THE WEST OF SCOTLAND AGRICULTURAL COLLEGE

TOMATO TRAINING SYSTEMS

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INTRODUCTION

In horticulture as in many other industries, the costs of production keep on rising faster than profits, so that more and more ways have to be found of increasing yields and reducing production costs. In recent years, tomato growers have appreciated the technical and financial advantages of controlling the environment in which the plant grows and, while there has been some realisation of the financial advantages of controlling other inputs such as labour, growers have been reluctant to make changes, unless they could be quite certain that they would be beneficial.

The most time-consuming operation in tomato growing is training the plants, and in recent years a number of new systems have been developed in order to reduce the time taken for this work. Various trials of these have been made in different parts of the country but no system has emerged as being predominantly better than the others. Clyde Valley growers have tried one or more of the new methods, but comparable information was not available under local conditions.

The only way by which a really accurate comparison can be made between systems is by carrying out controlled experiments in a glasshouse where the management and all the conditions are the same for each treatment, and the only difference is the system of training. Such conditions cannot easily be found in commercial glasshouses, but it was considered that a guide to the economy of different training systems might be obtained by applying work study techniques to the operations on holdings where new systems were being practised and comparing the performance data.

THE INVESTIGATION

The following training systems were examined, and the type of house in which they were carried out is also shown:

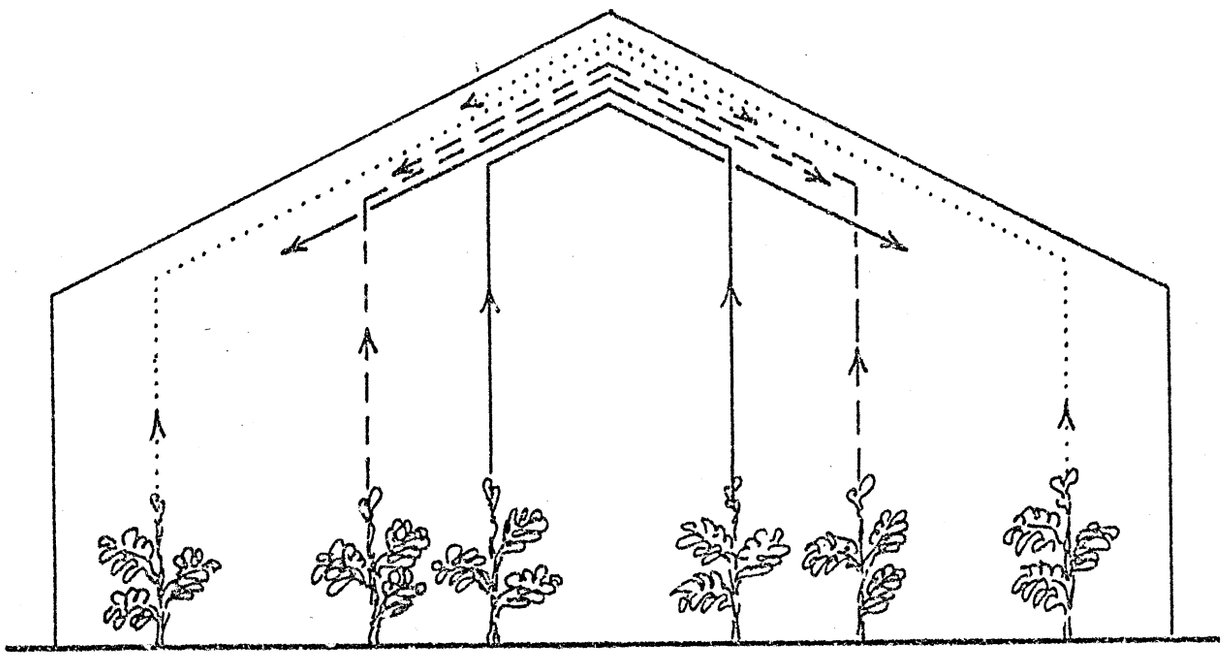
	System	House
1.	Traditional	Traditional (16 ft. wide) (4.88m)
2.	Layering	Venlo
3.	Arching	Traditional
4.	Cordon	Traditional

