Effect of rotary blade modification on residue retention into conservation agriculture practices

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Abstract: Conservation Agriculture (CA) has been a promising technique for better crop production. Manual seeding with conventional tillage practice is laborious and time consuming. However, strip tillage (ST) method incorporating seeding machines minimizes human drudgery and optimizes the crop yield. Many problems associated with ST have been rectified e.g. tiny furrow backfill, inaccuracy of seed and fertilizer placement, leading to poor germination and curtailed outcomes. This article focused on the effects of residue retention for the rotary blades design on a versatile multi-crop planter (VMP). Four types of modified rotary blades of VMP differed by 15° increment of tip angles were fabricated, and experimented with a linear speed of 2.625 $m\ s^{-1}$ (350 rpm) for ST operation targeting wheat and maize cultivation. Technical aspects related to the quality of strip i.e. width of furrow, depth of seed placement etc. were observed. Furthermore, the percentage of straw cut and seed emergence were visualized. From the observation, straw wrapping was almost disappeared due to rotating action with the sharp edge of the new modified blades in front of the furrow openers. Soil cutting depth of strips and seed placement depth was consistent all over the field by the modified blades during wheat and maize sowing. The set of 15° tip angle blades at 15 cm anchored rice residue (RH15) shown the improved seed germination rate of 95.89% for wheat and 78.65% for maize. The investigation enables scope for adopting modified blade for better performance into CA practice.

Keywords: strip tillage, rotary blade, tip angle, residue height

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1 Introduction

Conservation Agriculture (CA) contributes a comprehensive approach for pruning many risks that influence crop production. CA based practice performs better in the long-run in terms of yield increase (Jat et al., 2019; Sharifi et al., 2016) and improvements in soil health, system resilience, and sustainability (Hobbs et al., 2008). CA also enhances the biodiversity and natural biological processes above and below the ground surface (Kassam et al., 2019). Conventional tillage and hand broadcasting of seed is a laborious and time-consuming operation. Less dependency on man, machine and energy for agriculture has achieved by adoption of CA machinery (Sims and Kienzle, 2015). The promising CA practice have been developed to reduce the negative environmental effects of

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agriculture such as soil degradation of physical properties and soil erosion, leading to decreased productivity, involve minimum disturbance of soil, residues retention, and optimal rotation or association of crops (Jokela and Nair, 2016; Smart and Bradford, 1999). In addition, CA tillage ranges from zero tillage (ZT) to minimum like strip tillage (ST) where the ZT reduces yield significantly. However, the combination of other CA principals e.g. residue retention and crop rotation, negative results are minimized dramatically (Pittelkow et al., 2014).

Nowadays, two-wheel tractors (2WT) are the common tillage tool and popular among the small land-holding farmers for easy access to fields with affordable price. CA based tillage practices using appropriate scale equipment can help farmers to improve soil quality for sustainable agriculture (Temesgen et al., 2007). More than 30% of the soil surface is disturbed by ST practice, leaving most of the previous crop's residue intact. It consists of preparing strips of seedbed, 50-200 mm wide and 50-200 mm deep, with the soil between the strips not being disturbed and having a protective cover of plant residue (Friedrich et al., 2012).

Many of the CA research on strip tillage with 2WT operated seeder faced the problem of less furrow backfill, improper seed and fertilizer placement leading to poor germination (Matin et al., 2016; Haque et al., 2010). These problems are related with strip blade, rotational speed and furrow opener. Thus, research on identified problems of CA planters is of prime need. Matin et al. (2015) reported that the blade geometry and the rotational speed have an influence to improve the furrow backfill on the strip. The research studies of Yang et al. (2018) found that the C type blade configuration produced a uniform furrow profile compared with straight and hoe type, however, its furrow backfill was unsuitable for seeding. Besides, there is a problem of wrapping residues to the blade of ST planter, which hampers proper seed and fertilizer dropping, and causes loss of time. Zheng et al. (2019) experimented on the redesign of anti-wrapping blades to analyze wrapping process and found effectively reduced residue and weed wrapping of rotary parts. Although, there are potential scopes to improve the machinery for solving associated problems for 2WT operated strip tillage. There is immediate need to design rotary blades and optimized speed to achieve the better seedbed, improved furrow backfills and healthier seed emergence in the strip.

