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Trash distribution and cultivation depth in minimal tillage and direct establishment systems for winter wheat

by

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Contents

Abstract

A replicated experiment was conducted at four sites over two seasons to examine the effect of stubble raking and varying degrees of straw incorporation on the subsequent establishment and yield of winter wheat.

In each year two sites followed oilseed rape and two followed winter wheat. Different stubble heights and degrees of loose stubble were achieved by topping the harvested stubble. The loose trash was raked using a zig-zag or comb harrow. Soil was cultivated using a set of heavy discs once to a 7 cm depth or twice to a depth of 12 cm, or seed was direct-drilled with no prior cultivation. This resulted in a range of straw:soil mixtures.

Cultivation treatments (including raking) resulted in varying degrees of straw incorporation, assessed as straw on the seedbed surface. Subsequent establishment of the cereal crop was affected by the degree of cultivation. The poorest establishment was associated with the greatest amount of loose surface trash – achieved by trimming the stubble, not raking to distribute the trash evenly and sowing with a disc drill, which did no additional cultivation. The results were confounded to some extent by the deeper disc cultivation resulting in a loss of soil moisture which caused poorer establishment. Reduced yields observed in two of the eight trials were associated with the poorest establishment.

Raking loose trash should only be necessary if the stubble is short, resulting in a higher level of loose surface trash, or if trash is poorly distributed and the following crop is to be direct-drilled with a drill which does no soil mixing in its own right. In other situations, particularly where chopped straw is well spread behind the combine and some straw:soil mixing is achieved through subsequent cultivation, trash re-distribution will be unnecessary.

Summary

Large-scale replicated field trials were conducted at four sites (including light, medium and heavy soils) over two seasons (2003 and 2004). Four of these involved first wheats after oilseed rape, and four were second wheats. In each case the previous crop was harvested leaving long stubble (30cm+), and the wheat or rape straw was chopped and spread by the host farmer's combine. The sites were then divided into four blocks, and two were mown to reduce stubble height to 10-15cm. Half of each block was raked using a light zig-zag harrow at 90^{o} to re-distribute the trash on the soil surface.

Within each mow/rake combination, one strip was left for direct sowing, a second minimally tilled with discs to about 7cm depth, and one minimally tilled twice to about 12cm depth. Treatments were replicated three times. Two of the sites (one first and one second wheat) were drilled in late Sept. / early Oct. using a disc drill, and two with a tine drill. All subsequent inputs were applied by the host farmer according to their normal practice.

Cultivation treatments (including raking) resulted in varying degrees of straw incorporation assessed as straw on the seedbed surface. Subsequent establishment of the cereal crop was affected by the degree of cultivation. The poorest establishment was associated with the greatest amount of loose surface trash; this was achieved by trimming the stubble (not raking), to distribute the trash evenly and sowing with a disc drill which did no additional cultivation. The results were confounded to some extent by the deeper disc cultivation resulting in a loss of soil moisture which caused poorer establishment. Deleterious yield effects were observed in two of the eight trials and these were associated with the poorest establishment.

Raking loose trash should only be necessary if the stubble is short resulting in a higher level of loose surface trash, trash is poorly distributed and the following crop is going to be direct-drilled with a drill which does no soil mixing in its own right. In other situations, particularly where chopped straw is well spread behind the combine and some straw:soil mixing is achieved through subsequent cultivation, trash re-distribution will be unnecessary.

Introduction

Management of the previous crop's residue has been perceived as a major obstacle to the successful adoption of non-inversion minimum tillage and direct drilling due to its interference with the successful establishment of the following crop. This is less of a problem following oilseed rape as the stubble and trash is more brittle and it has had longer to decay prior to the establishment of the subsequent crop. Work has been done previously to demonstrate methods of establishing oilseed rape in the presence of large amounts of trash (HGCA Project Report OS55). This work showed that good establishment was possible as long as soil conditions were suitable to allow good seed: soil contact. A previous project (HGCA Project Report 311) highlighted the benefits from reducing the costs of establishment using minimum tillage and direct drilling and this project started as a result of the findings from the previous experiments.

