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RESIDUE HANDLING AND SOIL DISTURBANCE OF AN INCLINED TINE FURROW OPENER

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ABSTRACT

A vertical and an inclined tine-furrow opener, with 30° angle of inclination with respect to the vertical axis perpendicular to the toll bar, were compared and evaluated at different rake angles (60°, 75°, 90° and 105°) in terms of residue handling and soil disturbance.

Three straw conditions were used namely: 1) standing rice stubbles without cut straw, 2) standing stubbles with wet cut straws, and 3) standing stubbles with dry cut straws.

The thirty degree tine with 60° rake angle has the best residue handling capability but with lifting effect on soil. Inclined tine with 90° rake angle has a neutral soil working effect. The residue handling capability of the vertical and inclined tine decreases as the rake angle increases. Soil lifting effect was apparent at rake angles less than 90°. At rake angles greater than 90° there was soil compression.

INTRODUCTION

Furrow closing in direct seeding of rice under zero or minimum tillage condition requires special attention to have a good seed-soil contact for good crop establishment. Normally it require heavy (inverted V-shaped) presswheels to close the gap between the walls of slot created by a vertical tine or furrow opener in zero till condition. The presence of straw and stubbles further aggravate the problem.

The Agricultural Engineering Division at the International Rice Research Institute working to identify the best tine-furrow opener configuration, that could possibly eliminate the use of heavy presswheels, for application to the minimum tillage seeder in direct dry seeding of rice.

This report presents the initial findings on the performance of an inclined tine furrow opener in comparison with conventional tine configuration in terms of residue handling capability and soil working effect.

REVIEW OF LITERATURE

Study conducted at the Department of Agriculture in New South Wales on the Ground-Engaging Components of Seeders for Conservation farming (1986) have established tine-trash interaction in wheat as follows: 1) trash flow up the tine increases rapidly as the tine tilts rearward, 2) trash flow up the tine is not greatly affected by the friction between straw and steel, and 3) increasing the force of the straw against the tine will increase trash movement up the tine. Figure 1 summarizes this relationships.

Different tine configuration (profile in elevation) performed differently in terms of trash handling capability and soil working effect (Table 1).

The ability of tine to pass through plant residues is inversely proportional to the quantity of stubbles present and its moisture content (Figure 2). Higher moisture content increases the mass density of stubbles, its strength and toughness. The length of stubbles also affects trash flow (Figure 3). Shorter ones are easier to handle.

Several machine characteristics (Figure 4-6) affects the trash handling capacity of tined implements namely: 1) underframe clearance, 2) tine spacing, 3) lateral tine spacing (lateral distance between adjacent tine), 4) longitudinal tine spacing, 5) tine pattern or layout, and 6) clearance to other machine parts.

In heavy trash condition, a coulter in front of the tine can aid trash flow by cutting through the residues. At certain spacing two tines tend to act as one in impending trash flow. In wheat stubbles lateral spacing between two individual tine should be at least 500 millimeters. Underframe clearance depend on condition but at least 600 millimeters is recommended for wheat residues. A Vee-frame configuration is a better tine layout for good trash flow.

METHODOLOGY

A theoretical view of the furrow or slot created by an inclined tine was analyzed regarding the probable phenomena that could occur including seed position, possible soil failure, and movements (Figure 7).

An experiment in Randomized Complete Block (RCB) was conducted, in an upland area at IRRI experimental farm, to select the best tine angle of inclination. Four tine angles were evaluated namely 0°, 20°, 30°, and 45°, at a rake angle of 90° (Table 2a).

Two tine designs were considered (Figure 8a and b). Figure 8b design was chosen due to simplicity and the absence of torque which required bigger tine cross sectional area.

The selected angled tine and a vertical tine-furrow opener were tested in an RCB experimental layout using four rake angles (60°, 75°, 90°, and 105°), and three residue conditions namely: 1) standing rice stubbles only, 2) standing stubbles with wet rice straw, and 3) standing stubbles with dry straw. The quantity of dry rice straw was computed at 3 tons per hectare. Wet straw was simulated by soaking dry straw in water, and scattering them in a predetermined area.

The initial residue and soil conditions were recorded and used to determine their respective moisture content. Average standing stubble height and straw length were gathered. Underframe clearance was fixed at 380 millimeters, being limited by the toolbar attached to a two wheel tractor with steering clutches.

Qualitative performance and observations of the individual tine configuration at a given residue condition were recorded (Table 2b). Emphasis was focused on trash flow and soil manipulation.

