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Performance Evaluation of Different Furrow Openers for Sustainable Tillage: A Review

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***Abstract*:** Controlled soil disturbance, low draft and vertical force requirements are among the primary characteristics of a practical and efficient furrow opener. The furrow openers should also be capable of maintaining acceptable surface residue retention, precise and uniform seed placement, and regular inter-plant spacing when integrated into a conservation seeding system. The objective of this paper is to study and review various furrow openers based on their performance in terms of soil disturbance, draft requirement, seeding performance, seed emergence, and residue handling ability. The furrow openers that were reviewed included single disc and double disc type, hoe, shoe, shovel, runner, and inverted T type furrow openers. The double disc type is the most effective in terms of soil disturbance, while the single disc type requires the lowest draft force. The hoe and shoe type furrow openers are the most accurate in seed placement, while the double disc and inverted t type furrow openers resulted in the highest seed emergence rates. The inverted T, shovel and runner type furrow openers are effective in residue handling, while the hoe, shoe and double disc type furrow openers struggles in the heavy residue fields. The selection of furrow opener should depend on specific farming needs.

Keywords: Conservation tillage, Draft requirement, Residue handling, Seeding performance

The purpose of tillage is to transform soil physical, structural, and ecological properties so that a healthier crop can be produced (Mohanty et al 2007). However, tillage weaken soil structure and consequently decrease soil water holding ability and disturb soil biology, having an adverse impact on the nutrient stock and storage ability of soil (Lal 2004, Farooq et al 2011, Devine et al 2014). The reduced tillage system, has been advertised as a low-budget, energy-efficient method of increasing crop yields (Bianchini and Magalhães 2008, Farooq and Nawaz 2014). There are different types of tillage practices available, including no-tillage, zero-tillage, and conservation tillage. In practice, still, there is high attention in the no tillage system. There are a few advantages to no-till seeding, including the reduction in field passes, the reduction in soil compaction, labor saving, time reduction, and reduced fuel consumption (Tebrugge and Bohrnsen 2000, Chen et al 2004, Sarauskis et al 2009). Zero tillage is economically greater, and additional grain yield was noted under zero tillage as compared to traditional farming techniques (Nagarajan et al 2002). There has been a rise in yield by 5 percent to 10 percent with zero- tillage technology and saving in sowing time by up to 70 percent as well as 60 percent savings in operating costs (Rautaray 2004). The purpose of conservation tillage is to ensure that the soil surface is covered with at least 30% crop residue after seeding. As a result of this, water and wind erosion will be prevented, as well as significant water loss from naked soil surfaces (ASABE Standards 2013). In comparison to bare and fallow soil, this process reduces erosion by 50% (Karayel 2009).

It is important to manage crop residue well because residue interferes with sowing operations, especially in rice fields, which is a serious limitation to conservation tillage (Carter 1994). Due to the variation of soil texture, weather circumstances, and soil properties, paddy soils have a compound nature in term of soil failure and draft requirement (Tagar et al 2014). It is therefore vital to use adequate machinery, as well as manage residues effectively, in order to ensure precise sowing operations. Residue management as well as mechanical factors which affect seed germination and emergence are seed damage while metering; uniformity in sowing and placement of seed; and fertilizer mixing with seed while placing in the furrow. The furrow opener is a most important element of a seeding system because it loosens the soil and opens a furrow to create finest seed zone conditions for plant. The work of furrow opener is to precisely place the seed and fertilizer simultaneously in the prepared seed bed and create optimum condition for seed germination. Seed emergence and crop yield have been used to evaluate furrow opener performance by several

researchers. The furrow opener should be designed in such a way that it can perform the desired task precisely with minimum power requirement, particularly in no till paddy residue condition (Murray et al 2006) In tillage systems, there are several types of furrow openers, including hoes, chisels, and discs. These openers have their advantages and disadvantages in terms of soil disturbance, seeding performance, field condition and draft requirements (Chaudhuri 2001). Furrow openers should create a neat groove in the wet soil zone with least soil disturbance to escape mixing the top dry soil with the underlying moist soil at seed level. Degree of seed bed preparation can be determined by the size of soil aggregates in the seed bed preparation operation. The disc furrow openers have lesser soil disturbance as compare to the hoe type furrow openers (Parent et al 1993, Janelle et al 1995). These are typically adopted for effective seed placement as well as straw cutting to prevent the loose straw dragging and clogging with at the time of sowing. Throughout, several furrow openers double disc furrow performed adequately (Baker et al 1996). Furrow opener geometry, soil and straw conditions, directly affect the straw cutting performance of disc type furrow openers. Paddy soil requires a more draft force for tillage (Karayel and Sarauskis 2011) and loose paddy straw is pushed into soil without cutting, producing a hair pinning effect. Hence, augmentation of furrow opener performance in paddy filed under direct drilling conditions is still an important task.