This project set out to examine establishment of a cereal crop, either following oilseed rape or a previous cereal. Trials were established at four sites on varying soil types using different drills and employing varying degrees of trash mixing. There is a hypothesis that leaving long stubble will minimise the amount of free trash which might ease the establishment of the crop. This was examined using different types of drill (discs or tines) and different degrees of cultivation (direct drilling, shallow disc cultivation or deep disc cultivation). The free trash (as opposed to that attached to the root ball as stubble) is often the main cause of drill blockage and inhibition of good seed to soil contact, particularly if it is poorly distributed by the combine's straw chopper and spreader.

Drill design also has a role to play in the successful establishment of the crop. Those with single discs (eg John Deere 750A) are claimed to be more likely to result in poor establishment in heavy trash situations because they have no method of moving the straw to one side ahead of the seed coulter. Cultivator drills with discs (eg Vaderstad Rapid) fitted with discs ahead of the seed coulters are able to move the trash to one side thus preventing blockages and poor seed:soil contact. Drills with tines (eg Simba Horsch CO4) tend to provide more soil disturbance which assists with moving the trash away from the seed coulter. Disc drills are often associated with "hair pinning" where the straw is folded into the slot created by the disc coulter preventing good seed:soil contact.

Many machinery options and combinations are open to growers who wish to establish crops using non-inversion tillage. This project intended to investigate various factors to determine the effects of trash distribution on establishment and yield of winter wheat sown direct or following minimal tillage and the impact that stubble height and trash raking had on this and the importance of minimal tillage cultivation depth. These factors were compared in first and second wheat situations using a range of soil types, using tine and disc drills.

Materials and methods

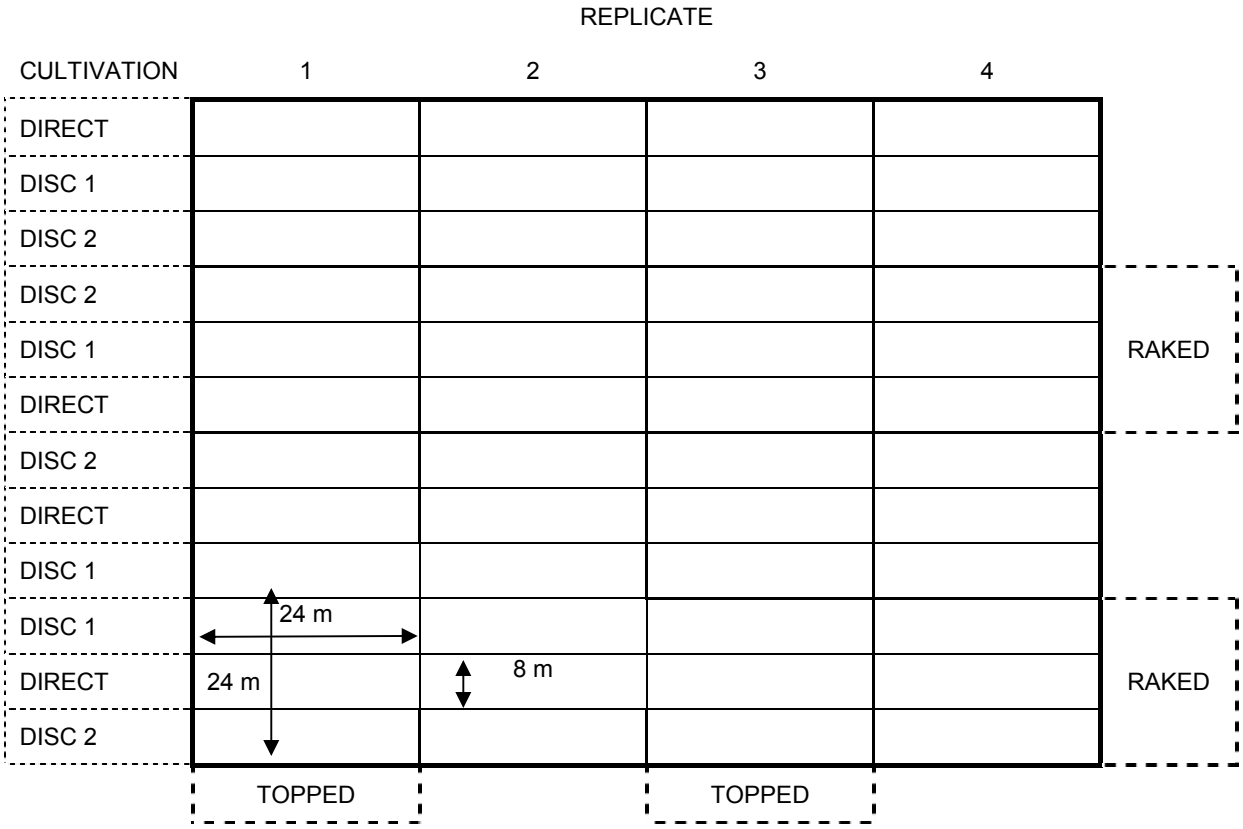
Table 1. Summary of sites, previous crop, soil type and drill used in the experiment

