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Soil bin studies on the selection of furrow opener for conservation agriculture

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ABSTRACT

Conservation agriculture is a set of soil management practices include conservation tillage, residue management and crop rotation. Conservation tillage deals with tillage practices that retain at least thirty per cent of previous crop residues. Present study is aimed to assess the effect of furrow openers and their forward speed on soil physical properties, soil disturbance and maize stalk residue cutting under soil bin condition. Four types of furrow openers were tested *viz.*, Inverted T-type furrow opener with plain rolling coulter, single disk furrow opener, double disk furrow opener and double disk furrow opener with plain rolling coulter operated at three forward speeds (1.5 km h^{-1}, 2 km h^{-1} and 2.5 km h^{-1}). Results showed that forward speed was inversely proportional to soil moisture retention, soil bulk density and soil penetration resistance. It was also observed that double disk furrow opener with plain rolling coulter resulted in maximum soil moisture retention (11.2%), higher bulk density (11.2 gm cc^{-1}), higher penetration resistance (1.37 MPa), minimum soil disturbance profile at forward speed of 1.5 km h^{-1}. The maize stalk residue cutting was effective at all forward speeds with double disk furrow opener with plain rolling coulter. Hence, the double disk furrow opener with plain rolling coulter was best suited for conservation agriculture.

Key words: Conservation agriculture, Conservation tillage, Soil physical properties, Soil disturbance profile, Coulter, Residue management

INTRODUCTION

Conservation agriculture management practices minimize disruption of soil structure and improves natural biodiversity. The basic principles of conservation agriculture are conservation tillage, residue retention and crop rotation. Conservation tillage is defined as tillage and planting system that retains at least 30% of cover crop residues of previous crop on the soil (McCarthy *et al.*, 1999). Conservation tillage system reduces erosion and labor requirement, improves soil environment for crop growth and conserves energy.

Conservation tillage has advantages along with associated risk of poor stand establishment and therefore limits its adoption by farmers. In conservation tillage, furrow characteristics influence the germination and emergence of crop in different soil conditions. Some of these characteristics are compaction of soil in the furrow, draft power requirement, operational speed and planting depth. Furrow opener is the only component of any seed drill which opens soil for seed bed preparation and sowing. Furrow opener opens slit in the soil and seeds and fertilizer are dropped in it. If furrow opener widens the slit, soil disturbance increases. Furrow opener selection depends on soil and operating conditions. Furrow openers used in conservation tillage are different than conventional tillage. In order to assess the performance of furrow opener, it is important to identify the factors which affect soil physical properties and germination of seed. Therefore, designing of furrow opener depends on many factors like type of soil, speed of operation and depth of operation. Numbers of experiments had been carried out to optimize rake angle of furrow openers (Siemens *et al.*, 1965). Johnson and Buchele (1961) studied the effect of varying soil granule and degree of compaction on soil moisture loss and plant emergence in sandy soil. A soil granule of 0.18 mm at top layer showed better moisture retention capacity as compared to 0.76 mm soil granule. Bateman (1963) studied the effects of soil compaction on soil properties and it was found that clay soil was susceptible to compaction which caused high mechanical impedance in crop establishment.

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Furrow opener can be evaluated in lab conditions to assess depth of sowing and soil disturbance profile and seed germination and crop yield and can be evaluated in the field. Researchers have studied different furrow openers and their effect on soil moisture and seed germination. Baker (1976) studied the performance of furrow openers including disc, chisel and hoe types in the lab. It was observed that germination was significantly higher with chisel (77%) than hoe (26%) and disc (27%). It was mainly due to more soil moisture retention achieved in chisel than hoe and disc furrow openers. Wilkins *et al*. (1983), evaluated single disc, double disc, hoe type and deep opener and it was observed that moisture retention was higher for hoe and deep furrow openers. Freebairn *et al*. (1986), studied 64 different openers in heavy soil texture and it was observed that coulter (50 mm diameter) with spear point furrow opener followed by a rubber press wheel was the most promising arrangement. Choudhary *et al*. (1988), introduced an inverted-T opener and observed that germination percentage was more compared to other furrow openers. According to Raoufat and Mahmoodieh (2005), planters equipped with rolling coulter attachment improves seeding indices in conservation tillage systems. They observed that plain rolling coulter had better performance as compared to notched ones specially for planting corn in irrigated wheat residues. Karll *et al*. (1978), reported that plain and rippled coulters cut the maize trash more clearly as compared to notched ones. Keeping in view the above studies and their outcomes, present study was undertaken to assess the effect of furrow opener and their forward speed on soil physical properties, soil disturbance profile and residue cutting.

