Sugar beets — Cost of production

University of Cambridge School of Agriculture

FARM ECONOMICS BRANCH

Mimeographed Report No. 63
(issued December, 1966)

SUGAR BEET PRODUCTION AND HARVESTING

A report on surveys of the 1965 crop in the Eastern Counties

by

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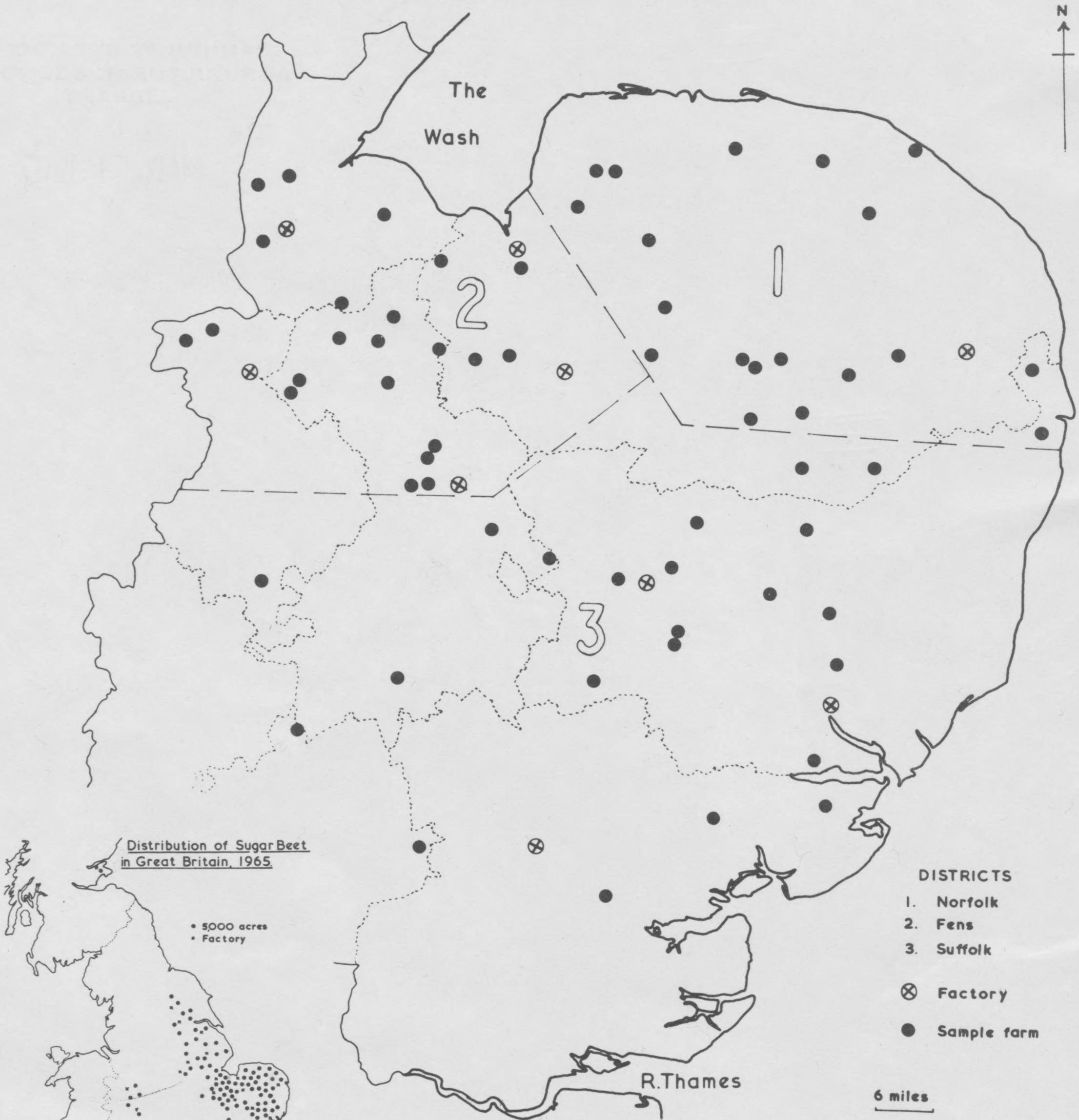

SUGAR BEET PRODUCTION AND HARVESTING, 1965

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Acknowledgements

The authors would like to thank the farmers who took part in the surveys, for their co-operation and help. The British Sugar Corporation, and farm machinery manufacturers, assisted in providing the sample of harvesters. Processing of the data was carried out by W. C. Housden, who also drew the diagrams.

Part I Output and Production Costs

Chapter 1

INTRODUCTION

This section of the report presents the results of an economic survey of the 1965 sugar beet crop in the Eastern Counties.[1] The total acreage of sugar beet in the region has risen in recent years to 290 thousand acres, just under two-thirds of the total in Great Britain. The

Sugar Beet Acreages 1965

	Acres	per cent of Great Britain
Eastern Counties	289,432	63.7
England and Wales	445,906	98.0
Great Britain	454,553	100.0

approximate distribution of this acreage is shown by the inset map on the frontispiece. As with most farm crops there are large numbers of small growers, but in this case they also account for an important proportion of the acreage. An estimate of the number of growers and beet acreage in different beet acreage size groups, is given in Table 1.1, which refers to the Eastern Counties only. It can be seen that in 1964 just over three-quarters of the growers had less than 20 acres each, and grew rather more than one quarter of the acreage. At the other end of the scale 6 per cent. of the growers accounted for 40 per cent. of the acreage. The present report differs from its predecessors in that the sample of growers was chosen on a random basis, which permitted the accuracy of the survey results to be calculated. Other points considered are the influence of the size of beet acreage on the results obtained and the effect on margins of a cut in the guaranteed price. A minor addition is in the figures for operational costs and labour requirements, where the tables show the average number of times each operation was performed.

1. Comprising the counties of Bedford, Cambridge (inc. the Isle of Ely), Essex, Hertford, Holland (Lincs.), Huntingdon (inc. the Soke of Peterborough), Norfolk and Suffolk.

Table 1.1 Sugar Beet Growers and Acreages,+ Eastern Region 1964

Acres of Sugar Beet per farm	Holdings No.	Holdings Per cent	Sugar Beet Acreage Th.acres	Sugar Beet Acreage Per cent
1 - 9¾	10,071	57.7	36.4	13.1
10 - 19¾	3,342	19.1	43.3	15.7
20 - 29¾	1,548	8.9	35.1	12.7
30 - 49¾	1,394	8.0	50.7	18.3
50 - 99¾	856	4.9	54.5	19.7
100 and over	253	1.4	56.6	20.5
Total Eastern Region	17,464	100.0	276.6	100.0

+Estimates based on data provided by the Ministry of Agriculture from the June 1962 and 1964 censuses.

The Survey Sample

To ensure a representative sample, about 70 growers were chosen on a random basis, with the probability of selection roughly proportional to beet acreage.[1] This meant that the sampling fractions were higher for large growers than for small, and to arrive at estimates of numbers of farms following particular practices, it was necessary to weight the results. On the other hand, per acre estimates could be obtained by a straight average of the per acre figures from each farm.

The sample size was chosen to allow for the loss of a few farms, and eventually completed records were obtained from 63 of the 65 farms growing beet in 1965. The distribution of the survey farms is shown on the map on the frontispiece. For the

1. To select the sample, holdings growing sugar beet were grouped into three strata, according to beet acreage:
   1 - 19.9 acres
   20 - 49.9 "
   50 and over "
   Within each stratum farms were selected systematically, the first one being chosen at random.

purpose of presenting the results the farms have been grouped into three districts, corresponding broadly to soil differences. For convenience the districts are referred to as Norfolk (light to medium soils), Suffolk (medium to heavy soils) and the Fens (peat and silt soils). The boundaries of the districts are shown on the map and it can be seen that "Suffolk" includes farms in Essex, Cambs and Hunts. The fact that district averages are shown separately does not necessarily mean that they differ significantly from one another. Significant differences are mentioned in the text.

Information on variable costs and beet sales was obtained for the whole of the beet acreage on each sample farm, a total of nearly 3 thousand acres of beet. Estimates of fixed costs were based on an operational record from one field on each farm, as described in Chapter 3. Beet acreages were recorded as the area of the beet fields, including bare headlands but not those drilled with another crop. Therefore the acreage recorded was sometimes slightly larger than the contract acreage. Drilling headlands with barley was common in Norfolk but less so elsewhere.

Table 1.2 gives details of the sample farms. It will be seen that most of the small growers are in the Fens. Although there was no necessary connection between beet, the amount of beet grown and the size of farm, in practice the correspondence was quite close. On average, sugar beet accounted for 13.5 per cent. of the arable land, and there was little difference between districts or size groups, except for small growers, where it was only 9.2 per cent.

Weather conditions for the 1965 beet crop were unusually wet. The relatively little sunshine during the summer resulted in low sugar percentages although yields of roots were good. Towards the end of the harvesting season a period of continuous wet weather made lifting conditions very difficult, and a small amount of beet had to be left in the ground, although on the survey farms the acreage lost was negligible. Weather conditions are described in more detail in Appendix A.

Table 1.2 The Survey Sample

Beet acreage size group	District			
	Norfolk	Suffolk	Fens	All districts
	Number of farms in the sample			
1 - 19.9	4	4	10	18
20 - 50	6	9	5	20
Over 50	9	9	7	25
Total	19	22	22	63
	Beet acreage on farms in the sample			
1 - 19.9	36.3	37.0	53.0	126.3
20 - 50	228.0	282.9	162.5	673.4
Over 50	713.7	889.0	528.5	2131.2
Total	978.0	1208.9	744.0	2930.9
Average per farm				
No. of beet fields	3.4	3.4	3.3	3.3
Beet acreage	51.5	55.0	33.8	46.5

Husbandry Methods

Estimates of the frequency of occurrence of some cultivation practices are given in Table 1.3, for both numbers of farms and beet acreage. The confidence limits are a guide to the accuracy of the estimates,[1] and it is obvious that the figures for acreage proportions are much more reliable than those for numbers of growers. This is not surprising as the sampling method was designed to achieve this result.

From Table 1.3 it can be seen that on average about 40 per cent. of the beet acreage was dressed with salt or kainit, but this figure conceals variation between districts. (It was not possible to draw the sample according to district, only size

1. i.e. one can be 95 per cent. certain that the true value lies within the limits shown. In other sections of the report the accuracy of estimates of average (mean) values is often shown by quoting the standard error alongside the mean. The 95 per cent. confidence limits are about twice the standard error on either side of the mean.

Table 1.3 Crop Husbandry Methods

	Number of farms		Percentages of farms Beet acreage	
	Average	95% confidence limits	Average	95% confidence limits
FYM application*	25	10 - 40	22	20 - 24
Salt or kainit application *	26	10 - 42	40	37 - 43
"Monogerm" seed (mainly Triplex)	17	4 - 30	11	9 - 12
Precision drilling	63	42 - 100	76	73 - 79
Band spraying	15	3 - 28	33	31 - 35
Thinning: hand only	98	82 - 100	93	90 - 96
machine & hand finishing	2	0 - 4	7	6 - 8
Harvesting:ǂ side-delivery	79	58 - 100	77	74 - 80
Tanker	6	2 - 10	21	20 - 22
Cleaner-loader	23	10 - 36	50	47 - 53
Beet acreage lifted	x	x	100	97 - 100

* Estimates of numbers of farms include those where only part of the acreage was dressed.

ǂ The figures for the two types of harvester do not add to 100 because a few farms used other methods. e.g. squeezer-lifters.

groups, and it is therefore difficult to calculate satisfactory estimates of this kind for each district). Some idea of these differences is given by the fact that all but one of the farms in the Norfolk district applied salt or kainit, more than half the Suffolk farms, but only two in the Fens.

Very little true genetic monogerm seed was used, but about 10 per cent. of the acreage was sown with seed of the Triplex type, which gives a high proportion of single plants. This type of seed was mainly found in the larger beet acreages, but there were no marked differences between districts. Band spraying was also concentrated on the larger acreages; the heavier rate of application needed on soils of high organic content reduced its use in the Fens, where there was a high proportion of small growers. Down-the-row thinning is still very much the exception, and only four of the sample farms used this method, too few to justify comments on the yields obtained. Tanker harvesters were mainly found on the larger acreages, while a few of the smallest growers used squeezer-lifters. Half the survey tonnage of beet was put through a cleaner-loader, sometimes supplied by the haulage contractor.

Some further details of seed and fertiliser practice, and the use made of contractors' services, are shown in the first two tables of Appendix B. Sharp's Klein E variety accounted for more than half the total acreage surveyed, and was particularly popular in the Suffolk district, but much less so in the Fens. Conversely Hilleshog N, the second overall favourite, was hardly grown in Suffolk. Average fertiliser application was 114 units per acre of nitrogen, 81 units of phosphate, and 148 units of potash (including that in Kainit).

<u>Future intentions</u>

The survey included questions on farmers' future intentions. Firstly, growers were asked how much beet they would grow if contracts were freely available i.e. the maximum acreage possible. Secondly, they were asked what acreage they actually expected to be growing in the immediate future. The estimates resulting are summarised in Table 1.4.

The first section shows the 1965 beet acreage in the Eastern Region (obtained from the Agricultural Returns) with an estimated breakdown into size groups based on the proportions found on the survey farms. The average beet acreage per (survey) farm is also given. The second section of Table 1.4 shows the estimated beet acreage which farmers would like to grow if the contracts were available, and also the average per farm. The greatest proportional difference between present and maximum acreages is shown by the small growers, which is consistent with their relatively low proportion of sugar beet in the arable acreage, referred to earlier. In total the survey indicated that growers in the region would like to increase their acreage by about 46 thousand acres, or 16 per cent.

Table 1.4 Future Intentions

Beet acreage size group	Small 1-19.9 acres	Medium 20-50 acres	Large Over 50 acres	Total
Present beet acreage (th.acres)	12.4	66.6	210.4	289.4
Average per farm(acres)	7.0	33.6	85.2	x
Maximum beet acreage (th.acres)	16.6	74.8	244.3	335.7
Average per farm(acres)	9.4	37.9	98.7	x
Average expected beet acreage per farm(acres)	7.3	34.2	88.6	x

The third section of the Table shows the average acreage per farm which farmers in the survey expected to be growing in the immediate future, and in all cases there is a slight increase over the present acreage. The corresponding total acreages are not shown because these figures included some amalgamations of existing contract acreages and therefore involved double counting (i.e. the regional total appeared to exceed the total contract acreage available).

Chapter 2

YIELDS, RETURNS AND GROSS MARGINS

Yield per acre is one of the main determinants of profitability, particularly the yield of sugar. This may be obtained through a large tonnage of roots, but to economise on harvesting and transport it is preferable to have a high sugar percentage rather than a large weight of roots. Average yields and sugar contents in each district are given in Table 2.1., together with their standard errors, which are a measure of the accuracy of estimation of the average.

A further indication of the spread of yields is given by the frequency distributions for yields of sugar and roots, included in Table 2.1. Although the Table shows numbers of farms, from the way the sample was drawn the figures should be taken as referring to the proportion of the beet acreage rather than the relative numbers of growers.[1] This also applies to other frequency distributions given in the report.

According to Table 2.1, the average sugar yield per acre was just over 49 cwts. With a standard error of 1.04, we can be 95 per cent. certain that the true average lies between 47 and 51 cwts. per acre i.e. the limits are twice the standard error on either side of the average.

District averages suggest that Norfolk was about five cwts. per acre lower than the others, but in fact statistical tests showed that only the Norfolk/Fens difference was significant (i.e. a real difference, not one caused merely by sampling error variation). This apparently odd result is explained by the greater variation in sugar yields within the Suffolk district, which makes the estimate of the average correspondingly less reliable.[2]

1. As the sample was drawn according to acreage, relatively few small growers were included.
2. In the present survey the districts were distinguished only as a general guide to local conditions. If equally reliable estimates of district averages were required, these results indicate that the sample in the Suffolk district should be increased relative to the others.

Table 2.1. Yields

District	Norfolk	Suffolk	Fens	Averages All districts
Sugar yield, cwts. per acre S.E.*	45.8 (1.59)	50.8 (2.15)	50.5 (1.41)	49.2 (1.04)
Clean beet, tons per acre + S.E.	14.4 (0.50)	15.8 (0.65)	16.8 (0.43)	15.7 (0.33)
Sugar percentage S.E.	15.9 (0.08)	16.1 (0.08)	14.9 (0.20)	15.6 (0.09)
Dirt tare, lb. per cwt. S.E.	13.9 (0.27)	15.1 (0.57)	16.4 (0.97)	15.2 (0.47)
No. of farms	19	22	22	63

* Standard error (see text).