Location	Previous crop	Soil type (soil series name)	Drill type
Bedfordshire 2003	Wheat	Heavy (Cannamore)	Disc (John Deere)
Gloucestershire 2003	WOSR	Light (Elmton 1)	Tine (Horsch)
Lincolnshire 2003	Wheat	Med/heavy (Andover 1)	Tine (Horsch)
Kent 2003	WOSR	Medium (Batcombe)	Disc (John Deere)
Suffolk 2004	Wheat	Heavy (Beccles)	Disc (Vaderstadt)
Gloucestershire 2004	WOSR	Light (Elmton 1)	Tine (Horsch)
Lincolnshire 2004	Wheat	Med/heavy (Andover 1)	Disc (Vaderstadt)
Kent 2004	WOSR	Medium (Batcombe)	Disc (John Deere)

Trials were established following harvest of the previous crop leaving long stubble. The short stubble treatment was trimmed using a topper to achieve two stubble lengths of 10-15 cm and 25-30 cm. The loose trash was raked at right-angles to the direction of combining on the relevant treatments using a light zig-zag harrow. Cultivations were then done in the same direction as the raking using a set of heavy discs to the required depth (7 cm or 12 cm) to create the two minimum tillage treatments. Drilling was done using the drill types shown in table 1. An assessment of surface trash was made at the time of drilling. Crop establishment was assessed in the late autumn and other differences in the treatments observed during the establishment phase. Slug and weed populations were monitored. A summer assessment of ear number was made and a final grain yield assessment was recorded.

The experiment lay out is shown in Figure 1. Stubble was topped in the direction of combining and the straw then raked at 90 degrees. The three cultivation methods were then randomised within each stubble/rake combination. This was replicated four times.

Figure 1. Layout of experiment.



Results

Second wheat - year 1

Table 2a. Observed straw cover on soil surface (%) and crop establishment (%). Bedfordshire, 2003

Stubble height	Cultivation system	% Straw cover		% Crop establishment	
		Raked	Not raked	Raked	Not raked
Short	Direct	84	68	59	49
	Disc 7cm	56	53	81	77
	Disc 12cm	29	34	81	86
Long	Direct	76	63	53	47
	Disc 7cm	51	50	74	77
	Disc 12cm	28	30	82	79

Raking increased straw cover (i.e. improved the distribution of straw) on the surface with direct drilling, particularly when the stubble was short. Cultivation (shallow or deeper min till) reduced surface trash levels and there was little difference between stubble heights. Crop establishment was improved where there was less trash on the surface. Raking tended to improve crop establishment when direct drilling was used.

Table 2b. Observed straw cover on soil surface (%) and crop establishment (%). Lincolnshire, 2003

Stubble height	Cultivation system	% Straw cover		% Crop establishment	
		Raked	Not raked	Raked	Not raked
Short	Direct	100	90	58	70
	Disc 7cm	80	72	72	65
	Disc 12cm	58	45	64	58

Raking increased trash coverage with all establishment methods. Cultivation to 12 cm reduced the amount of trash on the surface. Raking increased plant populations with shallow and deep min till, but reduced populations with direct establishment.

