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Development of Residue Management Unit for Direct Seeding in Rice Fields

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Abstract- Conservation agriculture is becoming increasingly important and it is being practiced to varying degrees in different countries to save production costs and generate more income. Wheat direct seeding in combine harvested rice fields is away to practice conservation agriculture in Egypt. The main operational problem in direct seeding in paddy straw residue is the accumulation and wrapping of loose straw on the tines of no-till drills. So, residue management unit was developed to overcome problems arising while sowing wheat in combine-harvested rice fields. The developed unit consists of two powered wheels. One wheel for cutting the residue and the other one for removing them away from no-till drill furrow openers. The experiments were carried out at Department of Agricultural Engineering, Faculty of Agriculture, Kafrelsheikh University, Kafrelsheikh Governorate during the years of 2014 and 2015.

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Abstract- Conservation agriculture is becoming increasingly important and it is being practiced to varying degrees in different countries to save production costs and generate more income. Wheat direct seeding in combine harvested rice fields is away to practice conservation agriculture in Egypt. The main operational problem in direct seeding in paddy straw residue is the accumulation and wrapping of loose straw on the tines of no-till drills. So, residue management unit was developed to overcome problems arising while sowing wheat in combine-harvested rice fields. The developed unit consists of two powered wheels. One wheel for cutting the residue and the other one for removing them away from no-till drill furrow openers. The experiments were carried out at Department of Agricultural Engineering, Faculty of Agriculture, Kafrelsheikh University, Kafrelsheikh Governorate during the years of 2014 and 2015. Experiments conducted in locally manufactured open-air rectangular soil bin to develop and test a prototype of residue management unit and to optimize its operational parameters. Three variables (Wheel rotational speed, angle of wheel and concentration of the residues) were taken. The results showed that using 5.4 km/h as rotational speed gave best results for cutting and removing the residue. The amount of residues clogged within the equipment decreased by increasing the rotational speed and lowest values obtained by adjusting the wheels with 20 ° degree. While, increasing the rotational speed continuously increase the residue flow.

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I. Introduction

High levels of crop residues present a constraint to the adoption of conservation tillage because residues mechanically interfere with seeding operations. Improved seedling equipment or residue removal may be necessary for successful direct drilling practices (Carter, 1994). The collection of straw after paddy harvesting is uneconomical and its end use is not yet wide spread. So, either residue is incorporated in the soil or burnt in the field. Incorporation of straw in soil has got some advantages in improving the soil fertility and yield. However, this process needs many operations which involve both time and money of the farmers and it delays sowing of wheat crop. According to Beri and Sidhu (1999) huge amount of straw is being burnt off annually as a waste product, which creates environment pollution. Burning also decreases the efficiency of some weedicides used for controlling weeds during wheat growth. Also, significant quantities of valuable biomass would have been lost due to burning. In heavy crop residue, or when row spacing is narrow, Hoe, chisel, winged chisel, and inverted T type drills are prone to blockages between adjacent openers (Wilkins et al. 1983 & Slattery, 1998). They also tend to cause large clumps of residue to form (Slattery and Riley, 1996). This adversely affects seeding depth uniformity, which is important for optimum seedling emergence and maximum yield of many crops, including cereals (Morrison & Gerik, 1985). An approach that has not been well explored is the use of powered devices to move the residue. Powered residue manipulating devices also offer flexibility in design alternatives. They could be designed to skim above the ground to avoid soil disturbance and are not limited in speed to the drill travel speed. With speed and control over the direction of rotation a variety of residue cutting, chopping and pushing devices can be considered. Furthermore, a powered device can be adjusted to direct residue where desired.

