Research Paper:

Effect of tool shape and operating parameters on soil disruption of cultivator sweeps in sandy loam soil

PUNAMCHAND SPAKALE, AJAY KUMAR SHARMA, T.B. BASTEWAD AND J.B. MAHAJAN

ABSTRACT

Both soil condition and soil physical characteristics like structure and texture demand different shapes of soil working tools as well as operating conditions. Hence, soil-tool-tillage complex need to be studied for a given location and tool geometry and is to be optimized for better tool performance and energy. Furrow parameters such as furrow bottom, soil throw, soil disturbance in vicinity of tool in relation to speed and depth of operation are affected by tool parameters like shape, size. In this paper effect of tool shape and depth and speed of operation on soil disruption of sweeps for tractor drawn cultivator is discussed. The experiments were conducted in sandy loam soil using two commonly used sweeps at four forward speeds (0.97, 1.25, 1.53 and 1.81 m/s) and depths (0.04, 0.08, 0.12 and 0.16 m) at soil moisture content of about 10.5 per cent (db) under controlled soil bin conditions.

Key words: Sweeps, Soil disruption, Soil profile

Tillage is an energy intensive farm operation consuming about 40 per cent of the total energy input required for crop production (Yadav et al., 2006). It is a basic operation in farming and is generally performed to breakup and pulverize the soil and allow the free movement of air and water in order to promote plant growth. Field soils loosened by tillage tend to become compact as the crops grow. The weeds destroyed by tillage grow once again and land tends to return to the state that existed before tillage therefore it becomes necessary to do tillage before growing every crops.

Cultivator is one of the most important tillage tools used by Indian farmer (Yadav et al., 2006). Even many organic farmers say that a pass with the cultivator has the same effect on the crop in dry weather as a half inch of rain (Klaas and Martens, 2005). It is primarily the type of tillage implement which is used for opening the land, preparing the seedbed for sowing of the seeds as well as after the crop has come up a few cm's above the ground (Jain and Grace Philip, 2003). The field cultivators are often used as secondary tillage tools for seedbed preparation. Reversible shovel, sweep, half sweep, furrower etc. are the different types of tool that can be attached to a cultivator shank for different applications.

Soil disruption, which is a measure of effectiveness of tillage implement is affected by type of tillage tool, speed and depth of operation. Soil profile or soil redistribution after tillage operation is important in several aspects such as seed placement and covering, incorporating manure and crop residues, protecting soil from wind and water erosion etc. (Liu and Kushwaha, 2006). The study of soil profile and soil redistribution by tillage has progressed slowly due to its complexity which involves many factors, such as soil types and properties, types of tillage tools and their operational parameters. Furrow parameters such as furrow bottom, soil throw, soil disturbance in vicinity of tool in relation to speed and depth of operation are affected by tool parameters like shape, size and spacing, operating parameters such as speed and depth of operation and soil parameters like soil type, moisture content, compaction etc. and are studied by various researchers (Dowell et al., 1988; Raper and Sharma, 2004; Raper, 2005; Darmora and Pandey, 2006, Godwin and O'Dogherty, 2006; Liu and Kushwaha, 2006). Keeping these points in view the study was conducted with the objective to study the influence of shape of sweeps, speed and depth of operation on soil disruption.

METHODOLOGY

The experiments using RBD design were conducted in indoor circular soil bin filled with locally available sandy loam soil at College of Technology and Engineering, Udaipur, Rajasthan, India during year 2008. It had an outer diameter of 5520 mm, inner diameter of 3490 mm and a depth of 900 mm. Thus annular width of 1010 mm was available for operating the tool frame. A DC variable shunt wound motor of 20 hp was coupled to worm gear for speed reduction in the ratio of 5:1. The vertical powered shaft was clamped to the horizontal beam of 3150 mm length and 65 mm diameter. A pneumatic wheel was
provided at the outer end of the horizontal beam outside the soil bin for continuous support during operation. A rectangular tool frame was clamped to the horizontal beam at 2420 mm distance from center. A control panel consisting of electrical switch, voltmeter and a regulator was used to increase or decrease the rpm of motor for obtaining the desired operating speed of the shovels. The forward speed of the tool was calculated as:

\[ V = \omega \times r \]  

where, \( V \) is forward speed of tool (m/s), \( \omega \) is angular velocity of horizontal shaft (rad/s), \( r \) is radius of rotation (m).