RESULTS AND DISCUSSION

Theoretical Analysis of an Inclined Slot

With reference to Figure 7, three possible phenomena could happen when an inclined tine passed through the soil. Figure 7a is an ideal case where a perfect slot is created and displaced soil is perched on one side of the slot and the upper wall is cantilevered. A pressure P is needed to attain seed soil contact. Figure 7b is a second case where some of the soil went back to the slot and there is partial collapse of the upper wall due to its own weight and surface agitation caused by the tine. A third case is a total collapse of the upper wall due to agitation by the tine and its shearing effect on soil.

Theoretically the smaller the angle __ the greater will be the tendency of the upper wall to collapse. The rate of the moisture loss, via evapotranspiration, in an inclined soil slot would be slower than in a vertical soil slot because it is less exposed to temperature variation and other environmental factors.

Performance of the Inclined Tine

Based on the performance of the tine with various angles of inclination (0°, 20°, 30°, and 45°, the 30° tine was chosen (Table 2a). The 30° angled tine and a vertical tine at 60°, 75°, 90°, and 105° rake angles were compared in terms of residue handling capability and soil working effect. Their qualitative performance are summarized in Table 2b.

The performance of the vertical tine at various rake angles, in terms of residue handling and soil working effect were synonymous with the corresponding tine configuration experimented with wheat stubbles (Table 1). As reported there was complete blockage of the tine under wheat straw length of 350 millimeters (Figure 3), but in this experiment with average rice straw length of 685 millimeters there was no complete blockage of the vertical tines with 60°, 75°, and 90° rake angles. Complete blockage of the vertical tine was observed at rake angle of 105°.

The inclined tines with rake angles of 60°, 75°, and 90°, performed relatively better than the corresponding vertical tines in terms of residue handling, but the inclined tine with 60° rake angle has the best residue handling performance although there was apparent soil lifting effect. At rake angle of 90°, there was neither compressive nor lifting effect on soil. There was soil agitation due to shearing effect of the tine. The slot created tends to closed itself and a slight press could achieved a favorable seed-soil contact for good crop establishment.

In general, as the rake angle increases the residue handling capability decreases (Figure 9). When the rake angle increases, the soil lifting effect becomes neutral at 90° and converts into a compressive effect (Figure 10).

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CONCLUSIONS AND RECOMMENDATIONS

The residue handling capability of the vertical and inclined tine was inversely related to the rake angle. But the inclined tine with 60° rake angle has the best residue handling performance although it has a soil lifting effect. The tines with rake angle greater than 90° has the worst performance when complete blockage and soil compression occurred.

As the rake angle increases (from 60° to 90°) the soil lifting effect becomes neutral and was shifted to a compressive effect past the 90° rake angle.

The following are recommended for further studies as related to the inclined tine: 1) soil moisture loss of an inclined slot, 2) presswheel requirement of an inclined slot, and 3) comparative crop establishment in an inclined slot.

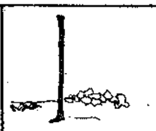
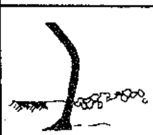
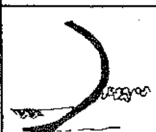
REFERENCES

Bolton, Floyd E. Strip-till Planting in Dryland Cereal Production ASAE Paper No. 79-1530.

(1986). Engineering Development Work on Ground-Engaging Components of Seeder for Conservation Farming. Department of New South Wales.

Wittmus, H.D., Delbert E. Lane, and Bertrand R. Somerholder. (1971). Strip-till Planting of Row Crops Through Surface Residue. Transaction of the ASAE.

Table 1. Tine configurations: their trash handling capabilities and effect on soil.

Description	Profile in elevation	Comments on Performance	Nearest Commercial Examples
1. Straight vertical tine		Constant angle of approach and neutral soil working effect, with some agitation at surface. Reasonable trash-shedding due to agitation.	Hoe Drills Janke
2. Angled forward		Soil tends to be forced up the tine, lifts clods. High agitation at surface. Residues work their way up the tine, clump than fall off.	Gessner chisel, Shearer & IH Scarifiers
3. Angled backward		Uniform approach angle, but compressive effect in soil, less agitation, low disturbance. Hairpinning tendency at pinch point.	Bomford "Earthquake" subsoiler
4. Arc of a circle		Varying angle of approach to soil & residues depending on working depth, changes performance. Aggressive soil lifting action - maximum disturbance.	McKay, HB, Shearer, Gason,, Leon, CJD
5. Parabolic		Varying angle of approach to soil with working depth.	Deep Rippers Standen, Lely, Multiplow
6. Low dogleg-angled forward		Hairpinning at pinch point unless agitated by soil action: material balls up around tine until clump dislodged.	MF, Shearer Trashworker, AFM
7. Low dogleg-angled backward		Residue rides up leg, can hairpin at mounting bracket.	Agrowplow Alfarm HC & CJD Scarifiers
8. High dogleg-angled backward		Residues tend to ball or clump at soil surface until agitated by soil.	Napier chisel Ryan Scaravator
9. High dogleg-angled forward		Residues ride up leg to dogleg then drop off in clumps	McKay, Napier cult.

