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RESEARCH ARTICLE

Design and Development of a Tractor-Operated Disc-Type Sugarcane Ratoon Management Device

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Abstract Ratoon occupies more than 50 % of sugarcane area. Productivity of sugarcane ratoon crop could be improved by performing cultural operations like stubble shaving, cutting of side old roots (off barring) and application of fertiliser near to root zone during initiation of ratoon after harvesting. Studies have indicated that leaving trash in the field after sugarcane harvesting improves soil health and sustain ratoon yield. The existing machinery can work only in trash-free fields due to the presence of tines and shovels for off barring which dragged the trash and got clogged. For performing cultural operations in ratoon field with trash, disc-type ratoon management device (Disc RMD) was designed and developed at ICAR- Indian Institute of Sugarcane Research, Lucknow, India. It was equipped with stubble shaving serrated blades mounted on a disc, two tillage discs for off barring (pruning of old roots) on either side of the stubbles and device for application of fertiliser at root zone. Performance of the equipment was evaluated in sandy loam soil of ratoon field within a week after sugarcane harvest during 2013–14 and 2014–15. The effective field capacity of the equipment was 0.28 ha h^{-1} at forward speed of 0.67 m s^{-1}. Use of Disc RMD saved cost of operation of ratoon initiation by ₹ 800 (US$ 12.04) ha^{-1} (35 %) and ₹ 2300 (US$ 34.60) ha^{-1} (60 %) when compared to earlier developed machinery and conventional practice, respectively. Use of Disc RMD resulted in labour saving of 112 labour-h ha^{-1} which was 15 times effective than conventional practice. The use of developed Disc RMD significantly improved tillering by 10.6 and 8.6 %, millable canes by 19.8 and 16.2 % and sugarcane yield by 10.8 and 13.4 % as compared to earlier developed machinery and conventional practice, respectively. The corresponding cumulative benefits due to saving in cost of operation and increase in yield of sugarcane, in case of Disc RMD, were ₹ 16,700 (US$ 251.24) and ₹ 21,600 (US$ 324.96) ha^{-1}, respectively.

Keywords Sugarcane · Tractor · Ratoon · Disc RMD · Off barring · Fertiliser · Stubble Shaving · Trash · Mulching

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Introduction

Sugarcane is an important cash crop of India. It is cultivated in about 5.3 million ha area (Anon 2016). Ratoon occupies 50–55 % of the total cane area. Raising ratoon crop of sugarcane has economic benefits not only for cutting down the cost of land preparation, seed material and cost of planting, but also ensure an economically high recovery in the initial phase of the crushing season because of early maturity than the plant cane. Raising a good ratoon crop has been a concern for the researchers as well as cane growers. On an average, yield of conventionally grown sugarcane ratoon crop is lower than the sugarcane plant crop (Biris et al. 2007; Srivastava 2000; Gomathi et al. 2013). Reasons for lower productivity of ratoon have been attributed to poor sprouting of stubbles, soil compaction (Verma 2002), decreased soil fertility (Hunsigi 2001) and inefficient use of applied fertilisers (Sundara and Tripathi 1989). Ratoon is initiated through proper management of stubble-buds. Contemporarily, these buds generate roots to be accommodated in the congestion of the existing old roots of stubbles. Off barring is recommended to provide free space for the new roots to sprouts. This is to be done in a precise manner without causing damage to the stubbles. Stubble shaving close to ground surface provides protection from root borer and scale insect damage. It helps in promoting uniform and vigorous tillering (Verma 2000). In sugarcane ratoon, mortality of tillers usually occurs, especially in case those sprouted from the uneven portion of cane left above the ground during harvesting. Productivity of ratoon crop was improved by applying crop inputs orderly in time and by executing cultural operations like shaving stubbles flush with the ground surface within a week of harvest of sugarcane, off barring or cutting old roots on either side of the stubbles and applying fertiliser (Srivastava 1978; Ahmed and Giridharan 2000).