A MS cylindrical roller of 310 mm diameter and 610 mm length was hinged to the tool frame by metal strip. The purpose of roller was to maintain uniform compaction and soil level through out the test to simulate the soil conditions observed in the field having average cone index value 1160 kPa. It was measured up to a depth of 0.15 m by field scout digital cone penetrometer. Soil moisture level of 10.5 per cent (db) was maintained during the experiments as agricultural operations are usually performed at this moisture level. Two types of commonly used sweeps i.e. sweep 1 (Duck foot sweep) and sweep 2 in tractor drawn cultivator for in the region were selected for the experiments (Fig. 1).

These sweeps were clamped on the shank which was mounted on the tool frame. The selected cultivator

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sweeps are normally used for tillage sowing and intercultural operations. Keeping these three operations in view the experiments were conducted with in the range of 0.04 m to 0.16 m depth and 0.97 m/s to 1.81 m/s speed of operation. These operations are normally performed within this range. Experimental parameters of the study are given in Table 1.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameters</th>
<th>Levels</th>
<th>Particulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool parameter</td>
<td>1 Tool type</td>
<td>2</td>
<td>Sweep 1, sweep 2</td>
</tr>
<tr>
<td>System parameters</td>
<td>1. Speed, m/s</td>
<td>4</td>
<td>0.97, 1.25, 1.5, 1.8</td>
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<tr>
<td>Soil parameters</td>
<td>2. Depth of operation, m</td>
<td>4</td>
<td>0.04, 0.08, 0.12, 0.16</td>
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<tr>
<td></td>
<td>1. Soil type</td>
<td>1</td>
<td>Sandy loam soil</td>
</tr>
<tr>
<td></td>
<td>2. Moisture content</td>
<td>1</td>
<td>10.5 %, (db)</td>
</tr>
</tbody>
</table>

Parameters measured during the experiment:

Soil disruption:

It was classified as surface and subsurface soil disturbance. The surface soil disturbance or spoil is a measurement of the amount of soil displaced above the original soil surface by the tillage process and subsurface soil disruption or trench is the area that is disrupted below the soil surface (Raper, 2005).

Soil disruption was measured with the help of soil profilometer. The profilometer was fixed across the trench and the main scale was adjusted with knobs and spirit level to keep it horizontally leveled. With the help of plum bob the vertical depth or height of the soil surface was determined at every 2 cm horizontal distance on the main scale. Replicated observations of soil disruption were recorded for each of the tillage tools. After completion of surface disruption measurement the profilometer was kept installed and the manipulated soil mass was removed from the trench below the profilometer with hand without disturbing the instrument and care was taken to ensure that only soil loosened by tillage was removed. The performance of sweeps were compared on the basis
geometric parameters of spoil and trench profiles (Fig. 2) and their areas of disruption. The data were statistically analyzed using SPSS software.

It was observed that at lower depths and speeds of operation sweep 1 resulted in 8.45 per cent higher crescent height than sweep 2 (0.0355 m). This value increased to 46.66 per cent of sweep 2’s crescent height (0.0225 m) when speed increased up to 1.81 m/s. A similar trend was observed at higher depth of operation where sweep 1 resulted in higher crescent height values of 0.074 m and 0.061 m as compared to that of sweep 2 (0.0715 m and 0.06 m), respectively. It suggests that low crescent height is observed at higher depths and higher speeds, respectively. This may be due to the speed factor which resulted in more soil movement out side the furrow. Similar findings have been reported by Liu and Kushwaha (2006) that speed of operation affects the crescent height of furrow.

RESULTS AND DISCUSSION

ANOVA showed that tool shape, speed and depth of operation and their interactions affected spoil and trench area significantly.