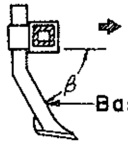
Source: Engineering Development Work on Ground-Engaging Components of Seeders for Conservation Farming. Department of Agriculture, New South Wales. 1986.

Table 2a. Performance of the tine-furrow opener at various angle of inclination with 90^{o} rake angle.

Angle of inclination (degree)	Average depth of penetration (mm)	Clod mean dimensions			Remarks and Observation
		Length (mm)	Width (mm)	Thickness (mm)	
0	70	79	58	40	Open slot created with surface agitation
20	80	76	52	36	Inclined slot. Difference with vertical slot not significant
30	45	77	53	40	Inclined slot. Some agitated soil fell to slot.
45					Tine cannot penetrate the soil. Tine when pushed down bent upward.

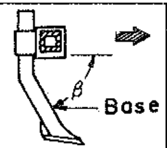
June 21, 1994, IRRI Central Research Farm. Zero tillage upland condition. Soil MC 21%.

Table 2b. Summary of comparative test result of slant furrower at various slant and rake angles.

 Slant Angle ø	 Rake Angle β	Condition of Straw	PERFORMANCE AND OBSERVATIONS
0°	60°	None	Pulled stubbles ride on tine, lumped, rotated around tine and fell. Created open slot. Noticeable soil lifting and agitation.
		Wet	Straws and pulled stubbles ride up the tine, rotated and fell. Created open slot. Noticable soil lifting and agitation.
		Dry	- do -
0°	75°	None	Pulled stubbles gathered at tine base, lumped and tend to rotate around tine. Minimal lifting of soil.
		Wet	Straws and pulled stubbles gathered and build up on tine base. Open slot made. Minimal lifting effect on soil.
		Dry	Pulled stubbles and straws gathered at tine base, lumped and tend to rotate around tine. Open slot made. Minimal lifting effect on soil.
0°	90°	None	Pulled stubbles accumulated at tine base as travel progressed. Created fully open slot. Agitation at soil surface due to chearing action of moving tine.
		Wet	Pulled stubbles and straw accumulated at tine base which tend to rotate. Open slot made. Minimum effect on soil with surface agitation.
		Dry	- do -

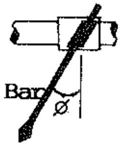
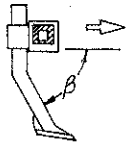
Moisture content (wet basis): Soil = 38.27%; Dry straw = 12.5%; Wet straw = 73.6%;
Straw length = 685 mm; Stubble height = 300 mm.

Table 2b. Continued...

 Tool Bar, φ Slant Angle Ø	 β, Base Rake Angle β	Condition of Straw	PERFORMANCE AND OBSERVATIONS
0°	105°	None	Pulled stubbles accumulated at tine base. Slot not well defined due to clogged base. Compressive effect on soil.
		Wet	Pulled stubbles and straw clogged at tine base. Not well defined slot. Compression effect on soil.
		Dry	- do -
30°	60°	None	Pulled stubbles ride on but fell immediately. Slot made okay and tends to close in. Has lifting effect on soil.
		Wet	Straw and pulled stubbles ride on tine, rotates and fell off easily. Slot made okay and tends to close in. Lifting effect on soil.
		Dry	- do -
30°	75°	None	Pulled stubbles ride on tine base, rotated and fell. Slot made okay. Minimum lifting effect on soil.
		Wet	Straw and pulled stubbles accumulated on base, lumped and fell. Slot inconsistent in quality. Lifting of soil minimal.
		Dry	Straw and pulled stubbles accumulated on base, lumped and fell to right side as in plowing. Slot wide open. Lifting effect on soil minimal.

Moisture content (wet basis): Soil = 38.27%; Dry straw = 12.5%; Wet straw = 73.6%;
Straw length = 685 mm; Stubble height = 300 mm.

Table 2b. Continued...

