# DEVELOPMENT AND TESTING OF BED FORMER IMPLEMENT POWERED BY HAND TRACTORS
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# *PENGEMBANGAN DAN PENGUJIAN IMPLEMEN PEMBUAT GULUDAN DENGAN SUMBER DAYA TRAKTOR TANGAN*

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*DOI: https://doi.org/10.35633/inmateh-65-25*

***Keywords:*** *agriculture engineering, appropriate technology, machinery, soil tillage, upland conservation*

## ABSTRACT
*Soil tillage, like making raised beds, is time-consuming and labour-intensive if it is done without the help of mechanization. Therefore, this study aims to develop and test a bed former powered by a hand-tractor for upland. It was carried out in the experimental field (sandy clay loam texture) at a furrower depth of 15 cm and 20 cm with a tractor forward speed of 0.5 m/s. The bed's former design results have dimensions of length, width, and height of 1200×1000×820 mm. The performance test results showed an increase in tillage depth resulted in increased bed height, bed width, bed width, and slip. However, field capacity decreases with increasing tillage depth. The bed former's performance was found to be satisfactory in general.*

## ABSTRAK
*Pengolahan tanah, seperti membuat guludan, memakan waktu dan tenaga jika dilakukan tanpa bantuan mekanisasi. Oleh karena itu, penelitian ini bertujuan untuk mengembangkan dan menguji alat pembentuk guludan yang ditarik oleh traktor tangan untuk lahan kering. Penelitian ini dilakukan pada plot percobaan (tekstur tanah lempung berpasir) pada kedalaman pengolahan tanah 15 cm dan 20 cm dengan kecepatan maju traktor 0.5 m/s. Hasil desain alat pembentuk guludan memiliki dimensi panjang, lebar, dan tinggi masing-masing sebesar 1200×1000×820 mm. Hasil uji performansi menunjukkan peningkatan kedalaman pengolahan mengakibatkan peningkatan tinggi guludan, lebar atas guludan dan lebar bawah guludan serta slip. Namun, kapasitas lapangan menurun dengan bertambahnya kedalaman pengolahan tanah. Kinerja pembentuk guludan secara umum sangat memuaskan.*

## INTRODUCTION
The raised beds are places for cultivated plants to grow by elevating the soil and giving special treatment. The purpose of making the raised beds is to make planting easier, both in terms of overcoming weeds, runoff and providing nutrition in the hope of producing maximum yields. According to *Govaerts et al. (2006)*, the size and shape of the raised beds made by the bed former machine will determine the commodity to be planted.

Bed forming can have an average length of 20-30 m depending on the area of land being cultivated. Raised beds can have an average bed height between 25 and 30 cm with an average bed width of 30-40 cm (Figure 1). As a result, the process of making raised beds requires a lot of time and energy in the process (*Dixit et al., 2018; Kato et al., 2007; Zhang et al., 2018*). Therefore, there are several researchers and engineers who have attempted to carry out the design of this machine. However, very few studies have focused on the developed bed former machine for upland crops until today.

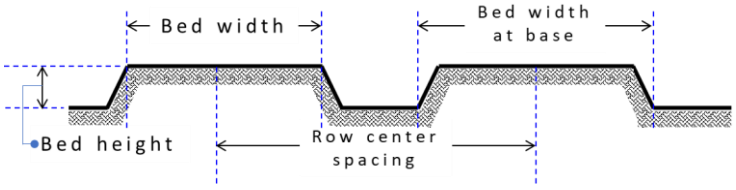



**Fig. 1 - View of the raised beds for growing crops**

*Dixit et al.,* (2018), have studied developing and testing a wide-bed former for vegetables towed by a 50 HP 2WD four-wheel tractor. The field capacity of this machine is reported as 0.31 ha/h with a forward speed of 2.75-5.25 km/h.

Another study from *Saha et al.* (2018) has carried out research on the performance of a bed former integrated with the planter and powered by a 52 kW 4WD four-wheel tractor. Bed width and bed height of bed former made are 1200mm, 200mm, respectively. Field capacity from this implement is reported to be 0.35 ha/h.

