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Sugar beets

University of Reading
Department of Agriculture and Horticulture

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MAR 1974
WITHDRAWN

THE CHOICE OF SUGAR BEET HARVESTING MACHINERY

G.E. Dalton and R.T. Coney

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THE CHOICE OF SUGAR BEET HARVESTING MACHINERY

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INTRODUCTION

The aim of most analyses of farm machinery selection problems is to recommend the best machine for different acreages by identifying the "least cost" point on a capacity cost curve. Such a curve shows the relationship between the average total machine costs and the acreage harvested. Normally, as the number of acres serviced increases, there is an initial fall in total costs as depreciation and interest charges are spread over more acres. Eventually, as the capacity of the machine becomes more fully utilised, total costs begin to rise due to the fact that further spreading of capital charges is more than matched by increases in both running costs and the costs associated with untimeliness of operations.

An attempt is made in this paper to compare, by means of capacity cost curves, the five following sugar beet harvesting systems:-

(a) 5 or 6 row multi-stage harvesters;

(b) 5 row two-stage harvester;

(c) a self-propelled one-row tanker;

(d) a tractor-drawn single-row tanker;

(e) a tractor-drawn side-delivery harvester.

The comparison is made for the prices which prevailed in the 1971/72 season, assuming average operational efficiency and average weather conditions, the main emphasis of the paper being to calculate the effects in money terms of harvesting time on costs and returns. The analysis, as such, ignores some of the more difficult problems of the application of capacity cost curves so that only general and qualified conclusions can be derived. Variation in the capacity of a machine caused by differences in the skill of the operator, by the performance of other machines within the same system, and by constraints imposed by the organisation of the whole farm, have not been considered. The effect of the weather on the choice of machinery has also not been analysed. It is unlikely that farmers decide to buy a machine on the basis of average costs in an average season, but are probably willing to bear the costs of a larger machine than is normally required, in order to avoid serious losses in a bad season.

TIME OF HARVESTING

The time of harvesting will be affected by a number of factors, namely:

(a) the change in the yield of sugar beet with time;

(b) the change in the yield of the following winter wheat crop with delayed planting (after a certain date it may be necessary on certain soils to plant spring barley);

(c) factory opening times and delivery permits;

(d) extra labour costs, due to slower rates of work as the season progresses;

(e) dirt tare and its effect on transport costs;

(f) the price of beet and bonus payments;

(g) storage losses in clamped beet;

(h) variation in field losses with the harvesting date;

(i) soil type.

All these factors need to be quantified and added to the capital charges and running costs of each machine, in order to produce a set of capacity cost curves.

(a) Yield of sugar beet

The value of the sugar beet crop normally increases up to about the middle of November. Several research workers have found increases of some $1\frac{1}{2}$ to 2 tons yield of beet per acre during October and $\frac{1}{4}$ to $\frac{1}{2}$ ton per acre in early November.[1] [2] The value of these increases in yield can be put at about £3 per acre per week in October and £1 per acre per week in the first part of November, based on a price of £7.50 per ton.

(b) Yield of winter wheat

The sugar beet crop is a good break crop in a cereal rotation and on suitable land the crop can be followed by winter wheat. The optimum time for drilling winter wheat according to the available experimental evidence [3] [4] seems to be during the first weeks of October. Delay after the second week in October results in a loss of about one cwt. per acre per week. Thus, a crop sown in early October with a potential yield of two tons per acre, might only yield some 33 cwts. per acre if sown seven weeks later in December. Failure to sow winter wheat by harvesting the beet late in the season will often result in spring barley being grown with a consequent loss in gross margin. Spring barley has, on average, a gross margin some £12.75 per acre less than that of winter wheat, provided each crop is planted at their own optimum time.

(c) Factory opening times

Delivery permits are spread evenly over an 18-week period extending from late September to the first week in February, so that lifting to meet delivery schedules must take place early in the season. Later in the season, as soils become saturated, lifting will exceed delivery permits and the beet will be stored. For example, in the Cranwell area of Lincolnshire, the average date of return of soil moisture to field capacity is December 6th, although in five years out of 20, this does not occur until January.[5]

(d) Labour costs

A problem in considering machinery systems in isolation from the rest of the farm is that the wage rate does not represent the opportunity cost of labour. Thus, if potatoes are to be lifted by the same labour force which harvests the beet, the two crops should ideally be considered together. Labour costs in terms of wage costs will increase as the season progresses because of the decline in the number of daylight hours and slower rates of work caused by more difficult soil conditions. In fact, most harvesters will take something like an extra two man hours per acre during November and December, which, at

a wage cost of 50p per hour, represents an extra labour cost per acre of £1.

