creased energy needed to market the plants. The only justification, and a poor one at that, is that the type of energy needed for production is not available at any cost, and the type of energy needed for marketing is available.

Energy requirements to manufacture plastics.

Nylon	3700 to 3900 BTU per cubic inch
PVC	1800 BTU per cubic inch
Polyethylene (low density)	1100 BTU per cubic inch
Polyethylene (high density)	1400 BTU per cubic inch

Some ways to "insulate" greenhouses.

1. Double layer of plastic sheeting, inflate.
2. Plastic over glass or fiberglass, inflate.
3. Attach plastic insulation material to glass.
4. Thermal blankets over crops.
5. On north walls, attach styrofoam on glass.

Some ways to seal openings, reduce infiltration of cold air into greenhouses.

1. Double doors with weatherstripping.
2. Air "bags" over vents, fan openings, etc.
3. Lapseal between panes of glass or sheets of fiberglass.
4. Louvers that shut tightly.
5. Heater vents have means of controlling drafts.

Energy requirements to manufacture fertilizers.

1 ton of nitrogen requires 511,280,000 BTU of natural gas.
1 ton of phosphorus requires 4,390,000 BTU of natural gas.

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ETIOLATION AND ROOT FORMATION

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Abstract: A review of literature pertaining to the promotory influence of etiolation on root formation in shoot cuttings is presented. Characteristic features of this phenomenon are discussed in relation to both the action of light on growth and development and to the possible role of growth substances. The interaction of ringbarking (girdling) treatment with localized etiolation of the stem, in relation to root production, was investigated and a summary of the experimental results is given.

REVIEW OF LITERATURE

The inhibitory effect of light on rooting of shoot cuttings has

often been demonstrated, mainly as corollary of the fact that exclusion of light from the developing shoot promotes root formation. This situation has been shown to obtain in several unrelated species, among which are *Clematis*, (15) *Phaseolus* and *Hibiscus* (9). Gardner (7) found that to be effective, etiolation of the growing shoot should be carried out at an early stage in its differentiation and that it was preferable to exclude light completely during the initial phase of growth. Working with avocado, Frolich (5) confirmed that shoot tissue was most susceptible to the inhibitory effect of light when first formed and further showed that the degree of inhibition was proportional to the duration of exposure. Conversely, increased duration of etiolation progressively increased root formation in cuttings of *Salix* (11). It is the usual practice to exclude light only from a short proximal segment of stem, in which case root formation is confined to that etiolated section (5) — i.e., the effect is strictly localized on the stem. In this, as in those other characteristics already mentioned, the effect is consistent in its operation over the species hitherto studied, as also are changes in stem anatomy and development resulting from growth in darkness. In the etiolated stem, differentiation of secondary tissue does not proceed to completion (14). This is a consequence of the tendency of etiolation to delay maturation of the tissue (16); conversely the action of light — qualitatively the same with regard to the two aspects of growth, cell multiplication and cell enlargement — is to accelerate initiation and completion of successive phases, so that both cell division and elongation start earlier and end earlier in light. However, striking as the differences in stem structure are, and although they also are completely localized in the etiolated segment (18), investigation has not borne out the thesis that the effect on regeneration is due to reduction in amount of the mechanical tissue which would otherwise restrict root emergence (5,9).

If anatomical differences do not account for the promotion of rooting, its origin presumably lies in the alteration to the physiology of the developing shoot. In view of the well known efficacy of auxins in stimulating root formation, increase in the effective level of endogenous auxin presents itself as a possible mechanism underlying the etiolation effect. Against this thesis must be set the fact that etiolation does not so much increase root formation in a quantitative manner, as induce in the shoot a predisposition to root formation which does not otherwise exist. In his review of the factors controlling root regeneration, Haissig (8) adduces experimental results to show that IAA only initiates root primordia in predisposed cells, so that in difficult-to-root subjects, where this disposition does not obtain, IAA is ineffective; moreover the balance of evidence cited finds

against the proposal that light controls the level of auxin via the auxin oxidase system (6), both generally and in the case of root regeneration. With reference specifically to localized etiolation, Herman and Hess (9), concluded that the difference in endogenous auxin content between etiolated and unetiolated tissue did not wholly account for differences in regenerative capacity. Again, Krul (13), did not ascribe the promotion of rooting, brought about by treating bean hypocotyls with 2,4 dinitrophenol (2,4 DNP) in darkness, to the prevention of auxin oxidation. It appears that light, in reversing this promotion, acts on 2,4-DNP, degrading it to an inactive compound, rather than on hypocotyl tissue, so that this effect is not primarily one of etiolation.