MATERIALS AND METHODS

Experiments were conducted in the soil bin at Division of Agricultural Engineering, IARI, New Delhi, India during Jan-March 2014. The dimensions of soil bin was 25 m long, 1.8 m wide with one metre deep, filled with loamy clay soil (sand 80%, clay 10% and slit 10%) as shown in Fig. 1. The soil was tilled by tiller to a higher depth than the derived working depth. To maintain uniform soil conditions such as soil moisture, bulk density, cone index, water was sprinkled on the soil and the moisture content was periodically monitored throughout the soil bin until derived moisture was achieved. The seedbed was prepared by levelling and compacting with smooth roller. Before test runs, three random samples were collected for measuring initial soil moisture content and soil bulk density. The soil moisture content was measured by keeping the sample in oven at 105 ^{o}C for 24 h. The tests were performed 96 h after achieving desired soil moisture condition (Abbaspour *et al*., 2009). A cone penetrometer of 28 mm base diameter and 30^{o} cone angle was used to measure the soil resistance. Before starting the test for uniformity of compaction, three observations of soil penetration resistance were taken in the soil bin. The soil-tool trolley was operated for uniform bulk density (1.5 gm/cc) and soil penetration resistance (1.45 MPa). Subsequent changes in soil moisture content, bulk density, penetration resistance and soil disturbance profile were observed after operating four types of furrow openers.

Furrow openers investigated were; inverted T with plain rolling coulter, single disk, double disk and double disk with plain rolling coulter. The degree of disturbance and displacement of soil mainly depends on the rake angle, depth and speed of operation. The design of furrow openers was based on optimum rake angle. Rake angle is angle which a furrow opener makes with horizontal line parallel to the direction of travel (Shiri and Raoufat, 2006). Furrow openers are generally of two types, one with rake angle less than 90^{o} and the other with rake angle greater than 90^{o}. The inverted T-type

Fig.1. Soil bin preparation

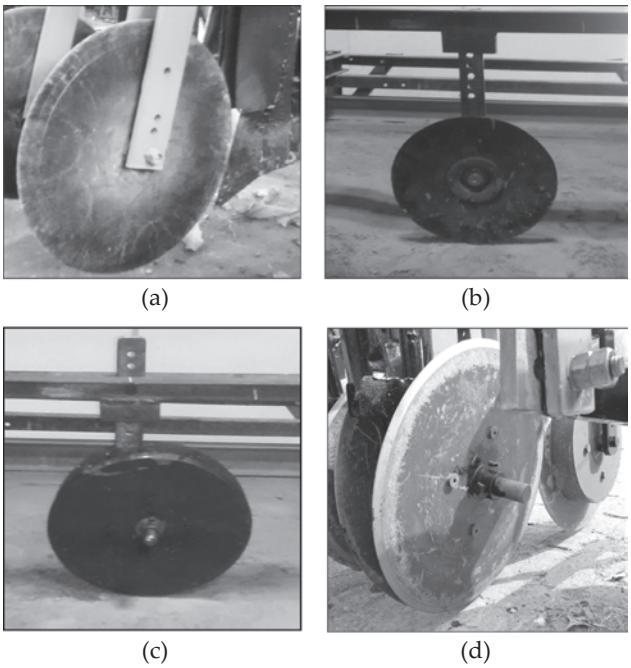


Fig. 2. Different furrow openers used for experimentation. (a) Inverted T-type furrow opener with plain rolling coulter (b) Single disk type furrow opener (c) Double disk type furrow opener (d) Double disk type furrow opener with plain rolling coulter

furrow opener with plain rolling coulter consisted of a single plain rolling coulter (36 cm Õ) followed by inverted T-type furrow opener [Fig. 2 (a)]. The plain rolling coulter cuts residues and makes a fine slit in soil and inverted T-type furrow opener widens the slit by displacing the soil outward. Single disk (Disk angle 30^0) furrow opener consisted of high carbon steel disk of diameter 38 cm and positioned at 10^o of tilt angle in the direction of travel [Fig. 2 (b)]. It had tendency to cut residues with minimum disturbance of soil and form a narrow slit in the soil. Double disk furrow opener consists of two plain rolling disks arranged in such a way that outer edges of the discs cut and displace soil downward and outward which results in 'V' shaped furrow in the soil [Fig. 2 (c)]. Double disk furrow opener with plain rolling coulter consists of a flat vertical disk coulter mounted in front and close to inclined double disc assembly [Fig. 2(d)]. The front mounted coulter assisted in cutting residues and form a vertical slit which tends to give less disturbance and more uniform furrow as well as more control over subsequent soil fracture.