In order to ensure that the methods are clearly understood a description of each system follows:

The Systems:

Figure 1 TRADITIONAL SYSTEM

Cross section of house

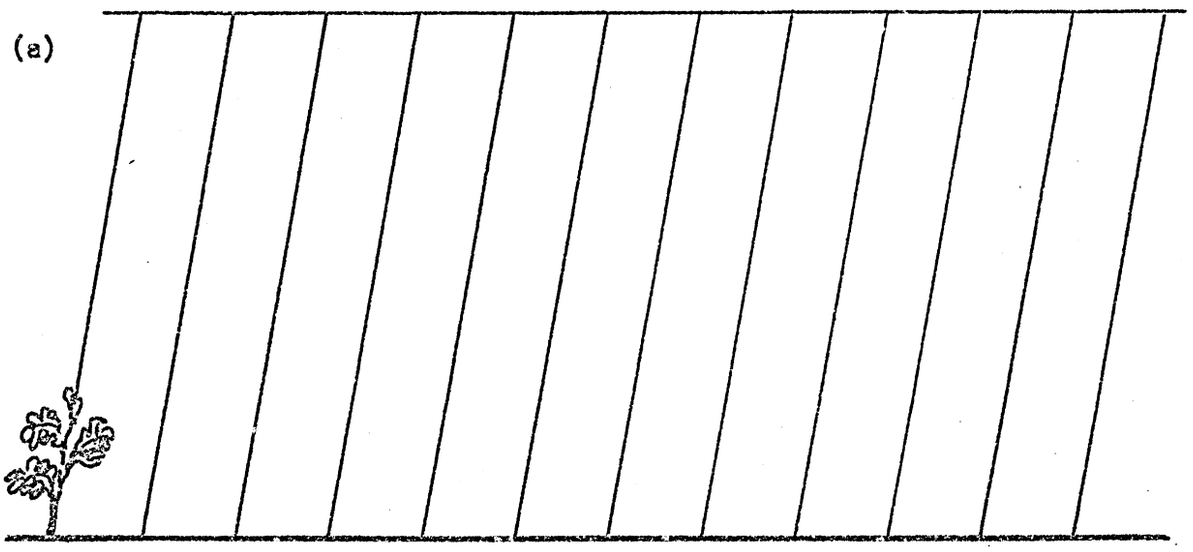


1. Traditional In the traditional systems, the plants were set out in three rows on either side of a central path in a 16 ft. (4.88m) wide house. The height of the house was about 4 to 5 ft. (1.22-1.52m) at the eaves and about 9 ft. (2.74m) at the ridge. The plants were strung by fastening a length of twine to the plant and tying it to a wire vertically above it which ran the length of the house, about 6 inches below the roof and was supported from it. The plants were trained up the strings and when they reached the wire they were trained on cross strings up and across the roof, see Figure 1. At the centre of the house below the ridge, plant stems crossed the wires in opposite directions and foliage at this part tended to be very thick. The house was a high one, higher than some traditional houses, and consequently, training and picking the centre rows had to be carried out standing on a bench.

