Factors that contribute to basal sweep in lodgepole pine

A. R. PFEIFER

Forest and Wildlife Service,
Sidmonton Place, Bray, Co. Wicklow, Republic of Ireland.

INTRODUCTION

An increase in the presence of basal sweep in lodgepole pine (*Pinus contorta* Douglas ex Loud.) crops has occurred in recent years following widescale planting of vigorous coastal provenances from Washington and Oregon. The attributes of low nutrient requirements and tolerance of severe exposure makes these provenances ideal pioneer crops for difficult sites, but the high incidence of sweep on exposed areas causes difficulties in both the harvesting and conversion of the timber. Despite extensive experimentation the problem of basal sweep has not been fully resolved. This has resulted in the favouring of lower yielding but straighter provenances or alternative species. In some cases these options may not be economic due either to inherent slow growth rate or the necessity for increased fertiliser inputs. The reduction or elimination of basal sweep in the south coastal provenances would therefore increase the profitabilty of growing timber on these difficult sites.

It has been suggested that the underlying cause of basal sweep is the result of strong winds (occasionally wet snow) acting on a tree which has an imbalance between the root and the shoot during the early years after planting. Many factors were considered as contributing to this imbalance, including poor physical condition of the soil, inadequate aeration or drainage, incorrect planting technique, defective nursery stock as well as those genetic features of the trees themselves which control the growth of the root and shoot (Lines and Booth, 1972). The objective of this paper is to examine these aspects of basal sweep and discuss possible courses of action to overcome the problem.

IRISH FORESTRY, 1982, Vol. 39, No. 1: 7-16

Environmental aspects of root development

Root systems of straight and swept trees:

It is generally known that basal sweep occurs in lodgepole pine as a result of trees being toppled by either wind or snow. However, what is not clear is the extent to which the roots and the aerial parts influence the stability of the trees and a study was initiated to examine morphological differences between straight and swept trees. The study was carried out in a nine year old one parent progeny test to ensure that the material being examined was of similar genetic background. The progeny test was established using conventional techniques of single mouldboard ploughing and slit planting of 1 + 1 transplants. A number of families were chosen at random and within these, two trees were further selected, one which had pronounced basal sweep and the other with a very straight stem. Both trees were of similar height, diameter and crown form to minimise any effect of vigour or crown architecture. Excavation of the root systems showed quite clearly that straight trees possessed a uniform radial arrangement of well developed lateral support roots around the stem. Trees with sweep had their lateral roots aligned in one direction or twisted around one another in such a way that they could not give adequate support to the main stem. As a result, the trees had toppled (Fig 1) and subsequent leader growth had grown vertically thus producing a bow in the lower stem.

Fig 1 Five year old south coastal lodgepole pine toppled by an autumn gale.

Root systems of planted and naturally seeded trees

Current establishment techniques appear to be the cause of basal sweep and a further investigation of planted and naturally seeded trees was undertaken to determine the impact of these techniques.

Two crops were selected which were growing on cutaway midland bog. This soil type was chosen because it provides an ideal rooting medium for conifers being free from stones, compaction and a high water table while at the same time being acidic and having good aeration. One of the crops was established using current techniques of double mouldboard ploughing and slit planting of 1 + 1 transplants, the other, by natural seeding after fire on an uncultivated site. Excavations of the root systems showed that naturally seeded trees possessed a common root structure with an even distribution of lateral support roots around the stem and a well defined tap root. Roots from the same tree seldom crossed or intertwined and all primary laterals originated from the tap root. In contrast, the planted trees had a much more variable root structure with a greater number of roots, usually of smaller diameter than the naturally seeded trees but often twisted and with no definite arrangement. Tap roots were almost entirely absent (Fig 2). Some root alignment along the ribbon was evident but this was not very pronounced since this particular peat type is relatively free draining. Basal sweep did occur to some extent in this crop but it is generally not a problem on this site type. The stem form of the naturally seeded crop was far superior to that which was planted, and the complete absence of basal sweep can be attributed to the stability of the natural root structure.