A completely randomized factorial design with four furrow openers and three operating speeds (1.5, 2 and 2.5 km h^{-1}) was performed. The effect of furrow openers and operating speed on soil physical properties, soil disturbance profile and maize stalk residue (5 t/ha) cutting was studied. Each treatment was replicated three times. The selected depth for operation was 5 cm. After each test run the soil surface disturbance profile and cross-sectional area opened by the tool were measured at three random locations. The effect of furrow openers and operating speeds on the soil physical properties and maize stalk residue cutting were assessed by least significant difference method ($p \leq 0.05$).

RESULTS AND DISCUSSIONS

This section focuses on the effect of four furrow opener and forward speed on the soil moisture retention, soil bulk density, soil penetration resistance, soil disturbance profile and maize stalk residue cutting under soil bin condition. Results indicated that the furrow opener had a significant effect on soil moisture retention, soil bulk density, soil penetration resistance and maize stalk residue cutting at the 5% level of significance. Whereas, the forward speed singificently effected soil moisture retention, soil bulk density and soil penetration resistance at the 5% level of significance but it did not effect maize stalk residue cutting significantly.

Soil moisture retention

Furrow opener and forward speed significantly affected the soil moisture retention (Table 1). The initial soil moisture content in the soil bin was 12% which reduced subsequently, after 24 hours of test run. The soil moisture retention was maximum in case of the double disk furrow opener with plain rolling coulter (11.2%), followed by double disk furrow opener (10.61%), single disc furrow opener

Table 1. ANOVA for effect of furrow openers and forward speed on soil moisture retention

Source of Variation	Degree of Freedom	Sum of square	Mean Square	F- Calculated	Significance
Furrow opener (A)	3	11.71	3.903	46,799.13	0.00*
Forward speed (B)	2	4.16	2.081	24,948.67	0.00*
A X B	6	0.49	0.081	972.292	0.00*
Error	24	0.002	$8.3x\ 10^{-5}$		
Total	35	16.36			

*Indicates significance at the 5% probability level.

(10.18%) and inverted T-type furrow opener with pain rolling coulter (9.35%) at 1.5 km h^{-1}. It was observed that the soil moisture retention decreased with increase in furrow openers speed (Fig. 3). This could be due to the fact that with speed, more soil gets disturbed and get exposed to wind. This is also supported by the fact that double disk furrow openers with rake angle more than 90° pushed the soil to the furrow wall making them firm resulted in minimum soil disturbance hence the soil moisture reduction was lowest in case of double disk furrow openers with coulter attachment. Similar reults of double disk openers are reported by Tessier *et al.* (1991).

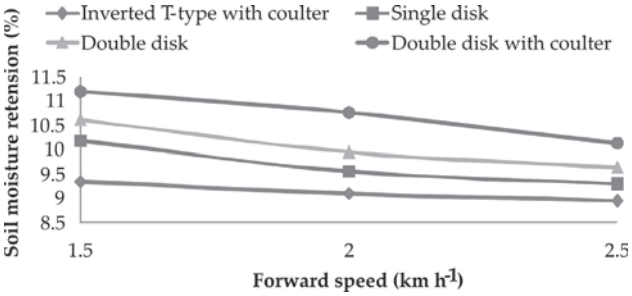


Fig. 3. Effect of furrow openers and forward speeds on soil moisture retention

Soil bulk density

The effect of furrow openers and forward speeds on soil bulk density at 5 cm depth was measured (Fig.4). Because of different soil disturbance with various types of furrow openers the soil bulk density is varied. Results indicated that there was a significant difference in soil bulk density after furrow openers operation at different forward speeds (Table 2). The highest bulk density (1.52 gm cc^{-1}) was observed at speed of 1.5 km h^{-1} in case of double disk furrow opener with pain rolling coulter whereas minimum bulk density (1.28 gm cc^{-1}) was found in Inverted T-type furrow opener with plain rolling coulter at speed of 2.5 km/h. As the forward speed increased the bulk density decreased. This may be due to fact that at higher speeds of operation, tractor's tractive efficiency

