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An Investigation of Weed Pest Problems in the Emerging Foliage Industry in Kerry

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Dedicated to my wife Vera and daughter Sarah

Abstract

The rapidly expanding cut foliage industry in the southwest of Ireland aims to satisfy the demands of an exacting market requiring quality stems for use in the manufacture of flower and foliage bouquets.

The studies identified, in detail, the type of weed pests that cause problems for growers of cultivated foliage crops and examined current weed control practice.

Residual herbicides with potential for use within the sector were screened and trials were set up in a number of important foliage species.

Recommendations on weed management regimes based on the findings from these trials and economic criteria are presented for *Paeony Roses*, *Pittosporum tenuifolium, Eucalyptus perreniana, Eucalyptus moorei, Erica veichii* and two cultivars of *Hypericum.*

General recommendations are made based on results taken from individual trials.

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1.0 Introduction

1.1 The Foliage Industry in the Southwest of Ireland

The ‘cut foliage’ industry in Kerry is a commercial operation involving the annual harvesting of both wild and cultivated branchlets, decorative in nature, from perennial plants. These branchlets are graded, bunched, packed and supplied to an expanding international market to be used as core ingredients and as fillers in the creation of bouquets and in flower arrangements. Cultivation of foliage species commenced in 1993 with the objective of developing a range of species to complement sales of wild rhododendron material. The cultivated foliage sector of the industry is based on selected ornamental perennial crops grown on productive mineral soils. Evergreen plants with green, silver or variegated foliage are most commonly used. These plants are intensively grown and managed with the aim of producing high quality stems or ‘greens’, which may also have flowers or berries according to species.

The cultivated foliage sector has developed from a small base of growers spearheaded by the company Forest Products Ltd., and extends to over 65 hectares of foliage-producing trees and shrubs in the Kerry region in 2004. The industry is also developing in other counties such as Waterford and Wexford. Demand for cut foliage has grown substantially over the past ten years. The total value of Irish foliage production in 2003 was over €2 million, most of which originated in the southwest of Ireland. This figure represents cultivated and wild foliage produce. Growth has been steady and production forecasters expect a significant expansion in Irish **cultivated** foliage production from 70 ha (2001) to 350 ha (2005), a boost in stem numbers to 15m per annum (Meagher & Whelton, 2002).

A strategic overview of the industry undertaken in 1997 outlined the key factors for success in the foliage industry (Kelly, 1997). The production of high volumes of quality foliage to satisfy the demanding specifications of buyers is one of the main findings within this document. The production of such quality cut foliage requires fine-tuned information on all relevant areas of crop management. Pollock (1982) identified weed control as one of the production requirements in a cut foliage programme. The potential for loss in growth and quality due to competition from weed infestations was recognised as a serious threat in particular to young foliage crops (Kelly, 1997). This is the context in which the current study was undertaken.

This study is one of five postgraduate applied research projects undertaken as a result of links established between the Kerry Foliage Committee and the local Institute of Technology in Tralee. The potential of the foliage industry in Kerry and the importance of technical support backed by a solid research and development programme had been recognised. The projects addressed specific technical problems and were targeted at providing research-based information where gaps existed within the foliage industry. The biological control of *Ctenarytaina eucalypti*, an insect pest in *Eucalyptus* species was considered in another research project (Purvis et al., 1998). This research focuses on weed pests and appropriate regimes for their control.

While this project was undertaken largely in a commercial environment and with a significant applied objective, the importance of using well-established and scientifically verifiable techniques was also recognised from the outset. To this end, research based on appropriate weed control regimes was planned following a detailed review of previous work of a similar nature within the literature. The need for trials to be set up and monitored in a controlled and systematic manner and for resultant data to be analysed using statistically sound techniques was also recognised.

2.0 Literature Review

Section 2.1 firstly introduces the main cultivated foliage crops grown in the southwest of Ireland and aspects of their growth patterns that may require specific weed control regimes. The challenges of weed development in foliage crops and similar crop production systems are then reviewed in Sections 2.2, 2.3 and 2.4.

An examination of weed control systems used and recommended by other researchers and authors in Section 2.5 leads to the selection of residual herbicides as a main focus for the project at hand in Section 2.6. The aims and objectives of objectives of the current study are formulated and presented in Section 2.7 based on what has been reviewed to date.

This is followed in Section 2.8 by a review of individual residual herbicides that were available and considered suitable for field trials in the foliage crops selected. The extent of relevant research work involving these herbicides on cut foliage or similar woody species varies considerably according to the chemical(s) involved. Reference is made to this research where it was found to have been undertaken. Information on individual herbicides is classified according to work carried out and possible further research that is merited.

Section 2.9 reviews chemical control systems used in other countries. The use of such control in the southern hemisphere was considered particularly relevant as it is the original home of species such as *Eucalyptus* and *Pittosporum*. Chemical control systems applied in areas such as the UK and Germany were also investigated. A summary of the herbicides reviewed and their relevance to the current project is presented in Section 2.10.

Section 2.11 looks at herbicide sprayers and research methods used in previous research as a guide to what would be appropriate in the current trials. Finally, Section 2.11 justifies the need for and the potential use of the current research.

A significant amount of information on general weed control in this project is gleaned from research papers found in the literature. However, a dearth of information was found to exist in relation to work completed on specific areas such as herbicide safety and efficacy in relatively new foliage crops in the southwest of Ireland. To this extent this author was fortunate to have regular contact with two researchers that have been continuously involved in the Kerry foliage industry since its inception. These researchers are Andy Whelton, Teagasc Adviser to the Foliage Sector in Kerry and Jim Kelly, former Head of Research in Teagasc, Kinsealy and who is retained as adviser to the Kerry Foliage Sector. Both of these individuals provided valuable information and insight through personal communication that considerably helped in the current research.

2.1 Cultivated Foliage Crops

The mild climate of the southwest of Ireland provides very favourable growing conditions and the opportunity for cultivation of a range of foliage species. While trials into new species and varieties are ongoing, a number of species currently form a basis for profitable production. The following is a brief summary of the main foliage crops grown in the southwest of Ireland and weed control requirements according to species.

Eucalyptus species form an important component of the Kerry Foliage Industry. *Eucalyptus* foliage has been cultivated for many years in southern France, Italy, the UK and USA. The market is based upon the attractive juvenile growth of species with round or oval waxy leaves that have a silvery sheen. With over 500 species the genus has a wide adaptation to temperate, subtropical and tropical climates. Varieties favoured under Irish conditions include *E. perreniana, E. parvifolia, E. pulverulenta and E.moorei* (Whelton, 2000). An example of *E. moorei* is presented in Plate 1. It is recognised that intensive production is critical to success in the Australian foliage industry. Plant care is essential for quality production and a viable industry (Sedgely, 1999).

The *Eucalyptus* species used in Kerry are raised from seed sown in a glasshouse in February and grown on until they reach about 20 cm in height. Seedlings are planted out into the field at three to four months typically during June to August. Seedlings are planted in rows at spacing of 1.3 metres (m) along and between rows. It is at early seedling stage that weed growth can seriously affect the development and success of a foliage crop. A clean weed-free site is required prior to planting out and to allow continued growth without harmful weed competition for all foliage species (Robinson, 1997, pers. comm).

Plate 1: *Eucalyptus moorei*

Pittosporum tenuifolium is a native of New Zealand and has black or purplish shoots covered with shiny, light green leaves that are between 2 and 3.5 centimetres (cm) long with wavy edges. The dark purple flowers are usually produced singly from the leaf axis in May. *Pittosporum* is currently showing considerable potential as a foliage crop and production is set to increase substantially in future years. Plant propagation closely follows that previously described for *Eucalyptus* crops. Seedlings in peat pots planted out during the growing season are vulnerable to weed growth in the early months. As with *Eucalyptus* and other species, the control of weed competition remains critical until the newly-planted seedlings have become established.

Paeony roses are herbaceous perennial shrubs grown from tubers. They were introduced as a foliage crop in order to satisfy the market demand for the provision of both flower and foliage on the same stem. Field establishment in the southwest has involved planting of *Paeony* tubers in plough ridges at approximately 70 cm spacing along and between rows during winter months. Shoots emerge above ground level from late February to early March and growth reaches a peak in mid to late June.

Paeony species differ in growth pattern from the *Eucalyptus* and *Pittosporum* species in that they die back and over-winter as underground tubers. Tubers increase in size and bulk below ground during the early years of crop development and shoot and flower production increase accordingly. For this reason, early control of weed competition is essential and safe herbicides are particularly required for this sensitive species. The use of residual, soil-acting herbicides with a wide target weed range would significantly benefit crop safety and husbandry (Costello, 1998, pers. comm.)

Hypericum androsaemum is a semi-deciduous herbaceous perennial species with narrow ovate foliage up to 3 cm long producing yellow flowers. Potted seedlings are planted at a spacing of 70 cm both along rows and between rows during winter months. Weed control is again essential for newly planted crops (Costello, 1998, pers. comm.). Limited spraying is possible during the dormant season. This is when the plant has lost its foliage and died back to hard wood. Low applications of a contact herbicide[1] such as **paraquat** are possible at this stage in order to target certain annual weeds (Whelton, 2004, pers. comm.). However both annual and perennial weeds growing close to the plants in established crops are difficult to spot treat with a systemic herbicide[B] such as **glyphosate** without the risk of damage during the growing season (Plate 2). Effective and safe soil acting residual herbicides or herbicide mixtures would therefore be desirable to minimise the development of such weed species in close proximity to the crop plants (Costello, 1998, pers. comm.).

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[1] A contact herbicide is applied typically to the foliage or shoots of plants and affects plant processes locally in the area of contact.

[B] A systemic herbicide is applied to the foliage or shoots of plants and moves through the plant, affecting processes in other areas such as the roots. This can result in a more effective kill than with contact herbicides.

Plate 2: Weed growth in Close Proximity to *Hypericum*

Heathers are planted to meet a demand for flowering shrubs of varying colours. The most popular heather species in Kerry Foliage is *Erica veitchii.* This species is grown on to the flowering stage in the Kerry region and was introduced to the UK market in 1996. It has been successfully offered for sale as a 'stand-alone' unit in bouquets in leading supermarkets. Potted **heather** species are planted out in summer months and early weed control is essential as with other foliage species.

Heather is a woody perennial shrub with a relatively shallow but extensive rooting system. It is often difficult to maintain a weed-free crop due to the growth of difficult perennial weeds up through the heather plants during the growing season, similar to weed development in *Hypericum* crops. The use of spot applications of contact or systemic herbicides is therefore risky under these crop situations. For this reason, alternative systems are desirable.

Ozothamnus is a woody perennial species again with considerable potential within the Kerry foliage industry. This Australian native cut flower crop, harvested solely from the wild in the late 1980's is now cultivated in all Australian states and in the

US. The commonly used herbicide simazine is not labelled for use on this crop. There is very little specific information in the literature on the herbicidal treatment of foliage crops of this species.

Other cultivated species that are becoming increasingly sought after in the Foliage Industry include *Vibernum, Cotinus, Photinia* and *Rosemary* species.

2.2 Competition from Weed Development

Weeds can be defined as "plants growing in the wrong places", which means every plant species is a potential weed. Successful weeds are aggressive, competitive and adaptable. Their most important attributes are efficient reproduction combined with mechanisms that permit survival under temporarily unfavourable conditions. The vast majority of weed species reproduce by seed and some are very efficient producers e.g. Willowherb 76,000 seed per plant and Ragwort 63,000 seeds per plant (Fletcher & Kirkwood, 1982). The significance of these figures is best appreciated when one considers that the multiplication rate for a cereal is commonly 25-30 times, grasses 30-80 times, White Clover 40-70 times. One dense weed stand has been estimated to produce more than 12,000 million seeds per hectare (ha) and seed production by a dense stand of **rushes** has been estimated at more than 9 million per square metre (Fletcher & Kirkwood, 1982).

Weeds fall into two main categories:

- **Annual** weeds propagate themselves by seeding from mature plants and only last one year. Typical examples are Chickweed and Groundsel.

- **Perennial** weeds spread by the roots and shoots, creeping under or over the soil as well as from seed. They persist from year to year. A typical example of a perennial weed is Creeping Buttercup.

Weeds are harmful to crops in many ways and cause many problems for growers. They provide direct competition for the main plant growth requirements:

- Competition for soil moisture
- Competition for nutrients
- Competition for light
- Competition for growing space above and below ground

2.2.1 Competition for Soil Moisture

The most critical months for water stress in foliage and other crops are usually April, May and June. During these months plant growth is rapid. From April through to the autumn there is a possibility of a deficit in soil moisture during periods of dry weather. It is therefore important to start control of weed pests as early as possible so that foliage plants start into growth with little or no competition. Weeds extract soil moisture through their roots thus drying the soil. They also intercept rainfall. Some of this rainfall will evaporate before it ever reaches the soil, thereby further depleting soil moisture. A dry layer forms relatively quickly on the upper horizon of a bare soil. This layer helps to reduce evaporational losses; vegetation transpires moisture faster and for longer before moisture availability limits further transpiration (Williamson & Mason, 1989). Therefore soil-moisture deficits are greater under weeds than bare soils and weed-induced moisture stress can reduce growth.

In order to survive, young plants growing on a weed-infested site will adapt to avoid moisture stress. They will produce fewer and smaller leaves to reduce their water stress. The leaf stomata will be closed for longer periods during the day to prevent water evaporation from the surface of the leaves. The plants will complete their shoot growth earlier in the season and may also drop their leaves prematurely. In their effort to reduce their moisture stress however, they also reduce their capacity for photosynthesis thus retarding shoot and root growth (Wall, 1997).

2.2.2 Competition for Nutrients

The availability of soil moisture and nutrients are very much interrelated, since without moisture plant roots cannot absorb available nutrients. Plants growing on weedy sites often appear less healthy, with paler foliage. This can be due to the combined effect of the moisture and nutrient deficiency. Once the moisture has been depleted from the upper soil layers plants can no longer extract nutrients from them. Fertilisation of crops on weedy sites will often invigorate weeds at the expense of crop plants. Removal of the weeds around the base of the plant will solve both the water and nutrient deficiency (Wall, 1997). Plant growth is also related to the area weeded around a plant. Larger planting stock should receive a larger weed-free area.

2.2.3 Competition for Light

Tall weeds may compete for light, especially those with large coarse leaves, which shade crop plants, and reduce their photosynthetic capacity. Dead and decaying vegetation that is not removed can physically damage crops when it collapses in the autumn. Tall weeds may in certain circumstances protect young crop plants from desiccation but if their roots are close to the plant roots they will also compete for moisture and nutrients. This is often more important than competition for light on grassy sites subject to water deficits.

Plate 3: The Effect of Grass Competition in *Pittosporum tenuifolium*

Herbicide Treated Untreated

2.2.4 Competition for Space

Weeds can compete with plants for growing space both above and below ground. This competition can limit the physical capacity for plant development as well as providing competition for light, moisture and nutrition. An example of such competition in a crop of *Pittosporum tenuifolium* is presented in Plate 3 above. Where grass and other weeds species are not controlled, there is a danger of crop plants being completely smothered.

2.3 Weeds as a Nuisance in Foliage Crops

The fertile soils and mild climate in the southwest confer a distinct advantage in the production of foliage crops. However, these favourable conditions also give rise to heavy weed growth and infestations in all foliage production systems. The importance of weed control in intensively cultivated crops is considered paramount by many authors. Weed development gives rise to direct competition as described previously. Such competition can seriously reduce crop growth and vigour and cause delays in achieving marketable produce. Weed competition can also reduce crop quality. Poor foliage colour or lack of stem extension will reduce the quantity of foliage sprays getting to the market for a given crop. Heavy weed infestations can significantly interfere with harvesting processes. The presence of nettles for example in a *Paeony* crop will create difficulties in manual harvesting of stems (Plate 4).

Plate 4: Nettle and Thistle Growth in *Paeony Roses*

Weeds can also serve as hosts for many pests that attack foliage crops including insects and disease. Weeds in *Pittosporum* crops can act as shelter and breeding grounds for aphid populations that will multiply and attack the *Pittosporum* itself (Whelton, 1998, pers. comm).

The favourable climatic conditions in the southwest region facilitate the growth of an extensive range of weed pests. It may be necessary at times to vary the selection of herbicides and control techniques used when controlling weeds in foliage crops

(Kelly, 1997). This is because of the variation in life cycle and growth pattern between different species. If weed control is delayed or neglected, it is likely that further generations of seed will cause additional problems for growers (Robinson, 1997, pers. comm). Weed control is an expensive practice and 'value for money' for any given set of treatments has to be maximized to sustain a viable foliage enterprise in a competitive foliage industry.

2.4 Site Preparation and Weed Development

Clay (1989) describes how the weed species causing problems within crop production systems are initially more likely to arise from characteristics of the site than of the growing system. Atwood (1996) also describes the weeds most likely to be present as those influenced by past cropping systems and knowledge of this is useful in planning the preparation of a field prior to planting.

The main areas for new plantings in Kerry foliage crops are medium to high quality agricultural land and perennial weeds will usually be the dominant problem. The extent or frequency of these weeds is often not apparent while land remains in pasture or arable crops, but removal of competition through cultivation enables a rapid build-up of weeds. The presence of a grass sward inhibits the aerial growth of Thistle and other weeds without killing their root systems. Clay (1989) also suggests that Bindweed and to a lesser extent Thistle are suppressed rather than killed by the dose of hormone-type herbicides used to treat cereal crops. He describes weed pests such as Creeping Thistle, Field Bindweed and Common Couch as frequent in arable land. Certain annuals, notably *Polygonum* species are also reported to cause particular difficulties because of their resistance to many residual herbicides.

Where land has been under pasture, Creeping Thistle is a common problem but Ragwort, Dock and Buttercup also occur frequently. Clay (1989) describes the overriding need for successful and rapid crop establishment within new crop production systems. Once established, there is also an ongoing requirement to sustain vigorous, weed-free growth within crops; both to maintain a healthy marketable product and to permit harvesting and therefore, return on investment as soon as possible. Weeds present one of the main obstacles to achieving this objective as they threaten the survival or growth of newly-planted crops. This is also the case for the foliage species grown in the southwest of Ireland.

Watson (1991), studying the effects of ground vegetation management in agri-forestry systems on tree growth, found that the growth of young trees was greater on ploughed rather than on uncultivated land. Ploughing is known to release nitrogen by stimulating mineralisation (Dowdell & Cannell, 1975) and this may have provided nitrogen to support extra tree growth. Ground cultivation will also improve soil aeration and drainage. This would suggest that some form of ground cultivation is desirable in the production of most foliage species. A disadvantage of cultivation is the possible hindrance of access for maintenance and harvesting operations due to the presence of plough ribbons or cultivation beds. This can be overcome with good site planning and the inclusion of tramlines for access in the overall design prior to establishment.

2.5 A Comparison of Weed Control Methods

The threat of weed pest infestations within the Kerry foliage industry has presented serious problems for growers of foliage crops and those involved in their management and marketing. The development and implementation of suitable weed control regimes for the range of species and cultivars is critical to the success of an industry that is new to Ireland and the Southwest in particular because it is in a costly development phase. This fact has been identified as one of the industries most pressing problems (Kelly, 1997).

Weed control regimes vary according to location but chemical control is widely used. There is consensus among many authors that the timely use of appropriate herbicides represents an effective and economic means of controlling weed growth when compared with other methods of control. South (1984) outlines the enormous cost and inefficiency of manual weeding compared to chemical controls in bare-root nursery production.

Clemens and Starr (1985) also demonstrated the efficiency of herbicide treatments in field establishment trials on container-grown *Eucalyptus botryoides*. Herbicides generally gave the most-cost effective weed control when compared with a number of alternative control treatments. These treatments included the following:

- Mowing 7 times
- Hoeing around plants 4 times
- Covering with a 0.1 mm polythene sheet
- Applying a 10 cm deep hardwood chip and leaf litter mulch around plants on two occasions for the initial growing season

Hytonen et al. (1994) also found the use of both mulch (particle board) and a cover crop (Clover) did not reduce root competition from weeds in seedlings of *Betula pendula* in Finland as effectively as did the best herbicides. Residual herbicides such as dichlobenil exhibited good weed control for two years and also increased the height growth of seedlings by 40-50 cm.

Precise weed control regimes will depend on many factors such as crop species, weed species, soil type and cultivation practice. Willoughby and Clay (1996) outline a general weed control regime for farm woodland on ex-arable land.

- Established weeds should be cleared before any cultivation through the use of a broad-spectrum contact herbicide.
- When cultivation takes place, a fine firm soil surface should be developed for the effective use of residual herbicides.
- Residual herbicides should be applied as overall or directed sprays immediately after planting to weed free sites.
- During the growing season, repeat applications of residual/foliar or selective foliar-acting herbicides to emerging weeds may be required. In general it is important to apply these products to young weeds before they become too large and established. Alternatively, directed sprays of broad-spectrum herbicides can be used to clear large established weeds. The site should be cleaned at the end of the growing season by the application of a broad-spectrum herbicide, if necessary directed away from the crop species.

Kelly (1997) considers planned weed control as essential to retaining high management standards. A combination of systemic and residual herbicide use is recommended. He agrees that perennial weeds in particular should be killed before planting takes place, as these subjects are difficult to control thereafter and herbicides likely to be considered for use in post-planting weed control should be applied with considerable caution. The prevention of weed growth from the seed of annuals is achieved by the application of residual herbicides applied before weed emergence and repeated where necessary during the season. As with the previous authors, Kelly (1997) agrees that spot-treatment against both annual and perennial weeds that have evaded preventative measures is required to maintain favourable growth conditions in the crop. Robinson (1997, pers. comm.) suggests a similar regime as a basic programme for weed control in woody foliage crops. He stresses the need for complete weed control that will prevent seeding and thereby avoid new generations of weed pests emerging. He recommends this control regime as the most cost effective in the medium to long-term.

2.6 Residual Herbicides - The Main Focus of this Project

Based on a consensus within the literature outlined in section 2.5, the focus of investigation in this project is mainly on the use of **appropriate residual herbicides or mixture of herbicides** that are safe and effective to use for selected foliage crops. It is desirable that such herbicides would be suitable for application by tractor mounted sprayer over the relevant foliage crops ideally before and/or during the foliage growing season. These applications would need to minimise the development of as wide a range of annual and broadleaved weeds as possible. This in turn would minimise the requirement for costly directed sprays of knockdown chemicals such as glyphosate which cannot be allowed contact the foliage plants.

2.7 Aims and Objectives of Current Research

It has been established from the literature review undertaken and from insight into researchers working within the foliage industry that significant gaps exist in available information relating to suitable weed control regimes across the existing range of cultivated ornamental species. The variation in the category of species cultivated gives rise to differences in the pattern of growth for each crop type. Kelly (1997) also describes the continuous requirement for new product formats in the cut foliage market. The industry continues to evolve with the waning in demand for certain crops as novel species and cultivars emerge. The view was taken that control systems recommended as a result of this project may have relevance for similar ornamental species categories in the future and may provide a basis for further research and refinement of control techniques. For these reasons the decision was made to investigate weed control systems in a range of cultivated foliage species. This approach was taken rather than adopting a more detailed research project with a limited remit in terms of crop species selected.

The **aims** of this study are as follows:

- To examine the range of weed species that can develop and compete within foliage crops in the southwest of Ireland.
- To develop weed pest management regimes specific to selected foliage species and growing conditions in the southwest of Ireland.
- To improve the economic return to growers by the development of safe and efficient control regimes.

- To enhance the knowledge of growers and managers in controlling weed pests within some of the main foliage species

The **objectives** of this study are:

- To identify appropriate herbicides or herbicide mixtures for use in field trials, given the weed problems encountered in some of the main foliage species.
- To carry out a comprehensive set of herbicide trials within foliage crops in a scientific manner.
- To determine herbicides safety within these trials using crop growth/performance parameters.
- To determine the efficacy of chosen herbicides within these trials by monitoring the pattern and extent of weed developments and foliage crop performance.
- To determine the indicative cost/benefit of alternative management regimes

In carrying out field trials, it is proposed that two variables be used, herbicides (or mixtures of herbicides) and varying concentrations of those herbicides (or mixtures). Analysis of response variables such as crop height and weed cover will be used to assess the safety and efficacy of herbicide treatments. The study will seek to determine if the factors used significantly influence the response variables. The hypotheses to be considered are that:

- There are no differences between herbicides (or mixtures)
- There are no differences between concentrations.

2.8 Individual Residual Herbicides Considered for Field Trials

All relevant information was considered when choosing appropriate chemicals for the trials undertaken, both published and through communication with research and advisory staff working within the foliage industry. Information and recommendations by herbicide manufacturers for specific chemicals is based on the results of extensive trials on safety and efficacy carried out prior to their approval for general use.

Table 1 outlines the main residual herbicides available for the nursery stock, horticultural and forestry sectors in Ireland. It also presents summary information relevant to each herbicide derived from the manufacturer's recommendations and technical information.

Section 2.8 then gives a brief overview of the chemical considered under the relevant headings as gleaned from the literature:

- Mode of Action
- Research Work Completed
- Research Work Needed

While the general mode of action of each herbicide is outlined in 2.8, a detailed investigation of the processes involved for each herbicide was not within the scope of the current study.

Table 1: Individual Herbicide Details

Herbicide	Rate (l/ha)	Timing	Mix with	Persistence (weeks)	Weed Range	Poor On
Atrazine	3	Dec-Mar	-----------	15	Grasses and annual weeds	Willowherb
Dichlobenil *	60-125 (kg/ha)	Dec- Mar	-----------	15	Grasses, annuals, some perennials	Ranunculus spp
Hexazinone	5-7	Spring or early Summer	------------	15	Grasses, annuals, some perennials	Broom
Isoxaben *	2	Oct – Mar	Pendimethalin	9-12	Annual weeds	Grasses Groundsel Willowherb
Lenacil	1-2	Any Time	Pendimethalin	9-12	Annual weeds	Willowherb
Linuron	2.3-3.5	Pre or early post emergence	Venzar Simazine	12	Grasses and annual weeds	Sowthistle
Metoxuron	5.5-9.0	Pre or Post Rosette stage	------------	12	Mayweeds	Grasses Speedwells
Metazachlor	2.5	Oct – Mar	Isoxaben Simazine	12	Grasses and annual weeds	Bittercress Fat hen
Napropamide	9.0	Dec-Mar	Simazine	12	Grasses Annual weeds	Grassses Some annuals
Oxyfluorfen	2 -4	Oct – Jan 31	Pendimethalin Propyzamide	10	Annual weeds	Some Grasses Chickweed
Pendimethalin	4 - 6	Oct – Mar	Isoxaben Lenacil Metazachlor Oxyfluofen	12	Grasses and Annual weeds	Grasses Some Annuals
Propyzamide *	2-3.75	Oct – Jan 31	Isoxaben, Simazine Metazachlor	12-16	Grasses and annual weeds	Mayweed Groundsel Charlock Smooth-sowthistle
Simazine *	2.5-4.5	Oct - Mar	Pendimemethalin	8-12	Annual Weeds	Grasses,Willowherb, Groundsel

2.8.1 Dichlobenil (Casoron G)

Mode of Action: Dichlobenil is a granular herbicide that is widely used in amenity plantings and as spot treatments in nurseries. It is approved for use on woody ornamental plants.

Following application, the active component of dichlobenil is released and adsorbed into the top layer of soil, forming a chemical barrier. Growth processes involving cell division are inhibited within this barrier. Such processes include seed germination and shoot extension through the soil. This results in the death of existing vegetation such as surface-rooted grasses and annual rooted weeds which are situated inside the barrier (Duphar, 1996). Certain perennial weeds that undergo a rest period during the winter and begin re-growth within the confines of the barrier are also vulnerable.

The active ingredient has a very low degree of water-solubility and a relatively high vapour pressure. Damage symptoms to non target species that can result from the use of dichlobenil include leaf yellowing and stem girdling at ground level. There are a number of susceptible trees and shrubs, and herbaceous plants near the treated area may show some damage.

Work Done: Dichlobenil kills both broadleaf and grass weeds successfully (Duphar, 1996). It also kills a broad spectrum of both perennial and annual weeds. All germinating seeds and seedling weeds from annual and perennial weeds are susceptible. Timing is therefore important for successful control of problem weeds. Dichlobenil has also proven effective on a number of difficult established weeds commonly found in foliage crops. These include *Cirsium arvense*, *Epilobium* spp., *Equisetum* spp., *Poa annua*, *Rumex* spp., *Senecio vulgaris*, and *Urtica dioica*. Dichlobenil is currently recommended for use on *Erica* species, except for the golden varieties which are susceptible to damage. It is also recommended that crops be established for two years prior to application of dichlobenil.

Work Needed: Dichlobenil could potentially be of major benefit if successful in dealing with difficult weed species in established foliage crops particularly where weeds already have a toehold. To this extent the herbicide merits testing on crops such as *Hypericum* and *Erica* to prevent or treat annual and perennial weeds growing up through existing crops.

There is also a lack of information on how **newly planted** foliage seedlings such as those of *Eucalyptus* species will react to a spring treatment, given the short window of dormancy under Irish growth conditions. Dichlobenil is not suitable for soft herbaceous plants such as *Paeony* roses, which are required to emerge through the herbicidal barrier. However, the herbicide could be useful in crops such as *Pittosporum*, particularly with the wide target weed range that includes many notable perennial species (Duphar, 1996).