First wheat - year 1

Table 2c. Observed straw cover on soil surface (%) and crop establishment (%). Kent, 2003

Stubble height	Cultivation system	% Straw cover		% Crop establishment	
		Raked	Not raked	Raked	Not raked
Short	Direct	52	52	82	81
	Disc 7cm	22	51	91	94
	Disc 12cm	49	24	92	94
Long	Direct	53	56	85	78
	Disc 7cm	21	56	89	85
	Disc 12cm	55	22	94	89

Raking and stubble height had little overall effect on trash coverage and there was no consistent effect of stubble height or trash raking on plant populations

Table 2d. Observed straw cover on soil surface (%) and crop establishment (%). Gloucestershire, 2004

Stubble Height	Cultivation System	% Straw Cover		% Establishment	
		Raked	Not raked	Raked	Not raked
Short	Direct	96	69	71	70
	Disc 7cm			76	65
	Disc 12cm			72	73
Long	Direct	97	66	66	68
	Disc 7cm			73	67
	Disc 12cm			65	65

Raking increased trash coverage but stubble height had little effect; it also increased plant populations with shallow min till, but not direct or deep min till, however overall differences were small. Short stubble tended to increase plant populations

Second wheat - year 2

Table 3a. Observed straw cover on soil surface (%) and crop establishment (%). Suffolk, 2004

Stubble height	Cultivation system	% Straw cover	
		Raked	Not raked
Short	Direct	74	62
	Disc 7cm	54	52
	Disc 12cm	32	34
Long	Direct	86	76
	Disc 7cm	49	43
	Disc 12cm	40	42

Raking improved straw coverage when no cultivation was done (i.e. direct drill) but cultivations either shallow or deep mixed trash satisfactorily.

Table 3b. Crop establishment (%). Lincolnshire, 2004

Stubble height	Cultivation system	% Crop establishment	
		Raked	Not raked
Short	Direct	30	35
	Disc 7cm	42	36
	Disc 12cm	38	42
Long	Direct	38	37
	Disc 7cm	40	38
	Disc 12cm	38	46

Crop establishment was poor due to dry seedbeds. There was no benefit from raking the trash.

First wheat - year 2

Table 3c. Observed straw cover on soil surface (%) and crop establishment (%). Kent, 2004

Stubble height	Cultivation system	% Straw cover		% Crop establishment	
		Raked	Not raked	Raked	Not raked
Short	Direct	64	88	85	63
	Disc 7cm	90	70	63	75
	Disc 12cm	30	24	86	90
Long	Direct	62	88	82	61
	Disc 7cm	90	55	87	67
	Disc 12cm	29	21	82	85

Raking the trash resulted in better establishment when the crop was direct drilled or where a shallow incorporation with discs was used where the stubble was left long.

Table 3d. Observed straw cover on soil surface (%) and crop establishment (%). Gloucestershire, 2004

Stubble height	Cultivation system	% Straw cover	
		Raked	Not raked
Short	Direct	90	74
	Disc 7cm	88	72
	Disc 12cm	89	76
Long	Direct	82	66
	Disc 7cm	79	64
	Disc 12cm	78	66

Improvements in straw distribution were evident from raking the trash especially when the stubble was short and a direct drill was used.

Second wheat - year 1

Table 4a. Yield (t/ha at 85%dm). Bedfordshire, 2003. LSD 0.86 t/ha

Stubble height	Cultivation system	Yield (t/ha at 85% dm) Not Raked	Raked
Short	Direct	8.16	9.17
	Disc 7cm	10.16	10.31
	Disc 12cm	10.26	10.24
Long	Direct	8.60	9.18
	Disc 7cm	10.35	10.48
	Disc 12cm	10.26	10.43

Raking the trash improved yield when the crop was direct drilled, particularly when the stubble was short and there was consequently more loose trash on the surface.

Table 4b. Yield (t/ha at 85%dm). Lincolnshire, 2003. LSD 0.77 t/ha

Stubble height	Cultivation system	Yield (t/ha at 85% dm) Not Raked	Raked
Short	Direct	9.57	8.66
	Disc 7cm	9.80	9.88
	Disc 12cm	9.06	8.95

At this site raking the trash appeared to reduce yield when the crop was direct drilled.