Functional requirements of furrow openers: The functional requirements (Fig. 1) of a furrow opener are to:

- Open the furrow with desired depth.
- Maintain the uniformity while making furrow.
- Furrow opening with least disturbance in the soil.
- Avoid over compacting the side of furrow.
- Ensure that soil does not flow back into the furrow before seeding.
- Promote enough soil back in the furrow for seed coverage.

There are several type of furrow openers are used, in this article some major type of openers by different researchers are discussed. Some important parameters viz. soil disturbance, residue handling/cutting ability, draft requirement, seeding performance (depth, speed, and variations), plant emergence are considered for performance of furrow opener. Broadly, furrow openers can be divided into two categories tine and disc type furrow openers.

Classification of tine furrow openers: Tine furrow openers are simple in construction and most popular in conventional seeding system. In the conservation tillage system, narrow pointed type furrow openers are used for sowing wheat in paddy stubble condition, generally they are known as Hoe type furrow openers (Barr 2018). Godwin and O'Dogherty (2007) define narrow tine tools as those that operate at depths between 1 and 6 times their widths (i.e. depth/width ratio = 1:6). Now a day's various narrow furrow openers are being used for sowing such as knife point, Inverted T furrow opener and spear point furrow opener shown in Figure 2 (Murray et al 2006, Desbiolles and Leonard 2008).

Several other types furrow opener used in conservation tillage seeding systems contain duck foot and curved chisel (Murray et al 2006, Hasimu and Chen 2014). Generally, the no tillage furrow opener designed for low or minimum soil disturbance while sowing. Narrow tine openers are considered for conservation tillage system because they create less soil disturbance and have a lower draft force than other tine openers (Solhjou et al 2012).

Tine Furrow Openers

Hoe type: There are several types of hoe type furrow openers, which include tines or chisels shaped to penetrate the soil vertically in the soil. A tube attached to the hollow tine generally has an open back end, where seed is conveyed. A pointed hoe digs furrow according to the depth setting of the furrow opener. It lifts and pushes the top soil towards the sides and forms a V-shaped groove. This type of furrow opener performs fine under extensive range of soil conditions but not in residue fields. Advantages of hoe type opener are they penetrate in the soil with less vertical load, low cost, easy maintenance. And lastly, they do not form mark on the surfaces at the sides of furrows. Some disadvantages of less residue cutting ability, obstruct with large stone and higher soil movement depending upon the shape of furrow opener. Baker (1976) explored the hoe, triple disc and chisel-type furrow openers in soil bin having sandy loam soil under no tillage system. In the hoe type furrow opener, 27 % wheat seedling emerged with four-time lesser vertical force requirement as compare to disc type furrow openers. The seeding performance of hoe type of openers were at par in term of seeding depth because hoe type openers place the seed at desired depth. However, shovel and shoe type opener do not place the seed at required depth. Sandy clay loam and loamy sand soil are best suited for the hoe type furrow openers for attaining better performance for separation of seed and fertilizer (Chaudhuri 2001). It is common for hoe furrow openers to move out of the soil depth (Altuntas et al 2006).

Shoe type: This kind of furrow opener delivers seeds and fertilizer concurrently in distinct bands at the desired depth. Its boot is protected by metal covering to avoid obstruction. Fertilizer is commonly placed in a band at the side of the seeds at identical depth. The furrow opener forms a narrow channel in the soil. The length of the shoe aids in pressing the bottom of the furrow. Study specifies that although the shoe-

type openers had superior compaction of the furrow bottom and not as much of variation in depth (Chaudhuri 2001). The shoe-type furrow opener, with either a single or twin boot, is used for sowing in heavy and medium soils, where seeds are placed at 20 to 70 millimeters deep. However, this type of opener has the tendency to sink the soil depth (Altuntas et al 2006).