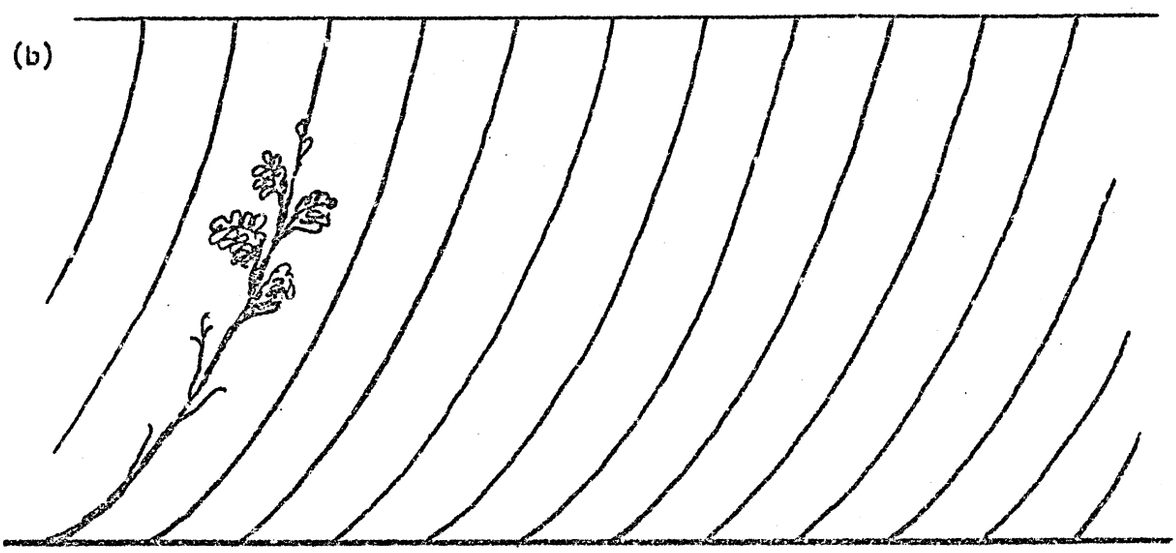
Figure 2

LAYERING SYSTEM

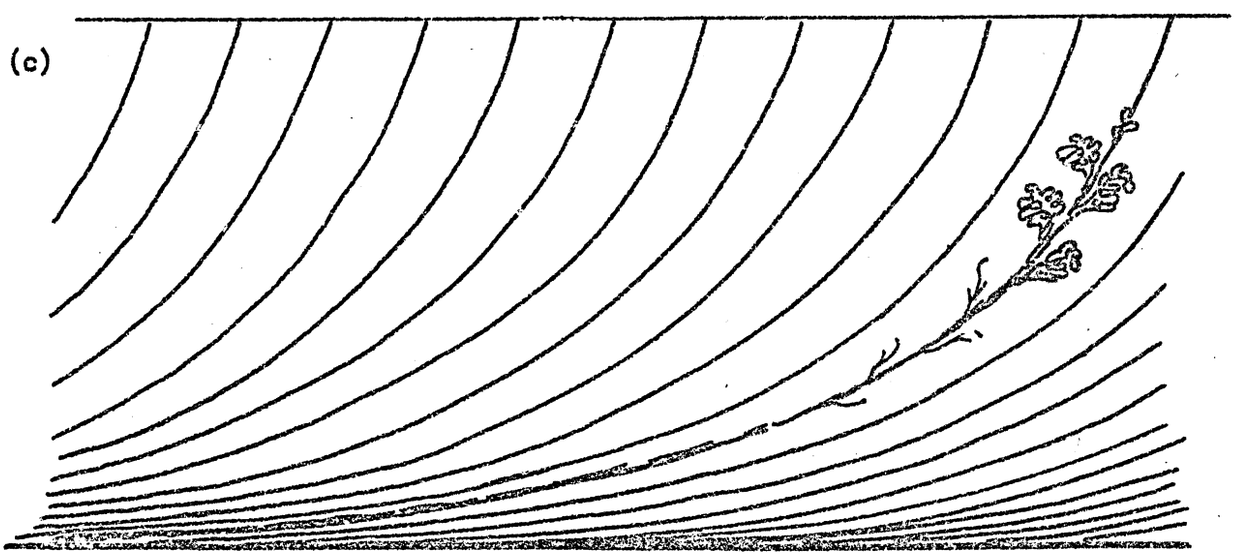
Sideview of plant row



At stringing



1st drop

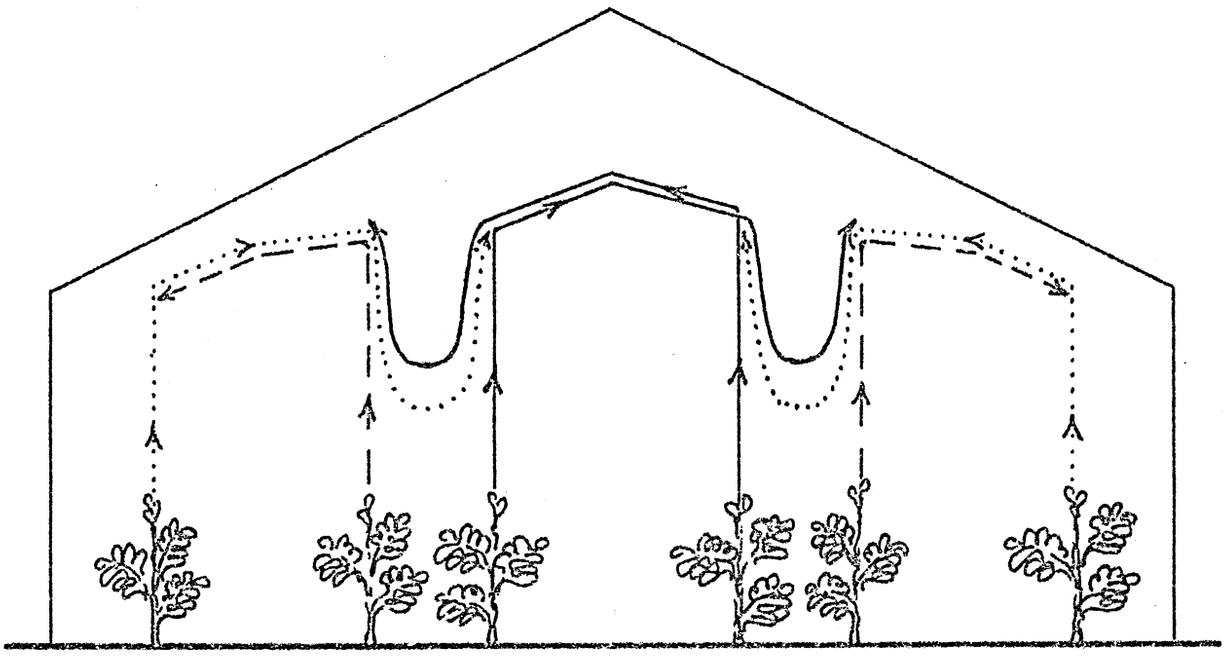


Final drop

2. Layering The plants were set out in 12 ft. (3.66m) wide venlo houses in four rows per house. A string was fastened to each plant and tied to the wire by a slip knot, each knot being directly above the next plant in the row. This gave the plant an initial inclination so that when it was later dropped, it was considered to be less liable to damage than if it had been set vertical, see Figure 2(a). When the plant head had reached the wire - a height of about 7 ft. 6 ins. (2.29m) - the slip knot was undone, the heads were lowered about 18 inches (46cm) and the string moved 2 to 3 ft. (61 to 91cm) along the wire and retied. The basal part of the stem lay near the ground and the rest, twined on the string, formed an arc from the wire, see Figure 2(b). When the plant heads again reached the wire they were again dropped. This process was repeated as required, amounting in all to about six drops in a season, see Figure 2(c). The original string was long enough to allow for the first drop but thereafter an additional length of string was tied to the existing piece at every alternate drop. At the end of a row of plants the stems were carried round to the next row, with the effect that rows were strung in pairs, with a path between each pair.

