Captions

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Fig. 8. Measurement of soil disturbance: (a) profile meter; and (b) layout

Fig. 9. Experimental application of sludge into grass

Fig. 10. Application of sludge into winter wheat with trailing umbilical hose to supply the sludge

Fig. 11. Soil dynamics laboratory results: (a) draught force, kN; (b) vertical force, kN; (c) estimated application rate, m^3/ha; and (d) specific resistance, N ha/m^3

Fig. 12. Effect of sludge injection six weeks after treatment

Fig. 13. Average grain yield standardised at 15% moisture content

Fig. 14. Commercial trial plots: (a) control; (b) injected I six weeks after treatment; (c) injected II six weeks after treatment; (d) control at harvest; (e) injected I at harvest; and (f) injected II at harvest

Fig. 15. Average surface disturbance profiles for 12 tine designs at 50 mm deep and at 75 mm deep: (a) leg profile I with 10 mm wing (S1); (b) leg profile I with 25 mm wing (S2);(c) leg profile I with 40 mm wing (S3); (d) leg profile II with 40 mm wing (S4); (e) leg profile III with 40 mm wing (S5); (f) cutter I with 40 mm wing (M1); (g) cutter II with 40 mm wing (M2); (h) disc with 40 mm wing (M3); (i) slipperfoot (C1); (j) shallow I (C2); (k) shallow II (C3); and (l) winged foot (C4)

Fig. 16. Surface disturbance under field conditions: (a) slipperfoot tine in cereals (M1); (b) tine with leg profile III and 40 mm wing in cereals (S5); and (c) tine with leg profile III and 40 mm wing in grass (S5)

Table 1
Predicted void space created by different tine widths for a given injector tine spacing of 250 mm (Negi *et al.*, 1976)

Tine depth, mm	*New void space, m^3/ha*		
	Tine width		
	10 mm	*25 mm*	*40 mm*
50	7.9-39.5	10.9-54.5	13.9-69.5
75	16.3-81.4	20.8-103.9	25.3-126.4

Table 2
Alternative tine designs

Code	*Single piece tines (Fig. 5)*	*Code*	*Multi piece tine cutters (Fig. 6)*	*Code*	*Commercial tines (Fig. 7)*
S1	Leg profile I with 10 mm wing	M1	Cutter I with 40 mm wing	C1	Slipperfoot
S2	Leg profile I with 25 mm wing	M2	Cutter II with 40 mm wing	C2	Shallow I
S3	Leg profile I with 40 mm wing	M3	Disc with 40 mm wing	C3	Shallow II
S4	Leg profile II with 40 mm wing			C4	Winged foot
S5	Leg profile III with 40 mm wing				

Table 3
Commercial trial treatments

Code	Treatment
Control	No sludge applied
Injected I	Sludge injected into the winter wheat at rate of 50 m^3/ha during February; plot used to set up and test injection system
Injected II	Sludge injected into the winter wheat at rate of 50 m^3/ha during February as a continuous operation

Table 4
Soil properties

Particle analysis, %	
Coarse sand	8.15
Sand	41.94
Fine sand	18.03
Silt	22.10
Clay	9.77
Cohesion, kN/m^2	7.0
Angle of friction, deg	23.0
Dry bulk density, kg/m^3	1450
Moisture content, %	9.6

Table 5
Estimated application rate for different tine widths for a given injector tine spacing of 250 mm

Tine Code	*Tine width, mm*	*Tine depth, mm*	*Estimated application rate, m^3/ha (Fig. 11)*
S1	10	50	45.7
		75	110.9
S2	25	50	49.6
		75	56.3
S3	40	50	69.3
		75	123.5