Shovel type: The shovel type opener is a tapered pointed furrower. The principal edge of the opener is a sharp-pointed. The opener is mounted on the standard with the help of bolts for easy replacement. At the back of the boot one or two tubes attached for seed and fertilizer distribution. In comparison to hoe or shoe type furrow openers, shovel type furrow openers have a more versatile function. Shovel type opener are easier to fabricate as compared to disc type openers (Altuntas et al 2006). These type furrow openers are the widely used in seed drills for trashy, stony, and light to medium soils shovel-type openers are used. Commonly there are three shovels used i.e. reversible, single point shovel and spear point shovel. In stony and root infested fields, shovel type openers are recommended. It is easy in assembly, inexpensive and easily repairable. In a study it was observed that the shovel type furrow opener attains low draft requirement and less soil penetration force for highest seed emergence rate (Altuntas et al 2006). Different types of furrow openers are given in the Figure 3.

Runner type: The runner type opener is used for crop which are sown at shallow depth such as maize. A backward sword shaped blade with sharp edge penetrate in the soil and form a furrow with minimum soil disturbance. It operates in fine prepared seed bed and used typically for shallow sowing crops. It compacts the soil in the furrow bottom because of its length. Abernathy and Porterfield (1969) evaluated the different sized runner-type furrow openers, for compaction analysis in sandy soil. They concluded that the runner type furrow openers does not compact the sandy soils. Also,

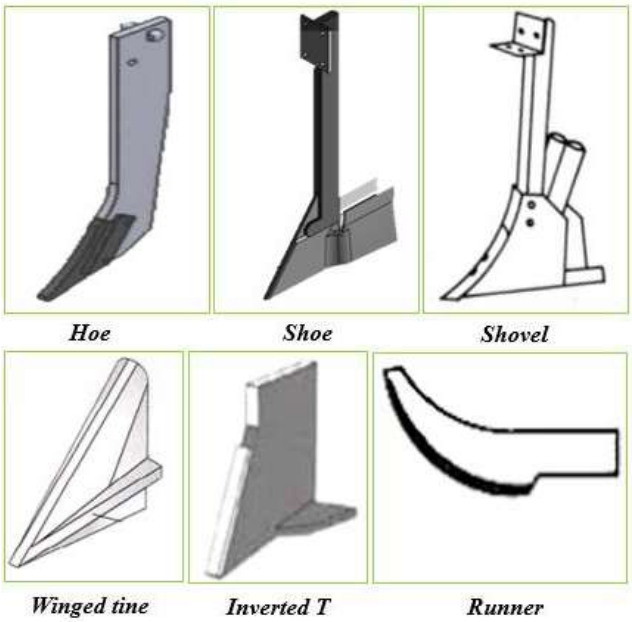
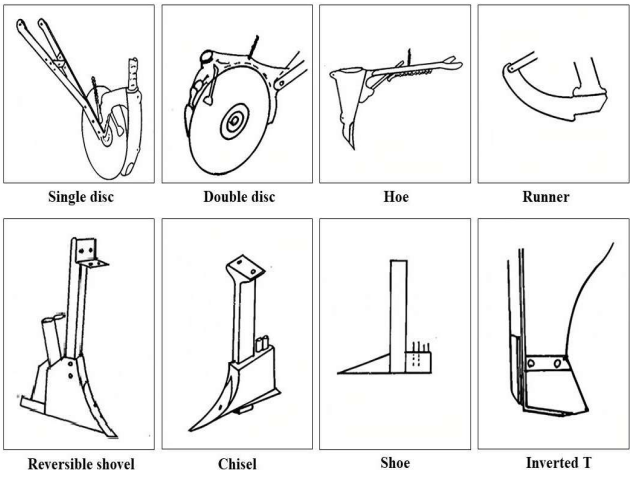


