A TIME MEASUREMENT STUDY: BENCH GRAFTING OF WOODY PLANTS UNDER GLASS

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INTRODUCTION

This study was made during my employment in the Ministry of Agriculture, Fisheries and Food when I was employed as a Horticultural Advisor. All the time studies referred to here were made on the nursery of Messrs. John Waterer Sons and Crisp and I would like to thank the management and staff for allowing me to undertake this work and to submit this paper to the I.P.P.S.

The reasons I chose to study bench grafting were that, as an area of work, it seemed to be unduly complex and time consuming in terms of output.

My objectives were to: (1) Eliminate unnecessary work; (2) To simplify the process; (3) To make it a more pleasant job; (4) To speed up work throughout.

The first question to be asked is—what is the end product? In this case, a grafted plant in a closed frame is required and all work must therefore be directed towards reducing the time taken to achieve this end; in so doing, one must eliminate or simplify the job elements. Any alternatives should be judged on efficiency and convenience and on improved technique. Eight plants were studied in detail: *Hamamelis, Fagus, Prunus* (2 species), *Clematis, Picea, Hibiscus,* and *Cupressus;* three others—*Cedrus, Wistaria, Betula*— were studied briefly.

Time study observations were made with a "split-action stop watch" (Heuer Taylor—costing £25). The watch has 2 hands of distinguishing colours; the small left-hand push-button stops one hand whilst the other hand continues. When the push-button is pressed again the stopped hand catches up with the one still recording. To stop or start both hands simultaneously the winding button is pressed consecutively It is easy, therefore, to take cumulative times without the need for subtractions at the end of the study. This is known as "fly back timing".

Times shown here can only be taken as a guide and should not be taken as a true indication of time taken to graft any particular subject or of the time difference between one species and another. Every worker will vary in his dexterity according to the ergonomic circumstances in which he operates and the materials with which he has to work. Basic times for each operation can be obtained if the rate of each person's working performance is taken into consideration before meaningful times are given.

Obviously an initial study such as this taken on only one nursery *with observations made on just 4 workers cannot make this a complete* time study of bench grafting under glass. In view of the many details recorded for each study I will confine my main remarks to *Hamamelis mollis* grafting and then finalise with specific tables and general comments covering all species studied.

Grafting Hamamelis. *Hamamelis virginiana* stocks are purchased from U.S.A. one year prior to grafting and potted up into 3½ inch clay pots. During the first week in January these are brought into a glasshouse at a temperature between 50° F. and 70° F. and stood on solid benches 39 inches high. The bench surface is covered with 2½ in. of sphagnum peat. Stocks are grafted two weeks after bringing into the glasshouse. Scions are collected by the foreman and cut into common lengths of 4 to 6 inches, having 2 buds on each scion. The stock is cut 1½ inches from the base to which a scion with a ½ inch long sloping cut is joined to form a side graft and then tied with raffia.

If one examines the job elements, from picking up the potted rootstock to putting down the English light on the frame, there are 10 operations, 2 inspections, 6 transports, 3 storages and 8 delays (see Appendix No. 1). Quite a formidable list, but from such an observation, key operations can be picked out and a calculation made of the number of observations needed on each of these to obtain a true picture (see Appendix No. 2.). An example of a time study recording sheet can be seen in Appendix No. 3.

When the recordings necessary for a reliable time study have been taken and when the man being studied has been rated, a calculation for basic time can be made To obtain basic time, multiply observed time by the rating factor and divide by 100; e.g. observed time = 0.50 mins., rating factor = 70: $\frac{0.50 \times 70}{100} = 0.35$ Basic Time = 0.35 mins.

Basic time is the time necessary for carrying out an element of work at standard rating.

To find what the standard time should be for a given job one adds contingency allowance for delay, unoccupied time, and interference allowance, where applicable. A relaxation allowance must also be made before calculating standard performance. Relaxation allowance is an addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological efforts of carrying out specified work under specified conditions and to allow attention to personal needs. The amount of allowance will depend on the nature of the job. Taking bench grafting as an example the following relaxation allowances could be added to the basic time:

A.	Energy Output — very light Light bench work — standing Equivalent to handling 0-5 lbs.	6 to 7½%
B.	Posture — standing (both feet)	1 to 2½%
C.	Motions — normal	0
D.	Visual Fatigue — nearly continuous eye attention Lighting, poor variable	2%
E.	Personal Needs — Women 4% Men	2½%
F.	Thermal Conditions — normal 55° to 70° F normal humidity	0
G.	Atmospheric Conditions — good	0
H.	Other Environmental Influences Absence of company	1
	RELAXATION ALLOWANCE	12½ to 15½%

The minimum overall allowance for women is 12% and for men 10%. An improvement of 2½ to 5½% could be made if the operator is seated comfortably in a well lighted room with one or two people working nearby.