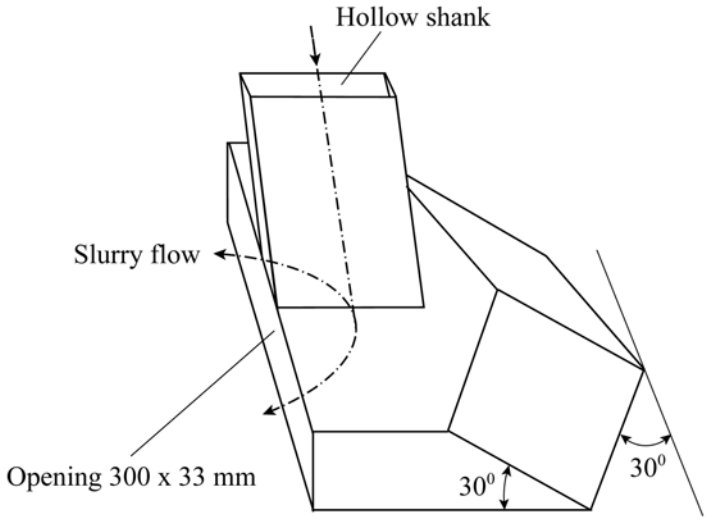


Fig. 1. Winged injecting foot

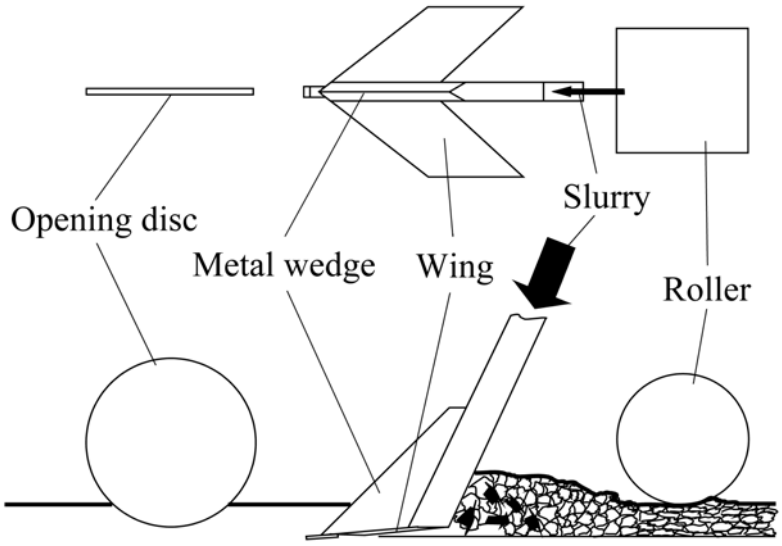


Fig. 2. Layout of deep injector for grass

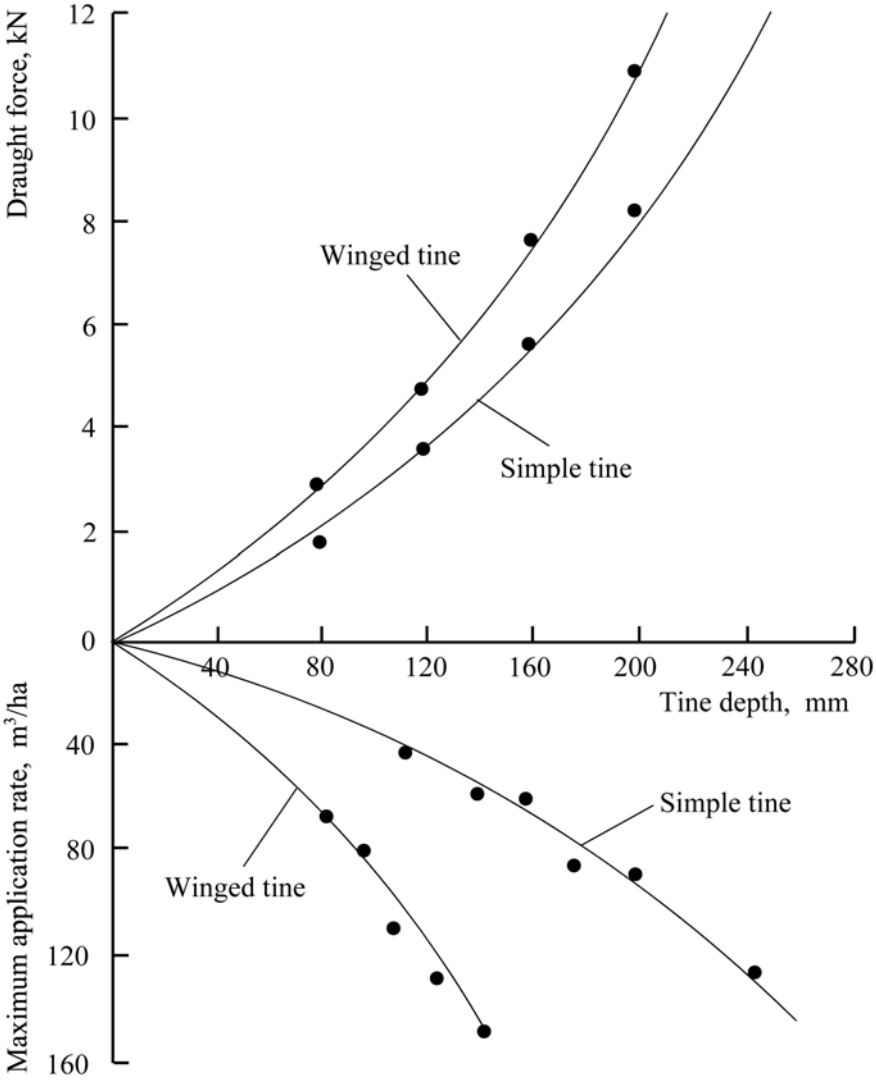


Fig. 3. Effect of depth on application rates and draught forces (Warner & Godwin 1988)

