Chapter (non-refereed)

Longman, K.A.. 1981 Possibilities of controlled reproduction in trees. In: Last, F.T.; Gardiner, A.S., (eds.) *Forest and woodland ecology: an account of research being done in ITE.* Cambridge, NERC/Institute of Terrestrial Ecology, 101-104. (ITE Symposium, 8).

Flowering and vegetative propagation

23. POSSIBILITIES OF CONTROLLED REPRODUCTION IN TREES

K.A. LONGMAN

Knowledge of the developmental physiology of woody plants is very incomplete, and nowhere are the gaps more noticeable than with the reproductive responses of forest trees. Primarily this can be attributed to the scientific and logistic problems of dealing with genetically diverse material growing on variable sites; moreover, trees generally do not start to flower until a large and complex shoot system has been built up, and even then flowering is often sporadic (Plate 15).

At present, forest trees are usually grown from seeds collected (i) in those parts of the natural range (provenances) of a species which appear most promising, or (ii) from thriving local plantations or smaller groups of trees. Only in a minority of instances has it been possible to harvest large, regular crops of seed from selected and tested parent trees, because the breeding of improved strains is in its infancy. This is certainly not due to a lack of genetic diversity, but rather because of the twin constraints of uncertainty as to what causes tree variation, and inability to stimulate heavy flowering in the chosen parents.

Two developments during the last 10 years or so have greatly increased the chances of more rapid tree improvement, besides having other potential effects on forestry and arboriculture. They are:

1. The rapid development of techniques for rooting cuttings taken from young trees (Hinds & Krugman, 1974; Bowen *et al.,* 1977; Eliasson, 1977), so allowing the production of clones of genetically 'identical' plants. It now seems likely that this may prove feasible for most of the world's commercial timber species, as well as for many fruit, shelter and ornamental trees. The implications of easy vegetative regeneration are far-reaching for genetical, silvicultural and other research, and also for temperate and tropical plantation practice.

2. Our increasing ability to stimulate male and female flowers at will in some species (Pharis & Kuo, 1977; Longman, 1975, 1978). For example, by treating *Thuja plicata* with the plant hormone gibberellic acid (GA_3), male and female cones can be obtained in all genotypes so far tested. They were produced, depending on sites and rates of application in small and large quantities on (i) large and small trees, (ii) whole and individual branches and (iii) "juvenile" and "mature" cuttings. In species reacting in this way to GA_3, the bulk production of quality seed from selected parents, and the breeding of improved strains and hybrids, can now go ahead on an annual programme. But for most other trees our knowledge of the control of sexual reproduction is deficient. However, in these instances other techniques, including bark-ringing, may prove to be of wide applicability.

Besides their immediate practical importance, these advances enable the examination of several difficult aspects of plant physiology from a fresh standpoint. Because small potted plants can now be used, the factors influencing the formation of flower initials may be studied experimentally in controlled environments. Micro-injection systems allow hormone solutions to be applied with a degree of precision, enabling the differences between male- and female-bearing shoots, and between juvenile and mature tissues, to be investigated (Longman, 1976). The effects of other growth substances can also be more readily determined against a background of flower initiation induced by gibberellin treatments than is the case when relying on sporadic natural initiation.

1. Some environmental factors influencing floral initiation

As plant physiologists now recognise, the change from a vegetative to a reproductive shoot apex is probably governed by a balance of hormones, inhibitors and other substances, the concentrations of which are presumably modified by changes of environment (see Krekule, 1979). Even in the commonly studied herbs, flowering appears to be evoked by specific combinations of external and internal conditions, and probably involves more than one step. In more complex structured forest trees, it is therefore not surprising to find that flower formation is influenced by many factors.

Photoperiod has been known for nearly 50 years to influence flowering in a few woody shrubs (Allard, 1935), as well as large numbers of herbaceous species. However, substantive experimental evidence for forest trees has only been produced during the last decade or so. For example, by rooting cuttings from specimens of *Pinus contorta* with a strong propensity for reproductive activity, clones have been identified which can form male and female cones freely from the stage when the plant is only 10-20 cm tall. When grown in short days (10 h), such trees formed 6 times as many female cones as were initiated in long days (19½ hr), both sets of plants having received the same daily amounts of light energy (Figure 45). Interestingly, *P. contorta* clone 8996 regularly tends to produce a preponderance of female cones, whereas clone 8997, from the same provenance, is more strongly male (see Figure 46).