Job Breakdown. In timing *Hamamelis* grafting I found it necessary to break the job down into 14 divisions (see Appendix No. 4.). Looking more closely at these divisions there were 5 key operations which were essential to the completion of the job. Such key operations are best called "job elements" since there is a clear distinction between one element and another. These elements are:

1. Weed pot and behead stock.
2. Make sloping cut on stock.
3. Select and cut scion.
4. Join and bind stock and scion with raffia.
5. Inspect and trim completed graft.

Obviously there is a limit to the breakdown of jobs into elements and this is usually determined by the time needed to record each stage. For instance, *Element 1.* "Weed pot and behead stock" was made up of 4 parts, *a.* pick up stock; *b.* weed pot; *c.* behead stock, *d.* put down stock; but because of the time factor these had to be made into a combined element.

Furthermore, some elements are not repeated so regularly as others; e.g. 5. "Inspect and trim completed graft", only occurred in 14 out of 21 observations so the times have to be aggregated and divided by 21 to obtain the average time per plant for that element.

If one wishes to interpret these figures into meaningful cost studies, then one should remember that they only constitute one job connected with the whole grafting process. They do not take account of cutting scions, proximity to glasshouse and subsequent operations such as pot movement, ventilation, graft failures and reties, etc. However, by studying the grafting operation in depth it is easier to pinpoint limitations in the method and unnecessary labour usage. This is where "method study" comes into its own and "critical examination" begins. By minor improvements such as graded stocks and scions, clean compost to the top of the pot, the use of rubber ties, use of a swivel seat on large caster wheels, and a hosepipe gun, the whole job could be completed in 5 operations compared with 10 operations in the original method (see Appendix 5). Appendices 6 and 7 illustrate present and possible new method man type process charts.

Grafting Other Subjects:

1 *Prunus x hillieri* 'Spire'
Rootstock—roots of *Prunus avium*
Method: whip tongue graft, root wiped with rag, raffia-tied graft painted with cold wax (Creotex).
Average time for grafting, including rootstock preparation, 2.12 mins.
Rating, 55.
Basic time, 1.16 mins.
Relaxation allowance, 14%=0.15 mins.
Standard time=1.31 mins.

2 *Prunus mume* 'Beni-shi-don'
Rootstock—'St Julien' roots.
Method—whip and tongue graft, on washed roots, tied with nutscene twine.
Average time for grafting, 1.10 mins.
Rating, 100.
Basic time, 1.10 mins.
Relaxation allowance, 14%=0.15 mins.
Standard time=1.25 mins.

3. *Fagus sylvatica* 'Riversii' ('Rivers Purple')
Rootstock —*Fagus sylvatica* in pots.
Method: side tongue graft, tied with raffia.
Average time for grafting, 1.92 mins.
Rating, 70.
Basic time, 1.34 mins.
Relaxation allowance, 14%=0.20 mins.
Standard time=1.54 mins.

4. *Picea pungens* 'Glauca Pendula' ('Kosteriana')
Rootstock—*Picea abies* in pots.
Method: side veneer graft, tied with raffia, removal of needles from base of scion.

Average time for grafting, 1.41 mins.
Rating, 100.
Basic time, 1.41 mins.
Relaxation allowance, 14%=0.20 mins.
Standard time=1.61 mins.

5. *Cupressus macrocarpa* 'Donards Gold'
   Rootstock—*Cupressus macrocarpa* in pots.
   Method: side veneer graft, tied with raffia, stocks cut back to 1 foot high.
   Average time for grafting, 0.95 mins.
   Rating, 105.
   Basic time, 1.00 mins.
   Relaxation allowance, 14% = 0.14 mins.
   Standard time=1.14 mins.
6. *Hibiscus syriacus* cultivars
   Rootstock—*Hibiscus syriacus*, sections of washed roots.
   Method: veneer graft, tied with 2-ply fillis.
   Average time for grafting, 0.67 mins.
   Rating, 110.
   Basic time, 0.74 mins.
   Relaxation allowance, 12%=0.09 mins.
   Standard time=0.83 mins.
7. *Clematis* cultivars
   Rootstock—*Clematis vitalba* 3-in pieces of root.
   Method: split leaf-bud root graft, tied with very thin raffia.
   Average time for grafting, 0.69 mins.
   Rating, 105.
   Basic time, 0.72 mins.
   Relaxation allowance, 12%=0.9 mins.
   Standard time, 0.81 mins.

Discussion of Methods and Equipment Used. Observing and timing people in the working environment is fraught with hazards and this particular study was no exception. Apart from the actual job being examined it is important also to take account of other aspects, indirectly or directly affecting the welfare of the worker and his work output. The working situation here was generally poor—workers standing next to a high bench in a dripping, low-roofed glasshouse or, alternatively, sitting on uncomfortable, unadjustable seats with insufficient room for maneuverability and with a naked light bulb hanging a foot or so from their faces.

Glasshouse benches were generally too high and too wide making examination of grafts difficult. Putting down and picking up grafts was awkward and speed of throughput was limited. Bottlenecks were mainly the result of scion collection as the material always had to be obtained some distance from the propagation unit and it was very often necessary to travel long distances by vehicle.

