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Nursery cultural practices have been shown to greatly influence the morphological and physiological condition of the seedlings - and ultimately their field performance potential. One such practice is the use of herbicides to control weeds in the nursery bed and thus reduce competition. Therefore, the use of herbicides should allow the production of better quality seedlings. However, while herbicides may control the weeds, they may also have an adverse effect on the quality of the seedlings. The phytotoxicity of most modern herbicides is caused by their disruption of plant metabolism. Herbicides disrupt plant growth and development, and occasionally lead to injury or death, depending upon the intensity of the effect. Thus it is unwise to use herbicides that damage the crop. Unfortunately, little is known about the effects of herbicides used in forest nurseries on seedling quality.

This project was initiated by COFORD in 1997 to address some of these problems. Sitka spruce (*Picea sitchensis* (Bong.) Carr.), ash (*Fraxinus excelsior* (L.)), beech (*Fagus sylvatica* (L.)), sycamore (*Acer pseudoplatanus* (L.)), and oak (*Quercus robur* (L.)) were selected as test species because they are some of the most important tree species used in Irish forestry today. The objectives of the study were:

- **To examine the efficacy of the herbicides oxadiazone, isoxaben, metazachlor, propyzamide, haloxyfop/isoxaben mixture, oxyflurofen, napropamide, simazine, and prometryn, in controlling weeds in a forest nursery;**

- **To study the seasonal effects of these herbicides on the morphology of ash, oak, beech, sycamore, and Sitka spruce seedlings.**

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The Impact of Herbicides on Tree Seedling Quality

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Background

Weed control is a global problem in bare root nurseries. Without the use of chemicals, some seedbeds have required over 10,000 handweeding hours ha^{-1}. As a result, weed control is potentially one of the most expensive steps in the production of tree seedlings. In some cases, the cost of handweeding has constituted 25 to 90% of the total production costs (Steven, 1932; Wakeley 1935; Boyer and South, 1984). Weed problems in forest nurseries can result from the common practice of leaving gaps of bare ground and growing single species crops that do not utilise all of the site resources. Left unmanaged, nursery weeds can virtually destroy entire planting programmes, or at least greatly reduce yield and quality.

To reduce the cost of weed control, nursery managers in Ireland rely heavily on the use of herbicides (although hand weeding is also still used for the larger weeds). Unfortunately nursery managers have tended to use the same few effective herbicides, and have been reluctant to experiment with new herbicides (Williamson *et al.*, 1993). This has resulted in the development of herbicide resistant strains of weeds (e.g. Simazine resistant groundsel) (Delaney and Moon, 1984) which are then difficult to control. Furthermore there is also a paucity of information about residual herbicides and their efficacy in the long-term control of annual weeds (Willoughby, 1996). Crop tolerance is another problem with new or untested herbicides. Furthermore, there has been little research on the effect of herbicides on seedling quality attributes.

Because herbicides are designed to be toxic to plants, the potential for crop damage is often high. Problems can result from applying too much of the chemical, improperly applying the chemical, or treating too frequently (Kuhns, 1982). Phytotoxic effects can take many forms. Possible symptoms in crop seedlings include germination failure (Cooper, 1984); needle chlorosis and burn (Meakin and Orpin, 1984; South, 1986); stem

Table 1: Herbicides used in the study

Active Ingredient	Trade Name	Mode of Action	Rate/ha
Napropamide	Devrinol	Residual	6 litres
Simazine	Gesatop	Residual	2 kg
Isoxaben	Flexidor	Residual	1 litre
Metazachlor	Butisan S	Residual + Contact	2.5 litres
Oxadiazone	Ronstar	Residual + Contact	4 litres
Prometryn	Gesagard	Residual + Contact	2 kg
Propyzamide	Kerb	Residual + Contact	3.75 litres
Haloxyfop/Isoxaben	Gallant Solo/Flexidor	Residual	2 litres/1 litre
Oxyflurofen	Goal 2e	Residual + Contact	1 litre

swelling or lesions (Callan, 1980); stunted or distorted growth of needles, shoots (Mason and Williamson, 1988), and roots (South, 1986); and mortality (Turner and Loader, 1980). Sometimes the damage is obvious (e.g. heavy mortality or severe stunting) while at other times the effects are so slight that they can only be detected by careful analyses.

Methodology

The seedlings used in this study were sourced at Coillte Teoranta, Ballintemple Nursery Co. Carlow (52° 44' N, 6° 42' W). All the herbicides were applied over the top of the crop species in July, August and September and the trials lasted three years (Table 2).

