Lham et al. 2022 Bhutanese Journal of Agriculture 5(1), 162-171
https://doi.org/10.55925/btagr.22.5113

Evaluation of Locally Fabricated Machine Attached to Tractor for Making Suitable Raised Bed for Vegetable Cultivation

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ABSTRACT

Growing vegetable on a raised bed improves soil physical parameters, and irrigation drainage and prevent waterlogging which ultimately increase the yield of vegetables. Making raised bed manually is not only time consuming but also a tedious job that involves much labour. A bed-making implement to be attached to a tractor machine was designed and tested to determine the dimensions of the bed formed specifically to suit the available plastic mulch width for cultivation of vegetable crops. A 34HP tractor was used as a power source for the bed making implement. The machine was tested at three different tractor forward speeds of 1.89, 2.54 and 5.04 km/h to record the width and height of the bed formed at these corresponding forward speeds. The results indicate that although the bed width increased with an increase in forward speed (76.89, 80.11 and 87.22 cm for 1.89, 2.54 and 5.04 km/h, respectively), the optimum bed width suitable for vegetable cultivation using the available plastic mulch was 80.11 cm with a bed height of 25.33 cm formed at the forward speed of 2.54 km/h. The machine field capacity recorded at the forward speed of 2.54 km/h was 3.80 acre/day, while that of a person's capacity to make the bed of the same dimension manually was 0.02 acre/day.

Keywords: *Bed making; Bed width; Bed height; Productivity*

1. Introduction

Although 49.9% of the population in Bhutan is engaged in agriculture (NSB, 2020), the country continues to import close to 30% of the food commodities from outside the country (Chhogyel & Kumar, 2018). The situation under the current Covid-19 pandemic has made it very clear that dependence on imports is not only unreliable but also highly risky. The country saw a major shortage of foods and vegetables during the lockdowns and their prices soared unrealistically. This has re-emphasized the importance of domestic food production to secure food security and self-sufficiency.

There is an urgent need to upscale the cultivation of vegetables in Bhutan as they are mostly perishable. Vegetable cultivation consists of various operations, the main one being field

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preparation. Field preparation entails making beds of suitable heights to prevent waterlogging and improving aeration, thereby increasing production. The tops of the beds are wide with furrows on either side and furrows serve primarily as drains and traffic lanes for the water to flow to reduce deep drainage. Hamilton, Bakker, Houlebrook, and Spann (2000) showed that the raised beds were engineered to create a root zone that is about 30 centimetres deep with a stable structure and a low density. The dimensions, stability, and low density of raised beds ensure rapid absorption of rainwater, drainage of excess soil-water and improved aeration. Excess soil-water drains sideways from the beds into the furrows and from there it flows into catch-drains, waterways and dams preventing deep drainage. Cultivation of crops on raised beds not only facilitates proper drainage during the rainy season but also ensures better input management and improvement in soil physical conditions (Campbell, McConkey, Zentner, Selles et al., 1996).

In the bed planting system, vegetable crops are planted on raised beds (David, Jagadish, & Elizabeth, 2003). Ismail and Ismail (2013) indicated that the vegetables planted on the raised beds receive better growth conditions as it realizes low levels of groundwater and high infiltration. In the bed and furrow irrigation system, the plants are grown on raised beds which not only use irrigation water more efficiently but also ensure better crop growth (Berkout, Yasmeen, Maqsood, & Kalwij, 1997). The bed planting system facilitates weed control, allows mechanical cultivation of crops, and improves the stands of the plants (Miah, Hossain, Duxbury, & Lauren, 2015). It also provides an opportunity for easy field entry resulting from row orientation on the beds, efficient management of irrigation water, and also requires less labour (Fischer, Sayre, & Monasterio, 2005). This system has many other advantages such as reducing the seed rate, increasing crop yield, low water use, higher nitrogen use efficiency, and reduction in crop lodging as compared with the conventional tillage/sowing systems (Hobbs & Giri, 1997).

