Programmed Plants™. A New Approach to the Production of Cell-grown (Containerised) Tree Seedlings©

Stan Thompson
Trees and Woods, 48e North Road, Forres, Moray IV36 1AR U.K.

The key to rapid height growth after out-planting is the speed with which the roots grow and so provide the young plant with adequate water and mineral nutrients for future shoot growth. "Programmed Plants" (Programmed Plants is an EU Registered Trademark No 1260249), result from manipulation of environmental variables, particularly daylength and temperature, which control induction of budset and shoot dormancy. Such plants leave the nursery in late summer with a well developed terminal bud, a full complement of leaves and an undamaged, young, actively growing root system. When planted into warm, moist soil the roots quickly grow away from the plug, a process which continues until the soil cools in early winter. Root growth starts again in early spring so that when the new shoot emerges from the overwintered terminal bud in late spring, it is able to elongate to its full potential driven by a well-established root system.

INTRODUCTION

It is every forester's wish to achieve rapid, cost-effective woodland establishment. Transplant shock following the transfer of bare-root, field-grown stock can greatly increase the time required before a woodland can progress unaided. Cell-grown plants, which reach the forest with undamaged root systems, have much better survival rates than bare-root stock and usually suffer less transplant shock. However, little effort has been made so far in the UK to control the growing conditions under which cell-grown tree seedlings are raised. Programmed Plants are reared under environmental regimes designed to produce planting stock which not only survives, but also thrives in the forest as if it had never left the nursery.

BIOLOGICAL PRINCIPLES

A plant's growth comprises the growth of all its component parts—roots, stems, and leaves. In northern-temperate perennial plants, the balance between the growth of these component parts differs with the season and each year's growth is separated by a period of winter dormancy. There are also marked differences in seasonal patterns of growth between tree species and this can control their ability to respond to environmental influences. In the production of Programmed Plants, growing conditions are manipulated to take advantage of these seasonal differences to minimise transplant shock when stock is transferred from nursery to forest.

Roots. Roots anchor the plant and absorb water and mineral nutrients. They do not have to be actively growing to maintain these functions but growth of the root system enables the plant to exploit increased soil volume to provide sufficient water and nutrients for the growth of the plant as a whole. Roots will continue to grow in the presence of sufficient warmth and moisture. In northern-temperate climates, the seasonal trend is for root growth to start in early spring as soil temperature increases. During the summer continued growth is strongly dependent on soil moisture deficit. In the autumn, root growth continues until the soil temperature falls and becomes limiting. Roots have the longest growing season of all the plant's components.

Stem. Growth of the main stem allows the plant to outstrip competing vegetation. Stem elongation can be either totally predetermined from stem units (internodes) held in a bud, or indeterminate from stem units being produced synchronously from an apical meristem. In the former, the duration of elongation is short, usually in spring. In the latter, shoot elongation can continue throughout the summer and be very responsive to prevailing environmental conditions. This pattern of "free growth" is common in seedlings during their first season. The development of branches enables a plant to colonise aerial space in three dimensions and to display the leaves for the best capture of incident radiation. Diameter growth of stems increases their stiffness to allow continued growth of the aerial parts.

Leaves. Leaves are the photosynthetic factory of the plant. Since they are associated with stem internodes their number can be fixed or indeterminate dependent on the pattern of shoot elongation. The size attained by each leaf varies according to internal and external constraints.

Buds. Buds are generally produced once shoot elongation has ceased. In species where shoot growth is predetermined, the process of bud development can take four to eight weeks, is strongly influenced by internal and environmental conditions, and can result in a bud containing several hundred stem units for elongation the following season. In species where shoot elongation is indeterminate, cessation of growth and the start of budset is often triggered by environmental factors, frequently declining daylength but also moisture stress and extremes in temperature. In such species, the duration of bud development is short and only a small number of stem units are over-wintered in the terminal buds.

PROGRAMMING SEEDLING PRODUCTION

Programmed Plants are cell-grown seedlings which have been induced to set terminal buds during their first growing season, moving the focus of growth away from shoots and leaves in favour of roots. When taken from the nursery and planted into warm, moist soils in late summer, the roots rapidly colonise the new site so that, when shoot elongation takes place the following spring, the plant can access sufficient water and mineral nutrients to exploit the full potential of each stem unit held in the overwintered bud.

Silver Birch (*Betula pendula*). In the first growing season from germination, all growth is "free" and continues until the start of budset, usually induced by naturally declining daylength. The terminal bud is small and contains a small number of leaf primordia and associated internodes. Lateral buds develop in the leaf axils. After budset the roots continue to grow until soil temperature or moisture becomes limiting and the plant enters a period of winter dormancy.

