all be provided, otherwise failure rate will be very high. It is unlikely that fruit tree raisers will wish to use bench grafting techniques, since other methods are more suitable. However, the general plant raiser already practices hand bench grafting and suitable machines may be very desirable. Machine grafting is not claimed to be faster than conventional methods but unskilled workers can soon be trained to master the technique, thus enabling better use to be made of staff during wet winter conditions. It would seem likely that with the continually increasing demand for trees and shrubs in containers a machine of this type could be invaluable to many nurserymen. Some slight modifications would probably be necessary, but a wide range of species could be tried using these techniques.

GROUND-COVER PRODUCTION FOR MAXIMUM NUMBERS

GEOFF J. E. YATES

Merrist Wood Agricultural College,
Worplesdon, Surrey

While some nurserymen are practicing ways of rooting larger and still larger cuttings to shorten the time between rooting and sale, I have begun to look for ways of propagating ground-cover plants commercially using the least possible plant and container material and, in some cases, to remove the need to stick individual cuttings or to pot or lift from the field. These alternatives are not new, but their use to mass-propagate plant material economically can be pursued with advantage.

Why should it be necessary to consider any new techniques when the majority of ground-cover plants are very easy to propagate and usually make a profit, and when the small numbers now produced are sold at prices as high as those asked for the normal run of flowering shrubs or perennials? In answer, if ground-cover is to be mass-planted as it must be to be successful, the plants offered in Great Britain will have to come down in price to an equivalent level to that of bedding plants and they need to be constantly available in large numbers, which few nurseries could now supply.

Among the present limitations to economic production are:

(a) Running out of stock material for normal division and cutting making.

(b) Slowness of production of some natives from seed or difficulty in rooting cuttings.

(c) Too many handling moves after rooting, e.g. potting, lining out, lifting, bundling and boxing.

(d) Higher costs of all kinds of individual containers, pots or boxes.

I want to start by looking at the use of parts of the plant other than the leafy green stems or the seeds, for many ground cover species have vigorous colonising roots and, more importantly, rhizomes which enable the plant to renew itself continually.

STICKING, SOWING AND DICING—RHIZOMES AND STOLONS

Sticking and Sowing. Of plants with rhizomes a number can be cut up and propagated from *leafless* stems (1). Although this method of propagation obviates leaf trimming and stripping, the result may only give a saleable plant after a longer period of time than from a cutting taken with leaves. *Pachysandra terminalis* (Fig. 1) has very vigorous underground stolons which can be cut up (30 mm long), stuck and rooted, but as the normal leafy shoots have stiff stems they are easily prepared and more quickly stuck by simply pushing into a cutting compost or into proprietary foam propagation blocks.

Fig. 1. Leafless stolons of *Pachysandra terminalis* cut to 30 mm lengths for sticking and rooted stolons three months later.

However, other plant species have soft aerial stems which are less convenient to stick rapidly or, as with *Ceratostigma plumbaginoides*, these soft stems soon become hardened, making later batches of cuttings for continuous production more difficult to root. This blue flowered perennial has an extensive running rhizome system, which can be lifted at most times of the year and cut into 10 to 20 mm lengths. These pieces are quite leafless, but have leaf scales, and the task of

sticking and ensuring polarity can be reduced by *sowing* the pieces horizontally over the surface of a compost. They may be covered slightly to keep moist and dark, and put in a glasshouse. After four weeks in a propagation house a mass of leafy shoots will appear, similar to those produced from root cuttings, and these can be potted in tufts. One step further is to sow the pieces of rhizome in the containers in which the *Ceratostigma* is to be sold The mutilated stock plants need not be wasted but boxed in peat to provide another batch of rhizomes.

When experience is needed to determine the ability of plants to regenerate by this method, the best time to start on the stock is April or early May when maximum rhizome or stolon activity occurs. Maximum activity will follow flowering and will consequently be much later for *Geranium macrorrhizum*. This species will normally divide giving 6 to 8 divisions from one clump in the winter or spring, but if these are lifted again in July each new clump will provide 12 or more new white rhizomes, which can be cut off with secateurs in 20 to 30 mm lengths and sown in boxes or in a prepared cold frame. Not all of the herbaceous geraniums follow this growth pattern, but none are so tolerant of drought and shade as this scented-leaved plant.

