Optimization of tine spacing, tine length and toolbar spacing for sowing of various crops in rice-wheat combine harvested field

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ABSTRACT : Rice straw in its loose form, left after harvesting by combine harvesters, results into frequent choking of furrow openers of no-till drill during drilling of wheat, which is one of the major barriers and make adverse situation for extensive use of no-till seed-cum-ferti drill. The residue handling capability of no-till drills could be enhanced probably by increasing the spacing of tines on toolbar, tine length as well as keeping more than two numbers of toolbars at optimum spacing. Keeping this in view, a study was conducted to evaluate the machine performance parameters based on straw accumulation (kg/ha) in between tine or around the tine. Tines were fitted in V-shape arrangement on three toolbars. Effect of furrow opener spacing, tine length and toolbar spacing on residue accumulation and residue flow indicated that, in general, with the increase in all these parameters, residue accumulation decreased. Minimum residue accumulation was found as 14.46 g/m/tine in wheat crop residue and 18.57 g/m/tine in rice crop residue for 65 cm tine length, 30 cm furrow opener spacing and 70 cm inter toolbar spacing.

Key words: Furrow opener spacing, toolbar spacing, tine length, crop residue management, furrow opener.

Rice-wheat is the major cropping system in Indo-Gangetic plain (IGP) and occupies an area of about 13.5 mha. It is also one of the major crop rotation in India and is grown in an area of about 10 mha (Saunders *et al*., 2012). Combine harvesters have become popular for harvesting rice and wheat crop especially in the state of Punjab, Haryana, UP and also in Tarai Region of Uttarakhand. These machines recover the grain and leaves crop residue in the field which causes successive field operations difficult. There are several options available for the management of residues of these two crops e.g. burning (quite common), baling and collection; incorporation and surface retention. Burning, in addition to accelerating loss of organic matter, nutrients and soil biota, also causes air pollution and associated ill effects on health of human being and animals. Incorporation is a better option but it requires large amount of energy and time (Pathak and Sarkar, 1994; Sharma and Bali, 1998). When crop residue is maintained as surface mulch no-till sowing is more beneficial as it reduces the cost of cultivation. However, the residue present on the soil surface posses lot of operational problem including frequent chocking of no-till drill furrow openers while direct seeding. Some research were carried out during the mid-late 1990s for improving the residue handling capability of no-till drills by keeping the effective vertical clearance of the frame more than 1.5 times the stubble height and critical inter furrow opener spacing as 1.8 to 2.0 times the stubble length or loose residue length (Slattery,1998; Slattery and Riley, 1997). Inter furrow opener spacing of drill is affected by crop row spacing, toolbar spacing, number of toolbar and furrow opener arrangement on toolbar. Since the crop row spacing is fixed according to type of crops, therefore, furrow opener arrangement on toolbar and number of toolbar is the easiest options for maintaining furrow opener spacing. Critical furrow opener spacing represents the likely bottleneck within a furrow opener arrangement on toolbar and need to be balanced with residue handling capability which would maximize the potential of no-till drills. Keeping this in view, a study was conducted to observe the effect of various inter tine spacings on residue accumulation in combine harvested rice and wheat field.

MATERIALS AND METHODS

Test setup

The test setup consisted of seed drill frame with three toolbar especially developed for this study and seven number of inverted-T type furrow openers (Fig.1). Two angle irons of 50×5 mm size having 2060 mm length were welded together to form a square hollow section beam with a cross-section of 50×50 mm. In all, three beams of

