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Effect of Tool Parameter, Speed and Depth on Performance of Soil Disruption by Commercially Available Reversible Shovels

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ABSTRACT

Reversible Shovels type furrow openers are basic in design and frequently used in cultivators for opening the soil; due to its simple low-cost manufacturing. The study used four varieties of furrow openers with operating speeds and depths of operation of (0.97, 1.25) m/sec and (10, 12) cm, respectively, to investigate soil disruption by reversible type furrow openers to enhance soil conditions in sandy loam soil. Tool T-4 increased the width of the spoil furrow, the depth of the spoil furrow, the crescent height, the spoil area and the trench area.

Keywords Reversible shovel, Soil profiles, Crescent height, Spoil area, Trench area.

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INTRODUCTION

Agriculture is the backbone of Indian Economy. Agriculture in India is extraordinary in its qualities having about 250 types of crops developed in different agro climatic areas. Indian agriculture sector represents for 18 % of India's gross domestic product (GDP) and gives work to the half of the countries workforce. India is an agriculture-based country, with agriculture employing more than half of the population (Yadav *et al.* 2021, Madhusudhan 2015). Agriculture in India is now developing at a compound annual growth rate (CAGR) of 2.8% on average (Aruna *et al.* 2020, Mehta *et al*. 2014). After the United States, India has the world's second-largest arable land area of 159.7 million hectares (Himani 2014). Agricultural engineering inputs have played a key role in enhancing yield by allowing for appropriate mechanization (Manchikanti and Sengupta 2012). In 2016-17, the total farm power available in Indian agriculture was 2.24 kW/ha. Tractors, power tillers, combine harvesters, diesel engines, electric motors, people, and draught animals contributed 1.324, 0.018, 0.021, 0.460, 0.193, 0.091 and 0.130 kW/ha, respectively (Mehta *et al.* 2019). The country's huge adoption of agricultural tools and machinery has been made possible by efforts from both organized sector, including village craftsmen and micro enterprises. One of the most essential tillage implements used by Indian farmers is the cultivator (Yadav *et al.* 2006). Many organic farmers claim that in dry conditions, a pass with the cultivator has the same effect on the crop as a half inch of rain (Klaas and Mary-Howell Martens, 2005). It is essentially a kind of tillage implement used for opening the soil, preparing the seedbed for sowing the seeds as well as after the crop has come up a few centimeters above the ground (Jain and Grace 2003). Field cultivators are frequently used for seedbed preparation as secondary tillage equipment. The different types of tools that can be added to a cultivator shank for different applications include reversible shovels, sweeps, half sweeps, furrower and so on. The primary purpose of a reversible shovel and sweep is to loosen and steer the soil. They are designed to be used on cultivators and are preferred for secondary tillage, but most farmers use them for main cultivation as well. They are used to open the furrow in seed drills so that seeds can be placed.

They generally do not have an inverting effect and can penetrate more easily in hard ground due to less upward soil reaction (Chen *et al*. 2004). Soil condition and physical qualities such as structure and texture require distinct shapes of soil working tools and operating conditions. As a result, the soil-tool-tillage complex should be studied for a specific area and tool shape and optimized for improved tool performance and energy efficiency (Yadav *et al.* 2006). With these considerations in mind, a study was carried out to offer information on soil disturbance for selected shovels for tractor drawn cultivators in order to enhance soil conditions.

MATERIALS AND METHODS

The experiment was carried out in an indoor soil bin filled with sandy loam soil at the Department of Farm Machinery and Power Engineering, College of Technology and Engineering, Udaipur, Rajasthan, India. The shovels were purchased locally in the Udaipur region, as shown in Fig.1 and 2. were compared to BIS standard, as given in Tables 1 and 2 . The experiment setup included an interior soil bin, a power transmission unit, a control panel, a tool frame and a soil compaction unit. The size of the indoor soil bin used was 20400 mm × 2300 mm × 600 mm. The power from a 2.24 kW DC variable shunt winding motor was delivered to the wheels of a trolley through a belt and pulley arrangement (Figs. 3 and 4). A regulator was used to raise or reduce the speed of the motor in order to achieve the required operating speed of the tools. During the test, the average cone index, as determined by a field scout digital cone penetrometer, was 1154 kPa up to a depth of 100 mm as a measure of soil strength. During the trials, the soil moisture was kept at 9-12% (db.). These values are commonly recorded in the field during tillage operations in the region.