2.8.2. Hexazinone (Velpar)

Mode of Action: Hexazinone is a broad spectrum herbicide with both contact and soil activity against a wide range of grasses, annual and perennial weeds and brush species. Hexazinone is a photosynthetic inhibitor. It is readily absorbed through foliage and roots, and translocation is primarily upward through the xylem. For this reason, the herbicide is soil-applied so that weeds will absorb the herbicide via the roots, although it also has foliar activity if applied with adjuvants and good spray coverage.

Work Done: The hexazinone product label recommends its use for selective weed control in plantations of certain coniferous tree species such as spruces and pines planted out for at least one year. Actively growing perennial herbaceous weeds are reported as being severely checked by an early application of the herbicide and small plants of some deciduous species are suppressed. According to manufacturer`s recommendations, species such as Creeping Thistle, Willowherb, Common Nettle and a range of grasses are controlled.

Work Needed: The herbicide is not recommended for use in ornamental foliage crops. There is very little information in the literature on trial work carried out on species other than conifers. However, based on its wide range of susceptible weeds, the herbicide may merit testing on foliage crops such as *Erica* species.

2.8.3 Isoxaben (Flexidor)

Mode of Action: Isoxaben is a soil-acting residual herbicide. There is strong soil absorption, which implies limited leaching of chemical (Robinson, 1997), even under high rainfall conditions that apply in the southwest region. Isoxaben works by entering the hypocotyl (that part of a developed seedling embryo immediately below the cotyledons) of certain germinating broadleaf weeds and inhibiting development. Plant processes affected include cell wall synthesis, cell division and protein synthesis. Isoxaben is recommended for application to newly planted or established trees and shrubs before weed emergence, as a directed spray or over the top application.

Work Done: Isoxaben can be safely applied to many species in the autumn or early spring prior to weed emergence. Two applications may be made per year in order to prolong the weed control period. Young broadleaf tree species such as Alder, Ash, Beech, Cherry, Oak and Willow are reported tolerant of the chemical on the product label, providing they have good root development. The product label recommends applications to newly planted sites, prior to weed emergence. Isoxaben will have little effect on most established weeds. Application of isoxaben as part of a weed control programme has become increasingly popular with growers of container trees and shrubs.

Work Needed: The tolerance of broadleaf tree species to applications of isoxaben would suggest that species of *Paeony*, *Eucalyptus*, and *Pittosporum* might also be suitable and worth incorporating in field trials. Limited information is available on the use of isoxaben in foliage crops. It has been used on heathers safely and with good weed control results (Farrell, 1997, pers. comm.). However use of isoxaben on its own does not cover a sufficiently broad spectrum of weeds (Atwood, 1996). Isoxaben will generally be used in a programme as a tank mix with other herbicides such as metazachlor or propyzamide. There is little information in the literature on the efficacy and safety of applying isoxaben as part of a herbicidal mixture to species such as *Paeony* roses, *Pittosporum* or *Eucalyptus*. In general autumn and winter treatments are safest for tank mix treatments. The possibility of extending treatments to spring applications needs to be tested in field situations.

2.8.4 Lenacil (Venzar)

Mode of Action: Lenacil is taken up through the roots of vulnerable weeds and moves rapidly into leaves where it interferes with the processes of photosynthesis (Robinson, 1997). Lenacil is mainly used against annual dicotyledons and Annual Meadow Grass in field grown herbaceous crops in the UK (Atwood, 1996). It is reported as unreliable under dry conditions. Conversely it can be injurious to crop plants through root uptake when heavy rain follows application (Atwood, 1996). The herbicide only controls weeds in the act of germination through root uptake. It has no contact action on established or seedling weeds. Timing of application is therefore vital. The margin of crop safety is not high and the herbicide should not be applied to light or sandy soils (Atwood, 1995).

Work Done: The weed spectrum misses a few important weeds such as Speedwells, Groundsel and Cleavers and therefore lenacil is often included as a component of a herbicidal mixture. Lenacil can be unreliable under very dry conditions and conversely damage through root uptake can occur when heavy rain follows application (Atwood, 1995). The herbicide is approved for use on both *Erica* and *Hypericum* species.

Work Needed: Lenacil has been tested in tank mixture with simazine on *Paeony* crops without any reported injury to the crop (Whelton, 1998, pers. comm.). There is little information available on the safety and efficacy of this particular tank treatment at varying rates of application and further work merited in this area.

2.8.5 Linuron (Afalon)

Mode of Action: Linuron is a photosynthetic inhibitor. It is classified as one of the Phenylurea group. Herbicides in these chemical groups have excellent soil activity. Its label reports both contact and residual action. Emerged weeds are killed by contact and translocating action and emerging weeds by residual action in the soil which is reported to persist for several weeks.

Work Done: The linuron product label recommends its use for selective weed control in potatoes, carrots, parsnips, parsley and celery. According to manufacturers, a range of annual weeds are reported to be controlled both pre- and post-emergence up to the seedling stage such as Sow-thistle, Chickweed, Fat hen, Redshank and Shepherds Purse. Linuron provides control of some grasses and annual broadleaf weeds only at the pre-emergent stage such as Annual Meadow Grass, Mayweed and Speedwell spp.

Work Needed: The herbicide is not approved for use in ornamental foliage crops. There is little information in the literature on trial work carried out on species other than vegetable species. However it may merit testing on species such as *Paeony Roses* whose cultivation and growth pattern is quite similar to that of potatoes. Its useful post-emergence control of many annual weeds to seedling stage makes it a suitable chemical for testing in woody ornamentals such as *Eucalyptus* species. Its product label confirms its compatability in mixture with a number of other herbicides such as simazine and lenacil.

2.8.6 Metazachlor (Butisan S)

Mode of Action: Metazachlor is a residual anilide herbicide used in Brassicas, nurseries and forestry. It is taken up by the roots of germinating weeds and inhibits cell division/enlargement in this area of the plant (Robinson, 1997). Limited translocation occurs within the affected plant.

Work Done: Metazachlor has been widely used for control of simazine-resistant Groundsel. Metazachlor is relatively safe to newly planted stock but is reported to have a low level of contact as well as residual action on weeds (Robinson, 1997). The post emergence control of weeds is very useful. Particular care is recommended in avoiding application to soft growth in the spring and early summer (Atwood, 1996). Application at the onset of growth in the spring has also caused problems on some crop species. Damage is reported to be exacerbated by the addition of isoxaben (Atwood, 1995). However the plants grow away with little effect by the end of the season in most cases.

Metazachlor when used on its own as a spray treatment can be of relatively short persistence, lasting about 3 months. The use of metazachlor particularly in a mix with isoxaben has been a very effective treatment lasting up to 6 months and has been very cost effective (Atwood, 1996). There also seems to be a reasonable margin of safety if application is made during autumn through to winter. Metazachlor can also be used in mixture with propyzamide. Work by the Forestry Commission in the UK has resulted in off-label approval for the metazachlor against broadleaf weeds on farm forestry (Atwood, 1996). This approval allows growers to use the herbicide for forestry purposes but at their own risk.

In preliminary studies by researchers within the foliage industry on *Pittosporum,* a limited number of herbicide mixtures and rates were applied site in September 1997 following planting. Treatments were applied on a one-off basis without replications and provided only observational value regarding control potential and crop tolerances of selected herbicides (Whelton, 1998, pers. comm.). Metazachlor was also applied over 4 adjacent lines of *Pittosporum* at a rate of 2.5 litres per hectare. There were no obvious signs of a reduction in plant health reported when the treated plants were inspected in late February 1998.

Work Needed: Atwood (1996) reports that the weed spectrum of metazachlor compliments that of isoxaben very well. He suggests that when used in tank mixture with isoxaben, metazachlor gives a full range of annual weed control lasting up to a year. This suggests a combination of these chemicals would be appropriate in herbicide trials. Metazachlor is not approved for use on the main foliage species. Due to its slight contact action there is a need to address the question of safety of application on crops such as *Pittosporum* and *Eucalyptus* during spring, when growth is still soft.

2.8.7 Metoxuron (Dosaflow)

Mode of Action: Metoxuron is a photosynthetic inhibitor. It is classed as being in the Urea chemical group. Its product label reports both contact and residual action. Emerged weeds are killed by contact and translocating action and emerging weeds by residual action in the soil which is reported to have good persistence in the soil.

Work Done: The metoxuron product label recommends its use in the control of Mayweeds and other annual broadleaf weeds in carrots. According to manufacturer's recommendations, it will control a number of important weeds up to the two-expanded true leaves stage of growth. These include Charlock, Chickweed, Fat Hen, Persicaria and Redshank.

Work Needed: The herbicide is not approved for use in ornamental foliage crops. There no reported information on trial work carried out on species other than vegetable species. Due to its contact activity, it merits consideration for screening on crops such as *Paeony Roses* where specific annual weeds have emerged and become problematic.

2.8.8 Napropamide (Devrinol)

Mode of Action: Napropamide is a soil-applied residual herbicide used in fruit and woody ornamentals. The roots of susceptible plants take it up and there is limited translocation in the water-conducting tissue. The herbicide affects root processes such as cell division/enlargement and protein synthesis.

Work Done: Napropamide has good activity against grasses and a range of broad-leaf weeds including Composites such as Groundsel. Best results are achieved by treatment pre-emergence of weeds. The herbicide is effective against simazine-resistant weeds, Knotgrass, Cleavers and Willowherb. It is weak on *Cruciferae* such as Sheperds Purse and Charlock. Napropamide is a herbicide of moderate persistence. The active ingredient is broken down by light, so it is essential to apply the herbicide when it can be washed in by rainfall under low light conditions.

Work Needed: There appears to be scope for use of napropamide as a possible alternative to simazine, particularly for weeds such as Groundsel that may have built up resistance. To that end, napropamide may be worth incorporating in field trials on suitable foliage crops. It is not recommended for use on shallow-rooting ornamental stock. It may have potential on species such as *Pittosporum* or *Eucalyptus*.

2.8.9 Oxyfluorfen (Goal 2E)

Mode of Action: Oxyfluorfen is an herbicide with good soil residual properties (pre weed emergence) and also contact activity (post weed emergence). It has uses on tree crops, nursery stock, and amenity situations. It is forms a treated layer in the soil when applied and causes rapid phytotoxicity to plants by damaging cell membranes. Seedling weeds are controlled as they come in contact with the soil-applied herbicide during emergence. The herbicide is also taken up through contact action on leaves and shoots.

Work Done: Oxyfluorfen is strongly adsorbed by the soil, has low water solubility and virtually no leaching potential (South, 1994). At present there is a limited range of tree and shrub species listed on the product label. Manufacturer's recommendations include safe application for such species as Flowering Cherry, Ornamental Pear, False Acacia, Lime and Oak.

Vanner et al. (1989/90) carried out trials on the tolerance of several *Eucalyptus* species (*E. botryoides*, *E. fastigiata*, *E. fraxinoides*, *E.nitens*, *E. regnans* and *E. saligna*) to different herbicides in the Forest Research Institute nursery at Rotorua, New Zealand. Post-emergence applications of oxyfluorfen were made at 0.24, 0.48, and 0.72 kg /ha in the period 6 to 11 weeks after emergence of *Eucalyptus* seedlings. The 0.24 kg ai/ha treatment to *E. nitens* showed a significant increase in growth over the standard nursery treatment. The height growth of *Eucalyptus* species was not significantly reduced although there was damage reported to the foliage. The soil type and its organic matter content were not referred to in the research paper. However since oxyfluorfen binds strongly with the soil and its solubility is very low, the potential for plant damage would appear to be less under the conditions prevailing in the southwest of Ireland.

Work Needed: Atwood (1996) suggests scope for a range of trees and shrubs to be successfully treated with oxyfluorfen given that the product is unlikely to be root absorbed by the crop. This could include newly planted subjects larger than 45 cm. There is a therefore a case for screening oxyfluorfen as a potential component in an overall weed control programme for the Kerry foliage industry. It is possible that *Eucalyptus* and *Pittosporum* species, with relatively hard and shiny foliage would safely tolerate an overall winter application of herbicide (Atwood, 1997). Bradley and McNabb (1996), confirm that it may be applied post-emergence to the base of cottonwood plantings and *Eucalyptus* plantings or applied over the top to these two trees before bud break occurs.

2.8.10 Pendimethalin (Stomp)

Mode of Action: Pendimethalin is a further residual soil-acting herbicide for control of annual grasses and dicotyledons. Like other Dinitroaniline herbicides, pendimethalin is taken up through the roots and disrupts cell division and cell wall formation. As in the case of metazachlor already described, pedimethalin has off-label approval on farm forestry in the UK.

Work Done: Lawrie and Clay (1987) carried out trials on the tolerance of forestry and biomass broadleaf tree species to soil acting herbicides in Long Ashton Research Station, Bristol. Trees were potted in March in sandy clay loam substrate and herbicides applied to moist soil 1 or 2 days later. Pendimethalin was not found to be damaging to common forestry species such as Ash, Beech, Oak, Cherry, and Sycamore at doses of 2.0 and 6.0 kg ai/ha. Pendimethalin also did not damage any of five biomass species when applied at 2.0 or 4.0 kg ai/ha. These species included Alder, Willow and Poplar. The authors conclude that pendimethalin is worth testing in further field trials, being one of the safest of the herbicides tested, when applied to dormant, newly planted trees and cuttings.

Vanner (1992) tested the tolerance of nursery seedlings of several tree species to pendimethalin in New Zealand. Species evaluated included *Eucalyptus botryoides*, *E. fastigiata*, *E.saligna*, *E globulus* and *E. nitens*. Only the growth of *E. nitens* was affected by pre- plus post-emergence applications of pendimethalin at a rate of 0.99 kg/ha when compared to a standard nursery treatment (nitrofen). Tolerance of *Eucalyptus* species to 1.32 kg/ha of herbicide varied between species and season. Seedlings of *E. botryoides* and *E. saligna* showed variable tolerance to the higher rate of application. Statistical comparison showed that the growth of *E. globulus* was not significantly suppressed by a post-emergence application of pendimethalin at rates of

0.99 and 1.32 kg/ha. No foliar scorch or distortion was observed on any of the species treated with pendimethalin. The author did not detail soil type and organic matter content, which would have a significant bearing on results. In post plant applications, the herbicide was also safe over a number of *Eucalyptus* species.

Atwood (1996) confirms that pendimethalin is suitable for use on established field grown trees. It can be tank mixed with a number of compatible herbicides including isoxaben, lenacil, metazachlor, propyzamide and oxyfluorfen.

Work Needed: Pendimethalin appears suitable for testing with a range of foliage species considering its reported safety on past trial species and the relatively broad spectrum of weeds controlled. Based on work carried out to date, trials on species such as *Paeony Roses* and *Pittosporum* may be merited due to its reported safety in many crop situations.

2.8.11 Propyzamide (Kerb)

Mode of Action: Propyzamide is a residual herbicide; its persistence in the soil is related to soil texture, moisture and temperature. There is virtually no breakdown of chemical in the soil below 5°C. It is absorbed by weed roots and kills susceptible species through an inhibition of root development. Affected weeds show symptoms of arrested growth followed by leaf chlorosis and death. The herbicide is insoluble and leaching losses are minimal during average weather conditions.

Work Done: The herbicide is particularly effective against annual and perennial grasses although it has significant activity against key broadleaf weeds (notably *Polygonums* such as Docks, Sorrell and Bindweeds). It can be safely applied over the leaves of all popular tree species without risk of damage. Propyzamide is recommended for use on ornamental trees and shrubs that have been planted in their final position for at least one season. Herbicide may be applied in the autumn following planting. Residual weed control in excess of 6 months can be achieved at higher use rates (Atwood 1996).

Propyzamide is sometimes used outside the normal application window (October – January) in the UK to give shorter-term weed control of difficult broadleaf and grass weed species. Generally no phytotoxicity has been noted provided very soft spring growth is avoided (Atwood 1996). The weed spectrum of propyzamide misses the Composite weeds (such as Mayweeds, Charlock and Groundsel). For this reason it is generally tank mixed in the UK with other herbicides such as metazachlor, isoxaben or simazine.

Haury (1983) undertook weed control trials on three *Eucalyptus* species in the south of France. Selectivity trials on *E. viminalis*, *E dalrympleana* and *E. macarthuri* showed satisfactory results with a 2 kg of propyzamide per hectare and application of a mixture of 1.0 kg propyzamide + 0.66 kg simazine per hectare. Lawrie and Clay (1989) investigated the tolerance of forestry and biomass broadleaf tree species to soil-acting herbicides. Six broad-leaved forestry species and five biomass species were tested. A mixture of simazine and propyzamide was shown to be relatively safe on the forestry species (Ash, Beech, Oak, Cherry, Birch and Sycamore). Earlier work on Oak (Turner & Clipsham, 1984) and other species (Bently & Greenfield, 1987) also showed that a simazine and propyzamide mixture was safe.

Putwain and Mortimer (1991) reported considerable enhancement of establishment and subsequent growth of broadleaf tree seedlings by the application of propyzamide to suppress competitive grass varieties. Tree species included Ash and Hawthorn. Clay et al. (1993) investigated the beneficial effect of herbicide mixtures to newly planted Poplar and Willow cuttings. Simazine was mixed with propyzamide (each applied both at 1.5 and 4.5 kg a.i./ha). There were no adverse effects of the herbicide treatments on crop development during the growing season or on weight of shoots recorded.

Metz et al. (1984) carried out trials on resistant weeds in heather crops in Regensburg, Germany. On nursery beds into which potted heather stock (*Erica gracilis*) was sunk, *Poa annua* became established despite annual applications of Simazine at rates beginning at 1.5 kg/ha for the first few years and increasing finally to 3.5 kg/ha. Effective control of *Poa annua* with good heather tolerance was obtained using 2-3 kg of propyzamide per hectare.

Work Needed: Propyzamide is recommended for use on many ornamental trees and shrubs. The herbicide would appear to have considerable potential if found suitable for use in a possible mixture on *Paeony* plantations. Manufacturers also recommend trees and shrubs be established in the final planting place for at least one growing season. However, the work carried out by Haury (1983) and Clay et al. (1993) outlined above suggests propyzamide might also be safe on newly planted seedlings of broadleaf species such as *Eucalyptus*. The question of the safety of herbicidal mixtures incorporating propyzamide on newly planted stock of a range of foliage species needs to be investigated here.

2.8.12 Triazines (Simazine and Atrazine)

Mode of Action: Simazine is absorbed almost exclusively through the roots. It is translocated through the xylem and acts as an inhibitor to photosynthesis in susceptible species. As there is little or no foliage penetration, simazine is unlikely to damage trees and shrubs as a result of uptake of chemical through the leaf. The solubility of the herbicide is very low and it is strongly adsorbed on clay colloids and soil organic matter.

Atrazine is more mobile in the soil than simazine. It may be taken up through the foliage as well as roots of certain species during active growth, and can cause phytotoxicity to particularly during active growth.

Work Done: Soil type largely determines the effect of simazine on both crops and weeds. The herbicide behaves very differently on different soil types. It is held at the soil surface on clays, peats and clay loams but can leach and cause plant injury in light sands and in sandy substrates (Robinson, 1997). It is necessary therefore to apply lower doses of simazine to medium soils and light loams than to heavy or peaty soils.

Simazine is effective when applied to firm, fine, moist soil at doses between 2.2 and 4.5 l/ha. These applications will only control weeds in the germination stage and thus the soil must be free from established weeds. When simazine is used on a regular basis it is important to prevent surviving weeds from shedding seed as resistant strains of Groundsel and other pest species can develop (Robinson, 1990).

A number of residual herbicides have been investigated in Australian Forestry for weed control efficacy and selectivity in *Eucalyptus* plantings. The triazines have received special attention because they have been found to give good long term, broad-spectrum pre-emergent weed control at relatively low cost and low mammalian toxicity. In addition tolerant tree species may receive a herbicide related direct stimulation of early root development termed the "triazine effect" (Ebert and Dumford 1976, Sands and Zed, 1979). Various residual herbicides, including triazine mixtures, have been recommended for *Eucalyptus* plantations as pre-plant sprays (Fagg, 1988) and as post-plant sprays (Cameron and Turvey, 1977, Flinn et al., 1979, Hall 1985). Preplant spraying can be carried out without risk of damage to foliage crops. However disturbance of herbicidal layer or barrier can occur with passage of machines and operators during planting.

The use of herbicides has become routine for *Eucalyptus* plantation establishment in Tasmania (Wilkinson et al., 1990). Triazine mixtures are predominantly used, usually as pre-plant applications in conjunction with knockdown herbicides. Although results have generally been very good there have been reports of unacceptable phytotoxicity under some situations. Previous experimental work is limited but does suggest that the tolerance of *Eucalyptus* to many of these sprays is variable and may depend upon a number of factors. These factors include herbicide rates; timing of application; *Eucalyptus* species; seedling stock-type; soil characteristics and other environmental conditions (Cameron and Turvey, 1977; Davenhill, 1978; Flinn et al., 1979; Fagg 1988).

Wilkinson and Neilsen (1990) carried out experiments on the effect of triazine herbicides on woody weed control and growth of plantation *Eucalyptus* seedlings in Tasmania. Various herbicides were applied to control woody weeds before and after planting with open-root and paper-pot seedlings of ***E. regnans*** and ***E. nitens***. Atrazine formed an integral part of many of the treatments used with simazine having a lesser role. Treatments included atrazine at 4 and 8 kg/ha both pre- and post-planting. Atrazine was also mixed with simazine (each herbicide at a rate of 2 kg/ha) pre- and post-planting. Glyphosate was tanked mixed with simazine (at rates of 0.72 + 3.0 kg/ha and 0.72 + 6.0 kg/ha respectively pre-planting).

In this trial all herbicide treatments resulted in significantly reduced weed cover during the initial six months of seedling establishment. It was concluded that atrazine at 4 kg a.i. per hectare was an effective and safe herbicide for pre-plant applications to plantation seedlings of ***E. regnans*** and ***E. nitens***. The growth response of seedlings was related to both weed control effects and direct herbicide effects. Post-plant applications of atrazine reduced the survival of potted seedlings but had no effect on the survival of open-root (barerooted) seedlings. The greater resistance of the larger and sturdier open-root seedlings is proposed as a reason for this difference. Pre-plant applications of atrazine even at 8 kg/ha did not reduce survival. This indicates that post-plant phytotoxicity was reported as probably associated with foliar rather than root uptake of atrazine.

At age one year, the poorer weed control treatments included simazine treatment at 3 kg/ha and the lowest residual level of atrazine (2 + 2 kg mixture with simazine). The pre-planting treatments of atrazine (at 4kg/ha) and an atrazine + simazine mixture (2 + 2 kg/ha) resulted in the greatest *Eucalyptus* seedling growth at age two years. Similarly, post-plant treatments of the above herbicides and rates produced similar and significantly reduced growth responses compared to the pre-plant applications. The better growth response of seedlings to the pre-planting treatments above compared with the post-plant applications suggests an earlier exposure to the "triazine" effect may result in longer-term growth advantages (Wilkinson 1990).

In a related study on this site, root excavation of seedlings planted in an atrazine-treated area indicate that seedlings had substantial root systems established within 4 months of planting. A direct stimulation of early root development is suggested as the reason for the significant growth response for treatments where herbicide efficacy was inadequate to maintain longer-term root control. There were no growth differences between simazine applied at 3 kg per ha and simazine at 6 kg per ha (with glyphosate 0.7 kg per ha). Neither rate produced seedlings as tall as the atrazine and simazine mixture (2 + 2 kg) by age two years, despite having equivalent weed cover. This suggests that simazine had much less direct effect on *Eucalyptus* seedling growth than atrazine. Therefore, the response to the atrazine plus simazine mixtures appears to be mainly due to the effect of the atrazine component.

Work Needed: Simazine is approved for use on species of *Hypericum*, *Pittosporum*, *Eucalyptus* and heather when applied as an individual herbicide and has proven safe and efficient for many years. It has also been used on *Ozothamnus rosmarinifolius* 'Silver Jubilee' with significant benefit for the species in terms of weed control efficacy. However, the question of safety arises when simazine is applied in a mixture with one or more further herbicides to broaden and extend the target weed range. The build up of resistance in weeds through repeated use of simazine requires substitute chemicals with a different mode of action that could be rotated with simazine or could possibly replace it in the future.

Atrazine has a broader weed spectrum than simazine and has some contact as well as residual activity (Atwood, 1995). It is therefore of interest for certain woody perennial foliage species but the safety aspects of the herbicide are of concern given its contact activity and propensity to move through the soil to a greater extent than simazine. The safety of atrazine merits investigated when applied to foliage crops growing in the field situation.

2.9 Chemical Weed Control Regimes in Other Countries

This section presents a review of weed control regimes used in different countries such as Australia, New Zealand, the UK and Germany. Much of the experimental work cited in literature on the effect of herbicides on *Eucalyptus* crops has been carried out in the Southern Hemisphere. Work carried out on nursery crops of herbaceous and woody ornamentals and field grown crops in countries such as Germany and the UK is also considered worthy of inclusion in this review. A summary of details of herbicides that are referred to in this section, particularly those used in the southern hemisphere that have not already been dealt with in Section 2.8 are presented in Table 2.

Table 2: Details of Herbicides arising in Section 2.9

Herbicide	Product Name	Weed Range	Mode of Entry (Action)	Timing	Persis-tence (Weeks)	Remarks
Clopyralid (200 g/l)	Dow Shield	Gorse, Broom, Clover, Thistles in woody ornamentals, cereals and horticultural food crops.	Foliar Action	Application during growing season	10-16	Specific for thistle problems Limited use for a range of weeds
Chloridazon (430 g/l)	Pyramin FL	Control of broadleaf weed in beet crops	Root and Foliar absorption	Pre-emergent or after beet have two expanded true leaves	12-16	No control of grasses. Mixed with Chlorbufam for grass control
Chloroxuron *	Tenoran (56)	Annual grasses and broadleaf weeds in horticultural crops such as onions, strawberries and celery	Residual- root absorbed	Pre-emergence or post-emergence only to tolerant crops. Before weeds are 4 cm high	12-18	Relatively good weed range
Diflufenican (500 g/l)	Quartz Brodal	Broadleaf weed control in cereal crops	Residual Root Uptake	Pre- mergence or during early weed growth	8-10	Compatible with simazine
Fluazfop-butyl (213 g/l)	Fusilade	Annual and perennial grasses only in horticultural food crops	Foliar Action	During early stages of growth	10-14	No control of broadleaf weeds
Haloxyfop (104 g/l)	Gallant	Annual and perennial grasses only	Foliar Action	During early stages of growth	10-12	No control of broadleaf weeds
Oxadiazon	Ronstar	Annual grasses and broadleaf weeds in nursery crops	Residual- root uptake. Foliar action during growth	January to July	10-12	Avoid foliage during growing season
Propazine *	Gesamil Milocep Propazin	Annual grasses and broadleaf weeds	Residual- mainly root uptake. Limited contact action	At or shortly following crop planting	11-20	High potential for leaching
Sulfometuron - Metyl*	Oust	Conifer plantations General weed control on non-cropland	Foliar and Root Absorption	Before or during early stages of weed growth	8 -10	Avoid spray drift onto crop plants

* Herbicides not registered in Ireland

2.9.1 Herbicide Treatments in Australia and New Zealand

A foliage industry is developing in Australia but is still in its early stages. The majority of available information on weed control in *Eucalyptus* crops has been derived from Australia's long-established nursery and plantation forest industries. There are over 500 species of *Eucalyptus* native to Australia and a number of the species are extensively grown as commercial plantations. *Eucalyptus* species also make up an important component of the forest industry in New Zealand and significant research work has also been completed here on weed pests and control regimes. Much *Eucalyptus* plantation silviculture has been modified from the extensive research and operational practices developed for *Pinus radiata* as they are both regarded as commercial forest species. Weed control in *Eucalyptus* is much more critical because of its less robust growth pattern than that of pines (Fagg, 1988).

The results of experiments in the Southern Hemisphere can provide useful information and offer some direction in developing a weed control programme for the Kerry foliage industry. However it is also essential to highlight the fundamental differences that exist between conditions and growth influences in the southwest of Ireland and those that exist in other countries and regions. Factors such as species grown, soil types and organic matter content, climatic conditions, growth rates (of crops and target weeds) and duration of growing season will vary widely between countries and regions. All these factors can have a highly significant influence on herbicide activity and efficacy within crops for any given location. The relative mobility of simazine and other residual herbicides in sandy soils compared to soils high in clay and/or organic matter is a typical example. These differences have to be considered when assessing results and the relevance of herbicide trials in the various countries of origin. Experience on nursery practice has found that different species of *Eucalyptus* vary in their tolerance to a particular herbicide (Vanner, 1997, pers. comm.). This suggests significant testing is required to validate results obtained with herbicides under specific Irish conditions.

