Development of manually operated maize planter cum vermicompost applicator for narrow terraces of Sikkim

Thokchom Macedonia Devi*, Narvendra Singh Chauhan

(Department of Farm Machinery and Power Engineering, College Agricultural Engineering and Post-Harvest Technology, Ranipool Sikkim, India, 737135. Email: thokchommacedonia@gmail.com)

Abstract: The purpose of the study was to develop a manually operated maize planter cum vermicompost applicator for narrow terraces of Sikkim. For the timely operation with less effort and drudgery, a lightweight manually operated planter cum vermicompost applicator is required for the uneven topography and small terrace. Three commonly grown varieties of maize (i.e. *sethi makai, pahelo makai* and *rato makai*) were used. The mean values of length, width, thickness, geometric mean diameter, sphericity and roundness of three varieties maize were determined for designing the cell size of metering drum. Laboratory test was conducted to optimize the operating parameters of manually operated maize planter cum vermicompost applicator. Optimum performance of the planter was recorded with cell size of 11 mm and 25 % hopper fill level. Furthermore, the planter was operated in the field and also compared with the traditional planting. Average heart rates while operating manually operated maize planter cum vemicompost applicator and traditional planting, were recorded as 114 and 126 bpm respectively. The BPDR experienced maximum in both cases but traditional planting observed extreme pain in backbone due to continuous bending posture. The ODR was found to be higher in traditional planting ranges from 7 to 8 whereas manually operated maize planter cum vermicompost applicator ODR was found in the range of 4 to 5.

Keywords: maize planter cum vermicompost applicator, heart rate, BPDR, ODR.

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1 Introduction

Maize (Zea mays), one of the grain crops, belongs to the grass family Gramineae and produces tiny edible kernels (Aremu et al., 2015). Globally, maize is known as the "queen of cereals" due to its high genetic yield potential (Dass et al., 2012). More than 170 countries produce 1147.7 million tons of corn on 193.7 million hectares with average yield of 5.75 tons per hectare (FAOSTAT, 2020). The United States (US) is the largest corn producer, responsible for 30% of production (Anonymous, 2022a). In the years 2020–21, India produced 30 million metric tons over an area of 9.9 million hectares (Ahmad et al., 2022). Maize is the second-most important crop in North Eastern Hill Region (NEHR) of India. In Sikim, maize is one of major crops and was grown in 38390 hectares in the state (Anonymous, 2022b). In Sikkim, most field operations are traditionally performed. Traditionally, seeds are sown by broadcasting, plowing furrows with a country plow, and dropping them manually (Tiwari et al., 2016). As a result, seeds are not uniformly

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* **Corresponding author: Thokchom Macedonia Devi,** M.Tech, Department of Farm Machinery and Power Engineering, Ranipool Sikkim, 737135, India. Email: thokchommacedonia@gmail.com.

distributed, and spacing between rows and plants is not maintained. Omara et al. (2016) developed a planter with the ability to make a hole and release a single seed for maintaining homogeneity of the plant population, decrease intra-specific competition, and improve yield potential. Smithers et al. (2010) designed the jab planter for operation in no-till conditions and to plant through a layer of organic matter. The envisaged impact of the planter was to help increase productivity in small scale agriculture by reducing labor requirements. Premkumari et al. (2018) realized the importance to assess the ergonomics and physiological costs of agricultural activities for improving women's productivity. In order to accurately specify the design considerations of mechanized planting equipment, some physical properties of the seed like size, shape, axial dimension, roundness, and sphericity were required to be measured to determine the size of the cup for seed plates Hijam et al. (2015). Since Sikkim was declared as organic state and use of chemical fertilizers and pesticides were banned, there is need of develop (Das et al., 2020).