Soil bin

The indoor soil bin having size 20400 mm x 2300 mm x 600 mm to be utilized for the various studies. It was filled with sandy loam soil and an average moisture content of 9-12% (db.) was maintained, allowing for different agricultural operations to be carried out.

Tool trolley unit

A tool trolley frame with dimensions of 2470 mm x 1510 mm was built to serve as a platform for the installation of the power transmission unit and tool frame assembly. The tool trolley's frame was rectangular in design. This was installed on forecast iron wheels with a diameter of 220 mm that were lying on a test track. The tool trolley frame was mounted

Table 1. Specification of reversible shovels as per BIS code 6023:1970.

Sl. No.	Notations	Dimensions (mm) As per BIS	As measured (T1)	As measured (T2)	As measured (T3)	As measured (T4)
1	A	270±2	314	270	297	340
2	B	75±2	55.36	75.20	78.00	116.20
3	C	35±1.6	77.13	35.00	78.22	58.34
4	D	15±0.5	10.48	15.10	10.79	12.64
5	E	45±0.25	40.72	45.00	43.28	44.19
6	α	45±5 deg	60	45	47	55

Table 2. Parameters considered in the study.

Sl. No.	Parameters	Levels	Particulars
A.	Tool parameter		
a	Reversible shovel	4	T1, T2, T3 and T4 commercially available
B.	System parameters		
a	Speed, m/s	2	0.97, 1.25
b	Depth, cm	2	10, 12
C.	Soil parameters		
a	Soil type	1	Sandy loam soil
b	Moisture content, db	1	9-12 %
D.	Parameters to be observed		
a	Soil disruption, m^2		
E.	Soil profile		
a	Spoil furrow width, m		
b	Spoil furrow depth, m		
c	Crescent height, m		
d	Spoil area, m^2		
e	Trench area, m^2		

on a 50 mm diameter axle using pedestal bearings. By ISMC 100 mm x 50 mm manufactured the tool trolley frame.

Soil processing trolley unit

A soil processing unit is made up of a rotavator, a roller and a leveler assembly. The soil preparation assembly's overall length and width were 2470 mm and 1510 mm, respectively. In addition, the rotavator and leveler assembly lengths were 1460 mm and 1530 mm, respectively. It was made up of 12 'L' style blades that rotate at a speed of 270 rpm. A motor provided power to the rotavator blades. Initially, a rotavator was used to pulverize the soil, which was then levelled using a leveler. Following the rotavator and leveler operations, the soil was compact by the roller assembly.

Soil disruption

Surface and subsurface soil disturbance are the two types of soil disruption. Surface soil disturbance or spoil is the amount of soil displaced above the original soil surface by the tillage process, whereas subsurface soil disruption is the area disrupted below the soil surface and trenched area (Raper and Sharma 2004). Soil disruption was measured using a soil profilometer. The profilometer was positioned across the trench and the main scale was settled with knobs and a spirit level. The vertical depth or height of the soil surface was determined using a plum bob at every 2 cm horizontal distance on the main scale. For each tillage tool, replicated observations of soil disruption were recorded. After the surface disruption measurement was completed, the profilometer was left in place and the manipulated soil mass was removed from the trench beneath the profilometer by hand without disturbing the instrument. Only soil loosened by tillage was removed, with great care. The

