Performance evaluation of furrow openers for sugarcane planting in sub-tropical India

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Abstract: The research was conducted to evaluate the effects of different types of furrow opener, depth and speed of operation on soil properties, draft force, soil disturbance and germination percentage and to select the best furrow openers for establishment of sugarcane crop. The experiment was conducted on a silt loam textured soil using three furrow openers viz. IISR furrower, IISR deep furrower and conventional type ridger operated at three average speeds of 0.96, 1.46 and 3.7 km h^{-1} and three depths of furrows 100, 150 and 250 mm. The parameters like draft force, soil penetration resistance, ridge height, volume of soil disturbed and germination percentage were determined. Soil penetration resistance decreased with increase operational speeds of each furrow openers type and increased with increase in depth of furrow. Soil disturbance characteristics and draft force requirements increased with increases in the speeds and depth of operation. The mean germination percentage was 12.9% to 41.6% at 30 and 45 days after planting (DAP) based on type of furrow opener, speed and depth. The lowest soil penetration resistance, clear furrow and better germination were found with Indian Institute of Sugarcane Research (IISR) deep furrower.

Keywords: furrow opener, sugarcane, soil penetration resistance, draft force, deep furrow

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1 Introduction

India, the second largest sugarcane (Saccharum *officinarum*) producing country after Brazil, cultivates sugarcane in 5.06 million ha area with a production of 334.5 million tonnes with average productivity of 66.08 thousand kg ha^{-1} (Anonymous 2012-2013). Among these, Uttar Pradesh alone occupies about 43.68% of the total area under sugarcane cultivation dominating in production but in terms of productivity, Tamil Nadu leads with 106.8 thousand kg ha^{-1} followed by Karnataka (80 thousand kg ha^{-1}) which is higher than the national average productivity. This crop needs the highest labour as compared to any other crop requiring more than 375 man-days ha^{-1} for different operations. Considering the present trend of availability of labour for sugarcane production, it has been experienced that use of modern machinery is inevitable. Use of machinery helps in labour savings, ensures timeliness of operations, reduces drudgery, helps in improving quality of work, reduces cost of operation and ensures effective utilization of resources.

Farmers still use conventional, energy intensive, less efficient tools and equipment to carry different cultural operations for sugarcane cultivation (Singh et. al., 2016). Tractor operated rotary plough, cultivator and conventional ridger are the main farm equipment in sugarcane cultivation. Furrow opening is the main unit operation in sugarcane planting performed by tractor/bullock operated conventional ridger by most of the farmers in India followed by the subsequent operations manual seed sett cutting, putting sett in the furrows, fertilizer & insecticides application and covering and pressing soil over the sett.

In sub-tropical India, sugarcane planting is done at 75

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and 90 cm row to row spacing during spring (February-March) and autumn (October-November) season, respectively. Different methods of sugarcane planting are being used viz. flat planting, trench planting, ring pit method, skip furrow irrigated method etc. A deep furrow/trench is recommended for sugarcane planting for higher yield and better ratooning. Hence, two type of furrow opener (deep furrow opener and furrower) was developed at Indian Institute of Sugarcane Research, Lucknow for opening the deep furrows/trench for planting sugarcane in furrows.

Furrow opener is an important component as far as sugarcane planter is concerned that influenced the germination and crop stand of sugarcane. Common type of furrow openers used in sugarcane planters are ridger type, slit type and disc type. Furrow characteristics influence the germination and emergence of crop under different soil conditions. Therefore, designing the furrow opener needs many factors that affect the performance of furrow openers. Plant emergence and crop yield can be affected indirectly by the performance characteristics of furrow openers and quality of operation. Some of these characteristics are the compaction in the furrow, planting depth, draft power and operational speeds. Increases in the depth of furrow openers increase the draft force and affect the recovering of soil in the furrows. Salata et al. (1986) found that the opener type affected soil strength and root growth of sugarcane in sandy soils. A scarifying furrow opener resulted in 25% less soil strength below the furrow compared with a Roseti and conventional furrow opener. The extent of soil disturbance is affected by many factors, such as the travel speed, working depth, and geometry of the opener (Gratton and Chen, 2003). Soil penetration resistance (SPR) has been used by several researchers to quantify the soil quality and to identify the layers with increased degree of compaction (Moraes et al., 2013).