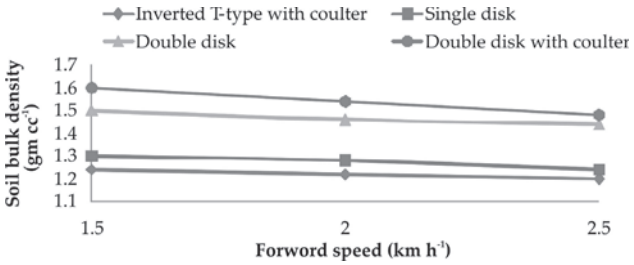


Fig. 4. Effect furrow openers and forward speed on soil bulk density

becomes very low leading to skidding. Similar results were reported by Kasap (2001) who found that bulk density decreased with increase in operating speed in conventional tillage and direct drilling, but there was no statistically significant difference on soil bulk density with operational speed. In contrast to this, Morad *et al.* (2007) reported that the soil bulk density increased with increasing forward speed this could attributed to vibrations of tractor and agricultural machine which increases bulk density.

Soil penetration resistance

Penetration resistance of the soil depends on its physical and mechanical properties, operating conditions (speed and depth) and penetrating tool geometry. Changes in the soil penetration resistance for four types of furrow openers were significant at 1% level of significance (Table 3). The highest soil penetration resistance (1.36 MPa) was observed at 1.5 km/h forward speed for double disk furrow opener with plain rolling coulter followed by double disk furrow opener (1.3 MPa), single disk furrow opener (1.21 MPa) and inverted T-type furrow opener with plain rolling coulter. The forward speed had significant difference with soil penetration resistance and furrow openers. However, the soil penetration resistance decreased with increased forward speed (Fig.4). Minimum soil penetration resistance was the effect of higher forward speed (2.5 km h^{-1}). This may be attributed to the more pulverization that tends to expose soil particles, increases soil void ratio, which in turn

Table 2. ANOVA for the effect of furrow openers and forward speed on soil bulk density

Source of Variation	Degree of Freedom	Sum of square	Mean Squares	F-Calculated	Significance
Furrow opener (A)	3	0.65	0.216	3,111.44	0.00*
Forward speed (B)	2	0.03	0.015	212.683	0.00*
Interaction A X B	6	0.006	0.001	13.321	0.00*
Error	24	0.002	$8.3x10^{-5}$		
Total	35	0.69			

*Indicates significance at the 5% probability level.

Table 3. ANOVA for the effect of furrow openers and forward speed on soil penetration resistance

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F-Calculated	Significance
Furrow opener (A)	3	0.813	0.251	2567.25	0.000*
Forward speed (B)	2	0.105	0.053	498.96	0.000*
Interaction A X B	6	0.014	0.002	22.44	0.000*
Error	24	0.003	$1.25x10^{-4}$		
Total	35	0.935			

*Indicates significance at the 5% probability level.

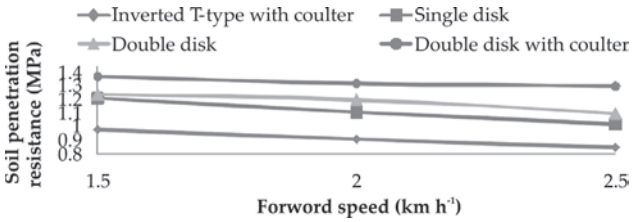


Fig. 5. Effect furrow openers and forward speed on soil penetration resistance

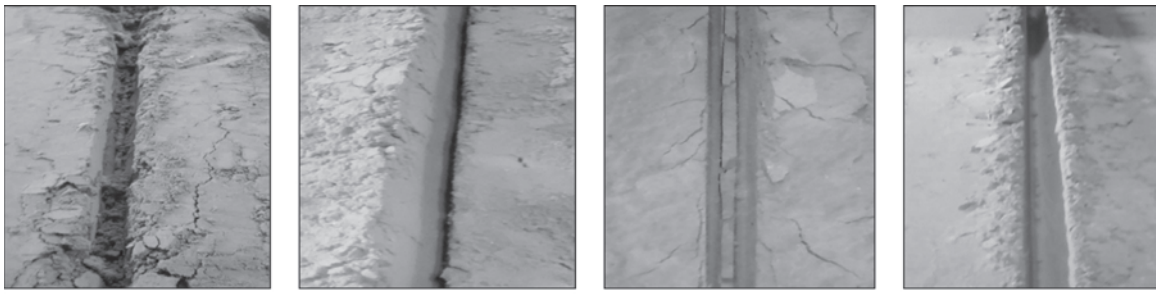
decreases soil penetration resistance. These results generally agree with earlier findings elsewhere under varying soil conditions that soil penetration resistance decreased with increase in speed of operation (Altuntas *et al.,* 2006).