Poor results and inconsistent quality were often due to the following:

1. Poor tying materials.
2. Bad knives.
3. Indifferent stock plants—ungraded, differing in thickness and depth in pot.
4. Scion wood not grown on plants for specific scion wood production and consequently ungraded.
5. Not enough trained staff (especially younger members).

Suggested Improvements. 1. Grow stock hedges of each cultivar for scion production and situate these close to the propagation unit 2. Grow stock plants in pots, filled to brim, making grafting easier. 3. Grade stock plants when potting off and when bringing into glasshouse. 4. Grade scions according to diameter of stock plant stems. 5. Prepare plants, materials and equipment well beforehand. 6. Teamwork is essential and the people studied could improve their performance on certain species if they worked in co-ordinated groups; e g one person preparing stock plant, one preparing scion, and another joining them together. 7 The working environment could be vastly improved if the job took place in a strip-lighted and heated room, with reasonable comfort on swivel chairs which should be adjacent to a bench of the correct height. 8. For most woody plants the knife should be sharpened on one side of the blade only. Why not use a scalpel, particularly for more delicate subjects? 9. Tying materials should be pre-cut into lengths. Materials which can be easily made into a slip knot are desirable. Rapidex rubber ties seem to have many advantages. Tying appears to take up the largest percentage of time of all the grafting operations and a close investigation of materials used, methods of tying and, indeed, the necessity for tying could prove very rewarding. A few comments have been made in Appendix 8. 10. Use secateurs whenever possible; e.g. beheading rootstock.

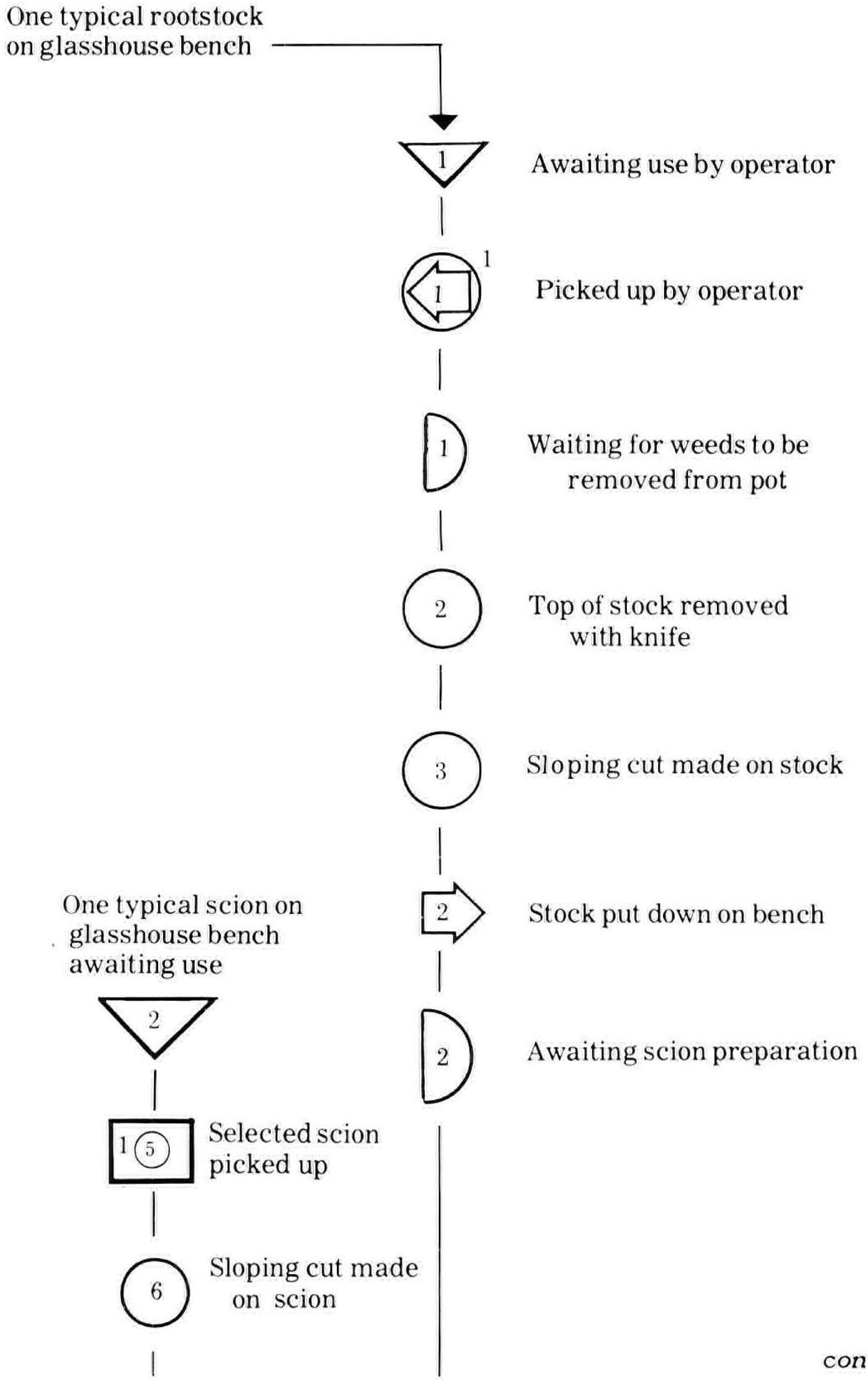
Glasshouse bench grafting is a costly technique in terms of heated glasshouse, glasshouse space and the skilled labour essential to do a worthwhile job, therefore it is important to achieve the maximum throughput with the minimum of effort and the highest percentage take. One can only achieve such high ideals by paying attention to detail, providing a reasonable working environment with the right equipment and having a nucleus of skilled, motivated workers.