All these operations are normally not carried out in majority of the cases due to involvement of high labour and cost. Tractor-operated 9/11 tine cultivator and in some cases bullock drawn 3 tine cultivator are used for interculturing/off barring operations. But rest of the operations like shaving of stubbles and fertiliser application near to root zone is skipped. These operations are not only difficult and arduous but also far too uneconomical to be carried over by using conventional tools like spades, and cultivators. Earlier workers had developed stubble shaver (Srivastava 1977, 1978), stubble shaver-cum-fertiliser applicator for stubble shaving, off barring and fertiliser application (Sharma and Singh 1984; Sharma and Srivastava 1979; Singh and Sharma 1986), ratoon management device for stubble shaving, off barring, fertiliser application, earthing up (Anon 2006; Singh et al. 2011) but not applied all the practice together by a common device. Applications of these devices were limited as they could work in a trash-free field due to the presence of tine rippers or reversible shovels which tended to be clogged in the presence of trash. Therefore, trash had to be either removed from the field or burnt for operating these machines. Problem of uprooting of stubbles was also observed with application of these machines.

About 10–20 t ha^{-1} trash is left in the field after sugarcane harvest which is usually removed or burnt for performing interculturing and fertiliser application. Trash burning resulted in loss of organic carbon, plant nutrients such as N and S (Hemwong et al. 2009). Long-term benefits of surface retention of trash resulted in increased soil organic matter (Vallis et al. 1996; Graham and Haynes 2005; Roberston and Thorburn 2007; Fortes et al. 2012), improved physico-chemical properties and ultimately crop yields (Wood 1991; Fortes et al. 2012). Basanta et al. (2003) indicated that unburnt trash remains as surface mulch resulted in annual recycling of 105 kg N ha^{-1} year^{-1} and therefore complemented to the fertiliser needs. Further, surface-retained trash is expected to improve soil water and thermal regimes in ratoon sugarcane during the following summer season (Denmead et al. 1997; Olivier and Singels 2007; Ng Cheong and Teeluck 2015). Trash mulching improved yield and economic returns in sugarcane ratoon crop (Singh et al. 2012). Nevertheless, practice of surface retention of trash in ratoon sugarcane is not becoming popular due to non-availability of appropriate machinery for carrying out recommended cultural operations like stubble shaving, off barring and fertiliser application during initiation of ratoon after harvesting along with trash available in the field. In the present study, a tractor-operated machinery named disc-type ratoon management device (Disc RMD) was designed and developed and tested in sandy loam soil.

Materials and Methods

Prototype of Disc RMD was designed and developed in Agricultural Engineering workshop of IISR. It consisted of main frame, stubble shaving, off barring, fertiliser metering and power transmission unit (Fig. 1).

Main Frame

Main frame was designed to rigidly support different units, namely stubble shaving, off barring, and fertiliser application units. It was made of mild steel (MS) square pipe (65 mm × 65 mm) having wall thickness of 5 mm. Main frame was provided with three point linkage for mounting the equipment with swinging drawbar and top link of the tractor.