First wheat - year 1

Table 4c. Yield (t/ha at 85%dm). Kent, 2003. LSD 0.80 t/ha

Stubble height	Cultivation system	Yield (t/ha at 85% dm) Not Raked	Raked
Short	Direct	11.85	12.30
	Disc 7cm	11.55	12.49
	Disc 12cm	11.92	12.70
Long	Direct	12.09	12.34
	Disc 7cm	11.96	12.75
	Disc 12cm	12.25	12.47

Raking the trash improved yield at this site.

Table 4d. Yield (t/ha at 85% dm). Gloucestershire, 2003. LSD 0.77 t/ha

Stubble Height	Cultivation System	Yield (t/ha at 85% dm) Not Raked	Raked
Short	Direct	7.72	8.64
	Disc 7cm	8.12	8.55
	Disc 12cm	8.32	8.56
Long	Direct	8.39	8.83
	Disc 7cm	8.67	8.86
	Disc 12cm	9.02	8.66

Yield was improved by raking when direct drilling into a short stubble with more loose trash.

Second wheat - year 2

Table 5a. Yield (t/ha at 85% dm). Suffolk, 2004. LSD 0.71t/ha

Stubble height	Cultivation system	Yield (t/ha at 85% dm) Not Raked	Raked
Short	Direct	10.07	9.97
	Disc 7cm	10.22	10.39
	Disc 12cm	10.06	10.37
Long	Direct	9.69	10.22
	Disc 7cm	10.53	10.32
	Disc 12cm	10.23	10.45

There were no significant differences at this site.

Table 5b. Yield (t/ha at 85% dm). Lincolnshire, 2004. LSD 0.96t/ha

Stubble height	Cultivation system	Yield (t/ha at 85% dm) Not Raked	Raked
Short	Direct	9.39	9.01
	Disc 7cm	9.75	8.32
	Disc 12cm	9.11	9.25
Long	Direct	9.16	8.72
	Disc 7cm	9.14	9.59
	Disc 12cm	9.06	9.50

There were no significant differences at this site.

First wheat – year 2

Table 5c. Yield (t/ha at 85% dm). Kent, 2004. LSD 0.62 t/ha

Stubble height	Cultivation system	Yield (t/ha at 85% dm)	
		Not Raked	Raked
Short	Direct	11.31	11.51
	Disc 7cm	11.46	10.82
	Disc 12cm	11.23	11.55
Long	Direct	11.17	11.48
	Disc 7cm	11.41	11.11
	Disc 12cm	11.34	12.34

Raking the trash improved yield where the stubble was long and deeper discing was employed. Conversely raking reduced yield where the stubble was short and shallow discing was used.

Table 5d. Yield (t/ha at 85% dm). Gloucestershire, 2004. LSD 1.53 t/ha

Stubble height	Cultivation system	Yield (t/ha at 85% dm)	
		Not Raked	Raked
Short	Direct	5.46	5.12
	Disc 7cm	5.19	6.95
	Disc 12cm	5.67	4.65
Long	Direct	5.77	5.16
	Disc 7cm	6.24	5.90
	Disc 12cm	6.03	4.52

This site suffered from a high black-grass infestation which was poorly controlled. There were no significant differences.

Table 6. Summary of first wheat following winter oilseed rape situations

Stubble height	Cultivation system	Not Raked					Raked				
		Glos 1	Kent 1	Glos 2	Kent 2	Mean	Glos 1	Kent 1	Glos 2	Kent 2	Mean
Drill Type		Ho	JD	Ho	JD		Ho	JD	Ho	JD	
	Direct	7.72	11.85	5.46	11.31	9.09	8.64	12.30	5.12	11.51	9.39
Short	Disc 7cm	8.12	11.55	5.19	11.46	9.08	8.55	12.49	6.95	10.82	9.70
	Disc 12cm	8.32	11.92	5.67	11.23	9.29	8.56	12.70	4.65	11.55	9.37
Mean				9.15					9.49		
	Direct	8.39	-	5.77	11.17	8.44	8.83	-	5.16	11.48	8.49
Long	Disc 7cm	8.67	-	6.24	11.41	8.77	8.86	-	5.90	11.11	8.62
	Disc 12cm	9.02	-	6.03	11.34	8.80	8.66	-	4.52	12.34	8.51
LSD		0.42	NS	NS	NS		0.42	NS	NS	NS	
Mean				8.67					8.54		
Mean				8.91					9.02		