Raised bed-furrow planting method is adopted by many farmers throughout the world (Govaerts, Sayre, Lichter, Dendooven et al., 2007). In raised bed and furrow method, the fields are divided into narrow strips of raised beds separated by furrows as per the requirement of the crops. The raised bed planting system is being evaluated and advocated for many crops including cereals and vegetables in South Asia (Singh, Dwivedi, Shukla, & Mishra, 2010).

Generally, farmers in Bhutan grow vegetables on raised beds that are prepared manually without maintaining the recommended size due to the unavailability of machines. The size of a raised bed has a significant impact on the total crop production and water consumption (Kukal, Sudhir, Humphreys, Amanpreet et al., 2010). Memon, Ullah, Siyal, Leghari et al. (2020) indicated that the size of a raised bed in the bed-furrow method has a significant effect on crop yield, water productivity, and salt distribution. The yield and crop water productivity were recorded higher under raised beds with a width of 80 cm. The optimal raised bed width for wheat in Koga (clay soil) is between 60 to 80 cm bed (Tewabe, Abebe, Enyew, & Tsige, 2020). Raised beds that are 81-91cm (32-36 inches) wide and 15-25 cm (6-10 inches) high are typically used for fresh market vegetable production (Clark & Maynard, 1992). Making raised bed manually is laborious, time-consuming, and expensive. Realizing the importance of raised beds for enhancing crop production and the difficulty in making beds of uniform size manually, this study designed and evaluated a bed-making implement attached on either side of the rotary tiller of the tractor for constructing raised beds of suitable size for the cultivation of vegetables using available plastic mulch films.

2. Materials and Method

2.1 Designing of the bed making implement

The bed making implement was designed to prepare a raised bed of heights 15-25 cm and 80 cm in width to facilitate easy access to the centre of the bed for weeding, crop and water management, and harvest. This bed width was made to suit the currently available mulching plastic film which is 120 cm wide and the provision of about 20 cm of plastic was kept for covering under the soil on either side of the bed to protect the mulch plastic against the wind. The frame and other working parts were made of a mild steel sheet of 3mm thickness and the parts were assembled with nuts and bolts to suit various dimensions. The process involved making the parts by cutting, grinding, and welding, followed by fitting and assembling. The prototype was tested in the field before this experiment.

The designed implement consisted of three units: (1) the front unit of width 110 mm connected by the shaft which is to be attached to the rotor of the tractor, (2) the rear unit (bed shaper) of width 80 mm (can be adjusted) which was made to form a raised bed of required width and height with sloping angle of 40°, and (3) a soil leveller unit attached to a roller shaft located between the two opposing sheets that slightly pressed the soil to level and compress the soil to form a flat and uniform bed top width. This unit could be adjusted according to the height and volume of the soil. The technical specification of the machine is presented in Table 1.

Table 1. Technical specifications of bed-making machine attached to tractor

S.N.	Particular	Dimension
1	Overall machine dimensions, (Length × Width × Height) (mm)	955×860 (rear) × 1070 (front) ×350
2	Power transmission	PTO (rotar) bed making attached to rotar
3	Width of furrow (mm)	500-600
4	Shaper	Flat sheet attached to roller shaft
5	Power (HP)	34 HP tractor
6	Field capacity (acre/day)	2.8 -3.8
7	Speed of operation (km/h)	1.89-2.54