(e) Dirt tare

As soil conditions become wetter, dirt tare increases although this can be reduced at the cost of slower loading rates by investing in a loader cleaner. In an average season, it is likely that tares will be as shown below in Table 1. Assuming a yield of 16 tons of beet to the acre, a transport cost of 75p per ton and the cost of cleaning to be 5p per ton, the extra cost due to the dirt tare ranges from £1.40 in October to £2.92 in December.

TABLE 1

THE COSTS OF TRANSPORTING SOIL,

AND SAVINGS ACHIEVED BY CLEANING.

Month	Dirt tare lb/cwt of beet	Tons/ acre of soil	Cost of transporting soil £/acre	Soil removed by cleaning tons/ acre	Cost of cleaning £/ acre	Savings in transport due to cleaning £/ acre	Net Cost of dirt tare £/acre
OCT.	11	1.75	1.35	1.00	0.80	0.75	1.40
NOV.	18	3.00	2.25	1.20	0.80	0.90	2.15
NOV/ DEC	22	4.00	3.00	1.80	0.80	1.35	2.45
DEC.	28	5.35	4.00	2.50	0.80	1.88	2.92

(f) Price of beet

The standard price for beet in 1971/72 was £7.50 per ton with an increase or decrease of 50p per ton for every 1% movement in sugar percentage above or below 16% sugar content. Bonus payments are also paid for deliveries in September, January and February and in 1971/72 these were as follows:-

Before September 24	-	62½p per ton
September 24 - 30	-	37½p per ton
January 1 - 7	-	19p per ton
January 8 - 14	-	25p per ton
January 15 - 21	-	37½p per ton
January 22 - 28	-	50p per ton
January 28	-	62½p per ton

Assuming that each grower makes regular weekly deliveries, the early bonuses will compensate him for yield losses, while the late bonuses compensate him for storage losses, additional handling and labour costs and the expense of making a frost-proof clamp.

(g) Storage losses

It has been found by research workers[6] [7] that even where beet is properly clamped, losses in weight and sugar content occur due to respiration. Over a six-week period there are likely to be losses in value of the following order:

1% loss of sugar content worth 50p per ton = £8 per acre;
1% loss in weight worth 0.16 x 760p per ton = £1.21
TOTAL LOSS = £9.21 per acre

Thus, the average storage cost per acre per week on a 16-ton crop will be of the order of £1.54.

(h) Field Losses

In October, dry ground makes harvester penetration difficult, which results in beet breaking off at or just below ground level. Such losses can amount to 1.5 tons per acre, or even more,(8) but more usually are of the order of $\frac{1}{4}$ - $\frac{1}{2}$ ton per acre. The extent of such losses will, of course, vary with the season and land type.

(i) Land type

On light soils it is unlikely that winter wheat will be grown after sugar beet. Medium soils, on the other hand, will enable a farmer to drill winter wheat up to the end of the first week in December, whereas on heavy soils it is probably wise to plan to have drilled winter wheat some three weeks earlier or by the end of the second week in November.

All the effects of harvesting date on costs are summarised in Table 2.

TABLE 2

SUMMARY OF THE EFFECT OF HARVESTING DATE

ON COSTS AND RETURNS

1. Yield increases: September - Increases by £3 per acre per week;

October - Increases by £3 per acre per week;

November - Increases by £1 per acre per week;

2. Losses from not planting winter wheat increase at the rate of £1.50 per acre per week after the second week in October. Planting spring barley results in a loss of £12.75, compared with early winter wheat.

3. Storage loss of £1.54 per week from the time of lifting. All storage losses after the second week of December are matched by the end of season bonus.