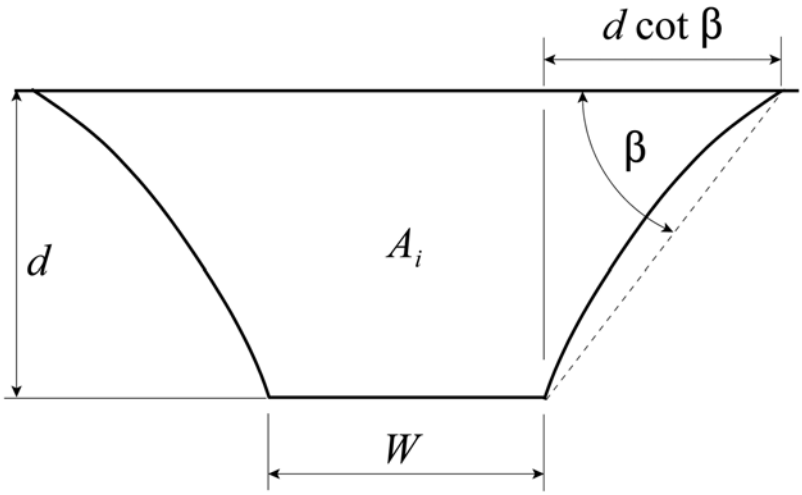


Fig. 4. Sectional area of soil disturbance A_i created by a tine of width W at depth d with an angle β subtended by a line joining the soil rupture surface and the tine edge

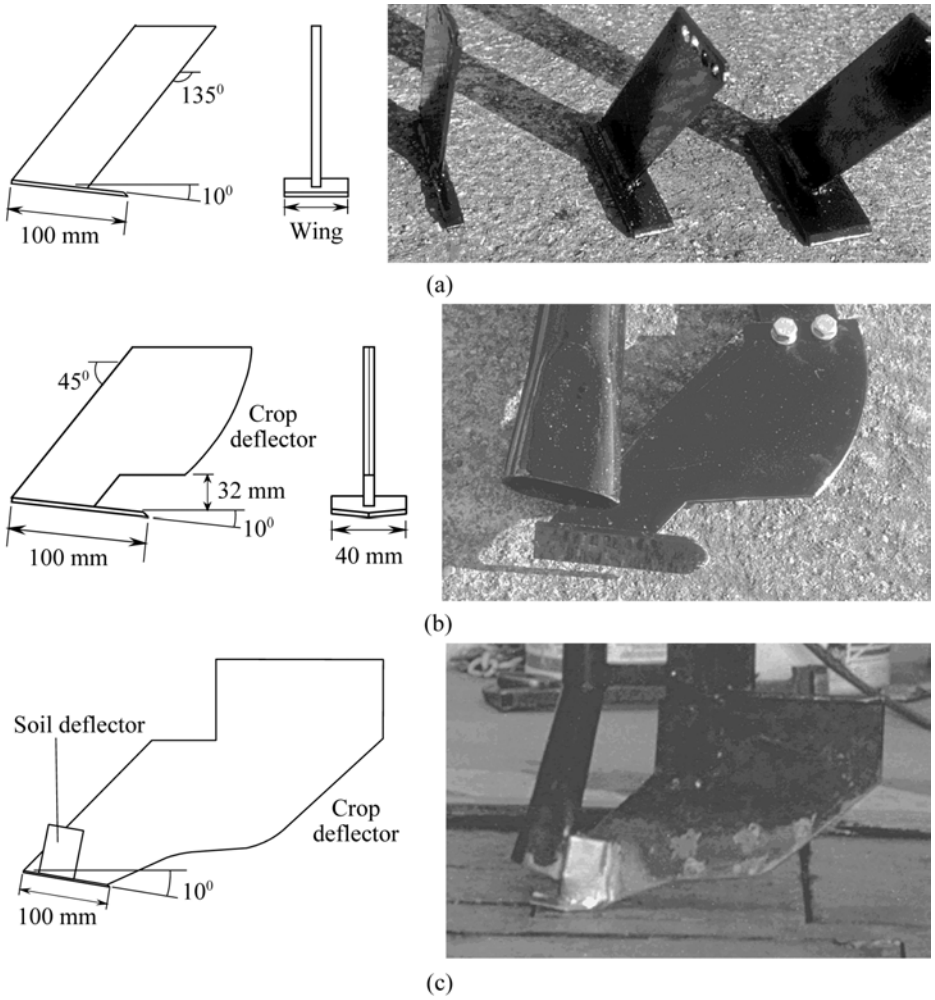


Fig. 5. Single piece tines: (a) leg profile I with 10, 25 & 40 mm wide wings (S1, S2 & S3); (b) leg profile II with 40 mm wing (S4); and (c) leg profile III with 40 mm wing (S5)