Fig. 2. Different types of tine furrow openers



Source: Chaudhuri 2001

Fig. 3. Different type of furrow openers

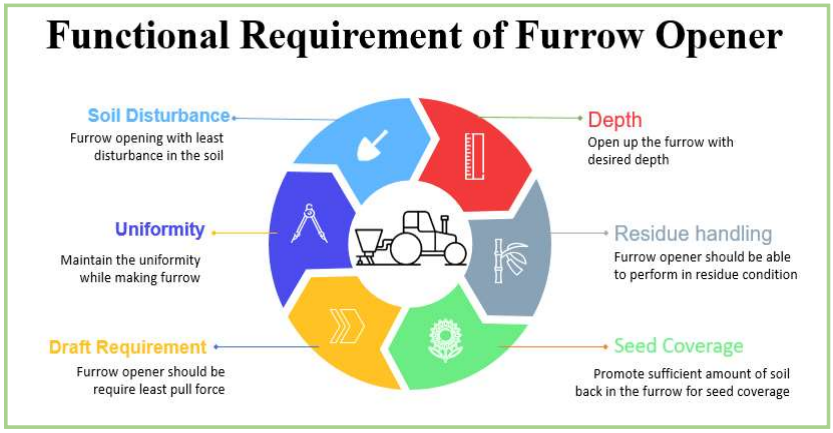


Fig. 1. Functional requirement of furrow openers

runner type furrow openers are not recommended in fields having less moisture content because it hampers in making good seed to soil contact. For shallow seeding depth, runner-type furrow opener could be best suited because it creates less soil disturbance. Moreover, the soil backfill in the runner type furrow openers is less due to shallow operating depth.

Inverted-T furrow opener: An inverted T furrow opener basically looks like a knife-type furrow opener with plane wings fixed to both sides and trailing from the bottom (Murray et al 2006). The Inverted-T furrow openers are recommended for direct sowing under upland soil conditions. The inverted -T makes a fine cut, therefore not cause too much soil disturbance, and establish good plant emergence under no-tillage conditions. The wings of the furrow openers creates an inverted t shaped profile in the soil. The purpose of making inverted t shape is to create sub surface disturbance to maintain favorable condition for the seed germination and growth within the furrow. As a result, moisture is conserved within the seed zone by keeping moister and deeper soil undisturbed. The wheat emergence was found better in comparison with other types of furrow openers. Additionally, Du et al (2004) found that inverted T openers produced the highest percentage of the emergence of sorghum compared with a winged point, narrow point, and triple disc openers. A total of 90% of the plants emerged in a single day in the Inverted-T-shaped slots, after which the rest emerged one to two days later. Furthermore, Baker (1976) found that an inverted T opener had the lowest vertical force (penetration resistance) in sandy loam soil at a depth of 38 mm, followed by a hoe and triple disc openers. It is possible to reduce moisture loss in the seed zone by inverting the T opener so that the seeds are shattered subsurface and high humidity chambers can be created for seed storage also, they have good residue handling capability (Aikins et al 2019).

Winged tine openers: Inverted T openers have wings on both sides and without wing narrow pointed openers can also be fixed with wings (Hasimu and Chen 2014). In winged type opener can be modified with various position of wings in horizontal and vertical positions and several lift heights and widths (McKyes 1985). If the lift height of the wing is increased the soil movement by the furrow opener also increases. As compare to same sized knife furrow opener lateral soil movement by winged furrow opener in much significant and the backfill by this furrow opener is also less in same working conditions (Hasimu and Chen 2014). The main advantage of winged furrow openers is it can effectively handle the residue as compare to without winged furrow opener (Aikins et al 2019). The draft requirement by the winged furrow openers is more than the hoe furrow opener. The higher draft requirement may be due to increase in surface are by wings in the furrow opener (McKyes 1985).

Disc type furrow openers: Disc type furrow openers are available as single, double, and triple disc types. Even though flat, plain, and notched disc, curved disc, waved and ripple types can be used individually as a furrow opener, they are pulled at an angle with the direction of motion to cut and shift the soil for furrow making. To achieve minimum soil disturbance and higher speed in seeding operation single and double disc type furrow openers are preferred (Ashworth et al 2010). Disc type furrow openers are usually demand higher vertical load for penetrating in the soil and maintaining uniformity in the depth of sowing (Murray et al 2006). Although, it was found that the disc openers has lower soil disruption and depth variation which results in good plant emergence and better crop establishment.

