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EVALUATION OF THREE SEED FURROW OPENERS MOUNTED ON A ZONE DISK TILLER DRILL FOR RESIDUE MANAGEMENT, SOIL PHYSICAL PROPERTIES AND CROP PARAMETERS

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This research was conducted to evaluate the field performance of three newly developed types of furrow opener. Wheat variety, Sehar-2006, was sown in the paddy stubble field. Three types of furrow openers (disk-type, reverse hoe-type, and hoe-type) were fabricated in the department of Farm Machinery and Power and installed on zone disk tiller drill and tested for their performance at three forward speeds of tractor, viz. 3.5 km/hr, 4.75 km/hr and 6.4 km/hr. The impact of furrow openers on residue management, soil physical properties and various crop parameters was evaluated. The mean values of density at the time of seedling emergence at 0-5 cm depth under disk-type furrow opener, reverse-type furrow opener and hoe-type furrow opener were 1.37, 1.35 and 1.34 g/cm^3 and at 5-10 cm depth were 1.48, 1.45 and 1.43 g/cm^3, respectively. The mean values of moisture content at the time of seedling emergence at 0-5 cm depth under disk-type furrow opener, reverse-type furrow opener and hoe-type furrow opener were 11.86, 11.12 and 10.04% and at 5-10 cm depth were 12.75, 11.26 and 11.07%, respectively. The mean seedling emergence rate index under disk-type furrow opener, reverse-type furrow opener and hoe-type furrow opener was 9.83, 9.42, and 9.33%/day, respectively. The disk-type furrow opener with speed 4.75 km/hr was the better attachment. The mean values of existing residue after 15 days of wheat sowing under disk-type furrow opener, reverse-type furrow opener and hoe-type furrow opener were 10.45, 9.68, and 8.62%, respectively. The measured residue under disk-type furrow opener at 3.5 km/hr speed was 1.08 and 1.22 times greater than that of reverse-type furrow opener and hoe-type furrow opener respectively. The seedling emergence rate index affected the final grain yield. The mean grain yield under disk-type furrow opener, reverse-type furrow opener and hoe-type furrow opener were 4.03, 3.91 and 3.81 t/ha, respectively. The disk-type furrow opener produced the highest grain yield 4.10 t/ha at speed 4.75 km/hr.
Keywords: Seed furrow opener, residue, yield, emergence rate index

INTRODUCTION

As agriculture in the developing world is in the process of substantial change, there is still a scope for introduction of energy-efficient technologies. Crop residues on the soil surface makes uniform seedling establishment difficult in conservation tillage systems. Additionally, high levels of crop residues stand present a constraint to the adoption of conservation tillage because residues mechanically interfere with seeding operations. Improved seeding equipment or residue removal may be necessary for successful direct drilling practices (Cater, 2002). Rice residue management is important in rice-wheat cropping system as machines are increasingly used for harvest. Several options available to farmers for the management of rice residues are burning, incorporation mulching, and removing the straw. Farmers use different straw management practices as per the situation. Commonly paddy residue after combine harvesting is either incorporated in the soil or burnt before field preparation. Incorporation needs extra tillage operations, where as burning creates environmental pollution and loss of nutrients (Kosina *et al.,* 2007). Another approach is sowing of wheat in standing stubbles and allowing the stubble to decompose over time as wheat grows. Zero drill machines are capable to seed through the residue cover, and provide a firm seed soil contact. The technique has been found useful specially for raising Rabi crops in the rice harvested fields. There has been an increase in yield by 5 percent to 10 percent with zero- tillage technology over the conventional tillage and saving in sowing time by up to 70 percent as well as 60 percent savings in operating costs (Rautaray, 2004). Bahri and Bansal (1992) evaluated the field performance of double disc opener, hoe-type furrow opener, and triple opener with two press wheel types on the basis of creating a favorable soil-seed environment for a good plant stand of wheat in no-till conditions. They found that in relatively moist and loose soils, double disc opener was the most suitable for use in a no-till grain drill, the hoe-type furrow opener was better suited for hard and dry soil conditions at sowing time because of its better penetration, and it also created the greatest amount of soil disturbance compared to other types of openers and developed. They found the press wheel type had no significant effect in many of the observed parameters. Chaudhry *et al*. (1991) studied the interactions between direct drilling opener design specification and seed groove micro-environments responsible for seed/seedling performance on a wet soil. The winged, hoe and triple disk openers were used. In the presence of crop residue, the winged furrow opener created inverted T-shaped groove and the hoe-type furrow opener created U-shaped groove that resulted in greater number of seedling emergence, oxygen diffusion rates and earthworms activity than V-shaped groove created by the triple-disk furrow opener. A compact zone adversely affects the seedling performance and earthworm activity around the groove profiles. Wilkins *et al*. (1983) conducted a field study and reported that the disk-type opening configuration forced some residues down into the seed trench and moved dry topsoil's into the seed zone rather than moved it laterally, thereby increased wheat emergence.