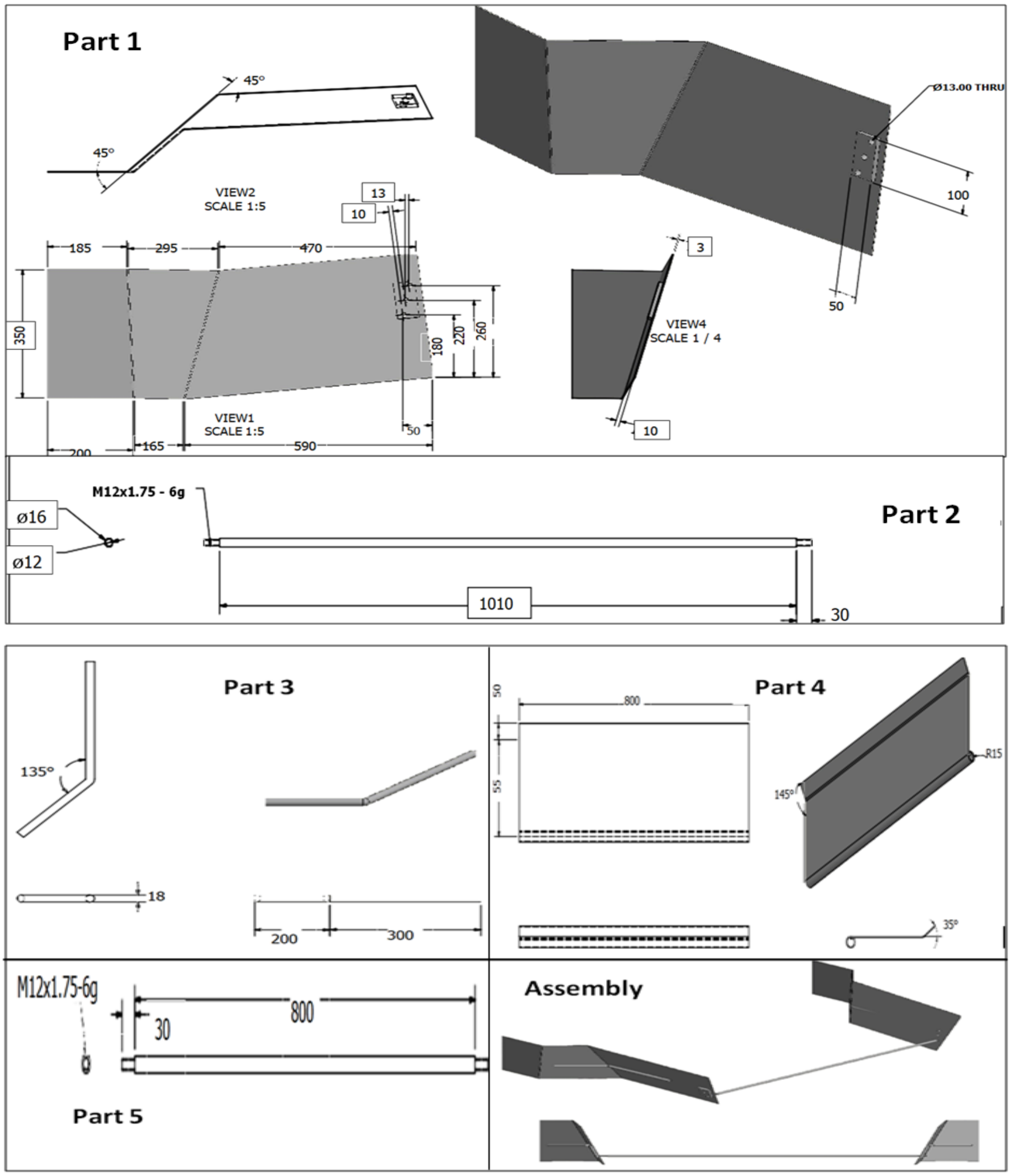

Figure 1. Schematic diagram of the machine design

2.2 Field experiment

The experiment was conducted in Genekha (27.3036° N, 89.6054° E), Thimphu, to evaluate the performance of the machine for making raised beds. The soil type at the site was sandy. The experiment was conducted adopting a completely randomized design (CRD) with three replications for each treatment. A total of nine plot units were selected for applying the treatments: i) forward speed of 1.89 km/h, ii) forward speed of 2.54k m/h, and iii) forward speed of 5.03 km/h for making the raised beds. The experiment was conducted in May 2021.

