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Design and Performance Evaluation of a Mini Tractor Mounted Clod Crusher

K. P. Jishna [a++*], M. N. Gajera [b#], V. R. Vagadia [c†] and P. P. Gajjar [c]

[a] *Department of FMPE, CAET, J.A.U, Junagadh, India.*
[b] *Department of Farm Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India.*
[c] *Department of Farm Machinery and Power Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Clod formation following ploughing or disking is a major concern in India's arid and semi-arid zones. Clod prevents seed - soil close contact and restrict the penetration of furrow openers used in the seed drilling. At present, the majority of the farmers in our country practice a small and marginal land system. Small-scale farmers can purchase small tractors, but smaller tillage implements suitable for mini tractors are not available in the market. To overcome the current problems in seedbed preparation, a mini tractor mounted clod crusher was developed. The developed implement was tested on the field and the data were analyzed statistically with ANOVA tests using computer software. The results showed that, overall best performance of the machine in terms of clod MMD, fuel consumption and field efficiency were found to be 9.25 mm, 7.696 l/h and 84.72 % at the forward speed of 3.0- 3.5 km/h with the dead weight of 100 kg respectively.

[++] *P.G Scholar;*
[#] *HOD;*
[†] *Assistant Professor;*
**Corresponding author: E-mail: jishnkp1@gmail.com;*

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1. INTRODUCTION

Indian context has the first largest population in the world and contributes nearly 17 to 18 % of the total population of the world. This increase in population points towards the need for improved productivity. Agricultural productivity is linked to the availability of farm power. At present, the majority of the farmers in our country practice a small and marginal land (area) system. Small-scale farmers can purchase small tractors, but smaller tillage implements suitable for mini tractors are not available in the market. Tillage or soil preparation is the mechanical manipulation of the soil to prepare seedbed at optimum tilth. About 16 - 25 % of the total energy available for the rural sector is used for agricultural production, of which, approximately 20 % of energy is consumed only in seedbed preparation [1]. Clod formation following ploughing or disking is a major concern in India's arid and semi-arid zones. Clod prevents seed - soil close contact and restrict the penetration of furrow openers used in the seed drilling. Keeping in mind of all the limitations of the existing clod crushers a mini tractor-mounted clod crusher was developed.

The fiield machines must be as light as possible to reduce the cost, soil compaction, and propelling power while still being strong enough to withstand shocks caused by uneven terrain or obstructions. Tubes or closed box sections are the strongest for their weight. Richy et al.[2] As all the sections are attached to the frame, the frame must be sturdy enough to prevent sagging and to keep the parts in place. Typically, a mild steel angle is used for the frame [3].

A rake angle is provided to the unit so that the soil clod can be hold and cut to fine particles without been topple over. A rake angle less than 30° reduces the draught [4]. An increase in rake angle and forward speed increased draught force, soil disruption, and soil loosening [5].

The field condition plays a vital role in the uniformity and the degree of soil disruption. Compared to all other soil moisture levels, decreased soil moisture considerably increased the amount of soil distribution [6]. The degree of soil breakup that is optimum for plant growth depends upon the seed size, the crop type, and the soil and weather conditions [7]. For corn stalks the average aggregate diameter of 6 mm and a bed of 2 to 6 mm gives good yield in wet and dry soil respectively. Larson and Swan [8]. A small capacity (5 kg/batch) biomass pyrolyser was designed and developed for making bio-char from the shredded cotton stalk as feed stalk [9].

The existing type of clod crushers were reviewed to overcome the limitations. A cultivator attachment with three different types of clod crushers: a square spike, round spike and a spiral arrangement of spike were analyzed on field and the better performance in terms of tilling quality of soil was obtained using square spike clod crusher attachment to the cultivator. The optimum values of clod MWD, field efficiency and fuel consumption were found as 13.64 mm, 78.37 % and 7.02 lit/ha respectively [10].

The tractor operated spiked roller was compared with a cultivator (control), rotavator, cultivator (cross) and blade harrow. The mean mass diameter (MMD) of clod of the developed spiked roller has been found lesser compared to all others [11].