4. Extra labour costs in November and December by £1 per acre per month.

5 Extra transport costs for November and December lifted beet:

1st and 2nd weeks November - £0.80 per acre
3rd and 4th weeks November - £1.10 per acre
1st week December - £1.10 per acre
2nd and 3rd weeks December - £1.50 per acre

6. Extra field losses:

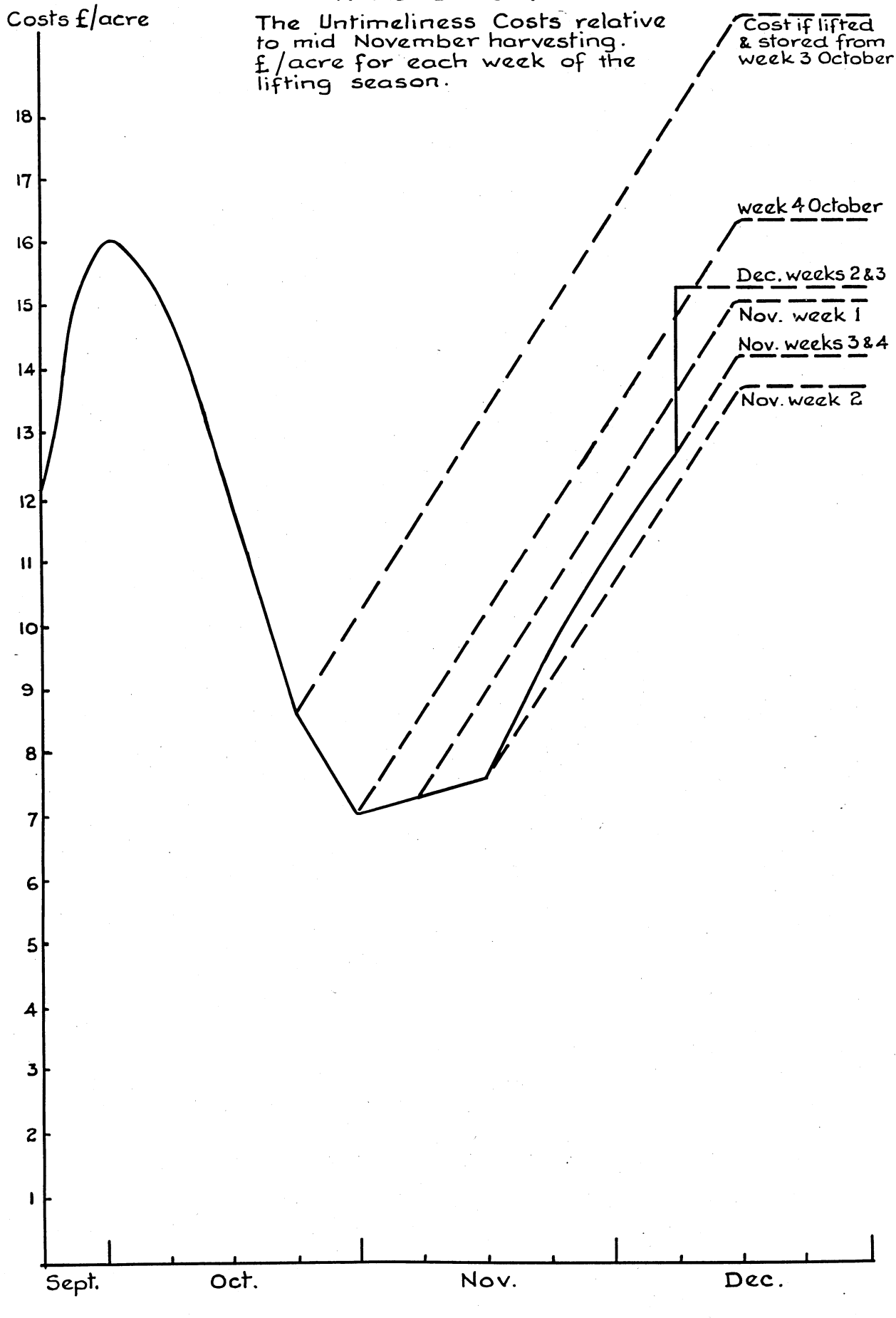
1st and 2nd weeks October - £4.0 per acre
3rd and 4th weeks October - £2.0 per acre

7. Bonus payments:

September 24th - 30th: 37½p per ton (£5.20 per acre).

GRAPH 1

A Medium Soil



Graph 1 depicts the variation in harvesting costs according to harvesting date for a medium soil. The graph is derived by summing all the items at the end of each week in the lifting season. If the crop is lifted and stored, the costs during the storage period are plotted as parallel lines from the end of each week. These lines show that after the second week in November, it is cheaper to lift and store beet for later delivery, rather than to lift and deliver direct. In fact, December lifting is always more expensive than lifting and storing in November, except for the comparison of late December lifting and early November lifting and storage. Similar conclusions can be drawn for a heavy land farm, except that lifting at an even earlier date is preferable because of the necessity to plant winter wheat before the soil becomes saturated.