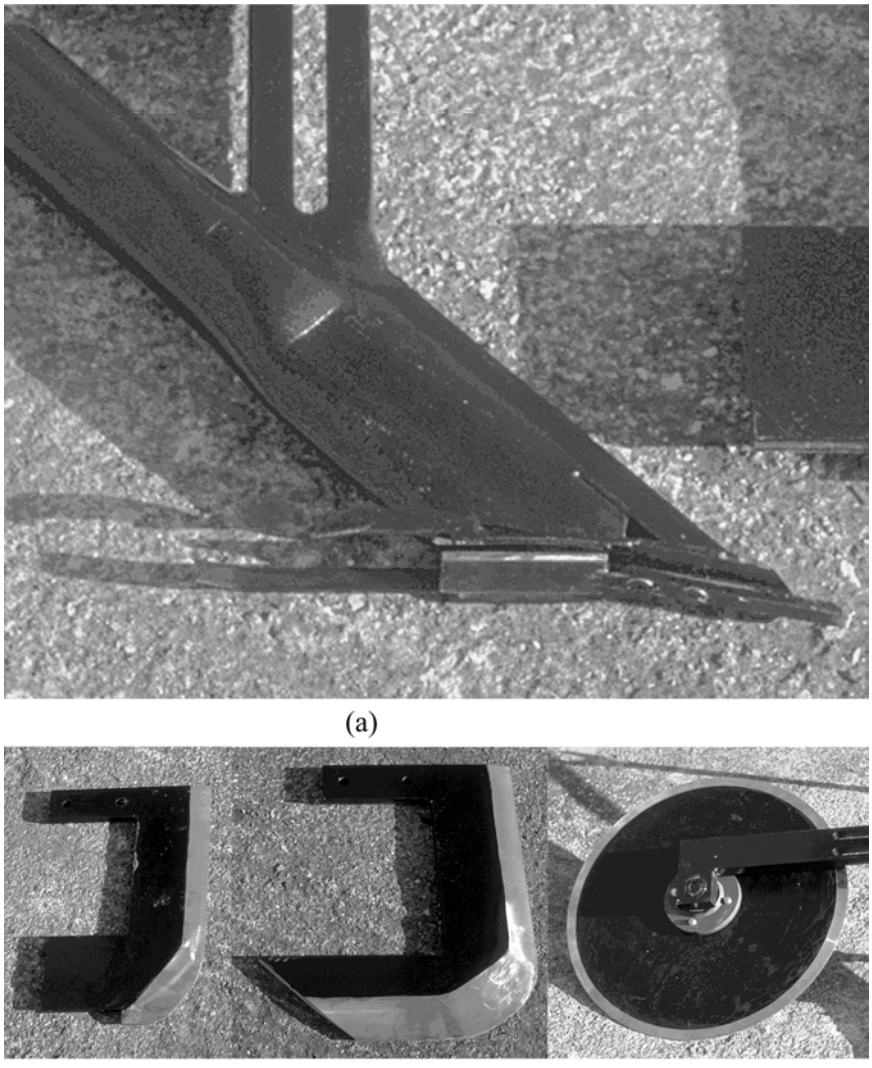
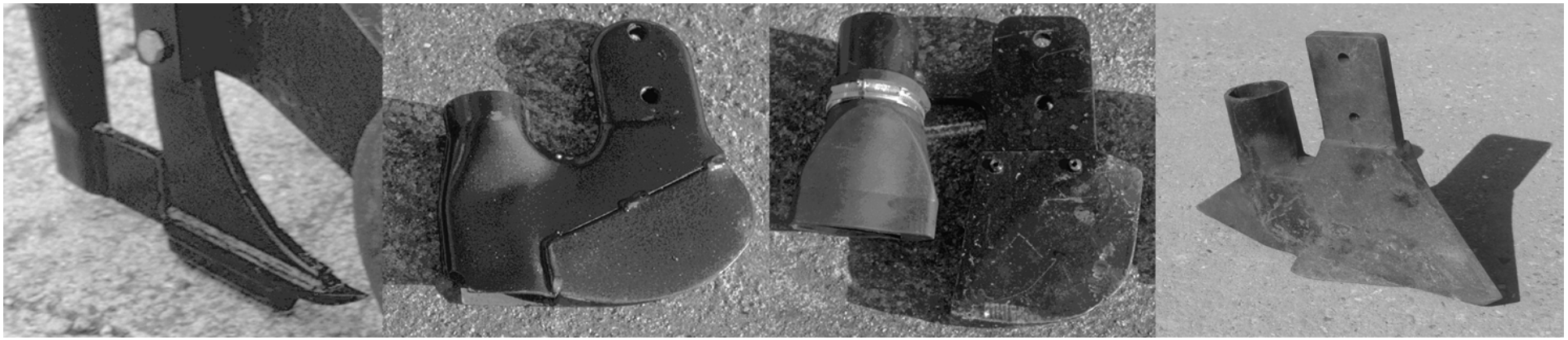
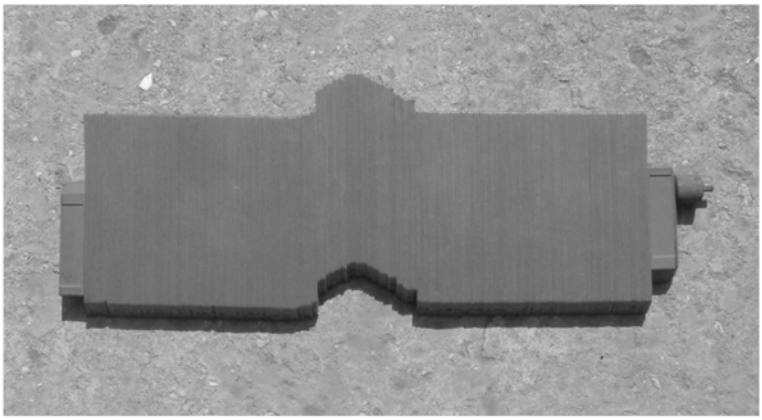