The objectives of the study are (i) To develop the manually operated maize planter cum vermicompost applicator for North Eastern Hill Region (ii) To evaluate the performance of developed planter in laboratory conditions (iii) To conduct the ergonomic evaluation of developed planter under field conditions

2 Materials and methods

2.1 Determination of physical properties of maize seeds

Three varieties of maize seed namely *ratomakai, pahenlomakai, and sethimakai* shown in Figures 1, 2 and 3 were considered for the study and 100 seeds were taken from each type of maize varieties for measuring the dimension. The length (*L*), breadth (*B*), and thickness (*T*) were measured using a vernier caliper with least count of 0.01 mm.

Figure 1 Rato makai

Figure 2 Pahenlo makai

Figure 3 Sethi makai

2.2 Determination of geometric mean diameter

Geometric mean diameter (D_g) was calculated using the equation (Mohsenin, 1986) and Gautam et al. (2016).

$$D_g = (LWT)^{\frac{1}{3}} \quad (1)$$

Where,

D_g =Geometric mean diameter, mm

L = Length of the seed, mm

W = Width of the seed, mm

T = Thickness of the seed, mm

2.3 Determination of sphericity

The criterion used to describe the shape of the seed is sphericity (Φ) which was calculated by using the equation suggested by Mohsenin (1986).

$$\phi = \frac{(LWT)^{\frac{1}{3}}}{L} \quad (2)$$

$$R_s = \frac{[\frac{W}{L} + \frac{T}{L} + \frac{T}{W}]}{3} \quad (3)$$

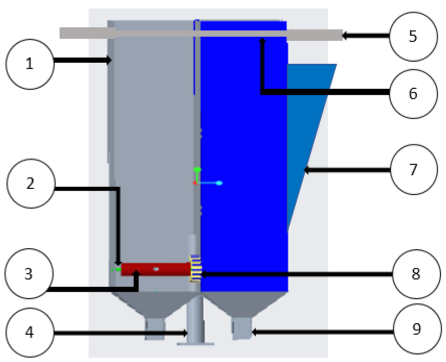
The roundness (R_s) of the seed was calculated using the equation (Gautam et al., 2016).

2.4 Anthropometric dimensions of the Sikkim workers for design of the planter

Anthropometric dimensions of Sikkim's workers have been used while developing the planter. The recorded anthropometric data of Sikkim's workers for the year of 2012-2015 were used for the study (Chauhan, 2017). The height of the handle from the ground was decided on the basis of the average standing elbow height. Based on the anthropometric consideration, the handle length should be as long as the widest part of the hand. Therefore, the 95th percentile of hand breadth across thumb was considered for the length of the handle and tool handle doesn't span the entire width of the palm, therefore high forces are created in the center of the palm (Lewis and Narayan, 1993). In order to improve grip, the handle diameter should not exceed the operator's middle finger palm grip diameter. Therefore, the 5th percentile of middle finger palm grip diameter was selected as handle diameter.

2.5 Components of the manually operated maize planter

Manually operated maize planter cum vermicompost applicator was developed for the terraces of Sikkim. The planter consists of a handle, metering drum, seed and vermicompost hopper, vermicompost drum, jaw, stand, and drum connector. The 3-D model of manually-operated planter is shown in Figure 4. When planter was pressed down, it moved into the soil. A drum connector with a metering bar rotates and the seed and vermicompost are dropped from the hopper into the soil.



1. Seed hopper
2. Metering bar Handle
3. Metering drum
4. Stand
5. Handle
6. Frame
7. vermicompost hopper
8. Drum connector
9. Jaw

Figure 4 3-D model

2.6 Metering drum

The maize seed's length, breadth, and thickness was measured to decide the cell of metering drum. The length, inner diameter and outer diameter of the metering drum were kept as 85 mm, 40 mm and 45 mm respectively. Similarly, length, diameter and opening area of vermicompost dropping drum were decided as 55 mm, 45 mm and 30 mm. Figure 5 illustrates how the seed metering drum was connected to the vermicompost dropping drum with the help of connector.

2.7 Seed and vermicompost hopper

Seed and vermicompost hoppers were made of plastic. For both seed and vermicompost hoppers, length, breadth and height were 80 mm, 92 mm and 380 mm respectively. A thin mild steel inclined box was attached to the side of the vermicompost hopper at an angle of 105°. It was designed to allow vermicompost to pass through without being disrupted.