Single disc: Generally single disc type openers have a large diameter up to 2 feet. It may be plane disc, notched, waved, ripped, or curved disc for residue cutting and making furrow by soil movement (Fig. 4). These types of furrow openers cut a furrow in the topsoil and drive the furrow portion to the side, in that way disturbing to the topsoil. Single disc furrow openers are extensively used in the cereal crop sowing. Single disc type furrower may be mounted as aligned, sole angle or multiple angle type. By disc and tilt angle both width and depth of furrow can be managed. For sowing in the trashy or mulched field disc, type furrower are performed well.

Double disc: Disc type furrow opener create furrow with the least disturbance but also provide better residue handling than the tine type furrow openers (Yang et al 2016). This allows them to operate in heavy straw load condition with minimum depth variation. However, it requires enough soil strength to cut the straw efficiently. In loose soil condition straw not cut properly hence choking or bulldozing may be occurred during the operation (Ashworth et al 2010). When double disc type furrow opener penetrates in the soil the cutting edge of the disc cut and displace the top soil and form a V shaped furrow. The seed tube is placed in such a position that the seed is delivered at the place where the trailing edge of the disc can bury the seed in the furrow bottom. Generally, for speedy operation in the trashy land, double disc type furrow opener provide efficient performance. Disk-type furrow openers can be operated under various soil conditions.

Since Disc type furrow openers can work in dense soil conditions adequately hence have need of big and strong frame, therefore it makes them costlier. Ahmad et al (2017) investigated that double disc furrow openers require more pull force than single disc furrow opener, when the greater operating depth is required. Double disc furrow opener can also be consisting of two plane, notched, waved, or ripped

Table 1. Research findings on furrow openers and performance parameters

Reference	Furrow openers	Operating speed (kmph)	Findings
Soil disturbance			
Brandelero et al 2015	Double disc	3.4-9.2	Soil disturbance area increased up to 23.7 % which leads to poor seed germination rate and badly affect the soybean yield by reducing up to 20 %.
Godara et al 2015	Shovel and Shoe	2-4.5	Soil disturbance was more for shovel type furrow opener with comparison to shoe type furrow opener because of wider design of shovel type furrow opener.
Hashimu and chen 2014	Hoe, Winged hoe, and Spoon type	2.7-8.1	Considering both soil stepping and draft force requirement, the hoe opener showed better performance than the winged hoe and spoon openers.
Francetto et al 2016	Hoe and Disc		Hoe type furrow opener has more disturb area of soil as compare to disc type furrow openers.
Seeding performance			
Burce et al 2013	Hoe, Tine, and Double Disc	4-8	Hoe furrow opener showed no significant difference in furrow shape even in hard soils with great soil penetration, and the variation of the lateral and vertical seed distributions was reasonable.
Karad and Gaikwad 2018	Shovel and Disc	2-4.5	The use of disc furrow opener achieves the uniform depth as well as uniform width of cut and hence there is uniform growth of plants and ultimately there is increment in farmer's yield.
Altikat et al 2012	Hoe, Disc and Wing hoe	2.7-8.1	Hoe type furrow openers had the lowest coefficient of variation (17.04%) followed by winged hoe type seeder (24.13%) and disc type seeder (21.02%).
Draft requirement			
Altuntas et al 2006	Hoe shoe and shovel	2-4.5	Lowest soil penetration resistance, draft and tuber emergence was found in shovel type furrow opener
Karad and Gaikwad 2018	Shovel and Disc	2-4.5	Shovel type furrow opener produce greater soil disturbance with ultimately requires unnecessarily more draft force for pulling of tractor
McLaughlin et al 2019	Hoe and triple disc	2.7-5.4	The main difference between the two opener types was the approximately 200 N per opener higher draft for the hoe opener
Ahmad et al 2017	Various disc type furrow openers (single disc; tooth-type; notched-type; double disc)	7-10	The draft and vertical forces for double disc and toothed-type single disc furrow openers were the highest and lowest, respectively for all operating depths and speeds
Seed emergence			
Altikat and Celik 2012	hoe, disc, and wing hoe type openers	2.7-8.1	The highest emergence percentage (77.13%) was obtained with hoe type furrow openers followed by the disc and the winged hoe type openers (73.72% and 67.34%, respectively). Hoe-type furrow opener provided better sowing performance and seed emergence in comparison to the no-till seeders with disc- and wing hoe type furrow openers.
Doan et al. 2005	Disc hoe type	2.7-5.4	The results showed that the disc opener produced a faster emergence than the hoe opener. Disc opener showed an average of 36% faster emergence rate than hoe opener in canola crop.
Ahmad et al 2017	Various disc type furrow openers (single disc; tooth-type; notched-type; double disc)	7-10	Notched-type and smooth-type single disc furrow openers pushed the straw into the paddy field (straw hair-pinning), which might reduce crop emergence due to decreased soil-seed contact.
Residue handling			
Altikat and Celik 2012	hoe, disc, and wing hoe type openers		The higher the stubble the larger the coefficient of variation of sowing depth. Coefficient of variation of 18.72% at 12-cm stubble height increased up to 19.24% at 24-cm stubble height. However, variation coefficient of sowing depth was 17.15% under the standing stubble conditions and 19.14% under the flat stubble condition.
Ahmad et al 2017	Various disc type furrow openers (single disc; tooth-type; notched-type; double disc)	2.7-8.1	Double disc and smooth-type single disc furrow openers had the highest and lowest straw-cutting efficiencies, respectively