Performance evaluations of various types of furrow openers have been studied by several researchers. The results showed that the characteristics of furrow openers have affected soil parameters, the draft force, seed distribution, plant emergence and plant growth (Chaudhuri, 2001). Giron et al. (2005) evaluated the effect of soil compaction and water content on resulting force acting on three seed drill furrow openers. The greater were the bulk density and water content of soil, greater was the draft force measured in three furrow openers. Doan et al. (2005) evaluated the effect of residue type on the performance of no-till seeder openers. However, no much work on performance of furrow openers for sugarcane planting has been reported.

The performance of the furrow openers for sugarcane planting concerned the quality of planting and furrow characteristics. Draft force is also an important performance indicator of an opener and any other soil engaging tools (Collins and Fowler, 1996; McKyes, 1985). Compactions of soil at planting depth, loose soil retained in the furrow, ridge height were considered as measure of quality of planting. The draft force, operational speed and depth of operation affect the performance of furrow openers and furrow characteristics. These parameters have a great concern for providing proper environment for establishment of sugarcane crop. The objective of this study was to evaluate the relationship between different furrow opener and soil parameters, draft force, germination in respect of operational speed and depth of operations. This study aimed to determine the most proper combination of furrow opener, depth and operational speeds to be recommended to manufacturers and growers.

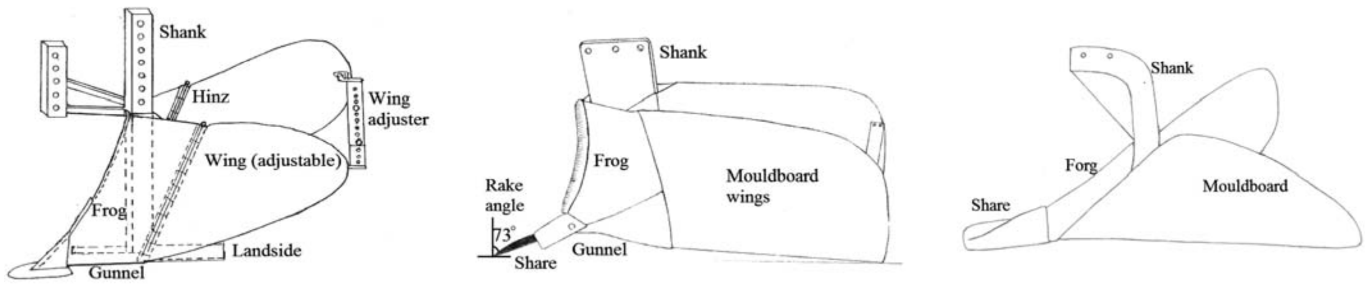
2 Material and methods

Field experiment was conducted at ICAR-Indian Institute of Sugarcane Research, Lucknow to evaluate the performance of three different type of furrow openers used for furrow opening for sugarcane planting. The experimental design was split-split plot design with three replications viz. furrow openers (three types-IISR furrower, IISR deep furrower and conventional ridger), operational speed (0.96, 1.46 and 3.7 km h^{-1}) and depth of operation (100, 150 and 250 mm). The size of the experimental plot was 6×2.25 m. The variety of sugarcane used in the experiment was CoLk 09202 planted at 75 cm row spacing on February, 2016. After furrow opening, manual planting of sugarcane was done by putting the setts in the furrows. All other inputs such as fertilizer and insecticide application etc. remain the same in all the plots. The details of the furrow openers used in the experiment are given in Table 1.

Table 1 Technical details of furrow openers used in the experiment

Parameters	Type of furrower/ridger		
	IISR furrower	IISR deep furrower	Conventional ridger
Overall dimensions, L×W×H, mm	950×460×750	1250×560×660	850×520×490
No. of bottom	3	3	3
Size of shank, L×W×T, mm	720×100×20	600×200×10	430×60×20
Rake angle, (°)	45	73	30
Width of tip of share, cm	8.5	2.5	7.5
Weight, kg	27.5	44	24