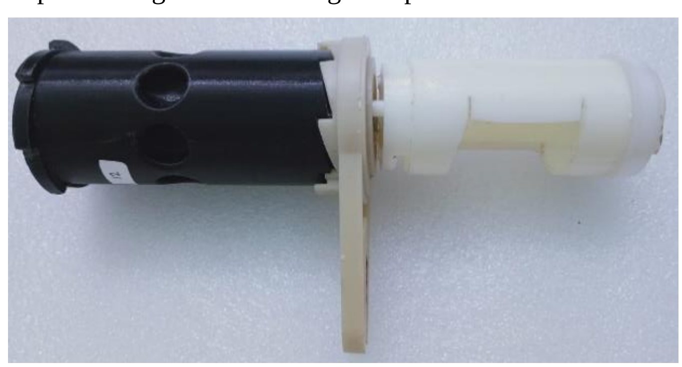


Figure 5 Drum connector

2.8 Handle

A frame with a size of 160 mm by 100 mm was attached on top of the hopper with handle length of 120 mm on both sides. It was used to hold and penetrate the jaw into the soil. The handle height and handle diameter was fixed based on the average standing elbow height and hand grip of the workers.

2.9 Jaw assembly

It is a soil-engaging part of the planter, which makes an opening for placing the seed and vermicompost is shown in Figure 6. The length of the jaw for both openings was 120 mm with a top width of 40 mm for seed and 25 mm for vermicompost. The jaws were created with two sections from stainless steel, one section was fixed to the bottom of the planter and the other section was movable against the axis provided at the top of the jaw. A wire was provided to give leverage to open the soil by jaw.

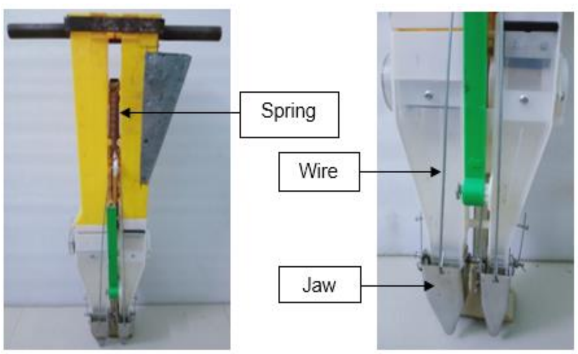


Figure 6 Jaw assembly

2.10 Stand

The stand was made of a mild steel rectangular channel (25 mm × 20 mm) with a plastic base at the bottom having dimensions of 100 mm by 70 mm shown in Figure 7. It was used to provide the power needed for operating jaw assembly and metering mechanism. A threaded bolt was attached to the top of the stand, the upper end of the spring was attached to this bolt, and the lower end was attached to the thread that holds the two hoppers together. An L-shaped lever was provided just below the lower end of the spring, and another small spring was attached to the hook of the L-shaped lever. At the bottom of the planter, the metering drum connector was mounted and connects to the stand's thread.

Figure 7 Stand

2.11 Laboratory condition

The performance evaluation of manually operated maize planter cum vermicompost applicator was conducted at Department of Farm machinery and Power Engineering, College of Agriclutural Engineering and Post-Harvest Technology, Ranipool, Gangtok, Sikkim as shown in Figure 8. The geographical location of the research is an altitude of 914.4 m above the mean sea level and lies on the geographical coordinates of 27 ° 28′ 90″ N, 88° 59′ 24″ E Latitude and Longitude point, respectively. A test plot of 5 m was prepared on the white sheet and plant to plant and row to row spacing were kept as 75 and 25 cm respectively. Experiment were planned in a Response Surface Methodology (RSM) using Design Expert Software. Vermicompost application rate was also calibrated with different hopper fill level.