Samples of the field soil were collected to assess the soil moisture content. The machine was tested to determine the height of the bed, width of the bed and furrow width at three forward speeds which were found by recording the time taken to cover a distance of 30 m. The three forward speeds of 1.89, 2.54 and 5.03km/h at three different gear positions of 1, 2 and 3 respectively were calculated by using the following formula:

$$V = \frac{\mathrm{Sx3.6}}{\mathrm{t}} \qquad (1)$$

Where;

V = forward speed (km/h); S = travelled distance (m); t = time of the experiment (sec);

3.6 = 1m/sec= 3.6 km/h

The theoretical field capacity (TFC), actual field capacity and field efficiency were also determined in testing the machine. Theoretical field capacity is the rate of field coverage of the implement, based on 100 per cent of the time at the rated speed and covering 100 per cent of its rated width. Theoretical field capacity was calculated using the following formula:

$$TFC = VxW \qquad (2)$$

Where;

TFC = theoretical field capacity (m^2/sec); V = forward speed (m/sec); W = rated width of implement (m)

Effective field capacity (Ef) is the total area covered/ total time taken to cover that area inclusive of the time lost time, etc.

$$Ef = \frac{A}{T} \qquad (3)$$

Where;

Ef = Effective field capacity (m^2/sec); A = total area covered (m^2); T = total time taken to cover that area (sec)

$$Fe = \frac{Ef}{TFC} * 100 \qquad (4)$$

Where;

Fe = Field Efficiency

2.3 Experiment with making bed manually

The separate experiment was conducted in a completely randomized design by three men with three replications each to find the time taken to make a raised bed of 25 cm in height, 80 cm wide and 10 m long in a well ploughed and pulverized field. The area coverage by each of them in a day (7 hours) was also calculated using the following formula.

$$HC = \frac{A}{T} * 7 \qquad (5)$$

Where;

HC = Human capacity (acre/day); A = Total area covered (acre); T = Total time taken to cover that area (h); 7 = Number of working hours in a day

2.4 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using the Statistical Package for Social Science (SPSS) version 21. Differences among treatment means were examined after statistical significance using the Duncan's Multiple Range Test (DMRT) at 5% significance level.

3. Results and Discussion

3.1 Effect of forward speed on the width of beds formed

Generally, the bed width and height were affected by the forward speed of the tractor at the same moisture content at 8%. Forward speed played an important role in the formation of optimum bed width. The result indicated that with increasing forward speed from 1.89 to 5.04 km/h, the bed width also increased from 76.89±1.35 to 87.22±3.8 cm respectively (Figure 2). There was no significant difference in bed width formed at forward speeds of 1.89 km/h and 2.54 km/h but the forward speed of 5.04 km/h was significantly different from the other two forward speeds.

A study conducted by Ismail and Ismail (2013) showed that increasing the forward speed increased the ridge profile upper width, but decreased the bed height since the increase in the forward speed increases the collapsed soil, and consequently more quantity of soil falls on the profile sides. The bed width 76.89 cm and 80.11 cm formed at forward speeds of 1.89 and 2.54 km/h, respectively in the present study was comparable to the finding of Kukal et al. (2010) who also recommended a bed width of 80 cm for growing vegetable crops under different dry region for the long-term agricultural sustainability.

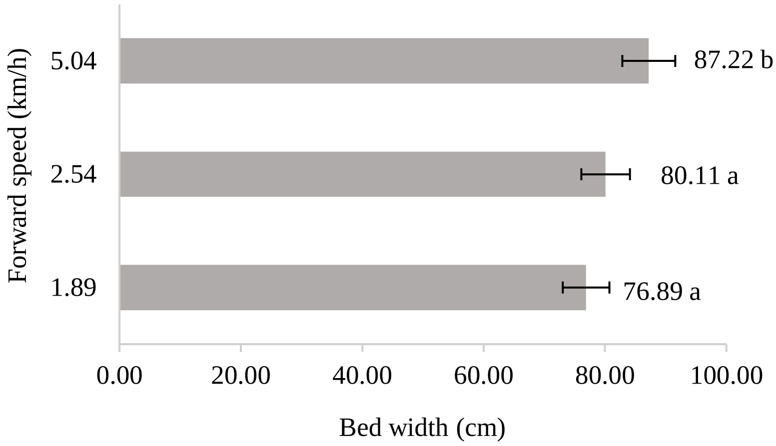

Figure 2. Effect of forward speeds on the width of planting bed formed (Error bars represent standard error of mean)