Figure 3 ARCHING SYSTEM

Cross section of house

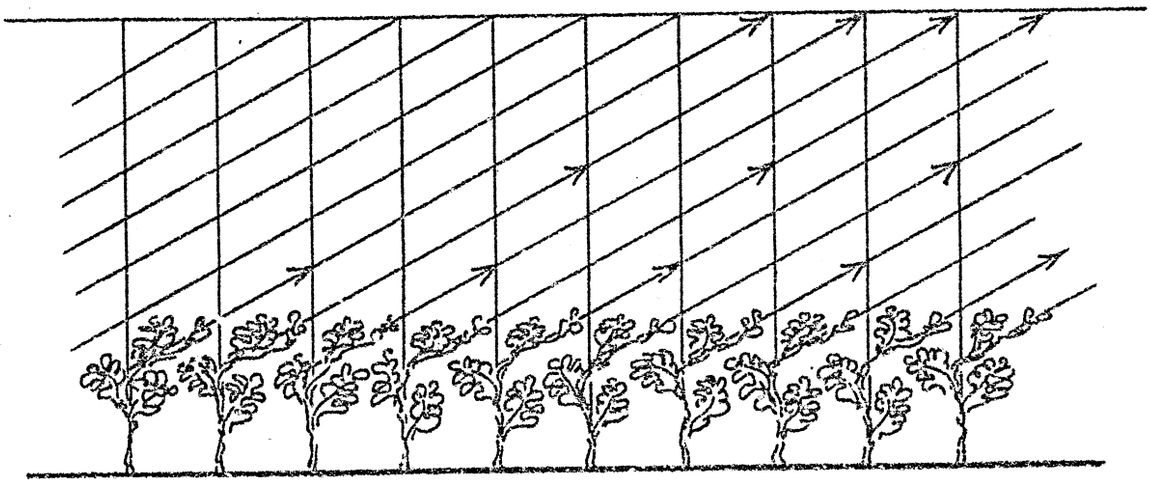


3. Arching - Improved Guernsey System In this system each plant was trained up a string as in the traditional method until it reached the wire. It was then trained along a cross string over the next wire to the 3rd wire and the head was tied to this wire using a slip knot. When the stem had grown sufficiently the slip knot was loosened and the stem dropped between wires 2 and 3, the head again being tied to wire 3. This process was repeated at intervals until the plant was stopped.

In the traditional house, where this work was studied there were three rows of plants on either side of the central path. The outside rows on each side of the house were trained over the mid row wire and the loops dropped between the mid and centre rows on the same side of the path. The centre row on each side was trained over the opposite centre row wire so that the loops hung between the centre and mid rows on the opposite side of the path, the head being led to the mid wire. Training the plants in the mid row presents a difficulty in the traditional house. In this case, they were trained over an extra wire running between the mid and outside rows, and were tied to the outside wire and thereafter trained along it.

Figure 4 CORDON SYSTEM

Sideview of plant row



4. Cordon In this system, the plants were set out in 3 rows in each bed on either side of the central path as in the traditional system. Each plant was strung to the top wire in each row in the normal way. Strings were then tied to each vertical string at about 18 inches (46cm) from the ground and were led diagonally upwards, and tied to each of the vertical strings until they reached the top wire at the 7th or 8th string from the plant. The top wire was about 6 ft. 6 ins. (198cm) from the ground. This formed a network of vertical and diagonal strings. As the plant grew, it was trained up the diagonal string, and if growth still continued after it had reached the top wire, it was trained along the top wire. At the end of the mid and centre rows the stems were trained round to the next row while in the back row plants were trained to the eaves and then diagonally up the roof.

Study Procedure

The work involved in each system was observed at intervals throughout the growing season. Time studies were made of all the operations concerned so as to cover the variations which might occur at different stages of growth and at different periods of the year.

Training was the principal job studied, but leafing, picking and clearing the house were also observed because the method of training could affect the time required to carry them out. Observations began at the first training operation after the initial stringing, because up to that point the work was the same for all training methods, and they continued until the houses had been cleared. Spraying and other disease control measures were not specially observed.

The Model Systems

From the information obtained the time taken to complete the various operations on each holding was calculated. In order to make a true comparison of the different systems every factor in production - glasshouses, layout, management, variety, feeding, work method, yield - should be identical for all systems and the only variable should be the method of training. Clearly such a situation would not be found in commercial nurseries, so in order to obtain the correct comparison, a model was drawn up of four hypothetical houses, one for each system, in which all conditions but the training system were identical. The following specifications were assumed:

1.	House:	100' x 16' (30.48 x 4.88m)
2.	No. of Plants:	450 per house
3.	Yields:	337 baskets of 12 lb. (5.4kg) each of which 95% was saleable. This is equivalent to a saleable yield of 200 12 lb. (5.4kg) baskets per 1,000 sq. ft. (93 m^2)
4.	Plants' first stringing began:	Mid March
5.	Crop Finished:	Mid October
6.	Intervals between training:	10 days
7.	No. of trainings in season:	17
8.	No. of Leafings in season:	8

The 100' x 16' house was chosen, since the majority of glasshouses in the area are of the traditional type. The operations required to be done over the season were set out and the relevant times taken for these were applied to the appropriate house and the total time taken for each system calculated. Details were shown in Appendix I.