Fig. 6. Multi piece tine: (a) injector; (b) cutter I (M1); (c) cutter II (M2); and (d) disc (M3)

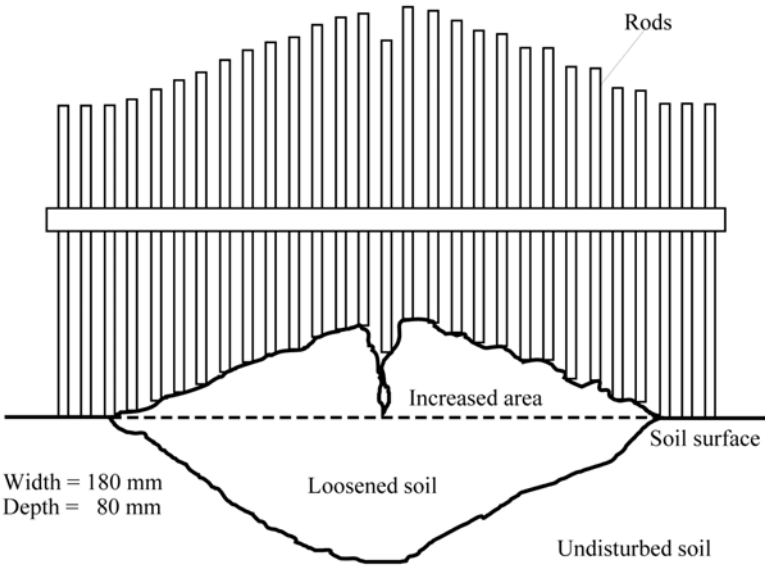


(a) *(b)* *(c)* *(d)*

Fig. 7. Commercial injector tines: (a) slipperfoot (C1); (b) shallow I (C2); (c) shallow II (C3); and (d) winged foot (C4)



(a)



(b)

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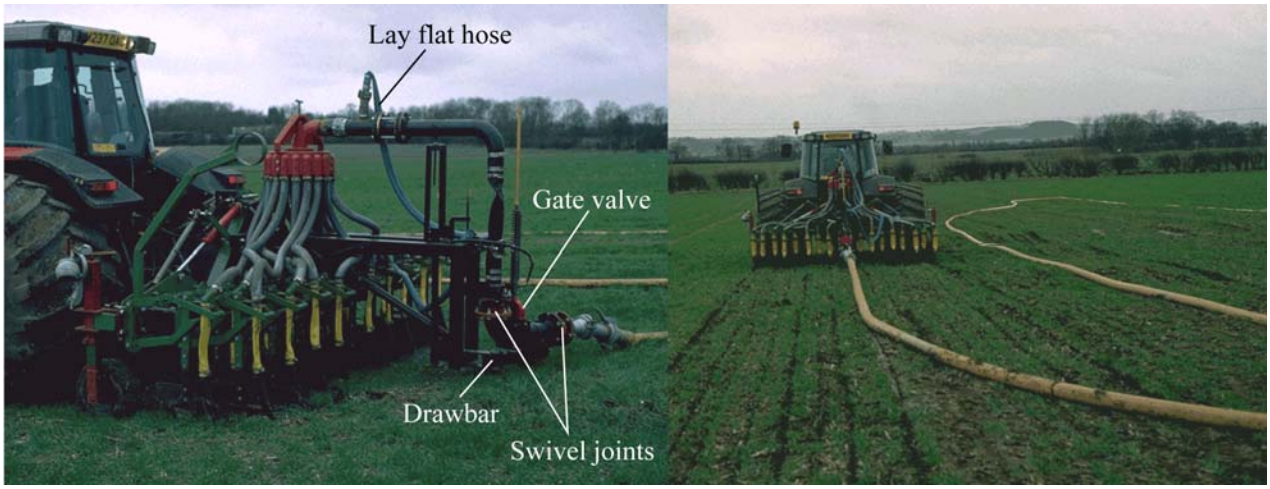