HARVESTER OPERATING COSTS

The next stage in the construction of the capacity cost curves is to make an estimate of the annual costs of operating each of the five different types of harvester.

The annual capital costs can be calculated given the initial price of the machines and the rates of depreciation and interest. Annual capital costs on an acreage basis will vary with the number of acres harvested. The number of acres it is possible to harvest in a season will depend on the work rate of the harvester, the length of the working day and the number of days on which harvesting takes place.

Repair costs also vary with the number of acres harvested by a machine in a particular year. Fuel and labour costs, however, will be the same for each acre harvested* but will change according to the size of the tractor and the number of men required by each machine.

Capital costs

The prices of the five types of harvester are shown below in Table 3. The one-row self-propelled tanker requires a tractor fixed into its framework and it has been assumed that a second-hand tractor would be suitable, costing £700. It has been assumed for the remainder of the harvesters that the tractors required would be available because of other farm operations, so that their capital costs have been excluded. This may or may not be true, depending on the particular circumstances of the individual farm.

TABLE 3

PRICES OF SUGAR BEET HARVESTERS

Machine	Description	Capital cost
A	5 or 6 row three-stage	£4,000
B	3 row two-stage	£2,400
C	1 row self-propelled tanker	£2,400 including £700 for tractor.
D	1 row tractor-drawn tanker	£1,000
E	1 row side-delivery-drawn harvester	£750

* A correction for slower rates of work as the season progresses is included in the timeliness costs.

ACREAGE HARVESTED

Harvester speed varies according to the type of machine and according to the month of operation. Some representative figures constructed from various sources[9] [10] are shown in Table 4.

TABLE 4

HARVESTER SPEED, ACRES PER HOUR

Machine	Month		
	October	November	December
A	1.50	1.30	1.00
B	1.00	0.66	0.66
C	0.50	0.40	0.40
D	0.45	0.33	0.33
E	0.45	0.33	0.33

The potential acreage it is possible to harvest on a given day has been calculated using the work rates shown in Table 4, together with the assumption that a working day is of nine hours during October, eight hours in November and seven hours in December. The resultant work rates on a daily basis can then be multiplied by the number of harvesting days in each month, shown in Table 5, to give the acreage it is possible to harvest in each month as depicted in Table 6.

TABLE 5

NUMBER OF HARVESTING DAYS

Month	Days in Month	Holiday and Weekend Days	Wet Days	Harvest Days
October	31	6	7	18
November	30	7	8	15
December	31	15 (including Christmas)	5	11

TABLE 6

ACRES HARVESTED PER MONTH BY DIFFERENT MACHINES

Machine	Acres per month				
	September*	October	November	December	TOTAL
A	61	244	160	84	600
B	40	160	80	51	330
C	20	80	48	30	178
D	18	72	40	24	146
E	18	72	40	24	146

*Assumes that harvesting begins on September 24th.

The operating costs for different acreages harvested are summarised in Table 7. The annual capital charge is worked out for two rates of interest, at 8% and 15%. Repair costs are taken from standards and fuel and labour costs are based on the number of tractors and men required, assuming a constant hourly charge of 12p per hour for a tractor and 50p per hour for a man.

(For Table 7, see page 9)

A most important difference between the five types of machine is the fact that the multi-stage harvesters waste less beet in the harvesting process and consequently have lower costs per acre than other machines. Autumn harvester demonstrations have shown that the three-stage harvester (machine A) can collect something of the order of one ton per acre more than machines C, D and E. Similarly, a two-stage harvester can save a half-ton of beet, as compared with the more conventional harvesters. The savings of field losses make a considerable difference to the total annual operating costs of the different harvesters, as illustrated in Table 7.

The effect of efficient utilisation of the harvester is clearly illustrated in Graph 2, where the annual operating costs are plotted against the acreage harvested. The effect on costs of savings in beet is also quite distinct on this graph, since correcting costs for the saving in beet makes machines A and B much more attractive; machine A being the cheapest machine available for more than 80 acres.

THE CHOICE OF HARVESTER

A more complete picture of the costs of harvesting can be gained by combining the operating costs calculated in Table 7 with the untimeliness costs depicted in Graph 1. A machine can only lift a certain amount of the crop at the optimum time so that every farmer is faced with the decision as to how to trade off the lower capital costs with the larger untimeliness costs as the acreage harvested by one machine is increased.