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II. Materials and Methods

a) *Design considerations and concepts*

From literature review, it is clear that the main operational problem in direct drilling is accumulation of paddy straw residues. The machine, therefore, needs to be designed and developed on the basis of cutting and removing of paddy straw away from the no-till drill. In order to facilitate the movement of straw, two processes are needed one for cutting the residue and the other for removing them. The importance of the residues cutting include reducing the length of loose straw and cutting stand stable which may be laying in front of no-till drill but still connected with the soil. To facilitate direct drilling practices, four basic patterns of coulters are available in the market: smooth, notched, ripple, and wave. These coulters have operational problems and usually do not cut the residue efficiently so, new design is needed for cutting wheel. Removing the residue as the second process very important in order to reduce the amount of residue clogged on furrow openers and make the line of sowing clear and clean from residues which affect no-till drill performance (Wilkins et al. 1983; Slattery, 1998; Slattery and Riley,1996; Morrison and Gerik, 1985). The other important concept is that the residue management device should be powered to overcome the problems which were found with using passive devisees.

b) Functional Design Requirements of the Residue Management Prototype

The various functional design requirements of the prototype are; it should be able to cut and remove residues from front of the furrow openers of the no-till drill; the shape and dimensions should be suitable for wheat sowing conditions and the no till drills; and power transmission should be adjustable, optimum rotational speed of the device should be used

c) Design and theoretical consideration for cutting and removing wheels

The design of cutting wheel is based on the idea that using star shape wheel (teeth) would essentially work as a narrow tool, but with a forward and rake angle as described by McKyes (1985). This will impart greater momentum to the wheel than that obtained with a smooth, waved, notched and ripple edged which commonly used to cut plant residues (Desbiolles, 2004). Besides, the wheel would penetrate the soil more easily and require less vertical force. The toothed wheel will cut the residues only if it penetrates the soil with little depth and rotates. This will happen only if there is enough vertical pressure from the wheel and a corresponding soil resistance to the draught force due to the action of the teeth. This can happen if we provide a power source to rotate the wheel with specific rotating speed and fixed position. For adjust the suitable distance between two consecutive teeth, one tooth should touch the residue surface when the previous one penetrate the soil (Bianchini, 2002). Keeping the above aspects in view, the present work was undertaken to develop a residue management unit for a no-till drills with the optimization of its operating parameters under soil bin conditions.

For designing the cutting wheel under above consideration, the calculation and assumptions based on standard machine design book were followed. Outside diameter for the cutting wheel was 320 mm, and the suitable number of teeth was 23 with 35 mm length for each edge. Also, to design present removing wheel, both curved fingers and wheel angle should take in consideration with adjusting the dimensions to attach this wheel with the cutting wheel. So, diameter of removing wheel was less than diameter of cutting by 20 mm to prevent soil-wheel interaction. The number of the finger used to manufacture the removing wheel was 12 with 30 mm length occupied with 40 x40 mm depth and width curved cross-section. The fingers were curved with 15 degree and the overall diameter was 300 mm and the fingers spaced equally around its perimeter. The material used for manufacturing the removing wheel was mild steel with 2 and 4 mm thickness. Both cutting wheel and removing wheel attached together in one unit as double wheel for testing in soil bin (Fig. 1).

Figure 1: Locally manufactured cutting and removing wheels

d) Dynamic laboratory experimental variables and treatments

The experiments were conducted at Department of Agricultural Engineering, Faculty of Agricultural, Kafrelsheikh University, Egypt. The experimental set-up for soil dynamic laboratory studies comprised a rectangular soil bin and an experimental unit. Establishment and manufacturing of a modern soil bin have been carried out to test a modified set of residue management unit which have been designed and manufactured. To run required experiments with defined variables and treatments and according to the dimensions of designed unit, a set-up for soil dynamic laboratory including soil bin have been prepared. The designed soil bin done to make it multipurpose with dimensions of 10 x 1.5 x 1.2 m as length, width and height respectively. Soil bin has free capacity of 18 m^3 and prepared to contain most available soil and media under different conditions. The soil bin was rectangular in shape and withstand under heavy conditions with multi-duty facilities. Materials used to manufacture such soil bin were steel, cast iron, hollow sections iron, wood, railway type move and wheels. Additional frame have been manufactured and used to carry required movable material and units, with dimension of 1.5 x 0.7 x 0.5 as width, length and height respectively and to be movable above the main frame of the soil bin. High quality materials and equipment used to provide the soil bin with required movement and desired arrangements. Two different motors and 5 hp invertor have been used to provide the required movements of the carriage during test. Soil bin' floor and walls covered by beech wood and plastic sheets to maintain the water and drainage. Electrical connections and circuits have been done carefully and with standards to control all movements and motors in on control unit attached to the bin (Fig. 2).