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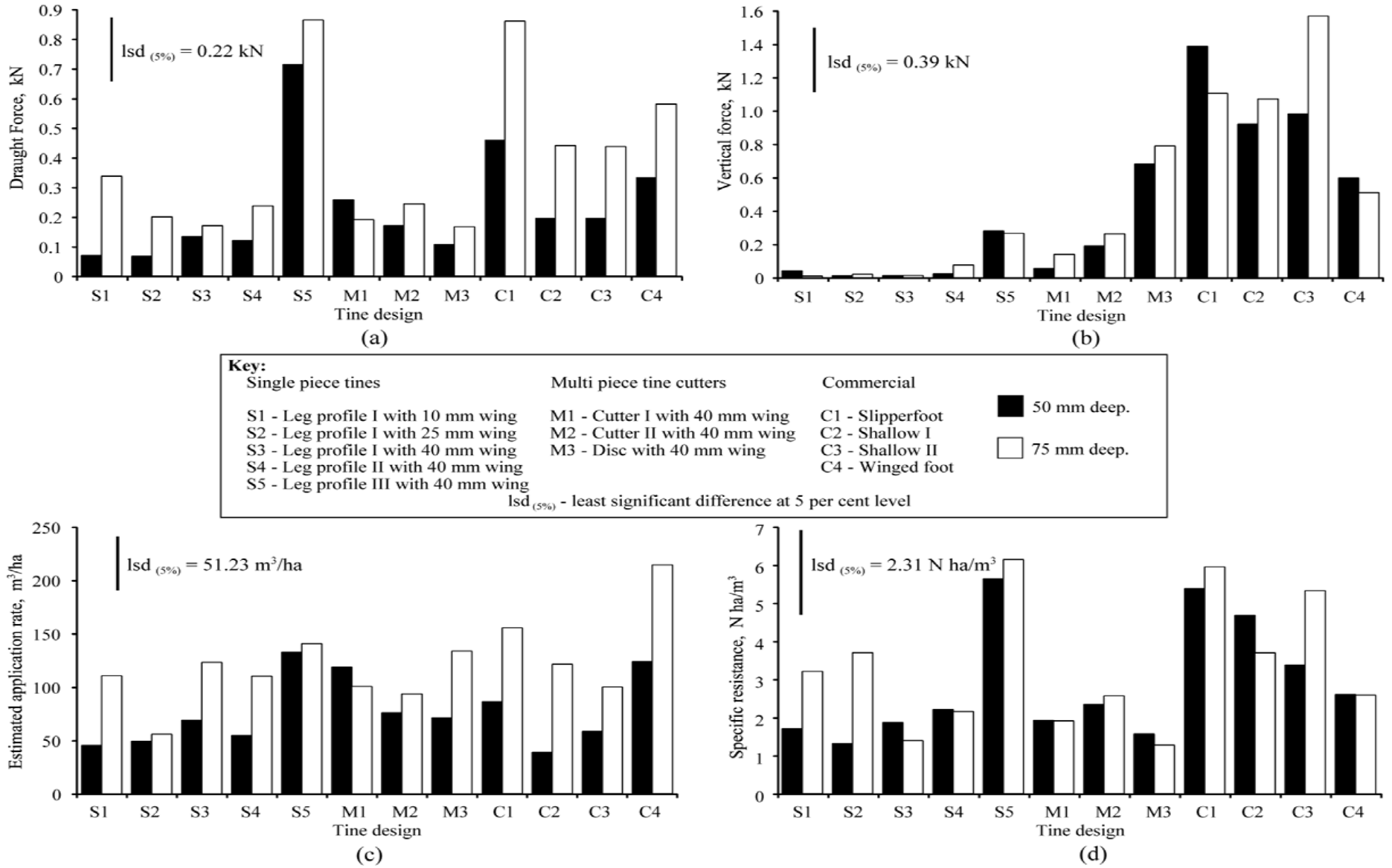

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Fig. 12. Effect of sludge injection six weeks after treatment