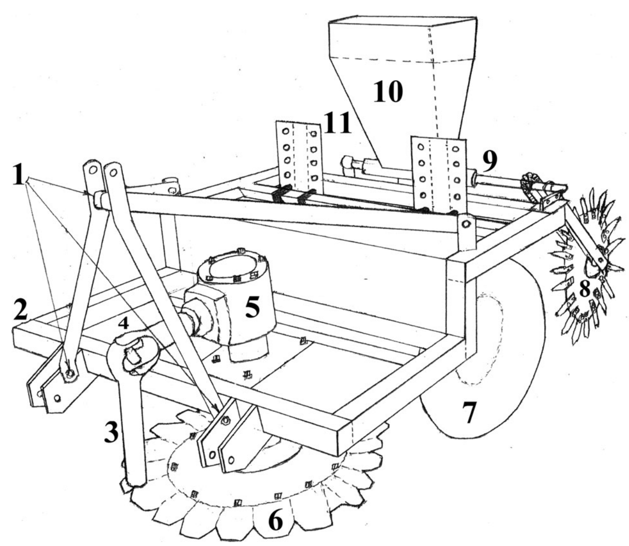

Fig. 1 Schematic view of disc RMD. *1* Three point linkage, *2* main frame, *3* telescopic propeller shaft, *4* UJ cross, *5* heavy duty bevel gear box, *6* serrated (V-notch) blades mounted on disc, *7* tillage disc, *8* ground wheel with spikes, *9* metering auger, *10* fertiliser box, *11* MS plate

Stubble Shaving Unit

A 500-mm concave disc with replaceable serrated cutting blades mounted on disc periphery was designed to spin through power take-off (PTO) drive of the tractor at a peripheral speed of 13–15 m s^{-1} for shaving stubbles close to ground level. It left behind a clean surface to facilitate synchronous and healthy sprouting of buds lying below the soil surface. The disc was mounted on a rigid and rugged mild steel frame with the help of couplings made of 12.5-mm-thick and 170-mm-diameter circular steel plate and 110-mm-diameter, 170-mm-long and 5-mm-thick hollow shaft. Disc blades were provided 5° angle tilt in the forward (suction angle) that caused suction for sharp shaving/cutting of stubbles without splitting and clogging. Suction angle of disc angle was selected as 5° based on a small trial conducted to see the blade performance at four levels (0°, 5°, 10° and 15°) of suction angles.

Off Barring Unit

In the earlier developed machinery and conventional cultivator cutting and pruning of side old roots (off barring) was a problem in the field having surface trash due to dragging action of tined reversible shovels during off barring. Dragged trash continuously piled up over shovels that caused its clogging and off barring (cutting of side old roots) was adversely affected. Therefore, prior to use of these machineries, trash was either removed or burnt in the field. In the developed machinery concave disc of 600 mm size having rehardened sharpened edges was provided at either side of stubbles for cutting and pruning of side old roots (off barring). Cutting and pruning of side old roots were performed by rolling action of sharpened edges of disc without dragging and clogging of surface trash. Removal or burning of field trash was not a prerequisite in case of Disc RMD. Selected disc angle was 18°, and tilt angle was kept at 0° so that cutting of soil takes place without much inversion and dragging of field trash (Fig. 2). Discs were rigidly attached with the main frame through disc housing having tapered roller bearings. Disc housing was attached with MS plate provided with holes at 50-mm intervals for adjustment of height of discs as per height of ridges in the field.

Fertiliser Application Unit

It consisted of a fertiliser box and MS metering augers (Fig. 3). Power to the fertiliser metering augers was transmitted through lugged ground wheel having spikes. In the earlier, designed machinery provision was not there for varying the rate of fertiliser which was a need as rate of fertiliser varied due to variation in *N*, *P*, *K* composition of different fertilisers. In the developed Disc RMD, an

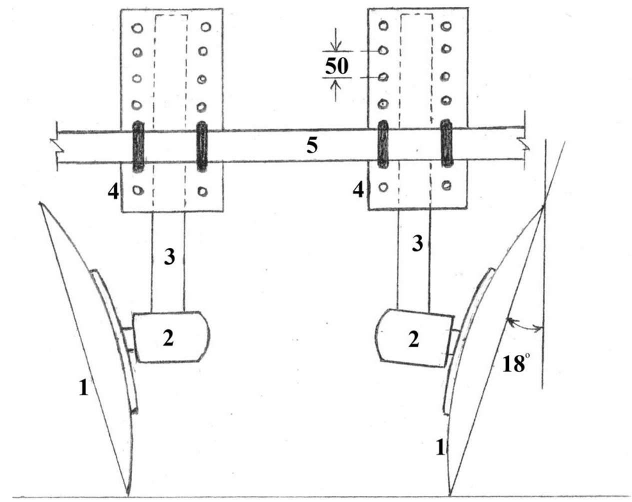

Fig. 2 Schematic view of off barring unit. *1* Tillage discs, *2* disc housings, *3* shank of disc housings, *4* MS plate for height adjustment of disc mounting, *5* main frame