3.2 Effect of forward speeds on the height of bed formed

Bed heights of 25.33±1.86 cm and 25±2.00 cm were observed at forward speeds of 1.89 km/h and 2.54 km/h, respectively (Figure 3). The lowest bed height (15.56±1.68) cm was formed at the forward speed of 5.04 km/h which could have been due to more agitation of the soil at the higher speed of the tractor. There was no significant difference in bed heights formed by different forward speeds of the tractor.

Ismail and Ismail (2013) indicated that this trend was caused by the effect of the forward speed that prevents the forming unit share from penetrating the soil, thereby discouraging more soil layers from accumulating to form the ridge profile. In most situations, the bed height of 20 – 25 cm was found very effective (Wightman, Peries, Bluett, & Johnston, 2005). Therefore, the forward speed of 1.89 and 2.54 km/h is recommended to make a bed of optimum size which will also be suitable for laying plastic mulch film of 120 cm width available in the market currently. The higher speed forms a bed of lower height and wider width which is not suitable for plastic mulching.

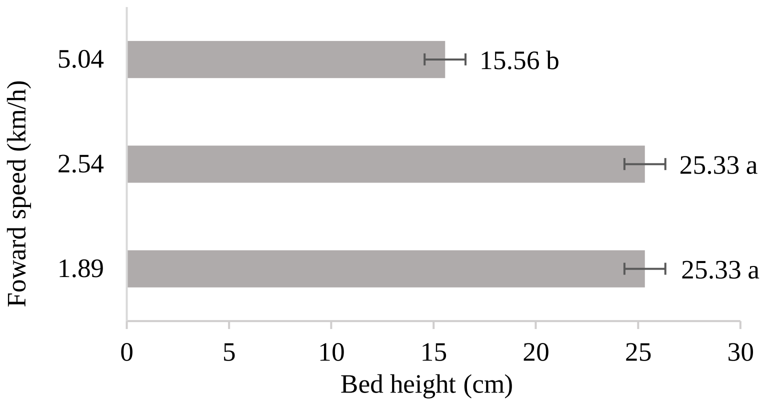

Figure 3. Effect of forward speeds on the height of bed formed (Error bars represent standard error of mean)

Figure 4. Bed-making machine attached to tractor

Figure 5. Bed making during field experiment

3.3 Bed-making machine productivity compared to bed making manually

A person took two hours to make a raised bed of height 25 cm, 80 cm wide and 30 m long covering an area of 0.02 acre/day inclusive of the time they took for breaks. There was no significant difference between the times taken among the men to make beds of similar bed dimensions. On the other hand, the field capacity of the designed bed making implement recorded was 3.8 acres/day at the forward speed of 2.54 km/h and made a bed of 80.11cm in width, 25.3 cm high and 30 m long in a minute.

4. Conclusion

To increase the productivity of vegetables and to use irrigation water efficiently, it is vital to cultivate vegetables on raised beds. Preparing beds manually is a tedious, time consuming and laborious job. Hence, the bed-making machine designed in this study offers better opportunities especially in terms of efficiency and in reducing drudgery. Based on the results obtained from the field test, the following conclusions can be drawn: i) the bed-making machine attached to the tractor makes a bed of optimum size for vegetable cultivation at the appropriate forward speed, ii) the machine also forms a bed dimension that is suitable for laying plastic mulch film, iii) the recommended forward speed of the tractor is 1.89-2.54 km/h to form the required bed dimension and iv) the field capacity of the machine recorded was 3.8 acre/ day when operated at the forward speed of 2.54 km/h against the human capacity to prepare a bed of the same size at only 0.02 acre/day.

Acknowledgement

The authors acknowledge the management and staff of the AMC for the support in fabricating the machine, and like to thank the extension officer of Genekha, Thimphu, for allowing us to use the farmer's field in his gewog to conduct this study.

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