THE RESULTS

In setting out the results of the investigation, training and leafing are shown combined. In the later stages of the arching system the two operations were combined and could not be shown separately. The estimated times taken for training and leafing are shown in Table I.

TABLE I

Training and Leafing

	System		Estimated time per annum - Hours per 100 ft. (30.48m) house
1.	Traditional	High House	136
		Low House	118
2.	Layering		72
3.	Arching		54
4.	Cordon		58

In the house in which the traditional method was carried out, the later stages of training were done standing on a bench. From other information available (1) a calculation was made of the time that would be taken if the wires were lowered so that all the work could be done standing on the ground - shown as Low House.

It is difficult to make an accurate estimate of the time required for picking, but in order to do so certain assumptions have been made. It is assumed that the total year's crop will be 337 12 lb. (5.4kg) baskets and, based on information available (2), that 70% of this will be picked before 31st July and 30% thereafter. It may be taken that after that date some picking will be at a height of about 6 ft. or over, and will therefore require a longer time per lb. than fruit picked at an earlier stage. The average time taken to pick a 12 lb. (5.4kg) basket over these stages of growth was ascertained and Table II shows the estimated time required per annum for each system, based on the above assumptions:-

TABLE II

Picking

	System		Estimated time per annum - Hours per 100 ft. (30.48m) house
1.	Traditional	(High House)	28
2.	Layering		25
3.	Arching		26
4.	Cordon		22

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(1) Glasshouse Tomato Growing. A Study of Stringing Tomatoes West of Scotland Agricultural College, Economics Department, Report No. 62, 1960.

(2) Tomato Costings. 1962, 1963 and 1964 Crops. A.S. Horsburgh, West of Scotland Agricultural College, Economics Department, Report No. 104, 1965.

Estimates were made of the time taken to clear the houses, but these are not all comparable, as the care which was taken to avoid disease infection differed with different managements. The traditional and layering systems were carried out on the same nursery, and after cutting and removing the stems, the plant roots were dug out by hand. The estimated time taken for clearing a 100 ft. (30.48m) house was as follows:

1.	Traditional	(High House)	10.25 hours/an.
2.	Layering		6.25 " / "

In the other two houses, plants were pulled out of the ground, cut down from the top, bundled and taken outside for burning and disposal.

The estimated times taken per 100 ft. (30.48m) house were as follows:

3.	Arching	3.1 hours/an.
4.	Cordon	1.4 " / "

DISCUSSION

The results given show the effect of the different training systems on the labour requirement, but this is not the only criterion by which a system should be judged and some of the other factors concerned must be mentioned.

The varieties of tomato grown must be considered, as some may be more suitable than others for a particular training system. For example, shortness of internodes may have an advantage in the cordon system where a long stem is difficult to train after it has reached the top wire. The time of maturity of varieties may be important and these aspects have to be balanced against probable yield. The varieties grown in the nurseries visited are shown in Appendix III. It was not possible to deduce any differences between these varieties in their suitability for different systems.

No information was available on the interaction of the different systems with yield. This may, to some extent, be bound up with the suitability of a variety for the system of training.

None of the nurseries visited were entirely free from disease, but, since different emphasis was placed on disease prevention in each, the incidence of any disease could not be attributed to the training system.

The choice of a training system also depends to a large extent on what is most suitable for the conditions on the individual holding and the facility with which the individual grower can operate a particular method.