\+ The yield of dirty beet can be calculated from:

$$\text{yield of dirty beet} = \frac{112 \times \text{yield of clean beet}}{112 - \text{dirt tare}}$$

Distribution of yields of sugar per acre

				Number of farms
60 - 69 cwts.	-	4	2	6
50 - 59 "	6	8	10	24
40 - 49 "	10	6	8	24
30 - 39 "	3	4	2	9

Distribution of yields of clean beet per acre

20.0 tons & over	-	2	1	3
17.5 - 19.9	1	4	7	12
15.0 - 17.4	6	7	12	25
12.5 - 14.9	9	5	1	14
Below 12.5	3	4	1	8

The average yield of roots in Norfolk was also lower than in the Fens, but not significantly different from that in Suffolk. On the other hand the Fens had a lower sugar percentage than the other two districts. The highest individual sugar yields in the sample were on Suffolk farms. Of the four farms there with over 60 cwts. of sugar per acre, (see the frequency distribution, Table 2.1) three reached just over 65 cwts. per acre, about five cwts. above the highest Fen yield. The general conclusion from these results is that although the Fens are generally credited with the highest crop yields in the Eastern Counties, in this particular year the evidence is that they did no better than Suffolk. In a drier year however, the Fens might have achieved a better relative position.

By comparison with most recent years 1965 can be regarded as an unusually favourable year for sugar beet yields, although the lack of sun kept sugar percentages rather low. This should be kept in mind when considering the figures for beet sales, and margins over costs, given in the remainder of the report.

Differences in yields and sugar percentages according to the size of the beet acreage are referred to later in the chapter.

Sales of beet

The gross return per acre from sugar beet corresponds very closely to the weight of sugar, but because the payment per ton of beet varies according to the sugar percentage, the correspondence is not exact. For the 1965 crop the guaranteed price was 130s.6d per ton of clean beet and 16 per cent sugar, plus or minus 10s. per ton for each 1 per cent of sugar above or below 16.[1] In addition there are early and late delivery bonuses.[2]

1. There is also an industry levy of 3d per ton of clean beet, for research and education, and a deduction of 1½d per ton, paid to the National Farmers' Union to cover the cost of growers' representatives at the sugar factories.
2. Details of bonuses are as follows:

For deliveries before 24th September	12/6 per ton
For deliveries between 24th & 30th Sept.	7/6 per ton
For deliveries between 1st & 7th Jan.	3/9 per ton
For deliveries between 8th & 14th Jan.	5/- per ton
For deliveries between 15th & 21st Jan.	7/6 per ton
For deliveries between 22nd & 28th Jan.	10/- per ton
For deliveries on 29th January or after	12/6 per ton

Average returns per acre from beet sales are included in Table 2.2, together with standard errors. It is not surprising that differences between districts follow a pattern similar to that for sugar yields, as already discussed. The output figures do not include any allowance for the value of beet tops, but an estimate of their value is given separately. The method of estimation is described in Appendix C.

Table 2.2 Gross margins

Averages per acre

District	Norfolk	Suffolk	Fens	All districts
	£	£	£	£
Seed	2.4	2.9	2.9	2.7
Fertiliser*	7.3	7.5	7.8	7.5
Sprays	1.6	1.3	0.9	1.3
Piece-work labour+	8.3	10.2	7.0	8.5
Contract haulage	3.4	4.8	5.4	4.6
Other contract	1.6	2.1	4.4	2.8
Total variable costs	24.6	28.8	28.4	27.4
GROSS MARGIN	69.3	75.9	74.8	73.5
S.E.	(3.9)	(4.5)	(3.2)	(2.2)
Beet sales	93.9	104.7	103.2	100.9
S.E.	(3.3)	(4.5)	(3.2)	(2.2)
Value of tops	2.6	2.3	2.1	2.3

* Excludes FYM, adjusted for residues

\+ Including regular labour on piece-work.

Distribution of gross margins per acre

Number of farms

£100 and over	-	3	1	4
90	2	1	2	5
80	4	6	5	15
70	2	2	7	11
60	6	7	4	17
50	3	1	2	6
Below 50	2	2	1	5

Gross Margins

Average variable costs and gross margins are also shown in Table 2.2. Variable costs are those which vary directly with the size of the enterprise, and for sugar beet they are the costs itemised in Table 2.2. Regular labour for chopping-out and singling has been included in variable costs if paid on a piece-work basis (as is usual). The result was to reduce the amount of variation between farms, and obtain a more realistic average figure for "casual" labour. The gross margin represents the contribution made by the sugar beet towards paying the fixed costs of the farm.[1] For farm management purposes this criterion of profitability has a number of advantages, since it does not involve allocating fixed costs irrespective of the opportunity costs involved.

The average gross margin for Norfolk district is about £6 lower than the other two districts but in fact no significant differences were found. This is a reflection of the wide spread of gross margins in all districts, as shown in Table 2.2. Variation in gross margins in different beet acreage size groups is mentioned below.

Margin over materials costs

The average gross margins shown in Table 2.2 allow for piece-work labour and contract work because these are costs which can be expected to vary in proportion to the beet acreage. While this approach is realistic for an individual farm, it tends to confuse comparisons between farms, by combining together farms using different systems, and situated at varying distances from the factories. Thus the costs of piece-work labour and contract work are the average over all farms, even though some did not make use of these services. The average figures for thinning costs, are fairly representative because they include regular labour working

1. Fixed or common costs are regular labour, machinery, rent and overheads such as office expenses. These costs do not vary directly with size of a particular enterprise, and in the short run may be considered fixed. However, if for example a farm made a substantial change in the beet acreage these costs might well change also.

on a piece-work basis, but contract haulage costs are only about half the cost on those farms using a contract haulier.

To avoid these difficulties and to help make the survey averages more useful for comparison with individual farm results, Table 2.3 shows the average margins over cost of materials, and standardised gross margins, calculated on the assumption that piece-work labour was used for thinning, and contract haulage for transport to the factory. The spray costs shown are for insecticides and are the average for those farms which actually sprayed. (A proportion of the cost of contract spraying has been included, to cover the cost of materials). Similarly the cost for thinning labour and haulage are the averages for those using these methods.

The average margin over materials for Norfolk is about £10 below the other two districts, but as in the case of beet sales, only Norfolk and the Fens differed significantly. Here again the reason for the apparently odd result is the greater variation in results within the Suffolk district.

Table 2.3 Margins over materials costs, and standardised gross margins

Averages per acre

District	Norfolk	Suffolk	Fens	All districts
	£	£	£	£
Seed	2.4	2.9	2.9	2.7
Fertiliser *	7.3	7.5	7.8	7.5
Sprays +	2.2	2.3	1.4	2.0
Total materials	11.9	12.7	12.1	12.2
MARGIN OVER MATERIALS COST	82.0	92.0	91.1	88.7
S.E.	(3.3)	(4.6)	(2.9)	(2.2)
Piece-work labour (thinning)	9.3	11.2	10.6	10.5
Contract haulage	10.7	9.7	10.0	10.1
STANDARDISED GROSS MARGIN	62.0	71.1	70.5	68.1
Beet sales	93.9	104.7	103.2	100.9

* Adjusted for residues

\+ Including an allowance for the materials applied by contractors.

Size of beet acreage

With the relatively few significant differences between districts in the yields and margins described above, it is of interest to compare the results from beet acreages of different sizes. For this purpose the three size groups shown in Table 1.2 have been used, and are referred to as small, medium and large. Table 2.4 shows the means and standard errors for sugar yield, beet sales, gross margin and margin over materials costs, in each of the three beet acreage size groups. Overall figures are also included.

Table 2.4 Output, gross margins and size of beet acreage

Averages per acre

Beet acreage size group	Small 1-19.9 acres	Medium 20-50 acres	Large Over 50 acres	Total
Sugar yield, cwt.	47.4	52.0	47.7	49.2
S.E.	(2.21)	(1.56)	(1.57)	(1.04)
Total returns £	98.5	107.3	98.2	101.2
S.E.	(5.0)	(3.2)	(3.3)	(2.2)
Gross margin £	65.7	81.8	73.3	73.8
S.E.	(5.2)	(3.7)	(2.4)	(2.2)
Margin over materials £	85.9	95.1	87.3	89.0
S.E.	(5.2)	(3.4)	(3.0)	(2.2)
No. of farms	18	20	25	63

In all the cases shown, the medium acreages appear to do best, but in fact the only difference found to be significant was that between the gross margins on small and medium acreages. Thus there is little evidence from this survey that output and variable costs are related to size of enterprise. However, when fixed costs are taken into account the situation changes, as described in the next chapter.

Contract rates

Table 2.5 shows some representative charges for contract work applicable to the beet crop, and the usual rates per acre for thinning. As precision drilling was the usual method, the figures for singling after an ordinary drill are based on fewer values. With precision drilling, the minimum and maximum figures for chopping-out and singling are also given. As stated, the lowest cost was for a field of monogerm beet, and only required the removal of every other beet plant, in a single operation needing 11 man-hours per acre. An inclusive rate for chopping-out, singling and second hoeing was common in the Fens, and the costs shown are based mainly on that district.

Table 2.5 Representative contract charges and piece-work rates

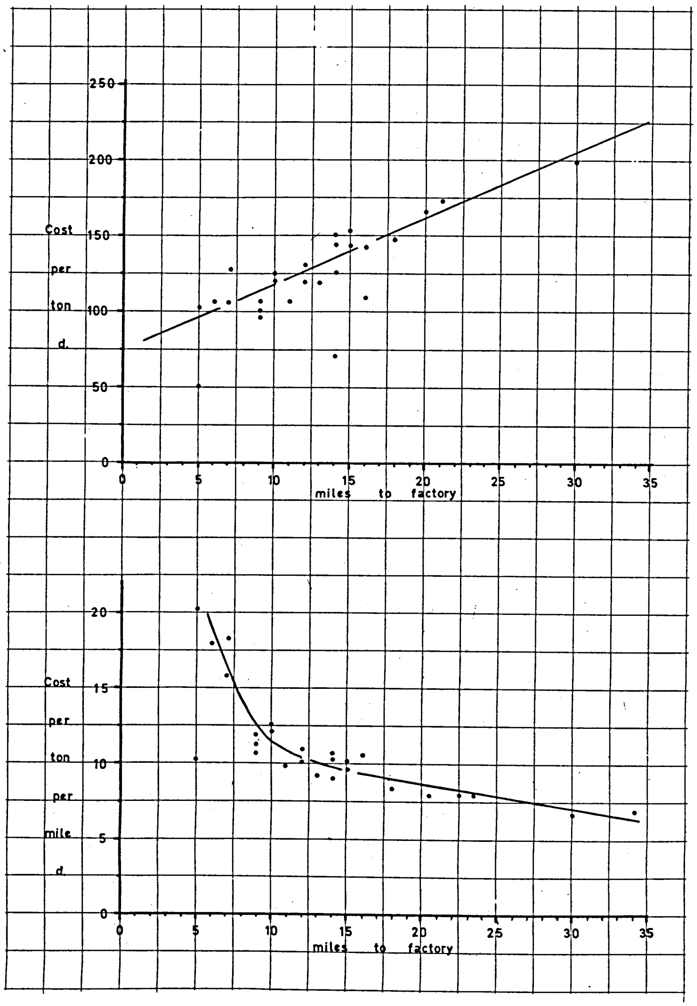
Spreading kainit (inc. materials)	£2.10s - £3.10s per acre (5 - 7 cwts. per acre)	
Haulage to factory (lorry & driver)	9d to 1s per ton-mile dirty beet (miles farm to factory) for hire of cleaner-loader (where available) add at least 1s per ton dirty beet.	
Thinning		
	after precision drill	after ordinary drill
excluding second hoeing	£7 - £10 per acre Minimum £4.5s (monogerm) Maximum £15.0s	£9.15s - £12.0s per acre
including second hoeing	£12 - £13 per acre	Insufficient data

The charge for contract spreading of kainit might be expected to vary according to the amount applied per acre, but the figures did not show a relationship of this kind. Therefore the range of costs shown does not necessarily correspond with the range in rates of application.

Contract haulage charges per ton vary according to the distance from the factory (among other things). Figure 2.1(a) shows cost per ton plotted against miles from factory, and it can be seen that on average the cost increases by nearly 4½d per mile from an initial 6s.3d per ton, which represents the loading charge. Although cost per ton increases, as shown in

Figure 2.1(b), where the curve has been fitted by eye. However, for the majority of farms, situated about 10 to 15 miles from a factory, a cost of 9d to 1s per ton-mile is representative.

Figure 2.1. Contract haulage



Chapter 3

PRODUCTION COSTS

Variable costs are relatively easy to allocate to particular farm enterprises, but normally they form well under half of total farm costs. It is therefore important to consider the use made by an enterprise of the resources included under the heading of "fixed costs" (i.e. those which do not vary directly with the size of the enterprise). Sugar beet for example, normally requires more labour and machinery time than cereals. To obtain data on labour and machinery use, a record was taken of the operations on one beet field on each farm. The field was chosen with probability proportional to acreage, following the principle used in selecting the sample as a whole. In a few individual cases the particular field chosen gave a rather untypical picture of resource-use on the beet crop as a whole, but the method is a practicable way of estimating average fixed costs without bringing in subjective judgements as to what is an average field. Ideally an operational record for every field should be taken, but with large acreages this is usually impracticable.

The figures for man and machine hours per acre were translated into money terms by charging for labour time at the hourly rate paid, and for non-specialised machinery and implements at standard costs per acre or per hour. Specialised machines such as harvesters were costed individually. Rent was charged at the actual amount paid per acre, or at the local market value, in the case of an owner-occupier.

Costs of liming and slagging were calculated separately from ordinary fertilisers and included in fixed costs. This procedure helps to make inter-farm comparisons more meaningful, although overall the cost per acre is not important. An addition to cover unallocated expenses must also be made, the object being to make the total costs of individual enterprises add to the farm total. Further details of the costing method used are given in Appendix C.

The results of these calculations for the survey farms are given in Table 3.1, and show an average total cost of about £70 per acre, and £28 per ton of sugar, with net margins of £30 and £12 respectively. These estimates require even more care in their interpretation than variable costs and gross margins. For example, however accurate the record of labour and machinery use on a field, the translation of the physical units into money terms produces results with some inherent shortcomings. This is because in the short run most of these costs would be incurred irrespective of what happened to the beet. The same is true of other fixed costs. Net margins are therefore not very useful for farm management purposes, since a negative net margin does not necessarily mean that the farm should cease to grow sugar beet. On the other hand, estimates of total costs do provide an indication of the share of the fixed costs chargeable to the beet crop, and as such the average figures are a guide to the profitability of the crop regionally or nationally. Similarly, total costs are a guide to a suitable contract price for growing beet, if this is necessary.

Average cost structures for individual districts are shown in the Appendix, Table B.3, but there were no significant differences between total costs or net margins.

Size of beet acreage

Average total costs and net margins for each of the usual three size groups are shown in Table 3.2. Beet sales are also included for comparison. Statistical tests showed that total costs on large acreages were significantly lower than on small or medium acreages. Conversely, net margins on small acreages were significantly lower than on medium or large. Net margins on medium acreages did not differ from those on large (in spite of cost differences) because of the compensating effect of higher beet sales.

Costs of the smaller growers are inflated to the extent that they often include a charge for the farmer's own labour, even when there was little other productive work to be done. Nevertheless a similar situation can also occur with paid labour on larger farms and from the national point of view this concealed underemployment is a real cost.

Table 3.1 Cost structure and net margin

	Averages for all districts £ per acre	£ per ton of sugar
Seed	2.7	1.1
Fertiliser*	7.5	3.0
Sprays	1.3	0.5
Casual labour+	8.5	3.5
Contract haulage	4.6	1.9
Other contract	2.8	1.1
Total variable costs	27.4	11.1
Regular labour	12.1	4.9
Tractors	6.7	2.7
Machinery	6.2	2.5
FYM, lime, slag	1.6	0.7
Rent and drainage rate	7.3	3.0
General overheads, 15%	9.2	3.7
Total fixed costs	43.1	17.5
(a) Total costs	70.5	28.6
S.E.	(1.89)	(0.91)
(b) Beet sales	100.9	41.0
S.E.	(2.2)	(0.19)
Net margin (b) - (a)	30.4	12.4
S.E.	(2.27)	(0.79)

* Adjusted for residues

\+ Including regular labour on piece-work.