Therefore, the study reported here was conducted to evaluate how to overcome or improve the above problems at different residue height on wheat and maize cultivation. The specific objective of the study is to modify and test the performance of rotary blades with different tip angle to optimize the reduction of straw wrapping and proper seed placement.

2 Materials and methods

2.1 General information

The study was conducted in the workshop and the research field of the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh (24°43' North Longitude and 90°25' East Latitude) during November 2016 to April 2017. The experiment was aided with a versatile multi-crop planter (VMP) (Model: 2BG-6A PTOS fitted to a 9.0 kW Dong Feng DF12 two-wheel tractor) shown in Figure 1 commonly used as strip tillage planter (STP). For the tests, the rotary blades of the seeding machine were modified and fitted with four sets of four blades at a spacing of 20 cm. At each position (left) bent C type blades, commonly used with STP were fitted with the bend facing (with tip angle) toward the center of the furrow (vertical face on the outside of the furrow).

The cutting edge of all blades was sharpened. Two level of residue retention was created with 15 cm and 20 cm standing residue (RH15 & RH20). Eight different experimental plots total area 1053 m^2 were used for the experiment with four different tip angles of blade and two different rice residue heights. Where, VMP was tested with 57.5° blade angle at a linear speed 2.625 $m\,s^{-1}$ (350 rpm) of rotary shaft. Then for each plot treatments were applied randomly. The designed blades were tested for planting of

BARI Gom-26 wheat and NK-40 maize variety into the experimental plots.

Figure 1 Versatile multi-crop planter

2.2 Modification of rotary blade

When a rotary blade is cutting into the soil, the angle α between the radius direction of the turning blade and the tangential line of its edge-curve (Figure 2) is the main key to be considered in designing the blade (Ju, 2007).

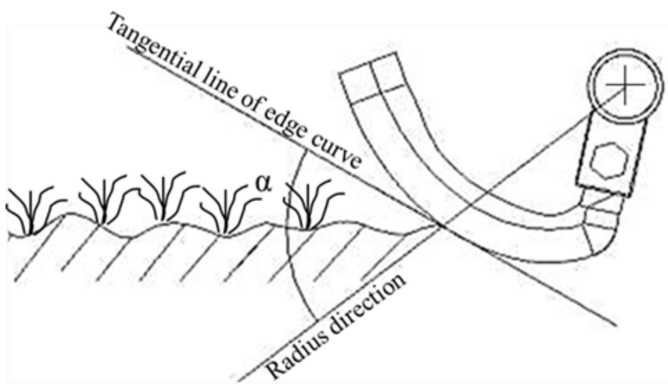


Figure 2 Sketch of α working on the soil

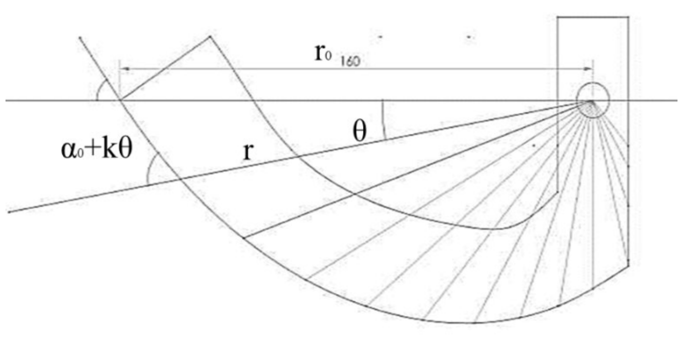


Figure 3 Sketch of new blade for strip tillage

Straighter lengthwise portion of the blade able to directly hooked the grass and straw when α is small. On the other hand, when α is large the grass and straw easily slip off the blade. If α is small, the area of the blade which goes into the soil is narrow which reflects in lesser friction area between the soil and blade and thus facilitate for lower tilling resistance. A model blade was modified by the Equation 1 proposed by Sakai (1978)

$$r = r_0\, sin^{\frac{1}{k}} \alpha_0\, sin^{-\frac{1}{k}}(\alpha_0 + k\theta) \qquad (1)$$

Where, r_O is the maximum radius at the tip point of edge curve (cm), as shown in Figure 3, $\alpha_O =$, the edge curve angle (degree), k is the constant to give changing angles and r is the calculated radius of the spiral (cm), that depend on the variable θ in the function.