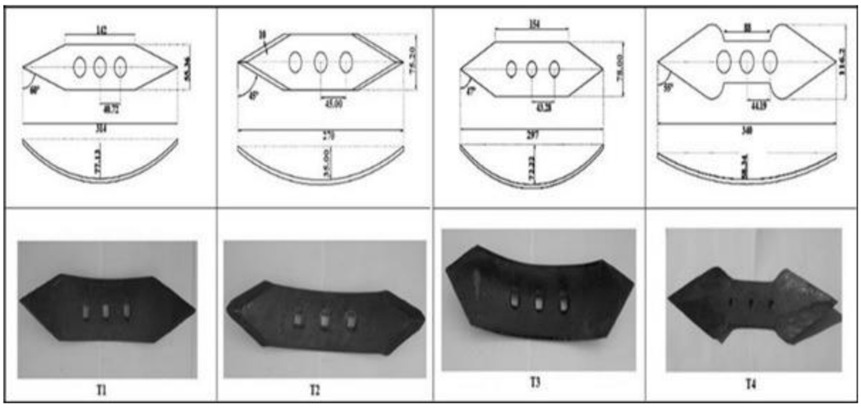


Fig. 1. Commercially available shovel (All dimensions in mm)

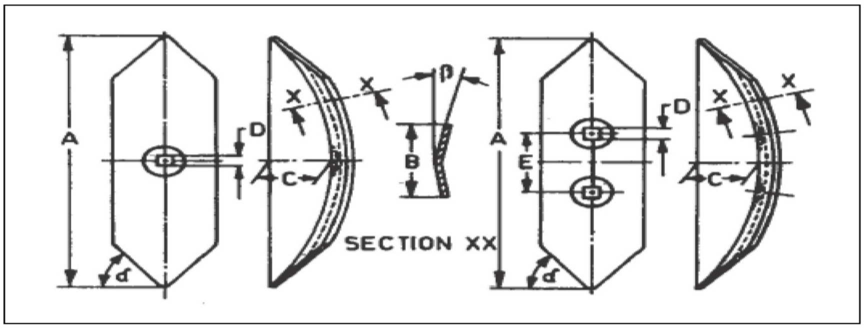


Fig. 2. Specifications of shovel as per BIS.

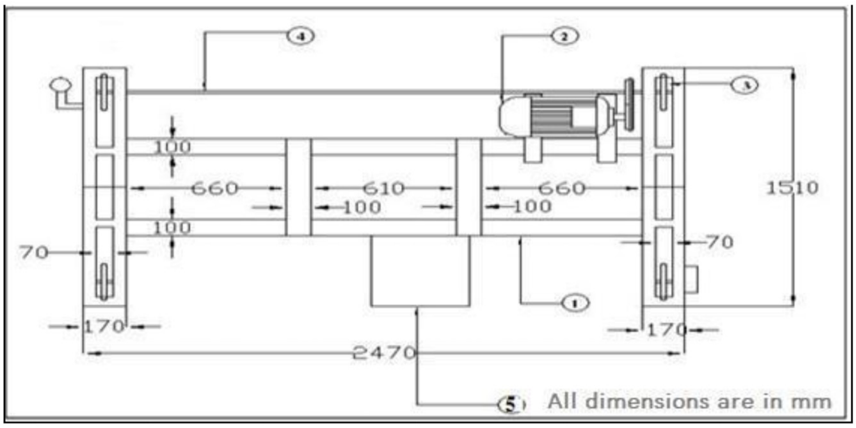
soil profile's area was calculated. The penetrometer was inserted into the soil at a rate of 25-30 mm/s and replication measurements were taken.

RESULTS AND DISCUSSION

Table 1 gives the various dimensions of the four shovels used in the study. The variable A, B, C, D, E and α corresponds to the dimension given in Fig. 1 out of the four shovels, dimensions of shovel T-2 matches with the BIS standard. The various parameter such as shovel geometry, speed, depth of operations and their interactions affected the spoil and trench area significantly.