With the old favourite lily-of-the-valley, *Convallaria majalis*, an excellent ground cover under cedar trees, small pieces of active rhizome will outgrow older dry material or one and two year old rhizomes. The following plants will respond to adaptations of this method:

Rhizome cut to:

20 - 30 mm	*Campanula poscharskyana* cvs.
40 mm	*Clematis heracleifolia* 'Wyevale'
30 - 40 mm	*Convallaria majalis*
25 mm	*Euphorbia robbiae*
100 mm	*Gaultheria shallon*
20 - 30 mm	*Houttuynia cordata* 'Flora Plena'
15 - 20 mm	*Maianthemum bifolium*, May Lily
40 mm	*Phalaris arundinacea* 'Variegata'
20 - 30 mm	*Saponaria officinalis*, Soapwort
100 mm	*Vaccinium myrtillus* and *V. angustifolium*

Bamboos have long been propagated from rhizomes cut into short lengths in April or May and stimulated to produce new shoots and roots. Whilst there is no shortage of stock to divide—they can be an incredible nuisance on sandy soil—the following are useful for ground cover and the sudden need for maximum increase may require the propagator to use these techniques:

Arundinaria vagans (syn. *Pleioblastus viridistratus vagans*)
A. fortunei (syn. P. *variegatus*)
A. humilis syn. P. *humilis*)
A. pumila (syn. P. *pumilus*)
Sasa veitchii (syn. *Arundinaria veitchii*)

Dicing rhizomes. (a) Leaves removed. The familiar rhizomatous plants *Bergenia, Polygonatum* and *Rodgersia* do not make abundant growth but slowly add to the length and diameter of the old existing rhizome in relation to the numbers of healthy leaves or leaf stems produced. *Bergenia* can be raised from seed to produce mixed races and will divide, but division is severely limited by the amount of available rhizome material. As shown in Table 1, work at Merrist Wood Agricultural College carried out by Diploma students has demonstrated, using all parts of the *Bergenia* rhizomes, old and new, defoliated and cleared of old scales and cut into sections, reproduced best at a length of 30 mm.

Table 1. Effect of rhizome length on root and shoot production. *Bergenia cordifolia.*

Rhizome cut transversly length in *mm*	Root growth	Shoots growth
2	— — — — — —	— — — — — —
5	— — — —	— — — —
10	— — — +	— — — +
15	— — — —	— — — —
20	— — + +	— + + +
25	+ +	+ +
30	+ + + +	+ + + +

More than one sample taken for each size, age mixed at random
\+ indicates growth from each piece
— indicates no growth from each piece

These apparently lifeless stems (up to 6 years old in these observations(have dormant leaf buds enfolded in them and when inserted in perlite at 20° C. (68° F.) basal heat and kept moist, will break dormancy, by sending up a vigorous leaf to start renewed

rhizome activity from an axillary bud. Heavy rooting occurs some weeks later. For our first winter trials (1970/71) the diced sections were pushed into perlite, but subsequent commercial procedures of cutting and dusting with captan gave as good results even when using old dessicated rhizome down to 15 to 20 mm length sections and inserted into equal parts of peat and sand compost. Experiments carried out by Jefferies and Thoday (2) at Bath University during the winter of 1969-70 established that *Bergenia* could be readily propagated from single buds excised from dormant rhizomes. It was further shown that the cutting of 70 mm intact lengths of rhizome resulted in a greatly improved yield of young shoots compared with the same total length cut into smaller pieces.

The age of the buds used as starting material, the depth of planting, the ambient temperature, and the length of rhizome pieces were examined for their effects on bud activity. The size of the shoots, the application of indolebutyric acid to the bases of the shoots, and the presence or absence of heels of parent rhizome material at the bases of the shoots were examined for their effects on root production by shoots. The state of root development, and the use of supplementary illumination, were examined for their effects on growing on of rooted shoots.

Other species with which I am working include the ginger roots, *Asarum europaeum* and *A. caudatum, Polygonatum multiflorum, Smilacina racemosa* and *Rodgersia.*

Dicing rhizomes. (b) Types with leaves. The technique without leaves was used with dormant stock or with species that would tolerate removal of all foliage. The need to increase Butchers Broom, *Ruscus aculeatus,* more economically than by ordinary division, led me to see how small one could reduce the hard woody rhizomes. The large dormant buds are not present in large numbers so these are noted and the rhizomes were cut with sharp secateurs to 20 to 30 mm, ensuring that each piece had an active green leaf stalk and a prominant dormant bud. The cut surfaces were dusted with Captan and all were boxed up in peat and placed in a cold frame during February. This has provided a fair and reliable increase for a very slow growing native.