If 10° increment is expected with in the range of 180°, $k = \frac{1}{18}$. By putting, $r_0 = 20$ cm, $\alpha_o = 57.5^{\circ}$, $k = \frac{1}{9}$ and θ ranging from $0° - 90°$ into Equation 1 results the edge curve where α_o is increasing with increasing of θ.

The modified blade was designed considering r_0=20 cm since, Chinese blade had the 200 mm radius of the curvature. To reduce the hooking character of the blades to straws α is taken as 57.5°. An increase of 10° changing angle and $k = \frac{1}{9}$. Different tip angles (e.g. tip angle: 0°, 15°, 30°, 45°) for left side and right-side tip was designed at constant tine angles of 57.5°. According to the model (Figure 3) the blades (a total of 64 blades and 16 of each type) were fabricated in the workshop of Department of Farm Power and Machinery, Bangladesh Agricultural University. The pictorial views of the developed blades are shown in Figure 4.

Figure 4 Blades with different tip angle

There were 16 blades used in strip tillage planter rather than 36 blades used for making strip in the soil. The length of the blade was 20 cm and the outside diameter of the rotary shaft with blades was 45 cm. Blade arrangements in a rotary shaft, four blades were placed at the same position. Blade arrangement of strip tillage planter is illustrated in Figure 5.

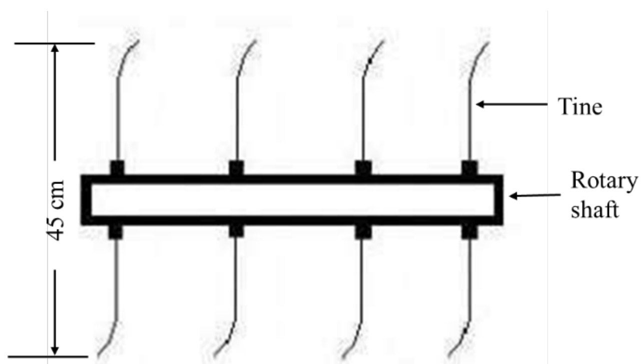


Figure 5 Blade arrangement of planter in ST mode

2.3 Experimental procedure

The Following data were collected e.g. Forward speed, rotational speed of rotary shaft, depth of strip, Width of strip, depth of seed placement, percentage of seed germination for both wheat and maize planting.

The speed of planter can be found using the following Equation 2 (Hunt and Wilson, 2015).

$$S = \frac{D}{t} \times 3.6 \qquad (2)$$

Where, S is the transplanting speed (km h^{-1}), D is the distance (m) and t is the time required to cover the distance D (s).

For seed calibration two third of the seed box was filled with seed. Transparent polythene bags were tagged with each of the four seed delivery tubes. The VMP was operated on a pre-measured 20 m travel distance with a sowing width of 80 cm, thus providing coverage of 16 m^2 area. After every 20 m linear distance run, seeds through tubes were weighed separately and the total seed weight was also measured. This method was repeated by acceleration and deceleration of the lever of seed rate control until the desired seed rate obtained. Since the seed metering device was connected by a chain sprocket arrangement to the power tiller wheel axel, the speed of the tiller should not be a factor in calibration, unless there was excess wheel slippage. The seed rate was determined through calculation by using the following Equation 3 (Hossen et al., 2014).

$$S_d = 10 \times \frac{W_s}{A_m} \quad (3)$$

Where, S_d is the seed rate (kg ha^{-1}), W_s is the total weight of seed (g) and A_m is the measured experimental area (m).