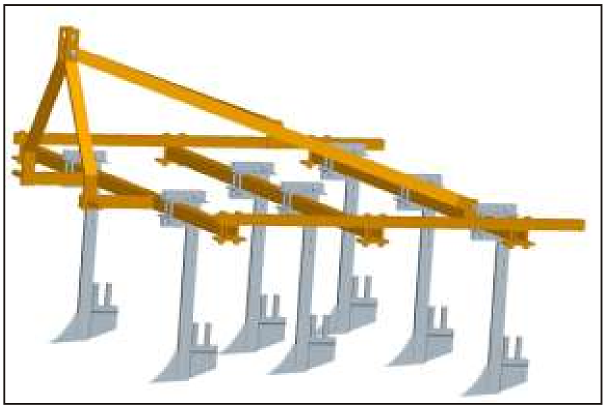


Fig. 1: Multi tool bar test setup for optimization of tool bar spacing, tine spacing and length of tine

identical size with above mentioned specifications were fabricated. All the three beams were joined together in parallel with another two side hollow square beams having cross-section of 40×40 mm to form a rectangular frame with overall length and width of 2060 and 1800 mm, respectively. Seven inverted-T type furrow openers were arranged on this frame with U- clamps with a provision to make adjustments both in horizontal as well as in vertical planes. The overall height of the furrow opener was kept 720 mm providing maximum clearance of 600 mm between ground and frame of the drill.

Experimental variables

Dependent parameter

Tine length

Tine length has considerable effect on the residue accumulation in furrow opener and the same is also affected by stubble height in the field. If tine length is less than stubble height then the residue accumulation by the furrow opener has been reported higher. Generally, the effective vertical clearance between frame and ground was kept more than 1.5 times of the stubble height. Therefore, this study related to residue accumulation was performed considering four levels of tine lengths as 50, 55, 60 and 65 cm.

Toolbar spacing

Toolbar spacing is important factor which affects the flow of residue around the furrow openers fitted on different toolbars. Four levels of toolbar spacing i.e. 55, 60, 65 and 70cm was selected to evaluate the multi-toolbar test setup in actual field condition.

Furrow opener spacing

In Indian condition most of the crops like rice wheat, green gram, cowpea, and black gram etc. are sown at 20 to 30 cm row spacing. Therefore, in this study the furrow openers were fitted at 20, 25 and 30 cm row spacing, to evaluate its performance in actual field condition for residue accumulation.

Independent parameter

Residue accumulation

The multi-toolbar test setup was operated for 20 m test run. The residue accumulation with the machine frame and furrow opener was collected manually from around the tine. Accumulated straw was weighed for each run and each furrow opener by the use of spring balance. The residue accumulation was finally converted in per meter per tine basis to express it as g/m/tine.

Test procedure

The furrow openers were mounted on an experimental test setup at different levels of toolbar spacing, tine length (vertical clearance of frame) and furrow opener spacing. The effect of different toolbar spacing, tine length and furrow opener spacing on residue accumulation in tines for V-shape arrangement on toolbar, which was found best in previous experiment, was studied (Sharma and Singh, 2014). The multi-toolbar test setup was operated in the field for 20 m long test run. The test setup with above mentioned variables was evaluated in combine harvested wheat and rice fields. The data obtained was analyzed statistically using three-factorial CRD to determine the level of significance.

RESULTS AND DISCUSSION

Field condition

Combine harvested rice and wheat fields were selected for the study. The quantities of loose residue of wheat along with stubbles were determined and the results have been presented in Table 1. The average height of stubble was observed as 40.3 and 35.6 cm with an average number of plants as 302 and 325 per square meter in wheat and rice crop, respectively. The length of loose residue was found as 41.5 and 40.2 cm for wheat and rice crop, respectively. The average density of crop residue in the wheat and rice was observed as 0.647 and 2.423 kg/m^2 at an observed moisture content of 11.4 and 31.5% (w.b.)

Table 1: Residue load and its parameter after combine harvesting in un-chopped test field

S. No.	Particulars	Wheat residue	Rice residue
1.	Moisture content of loose residue (wb), %	11.4	31.5
2.	Moisture content of anchored stubble (wb),%	12.6	65.1
3.	Loose residue load on surface, kg/m^2	0.265	0.856
4.	Residue load of anchored stubble, kg/m^2	0.382	1.567
5.	Total crop residue load, kg/m^2	0.647	2.423
6.	Residue cover, %	99.96	99.84
7.	Stubble height, cm	40.3	35.6
8.	Length of loose residue, cm	41.5	40.2
9.	Number of stubble/m^2	302	325

of loose residue and 12.6 and 65.1% (w.b.) in anchored stubble, respectively. The average percentage of residue cover on the surface was calculated as 99.9 and 99.8% in wheat and rice field, respectively.