Figure 2: Installing soil bin and attached control units and motors

e) Soil dynamic laboratory experimental variables

After installing the soil bin and its required connections and set-up, test of previously manufactured residue management unit followed the preparation as soil dynamic test under different variables and measurements as proposed to optimize the parameters of the residue management prototype. The experimental soil was dried to the initial moisture content and crushed to a fine uniform size before it was put into the soil bin. Experiments were conducted first in the driest state and water was added for the consequent runs until the moisture content of the soil reached an equilibrium state, The soil processing trolley was used for processing the soil mechanically in the bin in order to achieve uniform soil condition as desired for test-run throughout the soil bed. A reasonable agreement was found in the compaction level at the different locations along the length of the bin, this was achieved by rotavating the soil and passing the roller over it for a fixed number of times usually between 2 to 4. The cone penetrometer was used to monitor the uniformity of the prepared soil by comparing the cone indices of the sampled sites. After the soil processing was over, the residue management unit was mounted at desired depth and tested under variability of its angle (four levels of wheel angle 10°, 15°, 20° and 25°) and speed (2.52, 3.96. 5.4 and 6.31 km/h) to determine the best angle and suitable speed for residue management unit under two residue density and deferent conditions.

f) Soil and Residue Preparation

The soil was tilled and puddle in soil bin in presence of adequate water and the roller was passed up to 6 times. Thereafter , the soil bin was left to dry until the puddled soil moisture reached 15-16 percent and penetration resistance of about 0..84 MPa. At this moisture content, the soil reached to its friable range and cracks developed on the soil surface. Surface residue density was created by hand harvested wheat stalks. This was sun dried to the moisture level of 10-12 percent (w.b.). In soil bin the dry wheat stems of uniform length (450 mm) was cut and made in a lot of 100 pieces. It was weighted and laid in front of residue management device perpendicular to line of travel, covering surface area in such a way that necessary residue concentration can be created over the soil surface. Movable carriage with dimension of 1.5 x 0.7 x 0.5 m as width, length and height respectively to move above the main frame of the soil bin has been manufactured (Fig. 3).

Figure 3: Attaching residue management unit on specified carriage for testing

g) Measurement of Soil Moisture Content, Bulk Density and Cone Index

The measurement of soil moisture content and bulk density was done in soil dynamic lab by collecting soil samples with the help of standard core sampler. The moisture content and the bulk density were determined on dry weight basis by adopting oven dry methods. For measuring the soil strength in soil bin the cone index of soil was measured, which is defined as the resistance offered by the soil to push a standard cone penetrometer into the soil. The used device was cone penetrometer Baker (Type J12) ISI-IS 2092 having capacity of 1.3 kN to 2.21 kN and 0.002 mm to 5mm of cone base and about 20° cone angle

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h) Measurement of Residue Cutting, Residue Clogging and Residue Flow

Wheat straw of uniform size and hundred in number were placed centrally and perpendicular to the line of travel in front of the double wheel. After every pass the numbers of cut pieces of stalks were noted. Residue clogging was calculated as a number of wheat stalks remained entangled around the residue management device after every pass. Residue flow was calculated by determining the average distance which the residue moved from center line of travel.