Distribution of net margins per acre

	Number of farms		
£50 and over per acre	7	£20 & over per ton	6
40 - 49	13	15 - 19	20
30 - 39	14	10 - 14	18
20 - 29	14	5 - 9	11
10 - 19	8	0 - 4	5
0 - 9	4	Negative	3
Negative	3		

Table 3.2 Costs and net margins, by size of beet acreage

Averages

Beet acreage size group	Small	Medium	Large	Total
Total costs	79.7	71.5	63.3	70.5
S.E.	(3.65)	(2.81)	(2.61)	(1.89)
Net margin	17.8	35.8	34.9	30.4
S.E.	(4.71)	(3.80)	(2.41)	(2.27)
Beet sales	97.5	107.3	98.2	100.9
S.E.	(4.8)	(3.2)	(3.3)	(2.2)

Operational costs

An alternative way of looking at production costs is to consider the cost of each operation in turn. Here again the figures arrived at are not usually very useful for management purposes on a particular farm, but they give an indication of the distribution of resource use over the production period. Average costs for farms in the survey are shown in Table 3.3. Two methods of presentation are used, the first giving the average costs for those farms carrying out the operation, and the average number of times it was carried out. Figures for operations not typical are bracketed and are not included in the totals. (Typical means half or more of the farms). The second method lists the overall average costs for each operation, again with the average number of times. The total costs are very similar in the two methods. Materials costs, rent and an allowance for general overheads have been included, although these are not strictly operations. Overall average figures for individual districts are shown in Appendix B, Table B.5.

Effect of a cut in the guaranteed price

Although there is no indication that the government is thinking of reducing the guaranteed price for sugar beet, with the free market price of raw sugar down (at the time of writing) to a post war low of £14 per ton, c.i.f. London, this possibility cannot be entirely excluded. It is therefore of interest to consider how production costs compare with prices per ton.

Table 3.3 Operational costs

	All districts			
	Averages for farms reporting		Overall averages	
	£	No.of times	£	No.of times
Stubble cultivations	(1.2)	2.1	0.5	0.9
FYM application	(4.0)	1.0	1.8	0.4
Salt or kainit & application	(2.6)	1.0	1.0	0.4
Ploughing	1.6	1.1	1.6	1.1
Seedbed cultivations	1.5	4.1	1.5	4.0
Fertiliser*	7.3	1.2	7.3	1.2
Applying fertiliser	0.6	1.2	0.6	1.2
Seed	2.7	1.0	2.7	1.0
Drilling	1.2	1.0	1.2	1.0
Rolling	(0.2)	1.0	0.1	0.3
Hand thinning	8.3	1.0	7.9	1.0
Machine thinning	(1.7)	2.0	0.1	0.1
Tractor hoeing	2.6	3.5	2.6	3.4
Hand hoeing	4.6	1.1	2.7	0.8
Spraying	2.2	1.1	1.6	0.7
Pre-harvest total	32.6	x	33.2	x
Harvesting	12.6	1.0	12.6	1.0
Transport (inc.loading)	8.2	1.0	8.2	1.0
Rent & drainage rate	7.3	1.0	7.3	1.0
General overheads	9.2	1.0	9.2	1.0
Total costs	69.9	x	70.5	x

* Excluding salt & kainit; adjusted for residues.

At present the guaranteed price for sugar beet in Britain is 130s.6d per ton of washed beet at 16.0 per cent sugar. This is equivalent to a price of £40.15s.6d per ton of sugar to which must be added processing costs. For comparison, cane sugar producers included in the Commonwealth Sugar Agreement receive a negotiated price of £43.10s. per ton of raw sugar, f.o.b., plus various minor special payments for particular countries.

Although quantities traded on the world free market have been relatively small (a factor contributing to the wide fluctuations in price in recent years) the new plantings made as a result of the high 1963 prices, have yet to make their full impact on supplies. Therefore unless there is an effective international regulation agreement it seems likely that free market raw sugar prices will continue at a level well below £40 per ton.

For comparison with sugar prices the costs shown in previous Tables in the report must be expressed on a per ton basis, and this has been included in Table 3.1. The sub-total for materials alone is £4.6 per ton of sugar, but allowing for spray materials applied by contractors (as in Table 2.3) the figure is £5.1 per ton. Similarly the average variable costs in Table 3.1 include some contract work on a proportion of the farms only. Assuming average materials costs (£5.1), piece-work labour for thinning, and contract haulage, total "standardised" variable costs are £13.5 per ton. Total costs average £28.6 per ton. These figures are summarised in Table 3.4, together with the price per ton of washed beet which would be required to offset these costs exactly. To assist comparison with the existing price the figures assume a sugar content of 16 per cent, so that only 15.3 tons of washed beet are needed to produce 49 cwts. of sugar per acre (compared with 15.7 tons at 15.6 per cent sugar, on the survey farms). The average returns of £41.0 per ton of sugar, shown in Table 3.1, differ from the quoted price of £40.78 per ton because of the bonuses and deductions for sugar percentage and delivery dates.

Table 3.4 Summary of average costs per ton of sugar and beet

	Cost per ton of sugar £	Equivalent price for washed beet £ per ton	Sh. per ton
Actual materials costs	4.6	0.75	15s. 0d
Materials costs inc. contract spray materials	5.1	0.83	16s. 7d
Actual variable costs	11.1	1.79	35s.10d
"Standardised" variable costs	13.5	2.18	43s. 7d
Total costs	28.6	4.61	89s. 3d
Existing price		6.525	130s. 6d

From Table 3.4 it can be calculated that on average materials costs account for about 12 per cent of the standard price per ton, and actual variable costs about 27 per cent. "Standardised" variable costs are a third of the price, and total costs nearly 70 per cent. The remaining 30 per cent has to cover interest on working capital, as well as profit.

These figures show that in 1965, a good year for beet, the average producer was more than covering costs, but the average conceals the way in which profitability varies on different farms. An indication of this is given in the frequency distribution of margins included in Table 3.1. As mentioned before, from the way the sample was drawn the numbers of farms should be regarded as showing the proportion of the beet acreage being grown at different levels of profitability, rather than the number of growers operating at these levels.

The effect of a price cut on the spread of gross and net margins per acre is shown in Table 3.5. Distributions are given for three hypothetical lower beet prices, and that for the existing price is included for comparison (labelled 130s per ton). The margins resulting from the lower prices were obtained by reducing the total returns in proportion to the new price, and holding costs constant.

Table 3.5 Effect of lower beet prices on gross and net margins

Number of farms

Gross margin £ per acre	Sugar beet price, sh. per ton				Net margin £ per acre	Sugar beet price, sh. per ton			
	130s	120s	110s	100s		130s	120s	110s	100s
90 & over	9	4	4	-	50 & over	7	4	1	-
70 -	26	22	8	5	30	26	18	10	5
50 -	23	27	30	26	10	23	28	30	24
30 -	5	8	19	28	-9	5	11	16	24
below 30	-	2	2	4	below 10	2	2	6	10
Av.£ per acre	73.5	65.8	58.0	50.2	Av.£ per ac.	30.4	22.6	14.8	7.1

Each cut in the beet price results in the average gross and net margins falling by about £8 per acre, and the effect on net margins is proportionately greater, particularly for the smaller growers. This is illustrated in Table 3.6, which shows the proportion of sample farms with a negative net margin in each size group, for the four beet prices considered.

It cannot be said that growers making a negative gross margin will or should give up sugar beet, although on a regional basis the numbers in this situation might be a guide to the contract acreage allowed to lapse. However, as in most areas there is a waiting list for contracts the total acreage would probably be maintained, although at lower beet prices the waiting list might shrink considerably.

Table 3.6 Effect of lower beet prices, by size of beet acreage

Percentage of farms with negative net margin

Beet acreage size group	Beet price, sh. per ton washed beet 130s	120s	110s	100s
Small	17	28	44	61
Medium	0	5	10	25
Large	0	0	4	12
Total	5	10	16	29

Chapter 4

LABOUR REQUIREMENTS

The data collected on the survey enabled labour and tractor requirements for different seasons and operations to be calculated. The average figures for each operation are shown in Table 4.1, and are based on the number of farms carrying out the particular operation. (Work done by contractors is excluded). Figures for operations not typical are bracketed and not included in the totals. Similar figures for individual districts are given in Appendix B, Table B.6. In all these tables the averages for hand thinning and hand hoeing are based on information from farms which were able to make a good estimate of the time required. As most of this work is paid for on a per-acre basis, it was often difficult to ascertain the hours per acre.

It is of interest to compare these figures with the labour requirements found in the sugar beet surveys of 1961 and 1962.[1] In those years labour for thinning and hand-hoeing together averaged about 41 man-hours per acre, whereas in the present survey the total is 36 man-hours. The improvement in efficiency is presumably related to the greater use of precision drills (and band spraying). Half the farms in the earlier surveys used a precision drill, compared with an estimate of over 60 per cent in 1965. Harvesting labour efficiency remained exactly the same as in 1962 (although higher than 1961), at 1.34 man-hours per ton of dirty beet. Average dirt tares were very similar in the two years.

The average gang size for machine harvesting was 2.9 men, which with an 8-hour day and 17 man-hours per acre, is equivalent to a harvesting rate of 1.36 acres per day $\frac{(8 \times 2.9)}{17}$.

Tractor requirements are considerably below labour requirements, although still substantial at harvesting.

1. Described in Mimeographed Report No. 61.

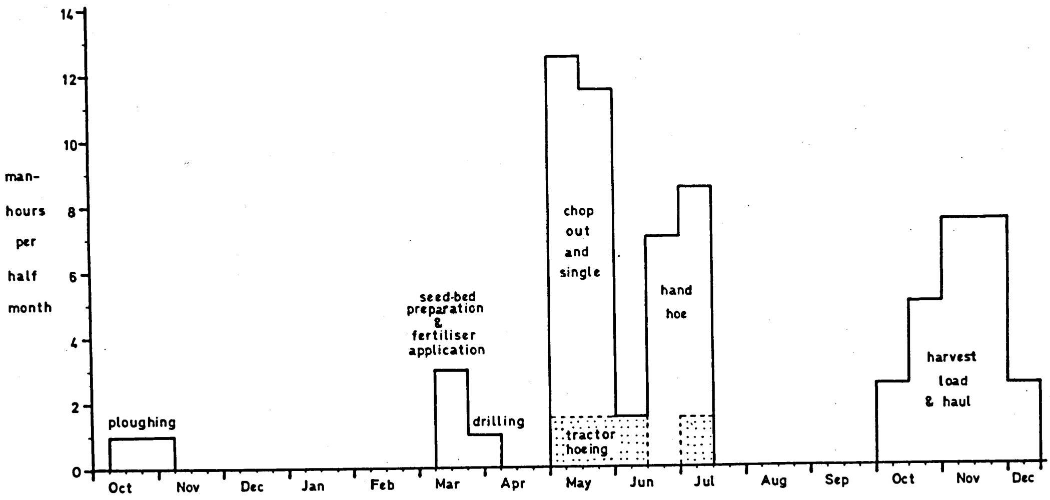
Table 4.1 Labour and tractor requirements

	All districts		
	Average man hours p.acre	Average tractor hours per acre	Average no. of times
Stubble cultivations	(1.5)	(1.5)	2.1
Applying FYM	(4.2)	(4.3)	1.0
Applying salt or kainit	(0.4)	(0.4)	1.0
Ploughing	2.2	2.2	1.1
Seedbed cultivations	2.0	2.0	4.1
Applying fertiliser	1.0	0.8	1.2
Drilling	1.1	1.0	1.0
Rolling	(0.4)	(0.4)	1.0
Hand thinning	21.1	-	1.0
Machine thinning	(1.8)	(1.8)	2.0
Tractor hoeing	5.2	3.2	3.5
Hand hoeing	15.0	-	1.1
Spraying	(0.5)	(0.5)	1.1
Pre-harvest total	47.6	9.2	x
Hand harvesting	(52.6)	-	1.0
Machine harvesting	17.0	15.7	1.0
Loading for factory	2.5	1.6	1.0
Transport to factory (own lorry or trailer)	5.4	(9.9)	1.0
Harvest total	24.9	17.3	x
Total	72.5	26.5	x
Average yield of dirty beet (tons)	18.2	x	x

Seasonal Labour

Seasonal labour peaks are particularly important in sugar beet growing, particularly thinning in the spring, and harvesting in the autumn. A representative pattern of work as found on the survey farms is shown in Figure 4.1, covering the sixteen months which may be needed for cultivations and harvesting. The distinction between chopping-out, singling and second (hand) hoeing is not always clear cut. Many farms for example, did not hand-hoe at all, and on those which did, the operation was partly to obtain a higher proportion of singles, and partly to eliminate weeds.

Figure 4.1. Seasonal labour requirements for sugar beet (per acre)



Labour requirements for thinning can be reduced by using a mechanical thinner, and although there were too few farms in the survey using this method, evidence from trials indicates that mechanical thinning followed by hand trimming does not affect yields adversely. A main advantage is that it enables the singling to be completed within a shorter time period. However, the survey indicated that most growers are hoping that satisfactory monogerm varieties will be developed before labour for hand-thinning becomes too scarce and expensive. One field of monogerm beet, for example, was singled with a labour requirement of only 11 man-hours per acre. Drilling to a stand would eliminate even this labour.

Part II

Mechanical Harvesting

Chapter 5

DESCRIPTION OF THE STUDY

Objectives

More than 90 per cent of the sugar beet crop in Britain is mechanically harvested, but there are now several different types of machine available. The earliest was the tractor-drawn type which lifts the beet from one row and elevates the roots into a trailer travelling alongside. From this was developed the tanker machine, which can store beet temporarily and therefore does not require a trailer to be present continuously (or at all). Recently, self-propelled and two-row models have been introduced, costing more than conventional harvesters. The economics of the new machines depend on the balance between additional machinery costs, and costs saved elsewhere, such as labour. These in turn depend on the machines' potential and the extent to which it is realised on particular farms. The latter is affected by farm circumstances such as soil type, beet acreage, and the number of men available.

The objective of the study described in this section of the report was to examine the advantages and disadvantages of the different types of harvester, in relation to the methods and techniques of operation. In carrying out the study performance data and estimates of repair costs were obtained, which should help growers to assess the economics of the newer machines on their own farms. This aspect is discussed in Chapter 8.

Two limitations of a study of this kind must be recognised. Firstly it is not possible to observe all types of machine in all working conditions. Secondly it is unlikely that the machines studied will all be operated in the most efficient manner. There is little point in studying an inefficient method except insofar as it helps to identify the factors which determine efficiency. In fact, the sample included a wide range of methods and performance, and it was possible to identify the main factors affecting efficiency.

Method of investigation

The method adopted was to measure the performance of different types of harvester at work in the field, using a stop-watch, measuring wheel (for distances) and spring balance (for yield estimates). Altogether 26 machines of five types were observed, but in a few cases the same machine was operated using more than one method, and the total number of effective observations was 29. The number of machines and observations for each type is shown in Table 5.1.

Table 5.1

Types of harvesters in the sample

Type of machine				No. of machines	No. of observations
1.	1-row	tractor-drawn	no tank	7	8
2.	"	" "	tank	6	6
3.	"	self-propelled	tank	6	8
4.	2-row	tractor-drawn	no tank	6	6
5.	"	self-propelled	tank	1	1
Total				26	29

Average results

Some of the results of the observations made are summarised in Table 5.2, for different types of harvester and gang size. Although some of the figures shown are in fact individual results, average figures of this kind are a very imperfect guide to the merits of different types of machine on a particular farm. Firstly because they combine the results from farms with different physical characteristics, methods of work, and operator-efficiency. Secondly because the two efficiency factors man-hours per acre and acres per hour, are not a sufficient guide to the most economic machine in a particular farm situation.