A technologically superior and economically viable zone disk tiller drill (ZDTD) has been developed to cater the planting needs of wheat. This machine sows seeds without removing the previous crop residue thus providing substantial saving to the farmer in terms of fuel, labor, and time (Iqbal *et al*., 2010). They reported that sowing wheat with zone disk tiller drill saved on an average 3.2 times fuel energy, 1.1 times irrigation water, and increased wheat grain yield by 1.4 times as compared with the conventional method of wheat sowing. Moreover, they reported that the zone disk tiller drill sows wheat in one pass operation whereas the conventional method of wheat planting needs 2-3 weeks to prepare seed bed employing two passes of rotavator, two passes of cultivator and two passes of planker and then sows seed with a seed drill. This study was conducted to determine the effect of different seed furrow openers installed on zone disk tiller drill on soil physical properties, residue management and their impact on crop recovery.

MATERIAL AND METHODS

This study was conducted to evaluate the effect of seed furrow openers on soil physical properties, crop residue management and their relative impact on seedling emergence and crop recovery. The experiment was conducted during the Rabi season of 2010-11 in untilled paddy stubble field. Seven wavy disks (457mm dia) rotating at 242 RPM were employed to cut and pulverize seed zones (50 mm wide and 100 mm deep) in front of seed furrow openers. The spacing between adjacent disks was fixed as 228 mm. Seeds were placed at a fixed depth (100 mm?) in furrows opened by furrow openers. The selected field was harvested with a combine and divided into three blocks for three replications. Twenty seven experimental units were prepared for three types of furrow openers under Randomized Complete Block Design (RCBD). Individual unit size had an area of 141.29 m^2 (3.56m × 39.69m). The total experimental area was 0.38 hectares. Fertilizer was applied to the field in three dozes. One full doze of Di-ammonium phosphate @85 kg / ha was applied uniformly to all blocks during sowing of wheat crop. Nitrogen was applied @123 kg / ha at two times, viz. half with first and the other half with second irrigation. The crop was irrigated (76 mm depth) at three stages of growth; first after complete germination, second at tillering and third at booting.

Zone disk tiller drill carries an extraordinary feature of sowing wheat without removing the previous crop residue thus providing considerable savings to the farmers in terms of time, labor and fuel. The ZDTD adds an additional option for fertilizer application, residue management, soil conservation, erosion control and other environmental friendly management practices. This technique appears to be a major improvement in conservation agriculture. Considering the specific requirements of sowing wheat seedling in rice-wheat cropping system, the design of furrow opening configurations requirements by ZDTD was carefully considered while developing and fabricating three different types of furrow openers (disk type, reverse hoe type and hoe type) in the Department of Farm Machinery and Power, University of Agriculture, Faisalabad.

Disk-type furrow opener**:** Single-disk-type furrow openers have gained popularity for use in conservation cropping systems over recent years, largely because the single disk-furrow penetrates soil with minimal disturbance of residue, enabling effective operation over a wide range of soil types and residue conditions without the need for a separate soil and residue cutting device (Desbiolles, 2004). Each disk-furrow opener had a 2.54 cm spherical curve in the centre in order to open a required width of furrow when mounted behind a wavy disk. sThe seed and fertilizer placement assembly was mounted on the concave side of each furrow opener. The standard was fabricated with mild steel and the disk with high carbon steel. In order to drop the seeds and fertilizer through separate tubes, a double boot type design was incorporated in the mechanism of disk-type furrow opener. A detailed view of the disk-type furrow opener is presented in Figure 1.