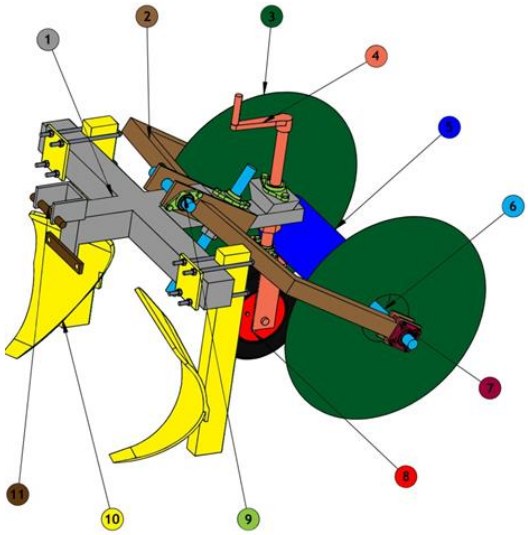
Besides, *Awad, (2016),* conducted the manufacture of a prototype of a raised-bed planter for wheat. This study suggests using a speed of 1.21 m/s in making raised beds for silty loam soil texture. This implement is also integrated with a planting device which is both pulled by a 2WD four-wheel tractor. The power required to pull these implements is reported to be in the range of 3.03 to 5.65 kW.

In addition, *He et al.,* (2009), have investigated the design of bed former for permanent raised beds. This study reports that his bed-former design can work more effectively. Unfortunately, the tractor power and field capacity of the designed implementation are not specifically reported.

To the best of our knowledge, the entire developed bed former uses a four-wheeled tractor to pull the bed former implements. So far, no other studies have been reported developing a bed former that was pulled using a hand tractor. In fact, hand tractors are more commonly used in Indonesia. Therefore, this study aims to develop and test the bed former with 10.5 HP hand tractors.

## MATERIALS AND METHODS

The conceptual design of the bed former as an implement is presented in Figure 2. The bed-forming equipment's main components are the furrower unit, bed former unit, third wheel unit, and mainframe unit. The furrower unit functions to make soil grooves and drain them to the bed former unit. Bed former functions to form raised beds. The third wheel will function to adjust the depth of soil tillage.




1-main frame;
2-frame bed former unit;
3-bed former wheel;
4-crank for adjusting the depth of soil tillage;
5-part for levelling the ground;
6-shaft;
7-bearing in a shaft of bed former units;
8-third wheel;
9-bearing in bed former frame;
10-furrower units;
11-hitch point

**Fig. 2 - Isometric design of bed former as an implement for hand tractor**

This analysis is used to determine the criteria for the material used in the bed's former machine's design. This estimation is to determine the maximum load that can be pulled by a hand tractor using Equation 1. Material flexibility is analysed using Equation 2 (*Bulan et al.*, 2019).

$$\sigma = \frac{F}{A} \tag{1}$$

$$\sigma = \frac{M_L}{W_L} \tag{2}$$

where:

$\sigma$ - tensile strength (MPa);

$F$ - force (N);
$A$ - cross-sectional area of the specimen (m²);
$\sigma_L$ - bending stress (Kg/cm²);
$M_L$ - bending moment (Kg/cm);
$W_L$ - linear moment (cm³).

The frame is the most important component of a machine that functions as a holder for other components. The frame also functions as a load-bearing so that the frame is not deflected. To calculate this effect, Equation 3 is used. The deflection caused by the loading is compared to the approval deflection calculated using Equation 4 (*Slaitas and Valivonis, 2021*).

$$\delta = \frac{PL^3}{48EI} \tag{3}$$

$$\delta_{izin} = \frac{1}{300} L \tag{4}$$

where:

$\delta$ - deflection that occurs (mm);
$P$ - power (watt);
$L$ - centre point (mm);
$E$ - modulus of elasticity (kg/mm²);
$I$ - moment of inertia (mm⁴);

Analysis of hand tractor power requirements is estimated by calculating each tractor power requirement and the power required to move the bed former. The power requirement of the tractor can be estimated using Equation 5. The power requirement to pull the implement bed former can be calculated using Equation 6 (*Usaborisut and Prasertkan, 2019*).

$$P_T = C_{rr} \cdot F_T \cdot V_t \tag{5}$$

$$P_{BF} = \mu \cdot F_{BF} \cdot V_t \tag{6}$$

$$P_a = P_T + P_{BF} \tag{7}$$

where:

$P_T$ - tractor power requirements (Watt);
$C_{rr}$ - rolling resistance coefficient;
$F_T$ - weight of hand tractor (N);
$V_t$ - tractor forward speed (m/s);
$P_{BF}$ - power requirements to pull implements (Watt);
$\mu$ - pull force coefficient;
$F_{BF}$ - weight of bed former (N);
$P_a$ - total power requirement of the tractor (Watt).