However, Table 5.2 does show that the usual rates of work were from $\frac{1}{3}$ to $\frac{1}{2}$ an acre per hour, requiring 5 to 10 man-hours per acre. The best results were about 1 acre per hour, and a labour requirement of about $2\frac{1}{2}$ man-hours per acre. These come from a 2-row side-delivery machine, and a 1-row tanker, emphasising the

Table 5.2 Average results for each type of harvester and gang size

Type	Gang size	Row length yds.	Speed in row mph (2)	Haulage distance yds. (3)	Yield of dirty beet tons (4) p. acre	Time clearing harvester as % of harvesting time	Time clearing harvester as % of total time (5)	Man hrs p. acre	Acres p. hour (1)	No. of observations
1. (1 row non-tanker)	2	320	2.34	75	15	6.8	5.9	6.6	0.32	3
	3	302	3.00	457	16	-	-	6.3	0.48	2
	5	309	2.12	1610	21	1.1	0.7	15.7	0.34	3
	All	311	2.42	746	17.5	3.0	2.5	9.9	0.37	8
2. (1 row tanker)	1	302	2.90	63	17	13.5	8.6	3.3	0.32	3
	2	341	2.45	412	20	4.4	2.1	9.4	0.22	2
	3	593	5.67	296	22	-	-	2.6	1.13	1
	All	364	3.21	218	19	8.2	5.0	5.2	0.42	6
3. (1 row s.p. tanker)	1	323	2.75	24	7	8.9	6.0	3.4	0.30	3
	2	345	2.48	237	18	6.9	5.1	5.1	0.39	3
	3	460	3.39	915	19	4.9	3.6	5.9	0.51	2
	All	365	2.81	327	18	7.1	5.1	4.7	3.9	8
4. (2 row non-tanker)	2	566	3.48	90	27	9.4	7.2	2.2	0.92	1
	3	423	2.48	542	18	15.3	12.1	5.1	0.60	5
	All	447	2.65	467	19	14.3	11.3	4.6	0.65	6
5. (2 row s.p. tanker)	2	248	1.91	135	20	16.6	13.3	4.3	0.47	1
ALL	x	363	2.72	442	18	8.0	5.9	6.2	0.45	29

Notes

1. Man hours per acre and acres per hour are "theoretical" i.e. in practice they will not be maintained continuously for (say) an 8-hour day (see text).
2. Speed in row excludes any delays for clearing harvester etc.
3. Haulage distance includes the average distance within the field, which in some cases was also the total distance.
4. Yields of dirty beet are the estimates made in the field, and are higher than the factory returns because of dirt loss in transit.
5. Total time includes turning, any stoppages for clearing, and any harvester waiting or travelling time.

point that the way in which the machine is used is at least as important as the type of machine. It should be remembered that the figures of man hours per acre and acres per gang hour are theoretical in the sense that they are based on timings for a varying but limited number of rows within a field. They include the time needed to clear the harvester of tops or stones, but not time for harvesting headlands, opening up lands, servicing the harvester, or minor repairs. The proportion of the theoretical rate likely to be achieved in practice will vary with the size and shape of field, age of machine, operator efficiency and so on. Figures of 60 - 75 per cent of the theoretical are suggested as realistic for overall average performance.

The average observed times for clearing the harvester of tops, weeds and stones are included in Table 5.2, and this evidence suggests that the 2-row machines are held up more frequently than the 1-row. On the 2-row non-tanker machines observed the tops were elevated to one side, constituting a form of top-saver. Many of the stoppages were caused by the volume of tops exceeding the clearing capacity of the elevator, and in heavy crops this rather than weight of roots may limit row speed.

Range of results

More interesting than the average results are the ranges, and the reasons for the differences between farms. Table 5.3 shows the best and worst values for the main efficiency standards, but as these are not adjusted in any way for haulage distance they are not directly comparable.

Table 5.3 Range of Results

	Best	Worst
Overall speed in row, m.p.h.	5.7 (1-row p.t.o. tanker)	1.53 (2-row non-tanker)
Man-hours per acre	2.2 (2-row non-tanker)	21.7 (1-row non-tanker)
" " " ton (dirty beet)*	0.082 "	1.09 "
Acres per hour	1.13 (1-row p.t.o. tanker)	0.18 (1-row pto tanker)

* These figures are theoretical, as defined above, and are not directly comparable with those found in the costing survey, and referred to in Chapter 4.

Speed in row is also included as one easily-recognisable factor influencing labour efficiency and work rate. However, a higher row-speed is not necessarily better, particularly where gang size is limited.

Some of the factors affecting man-hours per acre, and acres per hour are characteristics of the farm, which cannot be altered. Others are to a greater or lesser extent within the control of the farmer. The main factors of the first type referred to are the haulage distance from field to heap, the soil type, and to some extent the field size and shape. All these disadvantages can of course be avoided by not growing beet on the particular fields, but if it is grown harvesting is bound to be more difficult. Field size and shape may be alterable in the longer run.

Factors of the second type are varied in nature. The main ones depend on the equipment and organisation, while others are minor points of technique which may seem trivial but together can make a significant contribution to efficiency. Some of these mentioned below may seem obvious but in at least one case they evidently were not.

Equipment and Organisation

Here the main aspects are the capacity of the equipment, the way in which it is used, and the efficiency of the operators. Obviously a 2-row harvester has a greater output potential than a similar 1-row machine, but this may not be realised in practice if the rest of the equipment is not matched to the harvester. For example the larger machine will require a higher-powered tractor to maintain the same row-speed, and trailer capacity may need to be larger.

The balance between row length (i.e. yield per row) and tank or trailer capacity can make an important contribution to efficiency. Some limits on row length are set by the field shape, and on capacities by the equipment on the market. Nevertheless it is often possible to adjust row length to match the equipment, or modify trailers to hold more beet e.g. so that two rows fill the trailer (or tank). Dovetailing row length means planning ahead so that the crop is drilled in the appropriate way, and it may mean having a "headland" in the middle of the field.

Other things being equal, a high row-speed will help to increase output and efficiency, but there is no advantage in high speed if the transport cannot keep pace. Yield losses behind the harvester are also likely to increase at higher speeds, but as the Sugar Beet Harvesting Demonstrations have shown, there is no direct relationship.

Trailer tipping times were not in all cases measured directly, but calculations indicated that the average time was six minutes. The fastest tipping observed took just over one minute, as described in Chapter 7, case study B. In this instance the equipment was unusually good, but it is still difficult to justify six minutes, and this was the average, not the longest time.

Although a good plan provides the opportunity for efficient and rapid working, unless the operators are competent and interested, the opportunity is unlikely to be taken. A main conclusion drawn from the survey, albeit a rather subjective one, was that in many cases management was insufficient to realise the potential of the machinery used.

Points of technique

1. Tanker harvesters with an elevator unloading mechanism can be unloaded while the machine is harvesting, provided that the elevator drive can be engaged from the tractor drivers seat. This facility is not available on some older machines.

2. Where there are sufficient trailers to keep a non-tanker machine harvesting continuously, trailers can be changed with the minimum of delay by first synchronising the speeds of the trailers, one behind the other. When the front trailer is full the harvester is stopped for a moment, the second trailer immediately comes into position underneath the elevator, and the harvester then continues.

3. Trailers should be filled from the back forwards so that the capacity remaining can easily be seen.

4. Wheel widths on the tractor and harvester should be aligned so that they run in the same ruts i.e. between the original rows of beet. In this way steering is to some extent automatic, and it is also easier for a trailer running alongside to keep in a constant position relative to the elevator. This helps to maintain a high

row speed.

5. A wider row width, say 22 in. reduces the distance travelled by the harvester per acre, which is advantageous provided yield is not affected.

6. Where there are many bolters a pre-topper reduces stoppages to clear the harvester of tops.

7. Headlands can be lifted and lands opened with very little handwork, but even so the output per hour is below that for normal row work. The job should therefore be completed early in the season when more favourable weather conditions are likely to compensate for the lower work rate, and keep up with delivery permits.

There appears to be no necessity to hand-top the first row, either with a spade before lifting, or afterwards with a knife. Provided a square of beet, with side equal to the headland width, is hand lifted in each corner to allow the harvester to turn, all the remaining work can be done with the harvester. The first row of headland or land can be topped by altering the relative positions of the topping unit and lifting mechanism. The heel of the topping knife is fully lowered, and the spring pressure on the feeler wheel increased to the maximum extent. Using the tractor's hydraulics, the harvester can be lowered far enough to allow the topping mechanism to work, but the lifting wheels or shares are high enough to avoid lifting the untopped row of beet directly underneath.

It is an advantage for the harvester to be able to turn on the headland without reversing. Headlands in the survey fields averaged ten yards but the self-propelled machines could turn in 8 yards.

<u>Harvester repairs</u>

Repairs to the harvesters studied varied considerably. Taking repairs to be related primarily to the amount of use, and expressing the total cost on a per acre basis, the average was just under ten shillings, but the range was from about one shilling to one pound per acre. The costs recorded were mainly for spare parts, and the lower end of the range is explained by free replacements and repair work under guarantee. These cases also affect the average, and if a machine is not under guarantee it would be wise to budget for a cost of at least 15 shillings per acre.

The main items needing replacement were the main lifting chain and its associated sprockets, knives, and the rubber flickers to clear tops. For example three users of 2-row machines found that the main lifting chains required replacing every 100 to 120 acres, whereas another farmer with a 1-row machine on stony ground found 70 acres to be a usual life for the chain.

Chapter 6

HARVESTING MACHINES AND TECHNIQUES

Farm conditions which affect the working of harvesters vary so widely that performance standards possible on one farm may not be realistic for another. Nevertheless it is possible to compare the potentialities of types of machine, and harvesting systems, by making some reasonable uniform assumptions about such factors as row speed, tank and trailer capacity, yield, trailer speed and tipping time, etc. The effect of varying haulage distance and the number of men can then be seen. A simplified model of this kind facilitates comparison provided that the uniform performance data do not conceal real differences between machines.

In this chapter assessment of systems and machines is made in terms of man-hours per acre, and acres per gang-hour. These are not in themselves a sufficient guide to the most economic machine but they provide a basis on which to form a judgement, taking into account also the cost of the equipment, and labour requirements. This aspect is considered in Chapter 8.

Machines and system

Basically there are two types of machine and four harvesting systems. Machines can be divided into those with tanks and those without. Other differences are in the number of rows harvested simultaneously, and whether the harvester is self-propelled or tractor-drawn. The four harvesting systems are:-

1. Non-tanker machine unloading while harvesting. As a trailer must always be alongside the minimum gang size is two men.
2. Tanker machine unloading periodically into trailers while harvesting. Minimum gang size, two men.
3. Tanker machine unloading directly onto heap (in or near the field). Minimum (and maximum) gang, one man.
4. Tanker machine unloading into stationary trailer at row end. Minimum gang, one man. As a one man operation this method is quite similar to the third system above, since harvesting stops while the trailer is away. With larger gang sizes there may be more trailers than men hauling.

Two sets of standards are considered, one representing average equipment and performance, the other larger-capacity equipment and above-average performance.

Average equipment and performance

Assumed values:

Row length	350 yards
Row width	20 inches
Yield per acre	19 tons dirty beet
(Yield per row	15 cwts. dirty beet)
Tank capacity	30 cwts. dirty beet
Trailer capacity	3 tons dirty beet
Harvester speed in row	3 m.p.h. (also travelling)
Turning time per row	0.5 min. (0.8 min. where also unloading at row end)
Trailer av. speed when hauling	6 m.p.h.
Trailer tipping time	5 min. (also tank unloading at heap, allowing for tidying heap)
Tank unloading time (elevator)	3 min. (except at heap)
Time for driver to change from harvester tractor to trailer tractor (and vice versa)	1 min.

The effect of these assumptions is that a tank is filled with two rows, and a trailer with four rows. A 2-row harvester therefore fills the trailer in two passes instead of four. While it is not always possible in practice to achieve such an exact balance, the row length may be adjustable to give a yield consistent with tank or trailer capacity. Conversely the trailer capacity may be altered.

The machines and systems can be looked at from at least two standpoints. On the one hand the performance of the same machine and system can be considered in relation to varying gang sizes. Alternatively, the gang size can be held constant and the machine and system of work varied. Both these approaches are considered here, using graphs to show how man-hours per acre, and acres per hour change as haulage distance increases. (see Figures 6.1 and 6.2). The range of haulage distances covered is 100 to 1500 yards each way. The capital letters shown on the graphs have the following meaning:

A Harvester starts to be delayed (i.e. by lack of haulage capacity) (All 1-man units are already delayed at 100 yards haul).

B Additional trailer becomes justified (i.e. in terms of man-hours per acre, or acres per hour, not necessarily in other respects).

C Tanker becomes justified (again only in terms of man-hours per acre or acres per hour)

These letters are only shown on the man-hours per acre graphs, although they may also apply to the acres per hour.

The method of calculation of the graphs is demonstrated so that it can be repeated using different performance data (e.g. row speed) if required. As in the survey results quoted in Chapter 5, the calculations exclude time for headlands, opening up lands, and servicing the harvester. Unlike the survey results, however, the figures shown in this chapter also exclude any time necessary for clearing the harvester of tops or stones. The proportion of the theoretical rate achieved in practice is therefore likely to be slightly lower.

<u>Comparison of systems with varying gang size</u>

The four systems listed at the beginning of the chapter are compared in the graphs shown in Figure 6.1. Systems 3 and 4 are included together on graph 2, while system 1 has two graphs (3 and 4) to allow for 1-row and 2-row non-tanker harvesters. System 4 is not shown for gang-sizes larger than two men because on the assumptions used here the harvester is not delayed even with only two men.

Considering the four graphs in turn, graph 1 shows that with a tanker machine operated in the usual way, the harvester with one trailer starts to be delayed at 400 yards haul, and acres per hour start to fall immediately. However, man-hours per acre do not justify a second trailer until the hauling distance is just over 800 yards. Graph 2 indicates that beyond about 150 yards haulage, it is better to unload into a stationary trailer rather than drive the harvester to the heap. This result is influenced by the assumption that the harvester travels at only 3 m.p.h. when hauling, whereas a trailer averages 6 m.p.h. However, at these short distances tipping time is the main component of total hauling time and the difference in speed is correspondingly less important. The 2-man unit is always better in terms of acres per hour, but does not become more economical in man hours until 1500 yards. A point to consider here is that there may be some problem in assembling the tractors and trailers on the field each day.

Graph 3 shows the system most commonly used, the ordinary side-elevator machine with no tank. Here a second trailer becomes justified (in terms of man-hours per acre) at 350 yards haul, although acres per hour are considerably higher with 2 trailers even at 100 yards. A third trailer is not justified until just under 1200 yards. Graph 4 represents a similar system but with a 2-row machine. Here the potential output is an acre per hour, provided two trailers are present, until a haulage distance of 400 yards. A third trailer enables the acre-per-hour rate to be maintained until just less than 1200 yards.

As an example of the method of calculation by which these graphs are derived, consider the case of a 2-row non-tanker harvester, with two trailers, i.e. a 3-man unit. The haulage distance is 800 yards, a total distance of 1600 yards. The trailer speed when hauling averages 6 m.p.h., or 176 yards per minute. Therefore each trailer is away $\left(\frac{1600}{176} + 5\right)$min. = 14.09min. because 5 minutes are allowed for tipping. In this case a trailer is filled by two passes up and down the field i.e. four rows of beet. The schedule of operations can be listed as follows:

Operation	min.	
Harvest and unload 2 rows (into trailer 1)	3.98	
Turn	0.50	
Harvest and unload 2 rows	3.98	Trailer 1 leaves
Turn	0.50	
Harvest and unload 2 rows (into trailer 2)	3.98	
Turn	0.50	
Harvest and unload 2 rows	3.98	Trailer 2 leaves
Turn	0.50	
Wait for trailer 1 to return	4.63	Trailer 1 returns
Harvest and unload 2 rows (into trailer 1)	3.98	
Turn	0.50	
Harvest and unload 2 rows (into trailer 1)	3.98	Trailer 1 leaves

One cycle is formed by the nine operations beginning at the second turn, and ending with trailer 1 leaving for the second time. This is made up of:

	min.
Four turns	2.00
Four harvesting passes	15.92
One wait for trailer	4.63
Total	22.55 min. per 8 rows

In all these examples there are 24.9 rows per acre, therefore gang time per acre = $(22.55 \times \frac{24.9}{8}) = 70.1$ gang min. per acre.

With a 3-man gang man-hours per acre are $(70.1 \times \frac{3}{60}) = 3.50$ man-hours per acre. This is equivalent to $(\frac{3}{3.50}) = 0.86$ acres per hour. In this calculation it should be noted that the time spent waiting for the first trailer to return also represents time available for the second trailer to travel and tip. Thus there is only one trailer waiting time per cycle of two trailer loads, and this also holds for the cases where three trailers are employed, and the cycle is three trailer loads.