 Tool Bar, Slant Angle $\varnothing$	 Rake Angle β	Condition of Straw	PERFORMANCE AND OBSERVATIONS
30°	90°	None	Pulled stubbles gathered on tine base and tends to rotate. Slanted open slot made. Quality of slot inconsistent. No lifting of soil except for minor surface agitation.
		Wet	Straw and pulled stubbles accumulated on tine base, lumped and tends to rotate. Open slot made. No lifting effect on soil.
		Dry	Straw and pulled stubbles accumulated on tine base, lumped and tend to fell off. Slot in bad shape. No lifting effect on soil.
30°	105°	None	Pulled stubbles accumulated on tine base. Slot quality very inconsistent. Compressive effect on soil.
		Wet	Straw and pulled stubbles accumulated on tine base. Slot in bad shape. Compressive effect on soil.
		Dry	- do -

Moisture content (wet basis): Soil = 38.27%; Dry straw = 12.5%; Wet straw = 73.6%
Straw length = 685 mm; Stubble height = 300 mm.

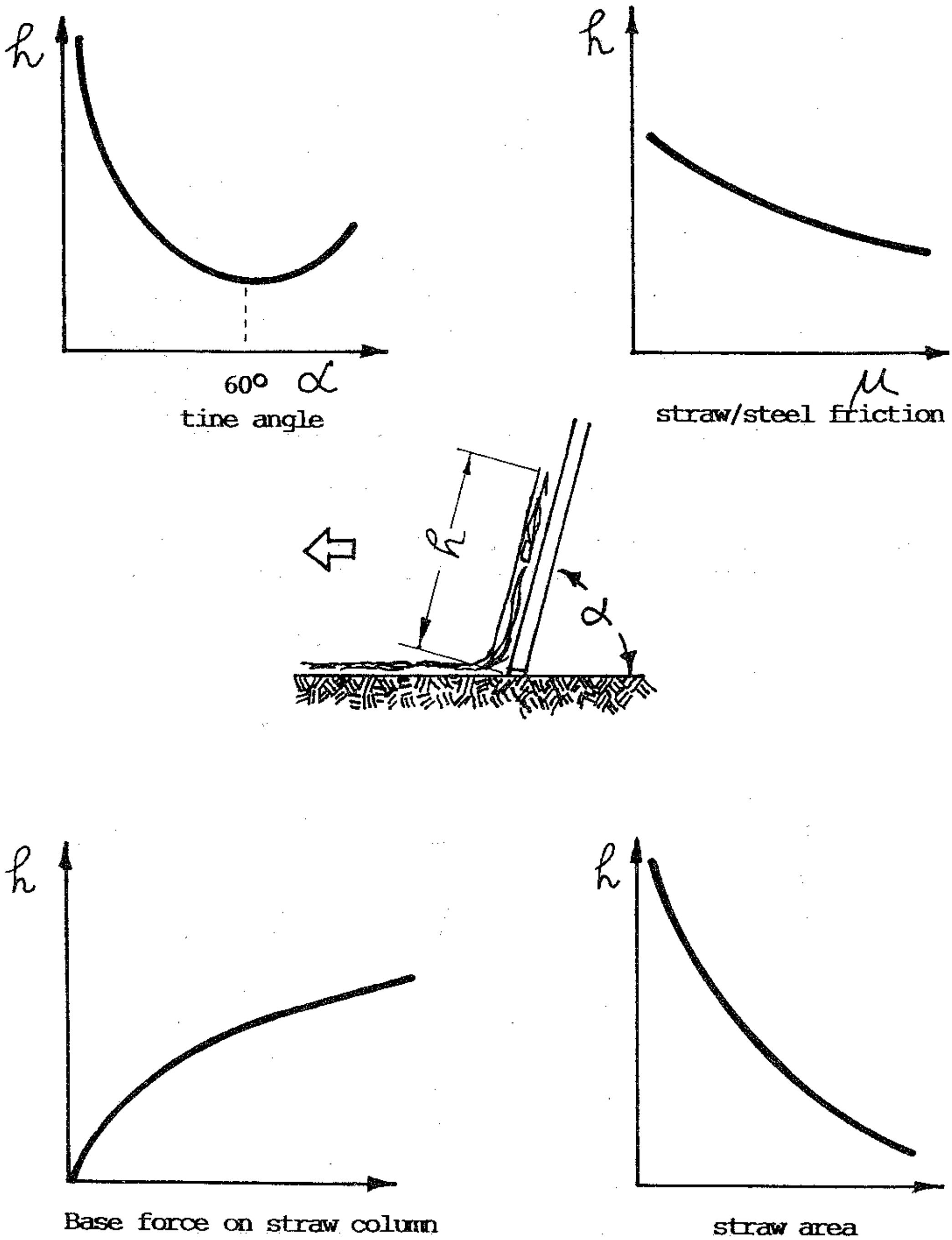


Figure 1. Prediction curves for some factors affecting trash height on a tine.