Effect of shovel, speed and depth of operation on soil profile of shovels

Figures 5 to 8 shows the spoil and trench profiles created by fours shovels at different speeds and depths. It is clear from the Figures that the spoil furrow width and spoil furrow depth increased with increase in either speed or depth for all the shovels. This may be attributed to increase in tillage speed and depth which resulted in tossing of more soil and redistributing it in a wider length outside the trench. Similar findings are also reported by Liu and Kushwaha (2006). Maximum spoil furrow width was observed for T-4 at 12 cm depth of operation at 1.25 m/s forward speed whereas minimum spoil furrow width of was observed for T-1 at 10 cm depth of operation at forward speed of 0.97 m/s. Also shovel T-4 gave highest values of crescent height and forward and furrow depth than all other shovels within the test range of depth of operation and forward speed. This may be attributed to spear shape of T-4 which resulted in higher values as compared to other shovels. Hanna *et al.* (1993) had also reported



1. Horizontal beam 2. DC variable shunt wound motor 3. Track wheel 4. Shaft 5. Tool frame

Fig. 3. Schematic diagram of experimental setup 1. Horizontal beam 2. DC variable shunt wound motor 3. Track wheel 4. Shaft 5. Tool frame.

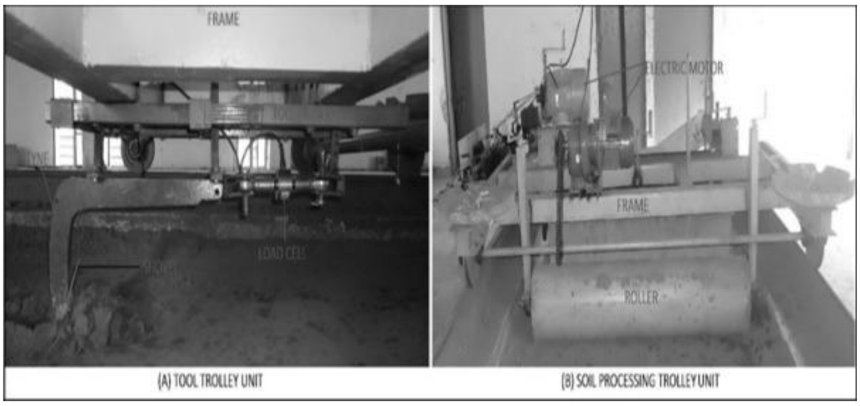


Fig. 4. Actual view of experimental system.

that wider shovels behave in a similar manner.

Effect of shovel, speed and depth of operation on spoil area

Figure 9 shows that spoil area increased with increase in depth and speed of operation for all shovels. However, T-4 resulted in more spoil area than all other shovels at all depths and speed of operation. It is also observed that for shovel T-1, T-2 and T-3, the effect of depth of operation was more dominant at 12 cm depth of operation whereas this reduced to 10 cm for T-4 at all speeds of operation. This may be attributed to shape of T-4 which might have resulted in this way. It was interesting to note that at operating depth 12 cm shovels T-1, T-2 and T-3 had non-significant effect on spoil area at forward speed of 1.25 m/s. It was also observed that shovels T-1 and T-2, T-2 and T-3 had non-significant effect at 10 cm and 12 cm depth of operation at 0.97 m/s forward speed respectively.