2. MATERIALS AND METHODS

Initially, the mean clod size of the soil from the region is measured to decide the blade spacing on the unit. The space from the main frame to the tire of the tractor was measured to decide the width of machine and length is decided according to the existing main frame. The total weight of the developed clod crusher was 111 kg. The testing was carried out at four deadweights (0 kg, 50 kg, 100 kg and 150 kg) and two forward speed combinations (2.5- 3.0 km/h and 3.0-3.5 km/h).

An existing main frame with three-point linkage available at the Department of Farm Machinery and Power Engineering, JAU, Junagadh was used in the study. The main frame is of 1220 mm × 395 mm in dimension made up of mild steel flats of C shape. A captain tractor of 25 hp was used for the field testing. The testing was carried out at Wheat Research Station Farm, JAU and the field parameter like moisture content and bulk density and the machine performance parameters like depth and width of work, operating speed, wheel slip, clod mean mass diameter, draft, fuel consumption, and field efficiency were measured and analyzed. All the parameters of the tractor-implement performance were measured and recorded with the recommendations of RNAM (Regional Network for Agricultural Machinery) test codes and procedures for farm machinery technical series [12]. Density was increased by 3.91 times and calorific value was increased by 1.19 times [13].

2.1 Primary Unit

The CRC pipes of 50 × 50 × 4 mm were welded together to form a 1520 × 150 mm rectangular frame. It has 13 numbers of V-notched blades each of length 150 mm, 40 mm in width and a thickness of 8 mm. A rake angle of 30˚ is provided to the frame so that the frame can hold the soil clod and prevent from topple over as it moves forward. The main purpose of the primary unit is to hold and break the soil clod and pass it over to the secondary unit for further size reduction. The blades are arranged such that the centre blade was held vertically and the remaining with an inclination towards the centre from both ends of the unit as shown in Fig. 2.

2.2 Secondary Unit

The purpose of the secondary unit is to further reduce the clod aggregate size passed from the primary unit to the ideal tilth condition. It also comprised of CRC pipes of 50 × 50 × 4 mm and that were welded together to form a 1520 × 150 mm rectangular frame. Another CRC pipe of same dimension was used to separate the secondary unit lengthwise into two portions each having 16 and 15 numbers of flat blades of 200 mm in length, 40 mm in width, and 6 mm in thickness. The blades are arranged alternatively in the first and second portion as shown Fig. 3.