Finally, considering the possible role of gibberellin, it has been shown (12), that the elongation of internodes of dark-grown plants may be the result of increased sensitivity to, rather than high levels of, endogenous gibberellin. As to root formation, exogenously applied gibberellin was inhibitory (1,2,10). However, when a range of gibberellins tested in vitro for root-inducing properties (16), they were qualitatively consistent in their action on tissue of artichoke; rhizogenesis was stimulated in darkness but inhibited in light.

SUMMARY OF EXPERIMENTAL RESULTS

A series of experiments, using as propagation material the difficult-to-root apple scion cultivar, 'Bramley's Seedling,' was begun with the object of investigating the mechanism of etiolation and root formation (3,4). Characteristics of the experimental method were: 1) treatments were applied to the stock plant only. After severance, the cuttings were rooted in conditions that were uniform insofar as possible. 2) The two treatments were: a) exclusion of light from the rooting area of the stem (etiolation), and b) interruption to the continuity of tissues external to the functional xylem (ringbarking).

Shoots were etiolated initially by starting growth of the stock plant under black polythene. When this cover was removed, etiolation of the proximal segment of the stem was maintained by wrapping it with black plastic film while the distal part of the stem continued to grow in full sunlight. Where etiolation was not continuous, root formation did not take place. Ringbarking at the stem base enhanced the effect of etiolation but did nothing to increase root formation in light-grown cuttings. The necessity for continuity of the localized etiolation was shown by the fact that to delay wrapping the stem base until five weeks after the beginning of bud extension extinguished the predisposition to root formation and a subsequent exclusion of light from the rooting segment of stem only par-

tially reversed the inhibition due to this initial exposure.

Indolebutyric acid applied at 2500 ppm increased rooting only in etiolated cuttings and the increment was small compared with that due to etiolation or ringbarking. Transposing the etiolated segment distally on the shoot did not alter the amount of root formation but simply changed the site of root emergence. However, positioning the ringbark distal to an etiolated segment reduced or completely eliminated rooting in that segment. Again, the amount of root formation was related to the length of the etiolated section of stem, increasing from nil at 9 cms etiolated to an optimum level around 7.5 cms. However, the effective length of an etiolated segment could be decreased by ringbarking it at its centre, in which case the number of roots was not reduced but they were formed predominantly distal to the excision.

The stimulus for root initiation appeared to take effect in less than five days after ringbarking but a period of 12 days elapsed before roots were visible at the surface of the stem.

In keeping with other light-dependent phenomena, it is probable that this inhibitory influence of light on root formation is exerted by specific wavebands within the range 320-800 nm. An experiment in which the usual stem wrap of black polythene was replaced by colored polythenes, which filtered sunlight differentially, did not unequivocally identify the inhibitory waveband but rather pointed to a close relationship between root production and total light energy incident on the stem. Further experimentation using artificial sources of broadband radiation failed to bring about differences in root production probably because the level of irradiation was not high enough. Inhibition of root formation in etiolated stems appears to require high levels (of the order of sunlight) and comparatively long durations, of irradiation (> one day). Work now in progress provisionally indicates that, at equal energy levels, wavebands toward the lower end of the visible range are more inhibitory than red or far-red light.

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MOBILE AERATED-STEAM SOIL PASTEURIZER UNIT

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The need for removal of pathogenic organisms in soil mixes to be used for seed germination and other propagation and growing purposes is well known and accepted (1,3,5,6,7). The