The traditional system required the greatest amount of labour for training, picking and house clearing - considerably more than any of the other systems. Probably its main advantages are the growers' familiarity with the system and the ease with which it fits in the traditional 16 ft. wide house.

In labour requirement, the layering system took less than the traditional, but a little more than the other two systems. A modification of the layering system has recently been developed. S hooks are hung on the top wire and the strings from each plant, looped at the end, are hung on the S hooks instead of being tied to the wire with a slip knot. This is said to facilitate moving the strings when dropping the plants, and will, no doubt, reduce the time taken for this work. The layering system is suited to a modern type of house where tomatoes are grown in rows with a pathway between each pair. It is not well suited to the traditional type of house where the height of the house to the eaves is only four or five feet, as the stringing of the back rows presents a difficulty. One problem with this method of training is that as the plants grow the stems lie on the ground alongside each other, and this may well become a predisposing cause of disease. Another disadvantage is than when dropping the plants, the whole weight of each plant has to be held in one hand while the string is being tied with another. This tends to add to the fatigue in this operation. Where this S hook method is used this is avoided.

There was little to choose in labour requirement between the arching and cordon systems. In the arching system the work of training is quite considerable up to the time the plant head is tied across to the next wire, but once a start has been made to drop the stem between rows, no further twisting is required. Although the method was being operated in a traditional house, it could be carried out more easily in a modern house.

Apart from the low labour content, one of the advantages of the cordon system is that the cordon stringing can be done in the early part of the season before work with the tomato crop becomes heavy. Once the cordon strings are fixed, the only training required is to deshoot, and twist the stems round the strings, so that the summer work load is reduced. Plants are usually spaced 15 to 16 inches (38 to 41cm) apart, and the slope of the cordon string can be set as required by adjusting the horizontal distance between the end of the string and its origin at the plant. If the slope is too steep, the plant tends to reach the top too early and must then be trained along the wire, or across to the next wire, thus defeating some of the advantages of the system. If the cordon string is set at too gradual a slope the plant stems run too close together and plant growth is checked. To overcome these difficulties a modification of the method observed may be used. In this method the diagonal strings are set initially at 45°. When the plant head approaches the top wire, each diagonal string is unfastened at the top and another piece of string added to it. The lower end of each plant is pushed down the vertical strings, so that the angle becomes less than 45°. An angle of 45° is maintained at the upper end of the plant by moving the string along the top wire and retying it. A disadvantage of the cordon system is said to be that if disease affects some of the plants near the top, spores can fall and infect the plants below. Like the layering system, it can be carried out more easily in a modern house.

CONCLUSIONS

To sum up, it is found that the traditional system of training tomatoes requires a considerable amount of labour compared with modern methods. There is not very much to choose between the other three systems examined and the choice may well depend on which system best suits the conditions on the holding. The modern systems fit best in modern tomato houses, because the rows of plants can conveniently be worked in pairs. In the traditional houses some makeshift arrangement is required at the low back row and the existence of three rows of plants in a bed complicates the method. In choosing a system of training, the probable effect of the system on yield, time of maturity and on the incidence of disease must be considered, and it may well prove that certain varieties are better suited to certain systems than others.

Few growers keep records of the kind of information needed to make comparisons of different work systems, and as a result, detailed and time-consuming studies have to be made to ascertain the data required for evaluation. If growers need information on different work methods, they could contribute much by keeping simple records of work done and time taken, which would make it possible to compare results on a wider basis. Such simple record keeping would result in a better understanding and assessment of work methods and would lead to better control of production costs.

Acknowledgements

The authors wish to express their gratitude to the growers on whose holdings the observations were made for their help and patience during frequent visits. They are also grateful to the Horticultural Advisers in Lanarkshire for much help and advice and to the Lanarkshire growers' study groups for useful comments.