Tomkins (1998, pers. comm.) describes the weed control regimes used in commercial afforestation in Victoria, Australia. The main commercial *Eucalyptus* species in Victoria are *Eucalyptus globulus* and *Eucalyptus nitens*. These species have only been grown on a large scale in recent years. Ripping and mounding of the planting site takes place in mid-April, which seasonally is equivalent to mid-Autumn in Ireland. This operation is followed by a pre-plant strip application of herbicide applied in June. Tomkins describes this mix as 3 l/ha of Roundup (360g/l glyphosate), 8-10 l/ha. of Gesatop (500g/l simazine), with sometimes a spike of 20-30 g/l of Oust (750g/kg sulfometuron methyl) together with 2% by spray volume of Liase or Boost (ammonium sulphate). The simazine rate used varies with soil type, being higher for the heavier textured soils. The ammonium sulphate is used to reduce antagonism between glyphosate and simazine. The sulfometuron is usually only used if there are weeds such as Sorrel or Dock present. Spray volume is usually 150 to 200 l/ha.

The chemical clopyralid has proven useful for thistles and many broadleaf weeds. Tomkins describes temporary side effects on *Eucalyptus* species in that it causes a weeping in tree leaders but they grow out of this quickly. The herbicide oxyfluorfen (Goal 240g/l) has shown promise for broadleaf control applied at 2-4 l/ha over the top of trees. Pendimethalin has also shown considerable promise and is used in Radiata Pine nurseries in Victoria and New Zealand. A rate of 8-10 l/ha is indicated either pre or post-planting. Tomkins expresses concern about the herbicide diflufenican (indicated rate 200ml/ha) as it is a bleacher and shows negative growth effects. The herbicide fluazifop-p-butyl (indicated rate 2-4 l/ha) is used successfully for annual and perennial grass species.

Vanner (1997) carried out research work on the use of herbicides in forest nurseries in Rotorua, New Zealand. The aim of nursery weed control regimes follow the principle of post sowing, pre-emergent applications of herbicides to the nursery bed, followed by post-emergent applications over the top of seedlings just as the pre-emergent applications were losing their effectiveness and new weeds were beginning to emerge. This practise minimises the need to use herbicides with a knockdown effect. In post-emergent applications, Vanner (1997) found the herbicides such as clopyralid, oxyfluorfen, napropamide and pendimethalin were safe over some species of *Eucalyptus*. However, the species tested did not include those used in Kerry Foliage.

New Zealand has several indigenous species of *Pittosporum*. Nursery managers use the herbicide chlorthal for post sowing weed control and chloroxuron or a mixture of propazine and chlorthal over newly lined out *Pittosporum* seedlings. The latter herbicide mixture has been used for many years to control weed around *Pinus radiata* in the nursery situation.

Hall (1997) describes current weed control practise in *Eucalyptus* plantations in New South Wales, Australia. Glyphosate is used as a preplanting treatment to remove annual and perennial weeds. Residual herbicides used include simazine and atrazine with propazine to a lesser extent. Atrazine is not currently used in the Kerry Foliage Industry but would merit consideration if found safe on *Eucalyptus* species. Control of grasses is achieved using the graminicide fluazfop-butyl. The herbicides oxadiazon and dichlobenil are commonly used in ornamental nurseries. The latter may have an application in foliage crops in the southwest.

2.9.2 Herbicide Treatments in the UK

Atwood (1996) discusses general weed control measures available for nursery stock production, herbaceous perennials, container-grown trees and shrubs and in established field grown trees in the UK.

Atwood recommends a limited range of residual herbicides that can be safely applied for **post planting annual weed control** in field grown trees. These include metazachlor, isoxaben, napropamide, oxadiazon and and chlorthal-dimethyl. In addition to the above chemicals Atwood suggests that it has been common practice to apply low rates of simazine and propyzamide post planting. Oxyfluorfen has also been used in trials but is not recommended for such general usage. Oxyfluorfen has a strong contact action and is not recommended for use over planting stock that has already broken bud unless as a directed spray to the base of transplanted stock. It is unlikely that this would be practical in foliage crops where tractor mounted sprayers are used where possible for speed and efficiency.

Where crops have already broken bud, Atwood recommends herbicides with minimal contact action including isoxaben, propyzamide and napropamide. However, he stresses the timing restrictions for these herbicides. The herbicide propyzamide is not recommended for use after planting on field frown trees. The addition of a low rate of simazine to the above herbicides is recommended to enhance the reliability of weed control. Atwood again stresses that such mixtures would not be covered by manufacturer's recommendations.

Recommendations for herbicide treatments on field grown trees that are established include simazine, propyzamide, oxyfluorfen, dichlobenil and pendimethalin. Atwood recommends the main choice as oxyfluorfen used with either low rate simazine, propyzamide or pendimethalin. However manufacturer's recommendations for oxyfluorfen restrict its use to a period prior to bud burst and summer applications would be injurious to most foliage species in production.

Experience in Cornwall

Rosewarne EHS in West Cornwall has been engaged in outdoor foliage production for many years. There is an important trade in the relatively mild areas of the south and west of England, where the growing season is relatively long and winters are mild, which mirror conditions in the Kerry region. In an early trial at Rosewarne a range of residual weed killers was applied to young plants in a collection of *Eucalyptus* species and no lasting damage was noted in any case (Forrest, 1994).

Foliage growers in Cornwall have experienced problems of weed pests similar to those under Irish conditions. Weed species such as Groundsel, Chickweed, and Sowthistle germinated within a few weeks of planting in spring 1990 (Forrest 1994). At first the weeds were removed by hand. This was a time consuming and costly form of vegetation control. A spot treatment of Roundup (glyphosate at 360g/l a.i. 41% w/w) was applied to the Sowthistle in July and an overall spray (mix) of Gramoxone 100 (paraquat 200g/l a.i.) and simazine (11.35ml/l a.i.) was applied. The latter mixture would be considered injurious to actively growing foliage crops. A mixture of Basta (glufosinate ammonium 200g/l a.i.) and simazine at similar concentration was applied to the weeds in September. Another combination of Stomp 330 (pendimethalin 330 g/l a.i., 32.8% w/w) and Devrinol (napropamide, 45%w/v) at concentrations of 7 ml/l a.i. and 13ml/l a.i. respectively was used on weeds in January 1991.

Forrest (1994) describes how Groundsel became serious weed problem in 1991 despite previous herbicide applications. This problem may have been due to a build-up of resistance by the Groundsel population to repeated triazine applications previously reported by Robinson (1990). In July, the weed growth was cut with a lawnmower and the area sprayed with Basta and Gesatop (simazine 500g/l 43.4% w/v) at a concentration of 19 ml/l of each chemical. In January 1992, a spray of Stomp 330 at a rate of 7 ml/l and Devrinol at a rate of 15ml/l gave satisfactory control of Groundsel (Forrest 1994). In August of 1992 a mixture of Roundup (22ml/l), Gesatop (19ml/l) and Sprayfast (di-p-methene plus nonyl phenol ethylene oxide at 1.1ml/l) was applied. During the growing season in 1993 spot treatments with Basta and Gesatop 500SC (both at 23ml/l) were applied where necessary for the control of Groundsel.

2.9.3 Herbicide treatments in Germany

Losing (1997) describes herbicides used as winter, spring and summer treatments in transplanted nursery stock in Germany. During the winter season weeds like Chickweed and annual grass are still growing even under conditions of low temperature. Most of these are easily controlled with herbicides such as paraquat, propyzamide and simazine. Paraquat (100g/l) is sometimes used successfully as a winter treatment on top of some deciduous trees and shrubs at a rate of 3-6 l/ha. Propyzamide (50%) is used as a treatment against grass and some annual dicotyledons. Isoxaben (500 g/l) is also used in combination with a partner such as propyzamide that controls grasses. Prolonged use of simazine (500 g/l) has given rise to many resistant weeds such as *Senecio* species.

Losing (1997) describes a range of chemicals used as a spring treatment for nursery transplants. Dichlobenil (6.75%) is applied before the onset of spring growth at a rate of 40-60 kg/ha. Linuron (47.5%) provides good control of Common Groundsel and viola in some species for about 3-4 months when applied at a rate of 2-4 kg/ha. Metazachlor (500 g/l) is used at a rate of 6 l/ha but is sometimes not sufficient to control Common Groundsel and Viola. Nursery managers find it possible to apply lenacil (80%) over the top of plants in spring and summer without irrigation.

Isoxaben is also used as a spring treatment but does not control *Epilobium* species and grasses. Pendimethalin (330 g/l) is a further pre-emergent spring treatment used at a rate of 3-5 l/ha.

2.10 Summary of Herbicides Reviewed and their Relevance to the Current Project

Sections 2.8 and 2.9 review information in the literature based on previous trial work carried out on a range of residual herbicides and recommendations based on experience of researchers over a range of growing conditions. **It is apparent that there is a lack of information on herbicides specifically suited to ornamental foliage crops grown in a commercial situation and particular to conditions in the southwest of Ireland.** In the absence of weed control data specific to cut foliage species, considerable effort has been made to access information on species with relatively similar growth patterns. Herbicide trials carried out on broadleaved forestry seedlings are regarded as useful in providing indications for weed control in woody ornamentals such as *Pittosporum* and *Eucalyptus*. Useful information can also be gleaned from weed control measures based on the production of nursery stock, herbaceous perennial plants and container grown woody plants in Ireland, the UK and other European countries. Work carried out on *Eucalyptus* and other woody species in the southern hemisphere was considered worthy of inclusion, despite obvious differences in soils, climate, seasons and both existing crop and weed species compared to the Kerry region.

The review of herbicides and their use in weed control systems has provided a range of options for the current trial work in cut foliage species. Herbicides will be selected based on their reported safety and efficacy in crop situations.

Work carried out using propyzamide applied on a range of crop species and in various locations (Haury, 1983; Metz et al., 1984; Lawrie & Clay, 1989; Atwood, 1996) suggest it as imminently suitable for inclusion in current trials. The triazine herbicides which include simazine, atrazine and propazine have received considerable attention and have been found very efficient in weed control in a range of situations both in Europe and the southern hemisphere. Propazine is not registered for use or available in Ireland. Both atrazine and simazine appear to have potential as components in weed control regimes (Forrest, 1994; Hall, 1997; Robinson, 1997, Tomkins, 1998, pers. comm.). The safety of atrazine on woody ornamental species as described by Wilkinson and Nielsen (1990) merits investigation. Atwood (1996) suggests simazine as a suitable chemical to mix with propyzamide in order to enhance the reliability of weed control. Isoxaben is a further option as a suitable partner for propyzamide (Atwood, 1996; Losing, 1997).

Pendimethalin is a residual herbicide that has shown promise both in European countries and in the southern hemisphere (Lawrie and Clay, 1987; Vanner, 1992, Atwood, 1997). Despite having a low level of contact as well as residual action on plants, metazachlor is reported as being effective and relatively safe when mixed with herbicides such as isoxaben or simazine (Atwood, 1996, Robinson, 1997). The potential application of these mixtures therefore merits investigation in ornamental foliage species.

A number of other herbicides can be considered for inclusion in herbicide trials for particular roles in overall weed contol regimes. Oxyfluorfen has shown promise in Australia when applied over the top of Eucalyptus species (Tomkins, 1998, pers. comm.). However, Atwood, (1996) describes its strong contact action as rendering it unsuited for use over planting stock that has already broken bud. Its reported good weed control efficacy suggests its potential for use in established *Eucalyptus* crops which have been pruned. The latter operation induces a delay in bud break (Whelton, 1998, pers comm.).

Linuron, which is routinely used on potatoes and other vegetable crops may be suited to application on *Paeony Roses*, which have similar growth pattern and husbandry (Kelly, 1997, pers. comm.). Lenacil is reported as compatible in mixture with this linuron on its product label. Napropamide, which is reported safe over some species of *Eucalyptus* in Australia (Vanner, 1997) may have a role in similar woody crops in the southwest of Ireland, possibly as an alternative to simazine. Dichlobenil, a granular herbicide whose manufacturer's recommendations report a very wide range of target weeds controlled, may be suitable as a weed control agent in crops of *Erica* and *Hypericum* species, where the spot application of systemic herbicides such as roundup may threaten plant health.

Herbicides such as fluazifop-butyl and haloxyfop, reported as used in the southern hemisphere purely for the control of annual and perennial grasses (Hall, 1997, Tomkins, 1998, pers. comm.) were not considered for inclusion in herbicide trials. This is due to the efficacy of other chemicals already outlined in controlling both grasses and perennial weeds. Other herbicides used in the southern hemisphere such as sulfometuron methyl and chloroxuron and chlorbufam are not registered in Ireland and not considered for these trials.

2.11 Review of the use of Sprayers/Application Methods

The method of application is an important consideration in assessing efficacy and safety of herbicide and is worthy of review.

A review of the literature of herbicide application techniques reveals significant variation in both the type of sprayer and application method used. Sprayer types include hand-pumped knapsacks and pressurised CO_2 and Logarithmic sprayers.

Wilkinsen and Neilsen (1990) studied the effect of herbicide on woody weed control and growth of plantation *Eucalyptus* seedlings in Tasmania. All trial herbicides were mixed with water and applied with a hand pump Birchmeir knapsack sprayer. The latter was fitted with twin nozzles calibrated to deliver 1.0 litre per minute at a walking speed of 1.0 metres per second (m/s) and a spray width of 1.75 m. This calibration gave a total spray volume of 95 l/ha. Dixon and Clay (1997) studied the control of Hedge Bindweed and Perennial Sowthistle in Popular short-rotation coppice. Treatments were applied using an Oxford precision sprayer fitted with an

8006 Spraying Systems T-jet at a pressure of 105 kiloPaschals (kPa) and a spray volume of 395 l/ha.

The same spraying system was used in further work on the evaluation of post-emergence herbicides for forestry seedbeds with a volume rate of 200 l/ha. Parfitt, (1989), measuring the response of established willow stools to herbicide application, also used an Oxford precision sprayer with a single deflector nozzle at a pressure of 1.0 bar and a volume rate of 500 l/ha to a 0.7 m swathe. Lawrie and Clay (1989), investigating the tolerance of forestry and biomass broadleaf tree species to soil-acting herbicides, used a laboratory track sprayer fitted with an 8002E T-jet giving 425 l/ha at a pressure of 175 kPa.

Valkova (1989), carrying out a long-term study of hexazinone efficacy in pine plantations, used a CP3 (Cooper Pegler) knapsack sprayer with a Polijet nozzle to spray the chemical as a soluble powder containing 90% active ingredient. Hall (1985), testing the tolerance of *Eucalyptus* seedlings to pre-emergent herbicides used sprays applied at 190 l/ha in water in 1.0 m strips using two passes of a Spraying System 8002E nozzle operated at 200 kPa pressure. Vanner (1994) tested the tolerance of several species of tree seedlings to oxyfluorfen in Rotorua, New Zealand. Treatments were applied using a tractor mounted plot sprayer fitted with four 8002LP nozzles at a volume of 450 l/ha. In further work testing the tolerance of nursery seedlings to post-emergent herbicides Vanner used a CO_2 pressurised hand sprayer fitted with two 80015 nozzles in a volume of 450 l/ha. Sumaryono and Crabtree (1992) used a small plot sprayer with four flat fan (SS8002) nozzles on a 2.0 m boom operated at 240 kPa pressure. Schumann (1991), carrying out a preliminary evaluation of herbicides for utilisation in afforestation of *Eucalyptus grandis* in South Africa used a portable Mini

Logarithmic sprayer delivering 287 l/ha at 300 kPa tank pressure from twin flat fan nozzles over a 1m wide spray swath.

A logarithmic sprayer may be used to deliver a constant rate of application or can be used to progressively increase/decrease the application rate along rows of plants. This will allow the trial to detect the rate at which damage or growth inhibition takes place. The literature also suggests that the logarithmic sprayer is most accurate in its herbicide delivery. However, many of the studies outlined use an approach comparing the effects of selected herbicides at high, medium and low rates. Kelly (1997, pers. comm.) and Robinson (1998, pers. comm.) suggests knapsack sprayers, calibrated accurately can deliver precise herbicide applications and recommend this approach for trials within foliage crops.

2.12 Review of Research Methods Previously Used

Culleton, Murphy and Hicks Jnr. (1994) investigated competition control for establishment of Ash transplants on a lowland soil in Ireland. The study was designed with six treatments, which included an untreated control where weed competition was left to grow unaltered. The statistical layout of this trial was randomised complete block design with six blocks, each containing all six treatments. Treatment plots consisted of six rows of 11 trees each, giving a total of 66 trees per plot. Each treatment was replicated six times. Height growth, total height and grade (good, medium and poor) using a subjective scale were measured. The data was analysed using analysis of variance to determine if treatment affected incremental and total height growth and grade. Duncan's Multiple Range Test was further employed to determine which means were significantly different.

Hall (1985) carried out work on the pre-emergent herbicides in *Eucalyptus*. He used 21 plots; each of dimensions 5m X 1m surrounded by a buffer area one metre wide. Five seedlings from four species were planted in each plot. Seedlings were planted 20 cm apart and species location was randomised within each plot. Three replications of six herbicide treatments plus a nil control were randomly allocated to the plots. Survival of seedlings was counted 15 weeks after planting. Seedling tops were also cut off and their dry weight measured. The results of treatments were assessed using analysis of variance.

O'Carroll and O'Reilly (1995) studied the effects of pre-emergence herbicides on the germination, survival and health of Sitka Spruce seeds. Five herbicide treatments and two covering materials were used in this experiment. Each herbicide was applied to six trays of both covering materials (12 trays with 50 seeds per tray). Twelve untreated trays served as controls. Seedling morphology, dry weight and number of surviving seedlings were recorded. For most variables the data were subjected to analysis of variance following randomised block design. The latter test was followed by the least significant test to determine which herbicides were significantly different.

Wilkinson and Neilsen (1990) studied the effect of herbicides on weed control and growth of *Eucalyptus*. Both pre- and post-planting spraying was carried out. There were 12 treatments, comprising 11 herbicide applications and a control (no herbicide or other weed control) with factorial combinations of two species and two stock types. Plots contained 10 trees with three replications as randomised complete blocks. Height of seedlings was measured at planting and at one and two years after planting. Weed competition was visually assessed as percentage of ground cover at six months, one and two years after planting. All regenerating weed species were recorded.

Analysis of variance and Tukeys test for cross-classification were used where appropriate for the collected data.

Sumaryono and Crabtree (1989) tested the differential tolerance of woody nursery crop seedlings to the herbicide napropamide. Treatments included combinations of three herbicide rates plus a nil control applied at two different time intervals following sowing. Treatments were arranged in a randomised block design with four replications. Plot size was six-crop row 2 m long with 0.5 m spacing between rows. In a second experiment, row length was four m long. Crop seedling response to the treatments was estimated by determining seedling survival and shoot fresh weights two months after herbicide application. Analysis of variance and Duncan's Multiple Range Test were used in analysis of data.

Observation on Previous Experimental Designs

Although there is variation in the literature on the design and layout of herbicide trials previously carried out, similar patterns are evident as to what was used. The incorporation of buffer areas into the design of experimental layout is common in previous trials reviewed. This is to prevent cross contamination between treatments. Two basic requirements that emerge across all trials are replication of each variety and randomisation of all plants within experimental areas or confines. Replicated randomised block design (one way restriction) is common to some of the research work undertaken. This is applied in order to eliminate the possibility of horizontal bias in field experiments where there is a source of variation in the subjects. Review of statistical techniques in the literature together with contacts with supervisors and research workers suggests a total randomised design as appropriate to experiments carried out in reasonably uniform experimental areas. Analysis of variance is applied in trial situations where experimental comparisons involve more than two populations. The above observations were considered as relevant to experimental design in the current trials.

2.13 Justification of Current Research

There is extensive information available on the use of specific chemicals to eliminate particular weeds in a range of horticultural crops. However, there is scant information available on the weed management requirements given the specific conditions found in intensively managed foliage crops in regions such as Kerry and the southwest of Ireland.

- Foliage crops and their production on a commercial scale are new to the Ireland and the Kerry area. The Kerry area is unique in its own right in that its climate is mild and humid compared to other parts of the Ireland and further afield. To this extent, growing seasons may be different for both weed and crop species. While much information has already been gathered on foliage crops since 1993, the industry is still at an early point on a learning curve regarding weed management techniques for the various species involved.
- The industry is producing a variety of crops from herbaceous shrubs such as *Paeony* roses to woody perennials such as *Eucalyptus*. Each species has unique growth patterns and therefore specific requirements in terms of suitable weed control regimes. Development of new varieties to satisfy market preferences is also ongoing.

- There is a lack of information on the safety and efficacy of individual herbicides on foliage crops and less information on the reaction of crops to herbicidal mixtures. For example, many herbicides are approved for use on crops established for one year. There is a need to ascertain the safety of applying such chemicals immediately after planting to a range of foliage crops and also the safety margin for mixing herbicides to widen the target weed range.

- Much of the existing research is from the southern hemisphere where factors such as species used, soil type, climate and duration of growing season are substantially different to those prevailing in the southwest of Ireland.

- Efficient weed control techniques can help enhance crop quality and growth and also reduce production and harvesting costs. Efficient mixtures and application rates of herbicide may also lead to a reduction in chemical inputs, which is desirable from a marketing and environmental viewpoint. For example, the use of 9 kilograms of active ingredient (kg a.i.) of the herbicides diphenamide and chlorthal per hectare (ha) in some bare-root conifer nurseries provides less weed control than 0.5 kg a.i. of the herbicide oxyfluorfen (Kozmak, 1989).

- Resistant weeds are developing due to over-dependence on individual herbicides and there is a need for viable alternatives. For example, a potential problem with simazine is the possibility of an increase in weeds resistant to this chemical (Holt, 1992). This has caused serious problems in nurseries in Belgium and in the UK (Sale and Mason, 1996). Some weeds that have developed simazine resistance include *Senecio vulgaris*, *Epilobium* spp, and

Poa annua (van Himme and Bulcke, 1989). The need for rotation of herbicides with different modes of action and the development of alternative herbicides, where efficacy has become an issue, is an area that needs to be addressed in this project.

The Kerry Foliage Committee, set up in 1995, has set specific targets of performance. There is the opportunity for a strong growth in production in the southwest and southeast of Ireland in future years. This opportunity must be coupled with the maintenance of a high level of efficiency in both the production and marketing of cut foliage crops. Kelly (1997) in his report on Kerry Foliage describes the main technical challenges which affect the production levels of high quality, marketable foliage material for this emerging industry. He highlights the need for 'a meaningful research and development programme that should study the cultural management of current and future crops'. An examination of weed pests and weed control within the industry is one of the key areas addressed in this research programme. The current research project is of an applied rather than basic nature.

3.0 Materials and Methods

Section 3 sets out material and methods used within the current project. The following is a general description of the approach adopted. Section 3.1 presents methodologies common to all trials. Methodoligies applied to trials on individual foliage crops are presented from section 3.2 to 3.6 inclusive. Statistical analysis methods used are described in 3.7.

Foliage Species

Experimental work involved herbicide trials on five distinct types of cut foliage crops:

- *Paeony Roses*
- *Pittosporum tenuifolium*
- *Eucalyptus (*2 species: *E. perreniana* and *E. moorei)*
- *Erica veichii*
- *Hypericum androsaemum* (2 cultivars: ‘Senario’ and ‘Excellent Flair’)

All trials apart from those involving *Eucalyptus* species were carried out on privately owned, commercial cut foliage crops. Trials on *Eucalyptus* species were undertaken on seedlings that were raised in a local nursery and planted out specifically for this research by the author. All plots used were withdrawn from commercial use for the duration of the trials.

Residual Herbicides

Residual herbicides were selected for trial in each crop type. Based on the literature reviewed, the decision was taken to use **mixtures** of compatible and complementary herbicides as well as **single herbicides** with good reported efficacy. In addition, the application rates (of mixtures and individual herbicides) were varied within all trials except in those involving two *Eucalyptus* species (due to limited available trial area). Varying of application rates was used as an investigative approach in line with previous work by other authors (Lawrie & Clay, 1989; Parfitt, 1989; Wilkenson & Nielsen, 1990; Vanner 1991) and based on personal contact with researchers within the foliage industry. Application rates described in the following sections are therefore at either **low**, **moderate** (recommended) or **high** rates.

Kelly, (1997, pers. comm.), also suggested repeating the application (at low or medium rates) of the most promising herbicides or mixtures as appropriate during the growing season. The subsequent safety and efficacy of repeated application could be compared with those of single high-rate applications. This was carried out in the early trials where project time constraints allowed. Thus a **treatment** within the context of the current trials consists of a single herbicide or herbicide mixture applied at low, medium or high rate either once or twice to a foliage crop during its growing season.

Mode of Action of Herbicides / Mixtures

It is important for those involved in the growing and management of foliage crops to have a basic understanding of the mode of action of herbicides and herbicide mixtures. The effect of herbicides and mixtures on both cut foliage and target weed pest species is investigated from a crop management perspective in this thesis. A study of herbicide mode of action is regarded as outside the scope of this project. While synergistic effects may be possible from the use of herbicide mixtures, their study may be appropriate for other projects in the field of plant physiology.

Experimental Layout

Design of experiments was carried out following a review of methods used previously and as reported in the literature. Advice and recommendations were also received from staff members within the Institute of Technology in Tralee.

Constraints on areas available for herbicide trials were set due to the commercial nature of the foliage crops involved. Each trial area was examined in detail for possible variations in factors that might influence either crop or weed growth. These included soil type, horizon depth, slope, drainage condition and degree of existing shelter. Locations for trial areas were chosen that appeared uniform in regard to the above factors and towards the central part of fields where possible.

The trial areas were subsequently divided into experimental plots. Buffer areas were incorporated in order to avoid cross contamination between adjacent plots during trial applications. Plot size was dependant on the established spacing of each foliage crop and the number of replicate plots required for each treatment. A minimum of 60 foliage crop plants per treatment were used in order to produce statistically verifiable results (Murphy, 1997, pers. comm.). A total randomised design was used in the allocation of treatments to plots within the trial areas as previously carried out by Hall (1985) among other authors. This system was used because of the uniform conditions within the trial areas selected.

Protection of Trial Areas from Crop Spraying

Herbicide application by tractor and boom sprayer to the surrounding crop was routine during the course of the field work for the project. There risk of experimental plots being contaminated by spray drift application crop was avoided by liaising with the relevant manager and covering the experimental area with large polythene sheets during the operation.

'Observational Trials'

During the current project opportunities arose to investigate the use of additional potential herbicides that were not part of the main treatment regimes under investigation. An example of this was the development of a persistence problem relating to Fat Hen in an established crop of *Paeony Roses* that was not part of the trial area. Such opportunites were considered to be of interest to the study and worth pursuing, though not followed to the same level as the main trials at hand. Analysis of this work was based solely on observations following treatments with specific herbicides.

Indicative Costs

An investigation of indicative costings relating to weed control was carried out for the various herbicide treatments applied. This involved a survey of costs relating to individual chemicals from local supply sources, application procedures and labour costs from rsearchers/advisers within the foliage industry.

3.1 Methodologies Common to All Trials

3.1.1 Sprayer Type

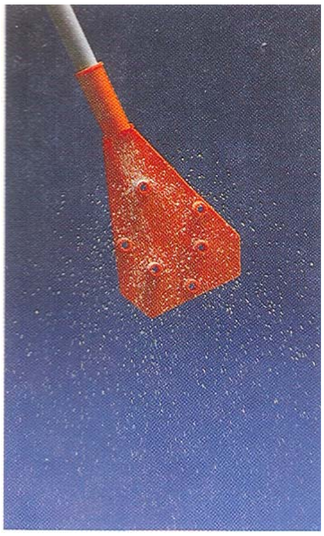
The sprayer type selected for herbicide application is similar to that used by Valkova (1989) when studying hexazinone efficacy in pine crops. All herbicides in liquid formulation were mixed with water and applied using a **Cooper Pegler (CP) Model 15** knapsack sprayer (Plate 5). The nozzle type selected for application was a VLV 100 (very low volume) floodjet single nozzle. The sprayer has a capacity of 15 litres. It was fitted with a pressure control valve that regulated the nozzle exit pressure to a set reading irrespective of pump pressure. A pressure guage was also fitted along the spray lance so that sprayer exit pressure could be continually monitored. These sprayer accessories were added for accuracy in chemical applications.

Plate 5: Cooper Pegler Knapsack Sprayer

Timing of walking speed was also critical in achieving accurate spray applications. Seconds were counted out on a mini tape recorder and were played back during herbicide application to regulate walking speed in plots. This process was carried out in plot applications for all herbicide trials. The spraying apparatus was calibrated regularly and tested using water over ground conditions similar to those in the trials prior to actual plot application. This was carried out to become familiar with and co-ordinate the spraying process.

The granular formulation of the herbicide dichlobenil was applied in trials using the 'Modern' granule applicator (Plate 6). This works using gravity flow, whereby granules are released in an even stream under their own weight. The dosage is regulated by means of an adjustable dosage disk. A deflection plate at the end of the feed tubes is designed to distribute granules evenly and accurately over the soil surface.

Plate 6: 'Modern' Granule Applicator for Dichlobenil



The application process was rehearsed repeatedly over a black polythene sheet of known area using seconds counted on the mini-recorder. Herbicide granules were applied over one square metre of black polythene in controlled conditions and then collected and repeatedly weighed in order to achieve accuracy in field applications.