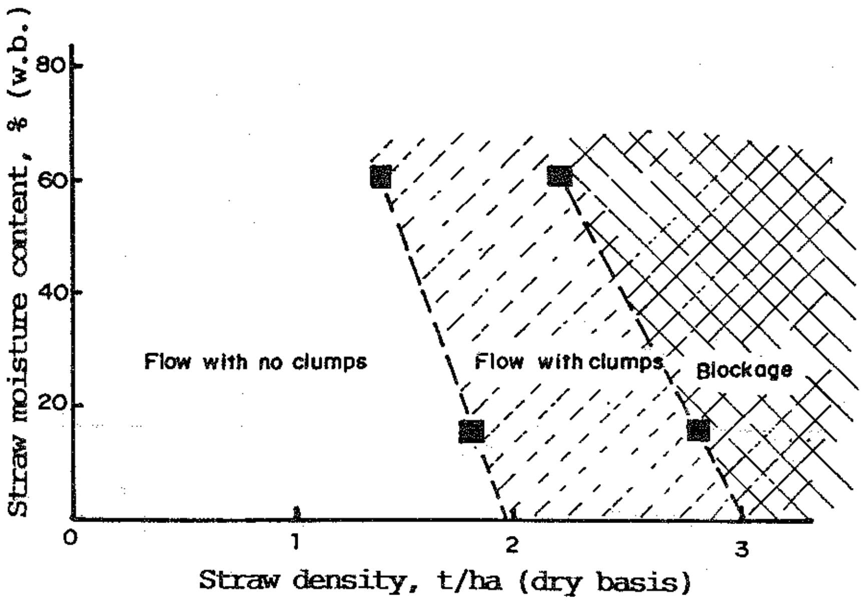


Figure 2. Effect of straw quantity and moisture content on tine passage. Three regimes of "trashflow" are identified for purpose of analysis.

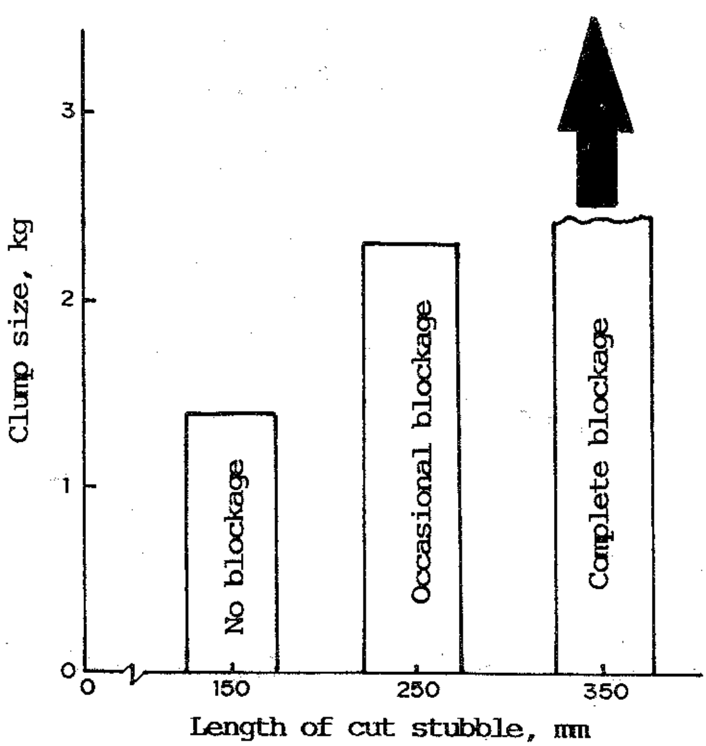


Figure 3. Effect of straw length on clump size and tine passage. Wheat stubble.

