Silage

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HARVESTING SYSTEMS FOR WILTED SILAGE

[East of Scotland College Agriculture.
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HARVESTING SYSTEMS for WILTED SILAGE

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CONTENTS

SUMMARY

1. This report is based on a 2-year study of wilted silage systems, involving 35 sets of field observations over 2 seasons (1972 and 1973). Twenty-five whole season records were also returned by farmers.

2. **Harvester performance**

Swath weight affects rate of work but the particular combination of yield, degree of wilting and width of mower which produces a given weight of swath is of no importance.

In light swaths, about 4 mph (say 16 tons per hour) can be expected with any size of tractor from 60 to 100 hp. In heavy swaths, 55/60 hp tractors will be limited to about 2 mph (say 18 tons per hour), compared with perhaps 3 mph (24 tons per hour) for 65 to 100 hp tractors. The advantage of 90+ hp is only likely to become apparent in very heavy swaths when output should be at least 30 tons per hour.

Considerably higher rates than the above are possible, but are not likely to be achieved consistently except by determined operators.

3. **Wide mowers** can result in a greatly improved pick-up rate but only in the case of larger tractors (say 70+ hp). Smaller tractors are less able to take advantage of the heavier swath (see 2 above).

Two-into-one swath turners may give similar benefits if the machine used can produce a stone-free double swath of even consistency.

4. **Wilting** to 30 per cent dry matter (DM) makes the swath at least 40 per cent lighter, which can allow higher pick-up rates. However, a gain in trailer capacity is not to be expected, so the overall result may be no different (if transport arrangements are already the limiting factor). Buckrake performance (tons DM per hour) should be at least 50 per cent better with good wilting.

5. **Precision-chop (P.C.) harvesters** were no faster than double-chop (D.C.) machines, other things being equal (such as tractor size, swath weight and adequate transport). But the effect on trailer capacity can be important – trailers can hold approximately 40 per cent more P.C. material than D.C. material. Although P.C. machines are generally considered to be more easily damaged, less time was lost from breakdowns of P.C. machines in this survey than from D.C. machines.

6. **Side loading** (i.e. trailers **not** hitched to the harvester) can speed up the operation by at least 20 per cent in conditions where trailers have to be changed frequently; e.g. trailers of only standard size, a fast pick-up rate, or D.C. material (which takes up more space).

7. **Systems**

Details of 6 systems are included, covering a range of performance from 1.0 to 2.7 acres per hour (expected overall rate). A simple guide to selection is also given.

INTRODUCTION

Since wilting and chopping are generally regarded as good practice at the present time, a 2-year study of silage making systems was carried out on farms where:

(i) **wilting** was practised;

(ii) the swath was picked up by either a **double-chop** or a **precision-chop** forage harvester;

(iii) the silage was made in a **horizontal** clamp.

The objective was to clarify the effect on performance of alternative items of equipment and the way in which they are organised.

It is hoped that this report of the results will reduce the lengthy process of trial and error by which silage-making systems are commonly adopted and adapted on the individual farm.

The information comes from two sources.

(i) Stop-watch studies in the field, based on 35 visits made in 1972 and 1973. Recording methods did not interfere with the progress of work; and, because of the efforts which were made to carry out these studies unobtrusively, it is considered that our presence had little effect on rate of work.

(ii) Records kept by farmers for the whole period of the 1st cut. Twenty-five satisfactory records were returned.

Part 1 presents the main findings as briefly as possible. Part 2 gives details of alternative systems, based on these findings. The Appendices give methods and results in detail.

The following definitions should be noted.

Spot rate is the rate of work during non-stop operation (e.g. when the harvester is actually picking up the swath).

Overall rate includes turns, trailer changes and any other delays which are part of the normal routine. This rate can be maintained throughout the working day (ignoring mealtimes, breakdowns and changing fields).

Swath 'weight' means weight per unit of distance (usually lb/10 yd).

Swath 'width' refers to the effective width of cut taken by the mower.

PART 1: RESULTS AND DISCUSSION

This section contains the main conclusions supported by only a summary of the data. A fuller presentation of the results can be found in the Appendices.

1. The effect of power on harvester performance

(a) 55/60 hp v. 65/75 hp.

Both the precision-chop (P.C.) and double-chop (D.C.) type of harvester can be used with a tractor of only 55 hp. However, the lower rate of work may with smaller tractors not be acceptable in heavy swaths, whether these are the result of heavy yields, poor wilting or wide mowers (Table 1).