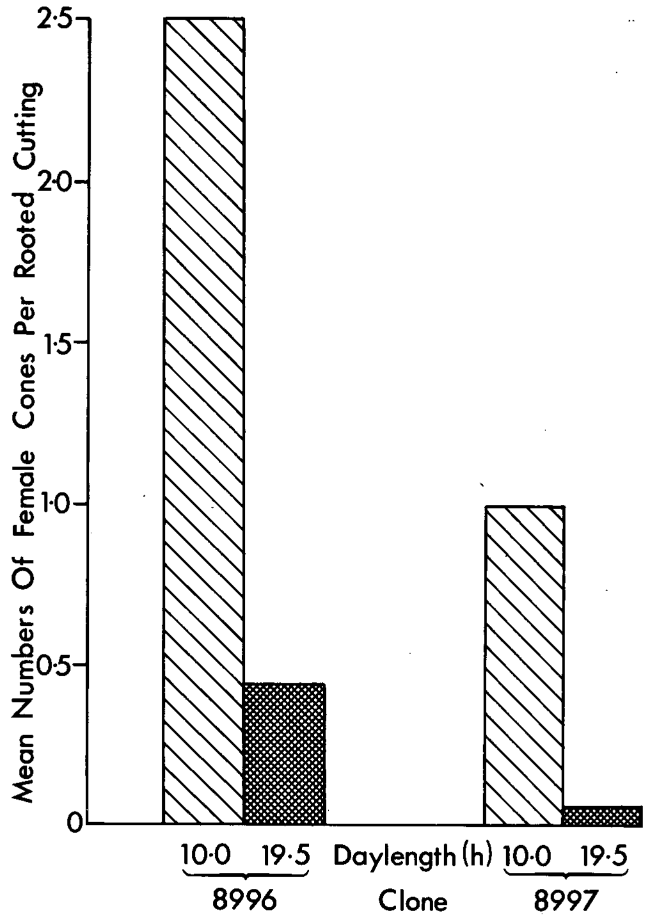

Fig. 45 *Mean effects of short (10 hr) and long (19½ hr) days on the production of female cones by cuttings of 2 clones (8996 and 8997) of lodgepole pine* (Pinus contorta). *Numbers of female cones per plant initiated in controlled environment cabinets, averaging over 2 temperatures and 2 hormone treatments.*

Unlike the situation in *P. contorta,* flower formation in *Thuja plicata* and *Cupressus arizonica* is favoured by long days (Pharis *et al.,* 1969). Using plants treated with GA_3, it is possible to show that male and female initiation commences freely in long days, but the proper development of cones is dependent on a period of short days.

Temperature also influences floral initiation in *T. plicata,* warmer temperatures interacting positively with long days during early initiation, and cooler conditions promoting subsequent cone development. A stimulating effect of warm temperatures during the critical first stage of flower initiation might perhaps explain, at least in part, the many reports of heavy flowering in other species of forest trees in fine summers, or when branches or whole plants are grown under polythene. However, when other factors cannot be excluded, it is unwise to make unwarranted generalisations. Indeed, in the *P. contorta* experiment described above there was apparently little or no effect of temperature on female cone formation, while male cones were significantly more frequent in cool conditions (Figure 46). Perhaps temperature will be found, in due course, to have a range of effects depending on specific day and night regimes, or on light intensities before, or during, experimental treatments.