Width and depth of each strip followed by the wheat and maize planting through VPM operation into every plot were measured and recorded. The collected data were analyzed to test the performance of the planter for this soil. The following Equation 4 was used to figure out percentage of seed germination for both crops. All the data collected from field was averaged from three observations from each experimental plot. The experiment was designed with randomized complete block design (RCBD) and the data were analyzed with tabular and graphical analysis.

$$\%\, seed\ germination = \frac{No.of\ seed\ germinated\ per\ meter\ length}{No.of\ seed\ placed\ per\ meter\ of\ length} \times 100 \quad (4)$$

3 Results and discussion

3.1 Forward and rotational speed of VMP

The forward speeds of strip tillage planter during the tillage operation were recorded shown in Table 1 for the tip angle of 0°, 15°, 30°, and 45°. The study was conducted at a constant rotational speed (350 rpm) of rotary shaft. The moisture content and bulk density of soil at 0-5 cm depth in the experimental plot was found 26% (wb) and 1.65 g cm^{-3} respectively.

Table 1 Forward speed of VMP during wheat planting

Blade at different tip angle	Wheat		Maize	
	Time, s (20 m distance)	Forward speed, m s^{-1}	Time, s (20 m distance)	Forward speed, m s^{-1}
0°	27.77	0.72	23.8	0.84
15°	28.57	0.7	25.64	0.78
30°	25.31	0.79	27.77	0.72
45°	29	0.69	22.72	0.88

3.2 Performance of blades at different residue level

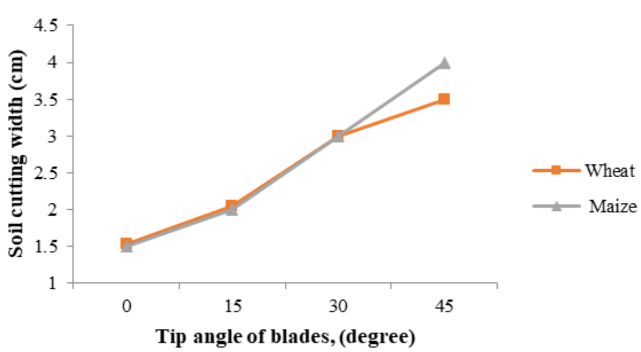


Figure 6 Strip width during ST operation

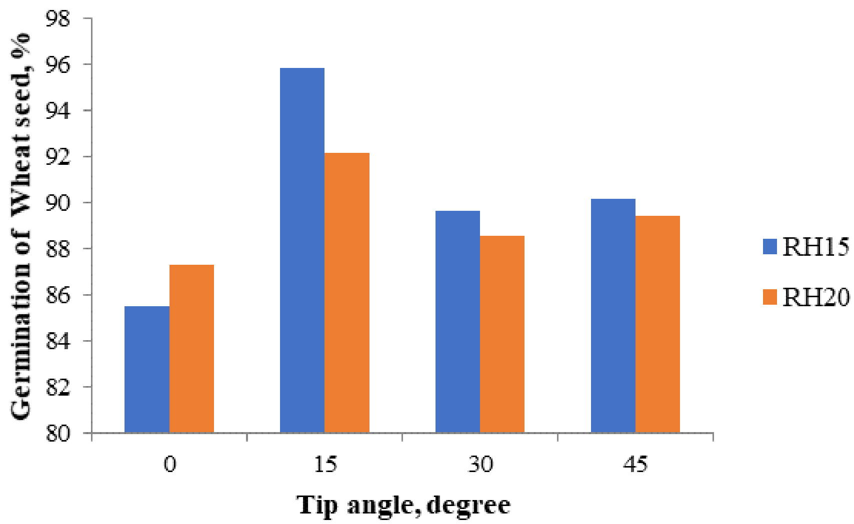
There was no straw wrapping observed for the modified blades during ST operation. Anchored rice residue was cut due to rotating action with the sharp edge of the new blades in front of the furrow openers which eliminated the wrapping into the rotating shaft and it was ranged from 93% to 100%. Strip width was increased gradually with tip angle of blades and it was ranged from 1.50 to 4.00 cm for retained rice residue during maize and wheat sowing illustrated in Figure 6.