Epimedium spp. divide well in May when there is maximum activity, and with suitable aseptic propagation conditions, moisture, and some heat there is no reason why live rhizomes should not be cut down to 20 mm in length provided a complete leaf is left with each piece. The North American, *Comptonia peregrina,* or Sweet Fern, which is not a fern, has long been subjected to similar methods by American nurserymen, but sufficient stocks are unlikely ever to be available in Great Britain.

ROOT CUTTINGS

Some of the best ground cover species belong to the *Boraginaceae* with rough leaves like comfrey. These are not exploited enough using the simple method of root cuttings; indeed they produce adventitious shoots so rapidly that they may as well be quickly "sown" horizontally in a frame using 30 to 40 mm pieces of thick young root. If you wish for finesse stick them vertically in boxes full of compost-filled peat pots or similar containers.

The following may be propagated from root cuttings: *Symphytum caucasicum, S. grandiflorum,* 'Hidcote Pink' and 'Hidcote Blue' and 'Rubrum'; *Brunnera macrophylla, Trachystemon orientalis, Cynoglossum spp, Anemone vitifolia, A. hupehensis* cvs. and *Myrica cerifera.*

LEAF, STEM AND BUD CUTTINGS.

Although I am more used to preparing cuttings with a knife, readily available stem cutting material that roots internodally can be made ready for sticking more quickly with secateurs or scissors. The ivies and *Rubus* provide two examples of plants used for ground cover effect that can be mass-produced without wasting a scrap of material. Three points should be considered—each cutting must have (a) a sound, well developed leaf, (b) a dormant axillary bud, and (c) sufficient length of stem to permit sticking quickly into a cutting compost, either in boxes or beds, or several cuttings to a small container. This type of cutting, compared to a terminal shoot or a length of shoot with several nodes, will provide a more even batch of plants since the shoots all break from one level. Where space for the stock plants is at a premium, or it is necessary to keep the cutting material clear of soil in case of soil borne infection, the stock plants should be grown up reinforced concrete mesh or pig netting; walls tend to encourage *Bryobia* mite in large numbers.

We sometimes take further rounds of cuttings off the cuttings, but the first batch must be fed, if not moved on, as the rate of growth will diminish if we take cuttings from stock which lacks nitrogen.

Vinca spp. can be placed in this category of cutting. They have opposite leaves so that each cutting can be made with a pair of leaves and has the chance of two axillary buds breaking into growth. In our experience, long cuttings will root as quickly as shorter ones but are not convenient to handle, and may take longer to form useful basal growth.

SHRUBS AND OTHER WOODY GROUND COVERS

Shrubs and other woody plants will necessarily be propagated by all the familiar methods including the rooting of half-ripe cuttings (*Cotoneaster, Euonymus*) and, in a few cases, from seed (*Mahonia*).

Increasing the availability of cutting material can be pursued in two directions: (1) Softwood cutting material forced under glass and (2) Deciduous and evergreen hardwood cuttings.

Softwood cuttings provide a fast means of producing large numbers, e.g. 80 to 90 *Lonicera pileata* cuttings per standard box; a useful increase in the first season's growth of the rooted cuttings can be obtained by starting the stock plants into growth under glass. We use this method where outside growth may give only one round of soft cuttings of the following—*Lonicera pileata, Hypericum x moseranum, Stephanandra incisa* 'Crispa' and some of the thin twigged spiraeas—*S. x arguta* 'Compacta', *S. x Bumalda* 'Anthony Waterer', *S. chamaedryfolia* 'Ulmifolia'.

Hardwood cuttings need little explanation. One deciduous shrub that is in steady demand for ground covering larger sites is the common spreading type of *Rosa rugosa.* It is easy from seed, but this involves more stages in production. Hardwood stems about 125 mm long, prepared in the winter, bundled and lined out in clean nursery land in spring, provide a swift uncomplicated operation. Some cultivars, such as 'Frau Dagmar Hastrup', are more effectively budded on stocks, but its hesitancy to root well can in some ways be overcome by taking hardwood cuttings from well-pruned stock hedges.

The rose 'Max Graf', which is a true hybrid with *Rosa wichuraiana* as one parent is normally budded, but this causes great problems when stock suckers appear at a later date on infrequently maintained landscape sites. Plants on their own roots, which can be made from the abundant annual growth, bundled and lined outside in the spring, are better.

