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Improvement of traditional dibbler with ergonomics consideration used in *Jhum* cultivation in Nagaland

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ABSTRACT

A study was conducted to improve the traditional dibbler used for sowing seeds in *Jhum* cultivation in Nagaland considering ergonomics. The improved multi-peg hand dibbler was developed and tested in the experimental field of School of Engineering and Technology, Nagaland University, Dimapur. The traditional tool was improved by a detachable supporting plate, anti-skid spongy handle grip, and high carbon steel for pegs. For ergonomic evaluation, the heart rate of the subjects during dibbling were measured. The average working heart rate of the subjects with traditional and improved multi-peg hand dibbler were found to be 116.8 and 123.0 bpm, respectively. The effective field capacity (0.021ha/hr) and mean working speed (0.123km/hr) of improved dibbler was higher than the traditional tool with field capacity and working speed of 0.001ha/hr and 0.076 km/hr, respectively. Moreover, the field efficiency of the improved dibbler was considerably high (75%). Though, the energy expenditure during work with improved tool is slightly higher (10.84 kJ/min), the newly developed tool has higher field efficiency with more speed of operation, and the energy expenditure is within the limit of the workers, hence the improved tool is suitable for working in hill topography.

1. Introduction

Nagaland is one of the mountainous states in northeast India bordering with Assam, Arunachal Pradesh, Manipur, and Myanmar. The state is predominantly an agrarian state as 70 percent of the total population is dependent on agriculture. The topography of the state is hilly terrain with a total geographical area of 16,579 sq. km. (Anonymous, 2011). Farmers of Zunheboto, Wokha, Mokokchung, Tuensang and Mon district of Nagaland predominately practice *Jhum* or shifting cultivation, in which hill slopes are cleared by slashing and burning the forests using primitive techniques for a limited number of years. In shifting cultivation, after cultivation for one season, the land is left to fallow for 10 -15 years and the farmers

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move to the next location to repeat the same process till they return to the starting point. However, to meet out the demand of food grain in most areas, the *Jhum* cycle is now reducing to 2-3 years instead of 20-25 years (Sati and Rinawma, 2014). The shifting cultivation system is associated with severe environmental issues like frequent deforestation, ecological imbalance, soil erosion and emission of greenhouse gases etc. However, alder based shifting cultivation, traditional know-how, is practiced by the Angami, Chakhasang, Chang, Yimchaunger, and Konyak tribes of Nagaland to retain soil fertility and minimize soil erosion, deforestation, and declination in forest productivity in Nagaland (Rathore *et.al.,* 2010). Though the shifting cultivation is often viewed as one of the serious environmental concern, farmers living in this region are bound to practice *Jhum*, as no worthwhile alternatives are available for their livelihood. Moreover, they persist in practicing shifting cultivation as a part of their culture and traditions (Pandey *et.al.* 2020). Despite the *Jhum* has been a common technique of hill agriculture, there is no complete set of the equipment described in the literature. Today also, traditional hand tools and equipment are the only farm implements and human power is the only source of farm power in Nagaland for shifting cultivation. The geographical conditions like steep slope, small terrace, undulating terrain, etc. restrict the use of modern agricultural tools and equipment (Singh *et.al.* 2015).

Though indigenous tools are generally un-preferred for their lower working efficiency and increase tiredness of the operator (Karthikeyan *et. al.* 2009), farmers of Nagaland are entirely dependent on traditional hand tools and equipment for *Jhum* cultivation due to non-availability of improved tools suitable for the hill ecosystem. There was the report of using pointed stone tools to open up land for sowing seeds, removing weeds and harvesting crops in twelve thousand years ago (Das and Nag 2006). In shifting cultivation, holes are made in the well-prepared sloppy field using wooden or bamboo sticks at desired depth and spacing (Figure 1.), where paddy seeds are placed by hand and then covered with loose topsoil. This technique of making holes and placing seeds thereon is called dibbling and