TABLE 1: The effect of power and swath weight on harvester performance (spot rate of work)

	EXPECTED RATE OF WORK					
	Swath weight:					
	light	medium	heavy	light	medium	heavy
Tractor size:	mph			tons per hour		
55/60 hp	3.8	2.8	2.1	16	18	18
65/75 hp	3.8	3.1	2.8•	16	20	24

Notes: 1. 'Light' = 55 lb/10 yd. 'Medium' = 82.5 lb/10 yd. 'Heavy' = 110 lb/10 yd.
The 'medium' swath corresponds to the average of 32 fields sampled.

2. These are not maximum rates but those to expect in practice from average drivers. Some drivers, prepared to operate nearer the maximum can improve on these rates by at least 20 per cent.

3. Detailed results in Appendix B.

In heavy crops, the smaller tractor has little in reserve and drivers can be expected to ease off to keep noise and stress to reasonable levels; larger tractors are better able to maintain forward speed.

In light crops, considerations of comfort and general control of the equipment will tend to limit forward speed to no more than about 4 mph with both sizes.

Fifty-five hp tractors are likely to be unsatisfactory in combination with P.C. harvesters when these are set for a very fine chop (e.g. for tower silos).

(b) 65/75 hp v. 90+ hp

On average, tractors in the 90+ hp class were no faster than 65/75 hp models (Appendix B). However, there is little doubt that they have extra potential. For example, one 90 hp tractor was recorded at 36 tons per hour (4.2 mph in a heavy swath). But the potential is not likely to be realised unless:

(i) a heavy swath is made;

(ii) the driver maintains at least 3.5 mph (except in the heaviest crops);

(iii) transport arrangements can cope with the output;

(iv) a precision-chop harvester is used. (Double-chop harvesters are usually designed for use with tractors of no more than 75 hp).

2. The advantages of wide mowers

Wide rotary mowers (9ft nominal width) took an effective cut of 7.8 ft on average, compared with 4.5 ft for mowers of 5 ft nominal width. The increase in swath weight (approximately 75 per cent) will normally slow down the harvester, but only by about 25 per cent if a 65/75 hp tractor is used (see mph v. swath weight trend in Appendix B). The result is a gain of 40 per cent in tons per hour. Smaller tractors are unlikely to benefit from a heavier swath (Table 1).

Faster mowing is another feature which makes wide mowers a desirable component of really high performance harvesting systems.

3. Two-into-one swath turners v. wide mowers

Ground-driven turners should be avoided because they tend to rake stones into the swath and, in common with up-and-over types, the double swath they produce appears to feed much less evenly into the harvester.

Machines which do not have these faults are likely to give the same benefits as a wide mower. They may even be preferable for haylage systems where it is sometimes desirable to disturb the swath in any case for faster wilting. However, they do introduce an extra operation into the system, and any advantage will be lost if:

(i) the pick-up operation is sometimes delayed as a result.

(ii) a tractor of only 55/60 hp is used with the harvester. Although the tractor may not be brought to a standstill by the double swath, an improvement in tons per hour is not to be expected except in the lightest crops.

4. Double-chop v. precision-chop

The precision-chop harvester was originally developed for the benefit of tower silo systems where the short-chop material packs down better and can be removed more easily. Their use with clamp systems is claimed to improve the fermentation process and to reduce losses through better consolidation which excludes air more successfully. Double-chop material is longer and presumably less effective in providing these benefits. However, this study was only concerned with field performance aspects.

(a) Rate of work

Rate of work in tons per hour was similar with both types of harvester (Table 2).

TABLE 2: Spot rate of work — double-chop v. precision-chop

Type of harvester	Mph	Tons/hour	Hp	Swath weight
D.C. (12 observations)	3.0	19.9	65	84 lb/10 yd.
P.C. (23 observations)	3.2	19.4	75	82 lb/10 yd.

The difference in mph is to be expected as a result of the higher average hp in the P.C. sample (see Table 1).

The figure for acres per hour was higher for the P.C. sample (2.2 v. 1.7) but again this fact is unrelated to type of harvester. Instead, it is a direct result of swath width (5.7 ft v. 4.5 ft) and larger tractors, the extra width of swath being due to a number of wide mowers and 2-into-1 swath turners. (In spite of the difference in swath **width,** swath **weight** is similar in both cases because of slightly better wilting and rather lower yields to start with in the P.C. sample.) The conclusion must be that, other things being equal, pick-up rate is unaffected by type of harvester.