APPENDIX NO. 1

PROPAGATION STUDY: *HAMAMELIS* GRAFTING, SURREY, JANUARY 1971. ORIGINAL METHOD.

FLOW PROCESS CHART (MATERIAL TYPE).

JOB: Grafting *Hamamelis mollis* scions onto *Hamamelis virginiana* rootstock.
CHART BEGINS: Potted rootstocks on bench in glasshouse.
CHART ENDS: Grafted rootstock in closed frame (case) in glasshouse.



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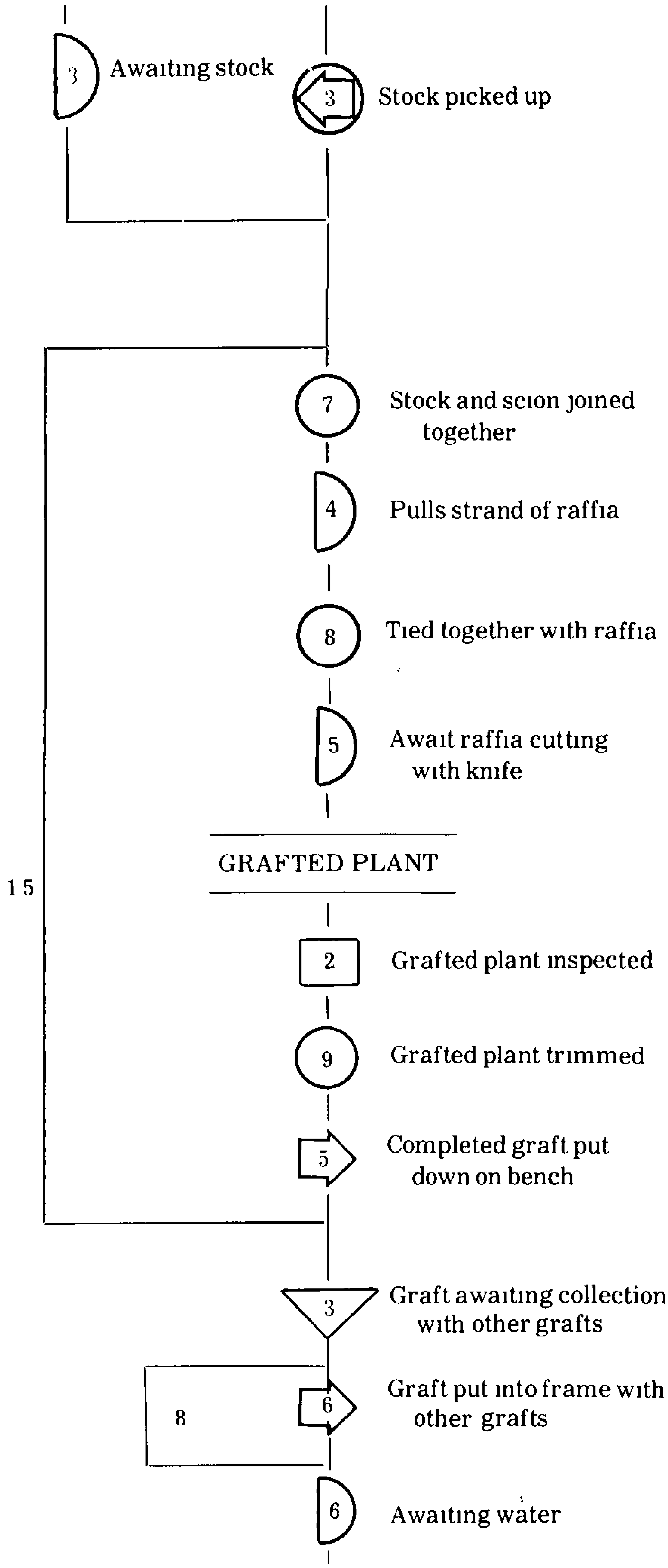