Figure 8 Laboratory performance

2.12 Field performance

Field performance was conducted at farmer's field in village Syari, East District, Gangtok Sikkim as shown in Figure 9. The geographical coordinates of field area lie on 27° 32′ 18″ N latitude and 88° 61′ 94″ E longitude. The heart rate, body part discomfort rating (BPDR) and overall discomfort rating (ODR) were measured for assessing how much pain each worker experienced when using the develop planter and also compared with traditional method of maize planting. The hopper was filled with 100% maize and 25% vermicompost and performed in three different fields. The distance between rows and plants were 75 cm and 25 cm respectively. This study used a variety of subjects ranging in age from 24 to 38. A total of 12 women performed field operations using a developed planter and each person's heart rate values during work for 10 minutes and after work for 10 minutes were recorded to calculate the physiological response. On the other hand, the traditional planting was also performed using hoe, and the heart rate values during work for 10 minutes and after work for 10 minutes were recorded.

Figure 9 Field performace

Table 1 Performance evaluation of developed planter under laboratory condition

Expt. Run	Seed fill level (%)	Cell size(mm)	Discharge rate (kg h^{-1})	Missing index (%)	Multiple index(%)	Mechanical damage(%)
1	25	13	0.42	0	55	0
2	25	13	0.47	0	80	0
3	100	13	0.46	0	65	0
4	100	13	0.44	0	75	0
5	25	13	0.51	0	85	0
6	100	13	0.42	0	75	0
7	100	13	0.50	0	85	0
8	100	12	0.42	10	50	0
9	25	12	0.46	0	65	0
10	25	12	0.46	0	60	0
11	100	12	0.41	10	55	0
12	50	12	0.41	0	55	0
13	50	12	0.46	10	60	0
14	75	11	0.24	10	15	0
15	50	11	0.32	15	20	0
16	100	11	0.21	10	10	0
17	25	11	0.25	20	15	0
18	75	11	0.37	10	20	0
19	50	11	0.29	15	15	0
20	100	11	0.21	10	10	0

3 Results and discussion

The values of length, width, thickness, geometric mean diameter, sphericity and roundness for *ratomakai* were 10.77, 10.21, 5.13, 8.24, 0.77, 0.64 respectively. Similarly, these values for *pahenlo makai* were 10.38, 9.74, 5.43, 8.17, 0.79 and 0.67 respectively and these values for *sethi makai* were 11.02, 10.56, 5.85, 8.78, 0.80 and 0.68 respectively. The performance of the developed planter was evaluated in the laboratory at different cell sizes of the metering drum and hopper fill level. The performance was assessed by determining the discharge rate of the planter, multiple index, missing index and mechanical seed damage shown in Table 1.