3.1.2 Spray Formulations Used

Table 3 lists the residual soil-acting chemicals that were used in the herbicide trials. Some of the herbicides listed were common to trials on a number of foliage species. Table 3 includes details of herbicide trade names as well as the formulation and concentration of each chemical.

Table 3: Residual Chemicals used in Trials

Chemical	Trade Name	Formulation	Concentration
Atrazine	Atrazol	Susp. Concentrate	500 g/l (45.9% w/w)
Dichlobenil	Casoron G4	Granular	4.0% w/w
Hexazinone	Velpar L	Susp. Concentrate	240 g/l
Isoxaben	Gallery 125	Susp. Concentrate	125 g/l (12.14% w/w)
Lenacil	Venzar	Susp. Concentrate	440 g/l (38.8% w/w)
Linuron	Afalon	Susp. Concentrate	450 g/l (37.6% w/w)
Metazachlor	Butisan S	Flowable	500 g/l (43.1% w/w)
Metoxuron	Dosaflow	Susp. Concentrate	500 g/l (43.8% w/w)
Napropamide	Devrinol	Susp. Concentrate	450 g/l
Oxyfluorfen	Goal 2E	Susp. Concentrate	240 g/l
Pendimethalin	Stomp	Susp. Concentrate	400 g/l (36.4% w/w)
Propyzamide	Kerb	Susp. Concentrate	500 g/l
Simazine	Simazine	Susp. Concentrate	500 g/l

3.1.3 Measuring and Recording of Data

Plant Safety

Safety of herbicide treatments was assessed firstly by inspecting plants in each plot for visual symptoms of herbicide damage. Table 4 outlines the health rating system used when inspecting treated plants for possible symptoms. This rating system has been adapted from that used by Auburn University Silvicultural Herbicide Co-Operative, Alabama (Muir, 1997, pers. comm.) The health/toxicity scale goes from **0** (no observed damage) to **6** (plant death) with corresponding physical descriptions, colour and indication of proportionate damaged tissue.

Table 4: Health Rating System

Health Rating	Damage Description	Colours	% of Damaged Tissue
0	No Damage	Dark green, green	0
1	Very Light	Pale, light green	1-5
2	Light	Yellow-green, pale yellow green	6-35
3	Moderate	Yellow, pale yellow	36-65
4	Severe	Any colour w/red	66-95
5	Very Severe	Any colour w/red and brown	96-99
6	Complete Death	Any colour w/red and brown	100

Any symptoms present on treated plants were noted. Possible symptoms that were anticipated arise apart from colour variation included the following:

- **Epinasty:** more rapid growth on one side of a plant that causes it to bend or curl.

- **Fasciation:** abnormal flattening or enlargement of plant stems, sometimes spiraling.
- **Fasciculation:** production of a multitude of branches, leaves, or needles at the tip of a non-elongating stem.
- **Necrosis:** localized death of tissue usually characterized in plants by browning and desiccation.
- **Stunting:** smaller than normal size.

The variable of **plant height** was also used as a measure of treatment safety. Individual plant heights were recorded for each trial plot on a regular basis following herbicide application. Safety would be assessed by analysis of variance of mean heights for treatments involved.

Weed Cover Data

The presence of each weed species in individual plots was first recorded prior to measuring weed cover. Weed species were divided into four categories for analysis- annual grasses, perennial grasses, annual broadleaf weeds and perennial broadleaf weeds. Identification of weed species and associated information on their growth patterns was aided by referral to authors such as Rose, (1981), Schering Agriculture, (1990), Phillips, (1994) and Uí Chonchubhair & Ó Chonchuir (1995).

Weed cover was assessed for individual plots on a regular basis, according to the foliage species in the trial. Previous authors such as Wilkenson and Nielsen (1990) and Schumann (1990) used visual estimates to access weed cover in herbicide trials. Weed cover was measured in these trials by laying a wire grid over the plot, section by section, and counting the number of individual squares (2.45 cm X 2.45 cm) filled by each weed species (Plate 7). Where only parts of squares were filled, estimates were used as to the total number of squares completed. Different overall grid dimensions were used according to the spacing of foliage species in order to fit between rows and cover the full plot area.

Absolute measurements were taken for entire plots in most cases of recorded weed cover. Sampling was used within plots for cover estimation where such cover exceeded approximately 40% in line with the general sampling method by Hall and Burns (1991). In such cases a 0.09 m^2 grid (30cm x 30cm) was held at pre-ordained locations at similar co-ordinates within each plot. Sample measurements of weed cover by species were then taken. The number of grid locations used was adjusted according to plot size in order to achieve a sample of 20% of total plot area.

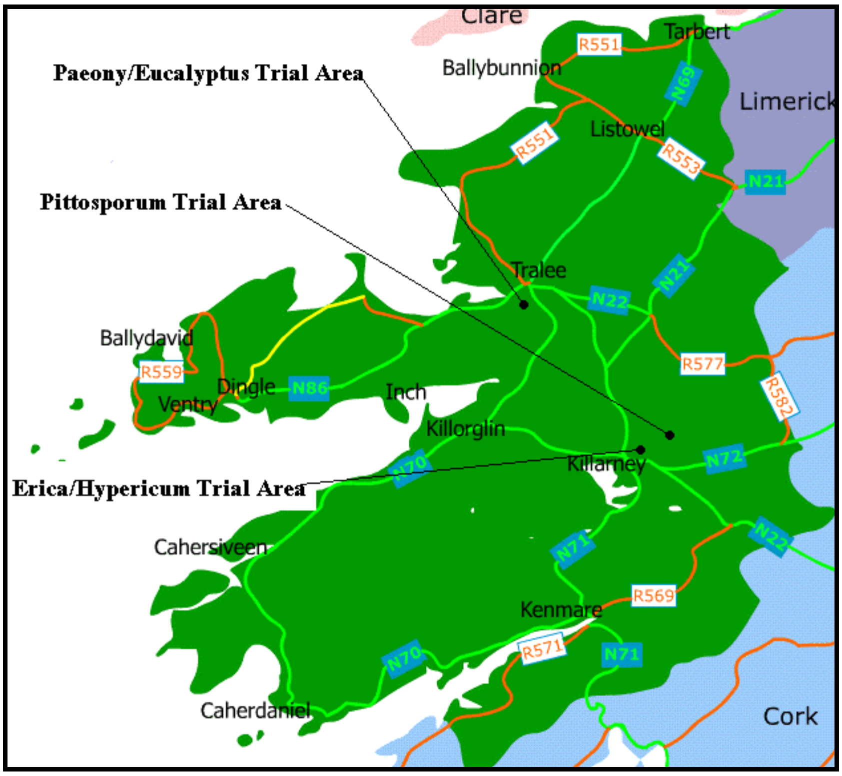
Plate 7: Estimation of Weed Cover in *Pittosporum*

3.2 Paeony Rose Experiments

3.2.1 Soil classification

Soil classification and characteristics were identified using physical site examinations in collaboration with reference to the general soil map of Ireland and its corresponding soil associations (Gardiner and Radford, 1980). The chosen experimental site is located in 0.8 km to the south of Tralee town. Figure 1 indicates the location of all trials within this project. Soil type is a **minimal grey brown podzolic** (Association No. 34) derived from a calcareous glacial till of predominantly Carboniferous limestone composition. There is a small admixture of sandstone in the profile composition. The topography is flat with an elevation below 60 m.

Fig. 1: Location of Foliage Trials



Gardiner and Radford (1980) describe the soil as moderately well drained, of loam texture and of high base status. The profile is characterised by a dark-brown loamy surface horizon on average 18-25 cm thick. This overlies a weakly leached A2 horizon and a clay loam Bt horizon with a small amount of clay accumulation. The surface horizon contains 22% clay and 37% silt. The soil structure is moderately well developed, roots are plentiful and penetrate to a depth of 15 cm. Moisture holding capacity is good. Appendix 1 provides analytical data for the soil association outlined above.

3.2.2 Site Cultivation and Establishment

Complete ploughing was carried out to a depth of 14 centimeters in mid December of 1997. This was followed by one pass with a tyne rotavator in late December. The site was laid out for planting by ploughing to leave a series of 13 plough ridges (of width 9.0 m) separated by tramlines of width 7.0 m across the field. These plough ridges provided suitable drainage and aerated conditions for establishment of a *Paeony* crop. Planting of *Paeony* roses took began on sixth of January 1998 and was completed within two weeks. The rootstock was manually planted along the plough ridges 70 to 75 cm apart. The top of the *Paeony* tubers were pit-planted to a depth of between 4 and 5 cm from the tip of the plough ridge and the original shape and profile of the ridge was re-established following firming in.

3.2.3 Herbicides Chosen in *Paeony* Trial

Herbicides and herbicide mixtures were selected as those considered most suitable following a review of the literature. Propyzamide was chosen due to its potential to control grasses and some broadleaf weeds. It was mixed with simazine and isoxaben as separate treatments because of documented compatibility and potential to improve the target weed range (Isoxaben was considered as a possible alternative to simazine to avoid the build-up of resistant weed biotypes). Metazachlor and isoxaben were chosen as a further separate treatment due to the reported success and longevity of their mixture in UK trials (Atwood 1996). Pendimethalin was applied on its own as a treatment due to the relatively broad target weed range including grasses and some annuals. The combination of linuron, lenacil and simazine were selected in a further herbicide mixture due to their compatibility and reported efficacy (Whelton, 1997, pers. comm.). The above treatments were used in different plots and replicated.

Table 5 outlines the herbicide or mixtures used along with the selected concentrations and mixing volumes.

3.2.4. Experimental Design

The site was firstly examined for variation in soil characteristics using profile inspections and soil cores. It was concluded that no significant variation in soil type existed within the area planted. An area of ground suitable for proposed herbicide trials was selected. This area was chosen in the central part of the field. This selection process eliminated possible growth effects due to proximity of hedgerows and edge effect.

Table 5 *Paeony* **Trial: Herbicide Treatments and Rates**

Tr.	Herbicides Mixed	Herbicide Rate(s) (l /treated ha)	Knapksack Volumes used of:			
			1st Herbicide (ml)	2nd Herbicide (ml)	3rd Herbicide (ml)	Water (l)
1	**Propyzamide + Simazine** (low)	2.5 + 2.0	**31.3**	**25.0**	**-**	4.94
2	**Propyzamide + Simazine** (med)	4.0 + 3.0	**50.0**	**37.5**	**-**	4.91
3	**Propyzamide + Simazine** (high)	6.0 + 4.5	**75.0**	**56.3**	**-**	4.87
4	**Propyzamide + Isoxaben** (low)	2.5 + 1.5	**31.25**	**18.75**	**-**	4.95
5	**Propyzamide + Isoxaben** (med)	4.0 + 2.0	**50.0**	**25.0**	**-**	4.92
6	**Propyzamide + Isoxaben** (high)	6.0 + 3.0	**75.0**	**37.5**	**-**	4.89
7	**Pendimethalin** (low)	3.5	**58.3**	**-**	**-**	4.94
8	**Pendimethalin** (med)	5.0	**83.3**	**-**	**-**	4.92
9	**Pendimethalin** (high)	7.0	**116.7**	**-**	**-**	4.88
10	**Metazachlor + Isoxaben** (low)	1.0 + 1.5	**12.5**	**18.7**	**-**	4.97
11	**Metazachlor + Isoxaben** (med)	2.0 + 2.5	**25.0**	**31.3**	**-**	4.94
12	**Metazachlor + Isoxaben** (high)	3.0 + 4.0	**37.5**	**50.0**	**-**	4.91
13	**Linuron Lenacil Simazine** (low)	1.7 + 1.4 + 2.25	**21.3**	**17.5**	**24.0**	4.89
14	**Linuron Lenacil Simazine** (med)	2.0 + 1.7 + 2.4	**25.0**	**22.0**	**30.0**	4.92
15	**Linuron Lenacil Simazine** (high)	2.8 + 2.5 + 3.0	35.0	32.5	37.5	4.89
16	**Control**	-	-	-		

The trial area was divided up into **80 rectangular plots, each of dimension 2.1m x 3.0m.** There were five treatments, each with three concentrations. Each treatment by concentration combination was replicated five times. Five plots were allocated as controls. A total randomisation design was used in this as well as other trials, as the experimental area was considered uniform. There was no slope in the field and no significant variation in soil profile or depth. Figure 2 details individual plot layout for the *Paeony* experiments. The plots were separated by an untreated plough ridge along their length and by a 30-cm strip along their width. These buffer areas were retained between experimental plots to avoid cross-contamination between treatments and to facilitate visual weed cover calls in the trial plots that were treated.

Each plot provided an average of 12 plants per sample plot. The experimental plots were carefully marked out for parameter recordings. The overall extremities of the trial area were further marked to define its boundaries and prevent accidental contamination from routine spray treatments to the surrounding commercial crop. Following crop emergence individual plant locations were marked with pin flags to allow individuals to be followed over time and speed up row location.

Fig. 2 Plot Layout for *Paeony* Trials

P + S L 5	**L+L+S** H 4	**Pend.** L 5	**I + M** M 1	**L+L+S** H 1	**P + S** M 4
Pend .L 3	**P + S** M 1	**I + M** H 1	**L+L+S** M 4	**P + I** L 3	**L+L+S** L 3
P + I M 2	**I + M** H 2	**Pend.** M 2	**I + M** H 5	**I + M** L 4	**Pend.** L 2
P + S H 2	**Pend.** M 1	**P + S** L 1	**P + S** L 2	**Ctrl** 1	**I + M** L 1
P + S H 4	**L+L+S** H 5	**P + I** L 4	**I + M** L 3	**P + I** M 5	**P + I** L 2
I + M H 4	**K + S** M 5	**Ctrl** 4	**P + I** H 2	**P + S** L 3	**Ctrl** 2
L+L+S L 1	**Pend.** H 5	**Pend.** L 1	**P + I** L 5	**L+L+S** M 5	**P + S** H 1
P + I H 4	**P + S** H 3	**L+L+S** M 1	**P + S** L 4	**Pend.** H 2	**P + I** M 3
L+L+S M 2	**Pend.** H 4	**P + I** M 1	**L+L+S** L 4	**I + M** L 5	**Pend.** H 1
Pend. H 3	**I + M** M 3	**P + I** H 5	**Pend.** M 5	**I + M** H 3	**Ctrl** 5
L+L+S H 2	**L+L+S** M 3	**I + M** M 4	**P + S** H 5	**Pend.** M 4	**P + I** H 3
P + I M 4	**Pend.** M 3	**P + S** M 3	**I + M** M 5	**P + I** H 1	**L+L+S** H 3
L+L+S L 2	**P + S** M 2	**I + M** M 2	**L+L+S** L 5	**Pend.** L 4	**P + I** L 1
I + M L 2	**Ctrl** 3				

Single Plot (2.1 X 3 m)

Buffer zone between plots

Key

P + S = Propyzamide + Simazine

(all P + S treatments are shaded)

P + I = Propyzamide + Isoxaben

L+L+S = Linuron, Venzar + Simazine

Pend. = Pendimethalin

I + M = Isozaben + Metazachlor

C = Control Plot

L = low treatment rate

M = moderate treatment rate

H = high treatment rate

1 – 5 = plot replication number for that treatment

eg. **P + S**
L 5

Propyzamide + Simazine

Low rate of treatment

Replicate plot 5

3.2.5 Herbicide Applications

In early February 1998, prior to application of pre-emergent herbicide treatments, weeds began to encroach on the trial area. Weed species consisted mainly of Annual Meadow Grass, Creeping Buttercup and Lesser Celandine. Since it was essential to commence experimental treatments on a clear, weed-free site, all weeds within the trial area were sprayed with **glyphosate** as an initial knockdown treatment. An application rate of 5 litres per hectare (l/ha) was incorporated in water giving an application volume equivalent of 200 litres of mix per hectare.

Herbicides and herbicide cocktails were mixed with water and applied with a lever-operated **CP** (Cooper Pegler) **15 knapsack sprayer**. The spraying system was calibrated to deliver 0.46 litres per minute at a walking speed of 11.5 metres per second (m/s) and a spray width of 1.0 m for an application volume of 400 l/ha. An application volume of 300 l/ha required a nozzle delivery of 0.46 l/min, a swath width of 1.0 m and a walking speed of 8.2 m/min. The total spray volume delivered was 300 l/ha for **pendimethalin** and 400 l/ha for all other tank mixes. A similar method of sprayer calibration was used for all trials. This is indicated in Appendix 8.

3.2.6 Weather Conditions during Application

Application of residual herbicides took place between the 9th and 16th March, 1998. Herbicide treatments were restricted to period of dry calm weather in order to facilitate even and accurate application on the plots. The temperature during that period was approximately 9 ºC.

3.2.6 Repeated (Second) Application of the most Promising Treatments

Following residual herbicide application on *Paeony Roses*, the plots were monitored over six weeks for the emergence of new weeds. At this stage, the most promising treatments were identified, as indicated by the absence/low incidence of new weed development in plots. These treatments were **propyzamide + simazine** and **linuron + lenacil + simazine** mixtures. A second application of the low and moderate rates of these treatments was then applied to the appropriate plots in the trial area which had already received similar applications in March.

3.3 Pittosporum tenuifolium Experiments

3.3.1. Soil Classification

Soil classification and characteristics were identified as for the previous site using physical examinations and reference to the general soil map of Ireland and its corresponding soil associations. The site is located in an area 1.5 km to the north of Killarney town. Soil type is a **brown podzolic** (Association No. 15) derived from a glacial drift of mixed Old Red Sandstone, shale and slate composition. The topography is again flat with an elevation below 85 m.

Gardiner and Radford (1980) describe this soil as well drained, of sandy loam to loam texture and of medium base status. The profile is characterised by a dark-brown loamy surface horizon on average 20 to 25 cm thick. This overlies a yellowish-red B horizon to a depth of about 45 cm. The surface horizon contains 14 to 18% clay and 35% silt. The soil structure is moderately well developed, roots are plentiful and penetrate to a depth of 15 cm. Moisture holding capacity is good. Appendix 2 provides analytical data for the soil association outlined above.

3.3.2 Site Cultivation and Establishment

Herbicide trials on *Pittosporum tenuifolium* were carried out on the 15th April, 1998. The trials were on a commercial crop that had been established the previous year (Plate 8). Site cultivation involving complete ploughing of the site was carried out to a depth of 15 centimetres in early July of 1997. This was followed by one pass with a tyne rotavator later the same month. A 'levelling' bar drawn by tractor was finally used to provide an even surface. This provided a clean, friable site for establishment.

Plough ridges or raised planting beds were not required due to favourable drainage conditions on the site which was slightly raised above the surrounding area, and therefore direct planting took place on the soil surface

Planting of *Pittosporum* seedlings began in early August 1997 and was completed within three weeks. Potted seedlings were used with a height range of between 12 and 20 cm. *Pittosporum* seedlings were pit-planted to root collar depth along lines at a distance of 90cm within the line and 1m between adjoining lines. The crop was spot treated with an application of glyphogen in September 1997.

Plate 8: Location of *Pittosporum* trials

3.3.3 Justification of treatments for *Pittosporum* Trials

Table 6 below indicates the herbicide treatments that were used in trials for *Pittosporum tenuifolium*. Some of the individual herbicides or chemical mixtures chosen (eg. **pendamethalin**, **propyzamide + simazine** and **metazachlor + isoxaben)** were similar to those used in the *Paeony* trials for reasons already described. However, application rates were deliberately changed to investigate the effect of concentration on residual control of target weeds.

Table 6 Herbicides Used in *Pittosporum* Trials

Tr. no.	Herbicides Mixed	Abbreviation	Herbicide Rate(s) (litres per treated hectare)
1	Propyzamide + Simazine (low, repeat)	**P+S (L, r)**	3.0 + 2.5
2	Propyzamide + Simazine (high)	**P+S (H)**	5.0 + 4.0
3	Metazachlor + Isoxaben (low)	**M+I (L)**	1.5 + 2.0
4	Metazachlor + Isoxaben (high)	**M+I (H)**	2.5 + 3.5
5	Pendimethalin (low)	**Pend. (L)**	4.0
6	Pendimethalin (high)	**Pend (H)**	6.0
7	Napropamide (moderate)	**Napr.**	8.0
8	Atrazine (low)	**Atr. (L)**	2.5
9	Atrazine (high)	**Atr. (H)**	4.0
10	Control	**Contr**	-

The application of trial herbicides in the *Paeony* trial was carried out prior to the emergence of herbaceous *Paeony* plants in spring. Application of herbicides in this *Pittosporum* trial would be to two-year-old plants that were actively growing at the time of treatment. While propyzamide is generally regarded as a safe herbicide, these trials investigated the efficacy and safety of application in mixture to plants during their period of soft spring growth and at rates higher that normally recommended.

Concerns over safety aspects of the **metazachlor + isoxaben** mixture raised by Atwood (1995) were addressed.

Atrazine was considered in this trial for use as a stand-alone herbicide due to its reported ability to control a relatively broad range of weeds and its longevity in the soil. As with some of the other herbicides on trial, safety of the herbicide applied over growing young crops was at issue as described by Wilkinsen and Nielsen (1990).

Napropamide was chosen in this trial as a possible alternative to simazine, particularly for weeds such as groundsel that may have built up resistance. Again, safety issue when applied over actively-growing young crops had to be investigated.

3.3.4 Plot Layout

The site was examined for variation in soil characteristics using profile inspections and soil cores. It was concluded that no significant variation in soil type existed within the field being used. As the trial site was located in a privately owned, commercial crop, the area available for experiment was confined to a single bay of plants, between two access tram lines, due to the possibility of plant damage from the treatments involved. This bay contained eight rows of plants. A suitable bay for proposed herbicide trials was selected. The herbicide treatments for plots were allocated randomly to plots set-up within the chosen bay.

Experimental plots were independently and randomly selected within the confines of the trial area. The plots had dimensions of 3.0 m by 4.1 m. All experimental plots contained a minimum of 15 viable *Pittosporum* plants. There were four replications for each treatment. The 40 sample plots within the trial area were carefully marked out for parameter recordings. The overall extremities of the trial area were further marked to define its boundaries and prevent accidental contamination from routine sprays to the surrounding commercial crop.. The confinement of the trial area to one bay of *Pittosporum* resulted in two rows of plots with this bay. A buffer zone was retained between these two rows of plots (Figure 3). Due to limited trial area in this commercial crop, buffer zones were not used between individual plots along each row. However, plastic panels were used on the plot borders during herbicide application and all possible care was taken to prevent cross-contamination between individual plots.

3.3.5 Repeated (Second) Application of the most Promising Treatments

As with the methodology carried out in the trial on *Paeony Roses*, the most promising treatment was identified in the *Pittosporum* experiments. This was indicated by the absence/low incidence of new weed development in plots. In this case the treatment was a **propyzamide + simazine** mixture. A second application of the low rate of this treatment was then applied to the appropriate plots in the trial area 6 weeks after the initial April application.

3.3.6 Weather Conditions during Application

Application of residual herbicides took place between the 15th and 20th April, 1998. Herbicide treatments were restricted to period of dry calm weather in order to facilitate even and accurate application on the plots. The temperature during that period was approximately 11 ºC.

Figure 3 – Plot Layout for *Pittosporum* Trials

Pend. L 1	**Atr.** H 1
Atr. H 2	**P+S** H 1
Pend. L 3	**M+I** H 2
Atr. L 4	**C** 4
Pend H 1	**M+I** H 4
C 1	**Pend.** H 2
P+S H 2	**Na.** 4
Na. 1	**Pend** L 4
M+I H 2	**P+S** L 1
C 2	**M+I** L 1
Atr. L 3	**M+I** H 3
M+I L 3	**Pend** H 3
Atr. **H 4**	**P+S** **L 4**
P+S H 4	**Na.** 3
M+I H 1	**Pend.** H 4
P+S L 3	**Pend.** L 2
M+I L 2	**Na.** 2
P+S L 2	**Atr.** H 3
C 3	**P+S** H 3
Atr. L 1	**Atr.** L 2

Buffer Zone

Key to Table

P + S = Propyzamide and Simazine

(All P + S plots are shaded as an example)

Pend. = Pendimethalin

M + I = Metazachlor and Isoxaben

Atr. = Atrazine

Na. = Napropamide

C = Control

Herbicide Concentration

L = low

H = high

Treatment Replication

1 – 4 = Plot replication number for that treatment.

Napropamide was applied to *Pittospo*rum plants at its **moderate** rate only

3.4 Eucalyptus *Experiments*

3.4.1 Experiment Location

The *Eucalyptus* herbicide trials were located in the same field as was used in the *Paeony* trial described previously. Soil type was therefore a **minimal grey brown podzolic** (Appendix 1).

The plots were located in an area towards the corner of the field. However, a buffer strip of 15 metres was retained between the field perimeter that consisted of a low hedgerow and the location of the trial area to minimize the possibility of outside factors. The trial area was also slightly raised compared to the remaining field and drainage conditions were considered good. The trial location was firstly examined for variation in soil characteristics using profile inspections and soil cores. It was concluded that no significant variation in soil type existed within the establishment area.

3.4.2 Cultivation of Eucalyptus Seedlings for Trial Purposes

Herbicide trials involving two species of *Eucalyptus* were carried out in September 1998. These trials were carried out on young plants cultivated from seed in a local nursery specifically for this herbicide trial. Seedling of *E. perreniana* and *E. moorei* were raised in a glasshouse in April 1998 and pricked out into fenpots (peat pots). The seedlings were then grown on and hardened off outdoors for two weeks in preparation for outdoor planting. A typical seedling of *E. Moorei* is shown in Plate 9.

Plate 9: Seedling of *E. Moorei* Prior to Planting for Trials

3.4.3 Site Cultivation and Establishment

The trial site was first treated with an application of glyphosate herbicide in August 1998 in order to eliminate existing vegetation prior to cultivation. Site cultivation, which involved complete ploughing of the site, was carried out to a depth of 15 cm in early September of 1997. This was followed by one pass with a tyne rotavator later the same month. A garden hoe was used to manually remove clumps of soil and dead vegetation in order to provide a clean, friable site for establishment. Plough ridges or raised planting beds were not considered necessary due to favourable soil and drainage conditions on the site, and therefore direct planting took place into the prepared site.

Planting out of *Eucalyptus* seedlings took place on the 14th of September 1998. The seedlings had a height range of between 12 and 20 cm. The seedlings were pit-planted to root collar depth along lines at 120 cm both within the lines and between adjoining lines. This gave a stocking density of 5000 plants per hectare.

3.4.4 Selection of herbicide treatments for *Eucalyptus* Trials

Table 7 below indicates the herbicide treatments that were used in trials for both species of *Eucalyptus*.

Table 7: Herbicides Used in the *Eucalyptus* Trials

Tr. no.	Herbicides Mixed		Herbicide Rate(s) (litres per treated hectare)
1	Propyzamide + Simazine	(P +S)	3.0 + 2.0
2	Linuron + Venzar + Simazine	(L,V,S)	5.0 + 4.0
3	Metazachlor + Simazine	(M + S)	1.5 + 2.0
4	Atrazine	(Atr.)	2.5
5	Dichlobenil	(Dch)	80 kg/ha
6	Control	(Contr.)	-

Treatments **1** and **2**, which comprised mixtures of **propyzamide** + **simazine** and **linuron** + **lenacil** + **simazine** respectively, were chosen due to early indications of their efficacy in the *Paeony* trials which had been set up in March 1998. The safety of applying linuron over newly planted *Eucalyptus* species would also be addressed in this trial. The mixture of **metazachlor** + **simazine** was chosen as treatment **3** in order to test the efficacy of this mixture, which had not been used in trials involving *Pittosporum* or *Paeony roses*. It was also intended to investigate the safety of

metazachlor applied over young seedlings of woody species such as *Eucalyptus*, given it has a slight contact as well as residual action (Atwood, 1995).

Both treatments **4 (atrazine)** and treatment **5 (dichlobenil)** were used as stand alone herbicides due to their propensity to control a relatively broad range of weeds and longevity. As with some of the other herbicides on trial, safety issues on young crops also needed to be addressed.

The above 5 treatments were applied at recommended rates (according to manufacturers labels) and in the same manner as the trial plots of *E. perreniana* and *E moorei.* The control plots received no treatment and were used for comparative purposes.

3.4.5 Layout of *Eucalyptus* Plots

3.4.5.1 *E. perreniana Plots*

Experimental plots were independently and randomly selected for trials of *E. perreniana* within the confines of the area available. This gave a total randomized design. All plots had dimensions of 4.8 x 4.8 m and 16 viable plants. There were 4 replications for each of 5 treatments selected, along with 4 control plots. This gave a total of 24 plots in total. Plots within the trial area were labelled for parameter recordings. Buffer areas were retained between plots as in other trials. Figure 4 provides a representation of the experimental layout for this trial.

3.4.5.2 E. moorei Plots

The herbicide trials on *E.* moorei also had a total randomized design. All plots in *E. moorei* trials had dimensions 4.8 x 4.8 m and 16 viable plants. The herbicide treatments applied were identical to those applied in the *E. perreniana* trials giving a total of 24 plots as before (Figure 5).