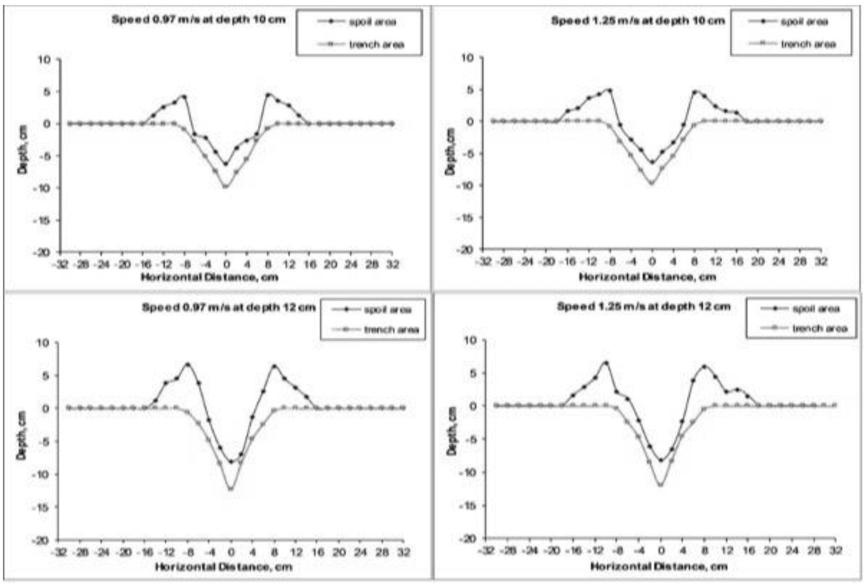


Fig. 5. Spoil and trench profile at different speeds and depths of operation for T-1.

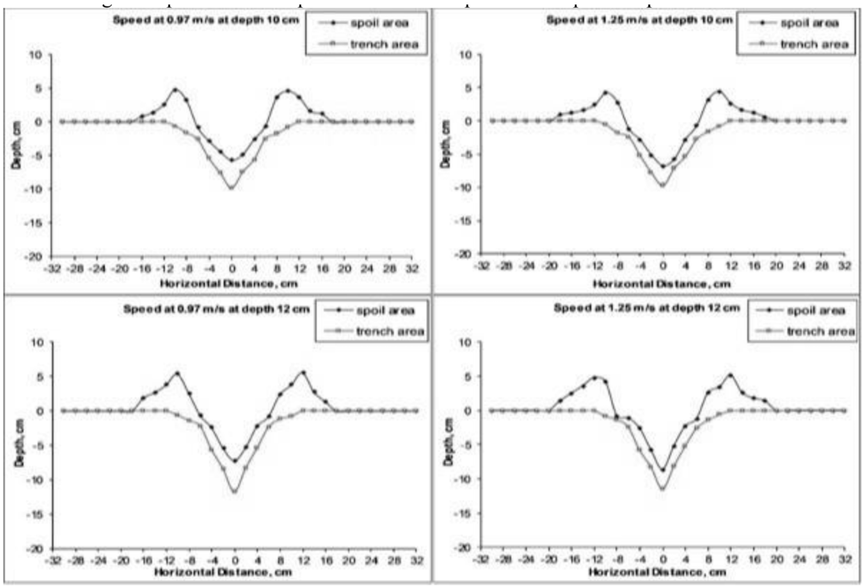


Fig. 6. Spoil and trench profile at different speeds and depths of operation for T-2 (BIS)

Effect of shovel, speed and depth of operation on trench area

Figure 10 shows that trench area increased with increase in depth and decrease with increase in speed of operation for all shovels. T-4 resulted in more trench area than other all shovels at all depths and speed of operation. This may be due to the wide cross section of the T-4 that disturbed a larger zone of soil than other shovels. In all shovels, the trench area varied all