The method of estimating the untimeliness costs is best illustrated by an example. Assume that on medium land 90 acres of beet are to be harvested by machine type B. Thus, with an 18-week delivery schedule, five acres must be delivered every week. Up to the first week in November it is best to lift beet as required for immediate delivery,

TABLE 7

MACHINE OPERATING COSTS £/ACRE

	A						B					C					D				E		
Rate of work ac/hr.	1 . 3						0 . 7					0 . 45					0 . 35				0 . 35		
Acres to harvest.	50	80	100	150	200	400	50	80	100	150	200	50	80	100	150	200	50	80	100	150	50	80	100
Yearly hours usage.	38	62	77	115	154	308	71	114	143	214	286	111	178	222	333	444	143	228	286	429	143	228	286
Machine life Years.	10	10	10	7	6	5	10	8	7	6	5	8	7	6	5	4	8	6	5	4	7	6	5
Cost of Spares & Repair £/yr.	120	160	180	200	240	360	96	120	144	168	216	135	152	169	203	237	60	70	90	110	45	53	68
Extra beet saved £/acre.	6.60	6.60	6.60	6.60	6.60	6.60	3.80	3.80	3.80	3.80	3.80	-	-	-	-	-	-	-	-	-	-	-	-
Fuel & labour costs £/acre.	6 Tractors @ 12p/hr 6 Men @ 50p/hr						4 tractors @ 12p/hr 4 men @ 50p/hr					2 tractors @ 12p/hr 2 men @ 50p/hr					2 tractors @ 12p/hr 2 men @ 50p/hr				3 tractors @ 12p/hr 3 men @ 50p/hr		
	2.86	2.86	2.86	2.86	2.86	2.86	3.54	3.54	3.54	3.54	3.54	2.76	2.76	2.76	2.76	2.76	3.54	3.54	3.54	3.54	3.52	3.52	3.52
Annual Capital Charge @ 8% interest £/yr.	596	596	596	768	865	1004	357	417	460	518	602	417	460	518	602	712	174	216	251	306	144	162	189
Annual Capital Charge @ 15% interest £/yr.	800	800	800	960	1060	1196	480	501	540	596	673	501	540	596	673	780	223	265	299	356	180	198	225
Operating costs £/acre without beet saved @ 8%	17.26	12.31	10.62	9.31	8.38	6.27	12.60	10.25	9.58	8.11	7.63	13.90	10.41	9.63	8.12	7.50	8.22	7.12	6.95	6.33	9.12	8.01	7.89
@ 15%	21.26	14.86	12.66	10.59	9.36	6.75	15.06	11.32	10.38	8.64	8.00	15.50	11.41	10.41	8.59	7.84	9.20	7.74	7.43	6.64	9.94	8.46	8.25
with beet saved @ 8%	10.86	5.71	4.02	2.71	1.78	0	8.80	6.45	5.78	4.31	3.83	13.80	10.41	9.63	8.12	7.50	8.22	7.12	6.95	6.33	9.12	8.01	7.89
@ 15%	14.46	8.26	6.06	3.99	2.79	0.15	11.26	7.52	6.58	4.84	4.20	15.50	11.41	10.41	8.59	7.85	9.20	7.74	7.43	6.64	9.94	8.46	8.25

so that the untimeliness costs can be calculated directly from Graph 1 as shown below:-

Total untimeliness cost:	Acres	x	untimeliness cost	=	Total
September, week 1	5	x	£16	=	£80
October, week 1	5	x	£15	=	£75
October, week 2	5	x	£12	=	£60
October, week 3	5	x	£8.5	=	£42.5
October, week 4	5	x	£7	=	£35
November, week 1	5	x	£7.3	=	£36.5

After the first week in November, it is cheaper to lift as much beet as possible and store for later delivery, as shown by the dotted line in Graph 1. Thus, in November, week 2, it is possible with machine B to lift 20 acres (see Table 6) which will provide enough beet for delivery up until the end of the first week in December. Following the dotted line in Graph 1, the untimeliness costs for these weeks are, therefore, as follows:-

Total untimeliness cost:					
November, week 2	5	x	£7.50	=	£37.5
November, week 3	5	x	£9	=	£45
November, week 4	5	x	£10.5	=	£52.5
December, week 1	5	x	£12	=	£60