(b) Effect on trailer capacity

Chopped grass is known to pack more closely than unchopped grass, but a substantial difference is also evident between double- and precision-chop material (Table 3).

TABLE 3: Trailer capacity — double-chop v. precision-chop material

Type of harvester	Tons of DM per 100 cu ft of trailer capacity
D.C. (9 observations)	0.123
P.C. (21 observations)	0.175

Note: Detailed results in Appendix C.

Precision-chopping increases trailer capacity by approximately 40 per cent and since transport delays are in fact fairly common with D.C. systems, this effect must be regarded as one of the main advantages of the more expensive harvester. It is probably the main reason for the better whole-season rates of work recorded by farmers using P.C. machines (Table 4).

TABLE 4: Whole-season rates of work (acres/hour)

Type of harvester	1972	1973
Double-chop	0.77 (5 farms)	1.16 (8 farms)
Precision-chop	0.88 (5 farms)	1.40 (7 farms)
Difference	+11%	+12%

Even if transport is not a limiting factor, some improvement in rate of work will result from fewer stops to change trailers.

(c) Reliability

It is recognised that stones and other objects can cause serious damage to the precision-chop mechanism. Simple flail harvesters are better adapted to survive damage from such materials. Double-chop harvesters are generally thought to be of intermediate susceptibility.

The results of this study do not allow comparisons to be made on this particular aspect of reliability. However, breakdowns occur for various reasons apart from the intake of foreign bodies (e.g. failure of bearings, shafts, shear pins, axles and hitches) and when breakdowns from all causes are considered (Table 5), there appears to be no reason to discriminate against the P.C. harvester.

TABLE 5: Reliability comparison — double-chop v. precision-chop

	Double-chop	Precision-chop
Time lost due to breakdowns (as % of working hours)	6.7% (range: 0-22)	4.3% (range: 0-14)
No. of working hours recorded	1189	705
No. of records	14	11

Nevertheless the results cannot be taken as proof of **better** reliability — the small difference could easily arise by chance when individual results vary so widely; or it could be the effect of newer machines in the P.C. sample.

5. The advantages of wilting

Wilting is good practice from the husbandry point of view:

(i) the chances of an undesirable type of fermentation are much reduced (especially when ensiling grass with a low sugar content);

(ii) losses of DM in effluent and in the fermentation process are reduced;

(iii) problems of effluent disposal may be avoided;

(iv) higher DM intake is possible with wilted silage and the profitability of many livestock systems is related to this factor.

These effects will be noticeable to some extent even with slight wilting but best overall results depend on reaching a DM content of 25-30 per cent.

Harvesting systems can also benefit from good wilting in a number of ways:

(a) Effect on harvester performance

A swath wilted to 25 per cent DM is about 28 per cent lighter than when cut fresh as, say, 18 per cent DM, or about 42 per cent lighter if wilted to 30 per cent DM.

In practice, 25 per cent DM is the level more commonly reached after a 24-hour wilt and this (referring to Table 1) is enough to reduce a 'heavy' swath to a 'medium' swath, or a 'medium' swath to a 'light' swath. The improvement in forward speed which this reduction allows can be substantial, especially for the smaller tractor.

For a given weight of swath, DM content does not appear to affect rate of work, at least within the usual range (18 to 33 per cent DM).

(b) Effect on trailer capacity

It is sometimes suggested that wilting increases the DM capacity of trailers, but the results of this study do not show this to be the case, either for D.C. or P.C. material (Appendix B). This means that the improvement in harvester potential (see above) will not improve the overall performance of the system unless transport arrangements are already more than adequate.

However, although trailer loads contain no more DM, they do contain much less water (Table 6).

TABLE 6: Expected capacity of standard trailer[1]

DM content	Weight of DM (tons)		Weight of grass (tons)	
	D.C.	P.C.	D.C.	P.C.
18%	0.44	0.63	2.5	3.5
25%	0.44	0.63	1.8	2.5
30%	0.44	0.63	1.5	2.1

(1) 'Standard' trailer = 10 x 6 x 6 ft.

This reduction in weight can sometimes be important. When hitched to the harvester, heavy loads can be dangerous on steep, downhill slopes; speed may be affected when working uphill and the harvester wheels may sink in soft ground, although this depends partly on trailer design.

(c) Effect on buckrake performance

Wilting can greatly increase buckrake performance (Table 7).