When soil temperatures increase in the following spring, root growth starts and can continue uninterrupted until late autumn. Providing the buds have experienced sufficient chilling to satisfy their dormancy requirements, they flush several weeks after the commencement of root growth. The lateral buds flush first to produce the first cohort of leaves. The terminal bud flushes later and the few leaf internodes it holds elongate to form a terminal shoot. Shoot elongation then continues in indeterminate mode, from internodes produced synchronously from an apical meristem, until the start of budset, usually induced by declining daylength. Height growth in birch can therefore be very rapid under favourable conditions.

Programmed silver birch plants are produced using short daylength to induce budset when the seedlings are about 20 cm tall. After 4 weeks of short days the plants will have a good terminal bud, carry a full complement of leaves and, of paramount importance, have a young, active root system which, when planted in a warm, moist forest soil in late summer, will rapidly grow away from the plug. Stem diameter growth will make the plants sturdier and the plants will become winter dormant under natural conditions. Root growth in autumn and early spring provides the seedling with the ability to take up sufficient water and mineral nutrients. This will elongate the internodes held in the terminal bud to their full length and allow the plant to progress into indeterminate growth. Thus, a 20-cm plant transferred to the forest in late summer could be more than 1 m tall 1 year later.

Scots Pine (*Pinus sylvestris*). Growth morphology and physiology in this genus is more complex than birch (Thompson, 1976; Thompson, 1981). Under natural conditions the growth of seedlings in their first season appears to be indeterminate and with the start of budset, height growth ceases and a seedling with typical 1-year-old shoot morphology (Type 1) results. There is a main axis composed of internodes, each with a primary leaf, and just below the terminal bud there is a rosette of primary leaves. As in birch, root growth continues until late autumn.

In early spring root growth recommences and, 4 to 8 weeks later, the shoot starts to elongate, initially using the internodes of the rosette and thereafter internodes held in the bud. Shoot elongation in pine is totally predetermined and does not enter a free-growth phase. The end of shoot elongation coincides with the start of the development of next season's terminal bud. The internodes held in the terminal bud of a Type 1 seedling do not subtend true leaves, they have been reduced to budscales, but they bear short shoots which produce the familiar pairs of "needles". These elongate from a basal meristem until their growth ceases in response to declining daylength in early August. The development of the terminal bud is also completed at this time. Root growth continues until late autumn.

Under natural conditions the shoot growth of pine is complex enough but when nurserymen have tried to hasten the height growth of pine seedlings in "improved" environments even greater morphological complexity was found (Thompson, 1981). Especially when raised under warm night temperatures, budset begins early and the seedlings tend to be short with a shoot morphology similar to that of a 2-year-old plant only 2 to 3 months from germination (Type 2). If such seedlings remain in these "improved" conditions the terminal bud flushes and an elongation shoot follows to produce a seedling with a shoot morphology similar to a 3-year-old plant (Type 3). Maintenance of Type 1 shoot morphology is essential to maximise the shoot growth potential for the second season. This is achieved by maintaining cool night-time temperatures from germination onwards.

Programming of Scots pine seedlings begins with germination in March at a constant temperature of 25°C. This is altered to 25/15°C day/night temperature once germination is complete. This ensures that the desired Type 1 shoot morphology is maintained. When the seedlings are 10 to 12 cm tall budset is induced by short daylength or by moving the crop outdoors where naturally declining daylength will induce budset—these seedlings can leave the nursery with 200 to 300 internodes in the rosette and terminal bud.

If these seedlings are transferred to the forest in late summer the roots will rapidly egress from the plug. Stem diameter growth will make the plants sturdier and the plants will become winter dormant under natural conditions. Root growth in autumn and early spring provides the seedling with the ability to take up sufficient water and mineral nutrients. This will elongate the internodes held in the terminal bud to their full length. Since each internode in seedling Scots pine is about 1 mm in length, a programmed seedling, which left the nursery only 12 to 15 cm tall, can increase its height by 20 to 30 cm during its first season in the forest.

Other Species. Other species can be readily programmed. The key feature is the early induction of budset. While short daylength may work with many, others may require moisture stress, nutrient stress, or low temperatures to initiate bud development. The other important principle is to transfer the plants to the forest in late summer when soils are moist and warm to allow the young root system to become fully established. Thus, when shoot elongation takes place the following spring, the plant has a root system which can provide sufficient water and mineral nutrients to exploit the full potential of each internode held in the overwintered bud.

AFTER PLANTING CARE

Finally, to ensure that Programmed Plants survive and thrive in the forest as if it had never left the nursery, it is essential that weed and pest control after out-planting are excellent.

LITERATURE CITED

Thompson, S. 1976. Some observations on the shoot growth of pine seedlings. Can. J. For. Res. 6:341-347.

Thompson, S. 1981. Shoot growth and shoot morphology in one-year-old Scots pine seedlings. Can. J. For. Res. 11:789-795.