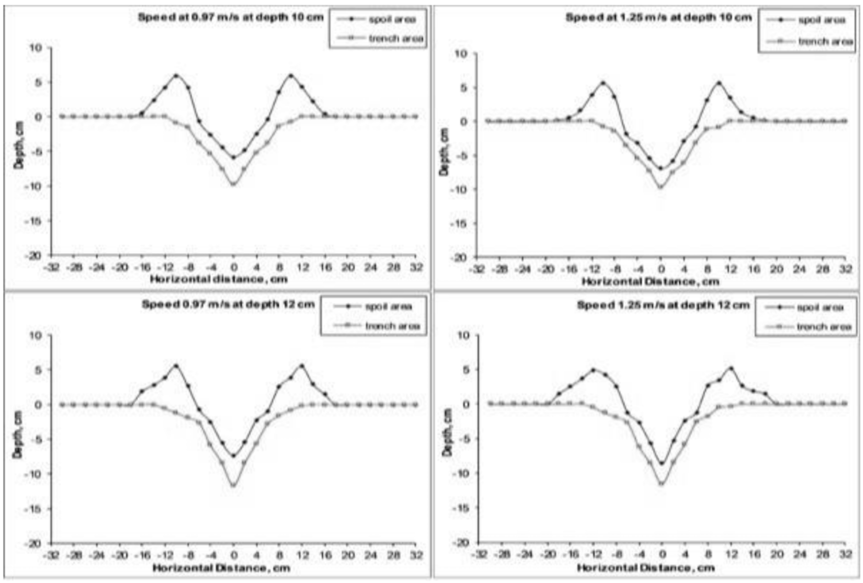


Fig. 7. Spoil and trench profile at different speeds and depths of operation for T-3.

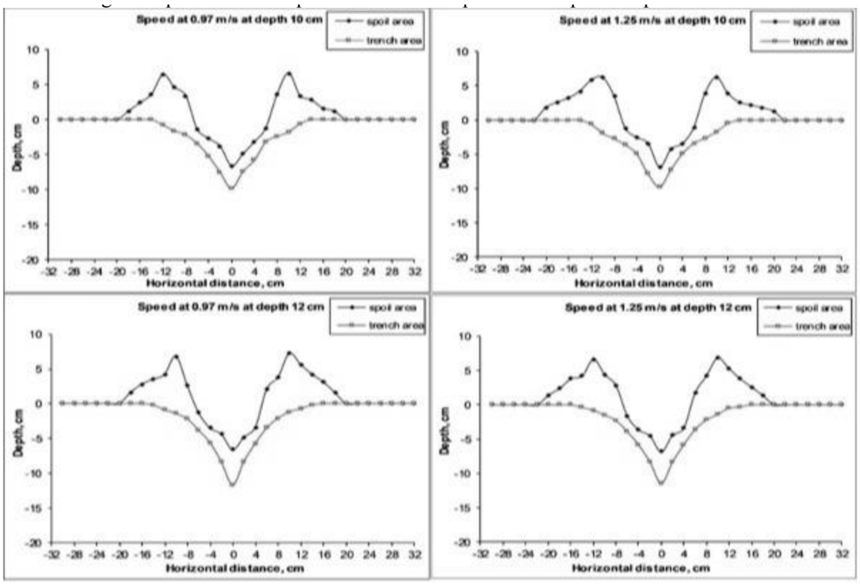


Fig. 8. Spoil and trench profile at different speeds and depths of operation for T-4.

most at steady rate with increase in depth and speed of operation. The effect was more dominant when depth of operation at 12 cm at all speeds of operation. This may be the effect of the geometrical parameters of the shovel. Similar findings have been reported by Sharifat and Kushwaha (1999) and Mielke *et al.* (2004). Figure 10 shows that speed has non-significant effect on trench area at a particular depth of operation for a given shovel. It is also observed that at lower 10 cm and higher 12 cm depth of operation,