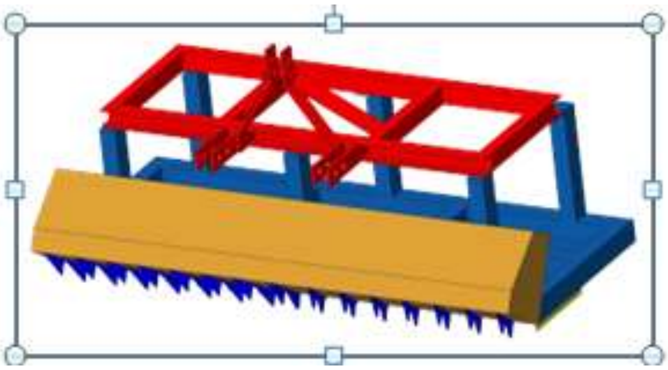


Fig. 1. Isometric view of mini- tractor mounted clod crusher

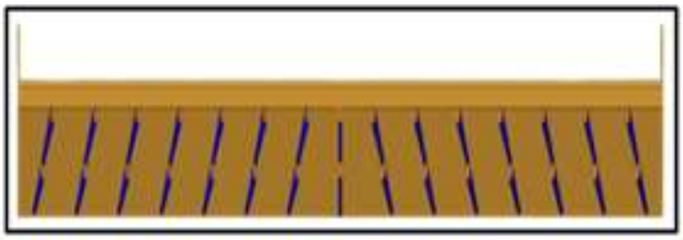


Fig. 2. Primary unit with v- notched blades

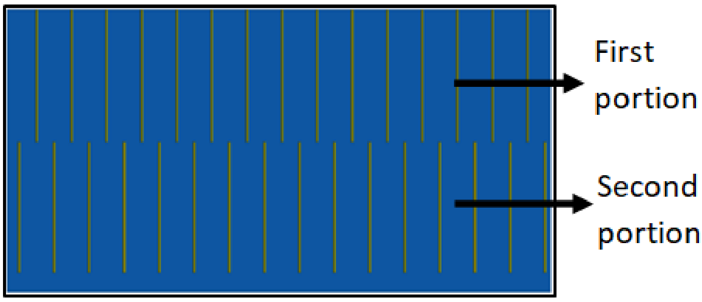
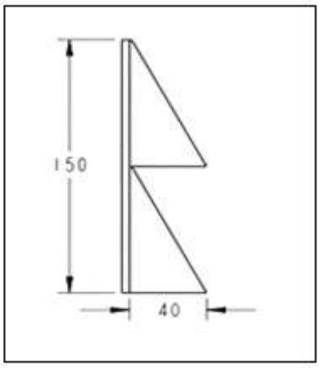


Fig. 3. Secondary unit with flat-type blades Blades



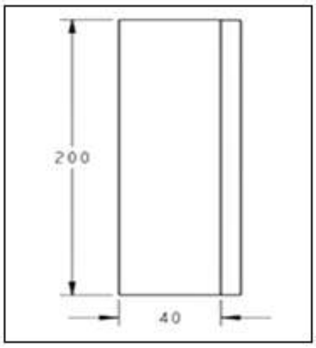


Fig. 4. V- notched and Flat blade on the first and second unit

2.3 Thickness of Blade

The thickness of the blade was calculated by the formula

$$M / I = F / Y \quad (1)$$

Where,

M = Bending moment acting on the blade section, kg-cm
I = Moment of inertia of cross section about the neutral axis, cm^4
F = Bending stress, kg/cm^2
Y = Distance from the neutral axis to the extreme edge, cm

As, M = Force × Distance = 111 (weight on blade) × 100 (length of blade/2) = 11100 kg-mm

Take F = Allowable bending stress for MS flat = 30 kg/mm^2 [14]

Y = 150 / 2 = 75 mm (Take depth of cut = 15 cm) (2)

Now, $I = t \times b^3 / 12 = t \times (40)^3 / 12 = 5333.33\ t$ (3)

Where,

t= Thickness of blade, cm
b= Maximum width of blade, cm

By putting the above values in eq (1)

t=11100 × 75 / (5333.33 × 30) = 5.2 mm

Considering, the factor of safety and availability of material, the thickness of the flat blade was kept at 6.0 mm. Whereas, the thickness of V-notched blade is kept at 8 mm considering more FOS since, it has to withstand more work force.

3. RESULTS AND DISCUSSION

The soil moisture content (*d.b*) and the bulk density was found to be 14.20 % and 1.28 g/cm^3 respectively. The developed mini tractor-mounted clod crusher machine has a working width of 1.50 m and the average depth of work was 5.97 cm.

3.1 Wheel Slip

As the speed increases, wheel slip also increases. It is due to traction limitation, the available traction between the tires and the ground decreases. This is especially true in field conditions. The tires struggle to maintain sufficient grip, resulting in increased wheel slip.

3.2 Draft

The additional weight increases the draft force required to overcome the resistance and to pull the implement through the soil. The heavier the deadweight, the greater the draft force needed.

At higher travel speeds, rolling resistance increases due to factors such as tire deformation, soil compaction, and uneven terrain. This increased rolling resistance adds to the draft force needed to pull the implement.

3.3 Cone Index

The additional weight leads to significant deformation of the soil resulting in lesser cone index values. Deformed soil has more pore space, making it easier for the penetrometer to penetrate, thereby decreases the cone index.

Higher travel speeds cause greater soil disturbance as the tractor and implement interact with the soil. This disturbance breaks the soil aggregates, leading to lesser cone index measurements.

Fig. 5. Fabricated mini tractor-operated clod crusher

Fig. 6. Blade arrangement on developed clod crusher

3.4 Clod Mean Mass Diameter

At higher speeds and added dead weight, the forces and vibrations on the soil increase which results in greater soil disturbance, which leads to the breakdown or disintegration of larger soil aggregates.