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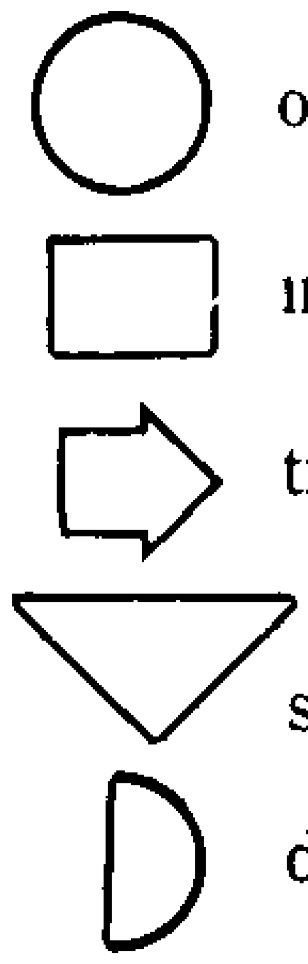
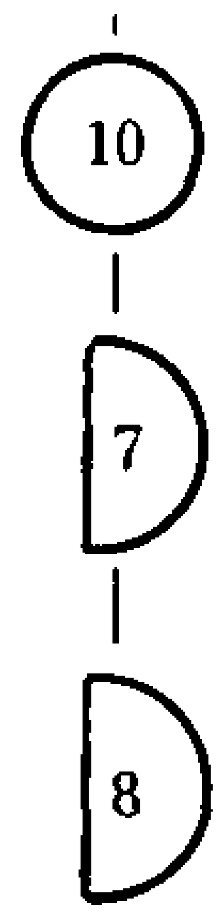
SUMMARY



operations	10
inspections	2
transports	6
storages	3
delays	8



Watered

Peat wetted in frame

Light put down on frame

APPENDIX NO. 2

CALCULATION OF NUMBER OF OBSERVATIONS NEEDED

SELECT STOCK

12 observations = total time of 1 93 mins = average time of 0 16 mins

Difference between highest and lowest observations = 0 14 mins (9 = lowest, 23 = highest)

Using $$N = \frac{(r)^2}{(0\ 077)\mp}$$

N = number

r = 14

$\mp$ = mean

$$\therefore N = \frac{(14)^2}{0\ 077) \times 16}$$

$$\therefore N = \frac{(14)^2}{(1\ 232)} = 128$$

Number of observations needed for $\pm$ 5% at the 95% confidence limits is 128

At $\pm$ 10% confidence limits is 32 observations

SLOPING CUT ON STOCK

12 observations = total time of 4 76 mins = average time of 0 40 mins

Difference between highest and lowest observations = 0 21 mins (29 = lowest, 50 = highest)

Using $$N = \frac{(r)^2}{(0\ 077)\mp}$$

$$\therefore N = \frac{(21)^2}{(0\ 077)\ 40}$$

continued

continued

$$\therefore N = \frac{(21)^2}{(3.08)} = 44.89$$

Number of observations needed for ± 5% at the 95% confidence limits is 45

At ± 10% at the 95% confidence limits is 11 observations

APPENDIX NO. 3

TIME STUDY — RECORDING SHEET:

JOB: *Grafting Hamamelis. Semi skilled male standing, operating at mobile bench in glasshouse.*

STUDY NO 1
SHEET NO 1
DATE 19 1 71
TIME OFF
TIME ON
ELAPSED TIME
RECORDER J B Gaggini

EQUIPMENT USED

Budding knife, raffia

SUBJECT *Hamamelis*

LOCATION *In glasshouse in top prop*

Element Description	R	OT	BT	Element Description	R	OT	BT
Move bench ready for grafting	70	54					
Sharpen knife		28					
Take 8 stocks out of frame		57					
Weed rootstock pot		21					
Cut stock		21					
Select and cut scion		34					
Tie raffia		53					
Pick up rootstock and cut		28					
Sloping cut on stock		25					
Cut scion		16					
Tie raffia		56					
Inspect graft and put down		20					

R = rating OT = Observed Time BT = Basic Time

APPENDIX NO. 4

JOB BREAKDOWN — *Hamamelis* GRAFTING TIME STUDY:

	Operation	No of Stocks or Observations	Average Time Per Plant / Observation
1	Cleaning weeds from pot / cutting off top of stock	3 85 mins	0 18 mins
2	Sloping cut on stock	3 30 mins	0 16 mins
3	Select and cut scion	4 79 mins	0 22 mins
4	Bind stock and scion	13 65 mins	0 65 mins
5	Inspect and trim graft	1 65 mins	0 08 mins
6	Taking stocks from frame	1 46 mins	0 05 mins
7	Putting grafts in frame	2 33 mins	0 12 mins
8	Filling jug with water	0 40 mins	0 02 mins
9	Watering peat in frame	0 66 mins	0 02 mins
10	Watering pots with jug	0 45 mins	0 01 mins
11	Putting down and covering frame	0 49 mins	0 02 mins
12	Moving grafting bench	0 54 mins	0 02 mins
13	Sharpening knife	0 28 mins	0 01 mins
14	Miscellaneous time	1 50 mins	0 05 mins
	TOTAL TIME PER GRAFT		1 61 mins