Reverse hoe-type furrow opener**:** A furrow opener with a curvilinear soil contact body was developed and fabricated and named as reverse hoe-type furrow opener. The reverse hoe type furrow opener had a 51 cm adjustable height, 1.2 cm thickness, and 51 cm long mild steel standard which was sharpened and bent backward at the bottom. A 10.2 cm ×13 cm ×2.6 cm furrow opening assembly was fabricated and attached to the bottom of the standard on the opposite side. The reverse hoe-type furrow opener had a rounded soil contact edge (Fig. 2) to assist with a slender cut with minimal soil disturbance. The curvilinear shape helped to reduce soil resistance and the amount of soil thrown during operation. The reverse hoe type furrow opener was connected to two flexible plastic tubes coming from seed and fertilizer boxes. Each of the seed and fertilizer tube diameter was 2.5 cm and bent at 15^0 with the vertical. A partition wall in each furrow opener prevented mixing of seed with fertilizer. The level of fertilizer aperture was designed such that the fertilizer was applied at a greater depth than seeding depth in the soil.

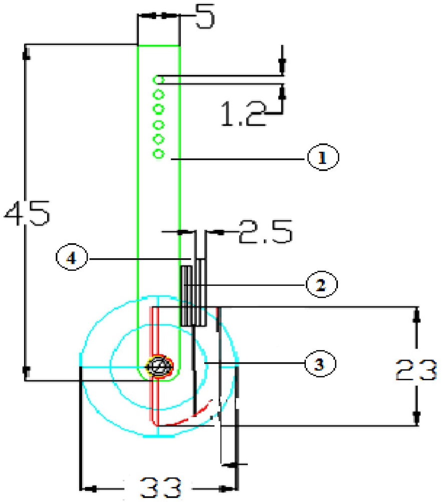

Figure 1. Disk-type furrow opener (1. standard, 2. fertilizer tube (2.5 cm dia) 3. disk furrow opener, 4. seed tube (2.5 cm dia),.[All the dimensions in cm]

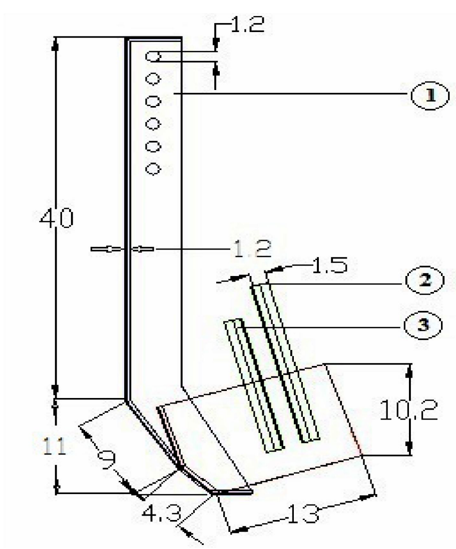

Figure 2. Reverse hoe-type furrow opener. (1. standard, 2. seed tube (2.5 cm dia), 3. fertilizer tube, 2.5 cm dia) [All the dimensions in cm]

***Hoe-type furrow opener*:** The penetration of furrow openers in the hard soil is a problem especially for disk-type furrow opener. Therefore, a sharp soil contact edge furrow opener named as hoe-type furrow opener was developed (Fig. 3) such that seed and fertilizer were unrestricted through separate tubes. In order to drop the seeds and fertilizer through separate tubes, a double boot type design was adopted. A partition wall provided in each furrow opener eliminated seed and fertilizer mixing. The fertilizer tube was designed to apply fertilizer at a soil depth greater than the depth of seeding.