The type of tractors used in this research is YZC series, 10.5 HP, 2400 RPM hand tractor. Hand tractor has a field capacity of up to 0.11 ha/h. The tractor speed applied in this research is 0.5 m/s. The slips that occur during tillage are also measured using Equation 8 (Shafaei *et al.*, *2021*).

$$S = \frac{D_t - D_r}{D_t} \times 100\% \tag{8}$$

where: $S$ - Slip (%); $D_t$ - theoretical distance (m); $D_r$ - real distance (m).

Field testing was carried out on a plot of land measuring 12 m × 10 m. The length of the track in one trial was 9.2 m. The bed former is tested at furrower depths of 15 cm and 20 cm. The test was carried out with three repetitions. The theoretical field capacity, effective field capacity, and efficiency are calculated using Equation 9 to Equation 11, respectively (*Kumar et al., 2013*).

$$F_{CT} = \frac{W_i \times V_t \times 3.6}{10^5} \quad (9)$$

$$F_{CE} = \frac{D_T \times W_t \times 3.6}{t \times 10^5} \quad (10)$$

$$E_F = \frac{F_{CE}}{F_{CT}} \times 100\% \quad (11)$$

where:

$F_{CT}$ - theoretical capacity field (ha/h);
$W_i$ - width implement (cm);
$V_t$ - tractor forward speed (m/s);
$F_{CE}$ - effective field capacity (ha/h);
$D_T$ - bed track length (cm);
$W_t$ - tillage width (cm);
$t$ - time of making the raised beds (s);
$E_F$ - effectiveness (%).

The shape and height bed from the designed machine are measured using a relief meter. Soil physical properties such as soil moisture content and bulk density were measured before and after making the raised beds. Soil moisture content was measured using the gravimetric method and calculated using Equation 12 and soil bulk density was measured using Equation 13. Soil sampling was carried out as 10 points from the experimental plot.

$$S_w = \frac{m_{sw} - m_{sd}}{m_{sd}} \times 100\% \quad (12)$$

$$B_D = \frac{m_{sd}}{V_{ol}} \quad (13)$$

where:

$S_w$ - soil moisture content (%, d.b.);
$m_{sw}$ - wet soil mass (g);
$m_{sd}$ - dry soil mass (g);
$B_D$ - bulk density (g);
$V_{ol}$ - soil volume (cm³).

**Fig. 3 - Measurement of raised beds with a relief meter**

## RESULTS

The bed former (Figure 4) is designed with dimensions of length, width, and height of 1200, 1000, 820 mm, respectively. The total weight of this implement is 96.7 kg. The bed former unit has a diameter of 600 mm with a steel plate material with a thickness of 3 mm. The total length of the bed former unit is 700 mm.

A connecting rod 25.4 mm in diameter is connected at the hitch point of a hand tractor. The total height and width of the furrower are 400 mm, 350 mm, respectively. The width of the bottom of the furrower is 44 mm with an angle of 45°. The thickness of the plate used in the furrower was 12 mm. A third wheel with a turning crank is used to adjust the depth of tillage. All parts are attached to the mainframe made of UNP iron measuring 80×45×6 mm.


1-hitch point;
2-hand tractor (10.5 HP);
3-handle soil tillage depth adjustment;
4-bed former unit;
5-third wheel;
6-furrower unit

**Fig. 4 - Bad former powered by hand tractors**

The soil composition in the test area has a sand content of 55%, silt 16%, and clay 28%. This shows that the soil texture for this implement test is sandy clay loam. The moisture content before making the raised beds was 27.91%. The moisture content after the process of making the raised beds was 24.58%. These results indicate that the moisture content has decreased after making the raised beds. The moisture content after tillage decreases because of evaporation generated by soil disturbance.

The result of bulk density measurement before making the raised beds is 1.26 g/cm$^3$. After making the raised beds is carried out, the average value of bulk density is 0.89 g/cm$^3$. These results indicate a decrease in bulk density after making raised beds by 29.37%. This phenomenon is in line with several studies *(Osunbitan et al., 2005; Evans et al., 1996; Li et al., 2019*) that state that the denser the soil the higher the bulk density. Besides, tillage will provide a lower bulk density value where the best bulk density for upland crop growth should be less than 1.53 g/cm$^3$ (*Xiu et al., 2019; Bilgili et al., 2017; Kundu et al., 2019*).

The relief of raised beds formed from furrower as deep as 15 cm are presented in Figure 5. It can be seen that the formed bed height has an average of 19.66±0.58 cm. The formed bed width and bed width at base were 46.33±1.53 cm, 65.66±1.54 cm, respectively. This bed height has followed several studies *(Niu et al., 2007; Jolliffe and Gaye, 1995; Simpson et al., 2019*), which state that bed height should be in the range of 15-23 cm. Besides, the effective field capacity of the tool with this treatment is 0.13 ha/h with an efficiency of 78.41%. It is smaller than the research results of *Saha et al. (2018)* and *Dixit et al. (2018)* which use a four-wheeled tractor as their power source.