Rating = 70 $\therefore \dfrac{1\ 61 \times 70}{100}$ = 1 03 mins Basic Time

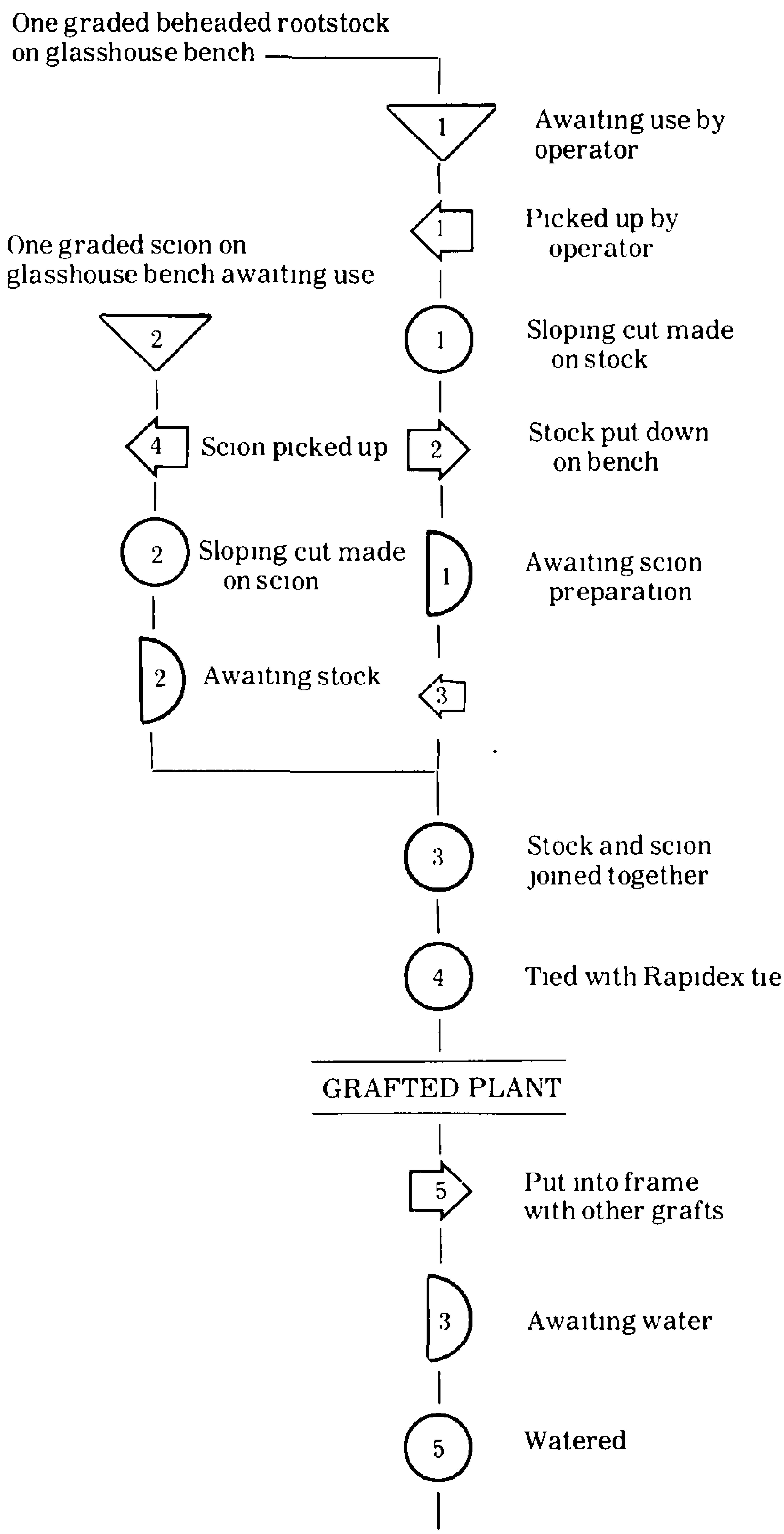
Add 14 % for relaxation allowances = 0 14 mins

$\therefore$ 1 03
0 14+

STANDARD TIME = 1 17 mins

APPENDIX NO. 5

FLOW GRAFT CHART — *Hamamelis* GRAFTING. Possible new method:



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SUMMARY

- operations 5
- transports 5
- storages 2
- delays 5

4 Peat wetted in frame

5 Light put down on frame

APPENDIX NO. 6

FLOW PROCESS CHART (Man Type):