Table 7. Summary of second wheat situations

Stubble height Drill Type	Cultivation system	Not Raked					Raked				
		Beds 1 JD	Lincs 1 Ho	Suff 2 Vd	Lincs 2 Vd	Mean	Beds 1 JD	Lincs 1 Ho	Suff 2 Vd	Lincs 2 Vd	Mean
Short	Direct	8.16	9.57	10.07	9.39	9.30	9.17	8.66	9.97	9.01	9.20
	Disc 7cm	10.16	9.80	10.22	9.75	9.98	10.31	9.88	10.39	8.32	9.72
	Disc 12cm	10.26	9.06	10.06	9.11	9.62	10.24	8.95	10.37	9.25	9.70
Mean				9.63					9.54		
Long	Direct	8.60	-	9.69	9.16	9.15	9.18	-	10.22	8.72	9.37
	Disc 7cm	10.35	-	10.53	9.14	10.01	10.48	-	10.32	9.59	10.13
	Disc 12cm	10.26	-	10.23	9.06	9.85	10.43	-	10.45	9.50	10.13
LSD		0.86	0.77	NS	NS		0.86	0.77	NS	NS	
Mean				9.67					9.88		
Mean				9.65					9.71		

Table 8. Overall summary of yield effects (t/ha at 85% dm)

Stubble height	Cultivation system	Yield (t/ha at 85% dm)		Margin over cultivation costs (£/ha)	
		Not Raked	Raked	Not Raked	Raked
Short	Direct	9.12	9.30	522	518
	Disc 7cm	9.53	9.71	527	543
	Disc 12cm	9.46	9.54	498	487
Mean		9.37	9.52		
Long	Direct	8.80	8.93	503	496
	Disc 7cm	9.39	9.38	518	503
	Disc 12cm	9.32	9.32	559	474
Mean		9.17	9.21		
Overall mean		9.27	9.36		

Costs of operations used for calculations (£/ha)

Direct drilling	25
Disc to 7 cm	45
Disc to 12 cm	70
Raking	15

Stubble trimming (in the experiment this was done as a separate operation (estimated cost £15/ha) in commercial operation this would be part of the harvesting cost and it would be fair to add some cost to cutting the stubble shorter in terms of reduced harvester output and increased fuel). This operation has not been costed in the table above.

The greatest margin was achieved by leaving the stubble long and cultivating to a depth of 12 cm. Raking was economic only when the stubble was short and the cultivation was shallow.

Discussion

Rotational position

Two positions were examined, firstly the establishment of a first wheat following oilseed rape (Table 6), perhaps the most obvious situation to consider minimal tillage and secondly a second wheat where the quantity of trash is higher (Table 7). It could be supposed that in the latter situation the problem of high levels of trash are more likely to impede establishment of the following crop where non-inversion cultivations are employed and that raking the trash to improve it distribution would be of maximum benefit. Conversely it could be argued that in the wheat following rape situation there would be a greater risk from slug damage and high levels of surface trash poorly distributed would encourage predation by slugs. Assessments of slug damage were made at all sites during the establishment period however damage was minimal in 2002/3 and the dry autumn in 2003 meant that there was no slug activity in the 2004 harvest year.

In year 1 (2003) raking improved yields at both first wheat sites (wheat following rape) but the reason is unclear as there was little effect on crop establishment from treatments in Kent (Table 2c) however at the Gloucestershire site raking did improve crop establishment particularly when shallow discing was employed (Table 2d). In year 2 (2004) raking the trash improved establishment only where the crop was direct drilled or where long stubble was shallowly incorporated at the Kent site (table 3c) and where the wheat was direct drilled into a short stubble at the Gloucestershire site(table 3d).