Soil disturbance profile

It was observed that as the forward speed of furrow openers increased, the soil disturbance increased. The slit opened by inverted T-type furrow opener with plain rolling coulter was widest (30 mm) compared to single disk furrow opener (25 mm), double disk furrow opener (20 mm), double disk furrow opener with plain rolling coulter (16 mm) (Fig.5). The soil disturbance profile made by double disk furrow opener and double disk furrow opener with plain rolling coulter attachment was similar with difference of furrow width and slit opening (Fig. 6).

Maize stalk residue cutting

The furrow openers had a significant effect on maize stalk residue cutting. Based on the Duncan's Multiple Range Test, the double disk furrow opener with plain rolling coulter had cut all maize stalk residue at all three forward speeds followed by inverted T-type furrow opener, double disk furrow opener and single disk furrow opener (Table 4). The maize stalk residue cutting performance of the furrow openers with plain rolling coulter works satisfactory compared to furrow openers without coulter. This may due to sharp coulter cutting of residue in front of furrow openers which prevented clogging of loose stalks by fixed tine furrow openers. Similar results were also observed by



(a) (b) (c) (d)

Fig. 6. Soil disturbance profile made by (a) Inverted T-type furrow opener with plain rolling coulter; (b) Single disk furrow opener; (c) Double disk furrow opener; (d) Double disk furrow opener with plain rolling coulter.

Table 4. ANOVA for effect of furrow openers and forward speed on maize stalk residue cutting

Source	Degree of freedom	Sum of square	Mean square	F calculated	Significance
Replication	2	1.055	0.5277	0.07	0.9289
Furrow opener (A)	3	22252.08	7417.36	1039.74	<0.0001*
Forward speed (B)	2	7.055	3.52	0.49	0.6165
Interaction (A) x (B)	6	9.16	1.52	0.921	0.9683
Error	22	156.94	7.13		
Total	35	22426.3			

R^2= 0.99; CV= 4.55; RMSE= 2.67; *Significant at 5 % level

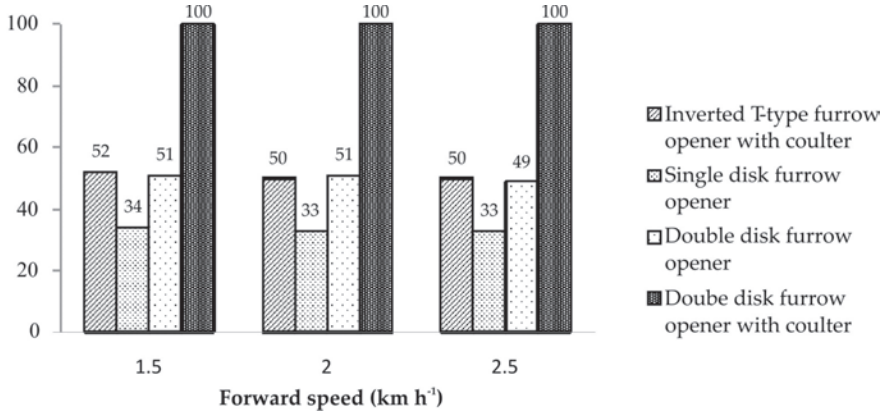


Fig. 7. Effect furrow openers and forward speeds on maize stalk residue cutting

Chang *et al.* (2013), they reported that sharpness was the most important coulter characteristic which influenced maize stalk residue cutting.

CONCLUSIONS

The effect of furrow opener and forward speed had a significant effect on soil physical properties such as soil moisture retention, soil bulk density and soil penetration resistance. The maize stalk residue cutting significantly differ with furrow openers. Forward speed did not have signifficant effect on maize stalk residue cutting (Fig. 7). The soil moisture retention, soil bulk density and soil penetration resistance decreased with increasing forward speed for all types of furrow openers. Lowest changes in soil moisture content, soil bulk density and penetration resistance were observed in case of double disk furrow opener with plain rolling coulter. Double disk furrow opener with plain rolling coulter attachment opened fine slit in the soil without much soil disturbance. The double disk disk furrow openers with plain rolling coulter cut all maize stalk residue at all selected forward speeds. Hence, the double disk furrow opener with plain rolling coulter is best suited for conservation agriculture in maize-wheat cropping system.

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