III. Results and Discussion

a) Effect of wheel rotational speed, wheel angle and residues density on residue cutting

The number of residues cut pieces was observed and expressed as percentage (Fig. 4 and Fig. 5). The results showed that increasing the rotational speed from 2.52 to 3.96 km/h and from 3.96 to 5.4 km/h increased the percentage of residues cutting by 24.2 and 34.4 % respectively at 20^{o} of wheel angle and low density condition of residues. However, increasing the speed further decreases the percentage of cut residues. It may be due to the shortage of time need to cut the residues when the speed was high.

Best cutting percentage obtained by using equipment under 5.4 km/h rotational speed with 20 degree wheel angle where the cut residue percentage increased by 4 and 8 % when the wheel angle increased from 10 to 15 and from 15 to 20 degree respectively at 5.4 km/h rotational speed and high residue condition,. The cut pieces always less in case of high residues density compared to the low density.

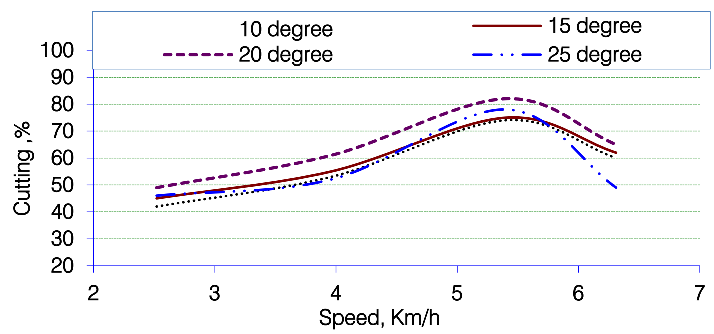

Figure 4: Effect of wheel rotational speed and wheel angle on residue cutting at low residues density

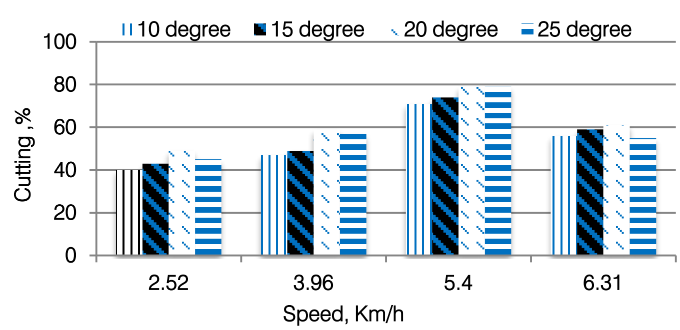

Figure 5: Effect of wheel rotational speed and wheel angle on residue cutting at high residues density

b) Effect of wheel rotational speed, wheel angle and residues density on residue clogging

The amount of residue clogged was observed and presented in Fig. 6 and Fig. 7. The results showed that the amount of residue clogged was more under low and medium speed, while it decreased by 6.25 % and 28 % when the speed increased from 2.52 to 5.4 km/h. and from 3.96 to 5.4 km/h respectively at 20^{o} wheel angle under low residues density condition.

Changing the wheel angle from 10 to 25 degree has no significant effect on the percentage of clogged residues. But the high density of the residues gave more clogged residues than the low density.

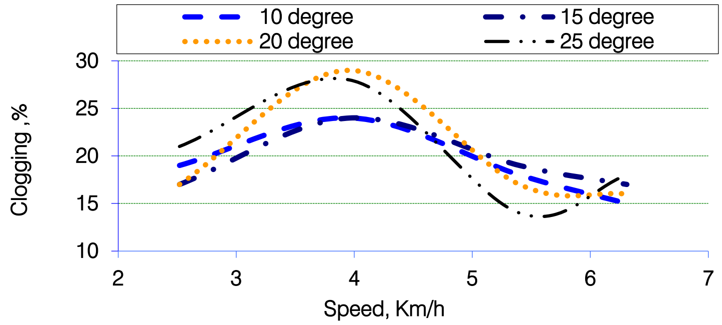

Figure 6: Effect of wheel rotational speed and wheel angle on residue clogging at low residues density