3.4.6 Weather Conditions during Application

Application of residual herbicides took place between the 21st and 27th September, 1998. Herbicide treatments were restricted to periods of dry calm weather in order to facilitate even and accurate application on the plots. The temperature during that period was approximately 13 ºC.

Figure 4: Layout of *E. Perreniana* Trial

Dichl. 3	**L+L+S** 1	**P + S** 3
Atr. 2	**M + S** 2	**Atr.** 4
P +S 2	**C** 1	**Dichl.** 2
Dichl. 4	**Atr.** 3	**M + S** 3
C 4	**L+L+S** 3	**P + S** 1
P + S 4	**M + S** 1	**L+L+S** 4
M + S 4	**Dichl.** 1	**C** 3
Atr. 1	**C** 2	**L+L+S** 2

Individual Plots (4.8 x 4.8 m)

Buffer Zones (1.2 m)

Key to Table

P + S = Propyzamide + Simazine

L+L+S = Linuron, Lenacil + Simazine

(All L+L+S plots are shaded as an example)

M + S = Metazachlor and Simazine

Atr. = Atrazine

Dichl. = Dichlobenil

C = Control

Treatment Replication

1 – 4 = Plot replication number for that treatment.

All treatments were applied to *Eucalyptus* seedlings at moderate (or recommended) rates.

Figure 5: Layout of *E. moorei* Trial

Individual plot (4.8 x 4.8 m)

Buffer Strip (1.2 m)

C 3	**Dichl.** 1	**P + S** 2	**M + S** 3
P + S 1	**Atr.** 2	**L+L+S** 1	**Atr.** 1
L+L+S 3	**C** 1	**M + S** 4	**P + S** 3
L+L+S 4	**M + S** 1	**Dichl.** 4	**C** 2
P + S 4	**C** 4	**Atr.** 3	**M + S** 2
Dichl. 3	**L+L+S** 2	**Dichl.** 2	**Atr.** 4

Key to Table

P + S = Propyzamide + Simazine

L+L+S = Linuron, Lenacil + Simazine

M + S = Metazachlor + Simazine

(All M + S plots are shaded)

Atr. = Atrazine

Dichl. = Dichlobenil

C = Control

Treatment Replication

1 – 4 = Plot replication number for that treatment

All treatments were applied at a moderate rate of application.

3.5 Erica (Heather) Experiments

3.5.1 Experiment Location

The *Erica* trials were located on the northern outskirts of Killarney town. Soil type is a **brown podzolic** (similar to Association No 15, previously described for the *Pittosporum* trials). The site is gently sloping with a south facing aspect. Soil analysis of this area was as follows: Phosphorus Index 2, Potash Index 2.

The plots were located in the central area of respective commercial foliage crops to minimize the possibility of outside growth factors. The trial location was firstly examined for variation in soil characteristics using profile inspections and soil cores. It was concluded that no significant variation in soil type existed within the establishment area.

3.5.2 Site Cultivation and Crop Establishment

The trial was located in an *Erica veichii* crop that had been established in June 1995. Cultivation method was similar to that already outlined for *Eucalyptus* species. The *Heather* plants were established in a series of 15 rows between tram lines. The plants had a spacing of 70 cm both along and between the rows.

3.5.3 Selection of herbicide treatments for *Erica* Trials

Table 8 below presents the herbicide treatments that were used in the *Heather* trials.

Treatments **1**, **2** and **3** consisted of low moderate and high rates of the herbicide **dichlobenil** respectively. These were applied as stand alone treatments on 5th April, 1998.

Low, medium and high rates of dichlobenil were included in order to test the safety and efficacy of the chemical in controlling the range of weeds that were observed both between the rows and growing up throught the foliage crops during the growing season. The control treatment (4) was included for comparative purposes and control plots received no herbicide treatment.

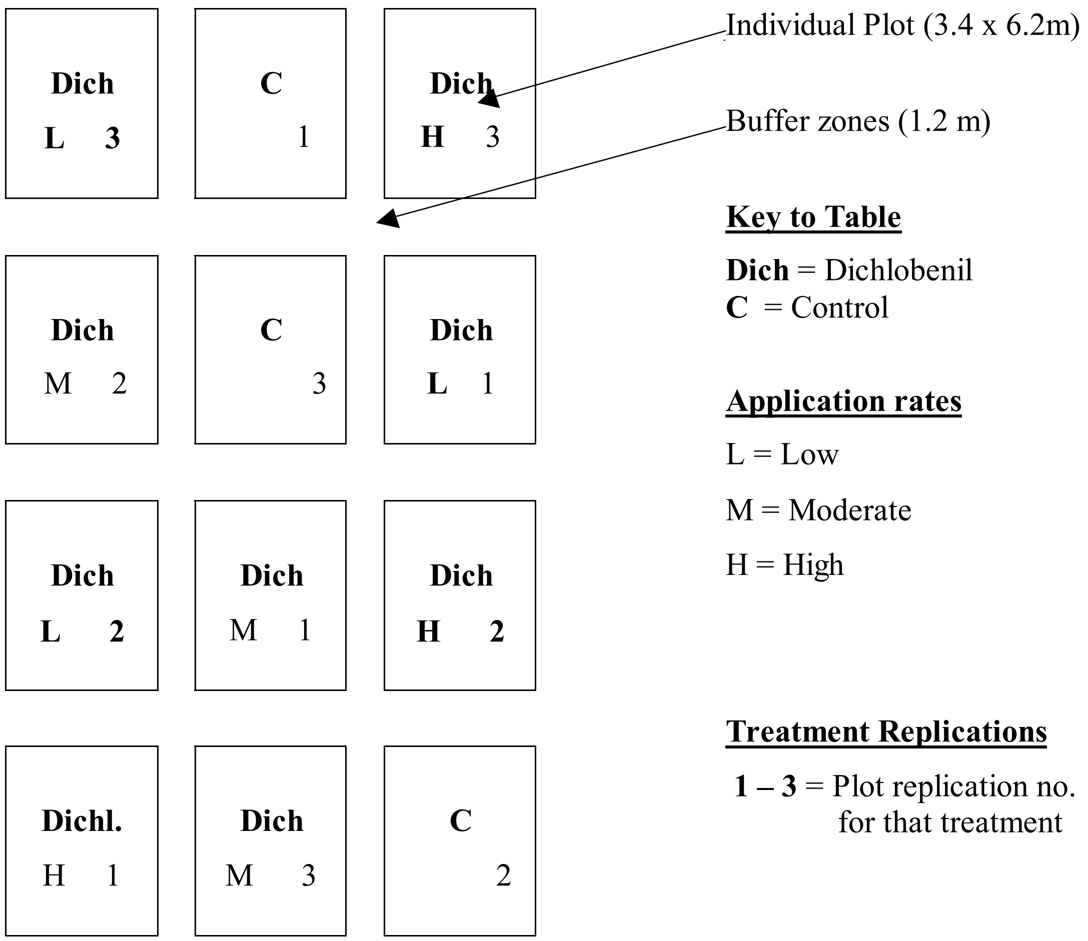
Table 8: Herbicides used in the *Erica* Trials

Tr. no.	Treatment/Treatment	Herbicide Rate (Kg per treated hectare)	Formulation
1	Dichlobenil	60 kg	Granular formulation
2	Dichlobenil	80 kg	Granular formulation
3	Dichlobenil	120 kg	Granular formulation
4	Control (C)	-	

3.5.4 Layout of Erica Plots

Experimental plots were independently and randomly selected for trials of *Erica vetchii* within the confines of the area available. This gave a total randomized design. All plots had dimensions of 3.4 x 6.2 m and 22 viable plants. There were 3 replications for each of 3 treatments selected, along with 3 control plots. This gave a total of 12 plots in total in the trial. Plots within the trial area were labelled for parameter recordings. Buffer areas were retained between plots as in other trials. Figure 6 provides a representation of the experimental layout for this trial.

Figure 6 - Layout for *Heather* Trials



3.5.5 Weather Conditions during Application

Application of the granular formulation took place on the 5th April, 1998. Calm, dry conditions were essential in order to facilitate even and accurate application on the plots. The temperature during that period was approximately 12 ºC.

3.6 *Hypericum* Experiments

3.6.1 Experiment Location

The *Hypericum* trials were located on the northern outskirts of Killarney town, the same location as previously outlined for the *Erica* trials. Soil type was therefore a brown podzolic (Appendix 2).

The site is gently sloping with a south facing aspect. Soil analysis of this area was as follows: Phosphorus Index 2, Potash Index 2 (Whelton, 2000).

3.6.2 Site Cultivation and Crop Establishment

An initial trial was located in plots of *Hypericum androsaemum* 'Scenario' on 25th April 1998. Following unacceptably high levels of damage in these plots resulting from the herbicide dichlobenil, a subsequent trial was laid down in plots of *Hypericum androsaemum* 'Excellent Flair' on 10th February 1999. Both *Hypericum* varieties had been established in June 1995. Cultivation method was similar to that already outlined for *Eucalyptus* species. The *Hypericum* plants were planted in a series of 15 rows between tram lines. The plants had a spacing of 70cm both along and between the rows.

The plots were located in the central area of respective commercial foliage crops to minimize the possibility of outside growth factors such as the provision of shelter from hedgerows. The trial location was firstly examined for variation in soil characteristics using profile inspections and soil cores. It was concluded that no significant variation in soil type existed within the establishment area.

3.6.3 Selection of herbicide treatments for *Hypericum* Trials

3.6.3.1 Hypericum androsaemum 'Senario'

The initial trial on *Hypericum androsaemum* 'Scenario' was laid down on 25th April 1998. The trial tested the safety and efficacy of the herbicide dichlobenil on this cultivar during active growth as new spring foliage was developing.

Dichlobenil was applied in granular formulation over the plants at low, medium and high concentrations. These treatments are shown in Table 9. The control plots were included for comparative purposes and received no herbicide treatments.

Table 9: Herbicides used in the 'Senario' Trials

Tr. no.	Herbicide/Treatment	Herbicide Rate(s) (Kg per treated hectare)	Formulation
1	Dichlobenil	60 kg	Granular formulation
2	Dichlobenil	80 kg	Granular formulation
3	Dichlobenil	120 kg	Granular formulation
4	Control (C)	-	

3.6.3.2 Hypericum androsaemum 'Excellent Flair'

Table 10 below indicates herbicide treatments that were used in trials for *Hypericum androsaemum* 'Excellent Flair'. Treatment **1,** consisted of a mixture of **propyzamide** + **simazine** at recommended rates applied to the crop on 10th February, 1999. This treatment also included a follow-up directed spray of **glyphosate**, applied on 15 April 1999. Care was taken to avoid the crop.

Treatments **2**, **3** and **4** consisted of low moderate and high rates of the herbicide **dichlobenil** (4% w/w) respectively. These were applied as stand alone treatments on 10th February, 1999. No directed spray of glyphosate was combined with these treatments. The control plots received no herbicide treatment at all.

Table 10: Herbicides used in the 'Excellent Flair' Trials

Tr. no.	Herbicide/Treatment	Herbicide Rate(s)	Knapksack Volumes used of:			
		Kg or litres (per treated hectare)	First Herbicide (ml)		Second Herbicide (ml)	Water (l)
1	Propyzamide + Simazine	3.0 + 2.0 (l)	30.0	+	20.0	3.95
2	Dichlobenil	60 kg	Granular formulation			
3	Dichlobenil	80 kg	Granular formulation			
4	Dichlobenil	120 kg	Granular formulation			
5	Control (C)	-				

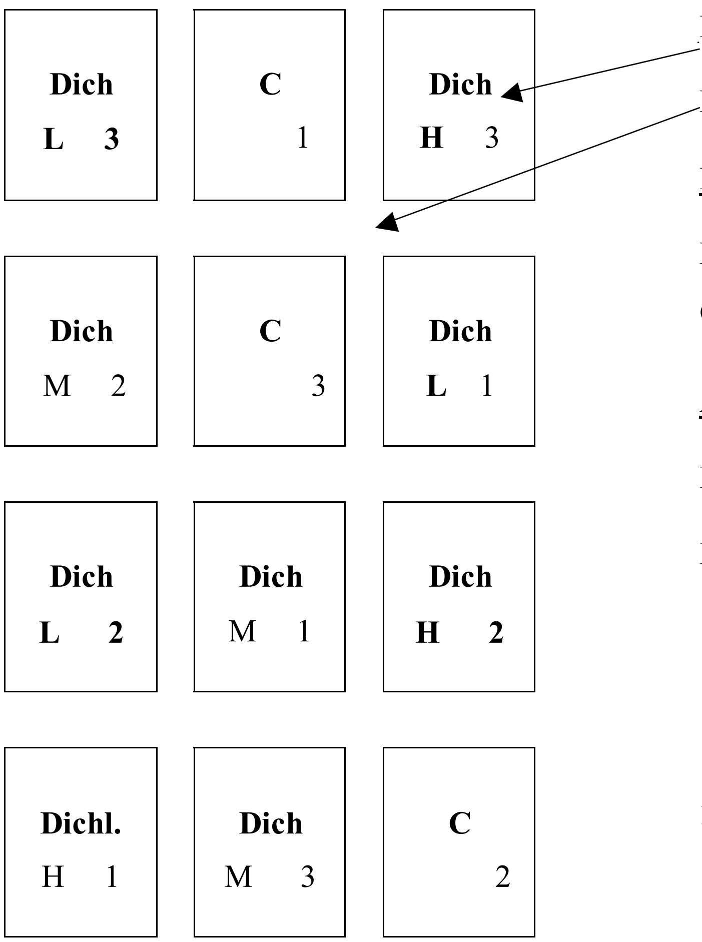
3.6.4 Design of *Hypericum* plots

The herbicide trials on *Hypericum* also had a total randomized design. All plots had dimensions of 3.4 x 6.2 m and a minimum of 22 viable plants. In the case of the 'Senario' cultivar, there were 3 replications for each of 3 treatments selected, along with 3 control plots. This gave a total of 12 plots.

A further treatment of **propyzamide + simazine** in combination with a (directed) spot application of **glyphosate** was included in the 'Excellent Flair' trials resulted in a total of 15 plots for the experiment. This treatment was included as it represented an alternative to the the dichlobenil treatment which was not found satisfactory in the earlier 'Senario' trial. The glyphosate component of the treatment was included to treat difficult perennial weeds not controlled by a **propyzamide + simazine** mixture on its own. Glyphosate was being routinely used in this manner in *Hypericum* crops at the time of the trials.

Plots within each trial area were labelled for parameter recordings. Buffer areas were retained between plots as in other trials. Figures 7 and 8 provide representations of the experimental layout for the 'Scenario' and 'Excellent Flair' trials respectively.

Figure 7: Plot Layout for *Hypericum androsaemum* 'Scenario' Trials



Key to Table

Dich = Dichlobenil

C = Control

Application rates

L = Low

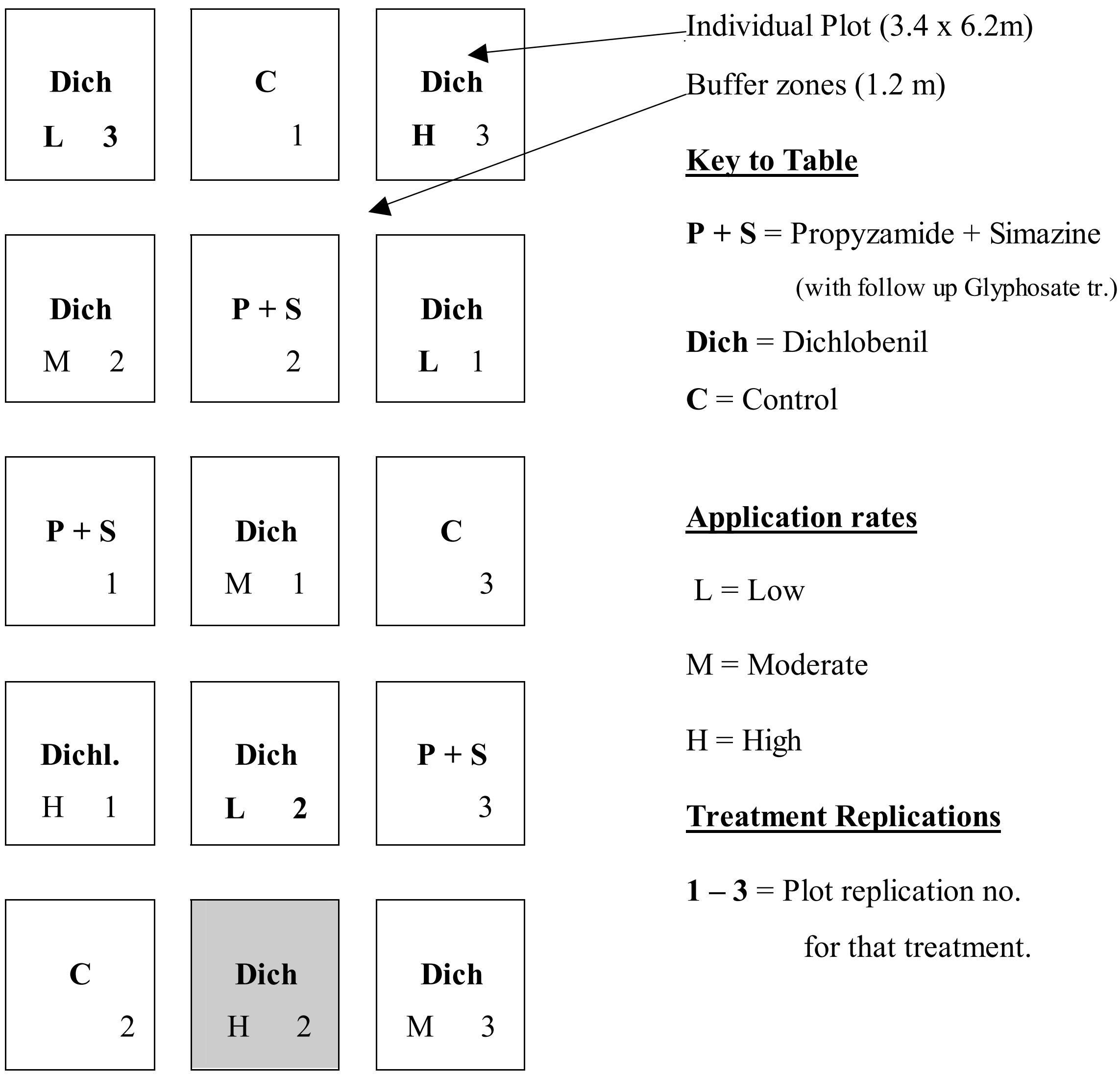
M = Moderate

H = High

Treatment Replications

1 – 3 = Plot replication no. for that treatment.

Figure 8: Plot Layout for *Hypericum androsaemum* 'Excellent Flair' Trials



3.6.5 Weather Conditions during Application

Application of the granular formulation took place on the 5th April, 1998. Calm, dry conditions were essential in order to facilitate even and accurate application on the plots. The temperature during that period was approximately 12 ºC.

3.7 Statistical Analysis

All statistical analysis was carried out using the Statistical Package for Social Sciences – **SPSS software**.

If data were found to be normally distributed, it was analysed using one way **Analysis of Variance (ANOVA) and a Least Significant Difference (LSD) test**, similar to previous work by Vanner, (1991), O` Carroll and O` Reilly, (1995) and other authors. The above analysis determined whether or not there was a significant difference between treatments, for example when different herbicides or concentrations were used.

Where recorded data were not found to be normally distributed, the **Arcsine or Angular formulas** were used in order to transform the distribution of data (where possible) to normality.

Where transformations still did not provide normally distributed data sets, the **non-parametric Mann-Whitney** test was employed in order to if significant differences existed between herbicide treatments (O` Flynn, pers. comm.).

4.0 Results/Discussion/Conclusions for Individual Foliage Crops

This section presents results from trials carried out in each of the cut foliage crops selected. The order of presentation of these results is as follows:

These results firstly indicate weed species identified in experimental locations. Trials on *Paeony Roses* and *Eucalyptus* shared the same location in Tralee. Trials on *Erica* and *Hypericum* species were also carried out on a single location in Killarney. Work on *Pittosporum tenuifolium* was carried out on a separate site in the Killarney area.

Results include the effects of herbicide treatments in terms of their safety when applied over the foliage crops selected. The effects of these treatments on the growth and cover of target weed species occuring is also an important part of trial findings. Indicative costings of treatments are presented in section 4.1 (*Paeony Roses)*. Trials on *Paeony Roses* covered the broadest range of herbicide mixtures, most of which were also included in subsequent trials. The indicative costings presented in Section 4.1 are also relevant for the other foliage species but are dealt with in this section in order to avoid repetition of results and to provide early insight into the treatment costs relevant to the results presented for the other trials.

The presentation of findings for each foliage species is immediately followed by a discussion of these results. Conclusions are then drawn for individual species which incorporate recommendations for future weed control regimes.

4.1 The Effect of Herbicide Application on Paeony Roses

4.1.1 Weed Species Arising in *Paeony* trials

Table 11 below shows the species found present in the *Paeony/Eucalyptus* trial areas (both shared the same location) and the extent of their occurrence. A total of 10 grass species, 9 annual broadleaf species and 18 perennial weed species were identified in this trial area. The most common weeds occurring in the trial area included Meadow Grass species, Chickweed, Fat Hen, Ragworth, Willowherb and Creeping Buttercup. Fat hen was also identified as a persistent weed species in an adjoining field containing an established crop of *Paeony Roses*.

The variety and extent of species occurring in a limited trial area gives an indication of the overall challenge facing commercial foliage growers in controlling invasive species.

Table 11: Weed Type and Occurrence in *Paeony* Trial Area

Common Grass Species	Latin Name (Family)
Annual Meadow	*Poa annua* (graminae)
Narrow Leaved Meadow	Poa angustifolium (graminae)
Meadow Foxtail	Alopecurus pratensis (graminae)
Couchgrass	*Elymus Repens* (graminae)
Rough Meadow	Poa trivialis (graminae)
Occasional Grass Species	
Cocksfoot	*Dactylis glomerata* (graminae)
Sheeps Fescue	Festuca ovina (graminae)
False Fox Sedge	Carex otrubae (graminae)
Meadow Oat	Helictottrichon pretense (graminae)
Red Fescue	*Festuca rubra* (graminae)
Common Annual Weeds	
Common Chickweed	*Stellaria media* (Caryophyllaceae)
Mouse Eared Chickweed	*Cerastium fontanum* (Caryophyllaceae)
Fat hen	*Chenopodium album* (Chenopodiaceae)
Prickly Sowthistle	*Sonchus asper* (Compositae)
Groundsel	*Senecio vulgaris* (Compositae)
Occasional Annual weeds	
Field Speedwell	*Veronica persica* (Scrophulariaceae)
Cleavers	*Gallium aparine (Rubiaceae)*
Pineapple Weed	*Chamomilla suaveolens* (Compositae)
Common Perennial Weeds	
Creeping Buttercup	*Ranunculus repens* (Ranunculaceae)
Creeping Thistle	*Cirsium arvense* (Compositae)
Ragworth	*Senecio jacobaea* (Compositae)
Willowherb	*Epilobium parviflorum* (Onagraceae)
Wavy Bittercress	*Cardamine flexuosa* (Cruceiferae)
Wild Turnip	*Brassica rapa* (Cruceiferae)
Nettle	*Urtica dioica* (Urticacea)
White Clover	*Trifolium repens* (Leguminosae)
Dandelion	*Taraxacum sp.* (Compositae)
Daisy	*Bellis perennis* (Compositae)
Occasional Perennial Weeds	
Broadleaf Dock	*Rumex obtusifolius* (Polygonaceae)
Curled Dock	*Rumex crispus* (Polygonaceae)
Burdock	*Actium sp.* (Compositae)
Dog Rose	*Rosa canina* (Rosaceae)
Field Bindweed	*Convolvulus arvenis* (Convolvulaceae)
Lesser Celandine	*Ranunculus ficaria* (Ranunculaceae)
Soft Rush	*Juncus effuses* (Juncaceae)
Sorrell	*Rumex acetosa* (Polygonaceae)

4.1.2 Survival and *Paeony* Health Rating

Visual examinations of plants carried out in May and June, 1998 following treatment indicated that the selected residual herbicide treatments had no adverse effect on survival of *Paeony* plants as no notable failures were recorded in the plots treated. *Paeony* plants were also visually inspected for changes in colour, growth patterns and other abnormalities. No adverse effects were recorded following herbicide treatments. Plant height was the growth parameter recorded in order to statistically compare the safety of herbicide treatments.

4.1.3 The Effect of Herbicide Treatment on *Paeony* Height Growth

The lengths of *Paeony* shoot extension occurring in plots were measured and recorded for the months of May and June. The occurrence of flowering in this crop was very limited as is normal in newly established *Paeony Roses,* whose tubers have not as yet bulked up in size sufficiently to support vigorous flowering.

Shoot extension was observed as ongoing during the month of May. Maximum extension growth was achieved during the month of June, after which shoots began to die back. Recorded heights for treatments and the control were statistically analysed. Analysis of Variance was used as the *Paeony* height data were found to be normally distributed. Table 12 compares mean *Paeony* height for each of the 15 herbicide treatments with untreated control plants.

Table 12: Comparing Mean *Paeony* Heights for May 1998

Treatment	(Conc.)	Tr. No.	Mean Ht. May *
Linuron, Lenacil, Simazine	**(high)**	15	29.8 a
Linuron, Lenacil, Simazine	**(med)**	14	29.7 a
Metazachlor + Isoxaben	**(med)**	11	29.6 a b
Propyzamide + Simazine	**(low)**	1	29.5 a b c
Propyzamide + Isoxaben	**(med)**	5	29.4 a b c
Propyzamide + Isoxaben	**(low)**	4	29.1 a b c d
Propyzamide + Simazine	**(med)**	2	28.6 a b c d e
Metazachlor + Isoxaben	**(low)**	10	28.3 a b c d e
Propyzamide + Simazine	**(high)**	3	27.3 a b c d e
Pendimethalin	**(low)**	7	26.9 a b c d e
Metazachlor + Isoxaben	**(high)**	12	26.8 a b c d e
Control	-------	16	26.5 a b c d e
Linuron, Lenacil, Simazine	**(low)**	13	26.0 b c d e
Pendimethalin	**(high)**	9	25.8 c d e
Propyzamide + Isoxaben	**(high)**	6	25.4 d e
Pendimethalin	**(med)**	8	25.0 e

* Values followed by the same letter are not significantly different at P = 0.05

Mean *Paeony* heights were found to be greater than those in corresponding control plots in the case of 11 out of 15 herbicide treatments in May 1998. However, these differences in mean height were not found to be significantly when Analysis of Variance was carried out on the data. A similar pattern emerged when mean heights were assessed for June of that year (Table 13).

Given the limited levels of weed cover developed by June, it is unlikely that the effects of weed growth would have impacted on *Paeony* heights by this stage. Mean height growth was found to be lower than in the case of control plants in four of the herbicide treatments, again for both May and June but not significantly so. The results indicate that a range of herbicide treatments were found safe under these trial conditions on *Paeony* Roses. The trials also indicate that selected herbicide treatments could be repeated during the growing season without compromising the safety of *Paeony Roses.*

Table 13: Comparing Mean *Paeony* Heights for June 1998

Treatment	(Conc)	Tr. No.	Mean Ht. June *
Metazachlor + Isozaben	**(med)**	11	33.4 a b
Linuron, Lenacil,	**(med)**	14	23.4 a b
Propyzamide + Simazine	**(low)**	1	33.0 a b c
Linuron, Lenacil,	**(high)**	15	33.0 a b c
Propyzamide + Isoxaben	**(med)**	5	32.1 a b c d
Propyzamide + Isoxaben	**(low)**	4	32.0 a b c d
Propyzamide + Simazine	**(med)**	2	32.0 a b c d e
Metazachlor + Isozaben	**(low)**	10	31.4 a b c d e
Propyzamide + Simazine	**(high)**	3	31.1 a b c d e
Metazachlor + Isozaben	**(high)**	12	30.3 a b c d e
Pendemethalin	**(low)**	7	30.0 a b c d e
Control	**-------**	16	29.9 a b c d e
Pendemethalin	**(high)**	9	29.9 b c d e
Linuron, Lenacil,	**(low)**	13	29.7 c d e
Propyzamide + Isoxaben	**(high)**	6	28.8 d e
Pendiethalin	**(med)**	8	28.1 e

* Values followed by the same letter are not significantly different at P = 0.05

4.1.4 The Effect of Herbicide Treatment on Weed Cover

The site preparation for this trial produced virtually weed-free conditions at the time of residual herbicide application. The trial focused on the **efficacy of selected residual herbicides and mixtures in controlling as wide a range of weed species as possible**.