Both the progeny test and the midland bog sites were at low elevations but the findings at these sites were confirmed by root excavations of straight and swept trees in a severely exposed plantation at 500m. At this elevation trees with straight stems did not grow vertically but tended to have a definite lean away from the prevailing wind.

Physical factors that affect the structure of lodgepole pine root systems

During the early life of a crop two main areas can be identified as influencing the form of lodgepole pine root systems, namely, nursery practice and planting method and quality. As the crop develops the type of cultivation can also have a profound influence on the shape of the root system.

Nursery practice

The current method of producing bare root lodgepole pine

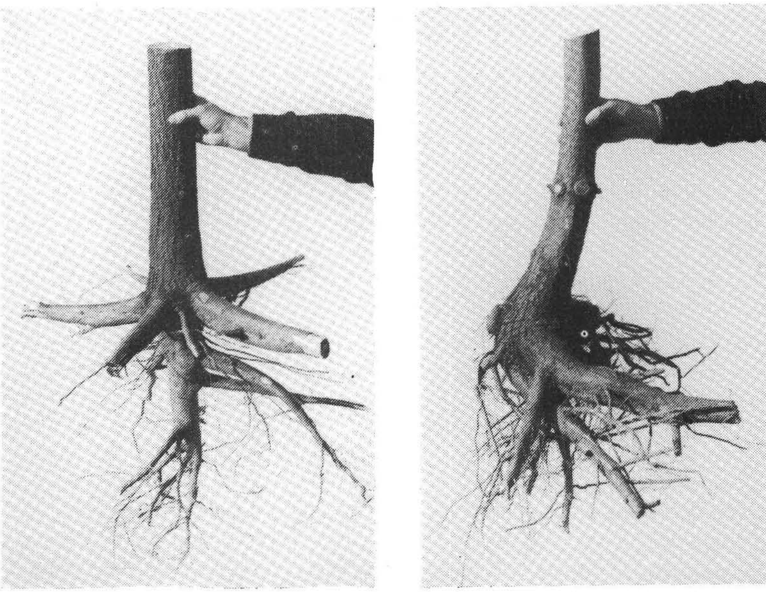

Fig 2 Effect of establishment techniques on the root structure of south coastal lodgepole pine. (Left) Natural seedling. (Right) Planted tree with basal sweep.

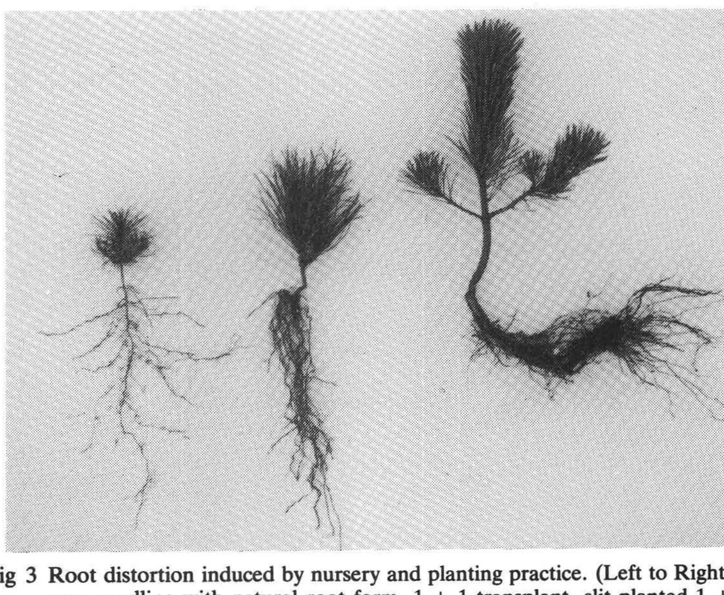

Fig 3 Root distortion induced by nursery and planting practice. (Left to Right) 1 year seedling with natural root form, 1 + 1 transplant, slit planted 1 + 1 transplant in the field for 1 year.

