RESEARCH NOTE

MORPHOLOGICAL MARKERS OF PHYSIOLOGICAL AGE FOR *PINUS RADIATA*

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INTRODUCTION

Rooted cuttings of *Pinus radiata* D. Don have been produced for more than 60 years (Field 1934; Jacobs 1939; Fielding 1954, 1964; Thulin & Faulds 1968). The effect of maturation or physiological ageing on rooting success of cuttings has been reported (e.g., Fielding 1964) but the strategic significance of ageing was not fully realised in the 1960s (Thulin & Faulds 1968). There are both advantages and disadvantages associated with physiological age (Menzies *et al.* 1988), and field trial results have now indicated that there is an optimum physiological age of 3–4 years when there are advantages of improved stem form with some ageing but not the disadvantage of early loss of stem diameter growth associated with older physiological ages (Menzies, Klomp, Holden, & Hong 1991; Menzies, Klomp, & Holden 1991; Forest Research Institute 1991). Reliable morphological markers of physiological ages are required to ensure that cuttings of the right age are selected for setting in nurseries for plantation establishment.

DEFINITION OF PHYSIOLOGICAL AGEING

Physiological ageing is defined as the process of change from juvenile to mature state. A particular physiological age refers to a particular developmental state or phase as indicated by the presence of phase-specific characters. The apparent physiological age of a tree may be different from its chronological age (time taken to grow from seed) because of environmental influences and cultural practices. This definition of physiological age has been in use for about four decades in New Zealand (Sweet 1964), and is consistent with the concept discussed by Robbins (1957), Borchert (1976), and others, but is somewhat in conflict with definitions published by other authors.

Wareing (1959, 1987) used the term "maturation" to describe the transition from juvenile to mature phase, which is difficult to reverse, and the term "ageing" to indicate loss of vigour associated with increasing complexity in the plant, which is easily reversed through horticultural practices. Fortanier & Jonkers (1976) referred to this loss of vigour as

"physiological ageing" in contrast to the more persistent "ontogenetic ageing" or "maturation". This is in conflict with the definition of physiological ageing developed in New Zealand.

We have made no attempt to separate the apparent physiological age, or process of change from juvenile to mature state, into the phenomena of maturation (or ontogenetic ageing) and the easily reversible loss of vigour. However, we have long been aware of the two distinct phenomena (Sweet 1964) and believe that most of the changes associated with physiological ageing, described in this research note, are due to maturation and are therefore very difficult to reverse.

DESCRIPTION OF MORPHOLOGICAL MARKERS

The following description of bud and foliage markers of physiological ageing is based on *P. radiata* plants grown in the central North Island. These markers were used to determine the age of material used in field trials for defining the optimum physiological age (Menzies, Klomp, Holden, & Hong 1991; Menzies, Klomp, & Holden 1991; Forest Research Institute 1991).

The morphological markers are the appearance of the terminal bud, length and colour of the primary needles, length of secondary fascicle needles, and the presence of lateral shoots (Table 1).

Cutting material from 1-year-old seedlings does not have sealed buds or lateral branches. The foliage consists of mostly large primary needles with the secondary needles or true fascicles usually shorter than the primary needles (Table 1, Fig. 1 and 2). The foliage is more supple than older material, and can be bent without damaging tissue. The apical bud is surrounded by a tuft of primary needles, and is not visible unless those needles are removed.

Cutting material from 2-year-old seedlings has shorter primary needles, and larger secondary fascicle needles. Sealed buds are rare in material from 2-year-old trees, although the apical portion of the stem and foliage is usually yellower and the apical foliage may be shorter than foliage from 1-year-old seedlings (Table 1, Fig. 2 and 3).

The foliage of cuttings from 3-, 4-, and 5-year-old trees is all very similar. The distinctive characteristics of each age group are the ratio of sealed buds in groups of cuttings, the increasing length of the foliage, and the darker green in the more mature cuttings (Table 1).

Buds of cutting material from 3-year-old trees are in a transition state, with an apical bud becoming clearly visible, but still surrounded by primary needles 1–2 cm long (Fig. 4). Some

TABLE 1–Shoot characteristics of cuttings from 1- to 5-year-old *Pinus radiata* trees

Physiological age (yr)	Cuttings with sealed buds (%)	Length of primary needle (cm)	Length of fascicle needles (cm)	Presence of lateral shoots (%)
	0	2.5–3.0	2.5–3.0	0
2	0–5	1.5–3.0	2.5–6.0	10–15
3	20–25	1.0–2.0	5–8	85–90
4	75–80	1.0–1.5*	8–12	100
5	90–100	0.5–1.0*	10–16	100

* The primary needles of cuttings from 4- and 5-year-old trees are often desiccated or perished.