Table 14: Comparing Grass and Annual Cover for *Paeony* Treatments

Treatment	(conc)	Abbreviations Used	Tr. No.	% Weed Cover*			
				July	August	Sept	Oct
Propyzamide + Simazine	(med)	P + S (l)	2	0.5 a b	1.9 a	4.3 a	10 a
Propyzamide + Simazine	(high)	P + S (H)	3	0.4 a	1.8 a	5.2 a b	15 a
Linuron, Lenacil, Simazine	(med)	LL S (M)	14	0.6 a b	2.0 a	5.3 a b	12 a
Propyzamide + Isoxaben	(high)	P + I (H)	6	0.7 a b	2.6 a	5.7 a b	12 a
Metazachlor + Isoxaben	(high)	M + I (H)	12	1.4 a b	2.5 a	5.8 a b	13 a
Propyzamide + Isoxaben	(med)	P + I (M)	5	1.7 a b	3.4 a	6.6 a b	14 a
Linuron, Lenacil, Simazine	(high)	LLS (H)	15	0.8 a b	3.0 a	7.0 a b	15 a
Pendimethalin	(high)	Pend. (H)	9	2.1 a b c	3.7 a b	7.1 a b	16 a b
Propyzamide + Simazine	(low)	P + S (L)	1	0.9 a b	3.2 a	7.6 a b	16 a b
Metazachlor + Isoxaben	(med)	M + I (M)	11	1.5 a b	3.5 a b	7.6 a b	17 a b
Linuron, Lenacil, Simazine	(low)	LLS (L)	13	1.3 a b	3.8 a b	9.5 b c	17 a
Propyzamide + Isoxaben	(low)	P + I (L)	4	1.6 a b	5.2 a b c	9.8 b c	14 a
Pendimethalin	(med)	Pend. (M)	8	4.1 c	8.1 c	14.0 c d	23 b
Metazachlor + Isoxaben	(low)	M + I (L)	10	2.7 b c	7.2 b c	18.7 d	31 c
Pendimethalin	(low)	Pend. (L)	7	7.7 d	14.5 d	25.7 e	35 c
Control		Contr.	16	15.1 e	28.5 e	43.1 f	50 d

*Values followed by the same letter are not significantly different at $P = 0.05$

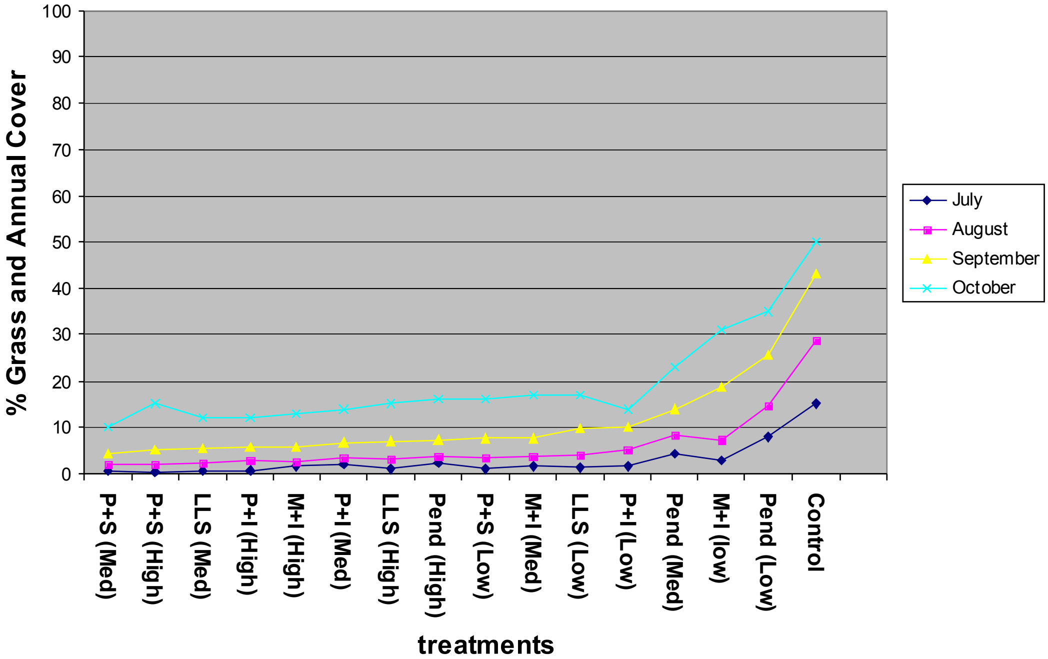
4.1.4.1 Grasses and Annual Broadleaf Weeds

Tables 14 above presents **cover of grasses and annual broadleaf weeds** as a percentage of overall plot area for the months of July to October 1998. Cover data was not found to be normally distributed when analysed. Non-parametric analysis (using the Mann-Whitney test) indicated that percentage weed cover from June onwards was significantly less than that in the control plots for all herbicide treatments.

The most effective herbicide treatment under the site conditions described was found to be a repeated application of **propyzamide + simazine** at rates of 4 litres and 3 litres a.i. per hectare respectively (medium concentrations). It is apparent that the effects of this treatment persisted over 5 months before grass and annual weeds began to reinvade. Plots were relatively weed-free up to August 1998. The above mixture restricted grass and annual weed development to less than 5% up to September and to 10% by October.

A number of other herbicide treatments also emerged as very effective in restricting grasses and annual weeds. Their apparent activity in the soil was also similar to that achieved for the **propyzamide + simazine** treatment outlined above (Table 14). Eleven of the other treatments applied restricted grass and annual weed cover to under 10% up to September and to under 18 % up to October. These treatments included single high rates of herbicide mixtures applied prior to emergence of the crop. There was no significant difference ($P = 0.05$) in the percentage of grass and annual weed cover between these treatments and the repeat treatment of a **propyzamide + simazine** mixture. A comparison of grass and annual weed cover for each treatment between the months of July and October is presented in Figure 9. This clearly indicates the efficacy of a range of treatments when compared to untreated control plots.

Fig. 9: Comparing % Grass and Annual Cover by Treatment for *Paeony Roses*



4.1.4.2 Comparing Total Weed Cover in Paeony Roses

Table 15 presents **total weed cover** as a percentage of plot area for the period July to October inclusive. Non-parametric analysis (using the Mann-Whitney test) indicated that percentage weed cover from June onwards was significantly less than that in the control plots for all herbicide treatments as would be expected.

Table 15: Comparing Total Weed Cover for *Paeony* Treatments

Treatment	(Conc.)	Tr. No.	% Weed Cover *			
			July	August	Sept	Oct
Linuron, Lenacil, Simazine	(med)	14	1.5 a b	4.1 a	9.8 a	23 a
Propyzamide + Simazine	(med)	2	1.0 a	4.3 a b	10.7 a b	25 a b
Propyzamide + Simazine	(high)	3	1.5 a b	5.1 a b c d	12.1 a b c	32 a b c
Linuron, Lenacil, Simazine	(high)	15	1.7 a b	5.5 a b c d	13.8 a b c d	31 a b c
Metazachlor + Isoxaben	(high)	12	3.5 a b c d	7.4 a b c d	15.2 a b c d e	35 a b c
Pendemethalin	(high)	9	5.0 b c d	9.3 c d	18.0 b c d e	37 c
Propyzamide + Isoxaben	(high)	6	3.2 a b c d	9.0 a b c d	18.5 b c d e	36 b c
Linuron, Lenacil, Simazine	(low)	13	3.2 a b c d	8.3 a b c d	18.6 b c d e	38 b c
Propyzamide + Isoxaben	(med)	5	5.0 b c d e	10.8 d e	20.1 c d e	39 c d
Propyzamide + Simazine	(low)	1	2.8 a b c d	9.2 a b c d	20.5 d e	40 c d e
Metazachlor + Isoxaben	(med)	11	4.0 a b c d	10.3 c d e	21.0 d e	40 c d e
Propyzamide + Isoxaben	(low)	4	5.9 d e	15.7 e f	22.8 e f	43 c d e
Pendemethalin	(med)	8	9.8 f	16.8 f	29.4 f g	50 d e f
Metazachlor + Isoxaben	(low)	10	5.6 c d e	17.1 f	35.8 g h	52 e f
Pendemethalin	(low)	7	14.4 g	24.1 g	43.9 h	61 f
Control		16	24.5 h	44.2 h	68.6 i	86 g

* Values followed by the same letter are not significantly different at $P = 0.05$

An application of **linuron + lenacil + simazine** at (moderate) rates of 2.0, 1.7 and 2.4 litres a.i. per hectare respectively, repeated during the growing season was found to restrict total weed cover to 10% up to September and to 23% up to October 1998. There was no significant difference between the apparent efficacy of this mixture and that of five other treatments up to October 1998. These other treatments consisted of a repeated application of **propyzamide + simazine** at moderate rates (25% cover), and single applications of **linuron + lenacil + simazine** (31% cover), **propyzamide + simazine** (32% cover) and **metazachlor + isoxaben** (35% cover) each at high rates.

A comparison of the efficacy of the above treatments with that of a control plot which received no residual application is presented in Plate 10. This series of photographs taken in October 1998 illustrate the varying levels of weed control achieved seven months following the application of residual herbicides. The *Paeony* plants had died back at this time of the year and are not visible above ground. The control plot is almost fully covered with grass and a range of other weed species. Despite the effect of shade, it is apparent that the repeated application of **linuron + lenacil + simazine** at moderate rates is particulary effective in controlling grasses.

Plate 10: Comparisons of Weed Cover in Paeony Plots for October

Propyzamide + Simazine: moderate repeat

Propyzamide + Simazine: single high

Linuron + Lenacil + Simazine: moderate repeat

Linuron + Lenacil + Simazine: single high

Metazachlor + Isoxaben: single high

Control Plot- No Residual Treatment

Figure 10 presents a graphical comparison of percentage weed cover (total) by treatment for the *Paeony Rose* herbicide trials. It indicates that 12 herbicide treatments restricted total weed development below 25 % of plot area from March to September 1998. While eleven of these treatments also maintained total weed cover below 40% up to October of that year, it is apparent that weed development increased sharply from September levels. It is likely that this is due to reduced soil activity as herbicides break down in the soil after their application in March.

Fig 10: % of Total Weed Cover by Treatment for *Paeony* Trial

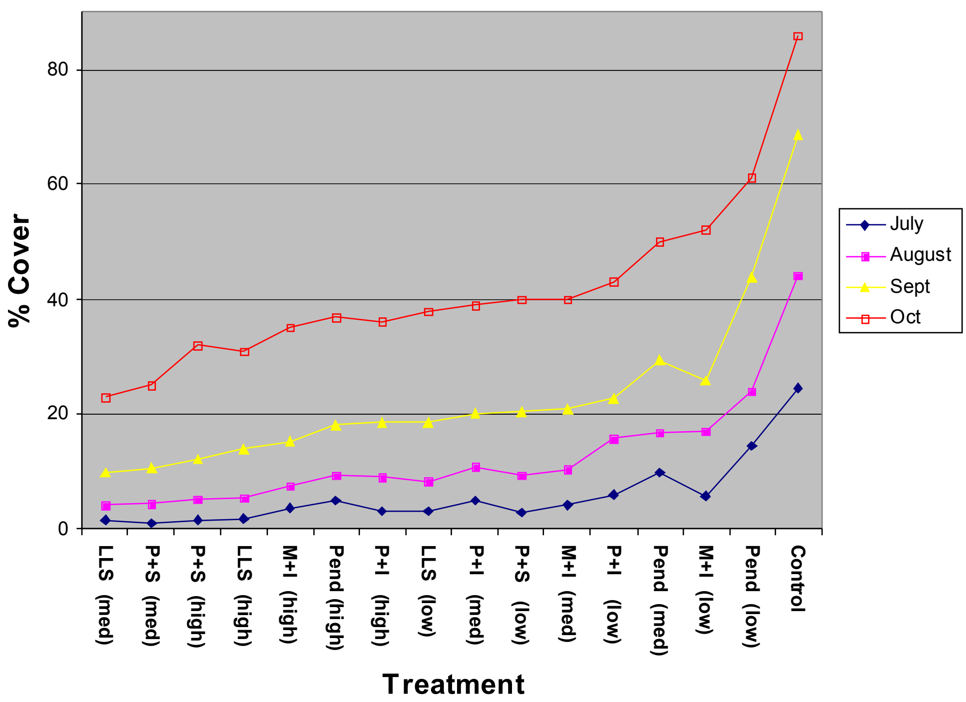


Table 16 represents sample field sheet showing the progression of cover (in cm²) for each weed species in a single *Paeony* plot following a repeated application of **propyzamide** + **simazine** at the moderate rate of application. Further sample field sheets for the most efficient treatments are presented in Appendices 3 to 7. Review of these field sheets indicate that repeated applications of **propyzamide** + **simazine** and **linuron** + **lenacil** + **simazine** showed high efficacy in controlling development of annual and perennial grass species up to October of that year. However the efficacy and apparent persistence of single high applications of these mixtures is also comparatively high. The relative costs of single and repeated application treatments will have a bearing on their potential usage and will be examined in Section 4.1.7.

Table 16: Progression of Weed Development (cm²) for a single *Paeony* Plot (6.3 m²) following repeated moderate treatment with Propyzamide + Simazine

	April	May	June	July	Aug	Sept	Oct
Annual Grasses							
Annual Meadow						42	200
Sub-Total	0	0	0	0	0	42	200
Perennial Grasses							
Cocksfoot							
Couchgrass			20	182	450	1025	2915
False Fox Sedge							
Meadow Foxtail							
Meadow Oat							
Narrow Leaved Meadow				24	104	280	1530
Rough Meadow							
Red Fescue							
Sheeps Fescue						25	145
Sub-Total	0	0	20	206	554	1330	4590
Annuals							
Chickweed							
Cleaver							
Common Mouse-ear Speedwell							
Fat Hen				28	243	615	702
Prickly Sowthistle						128	2784
Sub-Total	0	0	0	28	243	743	3486
Perennials							
Broadleaf Dock							
Burdock							
White clover							60
Creeping Buttercup			14	60	106	300	1420
Creeping Thistle				45	312	750	2570
Curled Dock							
Daisy							
Dandelion							
Dog Rose							
Field Bindweed					215	440	660
Lesser Celandine							
Groundsel						100	140
Nettle							40
Ragworth			20	76	185	365	1010
Soft Rush							180
Sorrell							
Adderstongue Spearworth							
Wavy Bittercress							
Wild Turnip					49	188	215
Willowherb					23	145	1480
Sub-Total	0	0	33	179	890	2279	7775
Grand Total	0	0	53	413	1685	4394	16051

4.1.5 Observational Trial with Metoxuron

A limited trial was carried out on an established crop of *Paeony Roses* in a field adjacent to the main trial area. The crop had been treated with simazine pre-emergence of the *Paeony* shoots. Fat Hen had been developing quite vigorously over two seasons and had built up a seedbank from which new generations were emerging (Plate 11). The herbicide Dosaflow (metoxuron 43.8% w/w) was applied as an overall treatment at a rate of 6.5 l/ha a.i and appeared to be safe based solely on visual inspection of the crop after treatment. The herbicide is specified for use on Carrots but provides good control of Fat hen from pre-emergence to the two expanded true leaves stage of growth (Novartis, 1998).

Plate 11: Problem of Fat Hen Development in *Paeony* Crop

4.1.6 Control Regimes Used in Commercial Crops during Trials

Weed control practice in commercial foliage crops while trials were ongoing was found to be similar for *Paeony Roses*, *Pittosporum tenuifolium*, *Eucalyptus* and *Erica* species. It incorporated a combination of residual and systemic herbicides applied in a timely manner. An overall application of Gesatop 50 WP (simazine 50% w/w) was carried out using a tractor and boom sprayer at 3.4 kg/ha as a residual herbicide prior to the onset of weed growth. This controlled and prevented flushes of some annual weeds during the growing season (Whelton, 2000).

Control of persistent annual and perennial weeds posed a more difficult challenge. A spot treatment of Roundup (glyphosate at 360 g/litre a.i.) at 3 l/ha was used sporadically during the growing season (Whelton, 2000). The treatment was carried out manually using a knapsack sprayer. This represented the most time consuming and costly element in chemical weed control systems applied. In addition to the cost element, there was also at times a risk of drift and damage to the foliage crop due to windy conditions or operator error.

4.1.7 Comparison of Herbicide Treatment Costs

4.1.7.1 Application Costs

Mechanical application by tractor and boom sprayer is relatively inexpensive with a current cost of **€35 per hectare**. In comparison, the application cost of spot treatment of a systemic herbicide (directed away from foliage plants) by manual application using a knapsack sprayer can range from **€140 to €180 per hectare** (Whelton 2004, pers. comm.). The latter treatment varies considerably according to the type of crop and intensity of perennial weed development on the site.

4.1.7.2 Herbicide Costs

Table 17 presents a summary of unit costs for the herbicides considered for use in the *Paeony* trials as well as the other trials in this study. All herbicides except dichlobenil are priced in terms of their liquid formulation.

Table 17: Summary of Current Herbicide Costs

Chemical	Trade Name	Concentration	Cost per Unit
Atrazine	Atrazol	500 g/l (45.9%)	€ 5.45 /litre
Dichlobenil	Casoron	4.0% w/w	€ 7.68 /kg
Glyphosate	Roundup	360 g/l	€ 4.90/litre
Hexazinone	Velpar L	240 g/l	€ 29.96 /litre
Isoxaben	Gallery 125	125 g/l (12.14%)	€ 109.90 /litre
Lenacil	Venzar	440 g/l (38.8%)	€ 37.50 /litre
Linuron	Afalon	450 g/l (37.6%)	€ 23.60 /litre
Metazachlor	Butisan S	500 g/l (43.1%)	€ 50.25 /litre
Metoxuron	Dosaflow	500 g/l (43.8%)	€ 49.65 /litre
Napropamide	Devrinol	450 g/l	€ 49.80 /litre
Oxyfluorfen	Goal 2E	240 g/l	€ 83.75 /litre
Pendimethalin	Stomp	400 g/l (36.4%)	€ 13.70 /litre
Propyzamide	Kerb	500 g/l	€ 65.72 /litre
Simazine	Simazine	500 g/l	€ 5.08 /litre

4.1.7.3. Comparing Seasonal Cost of treatments

Table 18 presents a summary of estimated cost for weed control treatments currently used within the Kerry Foliage Industry and potential treatments that that have been included for screening in this study. Only rates recommended on the manufacturers label have been used in each case.

Table 18: Indicative per Hectare Weed Control Treatments Costs

Treatment (Type)	**Application Rate**	**Application Type**	**Herbicide Cost**	**Treatment Cost**	Total Cost Per Ha.
Simazine (Overall)	3/l/ha	Tractor + Boom	€ 15.24	€35	€50.24
Glyphosate (Spot)	3.0 l/ha	Knapsack	€14.70	€160	€ 174.70
Propyzamide+Simazine (Overall)	3.0 + 2.0 l/ha	Tractor + Boom	€207.33	€35	€ 242.33
Propyzamide+Isoxaben (Overall)	3.0 + 2.0 l/ha	Tractor + Boom	€416.96	€35	€ 451.96
Linuron + Lenacil + Simazine (Overall)	2.0 + 1.7 + 2.4 l/ha	Tractor + Boom	€123.14	€35	€158.14
Pendimethalin (Overall)	5.0 l/ha	Tractor + Boom	€68.50	€35	€103.50
Metazachlor + Isoxaben (Overall)	2.0 + 2.0 l/ha	Tractor + Boom	€325.25	€35	€360.25
Metazachlor + Simazine (Overall)	2.0 + 2.0 l/ha	Tractor + Boom	€130.66	€35	€165.66
Metoxuron (Overall)	6.5 l/ha	Tractor + Boom	€322.72	€35	€357.72

Treatments Current at the Time of these Trials

The weed control treatment used at the time of these trials in a range of cut foliage crops consists of use of both residual and systemic herbicides. The residual component of this treatment consists of a single application of **simazine.** This is combined with periodic spot applications of **glyphosate** (to control perennial weeds) as the systemic component of the treatment. The indicative cost for this treatment is **€400 per hectare during the season** (2 full spot treatments are assumed per season). The cost of applying simazine as a residual is inexpensive (€50.24) compared to the follow-up spot application costs of glyphosate (€174.70 x 2).

Alternative Herbicides / Residual Mixtures

Table 18 indicates that the use of mixtures of residual herbicide in treatments such as **propyzamide + simazine, propyzamide + isoxaben, metazachlor + isoxaben and linuron + lenacil + simazine** will increase the residual component of the treatment cost compared to a simazine application on its own. However, the broadening of the range of weeds and persistence of the residual application will generally reduce the frequency of spot applications of glyphosate (systemic component) in treating perennial weeds (Kelly, 1997, pers. comm.). It is therefore assumed that the equivalent of one spot application of glyphosate is required per season when residual herbicide mixtures are used instead of simazine application on its own.

4.1.7.4 Estimate of Costs Over 3 Seasons

Table 19 presents indicative costs of herbicide treatments when applied over one and three seasons. It is assumed that most crops will be established within three seasons.

Table 19: Indicative per HectareTreatment Costs over 1 and 3 Seasons

Treatment		**Costing per season**	Costing over 3 Seasons
Residual	**No. Spot Applications (Glyphosate)**		
Simazine	**2**	**€400**	**€1200**
-----------------------------	**-----------------------**	**-----------------**	**-----------------**
Pendimethalin	**1**	**€278**	**€835**
Linuron/Lenacil/Simazine	**1**	**€333**	**€999**
Metazachlor/Simazine	**1**	**€340**	**€1021**
Propyzamide/Simazine	**1**	**€417**	**€1251**
Metazachlor/Isoxaben.	**1**	**€535**	**€1604**
Propyzamide/Isoxaben	**1**	**€627**	**€1880**

With the inclusion of one one spot treatment equivalent of glyphosate per season assumed in combination with the use of the above alternative herbicide or residual mixtures (to simazine), the overall cost of such treatments per season ranges between **€278** (pendimethalin) **and €627** (propyzamide + isoxaben)**.** The use of an individual alternative herbicide such as **pendimethalin** is shown to be a cost effective treatment. This is also the case for a combination of **linuron** + **lenacil** + **simazine** (table 19). The use of **propyzamide** + **simazine** is comparible in cost to the current treatment. Herbicide mixtures such as **propyzamide** + **isoxaben** and **metazachlor** + **isoxaben** are considerably more expensive. The differences in costs are more apparent when estimated over a period of three seasons. However, the potential for damage due to intensive use of glyphosate combined with overall simazine application may make the use of residual mixtures more desirable in terms of crop safety.

4.1.8 Discussion – *Paeony Roses*

4.1.8.1 Safety and Efficacy of Treatments Applied in Trials

Trials were carried out on a foliage crop of *Paeony roses* in order to determine if selected **residual** herbicides or herbicide mixtures would be appropriate to consider in future weed control regimes for this type of herbaceous foliage species, given the soil, site and climatic conditions under which they are grown. The selection of these residual herbicides was geared to broaden the range of grass, annual and perennial weeds controlled than had up to now been the case with existing control practice. The ultimate aim was to reduce the dependence on risky and costly spot application with systemic herbicides which was has been routinely used in foliage crops.

Trial results indicate that up to 11 treatments out of the 15 selected have potential in controlling a wide range of grass and annual broadleaf weeds. Control of some perennial weeds in *Paeony* crops would also be possible. In contrast, an overall application of simazine had been applied to the surrounding commercial crop in March 1998 and generally necessitated two spot applications with glyphosate using a knapksack sprayer during the course of the season.

Two of the herbicide treatments tested, pre-emergent (March) applications of **linuron + lenacil + simazine** and **propyzamide + simazine** mixtures at recommended rates and repeated in early May were found to be both safe (in terms of height growth and plant condition) and most effective in controlling a relatively wide range of weed species that occurred. The application of these two herbicide mixtures in one single treatment at higher rates prior to crop emergence were shown to provide acceptable levels of grass and annual weed control without the requirement and cost of a second application by tractor sprayer. Other herbicide treatments found to be safe and very effective in restricting the development of weed cover include single applications of **metazachlor + isoxaben, pendamethalin** and **propyzamide + isozaben** at rates higher than recommended.

4.1.8.2 Use of Approved Herbicides and Rates

Of the treatments that were examined in this trial, the herbicides **propyzamide, simazine** and **isoxben** are currently approved for use on ornamental crops such as *Paeony Roses*. These can now be considered for inclusion in weed control programmes when used at rates specified on the manufactures label. Other treatments incorporating herbicides such as **linuron, metazachlor and pendimethalin** were also found to be safe under these trial conditions. The use of these herbicides on ornamental foliage crops is currently not included on the manufacturer's label. Their use with 'off-label approval' which allows growers the use of specific herbicides but at their own risk is possible with authorisation from the Pesticides Control Service of the Department of Agriculture and Food. This process has already been initiated for growers in the Irish foliage sector.

The use of herbicides and mixtures above the recommended application rates and the use of repeated applications of chemicals were undertaken specifically for the purposes of these trials. This also applies to herbicides and mixtures used in trials of all other foliage crops undertaken during this current project.

4.1.8.3 Control of Perennial Weeds

The majority of residual herbicide mixtures used in these trials have limited effect on many perennial weeds that develop in this crop. However, young weeds germinating to 2-leaf stage for species such as Broadleaf Dock, Curled Dock and Creeping Buttercup are reported as susceptible to propyzamide on the product label. Other perennial weed species such as Ragworth, Daisy, Dandelion and Rosebay Willowherb need to be controlled in this crop at an early stage with a manual directed spray of **glyphosate** during the growing season in order to prevent new seeds and new generations of weeds being produced. The herbicide **clopyralid** has been successfully used to control Creeping Thistle in *Paeony* crops (Whelton, 1998 pers. comm.) and is recommended for use on ornamentals. Because of the herbaceous nature of the *Paeony* crop is, it is possible to 'clean up' difficult weeds developing on the site with an overall spray once the above-ground *Paeony* shoots have died back sufficiently in the autumn. This gives the grower of *Paeony Rose* more flexibility than would be possible if dealing with weed control in a woody perennial crop such *Pittosporum* or *Eucalyptus*.

4.1.9 Comparison of Treatment Costs

The current treatment system of using simazine as an overall spray with periodic spot application of glyphosate costs approximately €400 per season. Based on the analysis of indicative costs carried out, the use of alternative residual herbicides or herbicide mixtures such as **propyzamide + simazine**, **linuron + lenacil + simazine** and

pendimethalin coupled with corresponding reduced dependence on glyphosate are cost effective options as possible control regimes in *Paeony Roses.* Mixtures such as **propyzamide + isoxaben** and **metazachlor + isoxaben** are more costly but represent effective and safe options are herbicides such as simazine are phased out in the coming years.

4.1.10 Conclusions: *Paeony Roses*

Trials on selected herbicides applied on *Paeony Roses* indicate that a number of residual herbicides can be used either individually or in mixture to broaden the range of grasses and broadleaf weeds controlled. These may be incorporated into weed control regimes for the crop. Recommendations for weed control in *Paeony Roses* for growers include the following:

- Clear established weeds prior to cultivation using an overall application of glyphosate at rates indicated by the manufacturer.
- Ensure a good firm soil surface for the effective use of residual herbicides.
- Apply <u>one</u> of the following herbicides or herbicide mixtures according to availability and the presence of particular weed types. Apply post-planting of *Paeony* tubers in new crops and prior to emergence of shoots in existing crops. Use recommended rates according to label specifications. Rates may vary according to the brand and concentration of chemicals:
    - **Propyzamide + Simazine**
    - **Propyzamide + Isoxaben**
- The following mixtures are currently cost effective options for growers under off-label approval:
    - **Linuron + Simazine**

    - **Linuron + Lenacil + Simazine**
    - **Metazachlor + Isoxaben**
    - **Pendimethalin**
- During the growing season, a further application of a residual herbicide or mixture may prolong grass and annual weed control but only if required. Applications can be considered where recommended by manufacturers. In general it is important to apply these products to young weeds before they become too large and established.
- The residual herbicides recommended above will reduce the dependence on directed sprays of broad-spectrum herbicides such as **glyphosate.** These would only be used to clear large established weeds if required.
- A number of these treatments are cost effective when compared to the current treatment. These include the use of **pendimethalin** as well as mixtures of **linuron + lenacil + simazine** and **propyzamide + simazine.**
- Specific problem weeds may be tackled using appropriates herbicides such as:
    - **Clopyralid** to treat Creeping Thistle
    - **Metoxuron** to treat Fat Hen
- The *Paeony* site may be cleaned towards the end of the growing season by an overall application of a **glyphosate** (tractor and boom sprayer) when the risk of shoot uptake has receded due to plant senescence

Correct and timely application of suitable residual herbicides should help lower costs, avoid new generations of weeds through seeding and improve management efficiencies.

4.2 The Effect of Herbicide Application on Pittosporum tenuifolium

4.2.1 Occurrence of Weed Species on the *Pittosporum* Site

Table 20 presents the species that were present in the *Pittosporum* trial area and the extent of their occurrence. It includes a total of 9 grass species, 8 annual broadleaf species and over 18 perennial weed species. Many of the species identified were also found on the *Paeony* trial area. The latter did not contain Yorkshire Fog, a perennial grass, Scarlet Pimpernel, an occasion annual weed on this site or Lesser Spearworth, an occasional perennial species on this trial area.