Furrow openers used in the experiments are shown in Figure 1. The IISR furrower and IISR deep furrower was designed at ICAR-Indian Institute of Sugarcane Research, Lucknow and conventional ridger used was commercially available. The soil in the experimental plots was silty loam in texture (sand 30%, silt 46% and clay 24%). The soil samples taken from furrow depth were used for determination of soil moisture content and bulk density. A cylindrical core sample was used for taking core samples for bulk density measurement. These samples were then dried at 105° C to determined dry bulk density and moisture content. Soil penetration resistance was measured with hand held electronic cone penetrometer CP40 II. Cone penetrometer was used to record the reading from the bottom of furrow in all the treatments. Draft force was measured with the spring dynamometer attached between to the front of the tractor on which the implement was mounted. Another auxiliary tractor was used to pull the implement mounted tractor with the latter tractor in neutral gear but the implement in the operating position. The draft was recorded in the measured distance. Again, on the same field, implement was lifted out of the ground and recorded the draft. The difference of the both reading was the draft force of the implement. Furrow openers were operated through the soil at three depths and three different operational speeds and data was recorded from the dynamometer. The ridge heights were determined by measuring the top ridge to the ground level in all the treatments. Soil disturbed by the furrow opener per meter length was collected and weigh. Results of the split-split plot design were analyzed.



a. IISR Furrower b. IISR deep furrower c. Conventional ridger

Figure 1 Furrow openers used in the experiment

3 Results and discussion

The relationship between the three- furrow opener, speed of operation and depth of operation compared in term of soil parameters, soil disturbed, draft force, specific draft, ridge height and % germination of sugarcane crop is discussed in this chapter. The average soil moisture content and bulk density was 16.9% with 1.34 g cm^{-3} at 0-250 mm depth. Table 2 and 3 indicated the two-way variance and mean values of different parameters as affected by furrow openers, operating speed and furrow depth.

3.1 Effect of furrow openers on soil penetration resistance

According to Table 3, there was significant effect of furrow openers, speed and depth of furrow on soil penetration resistance. Both IISR furrower and conventional ridger showed the soil penetration resistance at par and it was 678.15 kPa with IISR deep furrower which is significantly lower than other two furrow openers. The soil penetration resistance decreased with increasing operational speeds. The soil penetration resistance decreases significantly with increase in operating speed and it was lowest (658.15 kPa) at

3.7 km h^{-1}. The depth of furrow also affects the soil penetration resistance significantly and it increases with increase in depth of furrows. However, up to 100-150 mm depth, the soil penetration resistance was observed less as compared to 250 mm depth. This may be due to the fact that normal ploughing in the soil takes places up to depth of 150-200 mm after that there is a hard pan which increases the compaction of soil. The IISR deep furrow openers have minimum soil penetration resistance at all depths followed by IISR furrower and conventional ridger. In this research, the effect of operational speeds on the soil penetration resistance was in accordance with Altuntas et al. (2006).

Table 2 Two ways analysis of variance for different parameters

Source of variation	Soil Penetration resistance, kPa	Ridge height, mm	Soil disturbed, kg m^{-1} length	Draft force, kN	Specific draft, N mm^{-2}	Germination %	
						After 30 DAP	After 45 DAP
F-value							
Furrow opener (F)	63.18^{*}	85.36^{*}	1453.3^{**}	16.67^{*}	127.75^{*}	11.71^{*}	35.06^{*}
Operating Speed (S)	426.98^{**}	53.13^{**}	65.97^{**}	44.27^{**}	83.52^{**}	3.47^{NS}	0.05^{NS}
Depth of furrow (D)	2884.98^{**}	343.48^{**}	449.25^{**}	64.02^{**}	432.83^{**}	40.07^{**}	17.75^{**}
F * S	5.36^{*}	0.177^{NS}	0.49^{NS}	0.36^{NS}	17.87^{**}	1.64^{NS}	2.60^{NS}
F * D	7.53^{*}	5.18^{*}	42.24^{**}	0.31^{NS}	24.13^{**}	2.67^{*}	1.87^{NS}
S * D	8.02^{**}	3.10^{*}	0.73^{NS}	0.54^{NS}	17.32^{**}	0.66^{NS}	4.44^{*}
F * S * D	0.53^{NS}	0.80^{NS}	0.52^{NS}	0.12^{NS}	3.03^{*}	2.72^{*}	1.05^{NS}

Note: *Significant at 5% (level of significance), p-Value<0.05-Significant at 5%, **p-Value <0.01- Significant at 1%, NS-Non Significant.