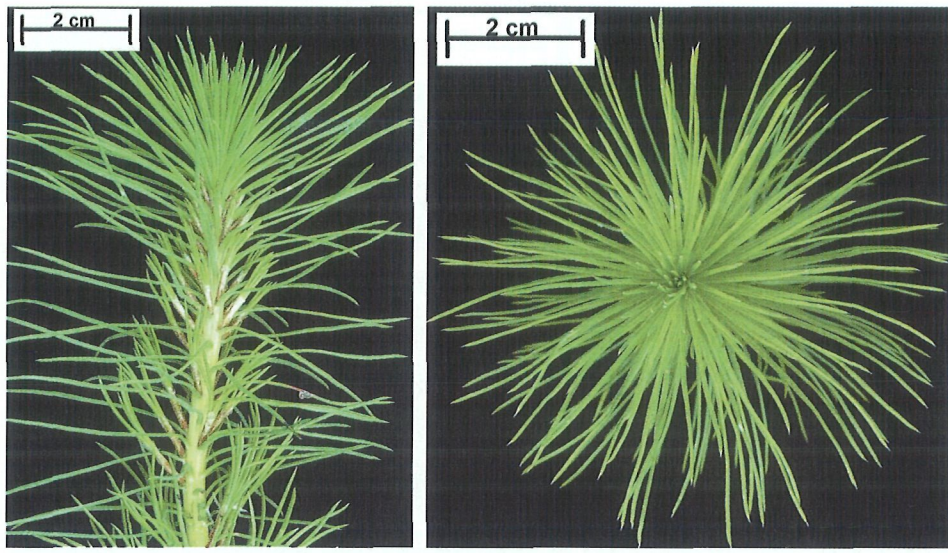

FIG. 1–Cuttings from 1-year-old seedlings; (left) side view, (right) top view.

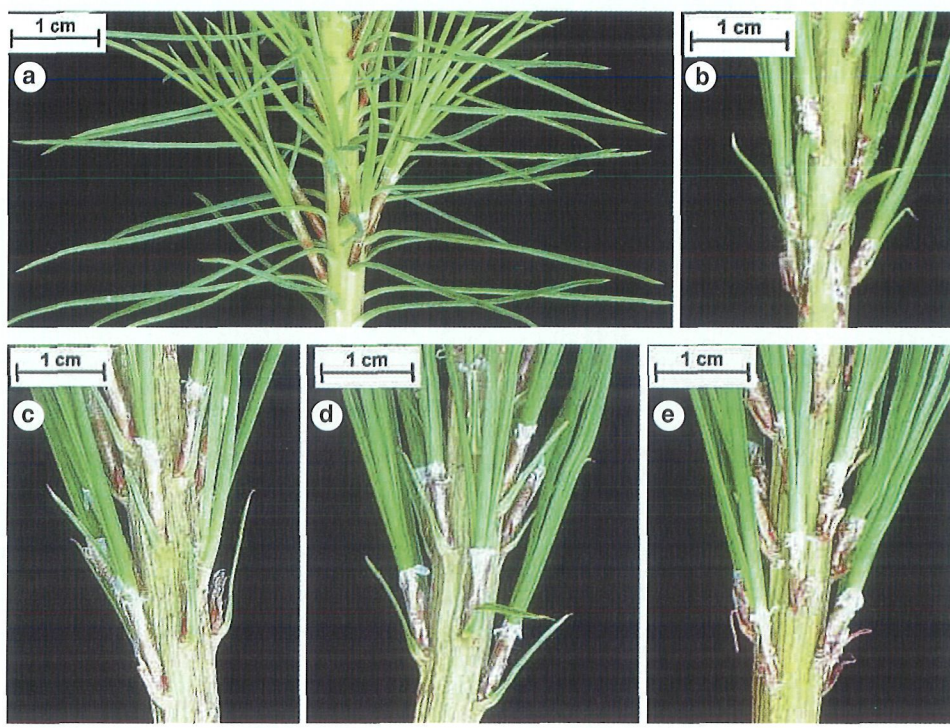

FIG. 2– Primary needles of cuttings from (a) 1-year-old, (b) 2-year-old, (c) 3-year-old, (d) 4-year-old, and (e) 5-year-old seedlings. Note decreasing length of primary needles with increasing physiological age, with primary needles from 5-year-old seedlings being desiccated brown bracts.