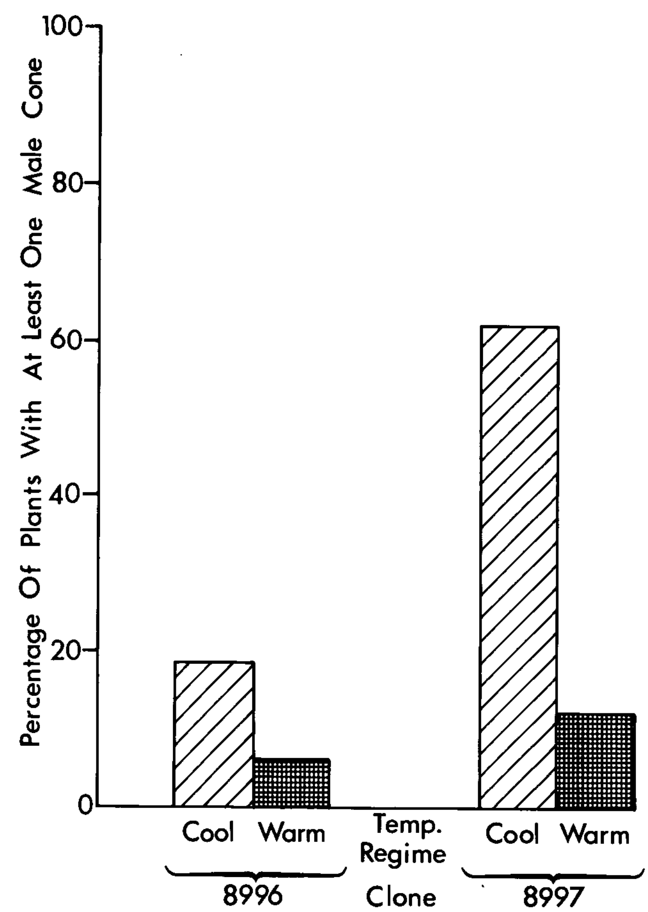

Fig. 46 *Mean effects of temperature on the proportion of trees initiating male cones by cuttings of 2 cones (8996 and 8997) of lodgepole pine* (Pinus contorta). *Temperature regimes: cool - 15°C day/ 8°C night; warm - 22°C day/15°C night.*

2. Developing practical techniques for flower induction

As already mentioned, intense cone formation can be reliably stimulated by GA_3, but this effect seems to be confined to trees in the Cupressaceae and Taxodiaceae. In *T. plicata,* for instance, seed yields of up to 45 kg ha $^{-1}$ have been obtained by injecting selected parent trees, 15 years old growing in a seed orchard, with 50 mg GA_3, in June of the previous year (Longman, 1978). In small potted plants, male and female coning has been stimulated in selected clones of *Cupressus macrocarpa* (Monterey cypress) and *Chamaecyparis nootkatensis* (Nootka cypress). By adjusting the date of injection with GA_3, the flowering of the 2 species has been synchronised, enabling crosses to be made. In an experiment done in a glasshouse in west Wales with the help of Mr H. Ovens, it is hoped that the many ripening cones will contain viable seed of new forms of X. *Cupressocyparis leylandii,* the valuable but sterile leyland cypress of which only 10 clones exist (Ovens *et al.,* 1964).

Using combinations of genetical selection, environmental control and hormone injection, it is clearly becoming easier for the physiologist to help the tree-breeder to (i) re-synthesize hybrids which originated from a narrow and not necessarily superior genetic base, (ii) attempt a range of new crosses including the transfer of specific desirable attributes. Furthermore, these gains could subsequently be evaluated or exploited by vegetative propagation.

In broadleaved trees, as with the Pinaceae, bark-ringing at present offers the most likely method of increasing the incidence of flowering (Longman, 1978). For instance, the removal of complete rings of bark about midway up the main stems of clonal plants of 2 provenances of *Betula pendula* greatly stimulated the formation of female catkins in years 1 and 2, and of male catkins in year 2 (Figure 47). The technique has also been used successfully in the field where, instead of mainstems, branches on larger specimens of several forest tree species can be treated, the effects being restricted to the parts distal to the zones of ringing. Similar responses were achieved by ringing 2 year old birch seedlings, indicating that the time from germination to first flowering can be substantially shortened in this genus. In the absence of bark-ringing, birch seedlings can be stimulated to flower early by continous growth in long days (Longman & Wareing, 1959), and crossing is now being achieved on a 2-year, or even a 1-year cycle in large polythene houses (Lepisto, 1973; Karki, pers. comm.).