Evergreen hardwood cuttings allow maximum increase, aided by the photosynthesising leaves. Into this group fall the *Berberis* and the more amenable *Mahonia aquifolium* cultivars. Seed of the latter is easily germinated in large quantities in spring if it is stratified for 3 months in sand in a warm glasshouse then sown outside on beds in February. They do, however, take time to make saleable plants, involving two transplanting moves. I find I can root up to three or four hundred cuttings from any old neglected bush. The branches are cut and brought inside during November or December and *all the wood*—some is probably 5 years old—is cut up with secateurs into variable stem lengths, but each with a complete compound leaf attached (Fig 2). The more vigorous top leaves may be shortened by cutting off the terminal leaflet. To encourage heavy rooting the stem bases are dipped into 0.8% IBA dust and stuck in a double-glazed frame outside with soil warming cables holding the media at about 20° C. (68° F.). By early summer the cuttings are well rooted and can be bedded, potted or left for lining out in the early autumn.

Winter propagation of *Hypericum calycinum* is probably as cheap as production from softwood cuttings during the growing season. We make hard stemmed cuttings with two pairs of leaves and with the softer terminal portion removed, dipping the base in 0.8% IBA. As this is mature stem growth not all the leaves are present but the vital axillary buds are. These cuttings are usually boxed and put in a glasshouse or double-glazed frame without heat. The latter facility is slow but eases the pressure on mist benches occupied with conifers.

Fig. 2. Hardwood evergreen leaf stem cuttings and leaf-bud cuttings of *Mahonia aquifolium* made from stems up to five years old (left). Rooted cuttings after four months (right).

CONTAINERISING GROUND COVER PLANTS BY THE USE OF POLYTHENE ROLLS

Ground cover production can be divided broadly into those plants sold from open ground and those produced in containers. Excepting for the woody shrubs and heavy foliaged perennials, smaller leaved ground covers are in the nursery ground for too short a period to pay for planting out, herbicide treatment and lifting. The heavy losses encountered using this open ground material of the common *Hypericum calycinum* on a rigorous landscape site are not really appreciated. Ideally plants, or several rooted cuttings, in a 75 mm (3 in.) or 90 mm (3½ in.) plastic pot, though more expensive to produce and handle, ensure fewer planting losses.

Rooted cuttings in boxes, which have to be separated by being torn apart at planting time like bedding plants, produce the greatest root

damage; greatest because ground cover plants may be lying around in boxes longer than petunias or such plants with their more limited shelf life.

Containers, such as plastic foam blocks and individually formed bedding packs, require the stability of at least a standard seed box to hold the unit together; this costs 3½p each for the wood, and the rigid plastic material after separation has to be laboriously picked up from the site, if it has not already blown away! Peat pots are excellent for growth, but the pots and boxes necessary to hold them together add on costs to the lower priced ground covers.

In the *Polythene Roll* method (Fig. 3), rooted cuttings are rolled in polythene, using the same compost and exactly the same quantity as required to pot into 75mm (3 in.) rigid plastic pots. The plants are separated laterally by the polythene strip and, because the roots are able to grow downwards for three times the depth of an ordinary seed box, the plants come out when unrolled with a large "plate" of roots, allowing excellent establishment of the individual plant.