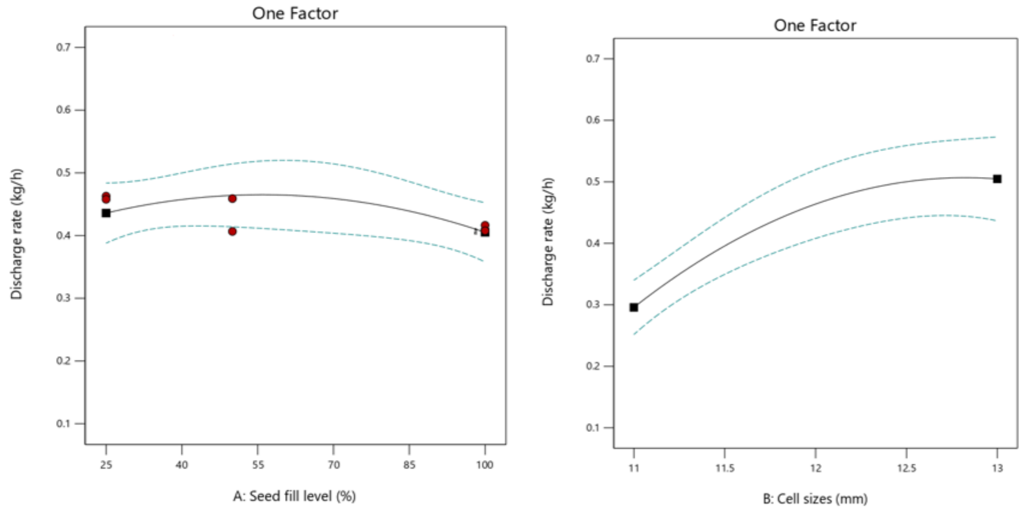


Figure 10 Effect of discharge rate on seed fill level and cell size

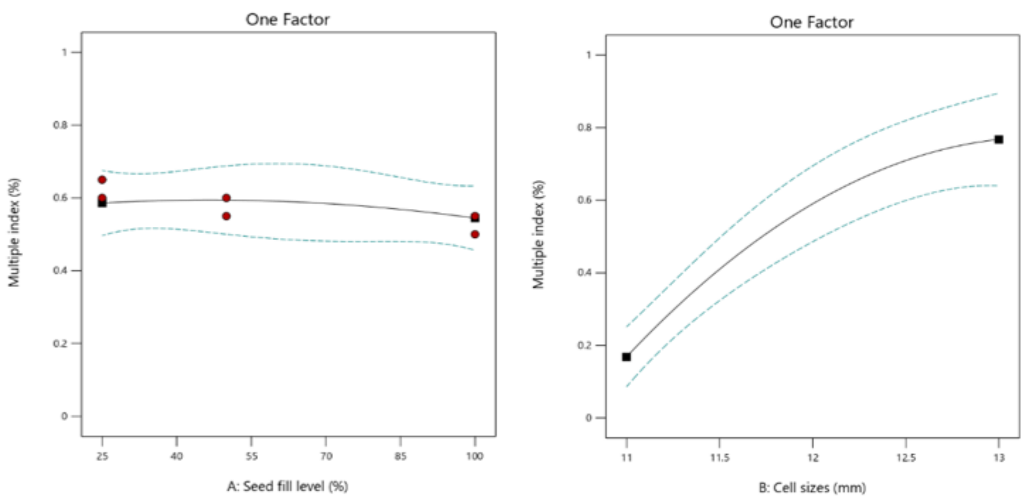


Figure 11 Effect of multiple index on seed fill level and cell size

The discharge rate (D_r) and multiple index (I_{mult}) varied from 0.21 kg h^{-1} to 0.51 kg h^{-1} and 10% to 85% between the different seed fill level and cell size. Second degree polynomial model was found as the best-fit model. The F-value of the model was 17.78 with *p*-value of <0.0001 which implies that the model is significant. As the size of the cells increased, the discharge rate and multiple index were found to increase. On the other hand, value of these parameter decreased with increase in hopper fill level shown in Figures 10 and 11. Missing index values varied from 0% to 20% at different levels of hopper fill levels and cell sizes. A linear model was found as the best-fit model. The F-value of the Model was 19.78 with *p*-value of <0.0001 which implies that the model is significant. As the size of the cells decreased, the missing index was found to increase and it decreased with increase in hopper fill level shown in Figure 12. The vermicompost application rate varied from 429.333 kg ha^{-1} to 645.333 kg ha^{-1} at different hopper fill levels.

A linear model was found as the best-fit model. The F-value of the Model was 25.09 with p-value of <0.0001 which implies that the model is significant. As the hopper fill level increases, the vermicompost rate increases shown in Figure 13. The seed damage rate for the 11 mm, 12 mm, and 13 mm cell sizes was 0%, indicating no damage to the seed. Based on ergonomic evaluation, average heart rate for developed planter and traditional method were found as 114 bpm and 126 bpm shown in Figure 14. In both cases, operator experienced BPDR in the shoulder, forearm and palm but in traditional method, the most pain was experienced in the backbone because of the constant bending posture. The ODR values for developed planter and traditional method were obtained as 4 to 5 and 7 to 8.