3.5 Fuel Consumption

At higher speeds, the friction between the tire and the road surface increases. This result in higher rolling resistance, which leads to more power requirement from the engine and subsequently more fuel.

Whereas, the addition of dead weight increases the overall load on the tractor engine. Hence, the engine needs to work harder to overcome the increased resistance caused by the heavier load, resulting in higher fuel consumption.

3.6 Field Efficiency

Field efficiency increases with forward speed whereas, decreases with deadweight. This is because, the effective field capacity decreases with deadweight since more time required to cover the same area due to the wheel slip caused by added load. Threshing efficiency was varied from 79.3% to82.38% with an average value of 81.08% for the variety GG-22[15].

Before treatment **After treatment**

Fig. 7. Field condition before and after treatment

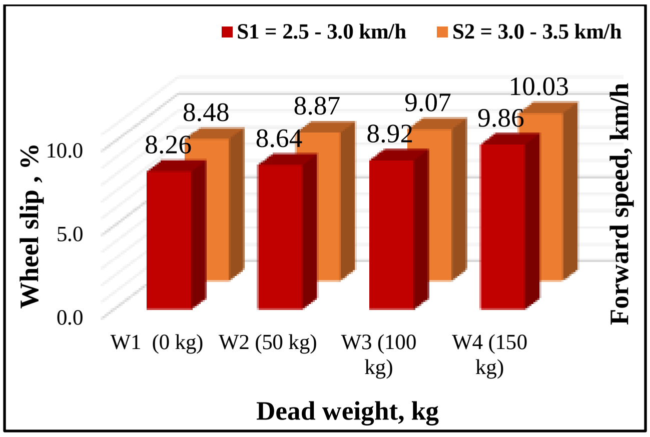


Fig. 8 Combined effect of deadweight and forward speed on Wheel slip

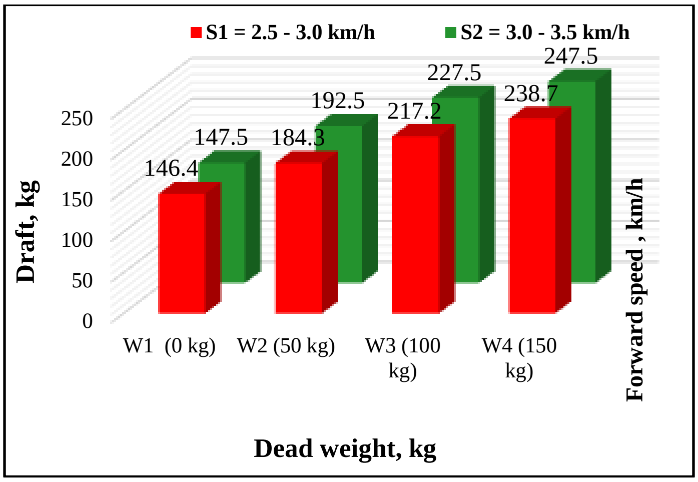