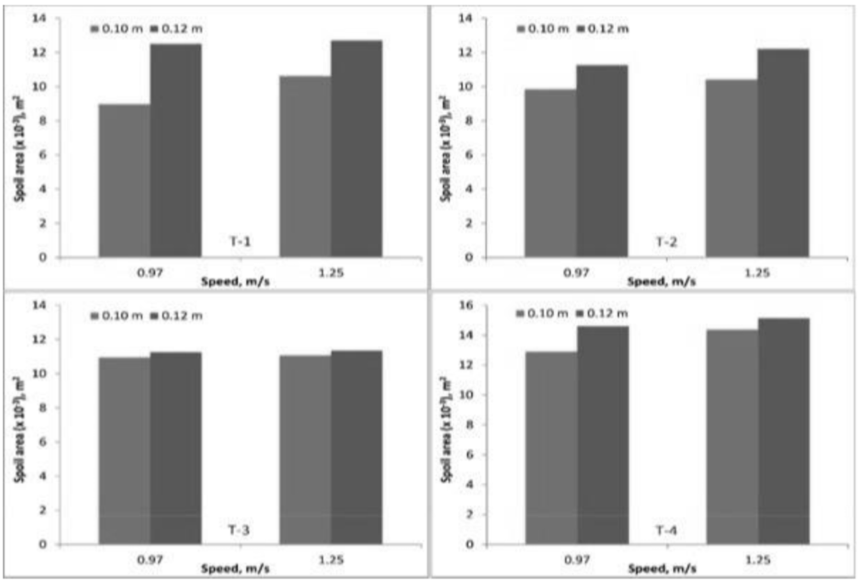


Fig. 9. Effect of speed at different depth on spoil area of different shovels.

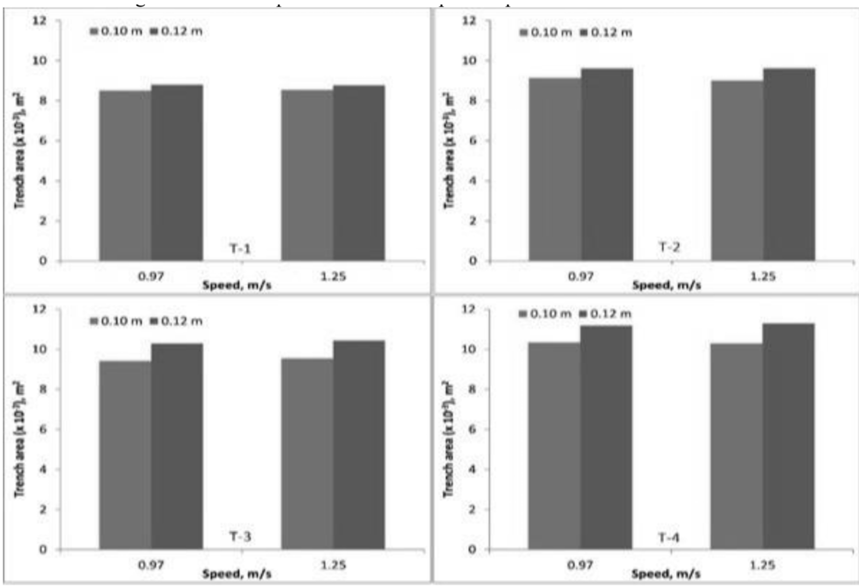


Fig. 10. Effect of speed at different depth on trench area of different shovels.

T-2 and T-3 shovels behaved in the similar manner at a given forward speed of operation. This may be attributed to geometrical shape and dimensions of these two shovels.

CONCLUSION

Normally it has been observed that most of the commercially available cultivator shovels do not follow BIS standard in many aspects which includes the reversible shovel. The BIS code 6023: 1970 for cultivator characterizes reversible shovel for cultivator for parameters like width and length. Not matching with the standard in terms of geometry may affect the quality of working cultivator and finally may be result in profitability in farming. Here, we conclude that the shovel T-2 match with the BIS standard at all aspects. For shovel T-1, T-2 and T-3 the effect of depth of operation was more dominant after 12 cm depth of operation. It was also observed that shovels T-1 and T-2, T-2 and T-3 had non-significant effect at 10 cm and 12 cm depth of operation at 0.97 m/s and 1.25 m/s forward speed respectively. Spoil area is directly proportional to depth and speed of operation whereas, trench area decreased with increase in speed of operation for all shovel. T-4 resulted in more trench and spoil area than shovels at all depth and speed of operation. In all shovels, the trench area varied almost at steady rate with increase in depth and speed of operation. It is depth of operation which affected more the spoil and trench area than speed of operation.

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