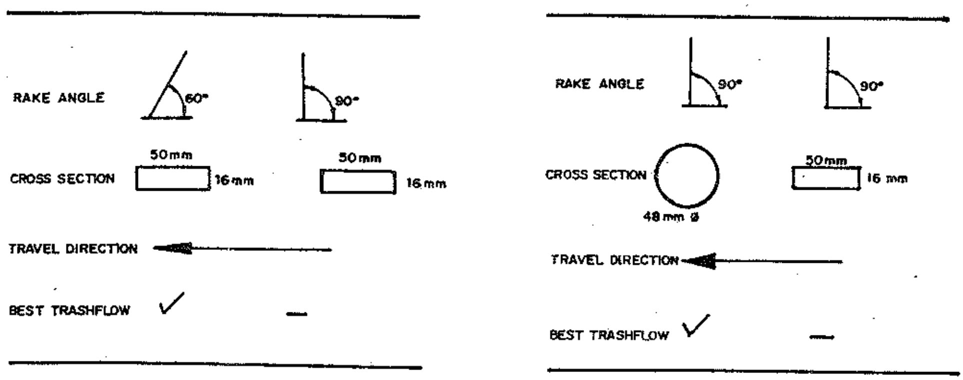
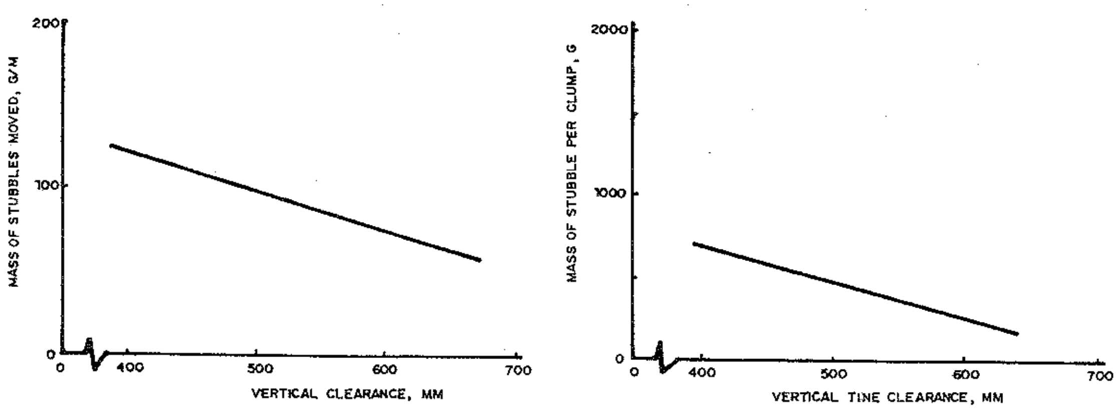


Figure 4. Effect of tine cross section and rake angle on trashflow parameters. Underframe clearance 560 mm; wheat stubble at 4.5 t/ha (dry basis) and 28% moisture content (wet basis); travel speed 6 km/h.

Vertical Tine Clearance

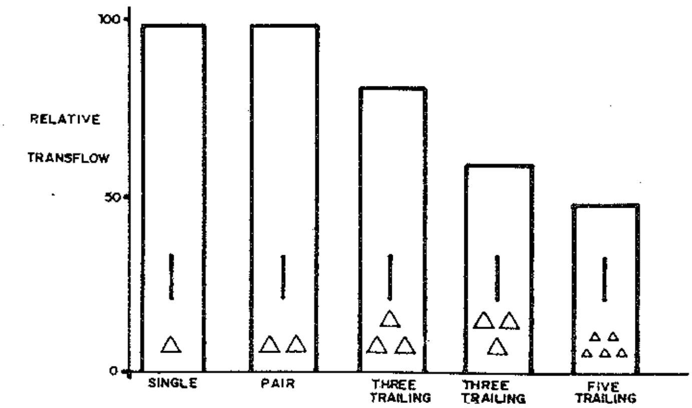
Adequate vertical tine clearance (or underframe clearance) is necessary to facilitate trashflow. Field tests with commercial tines confirm that both the mass of stubble moved per metre and the mass of stubble per clump are significantly reduced with increase underframe clearance. Blockages occur around tines with less than optimal vertical clearance or tine shape, refer Figure 5.



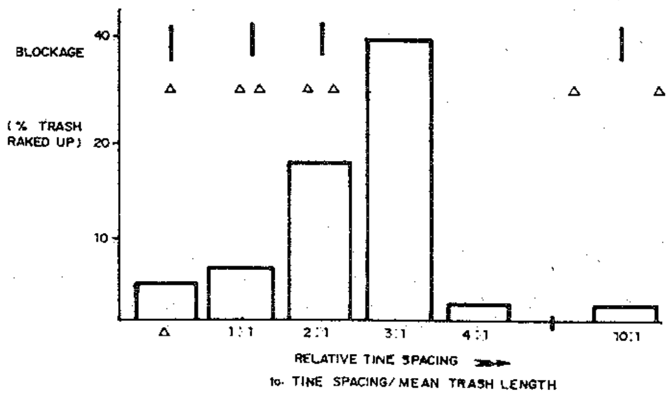
a) $y = 219 - 0.235x$
$r^2 = 0.28$ significant at 1%