Fig. 9. Combined effect of deadweight and forward speed on draft

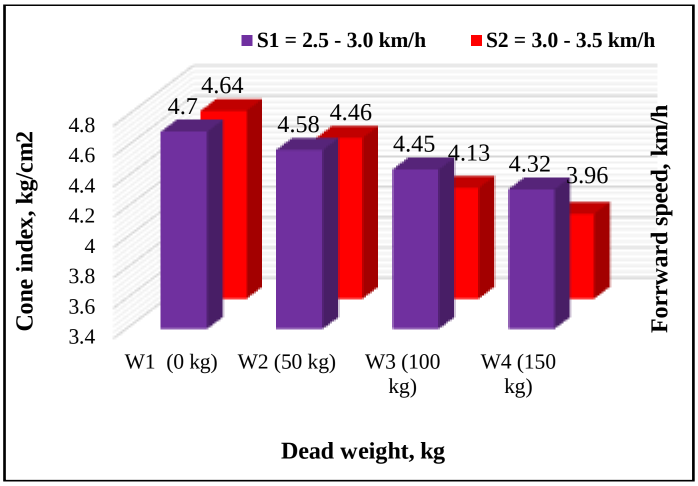


Fig. 10. Combined effect of deadweight and forward speed on cone index

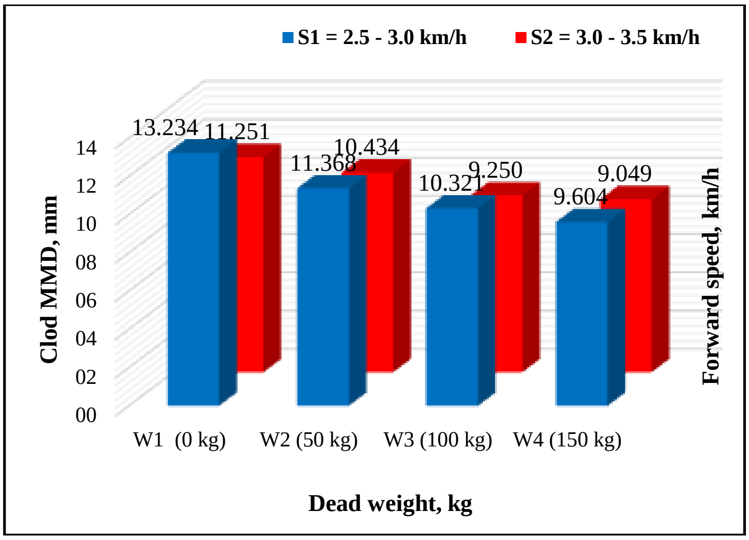


Fig. 11. Combined effect of deadweight and forward speed on clod mean mass diameter

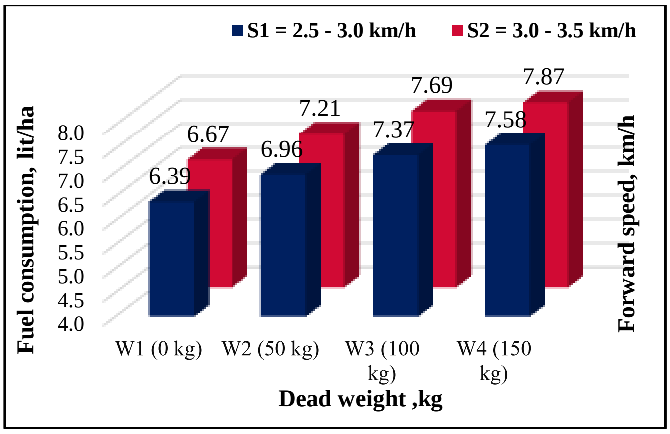


Fig. 12. Combined effect of deadweight and forward speed on fuel consumption

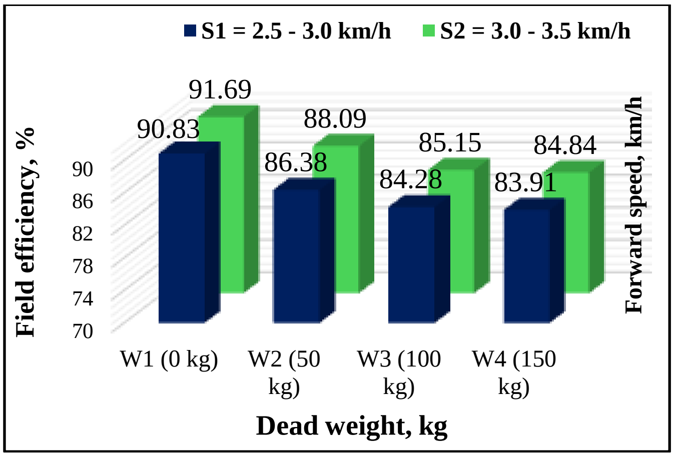


Fig. 13. Combined effect of deadweight and forward speed on field efficiency

4. CONCLUSION

The lowest slip (8.26 %) was corresponding to the forward speed of 2.5 to 3.0 km/h and 0 kg dead weight.

The clod crusher is having lower draft (146.4 kg) at 2.5 to 3.0 km/h travel speed and 0 kg dead weight.

The clod MMD was 35.17 mm at the controlled condition. At 0 kg dead weight and 2.5-3.0 km/h forward speed it was reduced to a diameter (13.23 mm) which is the largest among all the treatment combinations and the lowest/optimum clod mean mass diameter (9.05 mm) is at 150 kg dead weight and a forward speed of 3.0- 3.5 km/h.