(a) Traditional dibbler *(Xu-ja)* of Nagaland

(b) Traditional dibbler *(Matha)* of Meghalaya

Figure 1 (a) & (b) The traditional dibblers

the tool used for making the holes is called dibbler. In Garo hills of Meghalaya, for sowing seed holes are made by using traditional dibbler *(matha)* with a pointed metal attached at the tip for dibbling purpose (Das and Singh, 2017). The making hole with existing traditional dibbler to place the seed is time and labour consuming, tedious, and painstaking. Moreover, maintaining the uniform depth of the holes at a regular spacing is not possible with the traditional dibbler, which depends upon the experience and skill of the farmers. The working efficiency of traditional dibbler is very low and maintaining uniform seed to seed distance and depth of sowing is not possible, which affects the productivity of the crop. However, the limitations of traditional dibblers can be reduced by improving the existing dibbler with ergonomic and agronomic considerations. Though some tools like *Naveen* dibbler and Rotary dibblers were developed by the Central Institute of Agricultural Engineering, ICAR, Bhopal, these dibblers are not suitable in the hill ecosystem of the state. Therefore, there is the need of improving the exiting dibbler by taking care of ergonomics and field efficiency of the tool, so that it can be used in the hill ecosystem for a long time at a stretch with less drudgery.

Keeping in view the importance of the above facts and understanding the necessity of developing a dibbler suitable for hill ecosystem, a research was conducted (i) to improve the traditional dibbler and evaluate its performance, and (ii) to assess energy expenditure under actual field conditions.

2. Materials and methods

The research was conducted at Dimapur district of Nagaland under the School of Engineering and Technology, Nagaland University, Nagaland, India (25°54'45"N latitude, 93°44'30"E longitude and 135 to 130 m altitude). A visual survey was conducted to study the prevailing traditional dibbler used for making a hole for sowing paddy seeds in *Jhum* cultivation by the farmers to get the idea and design of improving multi-peg hand dibbler suitable for working in hill ecosystem. By considering ergonomics and agronomic deliberations, the existing dibbler was improved by modifying and supplementing a few components to the original tool. Details of the methodology of fabrication and evaluations of the improved tool are given below.

Fabrication of the improved multi-peg hand dibbler

The improved dibbler comprised of a handle, handle grip, hub, base plate, and pegs. The technical specifications of different components of the improved tool are discussed as under.

Handle/main body

The handle was light in weight and made of commonly available wood. The light weight material made the tool gender-friendly and developed less fatigue. The handle of the tool was modified by giving a round shape and polished to avoid any scratch in hand during the operation. In case of damage of handle, it may be replaced by the operator easily.

Handle grip and height

A grip of anti-skid and soft spongy material was used on the handle so that the farmer can use the tool for a long time with less slip on the grasp. For the improvement of the traditional tool, specific anthropometric data to suit their grip dimension and height were considered. Since the specific anthropometry of the people of Nagaland is not studied, anthropometry of male agricultural workers of north-eastern India was used for the tool. In view of that, the handle grip (3.7 cm) and height (100 cm) were finalized (Dewangan *et. al.* 2010).

Hub

A hub was incorporated in the modified tool to insert the handle and fasten by bolt and nut (Figure 2). The outer diameter of the hub was taken as 3.8 cm and it was mounted on the top of the base plate of the modified tool. The low-cost mild steel pipe was selected to fabricate the hub.

Base plate and peg fixing plate

The traditional dibbler was modified in such a way that it can be used for making six holes at desired spacing and depth for sowing different crops like paddy, maize, millet, soybean, etc. The base plate was fixed at the bottom end of the hub (Figure 2). There was a provision to fasten detachable plates to the base plate, where pegs were fabricated. To sow different seeds at desired spacing, the existing plate needs to be replaced by a predetermined plate with anticipated number of pegs. The length of the peg was taken as 5 cm for medium size seed like paddy, maize, millet, soybean, etc. as used for Feba bean (Ali and Idris 2015). Moreover, *Jhumias* prefer to place the seed in the depth of 5 to 6 cm, as the chances of sliding down of seeds during heavy rainfall are reduced greatly in contrast to shallow or surface sowing.

Weight

It was observed that the average weight of the hand hoe with a long handle used by the farmers in Dimapur district of Nagaland ranged from 1.7 to 2.1 kg. Therefore, the overall weight of the improved multi-peg hand dibbler was taken as 1.9 kg (average weight) for easy manoeuvring by both the genders.