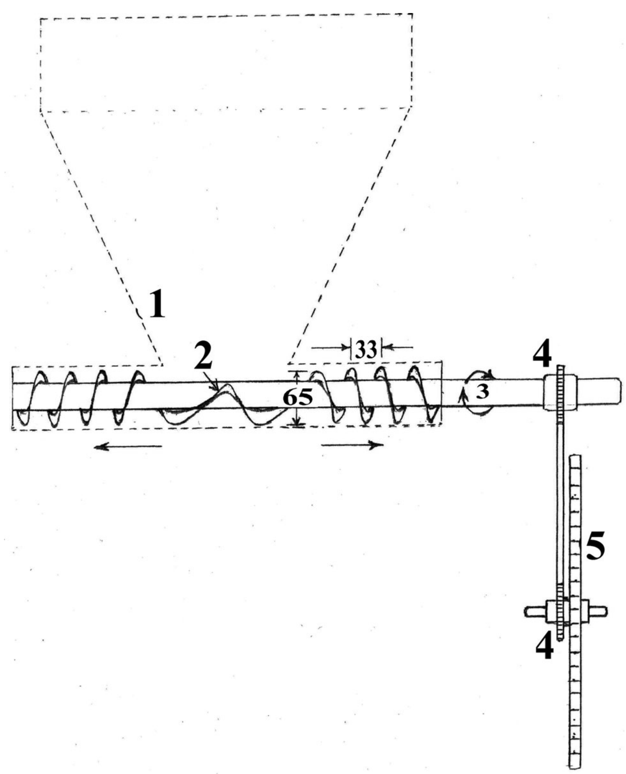

Fig. 3 Schematic view of fertiliser metering. *1* Fertiliser box, *2* auger worm, *3* shaft, *4* chain sprockets (16 T), *5* ground wheel

innovative approach was designed and incorporated in the equipment for regulation of fertiliser. The rate of fertiliser was varied by varying rotational speed of metering augers. The rotary speed of metering augers was varied with varying the length of exposure of spikes causing change in effective diameter and peripheral length of ground wheel.

Greater the effective diameter of ground wheel lesser was the rotational speed of the metering augers for a particular forward speed of the equipment. The equipment was designed to use fertiliser from 250 to 400 kg ha^{-1}.

Power Transmission Unit

Rotary power of tractor PTO shaft was transferred to stubble shaving disc blades. The power train consisted of universal joint (UJ) cross, telescopic propeller shaft, heavy duty bevel gear box (Fig. 4). Fertiliser metering augurs were powered through MS ground wheel having spikes. Power from driving ground wheel shaft to fertiliser metering rollers was transmitted through chain sprockets.

Technical specification of the designed Disc RMD is presented in Table 1. Different units of designed machinery was fabricated and assembled. It was tested in the laboratory for checking the adjustments and performance of different units. Thereafter, it was taken to the field for conducting field trials.

Performance Evaluation

Performance of the Disc RMD was evaluated in field of IISR located at 26°56′N, 80°52′E and 111 m above sea level with semi-arid sub-tropical climate having dry hot summer and cold winter (Fig. 5). The soil of the field was sandy loam (14 % clay, 26 % silt and 60 % sand) of Indo-Gangetic alluvial origin, pH 7.6, very deep (>2 m) well drained, flat and classified as non-calcareous mixed *hyper thermic udic ustochrept*. Performance trials of the equipment were conducted during 2013-14 and 2014-15.