Comparison of systems with given gang size

An alternative way of looking at the possible systems is to hold gang size constant and compare the results from different machines and systems. For many farmers this is a more realistic starting point than considering variable gang size. Figure 6.2 shows how man-hours per acre and acres per hour vary with haulage distance, for gang sizes of from one to four men. These graphs are a rearrangement of the data already shown in Figure 6.1, and to avoid confusion they are numbered from 5 to 8. (Here tanker machines are shown with solid lines and non-tankers with broken lines).

One-man systems are confined to tanker harvesters unloading either directly onto a heap, or into a trailer at the row end (Graph 5). The graph shows that the latter method is preferable for haulage distances greater than about 200 yards. The assumptions which affect this conclusion have already been mentioned in discussing graph 2 in Figure 6.1. Unloading into a stationary trailer at the row end is also possible with a 2-man unit, and in system (b) of graph 6 it is assumed that two trailers are available. The diagram shows that for short hauls the 2-row machine is best, but even at 100 yards it is being delayed by lack of haulage capacity and the longer the haul the more is its potential limited by having only one trailer. At 400 yards the tanker unloading while harvesting (system a) also starts to be delayed. Beyond about 900 yards the tanker unloading into trailers at the row end becomes the best system. As this system is not delayed by lack of transport, under the maximum haulage distance considered here, it is not included in the 3-man and 4-man units.

Graph 7 shows how the addition of a second trailer improves the performance of the 2-row non-tanker. Not until 400 yards does it begin to be delayed by lack of transport. From then on its performance gradually worsens but does not fall to that of the 1-row tanker machine. (The latter system is not delayed, and is therefore excluded from graph 8). Addition of a third trailer, as shown in graph 8, results in the 2-row machine operating at its full potential until 1200 yards, and the 1-row harvester is not delayed at all.

<u>Comparing graphs</u>

From the point of view of comparing systems it would be desirable to superimpose all the lines on two graphs, one showing work rate and the other labour efficiency. This is impracticable, and a certain amount of comparison between graphs is therefore

Figure 6.1. Comparison of harvesters, average performance standards.

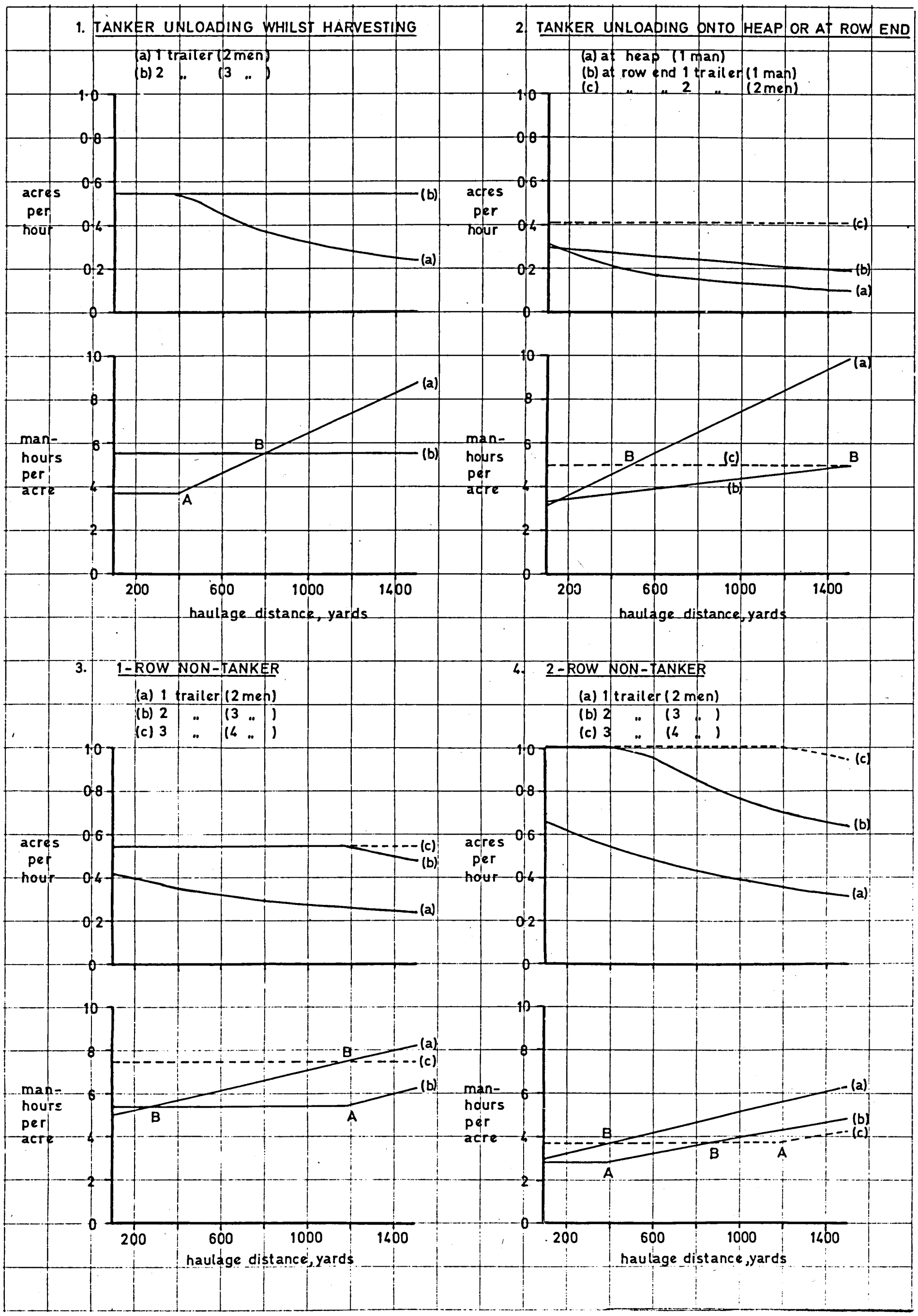


Figure 6.2. Comparison of gang sizes, average performance standards

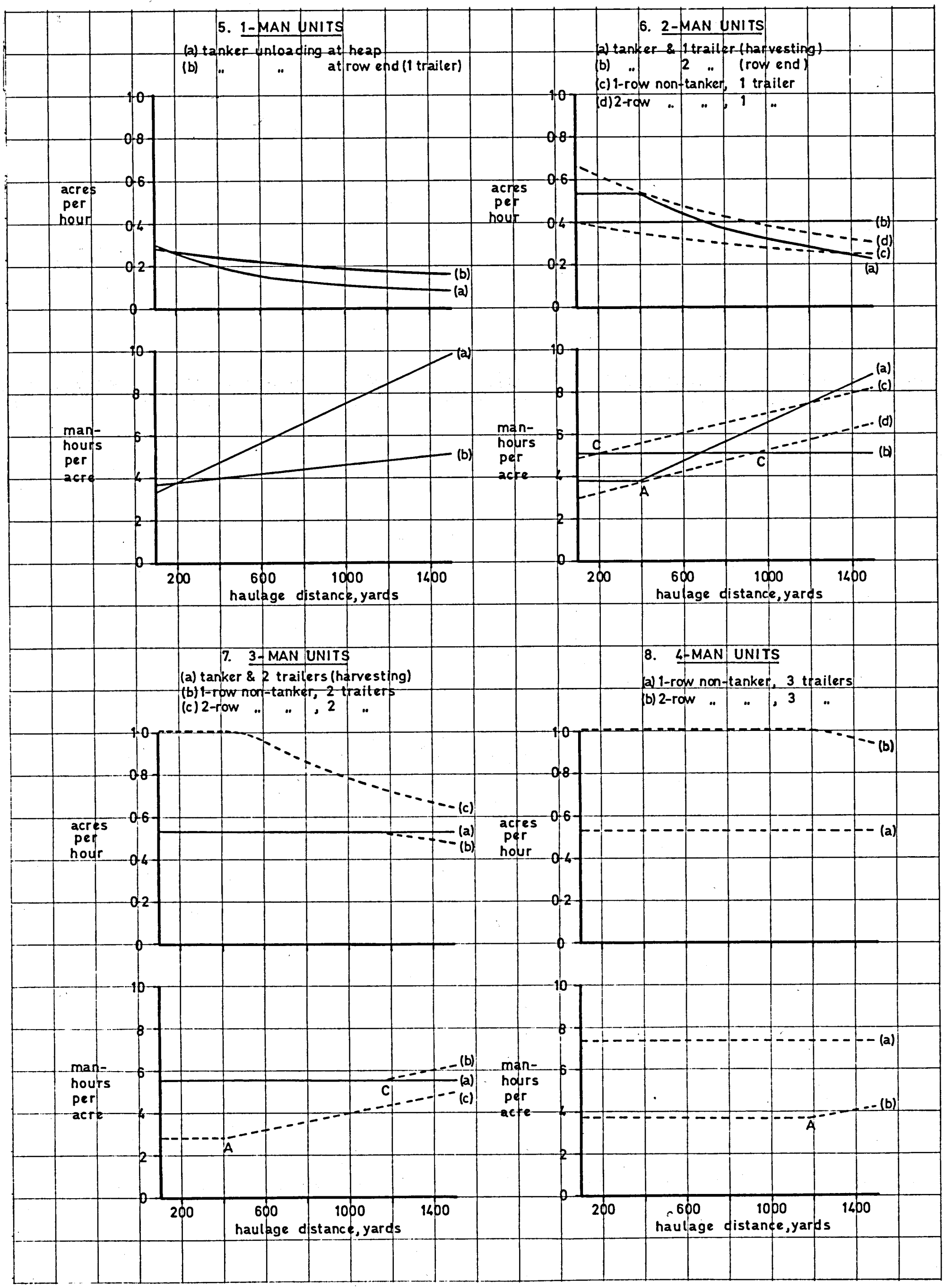


Figure 6.3. Comparison of harvesters, high performance standards

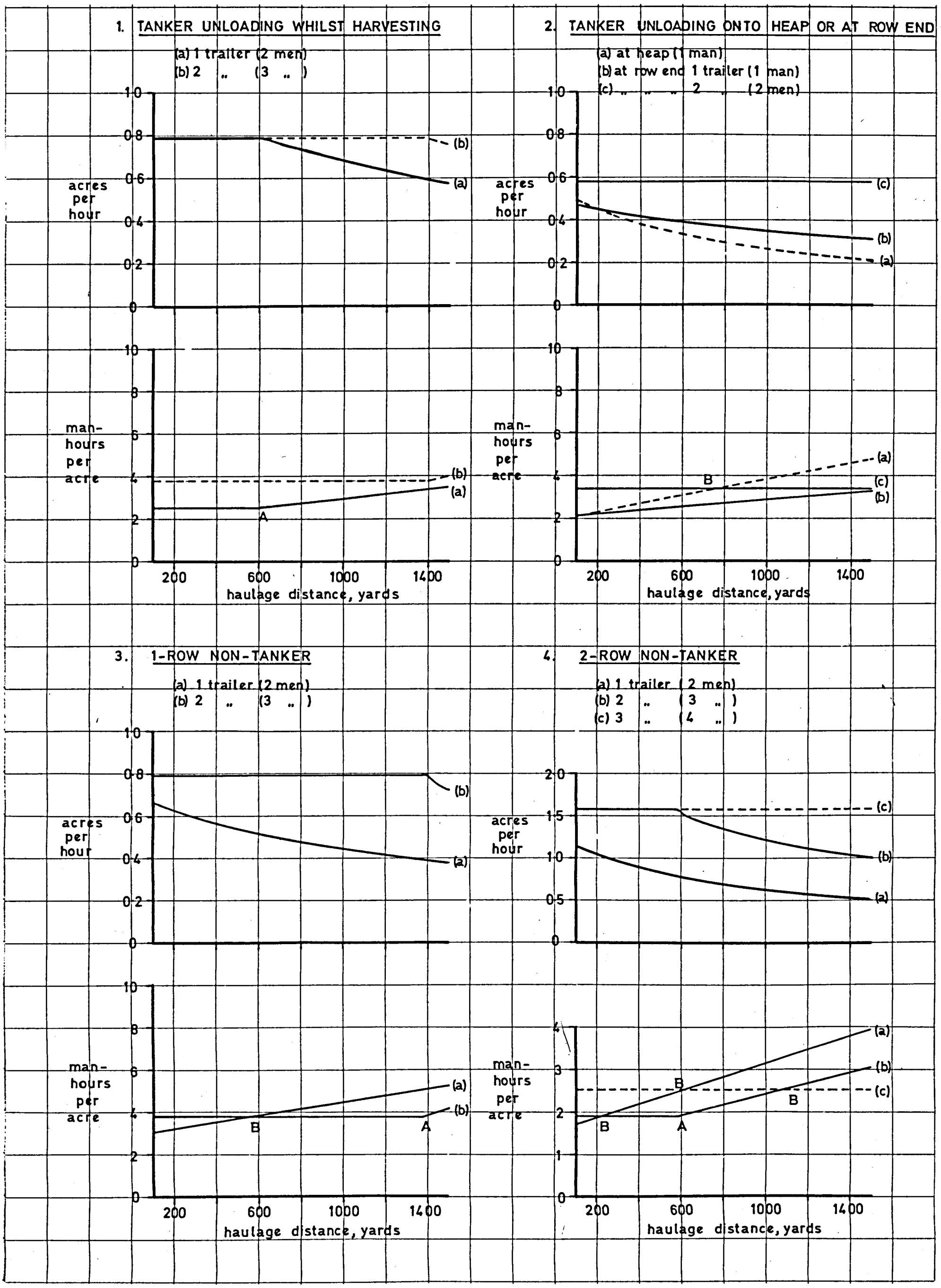
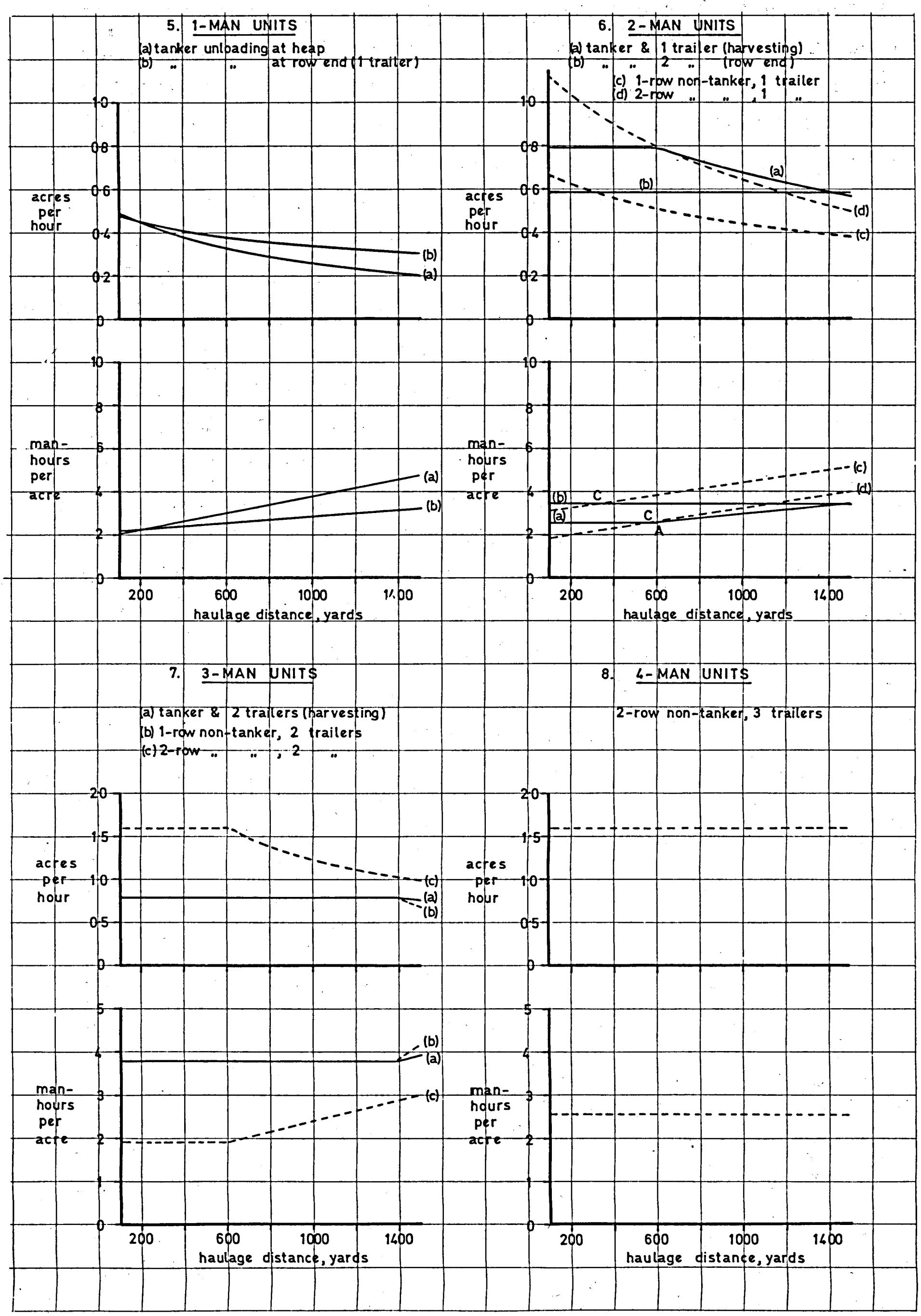


Figure 6.4. Comparison of gang sizes, high performance standards



necessary. For example it is often said that a tanker harvester saves a man, and this can be investigated by comparing system (a) or (b) on graph 6 with system (b) on graph 7. It can be seen that in acres per hour the tanker unloading while harvesting (2-man unit) is as good as the 1-row non-tanker (3-man unit) up to a haulage distance of 400 yards. However, in man-hours per acre the 2-man unit is better than the 3-man unit up to about 800 yards. Again, the other 2-man system (6(b)) has a rather lower work rate than the 3-man unit but man-hours per acre are also slightly less.