Yorkshire Fog is common in meadows, pastures and roadsides in the southwest of Ireland from sea level to 500 m elevation. It is sometimes found on poorer soils where better grasses will not flourish (Uí Chonchubhair and Ó Conchuir, 1995). The same authors describe Scarlet Pimpernel as a straggling annual plant, common on tilled ground and sand banks, in open situations from sea level to 300 m. Its fruit consist of globular capsules, which turn inwards when ripe to deposit its seed in the earth for new generations. Lesser Spearworth is found abundant in ditches, marshes, lakesides and riversides, in wet, open acidic or calcareous sites from sea level to 670 m elevation. It is a member of the *Ranunulaceae* family.

Table 20: Weed Type and Occurrence in *Pittosporum* Trial area

Common Grass Species	Latin Name (Family)
Annual Meadow	*Poa annua* (graminae)
Narrow Leaved Meadow	Poa angustifolium (graminae)
Yorkshire Fog	Alopecurus pratensis (graminae)
Rough Meadow	Poa trivialis (graminae)
Occasional Grass Species	
Couchgrass	*Elymus Repens* (graminae)
Sheeps Fescue	Festuca ovina (graminae)
False Fox Sedge	Carex otrubae (graminae)
Perennial Rye	Lolium perenne (graminae)
Red Fescue	*Festuca rubra* (graminae)
Common Annual Weeds	
Common Chickweed	*Stellaria media* (Caryophyllaceae)
Mouse Eared Chickweed	*Cerastium fontanum* (Caryophyllaceae)
Redshank	*Polygonum persicaria* (Polygonaceae)
Groundsel	*Senecio vulgaris* (Compositae)
Occasional Annual weeds	
Field Speedwell	*Veronica persica* (Scrophulariaceae)
Cleavers	*Gallium aparine (Rubiaceae)*
Scarlet Pimpernell	*Anagallis arvensis (primulaceae)*
Pineapple Weed	*Chamomilla suaveolens* (Compositae)
Common Perennial Weeds	
Creeping Buttercup	*Ranunculus repens* (Ranunculaceae)
Creeping Thistle	*Cirsium arvense* (Compositae)
Ragworth	*Senecio jacobaea* (Compositae)
Willowherb	*Epilobium parviflorum* (Onagraceae)
Wavy Bittercress	*Cardamine flexuosa* (Cruceiferae)
Bramble	*Rubus fructicosa* (Rosaceae)
Nettle	*Urtica dioica* (Urticacea)
White Clover	*Trifolium repens* (Leguminosae)
Dandelion	*Taraxacum sp.* (Compositae)
Daisy	*Bellis perennis* (Compositae)
Occasional Perennial Weeds	
Broadleaf Dock	*Rumex obtusifolius* (Polygonaceae)
Curled Dock	*Rumex crispus* (Polygonaceae)
Willow (seedlings)	*Salix sp.*
Bramble	*Rosa canina* (Rosaceae)
Field Bindweed	*Convolvulus arvenis* (Convolvulaceae)
Lesser Spearworth	*Ranunculus ficaria*
Soft Rush	*Juncus effuses* (Juncaceae)
Foxglove	*Digitalis purpurea* (Scrophulariaceae)

4.2.2 Survival and *Pittosporum* Health Rating

A visual examination *Pittosporum* plant condition in all plots was carried out on 31th May, 1998, six weeks after treatment. Plant survival did not appear to be affected at that stage. The examination indicated that plant health had been adversely affected by some of the herbicide applications. This was particularly apparent on *Pittosporum* plants over-sprayed with low and high rates of **atrazine** and a moderate (recommended) rate of **napropamide**. The main symptoms displayed were necrosis and dessication plant tissue, particularly where the fan-shaped spray of the chemicals generated from the knapsack sprayer had contacted the foliage. A sample of this damage is show in Plate 12.

Plate **12: Low and High Rate Atrazine Damage to *Pittosporum***

Damage levels were visually estimated six weeks after herbicide application based on the health rating system previously described. Table 21 presents an estimate of the proportion of plants in each health rating category for the three herbicide treatments in question.

Table 21: Estimate of % of *Pittosporum* in Health Categories by Treatment

Treatment	Health Rating Category (% damage per category)					
	1 (0-5%)	**2 (6-35%)**	**3 (36-65%)**	**4 (66-95%)**	**5 (96-99%)**	6 (100%)
Atrazine (low)	0	18	69	13	0	**0**
Atrazine (high)	0	0	29	63	8	**0**
Napropamide (mod)	**0**	**11**	**60**	**19**	**0**	**0**

Visual examination later in May 1999 indicated symptoms of stunting, most likely as a result of observed damage to the foliage and leading shoots of the *Pittosporum*. Plant height would later be used to statistically verify damage levels recorded.

4.2.3 The Effect of Herbicide Application on *Pittosporum* Height Growth

The heights of *Pittosporum* plants in each of the trial plots were recorded on a two monthly basis between July and November 1998. The recorded results were found to be normally distributed and treatments were compared using Analysis of Variance.

No significant difference was found between heights across all plots prior to treatment in March 1998. Differences in plant heights were found to arise in the months following herbicide treatment.

Table 22: Comparing Mean *Pittosporum* Heights for 1998

Treatment	(Conc.)	Tr. No.	Mean Ht. July [*]	Mean Ht. Sept [*]	Mean Ht. Nov [*]
Pendimethalin	**(low)**	5	52.5 [a]	83.2 [a]	106.9 [a]
Pendimethalin	**(high)**	6	50.5 [a]	81.4 [a]	105.5 [a]
Metazachlor + Isoxaben	**(low)**	3	49.1 [a]	78.2 [a]	104.1 [a]
Metazachlor + Isoxaben	**(high)**	4	52.9 [a]	82.4 [a]	104.1 [a]
Control	**-----**	10	51.0 [a]	78.2 [a]	103.8 [a]
Propyzamide + Simazine	**(high)**	2	50.5 [a]	80.9 [a]	103.1 [a]
Propyzamide + Simazine	**(low)**	1	51.0 [a]	78.0 [a]	101.4 [a]
Napropamide	**(reg)**	9	45.8 [b]	66.2 [b]	82.6 [b]
Atrazine	**(low)**	7	44.6 [b]	63.2 [b]	77.3 [b]
Atrazine	**(high)**	8	43.5 [b]	63.0 [b]	68.9 [c]

[*] Values followed by the same letter are not significantly different at P = 0.05

Analysis of height readings in July 1998 (Table 22) indicates no significant difference between the top 6 treatments (low and high rates of **pendimethalin**, **metazachlor + isoxaben** and **propyzamide + simazine** respectively) and the control. However a significant difference did exist between the above treatments and the bottom three herbicide applications (high and low rates of **atrazine** and moderate rates of **napropamide**). A similar pattern emerged for the month of September. This difference in height growth was even more apparent in the analysis of heights taken for November 1998. In this case, similar significant reductions in *Pittosporum* heights were found for the bottom three treatments, while plants in plots treated with a high rate of **atrazine** were significantly lower than those treated with all other herbicide applications.

4.2.4 The Effect of Herbicide Treatment on Weed Cover

The site preparation for this trial produced virtually weed-free conditions at the time of residual herbicide application. The trial focused on the **efficacy of selected residual herbicides and mixtures in controlling as wide a range of weed species as possible**.

4.2.4.1 Grasses and Annual Broadleaf Weeds in Pittosporum Trials

Table 23 presents cover of grasses and annual broadleaf weeds as a percentage of overall plot area for *Pittosporum* plots measured during September and November 1998. The Mann-Whitney (non parametric) test was used to determine significant differences between treatments as these data sets were not normally distributed.

Table 23: Comparing Grass and Annual Cover for *Pittosporum* Treatments

Treatment	(conc.)	Tr. No	% Weed Cover *	
			September	November
Atrazine	(high)	8	3.8E-4 a	1.0E-2 a
Atrazine	(low)	7	2.0E-3 a	1.6 a
Propyzamide + Simazine	(low,repeat)	1	1.6 a	6.6 b
Propyzamide + Simazine	(high)	2	2.1 a b	6.9 b
Napropamide	(moderate)	9	3.8 b c	9.5 b c
Metazachlor + Isoxaben	(high)	4	3.9 b c	10.6 c d
Pendimethalin	(high)	6	3.9 b c	11.6 c d
Pendimethalin	(low)	5	5.2 c d	13.7 d e
Metazachlor + Isoxaben	(low)	3	6.0 d	15.3 e f
Control		10	19.8 e	17.7 f

*Values followed by the same letter are not significantly different at P = 0.05

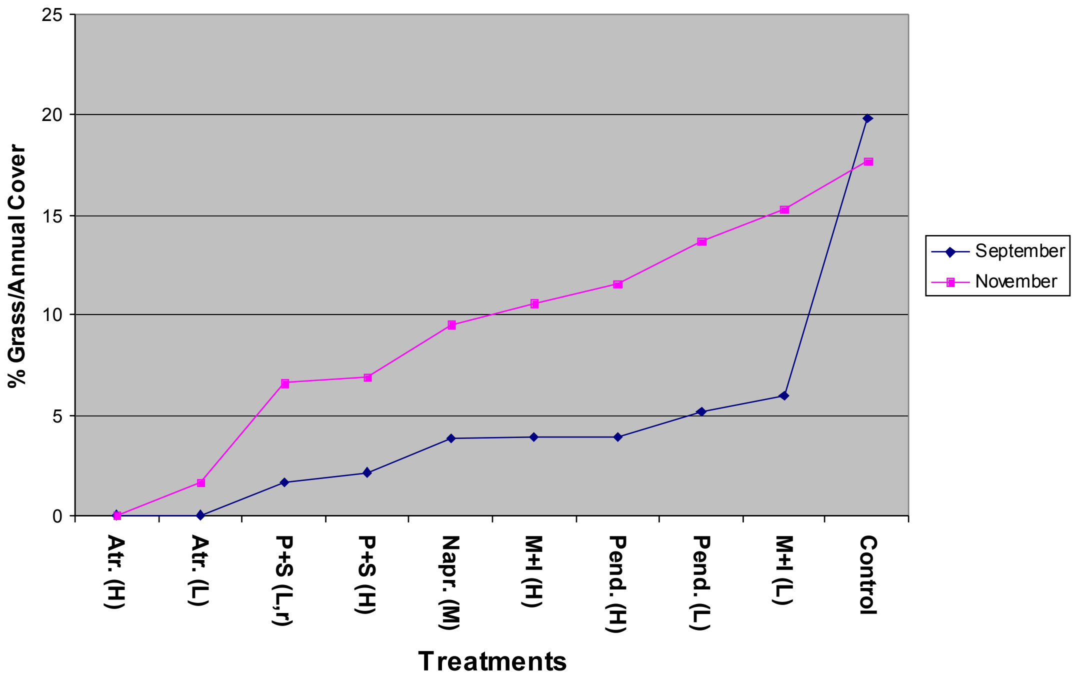
Analysis indicates that treatment of **atrazine** both at rates higher and lower than normally recommended showed the highest level of efficacy in maintaining plots virtually free of grasses and annual broadleaf weeds up to November 1998. These two atrazine treatments provided significantly higher weed control levels than all other treatments in this trial.

Another treatment using a moderate (recommended) rate of **napropamide** also was found to be relatively effective in restricting grass and annual weeds to 4% in September and below 10% up to November. However the safety of using the above two chemicals is at issue.

Two treatments using the herbicide mixture of **propyzamide + simazine** showed high efficacy levels for control of grass and annual weeds. There was no significant difference between a low rate (repeated during the growing season) and one single application of the mixture a high rate. Both such treatments of this mixture restricted grass and annual weeds close to 2% up to September and below 7% up to November 1998.

Other herbicide mixtures showing comparable levels of weed control included a single high rate of **metazachlor + isoxaben** and a single high rate of **pendimethalin**. All herbicide treatments maintained weed cover significantly lower that in the control treatment as would be expected. These results are presented and compared graphically in Figure 11. The percentage of grass and annual weed cover was higher in September than November in the control plots as perennial weeds took over the plot areas and annual weeds died back.

Fig 11: % Grass and Annual Weed Cover by Treatment for *Pittosporum*



4.2.4.2 Total Weed Cover in Pittosporum Trials

Tables 24 and 25 present total weed cover as a percentage of overall plot area for *Pittosporum* herbicide treatment plots measured during September and November 1998 respectively. Analysis of variance was used to determine significant differences between treatments as these data sets were found to be normally distributed.

Analysis indicates that the most favourable treatments in terms of total weed control for September 1998 were a single application of **atrazine** at high rate and a repeated application of **propyzamide** + **simazine** mixture at rates lower than generally recommended.

Table 24: Total Weed Cover for *Pittosporum* treatments (September, 1998)

Treatment	(Conc.)	Tr. No.	% Weed Cover *
			September
Atrazine	(high)	8	3.0 a
Propyzamide + Simazine	(low,repeat)	1	3.7 a
Propyzamide + Simazine	(high)	2	4.8 b
Atrazine	(low)	7	6.7 b c
Metazachlor + Isoxaben	(high)	4	6.8 b c
Napropamide	(moderate)	9	6.9 b c
Pendimethalin	(high)	6	7.8 c
Pendimethalin	(low)	5	9.1 c d
Metazachlor + Isoxaben	(low)	3	10.6 d
Control		10	35.6 e

* Values followed by the same letter are not significantly different at P = 0.05

There was no significant difference in percentage of weed cover between these two treatments when measured for both September and November (Tables 24 and 25). A single high application of **propyzamide + simazine** was also found to be comparable in effectiveness to these treatments in the November analysis, maintaining slightly lower total weed cover than the repeated lower-rate treatment of the same mixture.

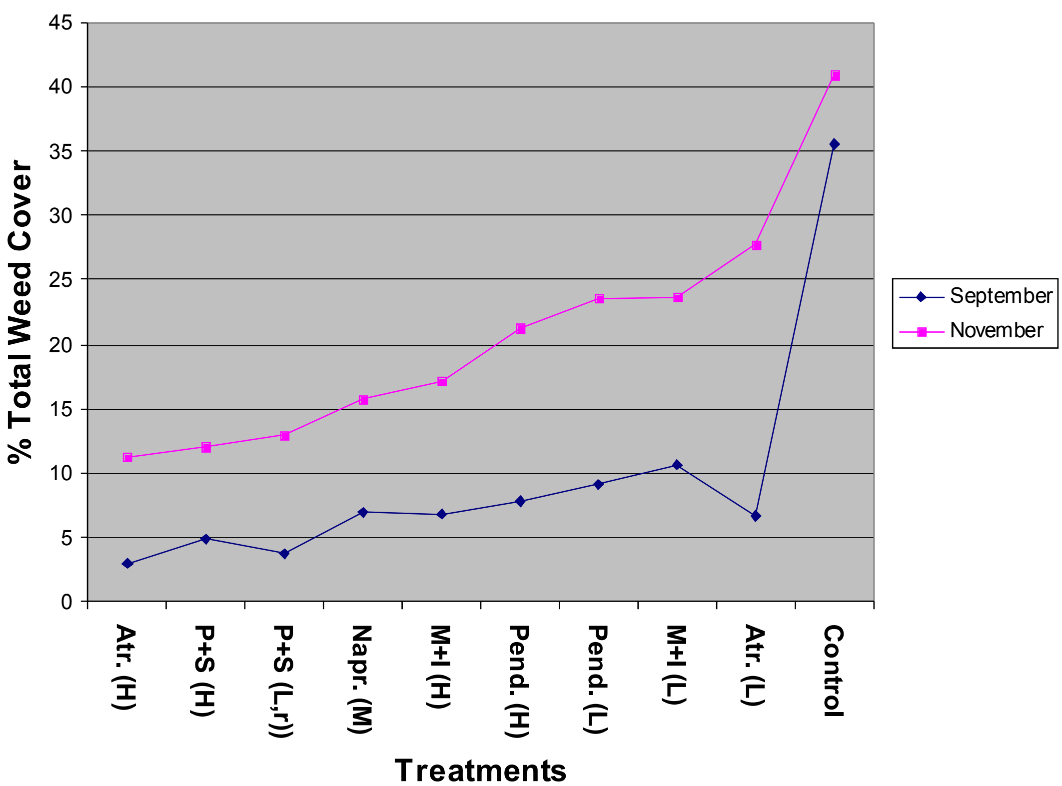
Table 25: Total Weed Cover for *Pittosporum* Treatments (November, 1998)

Treatment	(conc)	Tr. No	% Weed Cover *
			November
Atrazine	(high)	8	11.2 a
Propyzamide + Simazine	(high)	1	12.0 a
Propyzamide + Simazine	(low, repeat)	2	12.9 a b
Napropamide	(moderate)	7	15.7 b c
Metazachlor + Isoxaben	(high)	4	17.1 c
Pendimethalin	(high)	9	21.2 d
Pendimethalin	(low)	6	23.5 d
Metazachlor + Isoxaben	(low)	5	23.6 d e
Atrazine	(low)	3	27.7 e
Control		10	40.9 f

* Values followed by the same letter are not significantly different at P = 0.05

Other treatments that showed relatively effective control included a single high rate treatment of **metazachor + isoxaben** (17.1 % cover for November) and an application of **napropamide** at moderate (recommended) rate. The latter herbicide, along with both atrazine treatments have been shown to be unfavourable in terms of crop safety. A high rate of **pendimethalin** was found to restrict total weed cover below 8% up to September but seemed to slip down the rankings by November of that year (Fig. 12).

Fig. 12: % Total Weed Cover by Treatment for *Pittosporum* Trials



4.2.5 Observations of Dichlobenil Treatments on Established *Pittosporum*

The granular formulation of the herbicide **dichlobenil** was applied at varying rates to plots that had been used in the *Pittosporum* trials following weed cover estimation on 18th November 1998. These treatments were applied in order to test the suitability of the herbicide in controlling a range of annual and perennial weeds that were re-establishing in plots as the persistence of the residual treatments applied the previous March waned.

Dichlobenil was applied to plots previously treated with **propyzamide + simazine**, **metazachlor + isoxaben** and **pendimethalin** applications respectively. The herbicide was applied at a high rate of 120 kg per ha, directed between rows of plants within plots. The crop was establishing at this stage and its foliage limiting the development of weeds underneath. Therefore no herbicide application was considered necessary over the *Pittosporum* plants or towards the rooting area.

Recording of plant height following treatment was not undertaken as dichlobenil is approved for use on established *Pittosporum* and damage was not expected.

Observation of the efficacy of **dichlobenil** indicate very good weed control for up to 5 months in plots where weed species resistant to the chemical are not already present.

However, non-susceptible weeds such as Buttercup and Spearworth species were observed to proliferate between rows of plants in plots where they were present prior to application (Plate 13).

Plate 13: Dichlobenil Treatment on 2-year-old *Pittosporum*

Buttercup absent prior to treatment

Buttercup present prior to treatment

4.4.5 Comparison of Existing Control System with Dichlobenil Treatment

This section presents indicative costings for herbicide treatment with Dichlobenil. Costings for other recommended herbicides and mixtures used in *Pittosporum* trials have already been dealt with in the results for *Paeony Roses*.

The existing weed control system used for *Pittosporum* as well as other foliage species described previously includes an application of simazine as an overall spray with up to **two** spot applications of glyphosate per season. Table 26 below compares indicative costs for this treatment with a single application of dichlobenil at recommended rates.

Table 26: Indicative Treatment Costs

Treatment (Type)	**Application Rate**	**Application Type**	**Herbicide Cost**	**Treatment Cost**	Total Cost
Simazine (Overall)	3/l/ha	Tractor + Boom	€ 15.24	€35	€50.24
Glyphosate (Spot)	3.0 l/ha	Knapsack	€14.70	€160	€ 174.70
Dichlobenil (Overall)	**80 kg/ha**	**Motorised**	€614.40	€60	€674.0

The existing system costs up to €400 per hectare for one season as previously detailed for *Paeony Roses*. In comparison, a full single application of dichlobenil is costed at approximately €768 per hectare for one season. This is assuming application of dichlobenil over the full crop area. However, application of the dichlobenil to control weeds in the inter-row areas between establishing rows of plants would use approximately 60% of the chemical compared to full overall treatment. The indicative cost for this type of treatment is therefore €405. This may be considered as a safer option than spot application of glyphosate.

4.2.6 Discussion – *Pittosporum*

4.2.6.1 Safety and Efficacy of Treatments Applied in Trials

The safety and efficacy of nine different herbicide treatments were tested on a crop of *Pittosporum tenuifolium* in a field situation. These treatments comprised individual herbicides such as **napropamide, atrazine** and **pendimethalin** and mixtures of two herbicides (**propyzamide + simazine** and **metazachlor + simazine**). Low and high rate applications were used during these trials. The low rate application of the most promising treatment (**propyzamide + simazine**) was repeated once during the growing season. Control plots were used for comparative purposes and received no herbicide treatments.

The treatments using **atrazine** and **napropamide** were found to be among the most efficient at restricting development in the case of grass and annual weeds and also for total weed cover. However, both of these treatments were found to be injurious when applied in April and affected plant height growth. Due to damage levels encountered in these trials, application of **atrazine** or **napropamide** could not be recommended during active growth in a weed control programme for *Pittosporum*. Due to limited available trial area in the commercial crop testing of these herbicides during dormancy was not investigated but may be merited in future research work.

Three herbicide treatments were found to be satisfactory in terms of crop safety and weed control efficacy when applied over two-year old *Pittosporum* plants during active growth. Mixtures of **propyzamide + simazine, (**either at a single high rate or repeated lower rate) and **metazachlor + isoxaben (**at the higher rate)**,** when applied over two year old established *Pittosporum* plants restricted annual weed cover to acceptably low levels between April and November. Both herbicide mixtures have therefore potential for weed control in *Pittosporum* crops**.** Similar to results from *Paeony Rose* trial, the above mixtures will broaden the range of weeds controlled compared to the use of simazine (current weed control practice) and therefore reduce the need for systemic herbicide application of glyphosate. Though not concluded from this trial, the mixtures may well be safe over similar woody species cultivated in the southwest of Ireland.

Dichlobenil was found to be the very effective at cleaning up plots where a range of weeds were encroaching on the trial area. It was shown to have a good efficacy in controlling both annual and perennial weeds from November 1998 up to March 1999. This would be expected due to the wide range of weeds reported susceptible to the chemical in the literature. This increased efficacy appeared to diminish between March and May; most likely the herbicide broke down in the soil. Again this herbicide could be incorporated in a weed control programme particularly in situations where difficult perennial weeds are a challenge to growers. It appears to be useful in targeting a broad range of weed pests. It may be an alternative and safer option to spot application of glyphosate which is used to clean up sites during the growing season, despite its higher cost.

4.2.6.2 Use of Approved Herbicides and Rates

Of the treatments that were examined in this trial, the herbicides **propyzamide, simazine, isoxben** and **dichlobenil** are already approved for use on ornamental crops such as *Pittosporum*. These herbicides are generally recommended for use on ornamental shrubs that have been planted in their final position for at least one season. Such herbicides and mixtures could now be recommended for inclusion in weed control programmes when used according to the manufactures label. Other treatments incorporating herbicides such as **metazachlor** and **pendimethalin** were also found to be safe under these trial conditions. Their use may be possible in future, based on off-label approval, similar to the situation within *Paeony Roses***.**

4.2.6.3 Comparison of Treatment Costs

The current practice of using simazine as an overall spray with periodic spot application of glyphosate costs approximately €400 per season. Based on the analysis of indicative costs carried out for *Paeony Roses*, the use of alternative residual herbicides or herbicide mixtures such as **propyzamide + simazine** (€417 per season), and **pendimethalin** (€278 per season) coupled with corresponding reduced dependence on glyphosate are also cost effective options as possible control regimes in *Pittosporum.* Mixtures such as **propyzamide + isoxaben** (€672 per season) and **metazachlor + isoxaben** (€535 per season) are more costly but may be desirable to growers as safe and effective options in the future.

Application of dichlobenil to the inter-row area of establishing *Pittosporum* may be an option in terms of efficacy and indicative cost (€405 per treatment)

4.2.7 Conclusions: *Pittosporum tenuifolium*

Trials on selected herbicides applied in a crop of *Pittosporum* indicate that a number of approved residual herbicides can be used either individually or in mixture to broaden the range of grasses and broadleaf weeds controlled. These may be incorporated into weed control regimes for established crops.

Recommendations for weed control within *Pittosporum* crops established for at least one season include the following:

- Apply one of the following herbicides or herbicide mixtures according to availability and the presence of particular weed types. Apply early in the season prior to the onset of grass and annual weed growth. Use recommended rates according to manufacturer's specifications. Rates may vary according to the brand and concentration of chemicals:
    - **Propyzamide + Simazine**
    - **Dichlobenil**
    - **Isoxaben**

- The following mixtures may be an option for growers under off-label approval:
    - **Metazaclor + Isoxaben**
    - **Pendimethalin**
- During the growing season, a further application of residual herbicides or mixtures may improve grass and annual weed control if required. Applications can only be considered if allowed and recommended manufacturers. In general it is important to apply these products to young weeds before they become too large and established.
- Use of recommended residual herbicides should reduce the requirement for intervention with directed sprays of broad-spectrum herbicides such as **glyphosate.** The latter should only be used to clear large established weeds if required.
- A number of treatments are cost effective when compared to the current commercially applied treatment. These include use of **propyzamide + simazine** or **pendimethalin** as residual treatments combined with a single spot treatment equivalent of glyphosate per season.
- A *Pittosporum* site may be treated for broadleaf weeds towards the end of the growing season by the application of a **dichlobenil** in the space between rows. This may be a suitable and safer alternative to **glyphosate** application.

Correct and timely application of suitable residual herbicides should help to avoid new generations of weeds through seeding and improve management efficiencies.

4.3 The Effect of Herbicide Application on Eucalyptus Growth

4.3.1 Occurrence of Weed Species in Eucalyptus Site

The *Eucalyptus* trials were carried out in the same location as that of the *Paeony Rose* trials. To this extent, similar grass and broadleaf weeds were found to occur in both trials. Those species occurring and the extent of their occurrence are indicated in Table 11.

4.3.2 Survival and *Eucalyptus* Health Rating

A visual examination of both *Eucalyptus* species was carried out 6 weeks after treatment. Seedling survival at that stage did not appear to be affected. However, the examination indicated that plant health had been adversely affected by some of the herbicide applications. This was particularly apparent on *E. perreniana* seedlings oversprayed with a **linuron + lenacil + simazine** mixture. The main symptoms displayed were necrosis and dessication of tissue particularly on the outer parts of the foliage, resulting in curling of leaves either upwards or downwards. This unacceptable damage is represented in Plate 14.

Plate 14: Damage to *E. perreniana* seedling following treatment with Linuron + Lenacil + Simazine

All of the plants in the four replicate plots, which received this treatment showed damage symptoms, 29% of which showed health rating 3 (moderate damage levels) and 71% showing health rating 4 (severe levels). Visual examination later in May 1999 indicated symptoms of stunting, most likely as a result of observed damage to the foliage and growing points of seedlings. Plant height would later be used to statistically verify and quantify damage levels recorded.

Herbicide damage to *E. moorei* was not apparent. However, mild discolouration of the foliage tips was noted during the winter of 1998/99. These symptoms may have been at least partly due to wind damage but could not be compared with commercial crops of *E. moorei* as there were no such plantations of that age available.

4.3.3 The Effect of Treatment on *Eucalyptus* Height Growth 1998/1999

Seedlings heights of both *E. perreniana* and *E. moorei* were recorded for all plots in mid September 1998, prior to application of the selected herbicide treatments and retention of control plots. Following treatment, height measurements were taken for each plot in December 1998 and May 1999 in order to determine if growth of either *Eucalyptus* species had been affected by herbicide application. Mean heights for *E. perreniana* and *E. moorei* are show in tables 27 and 28 respectively. The recorded height results were later subjected to statistical analysis.

Heights of *E. perreniana* taken in September prior to herbicide treatments were normally distributed. Analysis of Variance indicated that there was no significant difference between heights across all plots prior to treatment.

Table 27: Comparing *E. perreniana* Mean Heights for 1998/1999

Treatment	Tr. No.	Mean Ht. *		
		Sept 98	Dec 98	May 99
Propyzamide + Simazine	1	28.2 [a]	36.2 [a]	59.2 [a]
Control	5	28.0 [a]	36.9 [a]	58.6 [a]
Metazachlor + Simazine	3	28.8 [a]	35.7 [a b]	57.6 [a]
Dichlobenil	6	28.9 [a]	35.7 [a b]	56.7 [a]
Atrazine	4	29.5 [a]	33.5 [b c]	50.2 [b]
Linuron + Lenacil + Simazine	2	28.1 [a]	31.0 [c]	46.7 [b]

* Values followed by the same letter are not significantly different at P = 0.05

However, analysis of height data in December 1998 indicates a significant difference between the bottom two treatments (**atrazine** and **linuron + lenacil + simazine)** and the top two treatments (**propyzamide + simazine** and the **control**) as indicated in Table 27. This difference in height growth was even more apparent in the analysis of measurements taken for May 1999. In this case the bottom two treatments were significantly different from all other treatments, including the control, at the 95% confidence level.

Analysis of Variance of plant heights for *E. moorei* presented in table 28 indicate an overall similar pattern to results found for *E. perreniana*. There was no significant difference in plant heights across all plots in September just prior to treatment.

