworkers prefer hoe types with less weight and longer handles.

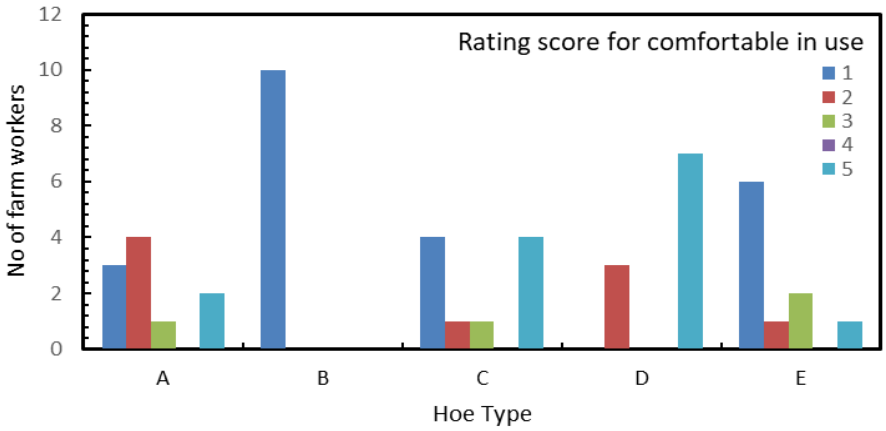


**Figure 3.** Rating score for the comfort in use

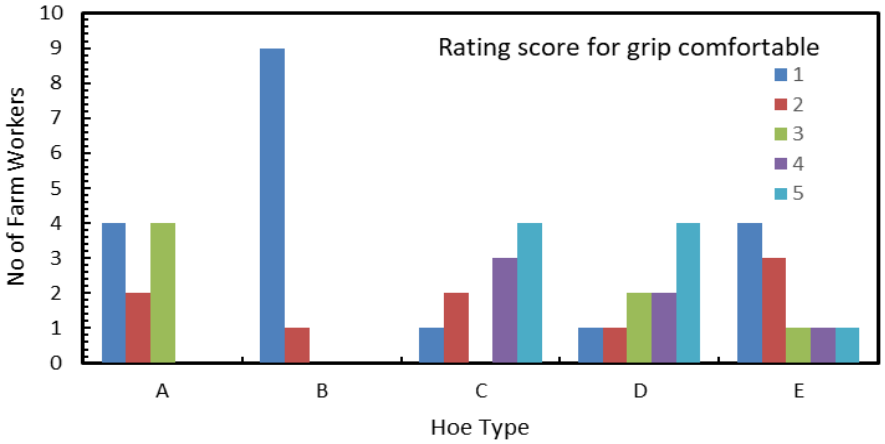

Figure 4. Rating score for grip comfortability

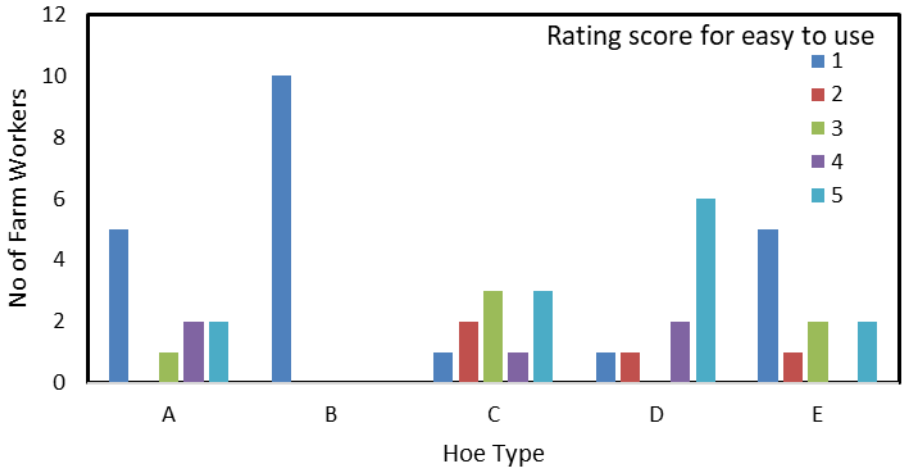


**Figure 5.** Rating score for easiness to use

**Table 5.** Mean rank order given by farmworkers for each hoe type

| Type | Sandy soil | |
|---|---|---|
| | Mean | SD |
| ***A*** | 2.4 | 1.34 |
| ***B*** | 1.6 | 0.51 |
| ***C*** | 4.0 | 0.66 |
| ***D*** | 4.4 | 1.26 |
| ***E*** | 2.6 | 0.96 |

The findings are in agreement with Vanderwal *et al*., 2011 who concluded that the long handle hoe is more comfortable. In another study, Norhidayah *et al*, 2015, stated that hoe handle needs to be long enough to maintain an upright and comfortable posture. However, in both the studies mentioned, the soil in which the hoes were used was not considered. In the case of sandy soil, since the work is the land clearing, farmworkers prefer "blade to handle angle" to be more open, the hoe type B is found with a blade to handle angle of 70°, which is higher than the other hoe types tested. However, the authors could not find literature on the preferred blade to handle angle for hoe type for different purposes and soil.

## Conclusion

The present study found that the physical characteristics of hoe types used by farmworkers vary regardless of the purpose of use since there are no recommendations available locally for manufacturing. The study found that the hoe type with longer handle (123cm), smaller blade size (width-21.4cm and length-16.3cm), less weight (1.8kg) and the blade to handle angle of 70° are preferred by farmworkers for use in sandy soil. The interesting findings of the study are that farmworkers can discriminate between hoe types based on their suitability for the task. The study suggests that further studies are needed to evaluate the existing hoe types to use in different soils for different purposes that will help improvement and redesign.

## Authors' contribution

Mohamed Gazzaly Mohamed Thariq developed the concept, designed the study and contributed to writing and evaluating the manuscript critically for important intellectual content. Koongodage Sayuri Ravi Hansika performed the field study, data collection and analysis. Abdul Munaf Mohamed Irfeey evaluated the result and contributed to the writing results and discussion section. All authors read the article and approved the final version to be published.

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## Competing interests

The authors have declared that no competing interests exist.

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