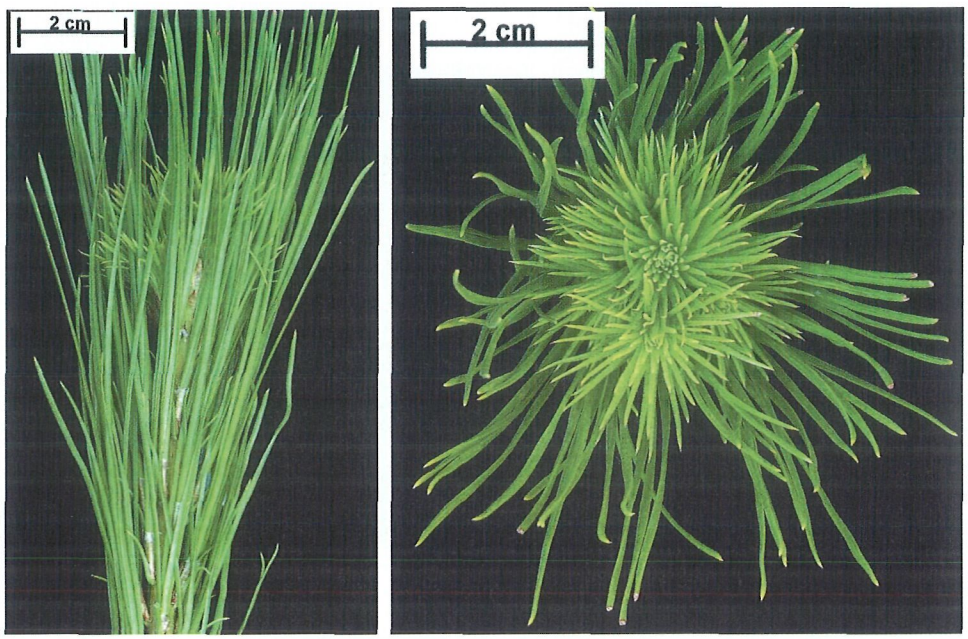

FIG. 3–Cuttings from 2-year-old seedlings; (left) side view, (right) top view.

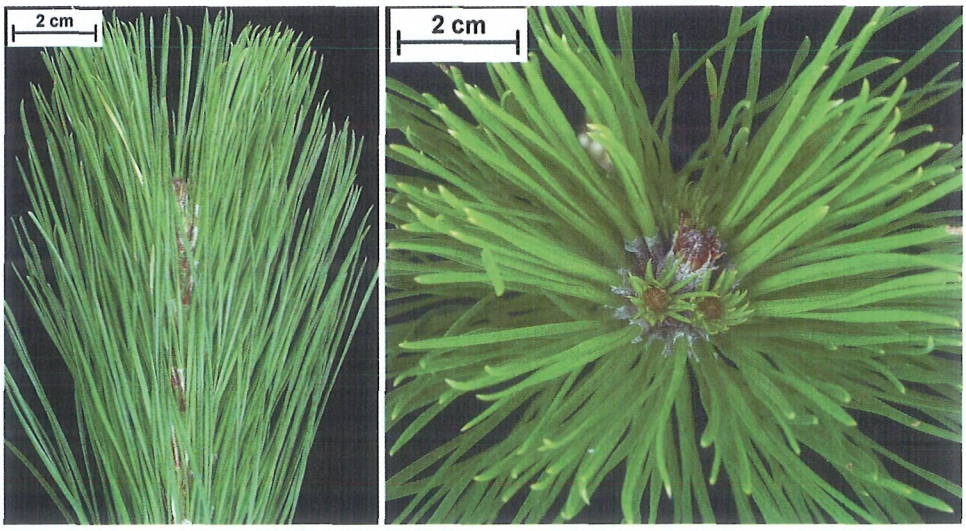

FIG. 4–Cuttings from 3-year-old seedlings; (left) side view, (right) top view.

cuttings have sealed buds by age 3 years (20–25%). However, by age 4 years, 75–80% of the cuttings have sealed buds (Fig. 5) and the primary needles are mainly short green or desiccated brown bracts (Fig 2).

Cuttings from 5-year-old trees have a whorl of sealed buds on every cutting. The secondary needles are all at least 10 cm long when they are fully grown and the primary needles are reduced to about 1 cm long and are often desiccated to small brown bracts, if they are present at all (Fig 2). The foliage is less supple than younger material and could very well snap if bent too far (Fig. 6).

The mean heights for trees aged 1 through to 5 years old (from seed), planted in field trials on typical central North Island sites (Kaingaroa), are 0.3 m for a 1-year-old seedling, 0.7 m for a 2-year-old tree, 1.5 m for a 3-year-old, 2.7 m for age 4, and 4.0 m for age 5.