type discs (Fig. 5). Ahmad et al (2017) evaluated different cutting edges like smooth, toothed, notched disc for draft force requirement and straw cutting efficiency. Smooth disc type furrow opener observed more draft as compare to other type. However, straw cutting efficiency was highest in toothed type disc. The use of disc openers is not suitable for working in wet soil conditions due to the excessive accumulation of soil, which can disrupt their functionality. Disc openers pushes the top layer of the soil in the furrow bottom (Chaudhuri 2001, Desbiolles 2006, Yang et al 2016). Due to various herbicide and low moisture of top soil into the seed zone delay the seed germination and emergence of plant. Moreover, their various rotating parts and complex geometry make them costlier than other furrow openers (Chaudhuri 2001, Murray et al 2006).The efficiency of double disc opener depends upon various factors such as horizontal and vertical force, straw cutting ability, straw load, type of coulter, operating speed, and strength of soil (Kushwaha et al 1986).

Furrow opener performance indicators: The soil disturbance may be prime factor for assessing the performance of furrow opener. Straw cutting ability and draft requirement are other serval factor that can be considered while evaluation of furrow opener (Vamerali et al 2006). These performance measures subsequently power the seedling emergence rate, crop growth and biomass/grain yield (Chaudhuri 2001). Some are the major performance characteristics are discussed in this article are given below

- Draft requirement for furrow opener
- Soil disturbance in furrow opening
- Accuracy and uniformity of furrow depth and seed placement
- Seed emergence rate
- Ensure seed delivery, spacing, and seed-soil contact are not interfered with by residues;
- Facilitate good spread and optimum separation of seeds and fertilizer (Conte et al 2011, Francetto et al 2016).

Soil disturbance: Soil disturbance contains soil loosening and movement of soil triggered by a furrow opening device. When a furrow opener penetrates in the soil, soil particle moves from one place to another with the help of soil cutting tool, predominantly in the vertical track (Barr et al 2019). Also soil drives in all three dimension in the furrow (i.e. Forward, Lateral and Vertical) (Conte et al 2011). Soil disturbance triggered by the opener should be the least possible, as it is accountable for extreme soil water losses and serious weed problems. It also affects the seed and fertilizer scattering pattern undesirably. Soil disruption increased with increasing operational forward speed of seed drill (Godara et al 2015). Darmora and Pandey (1995) and Conte et al (2011) acknowledged the necessity for the measurement of individual soil disturbance limits including furrow cross-sectional area, draft force requirement and effective depth to develop a soil disturbance performance index. In general, sandy clay loam soil has low disturbance as compare to loamy sand soil with the same size of furrow opener.