Weed Control

The efficacy of weed control was monitored by removing all weeds from the plots by hand before the herbicides were applied. One month after herbicide application, new weed growth was assessed by removing all weeds from the plots, dispatching them to University College Dublin (UCD) where the dry weights of the weeds per m^2 were determined for each plot and treatment. Prior to this weeding operation the weed species in each plot were identified. This approach ensured also that the effect of weed competition on the seedlings was minimised.

Morphology

In early January of each season, 50 seedlings, from each of the replicates (three replicates for each treatment), were lifted and dispatched to UCD for evaluation. This gave a total of 150 seedlings per treatment. The height, root collar diameter, and root dry weight of each seedling was then determined.

Table 2: Tree species and herbicide applications

Herbicides	Tree Species				
	Oak	Ash	Sycamore	Beech	Sitka spruce
Napropamide		✔			✔
Simazine					✔
Isoxaben	✔	✔	✔	✔	✔
Metazachlor	✔	✔	✔	✔	✔
Oxadiazone	✔	✔	✔	✔	✔
Prometryn					✔
Propyzamide	✔	✔	✔	✔	✔
Haloxyfop/Isoxaben	✔	✔	✔	✔	✔
Oxyflurofen					✔

✔ = applied to species

Results and Conclusions

The results of these trials are presented in summary form in Table 3.

While it must be borne in mind that the efficacy of herbicide applications depend on conditions at application time, soil type, and species of tree, the following conclusions may be drawn from these trials:

- The herbicides Isoxaben and Napropamide were very effective in controlling weeds in this trial and could be useful alternatives to Simazine in Irish nurseries. However, their effectiveness in controlling grass weeds was poor;
- Oxadiazone should be rigorously tested on each tree species before using commerically;
- Oxyflurofen should not be recommended for use in Irish nurseries.

In conclusion it must be stressed that nursery managers must determine the approval status of herbicide products before using them in their own nursery. Furthermore, small scale operational testing should be carried out before using any herbicide in a forest nursery.

More detailed results of this work can be found in Mc Carthy (2000).

Table 3: Summary results of species tolerance to herbicides applied in July, August, and September

Herbicide (Active ingredient)	Product used	Rate/Ha	Weed Control	Tolerant Species		Non-Tolerant Species	
Napropamide	Devrinol (450g/litre)	6 litres	Very Good	Ash Beech Oak Sycamore Sitka spruce	(August September) (August, September) (August, September) (August, September) (July, August, September)	Ash Beech Oak Sycamore	(July) (July) (July) (July)
Simazine	Gesatop 50F (500g/kg)	2 kg	Very Good	Sitka spruce	(August, September)	Sitka spruce	(July)
Isoxaben	Flexidor (500g/litre)	1 litre	Very Good	Ash Beech Oak Sycamore Sitka spruce	(August, September) (August, September) (August, September) (August, September) (August, September)	Ash Beech Oak Sycamore Sitka spruce	(July) (July) (July) (July) (July)
Metazachlor	Butisan S (500g/litre)	2.5 litre	Good	Beech Oak Sycamore Sitka spruce	(September) (September) (September) (September)	Ash Beech Oak Sycamore Sitka spruce	(July, August, September) (July, August) (July, August) (July, August) (July, August)
Oxadiazone	Ronstar (250g/litre)	4 litre	Very Good	Sitka spruce	(September)	Ash Beech Oak Sycamore Sitka spruce	(July, August, September) (July, August, September) (July, August, September) (July, August, September) (July, August)
Prometryn	Gesagard (480g/litre)	2 kg	Very Good	Sitka spruce	(August, September)	Sitka spruce	(July)
Propyzamide	Kerb Flow (400g/litre)	3.75 litre	Good	Ash Beech Oak Sycamore Sitka spruce	(September) (July, August, September) (September) (September) (September)	Ash Oak Sycamore Sitka spruce	(July, August), (July, August) (July, August) (July, August)
Halox/Isoxaben (Mix)	Gallant/Flexidor (104g/500g)	2 litre/1 litre	Very Good	Beech Oak Sycamore Sitka spruce	(September) (September) (September) (September)	Ash Beech Oak Sycamore Sitka spruce	(July, August, September) (July, August) (July, August) (July, August) (July, August)
Oxyflurofen	Goal 2e (240g/litre)	1 litre	Very Good			Sitka spruce	(July, August, September)

Notes: July = Sprayed in July August = Sprayed in August September = Sprayed in September