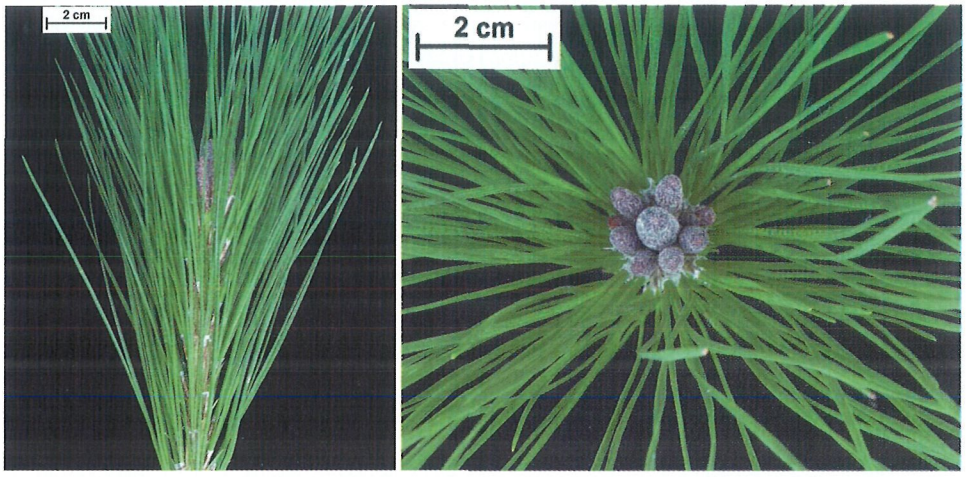

FIG. 5–Cuttings from 4-year-old seedlings; (left) side view, (right) top view).

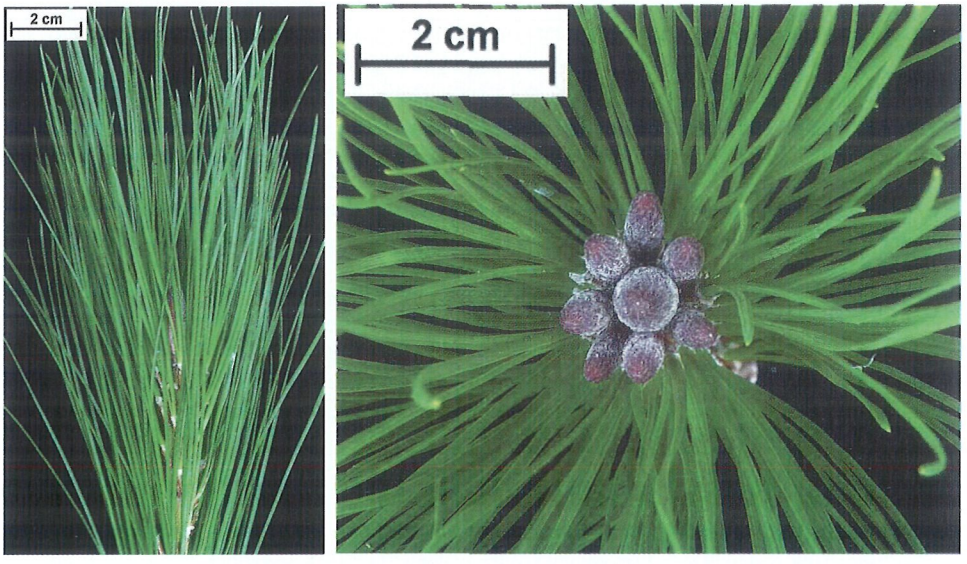

FIG. 6–Cuttings from 5-year-old seedlings; (left) side view, (right) top view.

DISCUSSION

The description of ageing characteristics is based on trees growing in the central North Island. *Pinus radiata* trees mature faster when they are growing more rapidly on milder or more fertile sites. This means that the physiological age of cutting material will be older than the chronological age of the trees on these sites. For example, cuttings from 4-year-old trees on a coastal Bay of Plenty site had an apparent physiological age of 6 years, based on their needle and bud characteristics, and the presence of pollen catkins. There are also differences based on the genetic make-up of trees, with some families or clones ageing faster than others, and this is the probable reason for the range in the percentages for various markers in Table 1. The recommended optimal physiological age (Menzies, Klomp, Holden, & Hong 1991; Menzies, Klomp, & Holden 1991a, b) is approximately 3 years, with age-3 cuttings having a transitional bud, as described above.

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