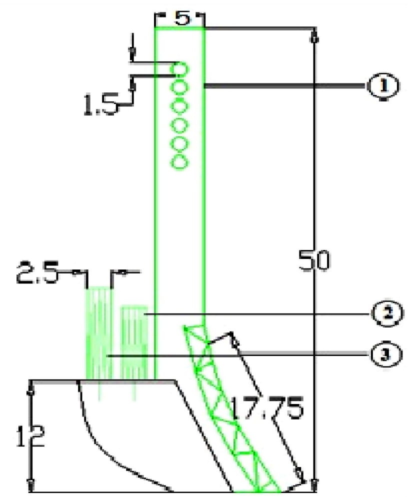

Figure. 3. Hoe-type furrow opener. (1. standard, 2. fertilizer tube (2.5 cm dia) 3. seed tube (2.5 cm dia)).[All the dimensions are in cm]

***Crop residue measurement*:** Paddy crop residue both before and after sowing wheat was determined by using the meter stick method (Al-Kaisi *et al*., 2002). Locations for residue measurement were determined randomly by throwing the meter stick with graduations into the air and taking measurements where it landed. After placing the meter stick on the soil surface, pieces of residue were counted between each centimeter mark on the edge and total residue along the meter stick was recorded. The resulting count was converted directly into the percentage of crop residue remaining in that sample area [138.6 m^2]. Using the same procedure, the residue was measured randomly before sowing, at seedling emergence and two weeks after sowing seed during each experiment.

***Soil and crop parameters*:** Soil and crop parameters studied were moisture content, bulk density, emergence rate index, and crop yield. The soil texture was determined using the method explained by Evans *et al.* (1965) and found to be as sandy caly loam. A soil core sampler (5 cm dia and 15 cm length) was used to take soil samples. The sampler was pressed into the soil and pulled carefully (Ryan *et al*., 2001) to collect upper 10 cm part of soil and divided into two equal lengths of 5-cm each. The samples were placed into sampling cans and carefully transferred to the laboratory for gravimetric analysis. Samples were oven dried for 24 hours to measure moisture content and bulk density of soil at 105°C (Allison *et al*., 1954). Following equations were used to determine soil moisture content and bulk density.

$$MC = \frac{Mw - Md}{Md} x100 \quad ------- (1)$$

Where, M C = Soil Moisture content (%), Mw = Soil wet weight (g), Md = mass of oven dried soil (g)

$$BD = \frac{Md}{V} x100 \quad ------- (2)$$

Where, B D = Bulk density (strictly, the dry density) of soil (g/cm^3), M_d = mas of oven dry soil (g), V = Volume of soil (cm^3)

Emergence rate index (ERI, Figure 3) shows the daily plant growth rate in a unit area. Three sites having an area of 1 m^2 with three rows were selected and marked randomly in each treatment to count seedling emergence and seed emergence rate index (Erbach, 1982). Daily seedling emergence counts were recorded for three weeks after sowing wheat to ensure emergence of all viable seedling.

$$ERI = \sum_{n=First}^{Last} \frac{\%n - \%(n-1)}{n} \quad .... (3)$$

Where, ERI= Emergence rate index, n = Number of days since planting, % n = Plant emergence on day n' as a percent of total seed, emerged, % (n-1) = Plant, emerged on day 'n-1' as a percentage of total seeds planted, First = day 1 after emergence started, Last = final day of counting when emergence completed.

In order to estimate grain yield and grain to straw ratios, three sites with an area of 1m^2 each were selected under each treatment. A total of 27 sites were selected for the crop recovery evaluation. Plants in selected sites were harvested (7-10 cm above ground surface), threshed, and winnowed manually. The grain and straw were weighed separately using an electronic balance. The following equations were used to measure crop yield.

$$Y = \frac{Wg}{CA} \quad .... (4)$$

Where, Y = Yield (ton/ha), Wg = Grain weight per unit area (g), C = Constant (100), A = Area (1 m^2)

RESULTS AND DISCUSSION

The data regarding paddy residue management and soil physical properties ERI and crop yield were statistically analyzed by using PROC GLM (General Linear Model) procedures of SAS software (SAS Institute, 2002-03). Table 1 shows that prior to planting, the bulk density of the soil sampled at 5-10 cm depth (1.54g/cm^3) was significantly greater than that sampled at 0-5cm depth (1.44 g/cm^3), indicating the effect of soil compaction. Similarly, the average soil moisture content was significantly greater at 5-10 cm depth than that observed at 0-5cm depth. So it is clear that the moisture content at the lower surface (5-10cm) was 1.11 times greater than that observed at upper (0-5cm) depth. This could be due to greater evaporation in upper soil layer as compared to the lower layer.