Performance of stubble shaving was compared at four disc blade suction angles, i.e. 0°, 5°, 10°, 15°. Observations on splitting and rupturing as well as uprooting of stubbles were recorded. Also chocking, overloading of stubble shaving blades and ease of operation were visually observed and recorded. Main consideration for quality assessment was the ease of operation of stubble shaving blades without sticking into the soil and uprooting of stubbles. Based on these observations, disc blade suction angle was adjusted and further testing of the equipment was conducted at the selected suction angle.

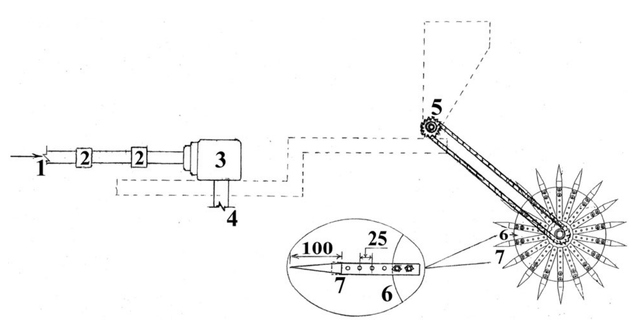

Fig. 4 Schematic view of the power transmission unit. *1* Rotary power from PTO shaft, *2* UJ cross, *3* heavy duty bevel gear box (1:1), *4* rotary power to stubble shaving blades (1:1), *5* chain sprockets (16 T), *6* ground wheel (diameter 420 mm), *7* adjustable spikes

Performance of fertiliser metering was evaluated at five levels of effective diameter of ground wheel, i.e. 420, 470, 520, 570 and 620 mm for different fertilisers, i.e. urea, diammonium phosphate (DAP), muriate of potash (MOP) and mixture of the three in equal proportion. Effective diameter of ground wheel was increased by increasing the length of exposure of spikes and vice versa. Different fertilisers were filled in the fertiliser box, and equipment was operated in the field at different effective diameter of ground wheel, and observations on rate of fertiliser application were recorded.

Crop parameters like variety; field parameters like type, moisture content and bulk density of soil, height of stubbles left after harvesting, number of stubble clumps left, row spacing; and machine performance parameters like forward speed, depth of penetration during off barring, tractor wheel slippage, time lost in turning at head land, filling of fertiliser were recorded. Theoretical as well as effective field capacity and field efficiency of the developed Disc RMD was analysed by using the mathematical relationships (Singh and Singh 2016). Mean values of two years field trials during 2013–14 and 2014–15 were worked out.

Recommended agronomical practices of the study area for raising ratoon crop were followed. Observations on plant population at 90 days after ratoon initiation were recorded for tiller count (tillering). Plant population at harvest and yield were also recorded. These observations were compared with earlier developed machinery and conventional practice of manual stubble shaving, interculturing with tractor-operated cultivator and manual surface broadcasting of fertiliser. Data on tillering, millable canes and sugarcane yield were compiled separately for both years, i.e. 2013–14 and 2014–15 and statistically analysed.

Cost of Operation

The total cost of operation was analysed by adding the fixed and variable cost of the tractor and the equipment and labour cost as per procedure used by Singh and Singh (2016).The parameters used in the analysis of cost components were either based on the actual performance data of the equipment or taken from Bureau of Indian Standards (IS: 9164-1979) for estimation of cost of farm machinery operations (Anon 1979).