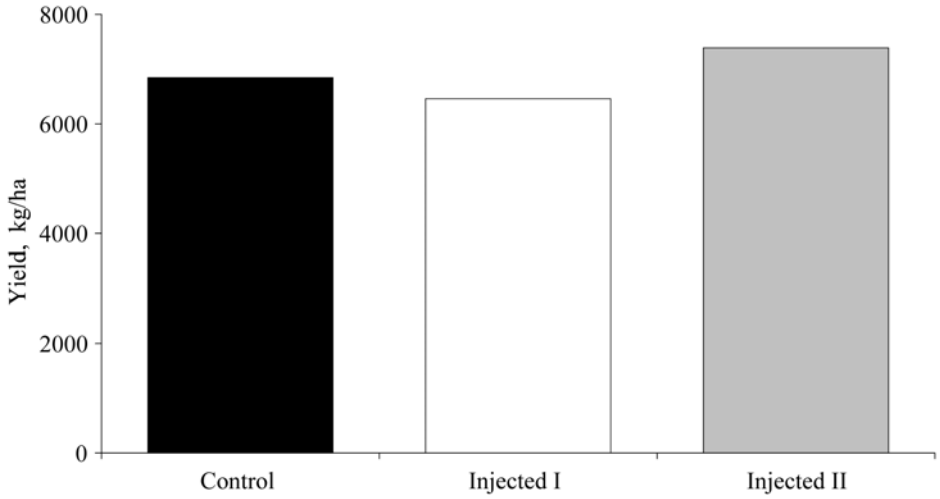


Fig. 13. Average grain yield standardised at 15% moisture content

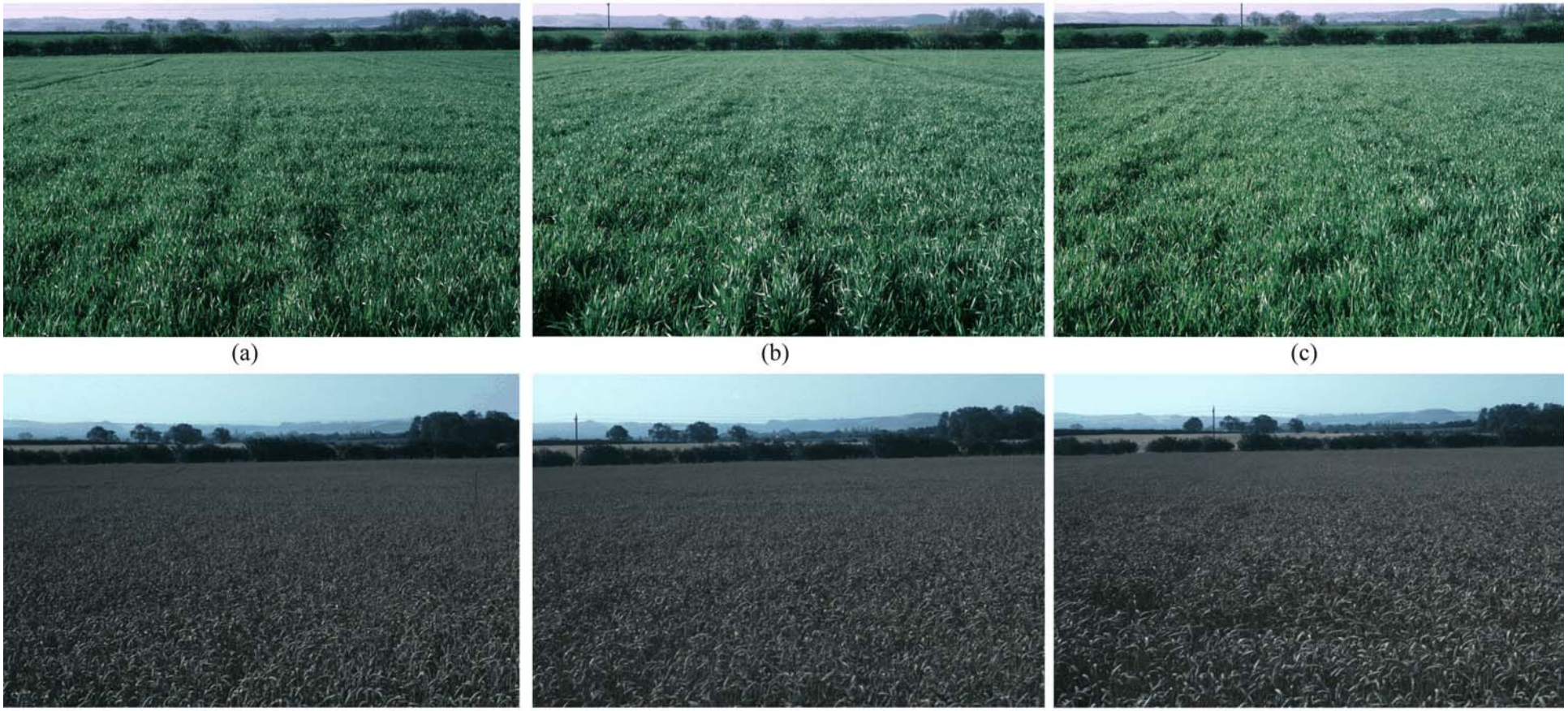


Fig. 14. Commercial trial plots: (a) control; (b) injected I six weeks after treatment; (c) injected II six weeks after treatment; (d) control at harvest; (e) injected I at harvest; and (f) injected II at harvest