Table 1. Mean values of bulk density (g/cm^3) and moisture content (%) before planting (n=9)

Depth(cm)	B D (g/cm^3)	M C (%)
5	1.44^a	11.74^b
10	1.54^b	13.13^a
Mean	1.49	12.44
LSD (0.05)	0.0274	0.787

Means sharing similar letters are statistically non-significant (α = 0.05).

***Soil physical properties at seedling emergence*:** The effect of furrow opener type and forward travel speed are plotted in Figure 4. For all treatments, soil BD increased with increased tractor forward speeds. The BD was significantly higher under disk-type furrow opener operating at all tractor forward speeds than the BD under reverse hoe type and hoe type furrow openers. This was due to the furrow opening pattern of disk-type furrow opener that provided the least soil disturbance as compared to the other two types of openers. The lowest BD at a speed of 3.5 km/hr was due to greater soil manipulation and the highest BD at the speed of 6.4 km/hr was due to lesser soil pulverization because of the constant circular motion (234 rpm) of wavy coulter of ZDTD. With an increase in forward speed of the tractor, the BD increased gradually which was due to lesser time available for ZDTD to pulverize the soil. High R^2 values for all treatments show that a strong correlation exists between the measured BD and tractor speed.

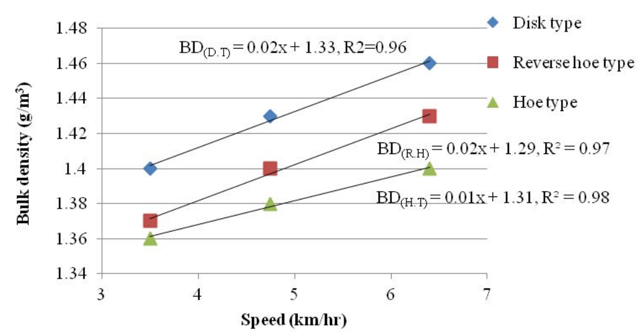

Figure 4. Effect of furrow opener and speed on soil bulk density (g/cm^3) at (0-10) cm depth

Figure 5 shows that the soil moisture content (MC) increased with increased tractor forward speed in all treatments. The significantly lower soil MC, under the hoe type furrow opener was due to extensive soil pulverization caused by this furrow opener resulting in greater surface moisture evaporation (Fig. 5). HighR^2 values for all treatments show that a strong correlation exists between the measured MC and tractor speed.

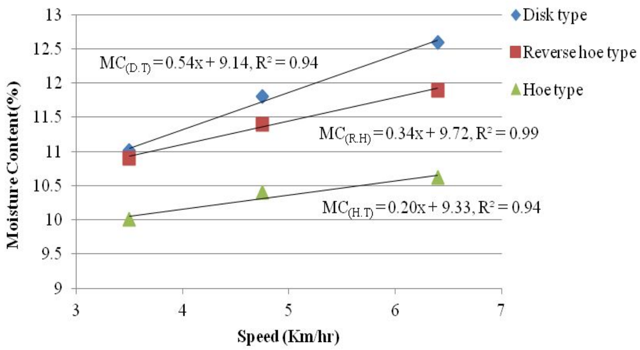

Figure 5. Effect of furrow opener and speed on soil moisture content (%) at (0-10) cm depth

Figure 5 also indicated that the soil MC was significantly greater under disk-type furrow opener at all speeds than those under reverse hoe type and hoe type furrow openers. This was due to the furrow opening characteristics of the disk type opener that caused the least amount of soil disturbance. The reverse hoe type has curvilinear soil contact edge and provided intermediate soil disturbance and moisture content value. The speed significantly affected the soil moisture content due to unusual degree of soil pulverization. The lowest tractor forward speed of 3.5 km/hr caused the ZDTD system to enhanced soil pulverization resulting in greater evaporation and lower soil moisture than the ZDTD operating at higher speeds.