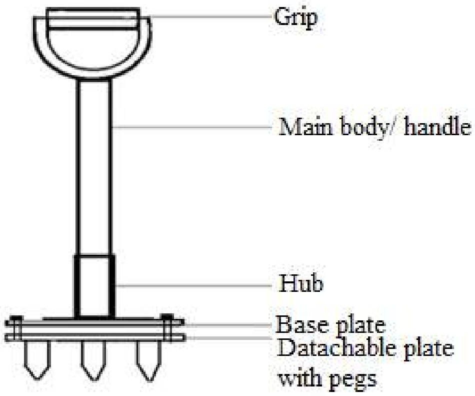

Figure 2. Evolved diagram of the improved multi-peg hand dibbler

Performance evaluation of the improved tool

Ergonomic evaluation

Physiological stress on the worker during the dibbling operation was assessed by using a heart rate monitor set (Polar M400, China) (Kishtwaria *et. al.* 2004) and observed resting and working heart rates of the worker. Here, the resting heart rate is the heart rate of the worker measured before the start of work in the working environment at mental and physical relaxed mode. The working heart rate is defined as the average heart rate of the subjects measured during the work schedule in the working environment for a particular work.

The ergonomic studies were conducted in three pleasant days, *viz.*, 4th April, 23rd April, and 18th May 2019 at 9.00 am for which six farm workers who were free from heart disease, neurological disorder, and physical ailment were selected as subject. For field performance evaluation of the tool, subjects from the age group of 25 to 35 years were chosen as suggested by previous workers (Gradjean P *et.al.* 1982).

The recording of heart rate data was done in three replications. The heart rate monitor was fixed in the chest of the worker firmly and the receiver was fixed in his left wrist so that the transmitted data may be recorded (Figure 3 and Figure 4).

After fixing the heart rate monitor in the body, the monitor was started to record the heart rate of the workers before the start of work up to 5 minutes. The initial 5 minutes heart rate data of the subjects were averaged and taken as initial resting heart rate. Then, the heart rate response of the subjects were measured for 30 minutes during the work. A bag with paddy seeds was carried by the worker in his left-hand shoulder from where the seeds were collected and placed in the engraved hole by the improved dibbler. Thereafter, the subjects were asked to take rest for 5 minutes to evaluate the recovery heart rate. Finally, the data were downloaded from the receiver, and average working speed, actual and theoretical field capacity, field efficiency, and energy expenditure during operation of the tool were calculated.

Figure 3. Heart rate monitor set and appropriate fitting in body

Figure 4. Working with multi- peg hand dibbler

Field performance evaluation

For performance evaluation of the improved multi-peg hand dibbler, test plots of both plain and undulating topography were selected at the fallow land of School of Engineering and Technology, Nagaland University. The soil of the selected field was sandy loam with bulk density and moisture content of 17.8 g cm^{-3} and 17.8 percent, respectively at the time of field testing. The plots were prepared by power tiller for attaining good tilth. Locally available popular paddy variety "*Heera*" was used for the field test.

With the help of the heart rate of the subject during dibbling operation, the energy expenditure rate (EER) was calculated for both traditional and improved dibbler by using the equation as shown below following previous researcher (Varghese M A *et.al.* 1994).

EER (kJ/min) = 0.159 x HR (bpm) – 8.72

The speed of operation, field capacity, and field efficiency of the newly developed and traditional tools were calculated using formulae explained below.

Speed of operation: It is the measure of the distance covered by the dibbler in per unit time during dibbling operation, which can be expressed as:

$$S = \frac{D}{T}$$

Where, S = Speed of operation (km/h)

D= Distance covered (km)

T= Time taken (h)

Theoretical field capacity (ha/hr): It is the rate of field coverage by the dibbler based on 100 percent time at the rated speed and width of the dibbler. The theoretical field capacity was assessed by the following relationship.

$$\text{Theoretical field capacity (ha/hr)} = \frac{W \times S}{10}$$

Where, W = Theoretical width of the dibbler (m)

S = Speed of dibbling operation (km/h)

Theoretical field capacity was used to compute the field efficiency of the tool.