Minimum fuel consumption (6.39 lit/ha) was observed at 2.5-3.0 km/h speed and 0 kg dead weight. The highest value of fuel consumption (7.87 lit/ha) was obtained at 150 kg dead weight and 3.0-3.5 km/h forward speed.

The field efficiency is increases with the forward speed (86.35 % to 87.44 %) whereas decreases with dead weight (91.26 % to 84.38 %). The higher value of field efficiency (91.69 %) was obtained at 3.0 - 3.5 km/h forward speed and at a dead weight of 0 kg.

From the results it has been concluded to use the clod crusher at 3.0 - 3.5 km/h forward speed and with 100 kg of dead weight. Even though 3.0 - 3.5 km/h forward speed and with 150 kg of dead weight has a lesser MMD than the other, it results in more fuel consumption and requires additional dead weight. Hence, from an economical point of view, 3.0 - 3.5 km/h forward speed and with 100 kg of dead weight is the most recommended treatment than others. So that, the farmers can use this machine at minimum cost for the tillage/seedbed preparation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Singh S, Mittal JP, Verma SR. Energy requirements for production of major crops in India. Agricultural Mechanization in Asia Africa and Latin America. 1997;28(4):13-17.
2. Richy CB, Jacobson CB, Hall CW. Agricultural engineer's handbook. First Edition, McGraw-Hill Book Company, New York. 1961;92(5):1-66.
3. Smith HP, Wilers LH. Farm machinery and equipment. sixth edition, Tata McGraw-Hill Publishing Co. Ltd, New Delhi. 1977;183-210.
4. Darmora DP, Pandey KP. Evaluation of performance of furrow openers of combined seed and fertilizer drills. Soil and Tillage Research. 1995;34(4):127-139.
5. Marakoglu T, Carman K. Effect of design parameter of cultivator share on draft force and soil loosening in soil bin. Journal of Agronomy. 2009;8(1):21-26.
6. Raper RL, Sharma AK. Soil moisture effects on energy requirements and soil disruption of subsoiling a coastal plain soil. Transactions of the ASAE. 2004;47(3):1899-1905.
7. Gupta SC, Larson WE. Modeling soil mechanical behavior during tillage. Predicting Tillage Effects on Soil Physical Properties and Processes. 1982;44:151-178.
8. Larson, W. E. and Swan, J. B. (1970). Tillage of wet and dry soils. *Crops Soils,* 22: 8- 11.
9. Makavana JM, Kalaiya SV, Dulawat MS, Sarsavadia PN, Chauhan PM, Development and performance evaluation of batch type biomass pyrolyser for agricultural residue. Biomass Conv. Bioref; 2020.
Available:https://doi.org/10.1007/s13399-020-01105-1
10. Ginoya CJ, Yadav R, Zilpilwar SR, Vagadia VR, Agrawat V. Development and Optimization of Mini Tractor Mounted Clod Crusher cum Planker. International Journal of Current Microbiology and Applied Sciences. 2019;8(1): 2319-7706.
11. Vagadia VR, Yadav R, Chavda DB, Tomar G, Patel DV. Development and Performance Evaluation of Tractor Drawn Cultivator Cum Spike-Roller. Agricultural Mechanization in Asia, Africa & Latin America. 2020;51(2):72-78.
12. RNAM. RNAM Test Codes and Procedures for Farm Machinery; 1995
13. Makavana JM, Sarsavadia PN, Chauhan PM. Effect of pyrolysis temperature and residence time on bio-char obtained from pyrolysis of shredded cotton stalk. International Research Journal of Pure and Applied Chemistry. 2020;21(13):10-28.
14. Sharma DN, Mukesh S. Farm machinery design: Principal and problems. Jain Brothers. New Delhi. 2010;196-199.
15. Amrutiya MD, Makavana JM, Kachhot AR, Chauhan PM, Tiwari VK. Performance evaluation of tractor operated groundnut thresher. Current Journal of Applied Science and Technology. 2020;38(6):1-15.

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