APPENDIX I

TRAINING AND LEAFING

1. Traditional System

		Minutes
Twist and deshoot	1st stage, to 5' (152cm) 6 times x 114 min/house	684
Leaf	1st stage, 3 times x 133.2 min/house	400
String Roof	1 x 240 min/house	240
Twist and deshoot	2nd stage, 5' to 8' 6" (152 to 259 cm) 4 times x 182 min/house	728
Leaf	2nd stage and 3rd stage, 5 times x 242 min/house	1,210
Twist and deshoot	3rd stage, on roof 7 times x 702 min/house	4,914
	Total	8,176

= 136 hours per annum

2. Layering

		Minutes
Twist and deshoot	1st stage, up to 5' (152cm) 6 times x 114 min/house	684
Leaf	1st stage 1st time @ 122 min/house	122
	2nd and 3rd times x 237 min/house	474
Twist and deshoot	2nd stage, 5' to 7' 6" (152 to 229cm) 5 times x 120 min/house	600
Drop strings, twist and deshoot	at 7' 6" (229cm) 1st time x 150 min/house	150
	2nd and 3rd times @ 167 min/house	334
Add string, drop, twist and deshoot	at 7' 6" (229cm) 3 times x 263 min/house	789
Leaf	2nd stage 5 times x 237 min/house	1,185
	Total	4,338

= 72 hours per annum

3. Arching

		Minutes
Twist and deshoot	1st stage, to 4' 3" (129cm) 5 times x 114 min/house	570
Leaf	1st stage, to 5' (152cm) 3 times x 133.2 min/house	400
Twist and deshoot and string roof, back to mid row	2nd stage, 4' 3" to 6' 6" (129 to 198cm) 1 x 123 min/house	123
Twist and deshoot and string roof, mid to back row	2nd stage 1 x 123 min/house	123
String centre roof	1 x 103 min/house	103
Twist, deshoot and leaf	2nd stage 2 x 102 min/house	204
Leaf	2nd stage at 6' 6" (198cm) 1 x 110 min/house	110
Deshoot, leaf and tie heads	3rd stage, at roof 1 x 184 min/house	184
Deshoot, leaf, tie heads and drop	3rd stage, at roof 1st time x 232 min/house 2nd time x 264 " / "	232 264
Deshoot, leaf and drop stems	4th stage, at loop 5 x 186 min/house	930
	Total	3,243

= 54 hours per annum

4. Cordon System

		Minutes
Twist and deshoot	1st stage, up to 2 ft. (61cm) 1 x 114 min/house	114
Cordon stringing	1 x 300 min/house	300
Training Tomatoes	2nd stage, up to 5 ft. (152cm) 8 x 121 min/house	968
Leafing	1st stage, up to 5 ft. (152cm) 4 x 133 min/house	532
Training Tomatoes	3rd stage. Above 5 ft. (152cm) 8 x 126 min/house	1,008
Leafing	2nd stage. Above 5 ft. (152cm) 4 x 139 min/house	556
	Total	3,478

= 58 hours per annum

APPENDIX II

PICKING

Assume — 2nd early crop saleable yield 200 x 12 lb. baskets/1,000 sq. ft. ($93m^2$).
5% substandards at grading.

For 1,600 sq. ft. ($149m^2$). Saleable Yield = 320 baskets

= 95%

100% = 337 baskets/an.

Before 31st July 70% = 236 baskets/an.
After " " 30% = 101 " "

1. Traditional System

	Minutes
236 baskets x 4.1 min/basket	967.6
101 " x 6.6 " "	666.6
Total	1,634.2

= 27.2 hours

2. Layering

236 baskets x 4.3 min/basket	1,014.8
101 " x 5.1 " "	515.1
Total	1,529.9

= 25.5 hours

3. Arching

236 baskets x 3.7 min/basket	873.2
101 " x 6.7 " "	676.7
Total	1,549.9

= 25.8 hours

4. Cordon System

236 baskets x 3.6 min/basket	849.6
101 " x 5.1 " "	515.1
Total	1,364.7

= 22.7 hours

APPENDIX III

VARIETIES GROWN

	Training System	Varieties
1.	Traditional	Moneymaker
2.	Layering	Moneymaker. Eurocross B.B. and a few other crosses.
3.	Arching	Mostly Eurocross B.B.
4.	Cordon	Eurocross B.B. and Moneymaker.