Effective field capacity (ha/hr): It is the actual area covered by the dibbler with reference to time, which can be expressed by the following relation.

$$\text{Effective field capacity (ha/hr)} = \frac{\text{Total area covered (ha)}}{\text{Total time taken (h)}}$$

Field efficiency (%): The field efficiency is the ratio of the effective field capacity to the theoretical field capacity and expressed by the following relation.

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

3. Results and discussion

Fabrication of multi-peg hand dibbler

Grip diameter, holding height, and weight of the improved multi-peg hand dibbler was decided and fabricated following ergonomics consideration (Table 1). To obtain a cushioning effect and to reduce irritation on the palm, the handle was fitted with an anti-slippery spongy material so that duration of work with the tool can be increased. The inclusion of ergonomics for fixing height and weight made the tool more efficient.

The exploded and complete view of the improved multi-peg hand dibbler is shown in Figure 5 (a) and b) and details of technical specifications are presented in Table 2. The tool comprised of six pegs in the bottom of the plate; hereby, six seeds can be sown at a time by the improved tool against one seed by the traditional tool.

Table 1. Ergonomics incorporated in design of improved multi-peg hand dibbler

Sl. No.	Specification	Dimension	Ergonomics consideration
1.	Grip diameter (cm)	3.7	The handle should grasp such that finger and thumb flex around the handle.
2.	Handle holding height (cm)	100	To facilitate the operator stand erect as far as possible to reduce musculoskeletal discomfort during operation.
3.	Weight of the tool (kg)	1.9	Conformed to the average weight of the medium spade used in Dimapur district of Nagaland

(a) (b)

Figure 5. (a) Exploded view (b) complete view of the improved multi-peg hand dibbler

Table 2. Technical specification of the improved multi-peg hand dibbler

Sl. No.	Particulars of item	Dimension
1.	**Handle grip**	
	Diameter(cm)	4.7
	Length(cm)	10.08
2.	**Main body handle**	
	Diameter(cm)	3.7
3.	**Hub**	
	Diameter(cm)	4.15
	Length(cm)	23
4.	**Base plate**	
	Length(cm)	23
	Breadth(cm)	22
5.	**Thickness of the plate(cm)**	0.25
6.	**Diameter of peg**	
	Bottom(cm)	1.6
	Tip(cm)	0.3
7.	**Length of peg**	5.0
8.	**Overall height(cm)**	96.0

The tool was developed to be operated at standing and frontward tilting posture in the undulating field, hence, the weight of the tool was kept low so that it is possible to operate for a long time. The overall weight and height of the tool were 1.9 kg and 100 cm, respectively as mentioned above.

Commonly available agricultural hand tools were not standardized regarding their size, handle dimension, the material of construction, comfortability, etc. Therefore, some novelties were added with the improved multi-peg hand dibbler. One detachable peg supporting plate was incorporated with the base plate. Plant to plant spacing of crops depends on the type of cultivars. The desired spacing can be obtained by replacing the existing detachable plate with another plate. The multi-peg hand dibbler had to come across with root or stone while operating which resulted in damage and bluntness of pegs. To eradicate this situation high carbon steel was used for making pegs.

4. Evaluation of the improved tool

Ergonomic evaluation

A perusal of data on heart rate response recorded during the work of the subjects (Table 3.) showed that the resting heart rate among the subject varied from 75.1 to 78.9 beats per minutes (bpm) with the mean value 76.6±1.3 bpm. The heart rate during work found more as compared to resting heart rate; while the increase was more in case of the improved tool with the mean value of 123.0±1.9 bpm as compared to traditional tool with the mean value of 116.8±1.17 bpm. The recovery heart rate in the case of traditional dibbler varied from 79.4 to 83.1 bpm with a mean of 81.7±1.3, while it was slightly higher in case of improved tool which varied from 80.4 to 83.3 bpm with the mean value of 82.1±1.0 bpm. The energy expenditure during work with traditional and improved hand dibbler varied from 9.63 to 10.12 kJ/min and 10.53 to 11.20 kJ/min, respectively. Thus, there was a 10 percent increased in energy expenditure with the improved tool as compared to the traditional tool, however, it was within the capacity of the user.