TABLE 7: **Effect of wilting on buckrake performance (spot rate)**

DM content	Tons of grass/hour	Tons DM/hour
20%	20	4.0
25%	21	5.4
30%	22	6.8

Note: Detailed results in Appendix B (Figure 3).

Since actual tons of grass per hour is apparently unaffected by DM content, tons of DM per hour is largely proportional to the degree of wilting.

6. Factors affecting buckrake performance

The average spot rate of work was 21.5 tons per hour.

Above-average performance depends on:

(a) good wilting (see above);

(b) good operators. (The fastest 5 operators averaged 32 tons per hour, the slowest 5 only 13.6 tons per hour);

(c) good equipment, and in particular powerful tractors. A clutchless forward/reverse gear change, double rear wheels and a wide buckrake are among the options which make high performance easier to achieve. Industrial or 4-wheel-drive tractors have enough performance to cope with any situation — one second-hand industrial tractor with a front-mounted buckrake was timed at a leisurely 64 tons per hour;

(d) good chopping. (The rate with P.C. material was slightly higher than with D.C. material — 23.0 v. 19.4 tons per hour).

Assistance at the clamp should not be necessary when handling P.C. material, especially if a push-off buckrake is used and the load can be deposited as a layer instead of in a heap. Even with D.C. material, the driver was usually unassisted.

7. Routines

The same basic routine (described overleaf) was used for almost all the systems studied. However, the trailers were sometimes hitched to the harvester ('rear' loading) or towed independently ('side' loading). The latter arrangement reduces idle time but requires an extra man and tractor. Appendix C gives more detail for various combinations of yield, trailer size, etc.

(a) Harvester routine

Element	Minutes per load:		No. of observations	Notes
	average	range		
Pick-up swath	7.6	3.9 – 14.8	35	Time depends on trailer size as well as rate of work
Turn	1.0	0.3 – 1.9	31	One 0.5 min turn per 320 yd row on average
Change over: rear loading	1.8	1.0 – 3.2	20	Automatic hitch
(or side loading)	(0.5)	(0.2 – 0.9)	(8)	A non-stop change–over is possible but a pause was more usual to avoid any loss of grass
Total	10.4 (rear loading) or 9.1 (side loading)			

(b) Transport routine

Element	Minutes per load:		No. of observations	Notes
	average	range		
Field travel	2.4	1.2 – 4.8	18	From harvester to gate (return). Slower speeds than on the road.
Road travel	6.0	1.7 – 17.2	21	From gate to clamp (return). Average mph was 11½ (range 7-19½).
Change over: rear loading	2.1	1.0 – 4.4	16	Automatic hitch
(or side loading)	(0.5)	(0.15 – 0.6)	(8)	See 'harvester routine'.
Tip at clamp	2.5	1.4 – 4.7	28	Tipping on a dump area– no trailers were being driven over the clamp.
Total	13.0 (rear loading) 11.4 (side loading)			

Self-unloading trailers feeding into a blower were timed on one farm on 2 separate occasions. Average turn-round times were 6.6 and 9.2 minutes. Tipping trailers are preferable in most circumstances.

(c) Buckrake routine

The average time to clear a load was 6.4 minutes (21.5 tons per hour). However, with most layouts, the buckrake cannot operate continuously because access to the grass dump is prevented for about 2 minutes of the trailer tip routine. On average, the overall rate to expect would therefore be one load per 8.4 minutes (16.4 tons per hour).

(d) Matching routines

Delays will occur if the transport routine is longer than the harvester routine, unless 3 trailers are used instead of 2, in which case the permissible transport routine time is doubled. An increase in trailer size allows extra time, roughly in proportion to the increase in trailer size. In practice, transport delays were fairly common, although sometimes disguised by a reduction in speed by the harvester.

Delays at the clamp were rare but they can easily occur if some special equipment (see Part 1.6(c) page 11) is not included as part of a high performance system.

PART 2: SYSTEMS

1. The main alternatives

The systems in Table 8 provide a range of performance options, from 1.0 to 2.7 acres per hour, by selection from the following equipment:

Mowers	5 ft or 9 ft (nominal width)
Tractors	60, 75 or 90+ hp (approximately)
Harvesters	D.C. or P.C.
Trailers	4 sizes:

1.	Small	(260 cu ft, eg 9½ x 5½ x 5 ft)
2.	Standard	(360 cu ft, eg 10 x 6 x 6 ft)
3.	Large	(488 cu ft, eg 12 x 6½ x 6¼ ft)
4.	Outsize	(588 cu ft, eg 14 x 7 x 6 ft)

The effect of these alternatives on rate of work has already been discussed in Part 1. Three possible trailer combinations are given for each system, along with the maximum time **available** for road travel if delays are to be avoided. To estimate the actual time **required** for road travel it is necessary to time the trailer over the return journey at realistic speeds. Average figures (say 5 minutes per mile) are a poor substitute because road conditions vary so much from farm to farm.