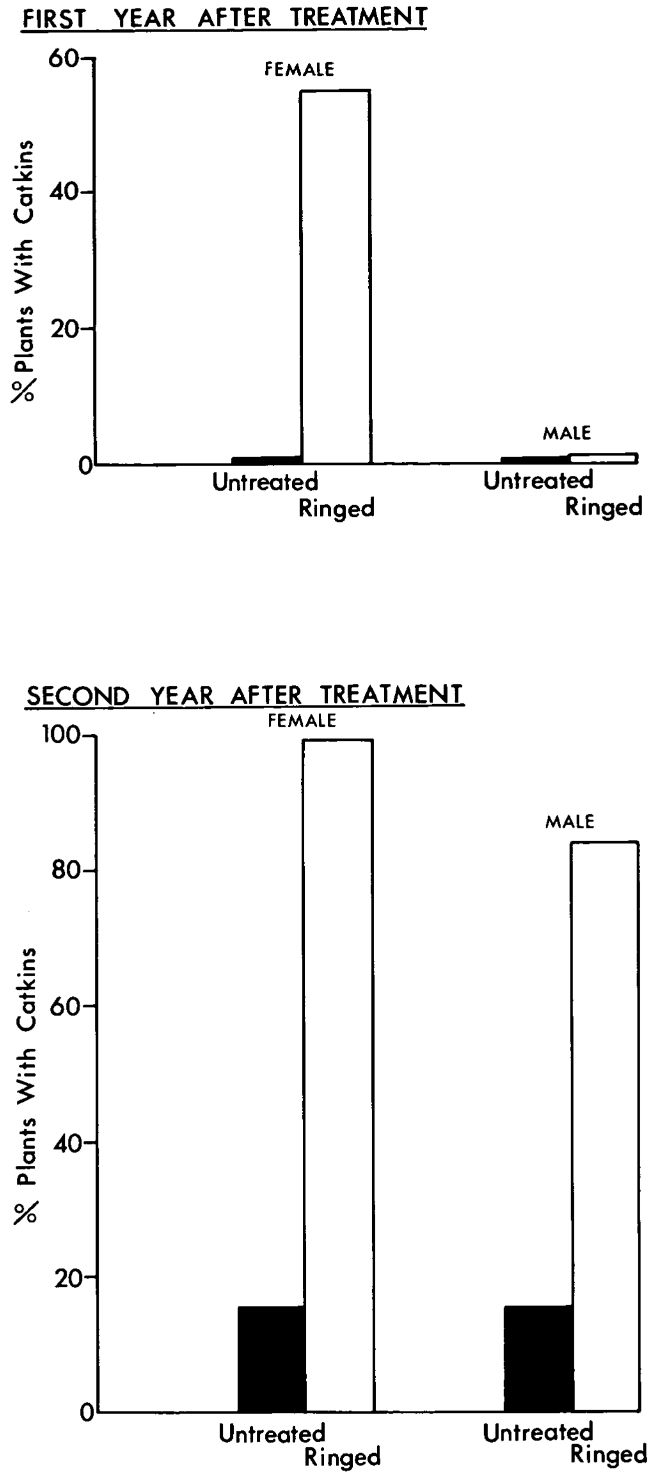

Fig. 47 *Effects of ringing mainstems of* Betula pendula *cuttings, grown in cool glasshouse conditions, on the production of female and male catkins in the first and second years after treatment.*

Perhaps the most important tasks in tree improvement during the coming decades will be the development and evaluation of strains of forest trees with better form and a greater tolerance of pests, pathogens and environmental extremes. To facilitate their production, testing and use, it is necessary to widen our knowledge of reproductive physiology to a more diverse array of species, native as well as introduced.

References

Allard, H.A. 1935. Response of the woody plants *Hibiscus syriacus, Malvaviscus conzattii* and *Bougainvillaea glabra* to length of day. *J. agric. Res.,* **21,** 27-34.

Bowen, M.R., Howland, P., Last, F.T., Leakey, R.R.B. & Longman, K.A. 1977. *Triplochiton scleroxylon:* its conservation and future improvement. *For. Genet. Resourc. Inf.,* no. **6,** 38-47.

Eliasson, L. ed. 1977. *Vegetative propagation of forest trees—physiology and practice.* Uppsala: College of Forestry, Swedish University of Agricultural Science.

Hinds, H.V. & Krugman, S.L. eds. 1974. *Vegetative propagation.* Conference proceedings, Rotorua, 1973. *N.Z. J. For. Sci.,* **4,** 119-458.

Krekule, J. 1979. Stimulation, inhibition of flowering: morphological and physiological studies. *Proc. Symp. Flowering, Gif-sur-Yvette, France, 1978.* Final report, Group 1.

Lepisto, M. 1973. Accelerated birch breeding—in plastic greenhouses. *For. Chron.,* **49,** 172-173.

Longman, K.A. 1975. Tree biology research and plant propagation. *Comb. Proc. int. Plant Propag. Soc.,* **25,** 219-236.

Longman, K.A. 1976. Some experimental approaches to the problem of phase-change in forest trees. *Acta Hortic.,* **56,** 81-90.

Longman, K.A. 1978. Control of flowering for forest tree improvement and seed production. *Scient. Hort.,* **30,** 1-10.

Longman, K.A. & Wareing, P.F. 1959. Early induction of flowering in birch seedlings. *Nature, Lond.,* **184,** 2037.

Ovens, H., Blight, W. & Mitchell, A.F. 1964. The clones of Leyland cypress. *Q. Jl For.,* **58,** 8-19.

Pharis, R.P. & Kuo, C.G. 1977. Physiology of gibberellins in conifers. *Can. J. For. Res.,* **7,** 299-325.

Pharis, R.P., Morf, W. & Owens, J.N. 1969. Development of the gibberellin-induced ovulate strobilus of western red cedar: quantitative requirements for long-day → short-day → long-day. *Can. J. Bot.,* **47,** 415-420.