Table 1 Technical specification of the developed disc-type sugarcane ratoon management device

S. No.	Particular	Details
1.	Framework	MS square pipe 65 mm × 65 mm × 5 mm
	Length	1325 mm
	Width	1200 mm
2.	Stubble shaving	Serrated (V-notch) blades mounted on disc
	Material of disc	High carbon steel
	Size of disc	600 mm
	Blade	High carbon steel V-notch blades mounted on the periphery of disc forming 70-mm-wide and 60-mm-deep V-notches
3.	Off barring	Discs mounted with main frame with disc housing/hanger on either side
	Number of discs	2
	Size of discs	500 mm
	Material of disc	High carbon steel with rehardened and sharpened edges
	Disc angle	18°
4.	Fertiliser metering unit	
	Fertiliser box	
	Material	MS sheet
	Thickness of sheet	1 mm
	Capacity of box	35,000 cc (35 l)
	Metering mechanism	
	Type	MS auger
	Pitch of flute	33 mm
	Depth of flute	17 mm
5.	Power transmission	
	To stubble shaving blades	Stubble shaving blades powered through tractor PTO shaft. Power train consisted of UJ cross, telescopic propeller shaft and gear box
	Gear box	Heavy duty bevel gear box
	Speed ratio of gear box	1:1
	To fertiliser metering roller	Fertiliser metering roller powered through MS ground wheel having variable length spikes for varying the effective diameter of wheel
	Diameter of ground wheel	420 mm
	Range of effective diameter of ground wheel	420–620 mm
6.	Overall dimension	
	Length	2500 mm
	Width	1200 mm
	Height	1350 mm
	Weight	340 kg

Results and Discussion

Effect of Disc Blade Suction Angle on Performance of Stubble Shaving

Effect of disc blade suction angle on performance of stubble shaving was studied for four angles, i.e. 0°, 5°, 10°, 15° and results presented in Table 2. It is evident from the table that at 0° suction angle, undesirable traits, i.e. splitting and rupturing of stubbles as well as stubble uprooting, were highest at 23.2 and 14.3 %, respectively. Table also revealed that at 10° and 15° angle average splitting and rupturing of stubbles were 8.7 and 9.5 % and stubble uprooting 8.0 and 8.8 %, respectively, which were within acceptable limits but disc blade, due to higher forward tilt (suction angle), penetrated into the soil causing overloading and clogging of stubble shaving blades. At 5° suction angle average splitting and rupturing of stubbles was 8.2 % and stubble uprooting 7.8 % (both were lowest out of the four angles) without clogging and any operational difficulty. Based on the above 5° suction angle was selected for disc blade for further field testing.

Effect of Ground Wheel Effective Diameter on Rate of Fertiliser Application

Effect of driving ground wheel effective diameter on rate of fertiliser application was studied for five diameters, i.e. 420, 470, 520, 570 and 620 mm (corresponding speed of metering rollers was 30, 27, 24, 22 and 20 rpm) for four fertilisers, viz. urea, DAP, MOP and mixture of the three in equal proportion. It was evident from Table 3 that as the effective diameter of wheel decreased from 620 to 420 mm rate of fertiliser application increased from 250.33 to 336.27, 289.20 to 392.24, 308.27 to 408.92 and 282.44 to 375.72 kg ha^{-1} for urea, DAP, MOP and mixture of all three, respectively. The increased rate of fertiliser with decreased effective ground wheel diameter was due to increased rotary speed of metering rollers at decreased effective diameter of ground wheel. The variation in rate of fertiliser application for different fertilisers was due to difference in bulk density of different fertilisers used. The range of fertiliser application was within the recommended basal dose of these fertilisers during initiation of ratoon. No clogging and bridging were observed during metering of different fertilisers. Seventeen-mm-deep and 33-mm-pitch length of flutes of metering augers facilitated free flow of fertilisers uniformly.