Above-average equipment and performance

The standards used to construct the diagrams in Figures 6.1 and 6.2 are representative of current machines and practice, and are useful for comparative purposes. The rates of work are however, considerably below what a number of farmers have shown to be possible, and they also underestimate some of the equipment now available. For this reason it is of interest to see how realistic changes in the standards affect the results. The revised list is shown below, with the original value bracketed.

Changed

Tank capacity	45 cwts. dirty beet (30 cwts)
Trailer capacity	$4\frac{1}{2}$ tons dirty beet (3 tons)
Harvester speed in row	5 m.p.h.(also travelling) (3m.p.h)
Trailer tipping time	3 min. (5 min.)
Row length	263 yards (350 yards)
(Yield per row	11.25 cwts. dirty beet) (15 cwts)

Unchanged

Row width	20 in.
Yield per acre	19 tons dirty beet
Turning time per row	0.5 min. (0.8 min. where also unloading at row end)
Trailer av.speed when hauling	6 m.p.h.
Time for driver to change from harvester tractor to trailer tractor (or vice versa)	1 min.
Tank unloading time (elevator)	3 min. (5 min. at heap)

Tank capacities of harvesters studied in the survey were not specifically measured, but experience of the row length (and yield per row) needed to fill a tank indicated that 45 cwts. of dirty beet is a reasonable maximum to allow for the largest of the tankers studied, since e.g. the load is reduced if the beet are large. To match this the trailer capacity has been increased, to take two tank loads, and the row length has been decreased so that four rows fill a tank. This does slightly increase the proportion of turning to harvesting time, but to have a tank filled with three rows leads to complications for the comparisons being made here, and can also have disadvantages in practice. The reduced trailer tipping time allows for trailers with automatic tailboard release. A row speed of 5 m.p.h. is quite realistic in favourable soils, provided the power unit is adequate, but it should be recognised that it does not allow much time for clearing the harvester e.g. of bolters. Tank unloading time is retained at 3 min. on the assumption that a larger tank will have a higher capacity elevator.

The results of the new assumptions are shown in Figures 6.3 and 6.4, where the labels A, B, & C. have the same meaning as before.

<u>Comparison of systems with varying gang size</u>

The arrangement of systems in Figure 6.3 is similar to that used in Figure 6.1. In particular, system 1 (non-tanker harvester) has two graphs, (3 & 4 on Figure 6.3) to allow for 1-row and 2-row machines. The general appearance of the graphs is similar to that of Figure 6.1, but with higher acres per hour and lower man-hours per acre, and the scales on graph 4 have been altered to allow for these changes. In general the effect of the revised standards is to increase the work rate by about half as much again, with corresponding reductions in labour requirement per acre.

The 2-man tanker unit (Figure 6.3, graph 1) is not delayed until 600 yards, compared with 400 yards on the previous standards. Even at 1500 yards output is higher than the maximum reached before, although man-hours per acre are about the same.

Tankers unloading at the row end need two men if high output is at a premium, although the 1-man unit is more efficient in labour use, up to and just beyond the maximum distance considered here (graph 2). A rather different picture is shown for 1-row non-tankers (graph 3), where the gang sizes are one larger. Here the 3-man unit becomes better on both counts at about 500 yards instead of 1500. Graph 4 emphasises how necessary it is to have adequate transport with a 2-row machine, except at the shortest distances.

Comparison of systems with given gang size

Graph 5 shows that for 1-man units, unloading at the row end maintains the advantage over heap-unloading which was demonstrated in Figure 6.2. The break-even haulage distance is again about 150 yards. If two men are available (graph 6), with a tanker harvester unloading while harvesting is better than unloading at the row end, up to 1450 yards. At short hauls the 1-row non-tanker is better than the tanker unloading at the row end. The 2-row non-tanker maintains its advantage over the tankers up to about 600 yards haul. As system (b) in graph 6 is not delayed by lack of transport, it is not included in the remaining graphs.

Whereas any non-tanker with only two men is almost bound to be delayed by the trailer, 3-man units can cope with considerable haulage distances before this occurs. Graph 7 shows that for the 1-row machine it is 1400 yards, and even for the 2-row the distance is nearly 600 yards. As the 1-row harvesters on graph 7 are hardly delayed by their transport, they are excluded from graph 8. Note that for graphs 7 & 8 the vertical scale has been changed.

Comparison between graphs

Looking again at the question of a tanker machine saving a man, by comparison with a non-tanker, system (a) on graph 6 is giving the same output as system (b) on graph 7, at haulage distances up to 600 yards. However, man-hours per acre are lower with the tanker machine, and remain so at all distances. It is therefore fair to say that up to 600 yards a tanker saves a man in comparison with a non-tanker, and beyond this distance if labour efficiency only is considered. In practice the two types of machine are not always entirely comparable as non-tankers can often work in conditions too wet for tankers.

Looking at the 2-row non-tanker from the same standpoint, it is in this context superior to the 1-row tanker at all stages. Presumably a 2-row tanker working at similar rates would save a man without loss of output or labour efficiency. Again in practice there would be difficulties at times with the working conditions.

Chapter 7

CASE STUDIES

The purpose of this chapter is to supplement the general observations on harvesting efficiency and comparisons of systems, by more detailed descriptions of four of the harvesting operations encountered in the survey. In the main the examples have been chosen to illustrate how high output and efficiency may be obtained, and they include an example from each of the main types of machine.

Case-study A is concerned with a 1-row self-propelled tanker harvester, in a situation where the potential capacity was severely limited by a shortage of transport, but output could nevertheless have been improved. Case studies B and D are all examples of high output and efficiency, the first two with non-tanker machines, the last with a tractor-drawn tanker. Case studies B and D show that annual outputs of 100 acres of harvested beet per man are becoming feasible.

Case study A. 1-row self-propelled tanker harvester, and 1 tipping trailer

With this system the harvester filled the tank from one row, and while harvesting the next row it unloaded the beet from both rows. The trailer then left for the clamp, and the harvester again filled its tank, ready for the trailer when it returned. In this case haulage capacity was limiting the rate of work, but as will be shown, output could have been higher without any change in equipment or basic method.

Observed data (average times, and row speed)

Soil type, heavy loam (fairly wet)

Row length 640 yards

Distance, field exit to clamp 440 yards

Total distance travelled by trailer (while away from harvester) 1550 yards

Time trailer away from harvester 13.3 min.

Harvester speed in row 2.0 m.p.h.

Time to lift one row (excl. turning) 10.7 min.

Turning time per row 0.5 min.

Total time per trailer load, 23.0 min.

Harvester tank capacity, rated 50 cwts. dirty beet

Trailer capacity, about 4 tons beet (not fully utilised)

Number of men 2

Estimated yield per acre 26.8 tons dirty beet (see footnote)

The harvester lifted one row, turned into a new row, and harvested a few yards, until the tank was full (level). It then waited a short time for the trailer to return. When the trailer was alongside, the harvester continued to lift the second row, periodically unloading into the trailer while harvesting. Near the row end, the trailer had a load and it left for the clamp (which was on a concrete standing).

Travelling at an average speed of 2.0 m.p.h. (i.e. while moving) the harvester was taking 10.7 min. to harvest a row and 0.5 min. to turn. The trailer was alongside for 9.7 min. in every other row. The yield was estimated at 26.8 tons dirty beet per acre[1], and with 14.3 rows per acre this gave 1.87 tons per row. The trailer was therefore hauling about 3.7 tons each trip, and as it required 23 min. per load, the theoretical output was 9.6 tons per gang hour requiring 0.2 man-hours per ton. These are equivalent to 0.37 acres per gang hour, and 5.4 man-hours per acre.

<u>Increasing Output</u>

It was clear that the harvester speed was being adjusted to fit the haulage capacity, as a row speed of 2 m.p.h. is quite low. In this situation the most obvious possible change is to add a further trailer, giving a 3-man gang. In practice no extra man was available, and improvements had to be looked for with the existing equipment.

1. The figure of 26.8 tons is the yield estimated by sampling along the rows; the average yield of dirty beet for the whole field, after loading over a cleaner-loader, was recorded by the factory as 19 tons per acre. The difference appears high but as 1.1 rows filled the tank, a yield of 26.8 tons per acre is well within the rated tank capacity.

   On this basis the harvester stopped when it was carrying 41 cwts. but the tank was only level full and the roots rather large.

One possibility is to increase the row speed. For example, by increasing the row speed to 3 m.p.h. the harvester would take only 7.3 mins. per row and correspondingly the trailer would fill in 6.6 mins. cutting the overall hauling time per load from 23 min. to 19.9 min. The hauling capacity is thereby increased to 11.1 tons per hour, equivalent to 4.75 man-hours per acre, and 0.42 acres per hour. Figure 7.1 shows how these two factors are affected by changes in the row speed, (up to a maximum of 6 m.p.h) with a 2-man gang.

It is evident that output per man-hour could have been higher, by increasing row speed, but this need only be on the unloading row. Maintaining a higher speed on the other rows would only increase harvester waiting time, unless the haulage operation could be speeded up. In view of the condition of the track to the clamp, this seemed unlikely.

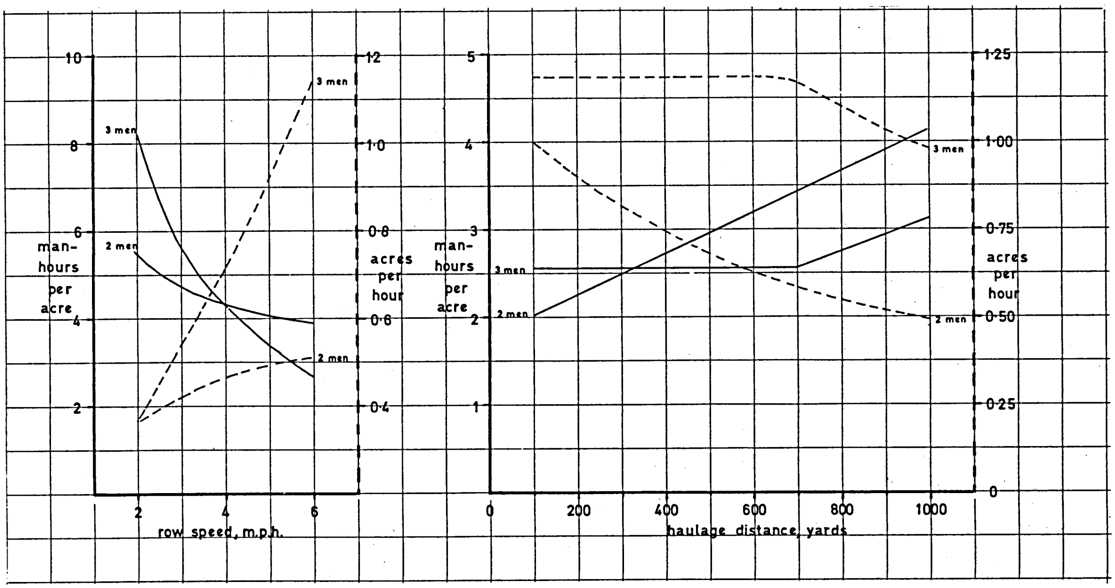
If another man had been available the haulage capacity could have been increased by using an additional trailer. This would have eliminated harvester waiting time at any feasible row speed, but the harvester speed (in all rows) would have had to be increased to 3.8 m.p.h. before man-hours per acre fell to that shown by the 2-man operating unit. This is shown in Figure 7.1, which also shows that the acres harvested per hour would be greatly increased with a 3-man unit.

<u>Case study B</u>. <u>2-row p.t.o. non-tanker harvester, and 1 tipping trailer</u>

This example illustrates how really low labour requirements can be achieved, together with a high rate of work. The harvester filled the trailer from two double rows, and back at the starting point, the trailer tipped its load at a clamp along the headland. Meanwhile the harvester turned and waited briefly for the trailer to rejoin it. Haulage capacity was therefore slightly limiting the rate of work, but the system enabled two men to lift 196 acres of beet during the season.

Figure 7.1. Effect of gang size & row speed (case study A)

Figure 7.2. Effect of gang size & haulage distance (case study B)



Observed data (average times, and row speed)

Soil type, silt (very wet, snowing)

Row length 566 yards

Average distance, row end to clamp, 90 yards

Time harvester waited for trailer, 2.6 min.per load (4 rows)

Harvester speed in row, 3.5 m.p.h.

Time to lift one row, 2.8 min. (excl. turning etc.)

i.e. 5.6 min. per double row

Total time per trailer load, 16.1 min. (incl. stoppage for clearing harvester)

Trailer capacity, about 7 tons beet

Number of men, 2

Estimated yield per acre, 27 tons dirty beet.

The harvester lifted two rows at one pass in just under 5.6 min., turned in 0.62 min. and lifted two more rows in a further 5.6 min. With a yield of 27 tons dirty beet per acre, and 16.5 rows per acre, the trailer load was about 6.5 tons. The trailer left the harvester, travelled to the heap, and tipped in an average of 1.16 min. This very rapid unloading was achieved with the help of a tailboard release operated by the hydraulic tipping mechanism. The harvester had ample time to turn, while unloading was proceeding, but assuming that the time needed for turning was the same at each end of the field, the harvester was delayed 2.6 min. for each trailer load of four rows.

In addition, although the machine was fitted with a rotary pre-topping unit, some time was needed for clearing the harvester and the total time per load averaged 16.1 gang minutes. This is equivalent to a theoretical 2.2 man-hours per acre, and 0.93 acres per hour. Not only are these high standards per acre, because of the high yield they are also exceptionally good when expressed per ton dirty beet, at 0.092 man-hours per ton, and 25 tons per hour.

Farm records showed that the overall harvesting rate, allowing for headlands, stoppages, etc., was 0.56 acres per hour, and in total the machine and two men harvested 196 acres in just less than three months. The high output can be attributed to a number of factors. Firstly, good forward planning, which ensured that two double rows of beet just filled a trailer, which then had only a short haul. Secondly, the operators were competent to realise the high output potential of the machine.

Increasing the haulage distance

The high labour efficiency and output shown by this example is partly attributable to the short haulage distance. If this had to be increased the system would eventually benefit by the introduction of another man. The effect of increasing haulage distance is shown in Figure 7.2, where the figures exclude any time for clearing the harvester.

The starting point is 100 yards haulage, compared with an average of 90 yards when the system was timed in the field. For these longer hauls trailer speed is assumed to average 4 m.p.h., compared with an average of 2.9 m.p.h. corresponding to the 90 yards haul.

With two men, man-hours per acre increase linearly with distance, as the harvester waiting time increases. Conversely, acres per hour decrease continuously. Adding another man carting, eliminates harvester waiting time until the haulage distance is 700 yards. However, man-hours per acre with two and three men are equal at about 325 yards, where acres per hour differ by 0.4. At 700 yards, even with three men the harvester is delayed by a shortage of transport.