b) $y = 1641 - 2.34x$
$r^2 = 0.21$, significant at 5%

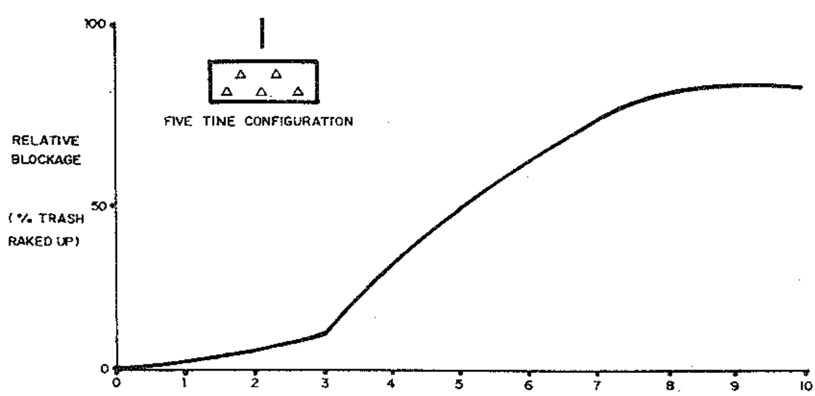
Figure 5. Effect of vertical tine clearance on trashflow parameters for commercial tines.



A. Tine layout obviously affects trashflow but there are some configurations which are superior to others.



B. At a certain spacing (around 4:1 in these experiments) two tines tend to act as one in impeding trashflow, beyond that critical spacing, trashflow capability improves with distance apart of the tines.



C. Trashflow capability declines as level of residues increases. In-field experiments are often "Go/No Go" situations, rather than gradual buildups.

Figure 6. Graphical summary of results from modeling experiments with wheat straw in the micro-bin, which is 1/10th scale.

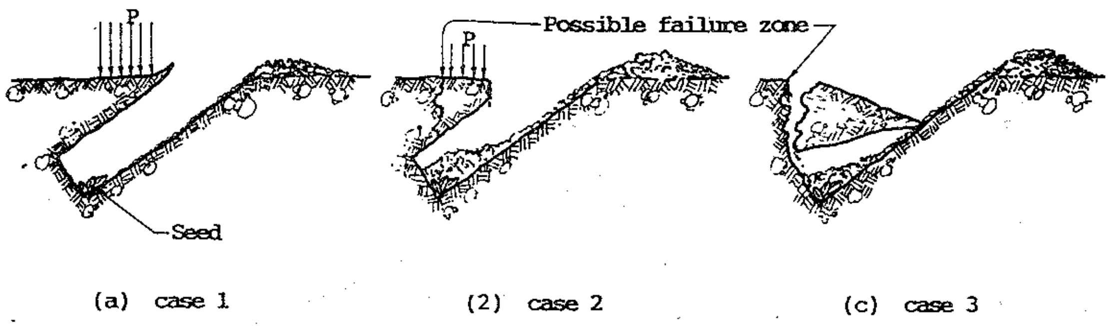


Figure 7. Theoretical consideration of a slot opened by an inclined tine showing seed position and possible failure zones with or without downward pressure P. Theoretically the smaller the inclined angle _ the greater the possibility of collapse above the seed which would result to automatic seed-soil contact and covering.

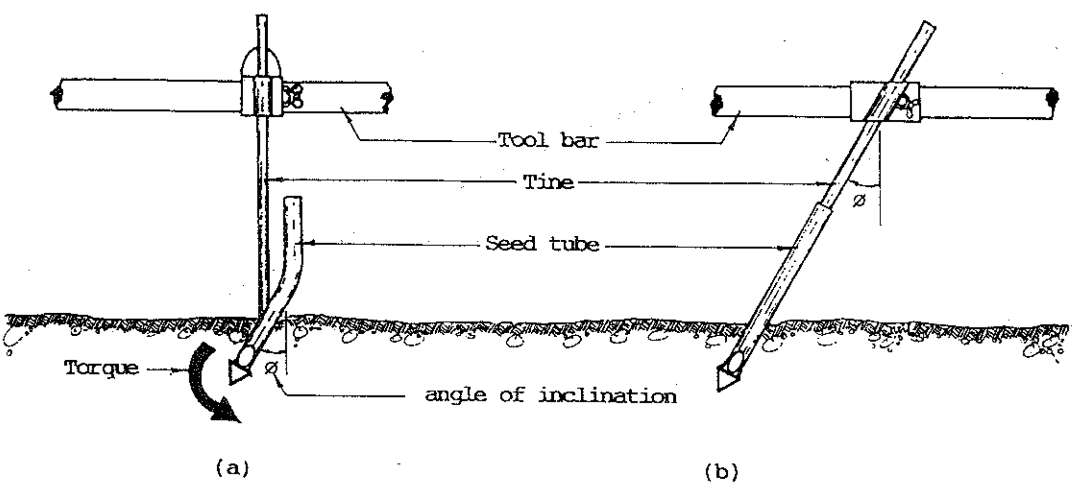


Figure 8. Two tine design configurations. Design (b) was chosen for simplicity.