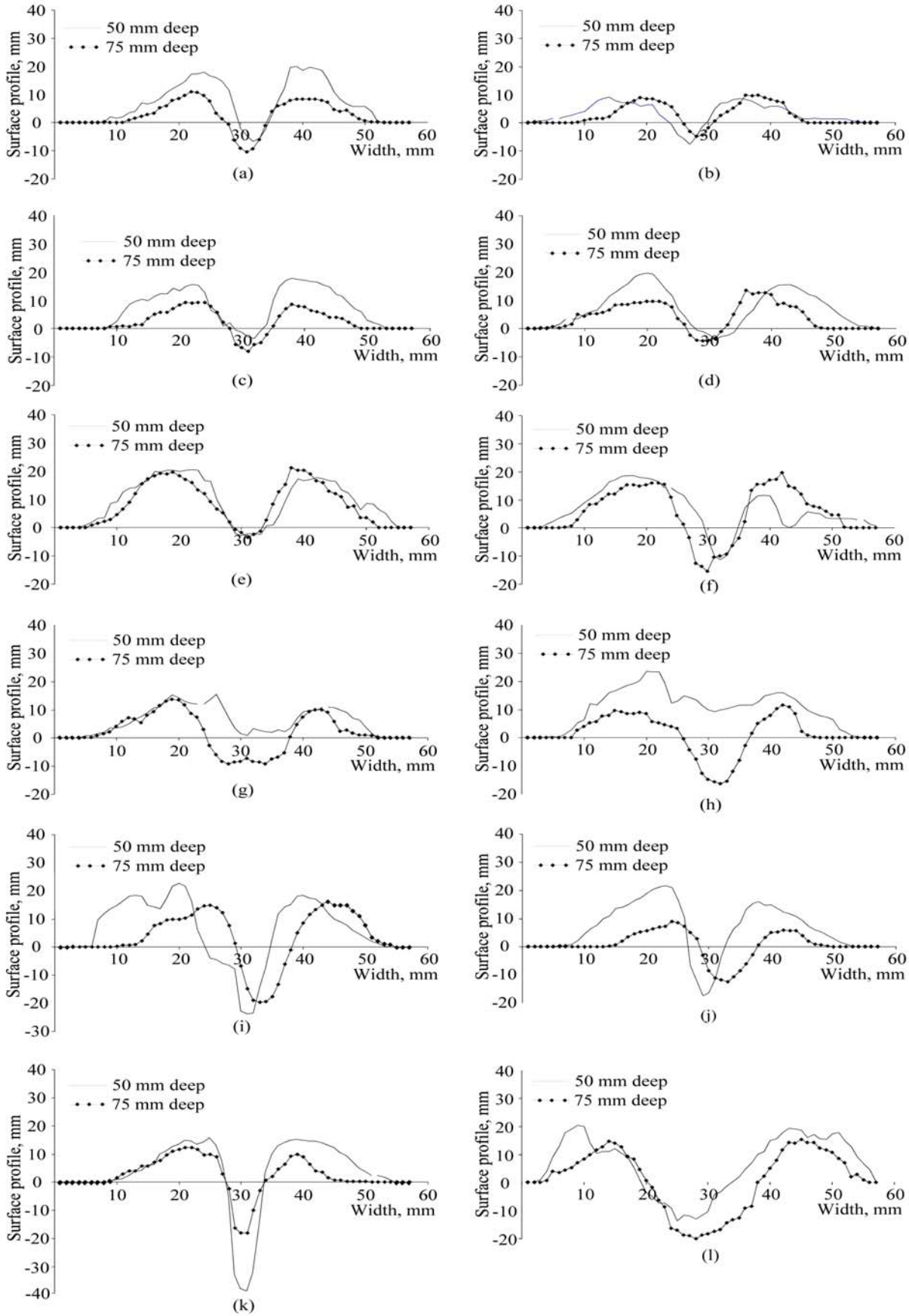
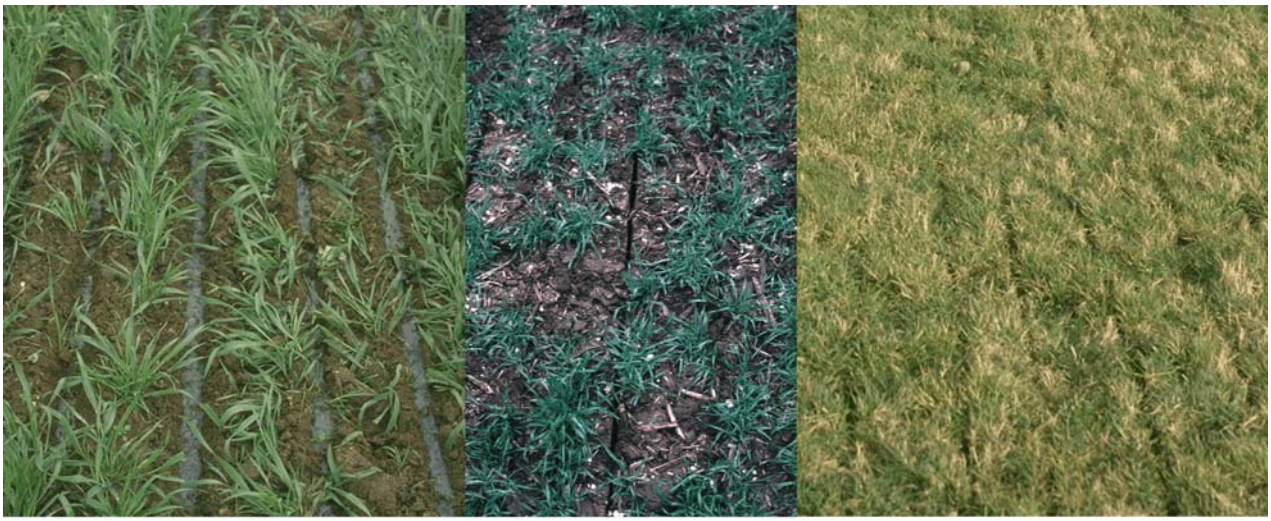


Fig. 15. Average surface disturbance profiles for 12 tine designs at 50 mm deep and at 75 mm deep: (a) leg profile I with 10 mm wing (S1); (b) leg profile I with 25 mm wing (S2); (c) leg profile I with 40 mm wing (S3); (d) leg profile II with 40 mm wing (S4); (e) leg profile III with 40 mm wing (S5); (f) cutter I with 40 mm wing (M1); (g) cutter II with 40 mm wing (M2); (h) disc with 40 mm wing (M3); (i) slipperfoot (C1); (j) shallow I (C2); (k) shallow II (C3); (l) winged foot (C4)



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