Case study C. 1-row p.t.o. non-tanker harvester and 1 tipping trailer

This system was very similar to that of case-study B except that the harvester was a 1-row model (also a different make), and had a top-saver. It illustrates what can be achieved with a 1-row machine, provided there is good organisation and a short haul.

Observed data

Soil type, clay loam (dry)

Row length, 565 yards

Average distance, row end to clamp, 30 yards

Time harvester waits for trailer, 3.2 mins.

Harvester speed in row, 2.8 m.p.h.

Time to lift one row, 9.45 mins.

Total time per trailer load, 18.9 min.

Trailer capacity, about 3 tons beet

Number of men, 2

Estimated yield per acre, 19.6 tons dirty beet (17 tons according to factory returns)

The yield was considerably below that in the previous example (B) and although the row length happened to be identical the combination of lower yield and a 1-row machine meant that a 3-ton trailer was just adequate to cope with two rows. With two rows forming one trailer load, and 15.4 rows per acre, theoretical man-hours per acre are 4.85, and acres per hour 0.41. These are rather less than half as good as in case B, because of lower row-speed and longer tipping time at the heap. On a per ton basis they are even poorer, at 0.25 man-hours per ton, and 8 tons per hour. Part of this difference can be ascribed to the top-saver, which always slows up harvesting. Nevertheless this 2-man team could reasonably be expected to lift at least two acres per day, and as the harvester and trailer were far from new very little capital was required. By comparison with the average grower, it was also very efficient, particularly for a harvester with a top-saver.

<u>Case study D.</u> <u>1-row p.t.o. tanker harvester, and two tipping trailers</u>

This example demonstrates a very high output per hour, in both acres and tons, and low labour requirements. The harvester was working between lands, with very little use being made of the tank. (At other times in the season only one trailer was carting, in which case the tank was fully used). The most interesting feature was the very high row speed, in spite of wet conditions, achieved with a 65 h.p. tractor. The result was a very high output per hour, and in total the machine lifted 240 acres of beet over the season.

<u>Observed data</u> (average times, and row speed)

Soil type black fen, (very wet)

Row length 593 yards

Average distance row end to field exit, 142 yards

Distance, field exit to clamp 154 yards

Harvester speed in row 5.7 m.p.h.

Time to lift one row 3.6 min.

Turning time per row 0.4 min.

Trailer capacity about $3\frac{1}{2}$ tons beet

Number of men, 3

Estimated yield per acre, 22 tons dirty beet

The harvester lifted down one row, meanwhile unloading into one of the trailers alongside. About 30 yards from the row end, unloading stopped and the trailer turned into the new row in a narrower arc, to avoid interfering with the harvester's turn. About 30 yards along the new row the trailer was again in position and unloading recommenced. Again about 30 yards from the row end unloading stopped, and the trailer left for the clamp. The other trailer was then waiting for the harvester when it had turned.

With 13.3 rows per acre, the yield per row was 33 cwts., and one trailer load was therefore about $3\frac{1}{4}$ tons of dirty beet. Travelling at 5.7 m.p.h. the harvester took 53.3 minutes to lift an acre. This is equivalent to a theoretical 2.7 man-hours per acre, and 1.13 acres per hour, or 0.12 man-hours per ton and 24.8 tons per hour. There were no stoppages for clearing or breakdowns while the harvester was observed, and it seemed that an overall work rate of 75 per cent. of the theoretical was quite realistic i.e. about 6 acres per day.

Reasons for high output

Clearly the main reason for the excellent performance was the high row-speed. A number of factors contributed to this. The soil, although very wet, was easily worked, and unusually suitable compared with most of the farms studied. On the other hand it produced large quantities of tops. Stoppages to clear the tops were prevented by having a rotary pre-topping unit, which shortened all the leaves (including bolters) to an even height. Steering was facilitated by careful wheel spacing, so that a regular rut pattern was formed, which also helped the trailer to keep in position under the unloading elevator. Adequate power for the harvester was obtained by using a large tractor, which might have been unnecessary in drier conditions. The haulage distance was quite short, but a much greater distance could have been tolerated without delaying the harvester, although more use would have been made of the tank.

The equipment was good but not exceptional, and conditions were reasonably favourable. All these factors contributed to the high output, but a further reason was the competence and enthusiasm of the operating team.

Chapter 8

ECONOMIC ASSESSMENT OF HARVESTERS

Performance standards such as man-hours per acre and acres harvested per hour are important but not decisive in assessing the most economic machine on a particular farm. They do however provide data on which to base a judgement. A technically more efficient harvesting system is not justified economically unless any additional machinery costs are outweighed by the resulting monetary benefits. In many cases a more efficient system can be obtained with no extra capital outlay (as was shown in the previous chapter), but often the question to be answered is whether capital expenditure on a new or different harvester is justified. This problem is discussed here in terms of a farm example, since generalisations are of limited value. One of the main considerations is labour use in the autumn and it is important to ensure that any improvement in work rates or reduction in man-hours needed per acre, is translated into a monetary saving. This can arise either through reductions in the regular or casual labour force, through reduction of contract work, or through better timeliness of other farm operations in the autumn.

Changing a harvester

As an example of the method of assessing the economic advantages obtainable from a new harvester, consider the case of a farmer planning to replace his 1-row non-tanker with a new machine, either a similar type, or a tanker, or a 2-row non-tanker. The farm consists of 450 acres of moderately heavy arable land, 80 per cent of which is in cereals. The rotation aimed at is:

wheat, barley, barley, barley, sugar beet or leys

The average cropping pattern is

	acres
wheat	90
barley	270
sugar beet	50
1-year leys	40
	450

The aim is to have all winter wheat, but normally only 70 acres can be drilled in time. However, the leys and most of the cereal stubbles are ploughed by December. As 40 acres of barley are undersown each year, only 230 acres of barley stubble are ploughed, together with 90 acres of wheat, a total of 320 acres. The leys are for hay or seed and can be ploughed up on wetter days during the cereal harvest. Therefore the autumn labour peak consists of the following operations, which must be completed in 32 working days (mainly October and November): Except for beet harvesting the work rates shown are taken as given. Only two high-powered tractors and ploughs are available.

	Acres per day	Gang size	Gang days	Man-days
Harvest 50 acres sugar beet	2.5*	3	20	60
Plough 320 acres stubble	8	1	40	40
Prepare 70 acres seedbed	5	1	14	14
Drill 70 acres wheat	20	2	3.5	7
			TOTAL	121

* 600 yards haul

At present three men are employed, giving a total of 96 man-days available. This is not sufficient to perform the operations specified, and some contract harvesting is necessary. In principle any of the other operations could also be carried out by a contractor, but here only ploughing and harvesting are considered, at £2.10s.0d and £12 per acre respectively. The variable costs of ploughing (repairs and tractor fuel) are assumed to be 10s. per acre. Similarly the variable costs of operating one's own harvester are taken as 25s. per acre. Then a day's ploughing (2 men) saves contract charges amounting to £(16 x 2.5) = £40, less £(16 x 0.5) = £8. The net figure is £32 per day. It will be profitable to plough and leave harvesting to the contractor until the harvesting rate is such that £32 are also saved by harvesting. Using one's own harvester saves £12 per acre but loses 25s. per acre, a net gain of £10.5s.0d. Therefore the break-even point is reached when the beet harvesting rate is 3.1 acres per day (i.e. 32/10.25).

Alternative harvesting systems

The existing pattern of operations in the autumn is shown diagrammatically in Figure 8.1(a). Although 96 man-days are available, not all can be utilised because of the gang structure. With beet harvesting the residual activity only 25 acres can be harvested, leaving 25 acres to be lifted on contract. The costs associated with this system are shown in Table 8.1, system 1. (Costs included are those relevant for comparing systems, not the total costs). Depreciation charges are one-seventh of the purchase price of the harvester, to allow for resale or trade-in value of the machine. The prices assumed are shown below.

	initial cost £	annual depreciation £
1-row non-tanker	460	66
1-row tanker	700	100
2-row non-tanker	950	136

With some labour not utilised under system 1, one obvious possible change is to use a 2-man gang for beet harvesting. The work rate for this system is derived from Figure 6.1, graph 3(a), again assuming 600 yards haul. Figure 8.1(b) shows that the change eliminates unused man days, and permits three more acres of beet to be harvested. In cost terms the result is a small improvement.

Another obvious possibility is a tanker harvester. Figure 6.2, graph 6, shows that at 600 yards a tanker unloading while harvesting is slightly better than one unloading at the row end, and the theoretical acres per hour are equivalent to 2.1 acres per day. The work pattern is shown in Figure 8.1(c). With this system 37 acres of beet can be harvested and Table 8.1, system 3, shows that the effect is a marked lowering of costs, even allowing for the higher depreciation.

The remaining type of machine considered here is a 2-row non-tanker harvester. A 2-man gang produces the results shown in Table 8.1, system 4, and the work pattern illustrated in Figure 8.1(d). Although there are no man-days unused, and the

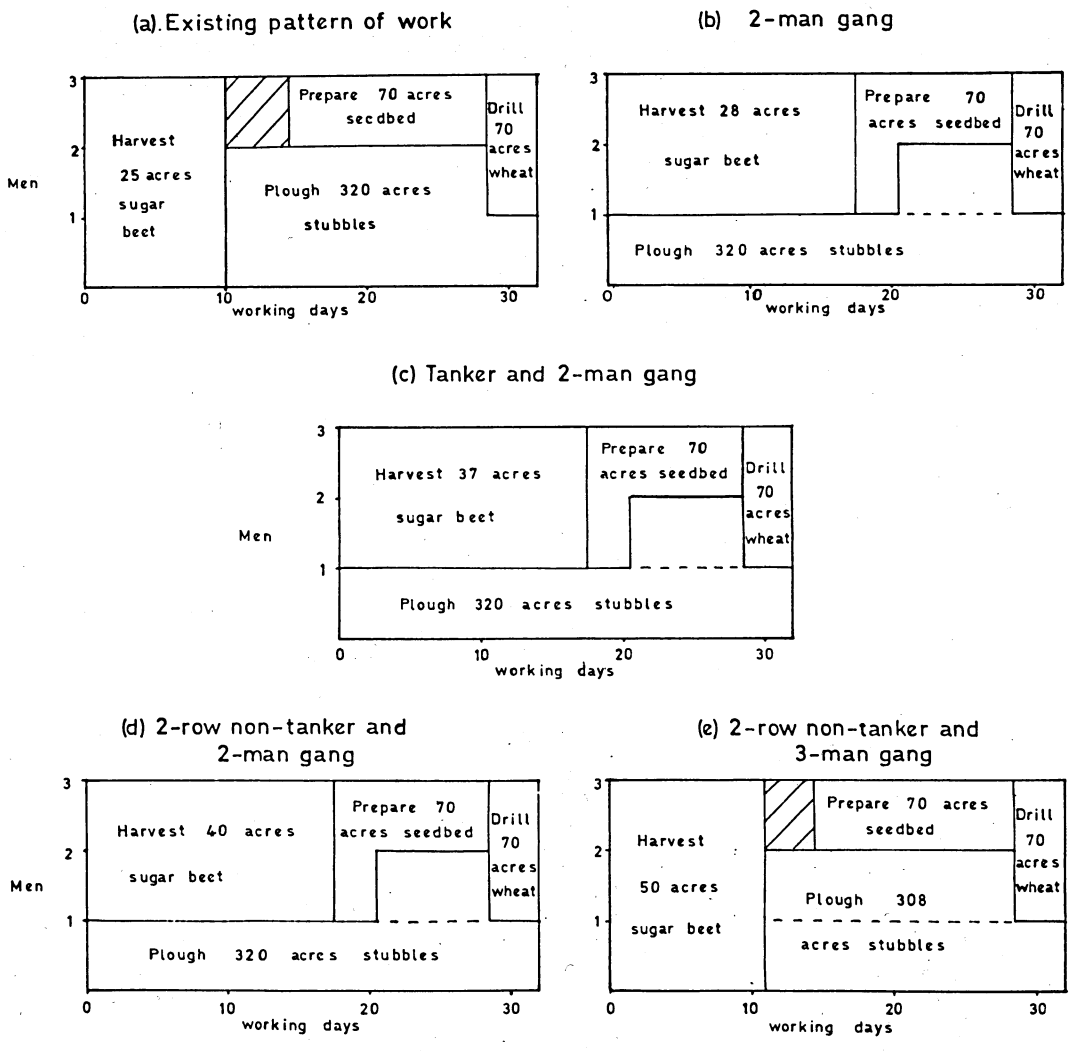
Table 8.1 Comparison of costs of harvesting with alternative systems (example farm)

System	Acres per day	Acres harvested Own	Contract	Contract Cost £	* Other Costs £	Total Costs £	Ranking
1. 1-row non-tanker (3-man unit)(Existing system)	2.5	25	25	300	97	397	5
2. 1-row non-tanker (2-man unit	1.6	28	22	264	101	365	4
3. 1-row tanker (2-man unit)	2.1	37	13	156	146	302	2
4. 2-row non-tanker (2-man unit)	2.3	40	10	120	186	306	3
5. 2-row non-tanker (3-man unit)	4.5	50	0	30	199	229	1

* These costs comprise harvester depreciation, plus variable costs of using one's own harvester, charged at 25s. per acre.

work rate is slightly better than system 3, because of the higher depreciation charge, total costs are very slightly higher. The trouble is that the machine's potential is not being exploited with only one man carting. According to Figure 6.1, graph 4(b), a 3-man gang can harvest at the rate of 4.5 acres per day. This is well above the "break-even" rate for contract ploughing and harvesting, discussed earlier, and it is therefore profitable to treat ploughing as the residual activity. Even so, Figure 8.1(c) shows that only 12 of the 320 acres of stubbles need be ploughed by a contractor. (In practice, this could probably be done by the spare man using a smaller tractor and plough). Then the only contract cost is 12 acres ploughing at £2.10s.0d per acre, or £30. Against this could be set the saving in variable costs of ploughing (£6), but as these variable costs of ploughing have

Figure 8.1. Gang-day structure for alternative harvesting systems



been excluded in the previous calculations, they are not included here. The cost position is shown in Table 8.1, system 5, and is easily the best of the alternatives considered. As the higher depreciation charge is allowed for the calculation, the conclusion is that the 2-row machine is the most economic.

These results depend on the particular farm circumstances and performance standards assumed here, and it should not be concluded that 50 acres of beet necessarily justifies a harvester of this type.