transplants is to sow seed broadcast in prepared seed beds, lift and line out the 1 year old seedlings. In the seedbeds the seedlings have the root form of the natural seedling with a pronounced tap root and an even radial arrangement of lateral roots arising from the tap root. Such root systems are very fine and delicate and highly susceptible to malformation during lifting and transplanting. Some form of root distortion is unavoidable no matter how carefully lining out is done (Fig 3). The badly deformed J-shaped root systems, which are a frequent occurrence in transplants lined out by traditional methods, have been reduced somewhat by the use of modern lining out ploughs, but despite their use, root distortion is still a problem in planting stock.

Containerised seedlings have been used on an experimental basis in both Britain and Ireland to try to reduce the incidence of basal sweep. It was argued that they would reduce the early rapid growth and low root/shoot ratio to which transplants were prone and thus produce a better balanced plant. Results to date appear encouraging and Lines (1980) reports that the tubed seedlings described by Low (1975) have markedly reduced the incidence of basal sweep, though without eliminating the problem completely. This can perhaps be attributed to the fact that root spiralling occurs in hard walled containers and Fig 4 illustrates the type of root

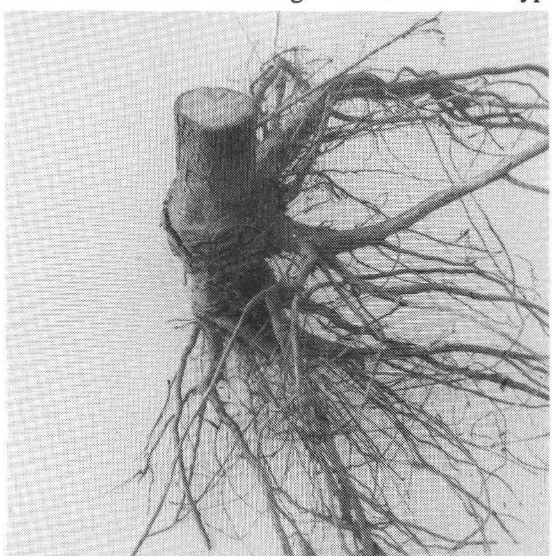

Fig 4 A common root form of lodgepole pine established as a tubed seedling. Note the absence of roots on one side of the stem due to impenetrability of the container wall.

system that a tubed seedling can develop. The "tap root" consists of the original tap root of the seedling and also the lateral roots which have been deflected downwards in a spiral towards the open end of the tube. Some of the laterals have emerged and radiated from the slit in the side of the tube (Low 1975). However, a sector opposite to the slit is without lateral support simply because the roots could not penetrate the wall of the container. Despite these shortcomings trees established in these containers have good juvenile stability.

Planting method

In Ireland the planting of lodgepole pine is largely confined to blanket peats and it is on these soils that present and future problems with the establishment of this species will mainly occur. The tough fibrous texture of these soils make it difficult to plant bare root stock without root distortion and the current method of slit planting on top of plough ribbons encourages L or J-shaped root systems. Transplant roots tend to be folded into the slit and when this is closed the plant possesses a bi-laterally compressed root system aligned in one direction, usually along the ribbon (Fig 3).

Lodgepole pine does not have the ability to produce adventitious roots from the root collar as does Sitka spruce. A strongly aligned root system will therefore result in early instability since the plant will not have a good radial distribution of lateral support roots and/or a tap root.

Cultivation technique

During the early establishment years instability appears to be caused mainly by poor quality plants and planting. As the crop develops rooting is confined mostly to the plough ribbons which often results in a strongly aligned root system, particularly on sites with a high watertable. Trees therefore do not have an even radial distribution of roots and support for the stem is strongest in the direction of cultivation. Consequently this can have a significant effect on the stem form of a crop particularly on a peat site.