The relief of raised beds from furrower treatment as deep as 20 cm are presented in Figure 6. It can be seen that the formed bed height has an average of 23.67±0.58 cm. Also, formed bed width and bed width at base was 41.67±1.15 cm, 67.33±0.58 cm, respectively. The effective field capacity with this treatment is 0.11 ha/h with an efficiency of 65.91%.

Bed former slip can reduce field efficiency and supply traction from the tractor used as a power source. The average slip for a furrower with a depth of 15 cm is 15.17±1.19%. At a furrower depth of 20 cm, the average slip that occurred was 23.0±0.67%. This slip is greater than the results of *Awad, (2016),* which reported that the maximum slip that occurs in testing the prototype of a raised-bed planter for wheat, towed using a 2WD tractor, is less than 15%. On the other hand, Syahri *et al.* (2019) also reported more significant slip (23.04%) from this study's results when using a hand tractor in traversing an inclined plane.

However, *Pranav et al., (2012),* explained that the slip in soil tillage activities is still within normal limits if it occurs in the range of 14% to 23%.

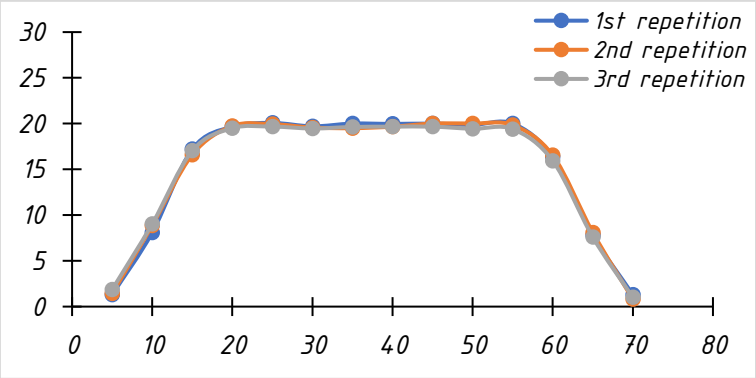



**Fig. 5 - Relief of raised beds at a furrow depth of 15 cm**

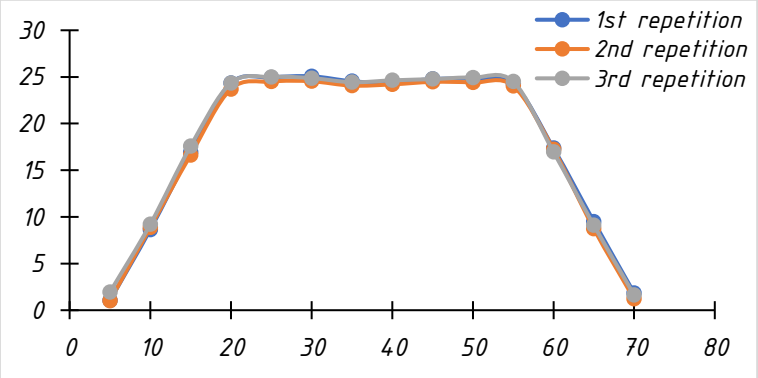



**Fig. 6 - Relief of raised beds at a furrow depth of 20 cm**

## CONCLUSIONS

A bed-former powered by 10.5 HP hand tractors has been designed and tested successfully for performance. Overall, this implement has dimensions of length, width, height, and weight of 1200 mm, 1000 mm, 820 mm and 96.7 kg, respectively. Field testing showed a decrease in soil bulk density by 29.37% after making raised beds on sandy clay loam soil types.

The implement's performance shows that the furrower depth of 15 cm and 20 cm produces raised beds with an average height of 19.66±0.58 cm, 23.67±0.58 cm, respectively. The bed width formed at a furrower depth of 15 cm and 20 cm is 46.33±1.53 cm, 65.66±1.54 cm. At a furrow depth of 15 cm and 20 cm, the bed width at base is 41.67±1.15 cm, and 67.33±0.58 cm. respectively. During the test, the slips with a depth of 15 cm and 20 cm were 15.17%, 23.0%, respectively. This indicates that bed height, bed width, bed width at base increase with increasing tillage depth. It is inversely proportional to the effective field capacity of the tool, which decreases with increasing soil cultivation depth. The maximum efficiency achieved in this test is 78.41%. The bed former's overall performance was considered to be satisfactory.

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