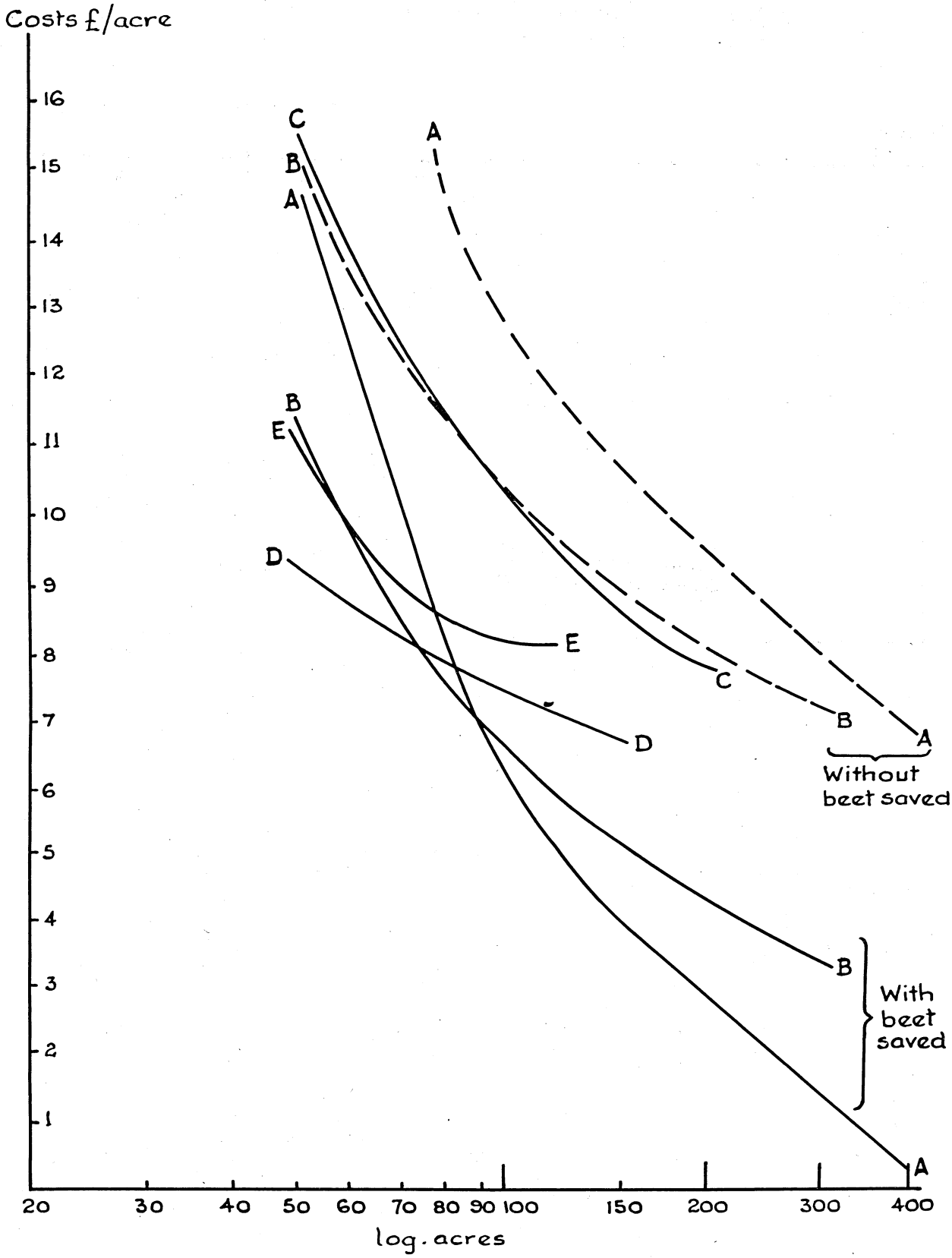
Similarly, the cheapest way to provide beet for delivery in the second week in December is to lift and store beet in the third week in November. After all this beet has been delivered, the cheapest source of beet is that lifted in the fourth week of November.

The total untimeliness cost for each acreage can be added together and the average untimeliness cost on an acreage basis deduced. The variation in the mean untimeliness costs per acre for the five types of machine on medium soil is drawn up in Graph 3 where it is clear that the larger machines, due to their greater speed, have lower untimeliness costs.

Combining the results shown in Graphs 2 and 3 produces Graph 4, which depicts the change in the sum of the untimeliness and operating costs for different acreages harvested.