Table 3. Heart rate response of the subjects before work, during work and recovery, and energy expenditure during work

Subject No.	Resting heart rate (bpm)	Working heart rate (bpm)		Recovery heart rate (bpm)		Energy expenditure during work (kJ/min)	
		TD*	ID	TD	ID	TD	ID
S_1	76.0	115.4	125.3	81.9	82.3	9.63	11.20
S_2	75.1	117.3	121.3	82.2	81.9	9.93	10.57
S_3	77.2	115.6	124.7	80.9	81.8	9.66	11.11
S_4	76.6	117.3	121.1	82.4	83.3	9.93	10.53
S_5	78.9	116.8	124.3	79.4	80.4	9.85	11.04
S_6	75.7	118.5	121.4	83.1	82.9	10.12	10.58
Mean	76.6	116.8	123.0	81.7	82.1	9.85	10.84
SD	1.3	1.17	1.9	1.3	1.0	0.18	0.31

*TD: Traditional Dibbler, ID: Improved Dibbler

A comparatively higher working heart rate was observed in case of the improved tool than the traditional tool, which might be due to an increase in the weight of the improved tool. The working heart rate recorded was within the acceptable limit as reported by earlier workers, who reported the mean value of heart rate as 121.82±3.80 bpm during work (Borah R and Kalita M 2016). The operation with the developed tool based on heart rate can be classified as heavy (Varghese M A *et.al.* 1994), however, acceptability of the tool would depend on working efficiency, effective field capacity, and field efficiency. Slightly higher recovery heart rate after the work with improved tool implies that more than 5 minutes rest allowances to be given to regain the heart rate while using the improved tool. To some extent more energy expenditure while using the improved tool was noticed, which might be due to more weight of the improved tool as well as difficult topography of the working field. It is to be mentioned that the weight of the improved tool (1.9 kg) was at par with the commonly used hoe.

Field performance evaluation

A perusal of the data generated during the field test (Table 4) showed the difference of effective field capacity and working speed of the traditional dibbler and improved multi-peg hand dibbler as 0.001 to 0.021ha/hr, and 0.076 to 0.123km/hr, respectively. Theoretical field capacity (0.028ha/hr) and field efficiency (75%) of the improved tools were observed to be satisfactory.

Table 4. Field performance data

Particulars	TD	ID
Effective field capacity (ha/hr)	0.001	0.021
Theoretical field capacity (ha/hr)	--	0.028
Field efficiency (%)	--	75
Average working speed (km/hr)	0.076	0.123

TD: Traditional Dibbler & ID: Improved Dibbler

Despite slightly higher energy expenditure, the newly developed tool was considered to be a better tool in terms of effective field capacity, working speed, and field efficiency. The field performance of the improved multi-peg hand dibbler was at par with the performance of the hand-push manual weeder with field efficiency of 75.1 percent developed earlier researchers (Attanda *et. al.* 2013). Moreover, the field capacity of the improved tool was higher than the push type dibbler and "Naveen dibbler" (0.015ha/hr) developed by CIAE-ICAR, Bhopal.

5. Conclusion

Despite lower productivity and associated environmental issues, *Jhum* is an unavoidable traditional agro-practice and livelihood of the people of Nagaland. In *Jhuming*, sowing is a key operation, which is generally conducted with help of a traditional tool made up of wooden and metallic sticks, and working with the tool is tedious, time-consuming, and less working efficiency. Moreover, it is not possible to maintain uniform depth and spacing of sowing with the help of traditional dibbler. However, the improvement made in the traditional dibbler with the specifications and materials in such a way that the improved dibbler with six pegs happened to be more efficient in terms of drudgery, actual field capacity, field efficiency and speed of operation. The overall height, grip diameter, weight etc. of the tool was fabricated in such a way that it can be easily operated for a long period in an undulating hill ecosystem. Field performance of the newly developed dibbler in terms of speed of operation, actual field capacity and field efficiency was at par with other improved hand tools and better than the traditional dibbler generally used by the farmers. Moreover, the tool can be fabricated by a local artisan with locally available materials at a very low cost. Thus, the newly developed multi-peg hand dibbler appeared to be suitable and can be adapted in *Jhum* cultivation of the state of Nagaland.

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