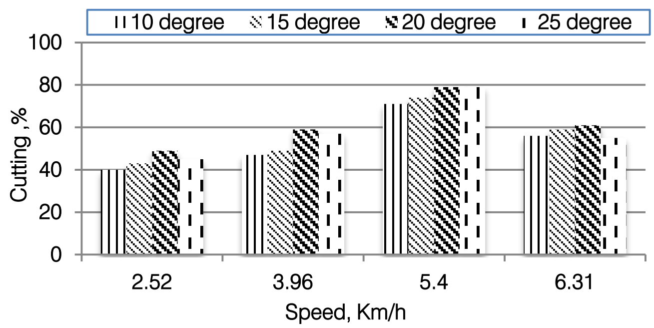

Figure 7: Effect of wheel rotational speed and wheel angle on residue clogging at high residues density

c) *Effect of wheel rotational speed, wheel angle and residues density on residue flow*

The distance of residue flow out from the center line of traveling increased from 5 to 7 cm and from 7 to 14 cm by increasing the rotational speed from 2.52 to 5.4 km/h and from 5.4 to 6.31km/h rotational speed respectively at 20 ^{o} wheel angle under low residues density condition. The best results obtained by using 5.4 km/h rotational speed and 20 degree angle of the wheel which gave flow around 7 cm where the residue can remain between two furrow openers (Fig. 8 and Fig. 9). While the flow distance more than 7 cm will move the residue into the furrow opener line.

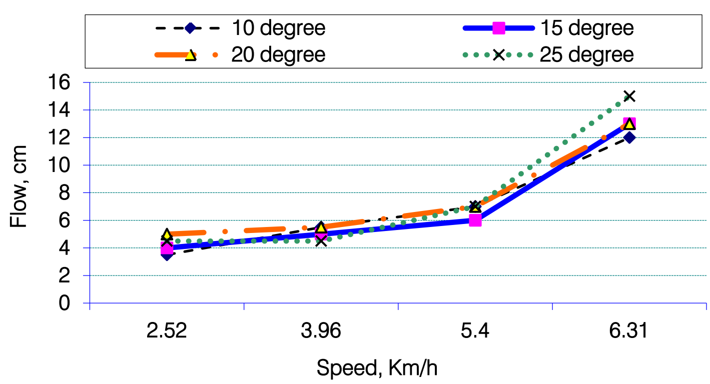

Figure 8: Effect of wheel rotational speed and wheel angle on residue flow at low residues density

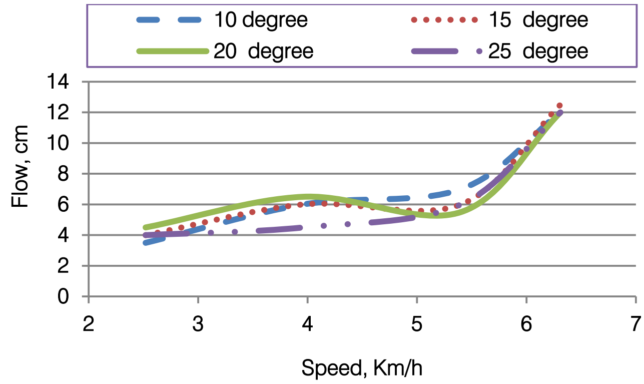

Figure 9: Effect of wheel rotational speed and wheel angle on residue flow at high residues density

IV. Conclusion

Increasing the rotational speed up to 5.4 km/h increased the percentage of residues cutting, while increasing the speed more than this decrease the percentage of cut residues. Using the residue management device with 5.4 km/h and 20 degree for the wheel gave good results in decreasing the amount of clogged residue. The suitable flow for the residue was around 70 mm which obtained by using the residue management device with 5.4 km/h and 20 degree for the wheel. The developed unit can be easily attached to any no-till drill with flexibility in assembling.

V. Acknowledgment

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