Fig. 5 Developed disc-type ratoon management device in field operation

Performance of the Disc RMD

The performance of disc RMD was evaluated in sandy loam soil of IISR farm during 2013–14 and 2014–15. Mean values of two years trial are presented in Table 4. Different components of Disc RMD, namely stubble shaving, off barring and band placement of fertiliser near to root zone on either side of stubbles worked well. The effective field capacity was 0.28 ha h^{-1} at forward speed of 0.67 m s^{-1} with field efficiency of 77.7 %. Function of stubble shaving was satisfactory with least splitting, rupturing and stubble uprooting at selected suction angle of 5° of disc blades. Rehardened sharpened edges of off barring disc penetrated deep into the soil 120–150 mm and cut the field trash without dragging. Dragging of field trash was a problem in the earlier developed machinery and conventional practice of using cultivator because of the presence of tines and reversible shovels which cut the side old root by dragging action. Developed Disc RMD worked well without dragging of field trash as the cutting of side old roots was done

Table 2 Effect of disc blade suction angle on stubble shaving

Suction angle	Splitting and rupturing of stubbles (%)	Stubble uprooting (%)	Overloading due to choking of soil/stubble residues	Qualitative assessment
0°	23.2	14.3	No	Average
5°	8.2	7.8	No	Very good
10°	8.7	8.0	Yes	Good
15°	9.5	8.8	Yes	Average

Table 3 Effect of effective diameter of ground wheel on rate of fertiliser application

Effective diameter of ground wheel (mm)	Speed of metering roller (rpm)	Rate of fertiliser (kg ha^{-1})			
		Urea	DAP	MOP	Mixture
420	30	336.27	392.24	408.92	375.72
470	27	313.22	365.12	384.24	353.56
520	24	292.15	340.57	357.94	326.34
570	22	270.88	315.45	328.35	306.34
620	20	250.33	289.2	308.27	282.44

Table 4 Field performance of the disc-type sugarcane ratoon management device

Parameter	Conventional practice	Earlier developed machinery	Developed Disc RMD
Variety	CoLk 94,184	CoLk 94,184	CoLk 94,184
Field parameters			
Type of soil	Sandy loam	Sandy loam	Sandy loam
Moisture content (% d.b.)	13	13	13
Bulk density of soil (Mg m^{-3})	1.46	1.46	1.46
Mean height of stubbles left after harvesting (mm)	78	78	78
Mean number of stubble clumps per m length	2.9	2.9	2.9
Row geometry (mm)	30:120	75	30:120
Performance parameters			
Stubble shaving	Manually	Mechanically	Mechanically
Fertiliser application	Manual surface broadcasting	Mechanical fixed rate near to root zone	Mechanical variable rate as per need near to root zone
Off barring	Cultivator	Tine rippers and earthing up	Tillage discs
Prerequisite field condition	Trash removed/ burned	Trash removed/ burned	Trash left in the field as surface mulch
Depth of penetration during off barring (mm)	100–120	150–180	120–150
Weight of fertiliser in the fertiliser box (kg)	NA	33–40	27–33
Mean percentage of tractor wheel slippage at load (%)	4.3	7.2	5.2
Mean forward speed, (m s^{-1})	0.67	0.67	0.67
Effective width of coverage (m)	3.0	1.5	1.5
Mean percentage of total time lost in turning at head land, filling of fertiliser and miscellaneous activities, decimal	0.195	0.389	0.223
Theoretical field capacity (ha h^{-1})	0.72	0.36	0.36
Effective field capacity (ha h^{-1})	0.58	0.22	0.28
Field efficiency (%)	80.5	61.1	77.7
Labour involved, labour-h ha^{-1}	120	10	8
Cost of operation of ratoon initiation (₹ ha^{-1})	3800	2300	1500
Mean plant population at 90 days after ratoon initiation (tillering) (ha^{-1})	182,220	185,600	201,600
Mean plant population at the time of harvest (ha^{-1})	81,100	83,600	97,200
Mean yield (t ha^{-1})	51.4	52.6	58.3

by rolling action of sharpened edges of off barring tillage discs. The Disc RMD performed uniform band application of fertiliser at 120–150 mm depth near root zone on either side of sugarcane stubbles at pre-calibrated rate as per the need for different fertilisers. This was the improvement over the earlier developed machinery wherein rate of fertiliser application was fixed and also over the conventional practice of manual surface application of fertiliser wherein irregular rate of fertiliser was applied that too not near to root zone.