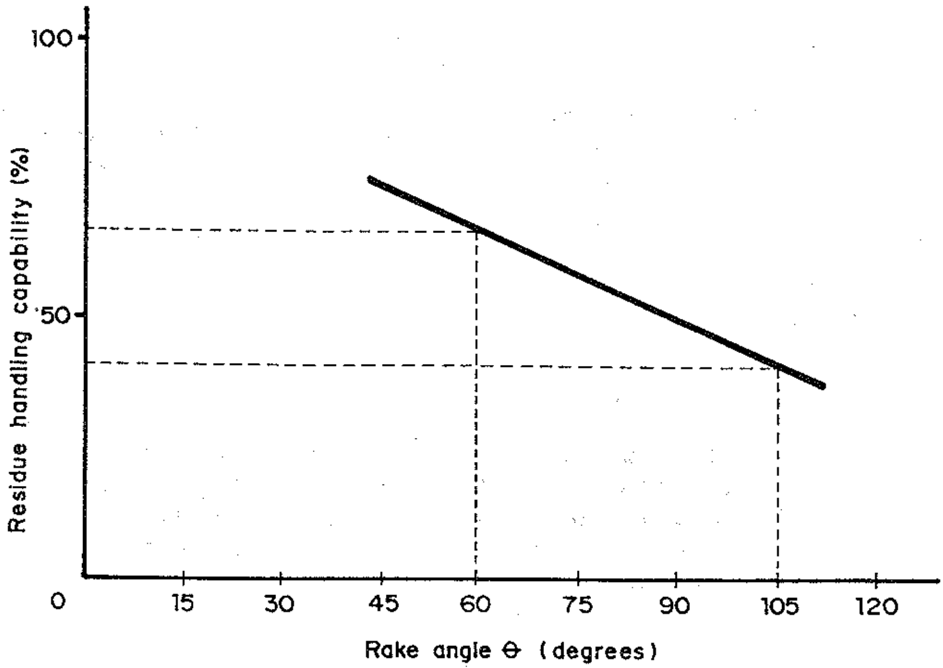


Figure 9. Effect of rake angle on residue handling capability of 0^{o} and 30^{o} tine.

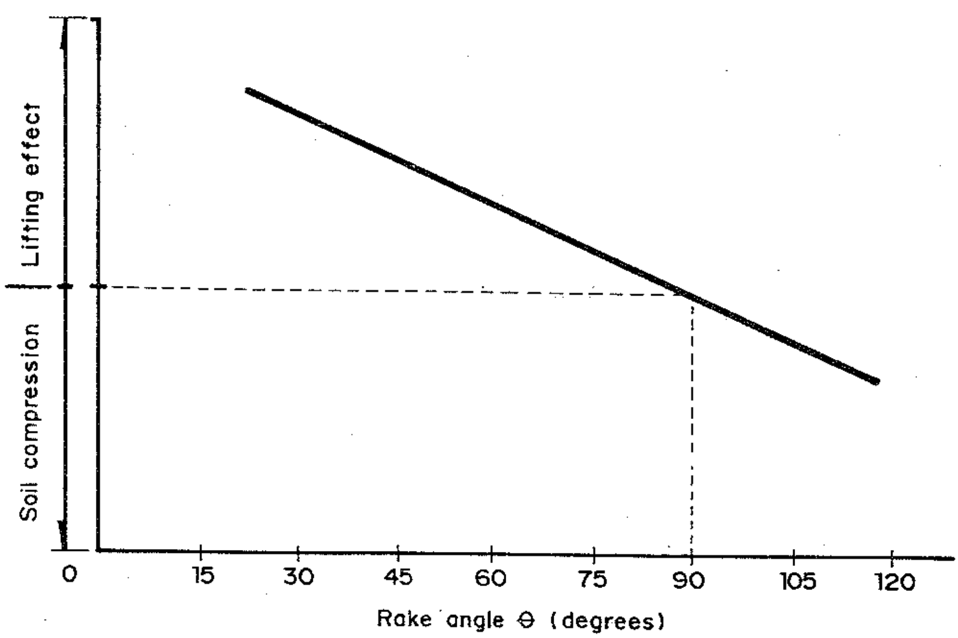


Figure 10. Effect of rake angle on soil disturbance of 0^{o} and 30^{o} tine.