Results from a direction of ploughing experiment (Hendrick and Pfeifer — In prep.) have shown that by aligning the ploughing direction into the prevailing wind it is possible to reduce the incidence of basal sweep. Ploughing at an angle or at right angles to this direction can increase sweep dramatically especially at the exposed edges of plantations.

Similarly, planting lodgepole pine on ground prepared by ripping can induce basal sweep particularly if the trees are planted in the rip channels. Few roots penetrate the walls of the channels but tend to run along the loosened soil in the direction of cultivation. This again results in a strongly aligned root system with little lateral support.

Genetic aspects of root development

The natural root form of lodgepole pine has evolved over millions of years in response to the environment in which the species colonised. Consequently, it is perhaps the most efficient structure for the absorption of water and nutrients while at the same time giving good support to the crown. Preliminary investigations revealed that both inland and south coastal ecotypes have the same basic root structure. However, differences in end of season root-shoot ratio do exist but this is a temporary phenomenon which reflects the extent to which the provenances are phenologically adapted to the length of the growing season in which they are grown. Provenances which produce small shoot dry matter in relation to total seasonal dry matter develop relatively large end of season root/shoot dry weight ratios and vice versa. Although these differences are temporary they do last through the autumn and winter months when wind damage is most likely (Cannell and Willett 1976). Inherent differences of 10-30% in root/shoot dry weight ratios between provenances have been reported (Lines 1971, Cannell and Willett 1976), which may make some contribution to differences in wind stability after planting. But morphological differences in shoot development and "sail area" are much greater and are therefore likely to have a more significant effect on stability. The vigorous denser crowned south coastal provenances are more prone to toppling as a result of root deformity since they place a greater strain on the stabilising root system than the less vigorous sparcely foliaged interior types.

Discussion and recommendations for future establishment practice

Present establishment techniques alter the natural arrangement of lodgepole pine root systems and both early and late instability are a consequence of departing from this basic structure. The reduction or elimination of instability in the south coastal ecotype will therefore be best achieved by ensuring that improved establishment techniques produce crops with a root structure similar to that of the natural seedling.

In the nursery, lining out is a major factor in altering seedling root forms and improvements in the production of nursery stock are required. The technique of conditioning transplants by box pruning developed in New Zealand for Monterey pine could perhaps be modified here for lodgepole pine. This would involve precision sowing of seed and employing a regime of undercutting, wrenching and vertical pruning on four sides of the seedling root system. Results with Monterey pine have shown that the tap root is preserved and a dense mass of lateral roots induced. The root system is robust and less likely to be badly damaged during planting. Careful packing in waxed cardboard boxes ensures that this root system is not damaged during transportation to the planting site (Chavasse 1978). While a similar regime could be envisaged for lodgepole pine for planting on mineral soils, the nature of the peat soil is such that even if this excellent root system could be achieved, distortion is still likely to occur during planting.

The problem of root distortion at planting can, however, be overcome by using some form of containers in which seedling roots are allowed to develop naturally and the root plug complete with growing medium is planted without disturbance (Burdett 1979). Dibbles and other tools have been developed which will open planting holes to the diameter of the root plug and allow the seedlings to be dropped in. Minimum root distortion will occur at this stage but it can occur within the containers themselves especially if the seedlings are left in these too long (Kinghorn 1978). However, recent developments such as those described by Burdett (1979) in which root morphogenesis can be controlled in hard walled containers offer real possibilities of overcoming the problem in this type of container.

Soft walled containers such as paperpots allow seedling roots to penetrate the walls of the pot but on peat soils the low level of biological activity does not allow rapid breakdown of the paper and roots have been observed to be confined mainly to the pots three years after planting. However, this could be overcome by simply removing the pot at planting. Alternatively peat plugs which consist of a cohesive mixture of sphagnum peat and cellulose fibre could perhaps be the simplest solution to container induced root distortion. A system using triangular shaped plugs has been devised (Erin Tree Starts) that allows air pruning of emerging laterals and this is currently being tested.