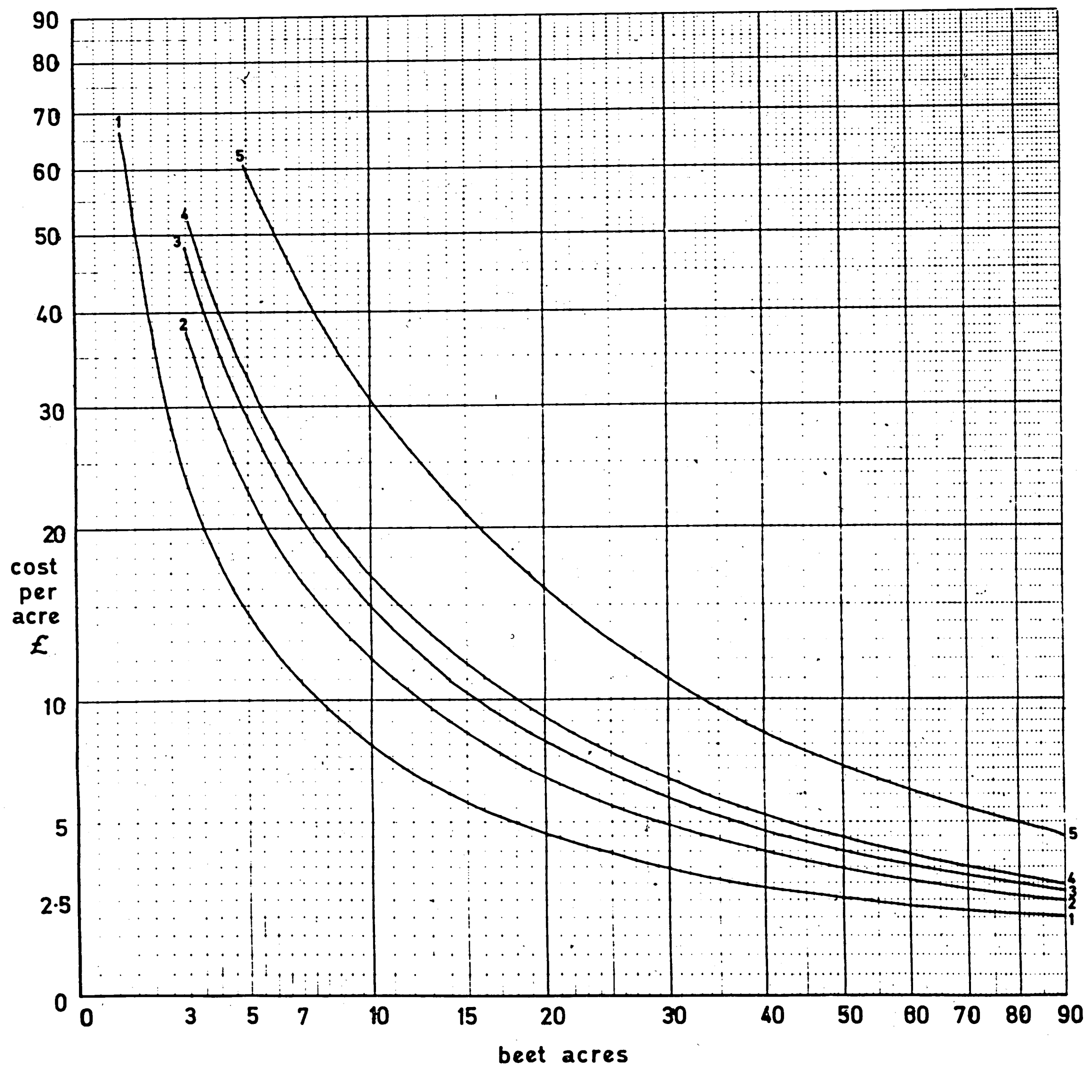
Minimum acreages for different types of harvester

It has been shown that in making an economic assessment of a harvester it is not sufficient just to compare a contractor's charge with the apparent cost of farm harvesting (calculated by dividing machinery costs, and possibly labour, by the beet acreage). It may be profitable to employ a contractor even when the charge is above the apparent farm cost.

On the other hand, when a contractor's charge is below the farm cost, employing a contractor is the better alternative, provided he is available at the right time. Thus there are certain minimum acreages below which it can be assumed that particular machines are not economic.

These acreages can be estimated by assuming realistic depreciation rates and repair costs, and finding the cost per acre at different beet acreages. A depreciation rate of 25 per cent annually, calculated on the reducing balance method, gives a capital value after five years of one quarter the initial value, and this represents the resale value. Thus the depreciation over five years is three-quarters of the initial cost, and therefore a reasonable estimate of the annual depreciation is obtained by taking a seventh of the capital cost. Repairs and variable costs of operating a beet harvester are estimated at 25s. per acre. The costs per acre for five different capital outlays are shown in Figure 8.2, which has logarithmic scales to save space. The capital costs were selected to correspond with current market prices of the usual types of machine available.

Figure 8.2. Cost per acre and beet acreage for various harvesters (logarithmic scales)



	Capital cost, £	Type of machine	Approximate minimum acreage
1.	460	1-row non-tanker	7
2.	750	1-row tanker	12
3.	950	2-row non-tanker	16
4.	1100 (excluding power unit)	1-row self-propelled tanker	18
5.	2050 (including power unit)	1-row self-propelled tanker	33

The type of harvester shown is only a guide, and in considering a particular machine the nearest capital cost should be taken. Interpolation on the graph is also possible.

If the contract charge per acre is £10, the minimum beet acreages for each of the capital outlays are as shown. The rather limited meaning to be attached to these figures must be made clear. Acreages above the minimum do not necessarily justify a machine of the capital cost shown. For example it would be easy to harvest 12 acres with a 1-row non-tanker, provided two men were available. On the other hand, acreages below the minimum are definitely too small for a machine of the corresponding cost.

Part III

Summary

Output and production costs

The 1965 sugar beet crop was costed on a random sample of 63 farms in the Eastern Counties. Output and variable costs were based on the total beet acreage grown on the survey farms (2931 acres) and estimates of other costs were made from an operational record for one field chosen at random on each farm.

Yields of roots in 1965 were high, but the lack of sun resulted in low sugar percentages. Harvesting at the end of the season was exceptionally difficult because of wet weather. Average yields, returns, costs, margins and labour requirements were as follows:

	Sugar yield, cwts p. acre	49.2
	Clean beet, tons p. acre	15.7
(a)	Beet sales £ p. acre	100.9
(b)	Variable costs "	27.4
	Gross margin " (a) - (b)	73.5
(c)	Total costs "	70.5
	Net margin " (a) - (c)	30.4
	Labour requirements, man-hours p. annum	72.5
	Tractor " , hours p. annum	26.5

Mechanical harvesting

A separate investigation of mechanical beet harvesting was made, with 29 observations on 26 machines of five different types. From the data obtained, average and premium performance standards were defined, and used in a simplified model to compare different machines and systems of harvesting, in terms of man-hours per acre and acres per gang-hour. These comparisons are supplemented by case studies, to illustrate the main conclusions which emerged. For good efficiency and output, the way in which a machine is used is just as important as the type of machine. Some factors are difficult to change e.g. soil type and haulage distance, but others depend on management e.g. a good balance between row length and tank or trailer capacity. However, man-hours per acre and acres per gang-hour are not in themselves an adequate guide to the most economic type of harvester on a particular farm. This question is discussed in terms of an example farm.

Appendix A

Weather Conditions

The weather in November 1964 was mainly dry and mild, and autumn cultivations were up to schedule except on the heavier land, where soils were too dry. December was colder, with snow around Christmas, but cultivations continued well forward. Cold conditions at the beginning of March (1965), followed by a dull, wet spell, delayed beet drilling except on the lightest soils. Finer weather at the end of March and beginning of April enabled drilling to make good progress, and by the end of April nearly all the crop was sown, in spite of cold and showery weather later in the month. Early-sown crops were germinating well.

May was mainly dull and unsettled, and low temperatures delayed growth of the beet, but singling started. Some damage from pests was reported. The crop grew well through June and July, in spite of cool, wet conditions. Some crops were gappy because of pest damage, and in June patches of virus yellows were evident. In Norfolk mildew was widespread. A week of warm sunny weather in August improved the crop, which was suffering from too much rain and too little sun.

September continued cool, dull and wet. Harvesting began by the end of the month, with good yields but low sugar percentages. Harvesting conditions improved in October, which was mild and mainly dry, and by the end rather more than a quarter of the crop had been lifted. November was sunny but colder, except for a mild spell in the second week, with rainfall above average. Nearly 70 per cent of the crop had been harvested by the end of the month, but there was some frost damage on exposed clamps. From the end of November harvesting conditions worsened because of above-average rainfall, and dirt tares were high. At the beginning of 1966 about 20 per cent of the crop was still in the ground. January was mainly cold, wet and windy, but almost all the remainder of the crop was lifted, although with difficulty.

Appendix B

Table B.1 Seed and fertiliser

Type of seed	Natural	Rubbed	Triplex
Percent of acreage sown	13	78	9
Average rate, lbs.p.acre	12¾	5½	4¾

Variety:	Percent of acreage
Sharpe's Klein E	57
Hilleshog N	14
Triplex M	9
Other	20

Average distance between seeds, precision drill	2.0 inches

Type of fertiliser	Compound	Salt and/or kainit	Top-dressing
Per cent of acreage	98	49	28
Average rate, cwts. per acre	8	5	1½

Average nutrient application, units p.acre	N	P	K (inc. kainit)
Norfolk	118	67	148
Suffolk	108	80	137
Fens	119	102	163
All districts	114	81	148

Table B.2 Use of contractors' services

Percentage of beet acreage

Beet acreage size group	Small	Medium	Large	Total
Salt or kainit application	24	14	25	23
Drilling	22	4	3	4
Harvesting	3	-	7	5
Transport to factory	84	35	20	26

Table B.3 Cost structures and net margins (by district)

District	Norfolk	Suffolk	Fens
	Averages		
	£	£	£
Seed	2.4	2.9	2.9
Fertiliser *	7.3	7.5	7.8
Sprays	1.6	1.3	0.9
Piece-work labour ‡	8.3	10.2	7.0
Contract haulage	3.4	4.8	5.4
Other contract	1.6	2.1	4.4
Total variable costs	24.6	28.8	28.4
Regular labour	10.6	12.2	13.4
Tractors	6.8	7.6	5.8
Machinery	7.8	6.7	4.3
FYM, lime, slag	2.1	2.4	0.4
Rent and drainage rate	5.5	6.1	9.8
General overheads 15%	8.6	9.6	9.3
Total fixed costs	41.4	44.6	43.0
(a) Total costs	66.0	73.4	71.4
S.E.	(2.4)	(3.5)	(3.6)
(b) Beet Sales	93.9	104.7	103.2
Net margin (b) - (a)	27.9	31.3	31.8
S.E.	(3.8)	(4.9)	(2.9)

* Adjusted for residues

‡ Including regular labour on piecework

Distribution of net margins per acre

	Number of farms		
£50 and over	2	3	2
40-49	3	7	3
30-39	3	3	7
20-29	5	4	5
10-19	4	1	4
0-9	2	1	1
Negative	0	3	0

Table B.4 Factor costs

average per acre

	All districts
	£
Seed	2.7
Fertiliser*	8.8
Sprays	1.3
Contract	7.4
Manual labour	20.8
Tractor power	6.9
Machinery	6.2
Rent and drainage rate	7.2
General overheads, 15%	9.2
Total costs	70.5
Net margin	30.4
Beet sales	100.9
Credit for tops	2.3

* Adjusted for residues

Table B.5 Operational costs (by district)

Overall averages p.acre

District	Norfolk	Suffolk	Fens
	£	£	£
Stubble cultivations	0.9	0.5	0.2
FYM and application	2.1	2.5	0.7
Salt or kainit, and application	2.2	1.0	-
Ploughing	1.4	1.8	1.7
Seedbed cultivations	1.3	1.4	1.7
Fertiliser*	6.4	7.5	7.8
Applying fertiliser	0.6	0.5	0.6
Seed	2.4	2.9	2.9
Drilling	1.4	1.1	1.0
Rolling (post-drilling)	0.1	0.1	0.1
Hand thinning	7.5	8.3	7.7
Machine thinning	-	0.2	0.1
Tractor-hoeing	2.6	2.7	2.6
Hand-hoeing	1.3	3.2	3.4
Spraying	1.7	1.5	1.5
Total pre-harvest costs	31.9	35.2	32.0
Harvesting	12.3	13.8	12.1
Transport (inc. loading)	7.7	8.7	8.2
Rent (inc. drainage rate)	5.5	6.1	9.8
General overheads, 15%	8.6	9.6	9.3
Total costs	66.0	73.4	71.4
Yield of dirty beet, tons per acre	16.5	18.3	19.7

* Excluding FYM, salt and kainit; adjusted for residues

Table B.6 Labour and tractor requirements* (by district)

Averages per acre‡

District	Norfolk			Suffolk			Fens		
	man hrs	tractor hours	no.of times	man hrs	tractor hours	no.of times	man hrs	tractor hours	no.of times
Stubble cultivations	1.6	1.6	2.8	(1.5)	(1.5)	1.4	(1.5)	(1.5)	1.2
Applying FYM	(4.8)	(4.0)	1.0	(3.9)	(4.7)	1.0	(2.5)	(2.5)	1.0
Applying salt or kainit	(0.4)	(0.4)	1.0	(0.3)	(0.3)	1.0	-	-	-
Ploughing	2.1	2.1	1.0	2.3	2.3	1.2	2.2	2.2	1.0
Seedbed cultivations	1.8	1.8	3.9	1.6	1.6	3.8	2.5	2.5	4.5
Applying fertiliser	0.8	0.8	1.3	0.8	0.7	1.3	1.3	0.9	1.1
Drilling	1.4	1.1	1.0	1.0	0.8	1.0	0.9	1.0	1.0
Rolling	(0.5)	(0.5)	1.0	(0.3)	(0.3)	1.0	(0.5)	(0.4)	(1.0)
Hand thinning	18.6	-	1.0	16.6	-	1.0	23.5	-	1.0
Machine thinning	-	-	-	(1.3)	(1.3)	1.7	(3.4)	(3.4)	3.0
Tractor hoeing	5.1	3.4	3.7	5.5	3.1	3.4	5.1	3.2	3.3
Hand hoeing	10.0	-	1.0	21.2	-	1.0	12.8	-	1.3
Spraying	(0.6)	(0.6)	1.0	(0.3)	(0.3)	1.0	0.6	0.5	1.2
Pre-harvest total	41.4	10.8	x	49.0	8.5	x	48.9	10.3	x
Hand harvesting	(36.8)	-	1.0	(120.0)	-	1.0	(34.6)	-	1.0
Machine harvesting	16.8	15.6	1.0	17.3	16.0	1.0	16.9	15.5	1.0
Loading for factory	1.3	1.3	1.0	2.2	1.8	1.0	3.8	(1.8)	1.0
Transport to factory (own lorry or trailer)	5.6	-	1.0	4.8	(6.3)	1.0	5.3	(17.0)	1.0
Harvest total	23.7	16.9	x	24.3	17.8	x	26.0	15.5	x
Total	65.1	27.7	x	73.3	26.3	x	74.9	25.8	x
Average yield dirty beet (tons)	16.5	x	x	18.3	x	x	19.7	x	x

* Totals do not include the bracketed figures

‡ Averages for farms reporting

Appendix C

Notes on the costing method

Labour was charged at 5/3 per hour for regular men, 3/9 per hour for women, and 3/3 for boys, plus 1d. per hour for every 5s. per week above the standard rate.. The basic rates are composite figures which allows for a proportion of overtime, as well as holidays and national insurance payments.

Tractors were costed at the following hourly rates, which include depreciation, fuel and oil, and repairs.

small wheeled	4s. per hour	small crawler	10s. per hour
large wheeled	5s.6d " "	large crawler	17s.6d " "

Farmers' own lorries used for hauling beet to the factories were costed individually, sharing overheads (inc. repairs) on the basis of annual mileage covered on different jobs. The depreciation rate used was 25 per cent., reducing balance method.

Non-specialised machinery was charged at standard rates, per acre or per hour, as follows:

	Per acre
ploughs	6s.
cultivators	2s.
discs	2s.6d.
harrows	1s.
rolls	9d.
rotary cultivators	11s.
fertiliser distributors	2s.9d.
" spinners	1s.
sprayers	2s.6d.
F.Y.M. spreaders	5s.
steerage hoes	3s.
	Per hour
foreloaders	2s.6d.
elevators	2s.
trailers	1s. (6d. if mainly stationary)

Specialised machines were costed individually, using the following depreciation rates (reducing balance):

Drills, and lifting ploughs or squeezers	20 per cent
Harvesters, thinners, cleaner-loaders	25 per cent

Repairs and replacements were brought to an annual basis where necessary. Where a farm had more than one machine of a particular type, the one used in the selected field was costed.

Seed, fertiliser and spray materials were charged at cost (net of subsidy, in the case of fertilisers) except that fertiliser residues brought forward or carried forward (1 year only) were estimated as one quarter the cost of compounds and straights (exc. nitrogen, and kainit)

Farmyard manure was charged at 15s. per ton, to cover the cost of nutrients, but the total costs, including application, were spread over two years. Similarly half the costs of farmyard manure applied in the previous year was brought forward; where information on application costs was not obtainable from the current years record, the survey average was used. A similar procedure was used for lime and slag, except that materials were charged at cost, and total costs spread over 3 years. Contract costs were also spread over the appropriate number of years. Average costs were based on the total beet acreage, not only where applied.

Rent was the actual amount paid per acre, or in the case of owner-occupiers, an estimate of local market value. Drainage rate was added where paid.

General farm expenses not allocated by the costing method were charged at 15 per cent. of total allocated costs. The addition is intended to allow for such items as labour time lost owing to bad weather or mechanical breakdown, labour employed on general maintenance such as hedging and ditching, and miscellaneous costs such as office expenses. A check made recently using data from the

Farm Management Survey showed 15 per cent of allocated costs is a reasonable average addition.

<u>Value of tops</u> was excluded from output figures, but the valuations shown separately in the tables were estimated as follows, based on half the weight of clean beet per acre:

ploughed - in,	5s. per ton
fed,	10s. per ton

Printed by Saffron Press Ltd., Saffron Walden, Essex.