Seeding performance: The furrow opener is a critical component of the seeding system, as it creates the furrow in which the seed is placed. The type of furrow opener used can have a significant impact on seeding performance, including seed placement accuracy, seed-to-soil contact, and soil moisture retention. One key factor that affects seeding performance is the depth and shape of the furrow created by the opener. Furrow openers that create a uniform and consistent furrow depth can improve seed placement accuracy

Table 2. Effect of furrow openers on the various parameter

Furrow opener	Functional requirement				
	Soil disturbance	Draft requirement	Residue handling	Seeding performance	Seed emergence
Hoe type		Low (FAO 2015)	Poor (FAO 2014)	Good (Darmora and Pandey 1995)	
Shoe	Low (Chaudhuri 2001)			Good (Altuntas et al 2006)	
Shovel		Low (Altuntas et al 2006).			High (Altuntas et al 2006)
Runner	Low			Poor (Abernathy and Porterfield 1969)	
Inverted T	Low (Baker 1976)		Moderate (Baker 1976; Aikins et al 2019)		High Du et al. (2004)
Winged tyne	High (Hasimu and Chen 2014)		Good (Aikins et al 2019)	Moderate (Hasimu and Chen 2014)	
Disc type	Low (Yang et al 2016)	Low (Tajudin and Balasubramanium 1995)	Good (Zhang et al 2016)		High (Munir et al 2012)

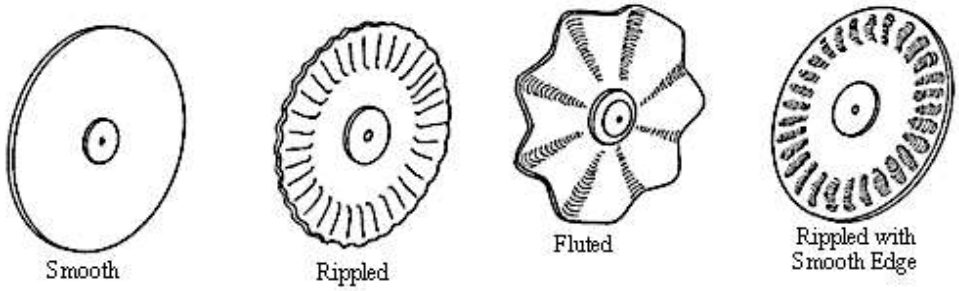


Fig. 4. Different type of disc used in disc furrow openers

Source: Francetto et al 2016

Fig. 5. Disc type furrow opener

and ensure consistent seed-to-soil contact. In addition, furrow openers that create a V-shaped furrow with sharp edges can help to retain soil moisture around the seed, which can promote germination and seedling emergence. A furrow opener's seeding performance can be evaluated by measuring the depth of seeding, the uniformity of seeding depth, and early crop growth. This includes crop emergence rate and plant density per unit area. Furrow opener type, soil condition, weather condition and residue type affect the seeding performance. Research has shown that different types of furrow openers can have varying effects on seeding performance. For example, a disc furrow opener may provide better seed-to-soil contact than a sweep or knife furrow opener, but may also create more soil disturbance. Similarly, a double-disk furrow opener may provide better soil moisture retention than a single-disk opener, but may also require more draft force. A furrow opener must be able to create and place the seed and fertilizer in furrows accurately with minimum depth variation. Attaining this leads to uniform seed emergence and batter crop growth, which ultimately provide higher yield (Aikins and Afuakwa 2008).

Draft requirement: The draft requirement of a furrow opener is an important consideration when selecting the appropriate tool for planting. Different types of furrow openers can have varying draft requirements, depending on factors such as the shape and size of the opener and the soil type. In general, furrow openers with a larger surface area or more aggressive design will have a higher draft requirement than those with a smaller surface area or less aggressive design. Draft is vital aspect that affect the seeding in the residue field. Low draft requirements by furrow opener leads to low fuel consumption and enable farmers to use smaller tractors. In developing contries it is desirable to reduce operating cost and use smaller tractor and machineries on the farm (Collins and Fowler 1996, Yao et al 2009). Draft requirement of furrow openers depend on the size of the wing of furrow opener, shape of furrow opener, depth of operation, residue condition, moisture content etc. The soil cutting theory also stated that the tool having wider cutting width need higher draft force as compare to narrow cutting edge (McKyes 1985). Darmora and Pandey (1995) evaluated seven different furrow openers, they also observed that draft force is related to opener width. Collins and Fowler, 1996 stated that for a 10 mm increase in seeding depth, the draft force increases by 20%. Altuntas et al 2006 evaluated the performance of different furrow openers for draft requirement and several other parameters, the outcome indicate that soil penetration resistance increase with forward speed of furrow opener. Also the shape of furrow opener influences the draft requirement.