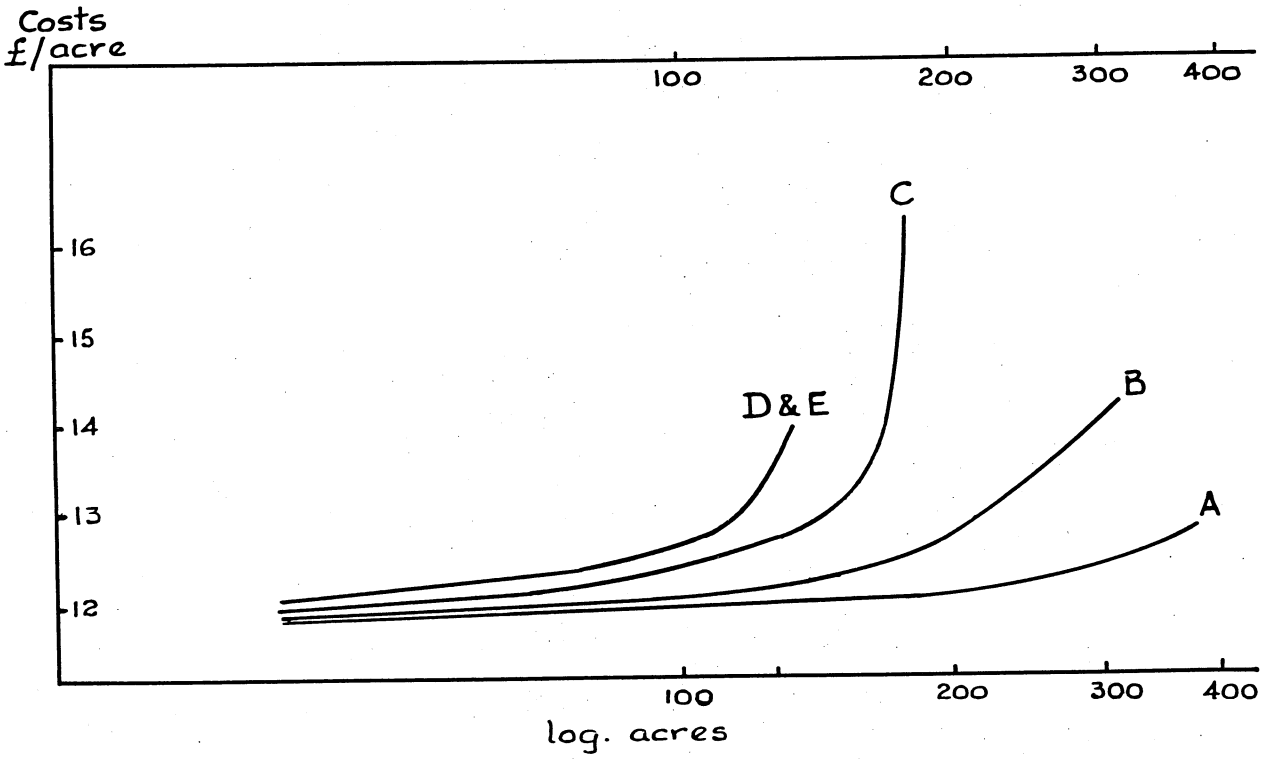
GRAPH 2

Operating Costs £/acre using interest rate at 15%.