Effect of furrow opener spacing and tine length on residue accumulation

The effect of furrow opener spacing and tine length on residue accumulation indicated that residue accumulation was non-significant for 60 and 65 cm tine length at 25 and 30 cm furrow opener spacing. In rice crop residue, the residue accumulation was found significant at all combinations of furrow opener spacing and toolbar spacing. At 20 cm furrow opener spacing, the residue accumulation decreased and was found as 46.9 % in wheat and 39.4% in rice when tine length increased from 50 to 65 cm (Fig. 2). At 25 cm furrow opener spacing, the residue accumulation gradually decreased and was observed as 55.7% in wheat and 39.0% in rice when tine length was changed from 50 to 60 cm. Similarly the residue accumulation was observed to decrease and was recorded as 5.93 and 5.03 % when tine length was increased from 60 to 65 cm in wheat and rice crop residue, respectively. The trend was observed similar for 30 cm furrow opener spacing as it was obtained for 25 cm furrow opener spacing. The multiple regression equation for the residue accumulation (kg/m) for the wheat and rice crop residue, incorporating the furrow opener spacing (f_s) and tine length (t_l) in meters, are given as under:

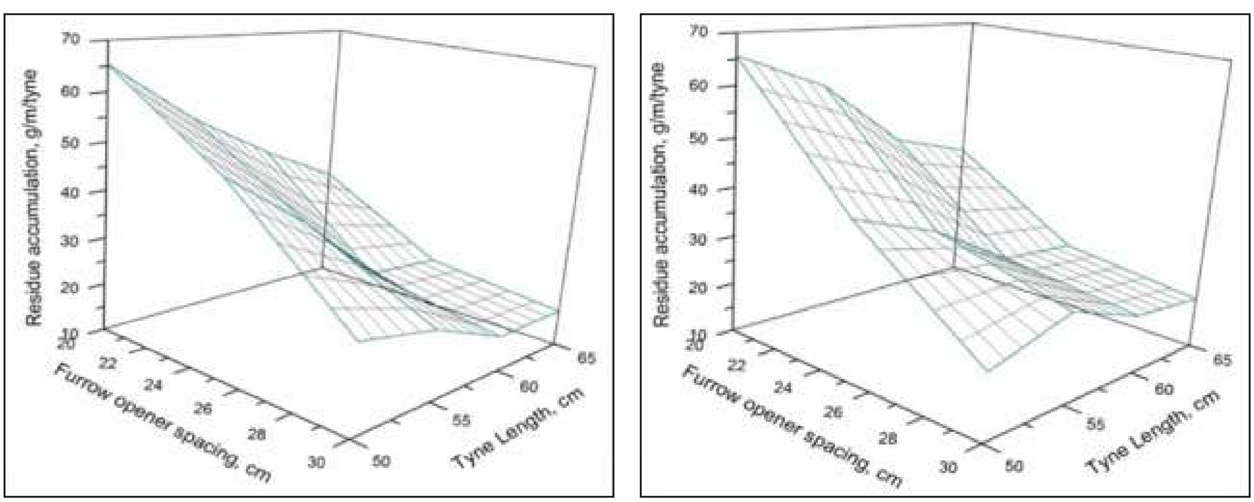
Wheat crop residue

$$Aw=0.659-1.610f_s-1.209t_l+1.222f_s^2+0.635t_l^2+1.266t_lf_s \quad ...1$$

Rice crop residue

$$Ar=0.558-2.472f_s-0.523t_l+2.587f_s^2+0.031t_l^2+1.548t_lf_s \quad ...2$$

The values for the coefficient of determination (R^2) were observed as 0.996 and 0.978, respectively for wheat and rice. The model was found significant for both the crop residues.