Seed emergence: Furrow opener can significantly affect seed emergence, as different types of furrow openers can create furrows at varying depths and with different levels of soil compaction and disturbance. The depth of the furrow is particularly important, as shallow furrows may not provide enough soil cover for the seed, while deep furrows may make it difficult for the seed to emerge from the soil. Soil compaction around the furrow can also impede seed emergence, particularly in heavy soils or soils with high clay content. In addition, the placement of the seed in the furrow is critical, as some furrow openers may place the seed too close to the surface or too deep in the soil. To ensure optimal seed emergence and crop establishment, it is essential to select a furrow opener that is appropriate for the specific planting situation, considering factors such as soil type, crop type, and planting conditions. Seed emergence directly affects the plant population and ultimately the yield of the crop. Seed emergence depends upon the type of furrow openers, placement depth, seeding environment, moisture content,

soil type and residue density (Altuntas et al 2006). In a study of the effects of soil compaction, depth variations, soil disturbances, and soil moisture content on emergence rate, it was determined that the soil moisture content within the furrow opener groove was critical (Siemens and Wilkins 2006). Choudhary et al 1985 investigated the effect of seeding performance on crop establishment in paddy harvested fields. Depth variation in sandy soil was 31% higher than in silty loam soil. The emergence percentage decreased with the increase in the stubble height (Altikat et al 2012).

Residue condition: The residue handling capacity varies according to type of furrow openers. The objective of residue handling is to confirm that the surface residue cover is minimum disturbed while avoiding the residues from interfering with the seed drill (Aikins et al 2019). The residue management of a furrow opener can be observed by the capacity to stop residue burial (hair pinning) with the soil into the furrow. That can considerably affect the germination and seed emergence rate. A furrow opener must be able to adequately handle crop residue during the seeding pass. Siemens and Wilkins et al (2006) conducted field studies to evaluated different furrow openers in the paddy stubble field for sowing of wheat. The residual moisture was present in the field for initial growth of the seed. To achieve this, deep furrow openers had the ability to place the seed in to moist condition and this result in better emergence even fluctuation in depth.

Comparison of disc and tine furrow openers: When compared with disc openers, tine furrow openers require less weight to penetrate hard soil and better adapt to these conditions. Generally, tine openers can create deeper furrows because of their improved penetration ability. Moreover, a tine opener causes more soil disturbance, especially at high speeds, so they cannot be operated at high forward speeds. Munir et al (2012) revealed that disk-type furrow opener has higher seedling emergence rate index (ERI) and grain yield as compare to the tine furrow opener. Particularly, in paddy stubble field it can be operated at higher speeds which creates good seed-soil contact and best soil conditions for water and nutrient availability to the crop. They are more likely to accumulate residue during sowing operations which leads to clumping and seeder blockage, ultimately which may affect seedling emergence (Altikat and Çelik 2012). The draft force required for disc furrow is comparatively less than the conventional tine furrow opener.

CONCLUSION

Research has shown that furrow openers that create a uniform and consistent furrow depth, provide adequate seed-to-soil contact, and minimize soil disturbance can improve seed emergence rates and ultimately crop yield. Disc type furrow openers causes greater soil disturbance due to there rolling and cutting ability at higher speeds. Moreover the disc openers causes less draft and better residue handling capacity due to sharp edges. However, the tine furrow openers has better penetration ability thus, work more consistently in hard soils. Also tine openers are limited due to clumping and blockage, hence not recommended for more than 3.5 kmph operating speed. Modification in the operating condition could help to achieve better performance with the tine openers such as increasing tine rake angle, tine width, and operating depth. Concave cutting edge on tine openers reduces soil disturbance and improve residue handling. For better results, it is preferable to operate a tine opener above its critical depth in order to prevent smearing and the exponential increase in draft. Compared to wingless openers, wing tine openers cause greater soil disturbance, but handle residue better. Through subsurface shattering and the creation of high humidity chambers dedicated to seeds, inverted T openers can help reduce moisture loss in the seed zone. Overall, the choice of furrow opener should be based on the specific planting conditions, considering factors such as soil type, residue management, crop type, and planting conditions. By selecting the appropriate furrow opener, farmers can optimize seeding performance, improve crop productivity, and ultimately achieve greater profitability.

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