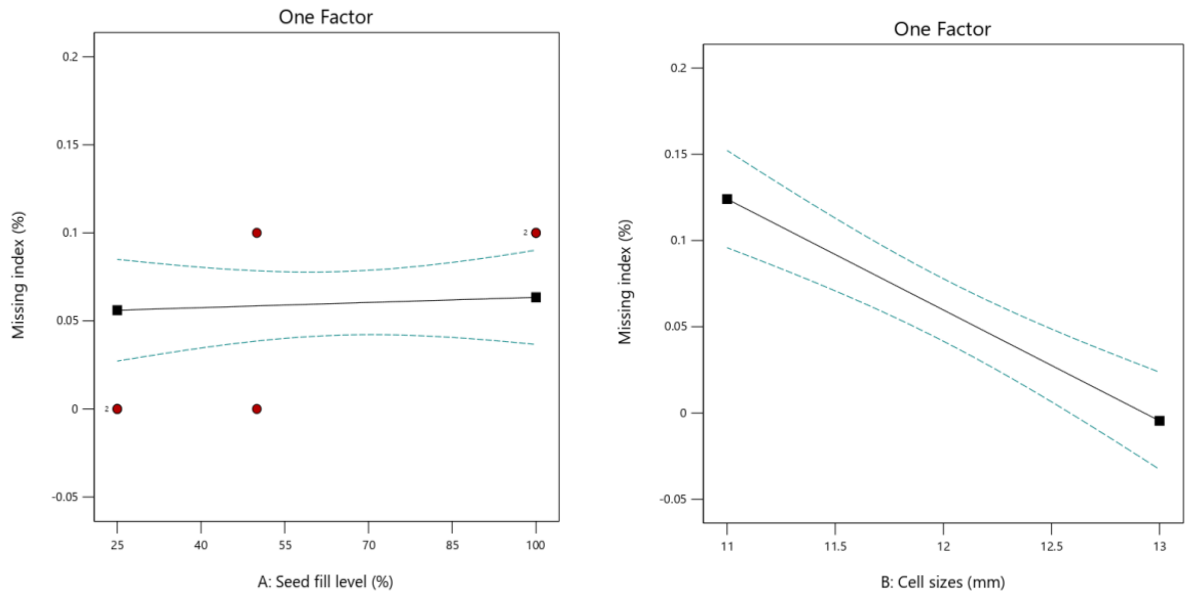


Figure 12 Effect of missing index on seed fill level and cell size

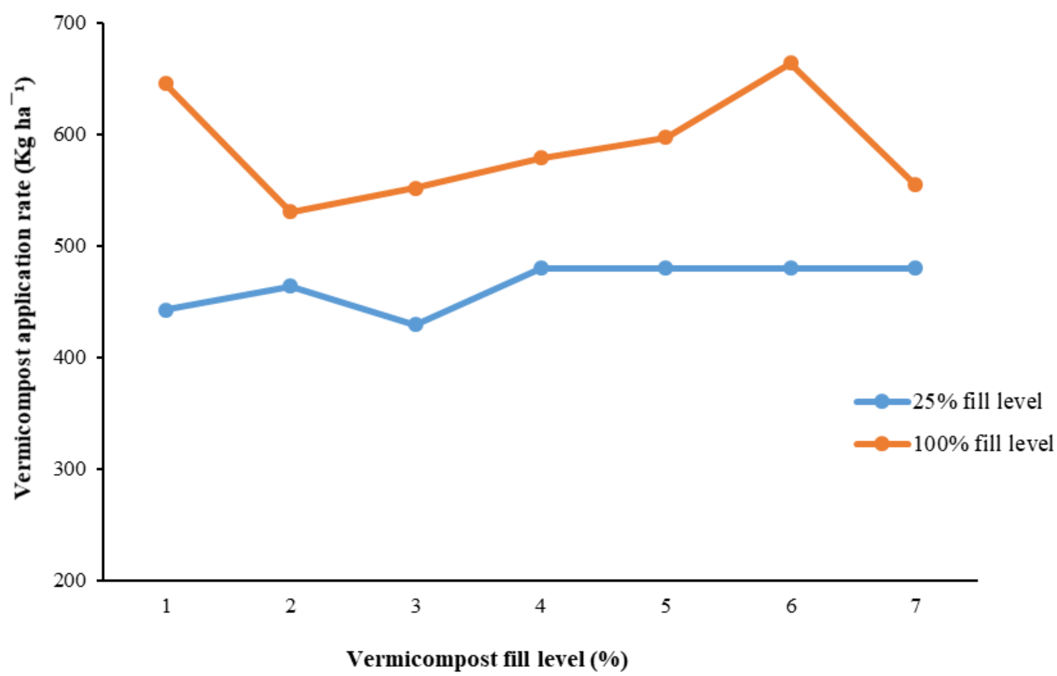


Figure 13 Effect of vermicompost application rate on vermicompost fill level

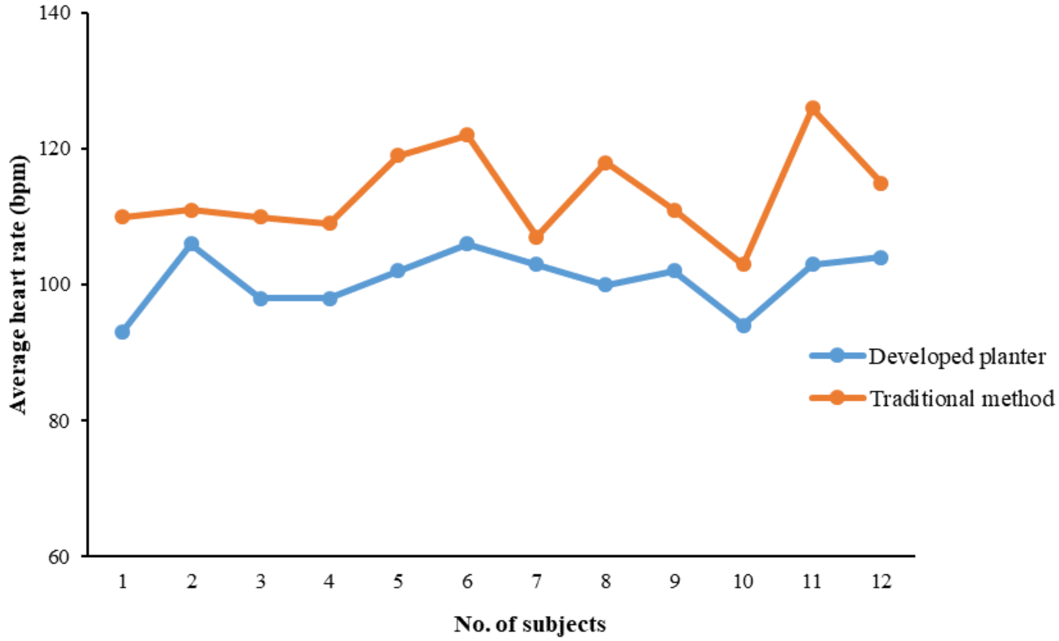


Figure 14 Average heart rate for developed planter and traditional method

4 Conclusions

Manually operated maize planter cum vermicompost applicator was developed and optimum cell size was found as 11 mm. The discharge rate and multiple index of the developed planter were found to increase as the size of the cell increases and decreases when the seed fill level increases. The missing index (I_{miss}) of the developed planter was found to increase as the size of the cell decreases. The missing index decreases when the seed fill level increases. The vermicompost application rate of the developed planter was found to increase as the vermicompost fill level increases. No seed damage was observed for metering drum of different cell sizes. The performance of the developed planter was evaluated in the laboratory at different cell sizes of the metering drum and seed fill level. The desirable cell size, seed fill level and vermicompost fill level were taken as 11 mm, 100% and 25%. Based on field evaluation and observation, the planter performed satisfactorily in narrow terraces (having width ranging from 1 to 2 m) of Sikkim. Based on ergonomic evaluation, average heart rate for developed planter and traditional method were found as 114 bpm and 126 bpm. Therefore, it can be concluded that the developed planter is light weight and ergonomically comfortable.

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