Table 3 Mean values of parameters as affected by furrow openers, operating speed and furrow depth

Source of variation	Soil Penetration resistance, kPa	Ridge height, mm	Soil disturbed, kg m^{-1} length	Draft force, kN	Specific draft, N mm^{-2}	Germination %	
						After 30 DAP	After 45 DAP
Furrow openers							
IISR furrower	758.15^{a*}	103.7^{b}	44.91^{b}	6.04^{b}	0.09^{a}	15.33^{b}	35.48^{b}
IISR deep furrower	678.15^{b}	117.3^{a}	55.59^{a}	6.99^{a}	0.06^{b}	18.54^{a}	38.99^{a}
Conventional ridger	784.81^{a}	85.0^{c}	27.50^{c}	6.22^{b}	0.09^{a}	14.92^{b}	32.17^{c}
SEd ±	9.83	0.25	0.53	0.18	0.0	0.82	0.81
C.D (*P*=0.05)	27.28	0.69	1.46	0.49	0.01	2.27	2.26
Operating Speed, km h^{-1}							
0.96	827.04^{a}	118.1^{a}	39.88^{c}	5.92^{c}	0.07^{b}	15.89	35.59
1.46	735.93^{b}	102.0^{b}	42.96^{b}	6.40^{b}	0.07^{b}	16.87	35.41
3.7	658.15^{c}	86.0^{c}	45.16^{a}	6.92^{a}	0.09^{a}	16.03	35.64
SEd ±	5.79	0.31	0.46	0.11	0.0	0.40	0.70
C.D.(*P*=0.05)	12.61	0.68	1.01	0.23	0.001	NS	NS
Depth of furrow, mm							
100	545.93^{c}	71.6^{c}	32.10^{c}	5.89^{c}	0.10^{a}	13.67^{b}	33.56^{c}
150	628.15^{b}	101.3^{b}	42.27^{b}	6.52^{b}	0.07^{b}	17.72^{a}	35.71^{b}
250	1047.04^{a}	133.2^{a}	53.63^{a}	6.84^{a}	0.06^{c}	17.40^{a}	37.36^{a}
SEd±	7.08	0.24	0.72	0.09	0.00	0.50	0.64
C.D.(*P*=0.05)	14.35	0.48	1.46	0.17	0.001	1.02	1.30

Note: *The main effect means for Furrow openers, Speeds and Depths within a column do not differ significantly (*P*=0.05) if followed by a similar lower-case letter a, b and c; NS=non-significant.

3.2 Effect of furrow openers on ridge height

There was significant effect of furrow opener ($P<0.05$), speed of operation and depth of furrows on ridge height. IISR deep furrower had the 117.3 mm ridge height which is significantly superior followed by IISR furrower and conventional ridger. The operating speed had also the significant effect on the ridge height. Ridge height decrease significantly with increase in operating speed of openers and it was 118.1 mm at 0.96 km h^{-1} which is maximum and the lowest 86 mm was observed at speed 3.7 km h^{-1} (Table 3). The ridge height also affected significantly by depth of furrow. Lower the depth of furrow, lower was the height of ridge and higher the depth of operation, higher the ridge height was found.

The maximum ridge height was observed with IISR deep furrow opener when it was operated maximum depth and at lower speeds. This may be due to more effective width and more depth of penetration of IISR deep furrow opener. The recovering of soil in the furrows was observed at higher speeds and at increased depth. Chaudhari (2001) also reported that the increases in depth with the furrow opener affected the recovering of soil in the furrow. However clear furrows at higher depths and at lower speeds was obtained in IISR deep furrower followed by IISR furrower and conventional ridger.

a. IISR Furrower

b. IISR deep furrower

c. Conventional ridger

Figure 2 Ridge and furrow formed by the furrow openers

3.3 Effect of furrow openers on draft force

The results of study from Table1 indicated that the draft force of furrow openers was significantly influenced by the size of furrow opener ($P<0.05$), operating speed and depth ($P<0.01$). As Chaudhuri, 2001 concluded based on the review of various seed openers, greater working depth results in higher draft force. Collins and Fowler, 1996 stated that for a 10 mm increase in seeding depth, the draft force increases by 20%. The comparison of three openers showed that IISR deep furrower had much draft force (6.99 kN). The highest draft force was obtained at 3.7 km h^{-1} speed of operation and at 250 mm working depth. This may be due to its greater rake angle and width than the other furrow openers. This is in accordance with the existing soil cutting theory that a tool with a wider cutting width requires higher draft force (McKyes, 1985). Darmora and Pandey (1995) also found that draft force is related to opener width, based on the test results of seven different openers. Many other researchers such as Sharma and Srivastava (1984), Giron et al. (2005), Altuntas et al. (2006) have studied the effect of some furrow openers design factors. They mostly agreed that greater the rake angle, speed of operation and width of furrow opener, greater is the draft force required. In this research, the effect of operational speeds on the draft force was in accordance with Sharma and Srivastava (1984), Altuntas et al. (2006). Hasimu and Chen (2014) also found that force requirements increased with the working depth of opener.