Direct seeding will produce plants with the natural root form but this establishment technique is more troublesome than planting. Young seedlings are subject to predation from many different agencies and the site must be made more fertile to ensure good growth. Early thinnings are also required to ensure an even distribution of plants at a desired spacing. Direct seeding may be suitable for certain sites but on exposed high elevation areas it is unlikely that it would give a crop with satisfactory stocking.

The present cultivation practice of producing continuous plough ribbons encourages root alignment and consequently instability. If this is to be avoided a change in cultivation practice will be required to encourage radial root spread. This might be achieved by the development of a plough which would break up the ribbon and produce isolated turves or mounds. If these can be planted with transplants or seedlings without root distortion then as the trees develop the roots will emerge radially from the mounds thus providing support for the tree in all directions. Other forms of cultivation that could be explored are bedding ploughs which form a low wide convex mound of cultivated soil rather than a high ribbon. Also the use of winged rippers on mineral sites will give greater soil shatter than the conventional tine thus allowing better root spread. The added advantage of using these alternative types of cultivation is that the extraction of timber will not be hindered by an uneven forest floor produced by conventional ploughing.

While this paper discussed instability in lodgepole pine the same basic arguments are applicable to other fast growing pines and species that do not have the ability to form adventitious roots at the root collar e.g. Bishop (*Pinus muricata* D. Don.) and Maritime pines (*P. pinaster* Aiton.) and Douglas fir (*Pseudotsuga* menziesii (Mirbel) Franco.) Greater attention to the establishment of these species is likely to improve crop stability and consequently stem form.

In the past, establishment practices have been judged mainly on survival and early rapid growth with lesser attention being given to the form and development of the tree root system. Greater emphasis should be placed on this aspect of establishment and its success is probably best judged by using the natural root form of the species as a standard.

REFERENCES

BURDETT, J. P. 1978. Control of root morphogenesis for improved mechanical stability in container-grown lodgepole pine. Can. J. For. 8: 483-485.

BURDETT, J. P. 1979. Juvenile instability in planted pines. Irish For. 36(1): 36-47.

CANNELL, M. G. R. and WILLETT, S. C. 1976. Shoot growth phenology, dry matter distribution and root/shoot ratios of provenances of *Populus trichocarpa, Picea sitchensis* and *Pinus contorta* growing in Scotland. Silvae Genetica 25: 49-59.

CHAVASSE, C. G. R. 1978. The root form and stability of planted trees, with special reference to nursery and establishment practice, pp. 54-64. In Proc. of root form of planted trees symposium. Victoria BC. BR. COL. M.N. For. and Can. For. Serv. joint Report No. 8.

HENDRICK, E. and PFEIFER, A. R. (In prep.). The effect of ploughing direction on the stem form of lodgepole pine (*Pinus contorta* Dougl. ex Loud).

KINGHORN, J. M. 1978. Minimising potential root problems through container design, pp. 311-321. *In* Proc. of root form of planted trees symposium. Victoria BC. BR. Col. Min. For. and Com. For. Serv. joint Report No. 8.

LINES, R. 1971. Provenances. Lodgepole pine. Studies of factors leading to basal bowing, pp. 39-40. *In* Rep. on For. Res. H.M.S.O. London.

LINES, R. and BOOTH, T. C. 1972. Investigation of basal sweep of lodgepole pine and shore pines in Great Britain. Forestry 45: 59-66.

LINES, R. 1980. Stability of *Pinus contorta* in relation to wind and snow, pp. 209-219. *In Pinus contorta* as an exotic species. Proc. of I.U.F.R.O. working party meeting on *Pinus contorta* provenances in Norway and Sweden. Swed. Univ. Agr. Sci. Rep. No. 30. Garpenberg, Sweden.

LOW, A. J. 1975. Production and use of tubed seedlings. Bull. For. Comm. 53. HMSO. London.