The performance of the Disc RMD was compared with the earlier developed machinery and conventional practice of ratoon initiation (manual stubble shaving, interculturing with cultivator by removing the field trash and manual surface broadcasting of fertiliser). Results of comparative crop performance are presented in Table 5. The use of developed Disc RMD improved tillering by 10.6 and 8.6 %, millable canes by 19.8 and 16.2 % and sugarcane yield by 10.8 and 13.4 % as compared to earlier developed machinery and conventional practice, respectively. It is evident from Table 5 that increased tiller count, millable canes and sugarcane yield were significant in case of Disc RMD. Increase in yield in case of the Disc RMD may be due to beneficial effect of cutting of side old roots (off barring) leaving the trash in the field as surface mulch and recommended dose of band placement of fertiliser near root zone resulting in increased tillering. Result was in agreement with findings of Choudhary et al. (2016) who had observed that band placement of fertiliser near to root zone and off barring by leaving the trash in ratoon field as

Table 5 Effect of different treatments of ratoon initiation on tillering, millable canes and sugarcane yield

Machinery for ratoon initiation	Plant population at 90 days after ratoon initiation (Tillering)			Number of millable canes			Sugarcane yield, t ha^{-1}		
	2013–14	2014–15	Average	2013–14	2014–15	Average	2013–14	2014–15	Average
Conventional practice	184,150	180,290	182,220	81,940	80,260	81,100	52.2	50.6	51.4
Earlier developed machinery	187,230	183,970	185,600	84,940	82,260	83,600	53.9	51.3	52.6
Newly developed Disc RMD	203,970	199,230	201,600	99,100	95,300	97,200	59.9	56.7	58.3
CD, 0.05	2762.7	3618.8		2501.1	2683.4		1.91	2.22	

surface mulch improved the cane yield by 22 % over the conventional farmers practice of manual broadcasting of fertiliser and trash burning.

Economics

The cost of ratoon initiation operation was ₹ 1500 ha^{-1} in case of Disc RMD, ₹ 2300 ha^{-1} for earlier developed machinery and ₹ 3800 ha^{-1} for conventional practice (Table 4). The corresponding saving was ₹ 800 ha^{-1} (35 %) and ₹ 2300 ha^{-1} (60 %) in case of Disc RMD as compared to earlier developed machinery and conventional practice, respectively. Only 8 labour-h ha^{-1} was involved in case of Disc RMD in comparison with 10 labour-h ha^{-1} in earlier developed machinery and 120 labour-h ha^{-1} in conventional system. Therefore, there was 15 times less labour investment in Disc RMD as compared to conventional practice of ratoon initiation. If we consider the savings in cost of operation and yield-benefit in the Disc RMD, the corresponding cumulative benefit was ₹ 16,700 (US$ 251.24) and 21,600 (US$ 324.96) ha^{-1} compared to earlier developed machinery and conventional practice, respectively.

Conclusions

Tractor-operated disc-type ratoon management device (Disc RMD) was designed and developed to carry out ratoon initiation operations such as stubble shaving, off barring and band application of fertiliser near root zone in a ratoon field having surface-retained trash. The effective field capacity (output) of the equipment was 0.28 ha h^{-1}. Use of developed Disc RMD saved the cost of operation by ₹ 800 ha^{-1} (35 %) and ₹ 2300 ha^{-1} (60 %); and labour by 2 labour-h ha^{-1} (20 %) and 112 labour-h ha^{-1} (93 %) in comparison with earlier developed machinery and conventional practice, respectively. Tillering, millable canes and yield of sugarcane increased significantly in case of Disc RMD as compared to earlier developed machinery and conventional practice. The corresponding cumulative benefits due to saving in cost of operation and increase in yield were ₹ 16,700 and 21,600 ha^{-1}, respectively.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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