***Paddy crop residue measurement*:** The effect of three types of furrow openers installed behind a ZDTD on residue management was determined at different forward speeds of tractor. Average residue measured over 27 samples before sowing was found to be 31.1%. Residue cutting included the reduction in the length of loose straw and cutting the stubble in front of ZDTD but still rooted in the soil. The geometry of the disk-type furrow opener was circular and it cut through the soil to open the furrow for proper seedling germination. The disk-type furrow opener cut the residues only if it penetrated to a shallow soil depth. The disk-type furrow opener operated without being clogged with residue. Therefore, the amount of residue that existed on the soil surface after the seedling emergence was higher where the disk-type opener was used as compared to the residue remaining on the soil surface after using reverse hoe type and hoe type furrow openers, respectively (Fig. 6). The reverse hoe-type furrow opener had curved geometry so instead of cutting through the residue, reverse hoe type and hoe type furrow opener accumulated streaks of heavy straw as they opened the furrow for seed and fertilizer placement. Hoe type furrow opener had bursting effects on soil (easy penetration and more soil loosening effect) due to its sharp edge contacting the soil. Hence, the measured residue that existed after using hoe type furrow opener both at seedling emergence and 2-weeks after sowing was less than that of other two types of furrow openers; disk type and reverse hoe type [at α=0.05] (Fig. 6). Figure 7 illustrates that as tractor forward travel speed increased, the remaining percentage residue, at the seedling stage, also increased after using all three types of furrow openers [at α=0.05]. This effect on residue was due to the low forward tractor speed that increased soil loosening because of constant speed of wavy coulters (242 RPM). Use of the disk-type opener resulted in the greatest percent residue remaining on the soil surface at all speed as compared to the other two types of furrow openers.

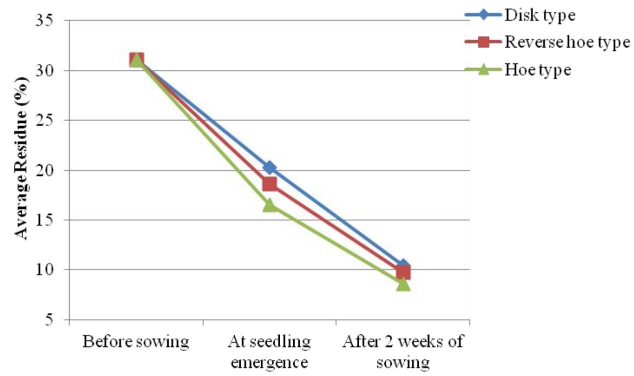

Figure 6. Effect of furrow opener and time on decomposition of paddy residue

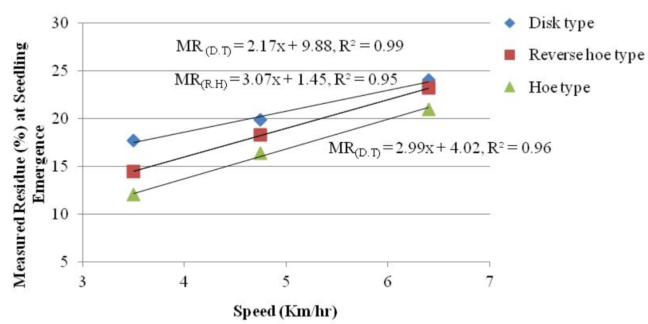

Figure 7. Effect of furrow opener and speed on paddy crop residue management at seedling emergence

***Effect of furrow openers on seed emergence rate index (ERI)*:** Optimum emergence is essential to attain maximum crop yield, particularly in reduced and zero-tillage systems. Figure 8 shows that emergence rate index (ERI) was significantly greater for disk-type opener than the other two types of openers due to better seed-soil contact when using the disk-type opener. A tractor forward Speed of 4.75 km/hr exhibited higher ERI than that observed at two other speeds; 3.5 km/hr and 6.4 km/hr (Fig. 8). These trends in Figure 8 also indicate that a better seed-soil contact was provided by all three types of furrow openers at a speed of 4.75 km/hr which resulted in greater ERI than the other two speeds. High R^2 values for all treatments show that a strong correlation exists between the measured percent ERI and tractor speed.