In the second wheat situations in year 1, raking improved crop establishment particularly when the straw was incorporated with discs at the Bedfordshire site (Table 2a) and subsequent yield (Table 4a) and this establishment effect was also observed at the Lincolnshire site (Table 2b) but the effect was not translated to yield where raking reduced yield particularly when direct drilled (Table 4b). In year 2, raking proved inconclusive in terms of crop establishment at both sites (Tables 3a and 3b) and there were no differences in yield (Tables 5a and 5b).

Drill type

The greatest differences in the series of experiments were observed when direct drilling was compared to shallow or deeper discing. Whatever the stubble treatment employed, direct drilling particularly at sites where the John Deere (JD) drill was used (Bedfordshire, year 1 and Kent in both years) and more particularly where levels of trash were greatest (second cereal at the Bedfordshire site) showed the greatest yield penalty. This drill was unique in that it was the only machine used in the experiment that did no cultivation as the seed was sown. This meant that surface trash was not mixed with the soils at all. In first wheat situations, where the machines were dealing with a lower level of trash following oilseed rape differences between establishment techniques were smaller (Kent , years 1 & 2). The Horsch (Ho) drill, which cultivates as it

sows still benefited from some primary cultivation and stubble treatment in a first wheat situation (Gloucestershire, year 1, Table 6) and a second wheat situation (Lincolnshire year 1, Table 7). In year 2 the Vaderstadt Rapid cultivator drill was used at the two second wheat sites; it too generally benefited from some primary cultivation but, as was seen with the Horsch at the Lincolnshire site in the previous year, there was a tendency for the deeper cultivation to result in lower yields (NS) particularly where the stubble was short (and consequently more loose trash was present).

Soil type

Soil type had a greater effect on overall yield than in differences between treatments although it was at the lightest site (Gloucestershire) that the only significant yield differences were observed in a first wheat situation. At the medium and heavy soil type sites the greatest yield differences between stubble treatments and establishment method were observed in Bedfordshire and to a lesser extent in Lincolnshire.

Overall trash raking improved yield marginally (0.09 t/ha), its benefit was greatest (0.15 t/ha) where the stubble had been trimmed with a topper ("short" in tables) to 10-15 cm. Where the stubble was left at 30 cm ("long") the effect was smaller still (0.04 t/ha). Overall trimming the stubble improved yield by 0.25 t/ha. This difference was largely confined to the situations where no subsequent cultivation was done, i.e. the crop was direct-drilled. Yield differences were not statistically significant. The mean figure hides some big variations and it is difficult to explain why in some cases there were larger positive and negative effects from raking. Yield reductions from raking were sometimes evident. One possible explanation was that the treatment encouraged surface soil moisture loss. On the other hand there were cases where there was a clear benefit (eg Beds 1)

Deep cultivation (12 cm), whilst visually reducing surface trash often resulted in dry seedbeds and subsequently poorer establishment and lower yields. This was particularly so in 2004 when there was a prolonged dry period in the autumn.

Vaderstadt, Horsch and John Deere drills were used but there was no clear advantage from any particular design although yield differentials between direct drilling and the two degrees of cultivation were greatest when the John Deere disc drill was used.

Different establishment techniques had an effect on the amount of surface trash and raking did improve matters in terms of improving the distribution of straw more evenly and in some cases the establishment of the following wheat crop. However, statistically different yield reductions were only recorded in two of the eight experiments and they were associated with direct drilling and were usually associated with more trash on the surface (even in the case of the Gloucestershire site when this was oilseed rape trash).

Trash raking can assist with establishment if the crop is direct drilled using a disc drill in particular or if a shallow cultivation is employed with a short stubble (with more loose trash on the surface) but is unlikely to be beneficial if any deeper cultivation that mixes the trash with the soil is employed. In the light of current fuel costs the justification for leaving the stubble very short and then raking the trash prior to a shallow minimum tillage establishment system is hard to contemplate. Leaving a longer stubble at harvest (maximising combine harvester output) and if contemplating direct drilling utilising a cultivator drill to minimise the problems with surface trash would seem the most economic way forward rather than to produce a set of circumstances where trash raking as a separate operation would be of benefit.

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