JOB: *Hamamelis* grafting — PRESENT METHOD

CHART BEGINS Picking up rootstock

CHART ENDS Closing frame

1 Picking up rootstock

2 Removing weeds from pot

3 Cutting off top of stock with knife

4 Make sloping cut on stock

5 Put stock down on bench

1 Select scion

6 Pick up scion

7 Make sloping cut on scion

8 Join stock and scion together

9 Pull strand of raffia

continued

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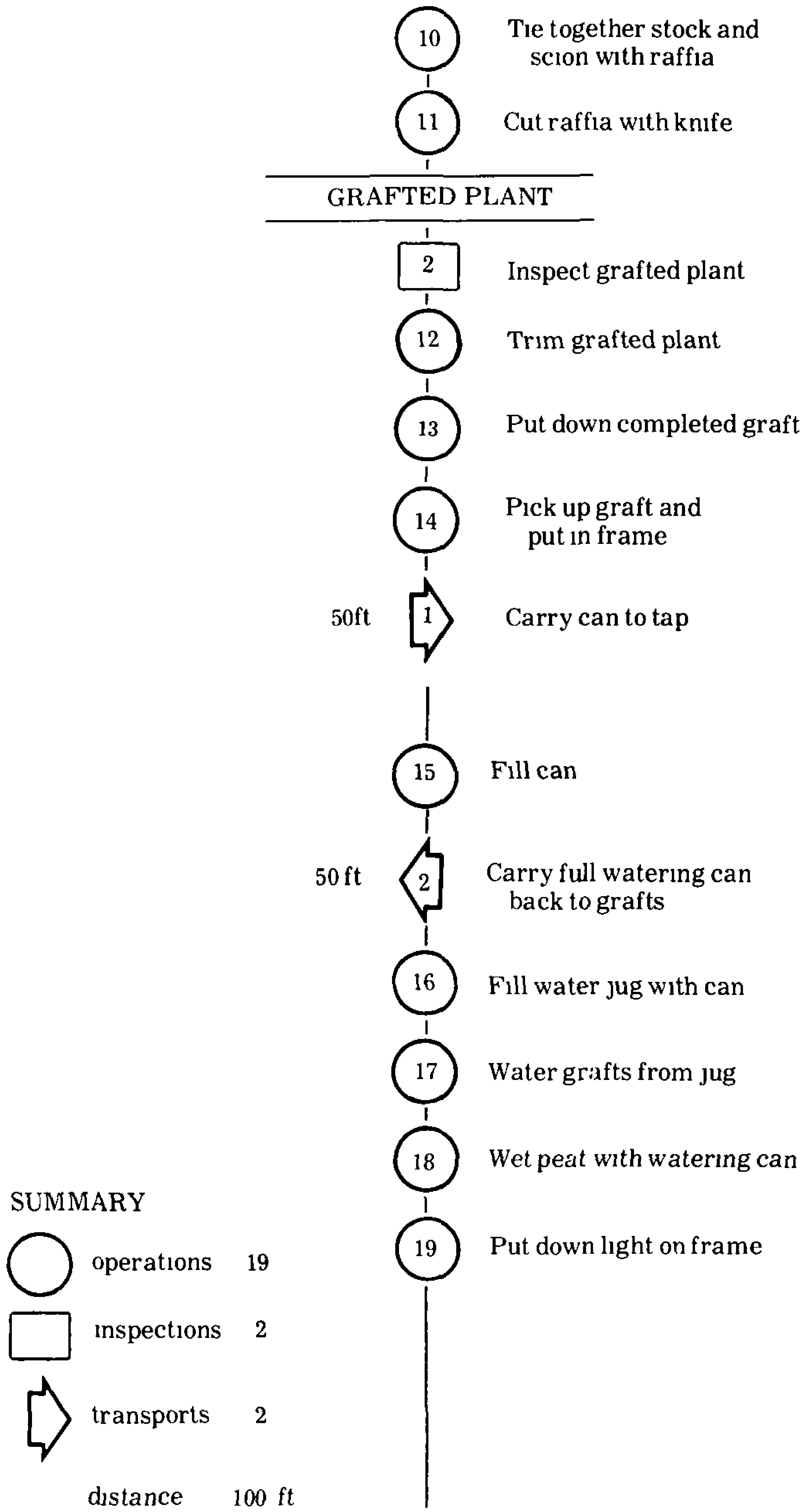
10 Tie together stock and scion with raffia
11 Cut raffia with knife
GRAFTED PLANT
2 Inspect grafted plant
12 Trim grafted plant
13 Put down completed graft
14 Pick up graft and put in frame
50ft 1 Carry can to tap
15 Fill can
50 ft 2 Carry full watering can back to grafts
16 Fill water jug with can
17 Water grafts from jug
18 Wet peat with watering can
19 Put down light on frame
SUMMARY
operations 19
inspections 2
transports 2
distance 100 ft

APPENDIX NO. 7

FLOW PROCESS CHART (Man Type):

JOB: *Hamamelis* grafting

CHART BEGINS: Picking up rootstock

CHART ENDS: Closing frame

POSSIBLE NEW METHOD

1. Pick up rootstock
2. Make sloping cut on stock
3. Put down stock on bench
4. Pick up scion
5. Make sloping cut on scion
6. Join stock and scion together
7. Tie with Rapidex tie

GRAFTED PLANT

8. Put down graft in frame
9. Water grafts and peat in frame using trigger operated hose
10. Put light down on frame

SUMMARY

◯	operations	10

APPENDIX NO. 8

TYING SCION AND STOCK TOGETHER:

Subject (stock)	Tying Material	Time Taken	Percent of Grafting Time
Fagus sylvatica	Raffia	0 83 mins	43
Hamamelis mollis	Raffia	0 65 mins	41
Picea abies	Raffia	0 53 mins	38
Prunus avium	Raffia	0 52 mins	25
Cupressus macrocarpa	Raffia	0 40 mins	42
Prunus 'St Julien'	Green twine	0 41 mins	37
Clematis vitalba	Raffia	0 28 mins	41
Hibiscus syriacus	Fillis	0 27 mins	33