The Performance of blades at different residue level during ST planting of wheat and maize is shown in Table 2. Straw cut percentage, soil cutting depth and seed placement depth of strips for wheat was found average 4.35 cm and 2.22 cm respectively. However, this value was little bit increased for maize cultivation incorporating suitable machine setup. The observation was not widely varied for different blades and residue level for the both crops.

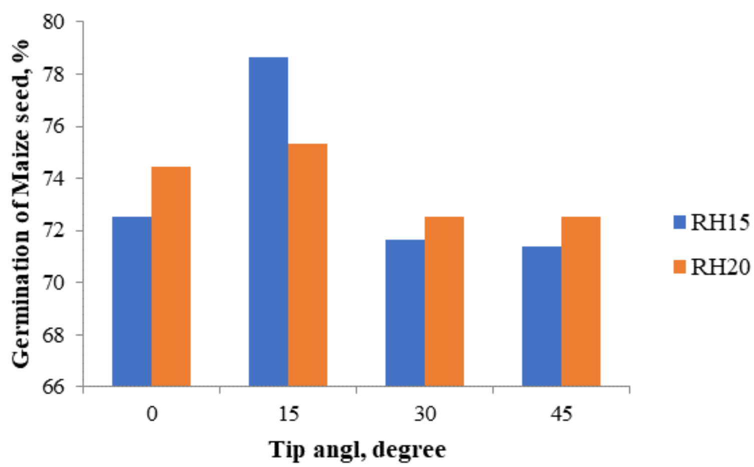
Seed germination observed from each plot is identical. The highest wheat germination about 95.89% was found for using 15° tip angle blades at 15 cm residue level. Moreover, about 78.65% germination of maize seed was observed using same configuration illustrated in Figure 7.

Table 2 Performance of blades at different residue level during strip till planting

		Tip angle (degree)								**Average**
		0°		15°		30°		45°		
	Residue height (cm)	15	20	15	20	15	20	15	20	
Wheat (Bari Gom-26)	Straw cut (%)	99	95	98	94	98	93	98	95	
	Soil Cutting Depth (cm)	4.38	4.37	4.4	4.39	4.37	4.36	4.2	4.3	4.35
	Seed Placement Depth (cm)	2.23	2.2	2.23	2.2	2.21	2.19	2.26	2.24	2.22
	Seed germination (%)	85.50	87.32	95.89	92.20	89.65	88.58	90.19	89.46	
Maize (NK-40)	Straw cut (%)	99	95	100	94	98	93	98	95	
	Soil Cutting Depth (cm)	5.08	5.1	5.05	5.09	5.1	5	5.1	5.2	5.09
	Seed Placement Depth (cm)	3.55	3.5	3.53	3.44	3.39	3.32	3.5	3.59	3.5
	Seed germination (%)	72.52	74.45	78.65	75.35	71.63	72.54	71.36	72.54	



(a) Wheat seed germination with different tip angle



(b) Maize seed germination with different tip angle

Figure 7 Germination rate for (a) wheat and (b) maize seed

4 Conclusions

Modified blade attached in VMP produced better seedbed and enhanced plant germination in the strip tillage planting. Four types of rotary blades which differed by tip angles $(0°, 15°, 30°, and\ 45°)$ were fabricated and experimented with a linear speed of 2.625 $m\ s^{-1}$ (350 rpm).

VMP was used to test the blades for ST operation for planting maize and wheat. From the study it was observed that there was no straw wrapping for the modified blades. Strip depth and width was almost consistent along with depth of seed placement. The results visualize that, the seed germination rate for wheat and maize is higher at the 15° tip angle blade with 15 cm residue height ST operation.

Therefore, using blades of 15° tip angle would be the preferred option over existing blades when undertaking ST using a VMP. In order to make the STP more efficient and acceptable there should be further research is needed to verify these results in other soils with varying moisture content since the present results suggest there is scope for adopting modified blade for better performance of strip tillage.

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