3.4 Effect of furrow openers on specific draft

Table 2 indicates that there was significant effect of furrow openers ($P<0.05$), speed and depth of furrow ($P<0.01$) on specific draft. Table 3 indicates that the specific draft of IISR furrower and conventional ridger was observed at par and it was having significant difference with IISR deep furrower. A decreasing response in specific draft was observed with an increase in depth of furrow whereas specific draft increases with increase in speed of operation. But the specific draft exhibited greater influence from depth of furrow than speed of operation in almost all the furrow openers. At 250 mm depth with all furrow openers, the specific draft was observed minimum as compared to other furrow openers. Among the furrow openers, IISR deep furrower was having lowest specific draft of 0.06 N mm^{-2} followed by conventional ridger and IISR furrower. This may be due to difference in size of the furrow openers and more furrows cross sectional area in IISR deep furrower than other furrow openers.

3.5 Effect of furrow openers on soil disturbed

Table 1 indicated that the furrow opener, speed and depth of furrow had significant effect (*P<0.01*) on soil disturbed per meter length of furrow. The soil disturbed was significantly differing with type of furrow openers. IISR deep furrower disturbed the maximum 55.59 kg of soil per meter length of furrow followed by 44.91 kg and 27.50 kg with IISR furrower and conventional ridger, respectively (Table 3). The weight of soil disturbed was found maximum at 3.7 km h^{-1} and 250 mm depth with IISR deep furrower followed by IISR furrower and conventional ridger. The weight of soil disturbed increased significantly with increase in depth of operation and speed of operation. Minimum soil disturbed was found at lower depth and at lower speed of operation and it is with conventional ridger. The present research results obtained were in accordance with Hasimu and Chen (2014) according to them soil disturbance characteristics increased with the working depth of opener.

3.6 Effect of furrow openers on germination

The statistical analysis indicated that the furrow openers (P<0.05) and depth of furrow (P<0.01) had significant effect on sugarcane germination at 30 and 45 DAP while operating speed had non-significant effect in both cases (Table 2). Among the furrow openers, IISR deep furrower showed the significantly higher germination percentage i.e. 18.54 % and 38.99 % after 30 and 45 DAP followed by IISR furrower and conventional ridger (Table 3). Many other researchers such as Kushwana and Foster (1993), Doan et al. (2005), Altuntas et al. (2006) studied the effect of furrow opener on seed emergence but one general conclusion is that the effect of furrow openers on plant emergence differs greatly. The germination percentage was 11.8% to 22.4 % after 30 days and it was 28.8% to 45.8% after 45 days of planting with different openers, depths and speeds. The germination was observed higher at higher depths. In case of IISR deep furrower at 250 mm depth, mean germination was 41.6% which was higher than the IISR furrower and conventional ridger, respectively. This may be due the fact that more moisture available at higher depths which helps in better germination. At all depths, germination with IISR deep furrower was higher and this might be due to its technically sound design which provide favourable environment for growth of the setts of sugarcane.

4 Conclusions

It was concluded for this study that the soil penetration resistance decreased with increasing operational speeds of each furrow openers type and depth of operation. The lowest soil penetration resistance at 100 mm was observed with IISR deep furrower. Soil disturbed and draft force requirements increased with the operational speeds and depth of operation. The draft force requirement was higher with IISR deep furrower where as specific draft was lowest than other furrow openers. The germination percentage was observed highest in IISR deep furrower. The performance of conventional ridger was found the lowest among all furrow openers. The management of soil by suitable scientifically designed furrow opener achieves a favourable environment for the germination and growth of sugarcane. Based on this study, IISR deep furrow openers found most efficient for sugarcane planting at average speed of 1.46 km h^{-1} and about 250 mm depth of operation.

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