Wheat crop residue **Rice crop residue**

Fig. 2: Effect of furrow opener spacing and tine length on residue accumulation

Effect of furrow opener spacing and toolbar spacing on residue accumulation

The residue accumulation varied from 72.36 to 19.26 g/m/tine for wheat crop residue and 70.89 to 21.32 g/m/tine for rice crop residue for different combinations of furrow opener and toolbar spacing. The minimum accumulation of residue was observed at 30 cm furrow opener spacing with 70 cm tool bar spacing in wheat and rice crop residue, respectively (Fig 3). The difference in residue accumulation was found non-significant at 5% level of significance for combination of 30-55, 30-60, 30-65, 30-70, 20-70 and 25-70cm furrow opener spacing and toolbar spacing. The residue accumulation was found to differ at 5% level significance in different combination of furrow opener and toolbar spacing. The multiple regression equation for the residue accumulation (kg/m) for the wheat and rice crop residue, incorporating the furrow opener spacing (f_s) and toolbar spacing (t_s) in meters, are given as:

Wheat crop residue

$$Aw=0.635-2.589f_s-0.625t_l+1.224f_s^2+0.173t_l^2+2.730t_lf_s \quad ...3$$

Rice crop residue

$$Ar=0.855-2.57f_s-1.386t_l+31.185f_s^2+0.779t_l^2+1.159t_lf_s \quad ...4$$

The coefficient of determination (R^2) for wheat and rice was observed 0.979 and 0.98, respectively. The model was found significant for both the crop residues.

Effect of tine length and toolbar spacing on residue accumulation

The relationship for the residue accumulation with respect to tine length and toolbar spacing is shown Fig. 4. It is evident from the figure that in general, the residue accumulation deceased with increase in tine length and toolbar spacing for both types of crop residues. The residue accumulation obtained at 60 and 65 cm toolbar spacing was observed similar. The lowest residue accumulation was found at 60 and 65 cm tine length with 65 and 70 cm toolbar spacing in both wheat and rice crop residue. The multiple regression equation was developed for the residue accumulation (kg/m) for both the wheat and rice crop residue, incorporating the tine length (t_l) and toolbar spacing (t_s) in meter and the same has been given as under:

Wheat crop residue

$$Aw=0.711-1.49t_l-0.49t_s+0.626t_l^2-0.182t_s^2+0.975t_lt_s \quad ...5$$

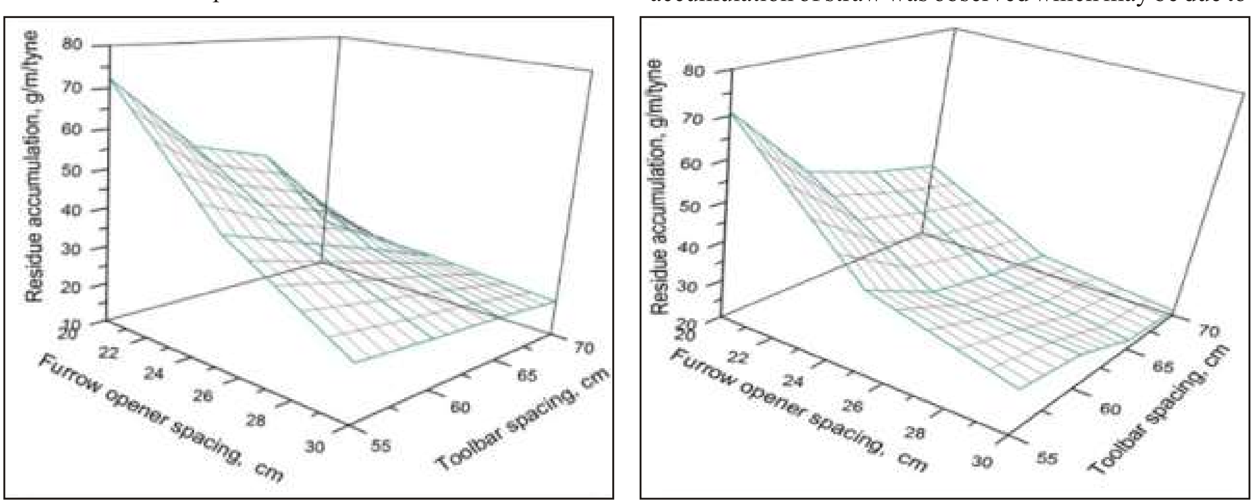
Rice crop residue

$$Ar=0.778-0.848t_l-1.359t_s+0.372t_s^2+0.779t_s^2+0.457t_lt_s \quad ...6$$

The coefficient of determination (R^2) was observed as 0.957 and 0.979 for wheat and rice crop respectively. The model was found significant for both types of crop residues.

Combined effect of all independent variable on straw accumulation

The residue accumulation varied with the furrow opener spacing, tine length and spacing of toolbar for the multi-toolbar no-till drill (Table 2). The amount of residue accumulation was found to differ significantly at 5% level of significance for wheat and rice crop residues. By increasing the toolbar spacing, tine length and lateral spacing between furrow openers, reduction in accumulation of straw was observed which may be due to



Wheat crop residue **Rice crop residue**

Fig. 3: Effect of tine length and toolbar spacing on residue accumulation

Table 2: Residue accumulation (g/m/tine) at various toolbar spacing, tine lengths and furrow opener spacing

Toolbar spacing, cm × Furrow opener spacing, cm		Residue accumulation at different tine length, g/m/ tine							
		Wheat				Rice			
		50	55	60	65	50	55	60	65
	20	99.57	67.86	68.57	53.43	83.00	75.00	64.14	61.43
55	25	68.14	55.57	22.14	21.93	59.29	44.29	32.14	27.86
	30	32.29	25.93	19.86	19.14	43.57	34.50	25.71	22.14
	20	66.00	58.71	45.21	42.29	67.14	58.57	42.29	37.36
60	25	54.14	44.43	20.50	21.21	40.00	36.43	25.00	24.29
	30	31.79	24.43	18.79	18.21	39.43	33.07	22.50	21.79
	20	68.71	53.57	40.36	26.07	57.86	51.43	37.50	34.64
65	25	50.36	24.86	21.21	20.36	34.29	31.43	22.86	21.43
	30	25.86	23.21	18.36	18.07	27.50	23.50	20.14	19.29
	20	27.36	27.00	17.71	17.29	54.93	48.57	35.21	26.07
70	25	25.57	24.43	17.64	16.79	31.43	27.86	20.71	20.00
	30	22.29	22.14	14.64	14.86	25.50	21.57	19.71	18.57
Factor		C.D. at 5% level of significance				C.D. at 5% level of significance			
Interaction w×*l*×s		9.90				1.63			

the passing of more straw through large horizontal and vertical space provided between the adjacent openers. Result for combination of all independent parameter fallowed a polynomial trend for both the types of crop residues. Multiple regression equation developed for amount of residue accumulated (kg/m/tine) for the wheat and rice crop residue at spacing of furrow opener (f_s), tine length (t_l) and toolbar spacing (t_s) all in meter, are given as under:

Wheat crop residue

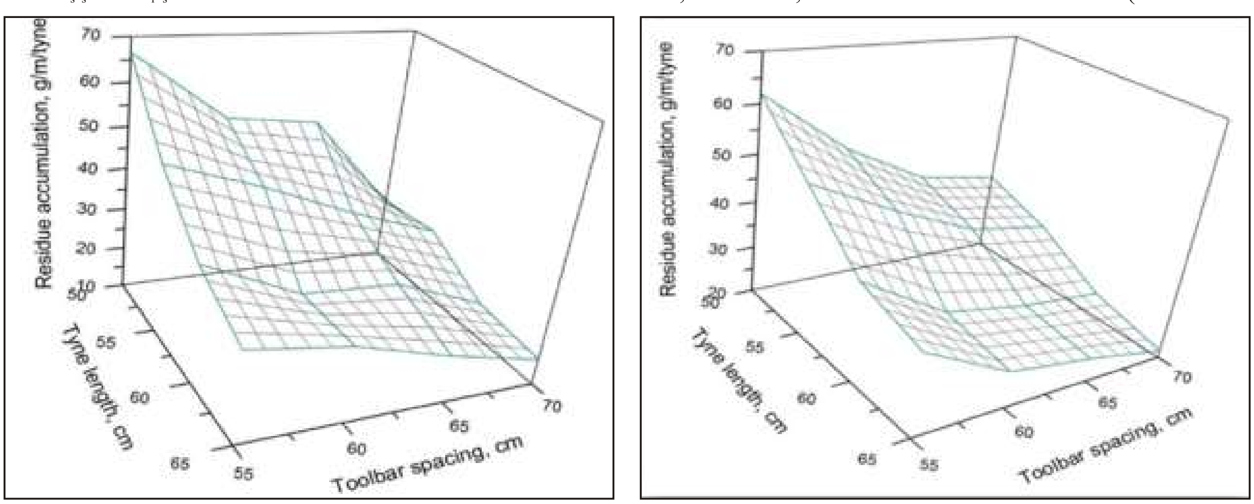
$$Aw=129-2.62f_s-1.76t_l+0.96t_s+0.88f_s^2+0.95t_l^2+0.08t_s^2+1.06t_lt_s+203f_st_s+0.39t_lt_s \quad ...7$$

Rice crop residue

$$Ar=1.35-3.09f_s-1.076t_l-1.65t_s+3.19f_s^2+0.37t_l^2+0.78t_s^2+0.89f_st_s+1.16f_st_s+0.46f_lt_s \quad ...8$$

The value of R^2 was found as 0.93 and 0.96 for wheat and rice, respectively. The model was also found significant for both the type of crop residues.

Effect of furrow opener spacing, tine length and toolbar spacing on residue accumulation and residue flow percentage indicated that with the increase in all the mentioned variables included in the study, residue accumulation decreased and residue flow efficiency increased, in general. The minimum residue accumulation of 14.86 g/m/tine in wheat and 18.57 g/m/tine in rice crop residue was observed for the combination of furrow opener spacing 30 cm, tine length 65 cm and toolbar spacing 70 cm. The optimum results were also found for the combinations of 20-65-70, 25-65-70, 30-60-70, 30-60-65 and 30-65-65 cm (i.e. furrow



Wheat crop residue **Rice crop residue**

Fig. 4: Effect of furrow opener spacing and toolbar spacing on residue accumulation

opener spacing, tine length and toolbar spacing). The difference was found non-significant at 5% level of significance. The reduction in straw accumulation around the tines was due to higher toolbar spacing and tine length, which provided more striking distance and space for loose residue between front and trailing tines. The results were found in accordance with the findings of Mead and Qaisrani, 2003 who reported that the greater toolbar spacing provided more space for residue to clear from leading tines and spread the same so that the trailing tine did not impede its flow.

CONCLUSION

Study showed minimum residue accumulation of 14.46 g/m/tine in wheat crop and 18.57 g/m/tine in rice crop for 65 cm tine length, 30 cm furrow opener spacing and 70 cm toolbar spacing. The optimum result was also found for combinations of 20-65-70, 25-65-70, 30-60-70, 30-60-65 and 30-65-65 cm i.e. furrow opener spacing, tine length and toolbar spacing. The residue accumulation was found non-significant for combination of 30 cm furrow opener spacing and 70 cm toolbar spacing. The lowest amount of residue accumulation was found for 60-65 cm tine length with 65-70 cm toolbar spacing in both wheat and rice crop residues.

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