Effect of tool, speed and depth of operation on soil profile:

Fig. 3 and 4 show spoil and trench profiles created by two sweeps at different speeds and depths. It is observed from the figures, that spoil furrow width (2b) and spoil furrow depth (d) increased with an increase in either speed or depth of operation for both sweeps. This may be attributed to increase in tillage speed and depth which resulted in loosening of more soil and redistributing it in a wider length outside the trench. Similar findings were also reported by Liu and Kushwaha (2006).

At lower depth of operation both sweeps resulted in about same spoil furrow width when speed of operation increased from 0.97 m/s (0.36 m) to 1.81 m/s (0.54 m). At higher depths of operation sweep 2 gave 16.66 per cent more spoil furrow width than sweep 1 (0.48 m) at 0.97 m/s speed. This increase reduced to 5.71 per cent when speed increased to 1.81 m/s. This may be attributed to the shape of sweep 2 which resulted in spoil throw with lower crescent height at higher depths of operation. Similar findings have been reported by Liu and Kushwaha (2006). Sweep 2 gave 14.81 per cent more spoil furrow depth than sweep 1 at lower depth and speed whereas sweep 1 resulted in 2.81 per cent more spoil furrow depth when speed increased from 0.97 m/s to 1.81 m/s. For same increase in speed at higher depths sweep 1 gave 5.88 and 54.54 per cent more spoil furrow depth than sweep 2, respectively. This may be due to more soil throw out of furrow by sweep 1 resulting in higher soil furrow depths as that of sweep 2.

Effect of tool, speed and depth of operation on spoil area:

Fig. 5 shows that spoil area increased with an increase in depth and speed of operation for both sweeps. Spoil area increased at a higher rate when depth of operation increased from 0.04 m at all forward speeds. However, at higher speeds of operation increase in depth beyond 0.04 m did not affect spoil area to a large extent specially for sweep 2. For the tools tested it was depth of operation which affected more the spoil area than the speed of operation. At lower depths with the increase in speed the rate of increase in spoil area was highest (14.59 per cent) for sweep 1 at given speed of operation. Sweep 1 operating at a depth of 0.12 m at forward speeds of 0.97 m/s, 1.53 m/s and 1.81 m/s resulted in non significant change in spoil area as compared to sweep 2 operating at 0.08 m depth and 1.25 m/s forward speed and 0.16 m depth at 0.97 m/s and 1.53 m/s forward speed, respectively.

Effect of tool, speed and depth of operation on trench area:

Fig. 6 shows that trench area increased with an increase in depth and decrease with an increase in speed of operation for both sweeps. Sweep 2 resulted in highest trench area (0.0198 m$^2$) among the tool tested.

Similar to spoil area, it was depth of operation which affected more the trench area than the speed of operation. At lower depth of operation (0.04 m) sweep 1 gave non significant change in trench area when speed of operation increased from 0.97 to 1.25 m/s and from 1.25 m/s to 1.81 m/s whereas at higher depth (0.16 m) trench area was non significant when speed increased from 1.25 m/s to 1.81 m/s. Also at all depths sweep 2 resulted in non significant change in trench area when speed increased.

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Fig. 3: Spoil and trench profiles at different speeds and depth of operation for sweep 1
Fig. 4: Spoil and trench profiles at different speeds and depth of operation for sweep 2.
from 1.25 m/s to 1.53 m/s. However, it increased at a higher rate for sweep 1 at 0.97 m/s (352.07 per cent) and 1.8 m/s (355.16 per cent) forward speed when depth of operation increased from 0.04 m to 0.16 m. This may be attributed to the wide wing shape of sweep 2 which caused more soil failure as compared to other tested tools resulting in higher trench area. The wide curved surface of sweep 1 might have resulted in higher rate of increase in trench area with increase in depth of operation. Similar findings have been reported by Hanna et al. (1993).

Conclusion:

Spoil furrow width and depth increased with the increase in depth and speed of operation whereas reverse trend was observed for crescent height which decreased with increase in speed of operation. Spoil area was directly proportional to depth and speed of operation whereas, trench area decreased with increase in speed of operation for both sweeps. It was depth of operation which affected more the spoil and trench area than speed of operation. However, Sweep 1 gave highest spoil area (16.0745 x 10^3 m^2) whereas Sweep 2 resulted in higher trench area (17.45 x 10^3 m^2).

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REFERENCES


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