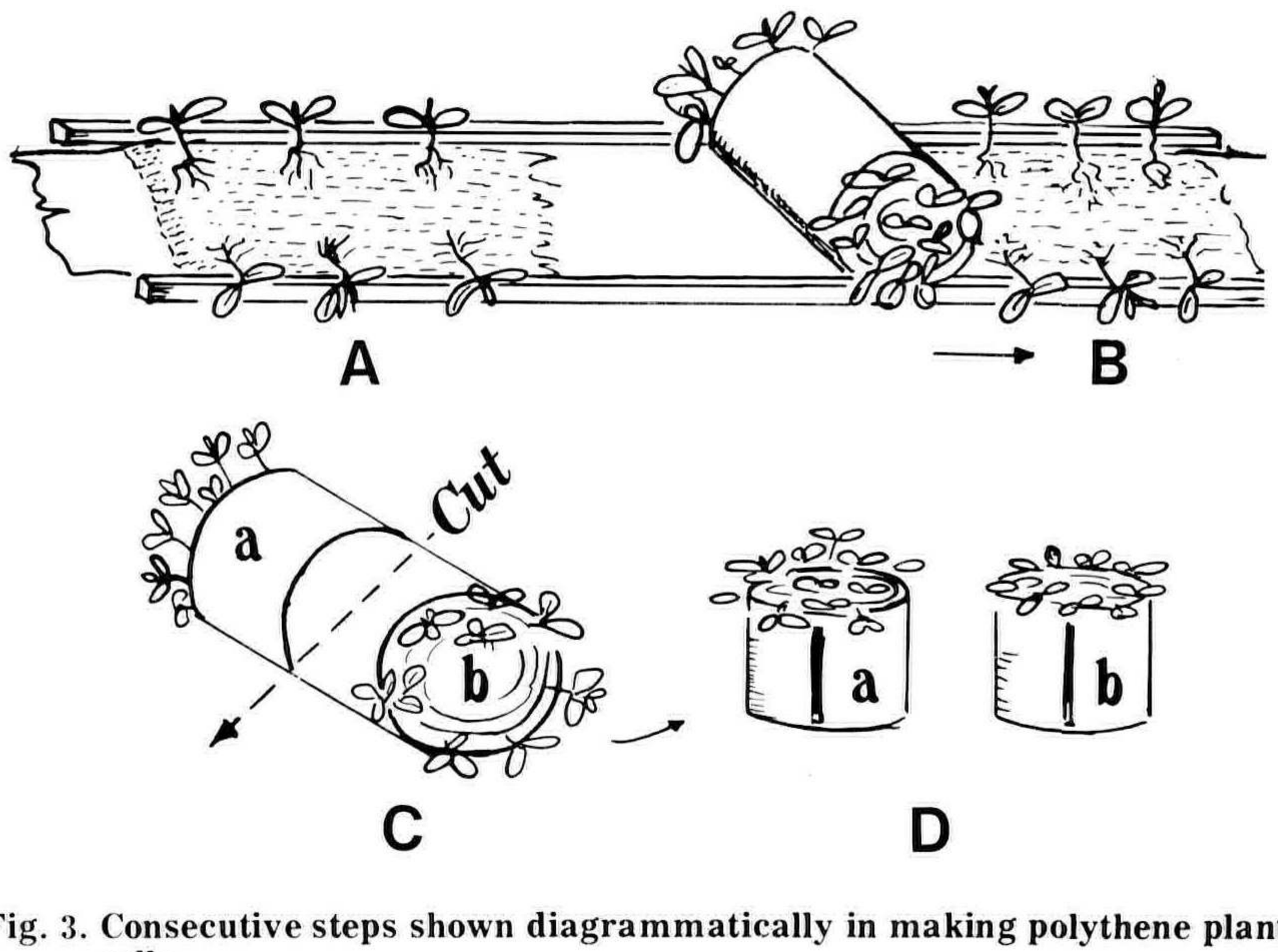

Fig. 3. Consecutive steps shown diagrammatically in making polythene plant rolls.

A roll of black polythene mulch, 150 gauge, is sawn into approx. 300 mm sections. One of these narrow rolls is unwound by laying it on a bench between 12mm (½ in.) battens to contain the compost. About 4 metre of polythene and bench top will be required to make the first

stage of the rolls which are in pairs. Compost is laid and flattened out with the hands over the polythene strip to provide an equal quantity required to fill 50 75mm (3 in.) pots. Next 25 to 28 rooted cuttings or divisions are placed along the top edge and the same number along the lower edge of the strip, which is then rolled up tightly by hand and secured after cutting with a narrow strip of PVC tape. The result is a tight "Swiss Roll" with plants sticking out of each end; this is then cut through the middle of the roll with a saw or a long knife and the two units, each with 25 plants are slid onto a flat board or truck for transport to the growing area. The compost does not fall out of the bottomless containers and, after watering and natural settlement, it is easy to move the 25 plants in one quick movement, compared to the laborious picking up and putting down of individual rigid pots. A thousand plants can be rolled as quickly as potting with great saving in time when moving out and setting down.

This method differs from the patented Finnish "Nisula" system developed for forestry seedlings by the following points. The rooted cuttings are not placed on separate pads of compost to separate them longitudinally; a heavier commercial horticultural grade of black polythene is used and normal sand, peat, and soil composts are used rather than one of all peat. Some costs between potting and the use of the polythene roll are compared in Table 2.

Table 2.Current production costs at Merrist Wood Agricultural College for potting and for polythene rolling as determined for *Vinca, Pachysandra, Hypericum, Hedera* and *Ophiopogon.*

Potted	Polythene Rolled
75 mm (3 in) polystyrene pots	25 per roll
£ 13.36 per 1,000	£ 10.00 per 1,000 plus additional saving by reduced handling costs at despatch.

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