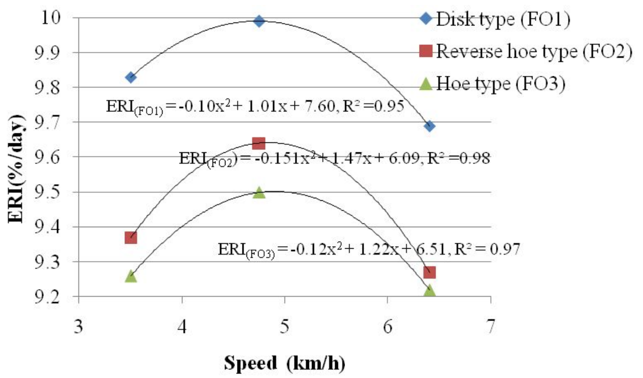

Figure 8. Effect of furrow opener and speed on emergence rate index

***Effect of furrow openers on grain yield*:** The significantly greater crop yield (Fig. 9) resulting from using disk-type furrow opener, as compared to the other two openers, at a tractor forward speed of 4.75 km was due to the best ERI (Fig. 8) for disk-type opener at this speed. The grain yield for disk-type furrow opener was 4.13 t/ha followed by yields produced by reverse hoe type (3.97 t/ha) and hoe type furrow openers (3.85 t/ha) at a speed of 4.75 km/hr (Fig. 9). So it is evident from these results that better seed emergence leads to better crop yield. As the tractor forward speed increased from 3.5 km/hr to 4.75 km/hr the emergence rate and crop yield also increased. On the other hand as speed was increased from 4.75 m/hr to 6.4 km/hr the ERI and crop yield were decreased which was due to the lack of soil to seed contact. High R^2 values of crop yield and tractor forward speed indicated that observed yield at different forward tractor speed.

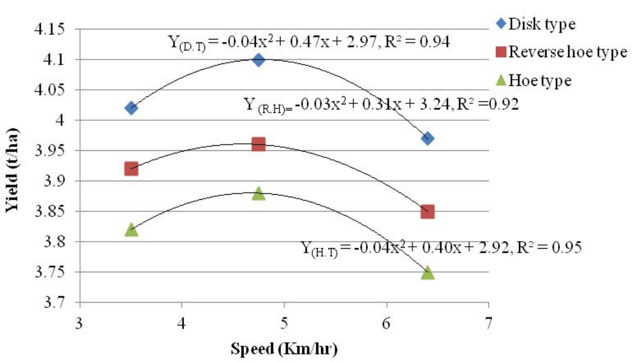

Figure 9. Effect of furrow opener and speed on grain yield

***Conclusions*:** The seedling emergence rate index (ERI) was higher under disk-type furrow opener than those under the reverse-hoe-type furrow opener and hoe-type furrow openers. Emergence Rate Index was greatest at tractor field speed of 4.75 km/hr. The grain yield was higher under disk-type furrow openers than those under reverse-type-furrow openers and hoe-type furrow opener. The disk-type furrow opener provided higher grain yield at speed 4.75 km/hr. The hoe-type furrow openers managed residue properly in a way that it helped leaving some residue over soil surface for reducing the soil moisture loss during seedling emergence and crop stand establishment.

Based upon the findings of research conducted, disk-type furrow is recommended to be operated at the intermediate tractor speed (4.75 km/h) to produce best soil conditions for good seed-soil contact for water imbibitions and nutrient availability to emerging seedlings. Ultimately there will be good crop stand establishment and maximum crop yield.

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