COMMENTS

Slow speeds of working are due to the use of raffia which is of poor quality, breaks easily, has to be split further by the knifesman, is not cut to pre-determined lengths and is of variable thickness Good raffia at a reasonable price is a scarce commodity

Green twine and fillis is easy to use if cut to pre-determined lengths and one needs to bind it in position to obtain a similar finish to raffia tying Therefore, ease of grasp and uniform thickness of twine brings the final time taken into line with raffia

I have not considered polythene or rubber strips which seem to have certain advantages over other materials studied and have given every indication of higher percentage takes

The advantages of cutting raffia or twine to length, or having other materials of pre-determined lengths, is cancelled out if there is a wide variation in size grade of stock or size grade of scion

G. YATES: You started your study with work measurement of the existing situation. Why wasn't *method study* rather than the *time measurement* carried out first in order to cut out some of the unnecessary movement of stocks, scions and materials which you highlighted in your case study?

J. GAGGINI: You have hit the nail on the head; it could certainly be argued that this is a method study job and this should have been looked at first. My reasons for proceeding as I did were purely personal, as I wished to find the basic times for some of these traditional operations. In the Advisory Service we were being asked how many grafts should one do in a day, and we have no information from which to answer such questions. I take the point, however, that there is scope for method study here.

B. HALLIWELL: Surely it must be important to take into account the percentage of successful takes?

J. GAGGINI: Not for the actual grafting operation. You take this factor into account in the subsequent business study of the whole nursery.

J. WELLS: I spent two years at D. Hill Nursery, Dundee, Illinois, and they had a very well planned production line for grafting junipers. The jobs were divided up, with everybody sitting down in a warm place; it was a well organised unit producing a quarter of a million junipers each year. When I was there they wanted to apply the same techniques to Koster spruce and I argued against it. Tony Thomson (a member of this Region, now in Denmark) and I, grafting in the orthodox manner, averaged 700 a day between us with 86% success. The production line did about 5,000 grafts and got 14% take.

J. GAGGINI: I am not advocating speed rather than skill. All that I am doing is to try to compare the time it takes, for example, to graft 100 *Fagus sylvatica* with that to graft 100 *Picea pungens* 'Glauca'. I want some figures on which to base our future programmes; if I want to expand a certain line I want to know how much labour is required for that particular purpose.

F. WILLARD: But if this labour is not the right kind you will get back to the low percentage take again.

J. GAGGINI: Yes, but of course the manager should realise this before he starts on this kind of investigation. He has to examine his workers critically. He must know what he has got and, if suitable workers are not available, he clearly cannot proceed with that type of programme.

F. WILLARD: A man can be motivated to do a job without necessarily having the skill to be able to perform it successfully.

J. GAGGINI: I would not start any measurements on anyone who did not have the basic skills. He would either be trained until he was proficient or he would be discarded.

DR. B. HOWARD: Were any of the persons on whom the measurements were taken producing bad results?

J. GAGGINI: They were all producing average takes, and there was quite a variation of performance as you can see from the rating of 55 to 110. So some people were producing twice as many grafts as others yet the percentage take was about the same.

F. WILLARD: This emphasises the point I am trying to make—with such variation can you really define what is an average time for a good job? One man might do a thoroughly good job at a much faster rate than another.

J. GAGGINI: I am sure you have got to do so. This is a business and we have got to look at it that way.

B. HALLIWELL: You do not speed up a job to do it inefficiently. You aim to use the skills as effectively as possible in relation to time. One of the important things which comes out of such a study is the knowledge of how much should be done in a certain time and it is not good management expecting double this to be achieved. Management must see that quality control is effectively applied and, if rates go up beyond a certain level, it may well be seen that quality is suffering.

J. WELLS: I am sure that this methodical approach to our problems is extremely important, and John's talk today is one of the most important things you are likely to hear at this Conference. This is fundamental, and if you put your mind against it you are making a great mistake.

P. THODAY: Would Jim Wells tell us whether, if he and his colleague had placed themselves in key positions in the grafting team which he described recently, they could have raised the abysmally low percentage of take and maintain their own individual performances?

J. WELLS: Yes. I think that if we had placed ourselves in the production line putting stock and scion together and binding them we could have greatly improved the overall take.

DR. CAMPBELL: The fact that tying took 40% of the time suggests that this is the part of the operation you want to attack. Why were you using so many tying materials?

J. GAGGINI: In this case there were three materials used, fillis, Nutscene and raffia, and I think the reason was just tradition.

C. A. WILLIAMS: May I add that with a lot of grafting the union is buried in soil or peat; you must, therefore, have the type of material which will not come undone under these conditions. For example, using Nutscene, I can do *Hibiscus* and know that the string will last the whole of its time, and when it starts swelling it will burst; this cannot be done with raffia or rubber ties.