GRAPH 3

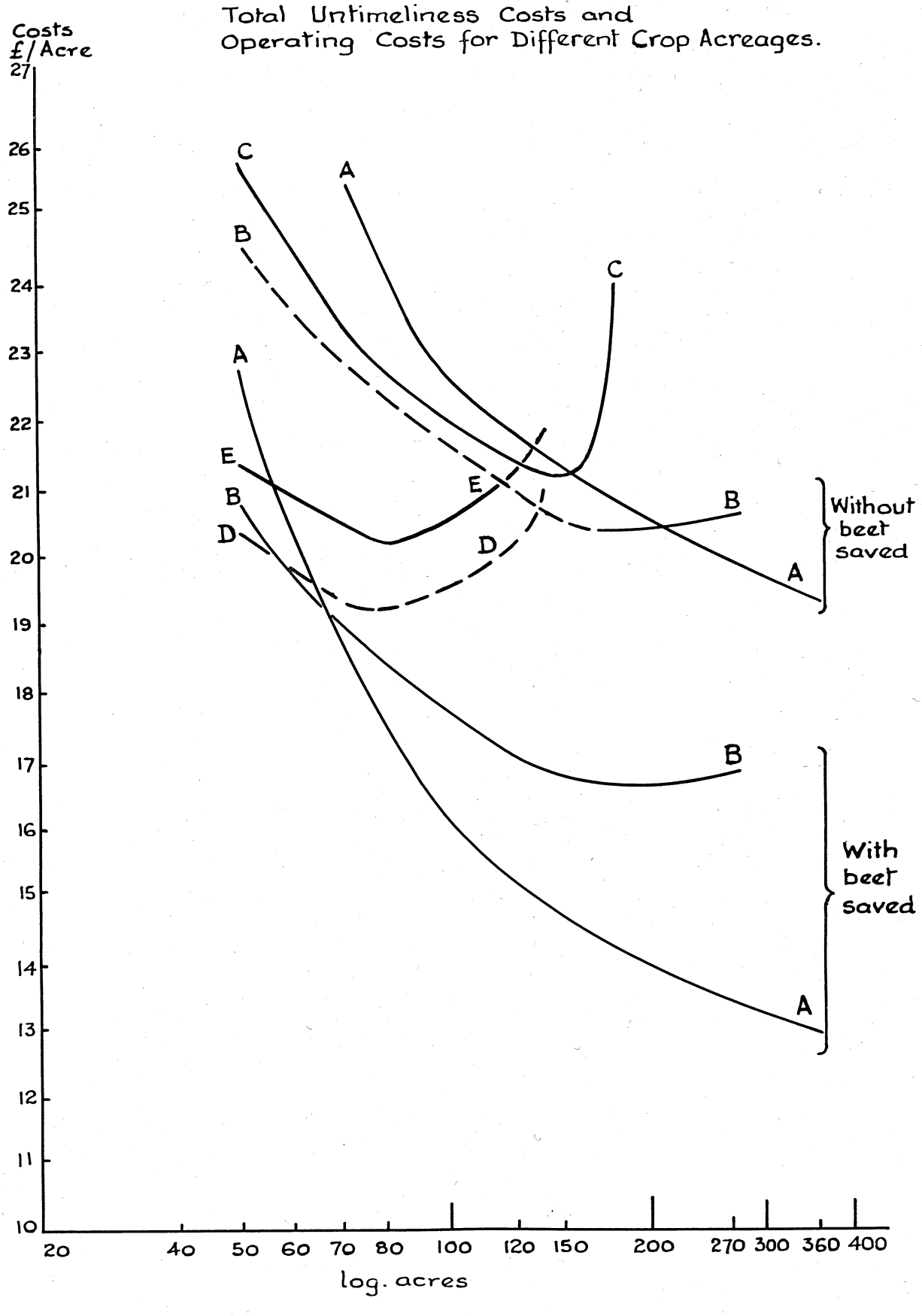
Crop Acreage vs Untimeliness Costs £/acre for each of the Harvesters on a Medium Soil.



GRAPH 4

A Medium Soil

Total Untimeliness Costs and Operating Costs for Different Crop Acreages.



CONCLUSIONS

It is clear from Graph 4 that the largest and most expensive machine, type A, the three-stage harvester, becomes the cheapest to operate at an acreage beyond 60-70 acres, when allowing for the greater efficiency of harvesting. The two-stage machine, B, seems to have a small cost advantage over the others between 55-65 acres, but below 50 acres the one row tanker, D, is the cheapest machine to use. The single row self-propelled tanker, C, is widely used on farms at present. It does have the advantage that it requires less man hours per acre than other machines and so at the time of year when labour is in great demand, may be a more sensible machine to use. C also has a higher daily capacity than D, so that in a wet year management of the harvest may be easier.

The multi-row harvesters have only recently been introduced into this country. If the costs included in Graph 4 are a correct representation of reality then it seems highly likely that they will be adopted very quickly. They have a high rate of work and they become the cheapest available system well within the range of their potential capacity. The multi-row harvester also makes fewer passes over fields, which should be beneficial from the point of view of soil structure. The only technical disadvantage with the large multi-row harvester, A, is that it picks up stones with the beet, which have to be picked off during loading. The other major drawback of multi-stage harvesters is the beet acreage required to justify their purchase and the large number of required supporting tractors and men. These difficulties can perhaps be easily overcome by group organisation of the sugar beet harvest. Indeed, the benefits of such an organisation are large, the cost of harvesting 70 acres of sugar beet with machine A being of the order of £19 per acre, whereas the cost of harvesting 200 acres is some £5 lower at £14 per acre. It would appear that even farmers currently growing relatively large acreages of sugar beet will gain by co-operation with their neighbours.

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