TABLE 8: **Six wilted silage systems — a guide to rate of work and transport requirements**[1]

	Yield of DM[2]: Loading arrangement:	2 tons/acre rear	2 tons/acre side	3 tons/acre rear	3 tons/acre side
SYSTEM 1	Acres per hour (overall)	1.4	1.7	1.0	1.2
	Time available for road travel with:	mins		mins	
D.C. harvester,	2 x size 2 trailers	2.2		1.2	
60 hp tractor and	2 x size 3 trailers	4.9		3.6	
5 ft mower	3 x size 1 trailers	7.4		6.2	
SYSTEM 2	Acres per hour (overall)	1.4	1.7	1.1	1.4
	Time available for road travel with:	mins		mins	
D.C. harvester,	2 x size 2 trailers	2.2		0.7	
75 hp tractor and	2 x size 3 trailers	4.9		3.0	
5 ft mower	3 x size 1 trailers	7.4		5.4	
SYSTEM 3	Acres per hour (overall)	1.5	1.7	1.0	1.3
	Time available for road travel with:	mins		mins	
P.C. harvester,	2 x size 2 trailers	5.3		4.0	
60 hp tractor and	2 x size 3 trailers	9.2		7.4	
5 ft mower	3 x size 1 trailers	12.0		10.2	
SYSTEM 4	Acres per hour (overall)	1.5	1.7	1.2	1.4
	Time available for road travel with:	mins		mins	
P.C. harvester,	2 x size 2 trailers	5.3		3.2	
75 hp tractor and	2 x size 3 trailers	9.2		6.3	
5 ft mower	3 x size 1 trailers	12.0		9.0	
SYSTEM 5	Acres per hour (overall)	2.1	2.4	1.8	2.0
	Time available for road travel with:	mins		mins	
P.C. harvester,	2 x size 2 trailers	2.3		0.6	
75 hp tractor and	2 x size 3 trailers	5.1		2.8	
9 ft mower[3]	3 x size 2 trailers	11.6		8.2	
SYSTEM 6	Acres per hour (overall)	2.4	2.7	2.0	2.3
	Time available for road travel with:	mins		mins	
P.C. harvester,	2 x size 3 trailers	3.8		1.6	
90/100 hp tractor and	3 x size 2 trailers	9.8		6.6	
9 ft mower[3]	3 x size 3 trailers	14.6		10.2	

(1) Further details in Appendix C.

(2) The average of 32 fields sampled was 2.3 tons per acre. Five fields were 3 tons per acre or more, and 10 fields were less than 2 tons per acre (some of these were second cut or had been grazed earlier in the year). In all cases, the crop is assumed to be wilted to 25 per cent DM.

(3) A 2-into-1 swath turner is a possible alternative (but see Part 1: 3, page 6).

Comments on Table 8

(a) Transport

Two size 1 trailers cannot keep up with any of these systems, and they can be filled so quickly that even a small transport delay will result in the harvester spending more time out of the crop than in it (especially if rear loading).

Apart from more or bigger trailers, time available for transport can be increased by a change to P.C. (ie system 3 or 4 instead of system 1 or 2). Also, if the best driver is put on transport, he may beat the average times for change over, field travel and tipping.

Side loading gives more loads per hour, but the time available for road travel hardly changes. (This is because approximately 1½ minutes are saved from both the harvester and transport routines.)

(b) Fast operators

For a given system and crop yield some harvester operators can be expected to drive up to 20 per cent faster than average. Haulage capacity needs to be generous to take proper advantage, unless the transport driver is also faster than average. (Conversely some operators will be up to 20 per cent slower than average and they should be encouraged to do better.)

(c) Buckrake

Performance with systems 5 and 6 needs to be above average. Some of the special equipment options already mentioned will avoid a bottleneck and save the driver's energy for overtime.

(d) Team size

Complete systems need 4-6 men:

	Rear loading:		Side loading:	
	2 trailers	3 trailers	2 trailers	3 trailers
	number of men			
Mower	1	1	1	1
Harvester	1	1	1	1
Buckrake	1	1	1	1
Trailers	1	2	2	3
Total	4	5	5	6