Table 28: Comparing *E. moorei* Mean Heights for 1998/1999

Treatment	Tr. No.	Mean Ht. *		
		Sept 98	Dec 98	May 99
Control	5	35.6 a	40.1 a	56.8 a
Metazachlor + Simazine	3	36.2 a	39.7 a b	56.0 a b
Propyzamide + Simazine	1	35.0 a	`39.6 a b	55.8 a b
Dichlobenil	6	34.7 a	39.9 a b	55.7 a b
Atrazine	4	35.2 a	38.0 a b	52.8 b
Linuron + Lenacil + Simazine	2	36.6 a	37.9 b	48.8 c

* Values followed by the same letter are not significantly different at P = 0.05

There was also no significant difference in *Eucalyptus* heights between the top five treatments in December, with the control plots marginally producing the larger plant heights. Only the plants treated with the **linuron + lenacil + simazine** mixture were significantly different from the **control** treatment for December. In the final analysis for May 99, the **linuron + lenacil + simazine** treated plots produced plant heights significantly different from those subjected to all other treatments.

4.3.4 The Effect of Herbicide Treatment on Weed Cover for *Eucalyptus* Trials

4.3.4.1 Grass and Annual Broadleaf Weed Cover

Tables 29 presents results on cover of grasses and annual broadleaf weeds as a percentage of overall plot area (combined for both species of *Eucalyptus*) measured during March and May 1999. The Mann-Whitney test was used to determine significant differences between treatments as the data were not normally distributed. Analysis indicated that the herbicide mixture of **linuron + lenacil + simazine** showed the highest level of efficacy in controlling grasses and annual broadleaved weeds for both the months of March and May 1999 (but also the most damage levels).

Table 29: Comparing Grass and Annual Broadleaf Weed Cover in *Eucalyptus*

Treatment	Tr. No.	% Weed Cover *	
		March	May
Linuron + Lenacil + Simazine	2	1.4 [a]	8.5 [a]
Metazachlor + Simazine	3	2.1 [a b]	11.1 [a]
Atrazine	4	2.0 [a b]	11.3 [a]
Propyzamide + Simazine	1	2.7 [b]	16.4 [b]
Dichlobenil	5	2.1 [b]	22.5 [c]
Control	6	18.5 [c]	61.5 [d]

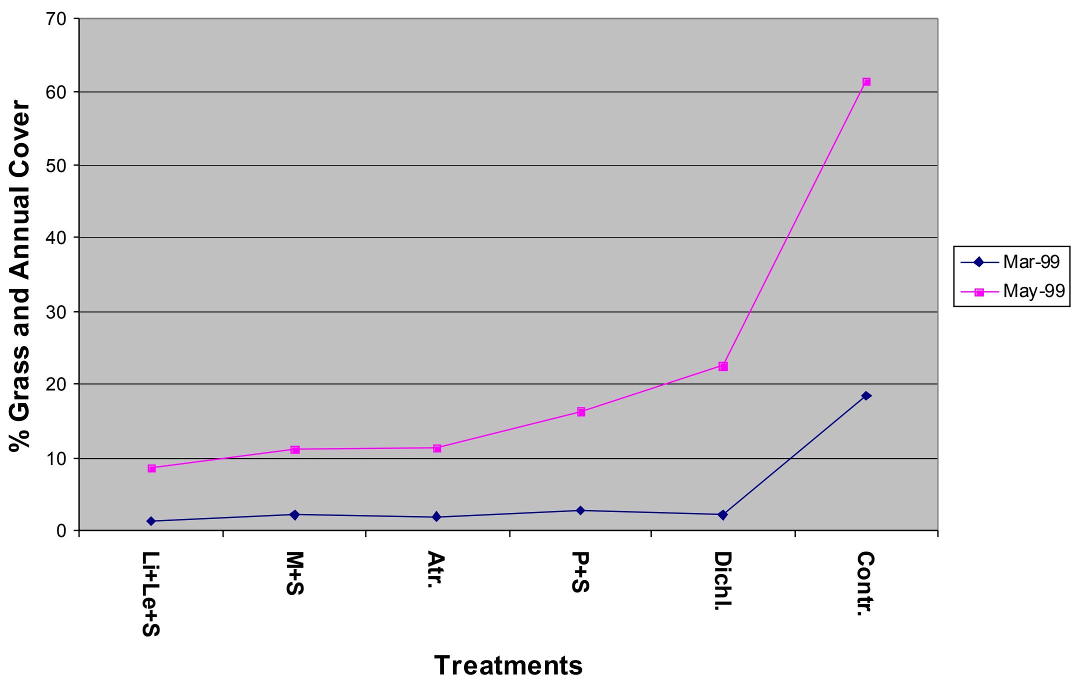
* Values followed by the same letter are not significantly different at P = 0.05

The four remaining herbicide treatments (**metzachlor + simazine**, **atrazine**, **dichlobenil** and **propyzamide + simazine**) maintained grass and broadleaf weed cover below 3% up to the end of March 1999. There was no significant difference in efficacy between these treatments in the analysis of March cover data. However, significant differences were found between treatments in May. Both **atrazine** and

metazachlor + **simazine** treatments showed a higher degree of efficacy in maintaining grass and annual broadleaf weed cover close to 11%. The **propyzamide** + **simazine** treatment restricted weed cover to below 17 %. All treatments maintained weed cover significantly lower that in the control treatment as would be expected. There were no commercial plots available for comparison with trial data.

A comparison of percentage grass and annual weed cover by treatment is presented graphically in Figure 13 for both the months of March and May 1999. This clearly shows the most efficient herbicide treatments as outlined above.

Figure 13: Comparing Grass and Annual Weed Cover by Treatment for Combined *Eucalyptus* Plots



4.3.4.2 Total Weed Cover

Tables 30 and 31 show total weed cover as a percentage of plot areas (combined for both species of *Eucalyptus*) measured during the months of March and May 1999 respectively. Plots were relatively weed free in December 1998 and therefore weed cover was not analysed at this time. Mann-Whitney tests indicate significant differences (P = 0.05) between treatments for both months. The **dichlobenil** treatment produced the lowest total weed cover (5.3%) up to March 1999. Both the **atrazine** and **linuron + lenacil + simazine** treatments restricted weed cover below 9% during this time. **Simazine,** when combined with either **propyzamide** or **metazachlor** produced herbicide mixtures that restricted total weed development in plots to approximately 10 % and 11 % respectively up to March 1999.

Table 30: Comparing Total Weed Cover in *Eucalyptus* Trials for March 1999

Treatment	Tr. No.	% Weed Cover [A]
		March 1999
Dichlobenil	5	5.3 [a]
Atrazine	4	8.6 [b]
Linuron + Lenacil + Simazine	2	8.8 [b]
Propyzamide + Simazine	1	10.1 [b c]
Metazachlor + Simazine	3	11.4 [c]
Control	6	26.5 [d]

[*] Values followed by the same letter are not significantly different at P = 0.05

The degree of weed control by herbicide treatments and their efficacy ranking between treatments was found to have changed by the end of May 1999. It is apparent that the effect of all herbicides was waning at this stage, over eight months after their application. The **atrazine** and **linuron + lenacil + simazine** treatments were found to be the best at restricting total weed cover by then. This was also found to be the situation with grass and annual weed cover previously.

Table 31: Comparison Total Weed Cover in *Eucalyptus* Plots for May 1999

Treatment	Tr. No.	% Weed Cover *
		June 1999
Atrazine	4	51.3 a
Linuron + Lenacil + Simazine	2	52.4 a
Metazachlor + Simazine	3	58.1 b
Dichlobenil	5	60.0 b
Propyzamide + Simazine	1	68.8 c
Control	6	88.6 d

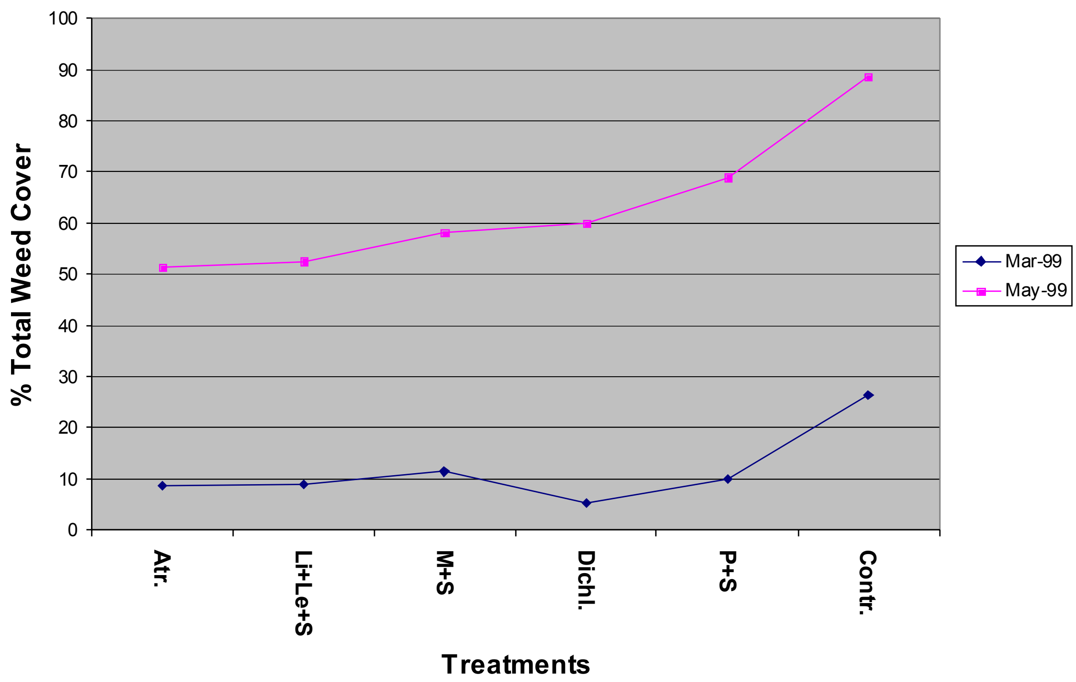
* Values followed by the same letter are not significantly different at P = 0.05

Both **metazachlor + simazine** and **dichlobenil** treatments resulted in total percentage weed cover of 60% in plots at the end of May, 1999. These treatments were found to be significantly different from the atrazine (51% cover) and linuron + lenacil + simazine (52% cover) treatments. Mean weed cover in the **propyzamide + simazine** treated plots was 69%. In comparison, 90% of the control plots were covered with weed species. Follow up herbicide applications would be required in commercial circumstances but were not persued here due to time constraints on the project.

A comparison the efficacy of treatments in terms of percentage total weed cover is presented in Figure 14 for both March and May 1999. It is clear from this graph that herbicide treatments used were effective from September 1998 to March 1999. However, between March and May 1999, herbicide efficacy decreased considerably.

This is apparently because the persistence of herbicides in the soil (as previously outlined for chemicals in Table 1) had run its course.

Fig. 14: Comparison of Total Cover in Combined Eucalyptus Plots by Treatment



4.3.5 Observations of Oxyfluorfen on *E. pulverulenta*

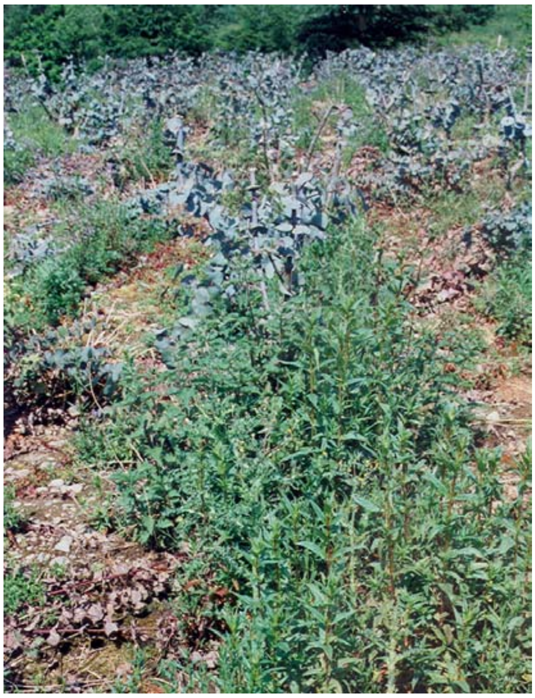
Oxyfluorfen was applied to a single plot of *E. pulverulenta* following pruning on 3rd March 1998. The herbicide was applied at a rate of 2.5 l/ha over *Eucalyptus* plants that had recently been pruned to a 1.2 m framework. This practice encourages regeneration from lignotubers (swelling composed of meristematic tissue capable of producing new buds) which is essential for species grown for cut foliage (Whelton, 2000). No movement in bud development was noted until late March. This observational trial was set up in response to a query from workers within the foliage industry to investigate if application of oxfluorfen would affect regeneration when applied after pruning.

Results from this trial indicated no adverse effect on regrowth of *Eucalyptus* shoots. Oxyfluorfen was noted as being effective in controlling growth of a range of weed species for a period of 3.5 months following treatment. The efficacy of Willowherb control was notes as being particularly good. This control efficacy is indicated in Plate 15.

Plate 15: Efficacy of Oxyfluorfen on *E. pulverulenta*

Early March Treatment After Pruning

No treatment –Willowherb Problem



4.3.6 Natural Weed Exclusion by Moss Species

During the course of the herbicide trials undertaken, the natural development of beneficial moss species was observed in established *Eucalyptus* crops. These moss species establish along cultivation ridges on sites where specific management and cultural regimes have been applied. These management operations undertaken which encourage the growth of moss species includes yearly pruning of *Eucalyptus* and ‘gentle’ herbicides applied to control weeds. Pruning of the *Eucalyptus* plants back to a stool or sparse framework between 60 and 120 cm in February/March period is routinely carried out. Weed control consisted of an overall application of Gesatop 50 WP (simazine 50% w/w) with a tractor-mounted sprayer. This would routinely be followed up with selective spot treatment of perennial weeds during the growing season using a knapsack sprayer with Roundup (glyphosate at 360g/litre a.i.) at a rate of 3 l/ha. The development of species such as *Polytrichum piliferum* and *Polytrichum commune* were observed forming a barrier or layer above the soil surface that excludes the germination of important weed species such as Willowherb (Plates 16 and 17).

Plate 16: Development of *Polytrichum* spp. in *E. pulverulenta*

The combination of these treatments appears to encourage the development of beneficial moss species in the years following establishment, particularly when the cultivation ridges settles after the first year. Based on evidence from investigation of other commercial crops, *Polytrichum* species are not affected by herbicides such as simazine. The species found to be present occur naturally and are spread by airborne spores. They tend to colonise moist acidic soils with good drainage conditions and benefit from partial shade. These conditions would be generally found within foliage crops such as Eucalyptus among other species.

Research work presented in Unisylva (1994) indicates that *Polytrichum* species have the potential to cover the ground solidly. It suggests that such species can create unfavourable conditions for crop plant growth. They can intercept and absorb precipitation and prevent water from penetrating the ground. It is also suggested that dense development of *Polytrichum* can also interfere with the passage of gasses between the soil and the atmosphere. It is clear from the above that research would be required to investigate techniques that would control *Polytrichum* development to desirable areas such as between plant rows. Such work might lead to weed control benefits from the species without compromising foliage crop growth.

Plate 17: Exclusion of Willowherb by Moss species

4.3.7 Discussion – *Eucalyptus*

4.3.7.1 Safety and Efficacy of Treatments Applied in Trials

Trials on two species of *Eucalyptus* involved testing the safety and efficacy of five different herbicide treatments on newly planted seedlings in September 1998. These treatments comprised individual herbicides such as **atrazine** and **dichlobenil,** mixtures of two herbicides (**metazachlor + simazine** and **propyzamide + simazine),** and one combination of three herbicides (**linuron + lenacil + simazine**). Herbicide application rate was not varied in any of these treatments; recommended rates were applied in all cases.

The treatments of **linuron + lenacil + simazine** and **atrazine** were found to be among the most efficient at restricting development in the case of grass and annual weeds and also for total weed cover. However, the **linuron** mixture affected seedling height in plots of both *E. perreniana* and *E moorei.* It also caused significant damage to *E. perreniana* seedlings. Due to these findings, application of the linuron-based herbicide mixtures is not recommended as part of a weed control programme for *Eucalyptus* species.

While application of **atrazine** showed promise in terms of weed control, its application resulted in significant height reductions for *E. perreniana*. Observations on the safety of the herbicide in *E. moorei* were compromised by the occurrence of apparent wind damage to plant foliage so conclusive findings could not be drawn. In earlier work, Wilkensen and Nielsen (1990) found that post-planting applications of atrazine damaging to seedlings of *E. regens* and *E. nitens,* while all pre-plant applications were found to be safe on seedlings . Recommendations for use of atrazine would have to be reserved unless further trial work confirmed its safety. Due to environmental concerns, it has emerged since the trials that general use of atrazine will be phased out completely by 2007 (Pesticide Control Service, 2004.)

Three other herbicide treatments were found to be satisfactory in terms of safety and efficacy when applied over newly planted seedlings of both *E. perreniana* and *E. moorei.* Mixtures of **metazachlor + simazine** and **propyzamide + simazine,** when applied over *Eucalyptus* seedlings post-planting in September 1998 restricted annual weed cover to below 3% of plot area up to the following March. The control efficacy of the **metazachlor + simazine** mixture was found to be significantly better further into the growing season. Similar trends were found when total weed cover figures were analysed. The use of **propyzamide** earlier than the normal window of application (November to January) may explain the breakdown of chemical at a somewhat faster pace than the metazachlor mixture (Atwood 1996). At the same time, both herbicide mixtures may have potential for weed control in *Eucalyptus* foliage crops**.** Though not concluded from this trial, the mixtures may well be safe over the range of *Eucalyptus* species cultivated in the southwest of Ireland. Further trials would be needed and may be appropriate in order to verify this in the future.

Dichlobenil was found to be the very effective at controlling both annual and perennial weeds from September 1998 up to March 1999. This would be expected due to the wide range of weeds reported to be susceptible to the chemical (Duphar, 1996). This increased efficacy appeared to diminish between March and May. It is likely this was due to a break down of the herbicide in the soil over 5 months after application, as indicated on the product label. Again this herbicide could be considered as part of a weed control programme particularly in situations where difficult perennial weeds are a challenge to growers. It appears to be useful in targeting a broad range of weed pests. However growers may find its cost prohibitive unless used on a limited scale, perhaps over one growing season.

It was apparent from an observational trial based on the application of **oxyfluorfen** to established *E. pulverulenta* (pruned back to 1.2 m in March 1998) that this herbicide was effective in controlling development of Willowherb. The latter had been a problem in the overall crop. No damage to shoot regeneration was noted in the weeks following application. While manufacturer's recommendations for **oxyfluorfen** specify contact as well as residual activity, it is likely that the safety of this application was aided by the induced short-term delay in bud development following pruning back of the species (Whelton, 2004, pers. comm.).

An interesting observation during the course of these trials was the natural development of *Polytrichum* species within commercial crops of *Eucalyptus* crops. This natural growth acts as a barrier to the development of difficult perennial weeds species. Promotion of natural processes such as the use of herbicides which don't affect *Polytrichum* species, providing conditions of good drainage and varying of the light/shade conditions in the crop may lead to development of a natural weed barried in the inter-row space. This may have a role to play in future weed control within ornamental foliage species. Research may be merited in this area

4.3.7.2 Use of Approved Herbicides and Label Specifications

Of the treatments that were examined in this trial, the herbicides **propyzamide, simazine,** and **dichlobenil** are currently approved for use on *Eucalyptus* species. These herbicides are generally recommended for use on ornamental shrubs that have been planted in their final position for at least one season. Other treatments incorporating herbicides such as **metazachlor** and **pendimethalin** were also found to be safe under trial conditions. These herbicides may be used in the future (with off-label approval).

4.3.7.3 Comparison of Treatment Costs

The current treatment system of using simazine as an overall spray with periodic spot application of glyphosate costs approximately €400 per season as detailed earlier for *Paeony Roses*. Based on the analysis of indicative costs carried out for the latter crop, the use of alternative residual herbicides or herbicide mixtures such as **pendimethalin** (€278 per season), **metazachlor + simazine** (€340 per season) and **propyzamide + simazine** (€417 per season), and are cost effective options as possible control regimes in *Eucalyptus.*These residual herbicides would be couple with a reduced dependence on glyphosate. Mixtures such as **metazachlor + isoxaben** (€535 per season) and application of **dichlobenil** (€674 per season) are more costly but are effective and safe options, based on work on these trials.

4.3.8 Conclusions: *Eucalyptus* species

Trials on selected herbicides applied on two *Eucalyptus* species indicate that a number of approved residual herbicides can be used either individually or in mixture to broaden the range of grasses and broadleaf weeds controlled. This in turn would reduce the dependence on costly spot application of systemic herbicides. These residual treatments may be considered for incorporation into weed control regimes for the crop.

Recommendations for weed control within new *Eucalyptus* crops and within *Eucalyptus* crops established for at least one season include the following:

- Apply one of the following herbicides or herbicide mixtures according to availability and the presence of particular weed types. Apply early in the season either post-planting or prior to the onset of grass and annual weed growth. Use recommended rates according to manufacturer's specifications. Rates may vary according to the brand and concentration of chemicals:
    - **Simazine**
    - **Isoxaben**
    - **Propyzamide + Simazine**
    - **Propyzamide +Isoxaben**
    - **Dichlobenil**

- A mixture of **metazachlor + simazine** may be an option for growers under off-label approval previously referred to.
- During the growing season, repeat or alternative applications of residual herbicides or mixtures may improve grass and annual weed control if required. Applications can only be considered if allowed and recommended by the manufacturers.
- Directed sprays of broad-spectrum herbicides such as **glyphosate** may be reduced with proper used of residual mixtures. Application of **dichlobenil** could be considered as an alternative.
- Application of oxyfluorfen may be applied in established crops to control Willowherb growth following a spring pruning.

4.4 The Effect of Herbicide Application on Erica veichii

4.4.1 Occurrence of Weed Species in *Erica/Hypericum* Trials

Table 32 presents the weed species that were present in the *Erica/ Hypericum* trial area and the extent of their occurrence. A total of 10 grass species, 8 annual broadleaf species and 22 perennial weed species were identified in this trial area. Many of the species found in other trials sites were present here also. Yorkshire Fog and Cocksfoot were prominent among the grass species present. The latter is described as a tufted perennial, plentiful in meadows and pastures, hills and dale, hedgerow and woodland. It is found from sea level to 350 m elevation (Uí Chonchubhair and Ó Conchuir, 1995). Foxglove, Sorrel and Adderstonge Spearworth were present as occasional perennial species.The fruit of Foxglove is an egg-shaped capsule, splitting lengthwise and producing numerous seed. Sorrel is common in meadows and open places and found up to 1000 m (Uí Chonchubhair and Ó Conchuir, 1995).

Table 32: Weed Type and Occurrence in *Erica/Hypericum* Trial area

Common Grass Species	**Latin Name (Family)**
Annual Meadow	*Poa annua* (graminae)
Narrow Leaved Meadow	Poa angustifolium (graminae)
Yorkshire Fog	Alopecurus pratensis (graminae)
Rough Meadow	Poa trivialis (graminae)
Cocksfoot	Dactylis glomerata (graminae)
Occasional Grass Species	
Couchgrass	*Elymus Repens* (graminae)
Sheeps Fescue	Festuca ovina (graminae)
False Fox Sedge	Carex otrubae (graminae)
Perennial Rye	Lolium perenne (graminae)
Red Fescue	*Festuca rubra* (graminae)
Common Annual Weeds	
Common Chickweed	*Stellaria media* (Caryophyllaceae)
Mouse Eared Chickweed	*Cerastium fontanum* (Caryophyllaceae)
Redshank	*Polygonum persicaria* (Polygonaceae)
Groundsel	*Senecio vulgaris* (Compositae)
Occasional Annual weeds	
Field Speedwell	*Veronica persica* (Scrophulariaceae)
Cleavers	*Gallium aparine (Rubiaceae)*
Scarlet Pimpernell	*Anagallis arvensis (primulaceae)*
Pineapple Weed	*Chamomilla suaveolens* (Compositae)
Common Perennial Weeds	
Creeping Buttercup	*Ranunculus repens* (Ranunculaceae)
Creeping Thistle	*Cirsium arvense* (Compositae)
Ragworth	*Senecio jacobaea* (Compositae)
Willowherb	*Epilobium parviflorum* (Onagraceae)
Wavy Bittercress	*Cardamine flexuosa* (Cruceiferae)
Bramble	*Rubus fructicosa* (Rosaceae)
Nettle	*Urtica dioica* (Urticacea)
White Clover	*Trifolium repens* (Leguminosae)
Dandelion	*Taraxacum sp.* (Compositae)
Daisy	*Bellis perennis* (Compositae)
Occasional Perennial Weeds	
Broadleaf Dock	*Rumex obtusifolius* (Polygonaceae)
Curled Dock	*Rumex crispus* (Polygonaceae)
Bramble	*Rosa canina* (Rosaceae)
Field Bindweed	*Convolvulus arvenis* (Convolvulaceae)
Adderstongue Spearworth	*Ranunculus ficaria* (Ranunculaceae)
Soft Rush	*Juncus effuses* (Juncaceae)
Foxglove	*Digitalis purpurea* (Scrophulariaceae)
Sorrell	*Rumex acet*osa (Polygonaceae)

4.4.2 Survival and *Erica* Health rating

A visual examination of plants in plots containing *Erica viechii* was carried out 6 weeks after treatment on 18th May 1998. The examination indicated that plant health had not been adversely affected by application of dichlobenil. The browning which is indicated in Plate 18 is the withering of the flowerheads rather than herbicide damage. This browning is also evident in the control plot. Plant heights were analysed to further affirm plant health for *Erica veichii*.

Plate 18: Efficacy of Dichlobenil Treatment on *Erica veichii*

Control Plot

Dichlobenil at 80 kg/ha

The herbicide **hexazinone** was applied to a single plot of *Erica veichii* at the recommended rate of 3.5 l/ha to observe its potential for controlling a reported broad range of weed species. Of particular interest was the safety of the chemical applied as an overall treatment in *Erica* crops.

Observations from this trial are indicated in Plate 19. While the herbicide provided very good weed control efficacy, it also resulted in complete mortality of *Erica veichii* plants. Thus the herbicide was deemed to be completely unsafe for used in such circumstances within heather foliage crops. No further analysis was carried out for this chemical in the context of these trials.

Plate 19: The Effect of Hexazinone on *Erica veichii*

4.4.3 The Effect of Dichlobenil on *Erica* Height Growth

The heights of *Erica veichii* plants in each of the trial plots were recorded on 2nd February 1998 prior to treatment and again on 31st June 1998, over 4 months after herbicide treatment. The recorded results were found to be normally distributed and treatments were compared using Analysis of Variance (Table 33).

Table 33: Comparing Mean Plant heights for *Erica veichii* Treatments

(February and June 1998)

Treatment	(Conc.)	Tr. No.	Mean Heights*	
			Feb	June
Dichlobenil	(low)	1	68.7 a	82.7 a
Dichlobenil	(med)	2	68.9 a	82.7 a
Dichlobenil	(high)	1	69.0 a	82.3 a
Control	-	4	69.5 a	83.6 a

* Values followed by the same letter are not significantly different at P = 0.05

Analysis of data for February indicated no significant difference in *Erica* heights in plots prior to application of **dichlobenil** treatments. Further analysis of heights taken in June, over 4 months after treatment indicated that no change from this situation. While there was a slight decrease in the plots treated with the high rate of **dichlobenil**, mean height of plants subjected to this treatment was not found to be significantly different from those of other treatments or the control.

4.4.4 The Effect of Herbicide Treatment on Weed Cover

4.4.4.1 Grasses and Annual Broadleaf Weeds in Erica Trial

Table 34 presents cover of grasses and annual broadleaf weeds as a percentage of overall plot area for *Erica veichii* plots measured on 21st July and 8th October 1998. Analysis indicates that the three **dichlobenil** treatments restricted grass and annual weed development below 1.5% up to June 1999. There was no significant difference in efficacy found between these treatments for July but all three were found to be significantly better that the control in restricting such weed categories.

Table 34: Grass and Annual Cover for Erica Treatments (July and October 1998)

Treatment	(Conc.)	Tr. No.	% Weed Cover	
			July	Oct
Dichlobenil	**(high)**	3	0.9 [a]	2.3 [a]
Dichlobenil	**(med)**	2	1.0 [a]	7.0 [a b]
Dichlobenil	**(low)**	1	1.4 [a]	10.7 [b]
Control	**-**	4	20.0 [b]	37.1 [c]

[A] Values followed by the same letter are not significantly different at P = 0.05

It is apparent from analysis of grass and annual weed cover for October that the high rate application of **dichlobenil** was more persistent and active in the soil. This treatment was found to be significantly better than the corresponding low rate treatment in restricting grass and annual weed cover under 3%.

4.4.4.2 Analysis of Total Weed Cover in Erica veichii Trials

Tables 35 presents total weed cover of as a percentage of overall plot area for *Erica veichii* herbicide treatments measured on 21st July and 8th October 1998. The Mann-Whitney test was used to determine significant differences between treatments as these data sets were not normally distributed.

Table 35: Total Weed Cover for *Erica veichii* Treatments

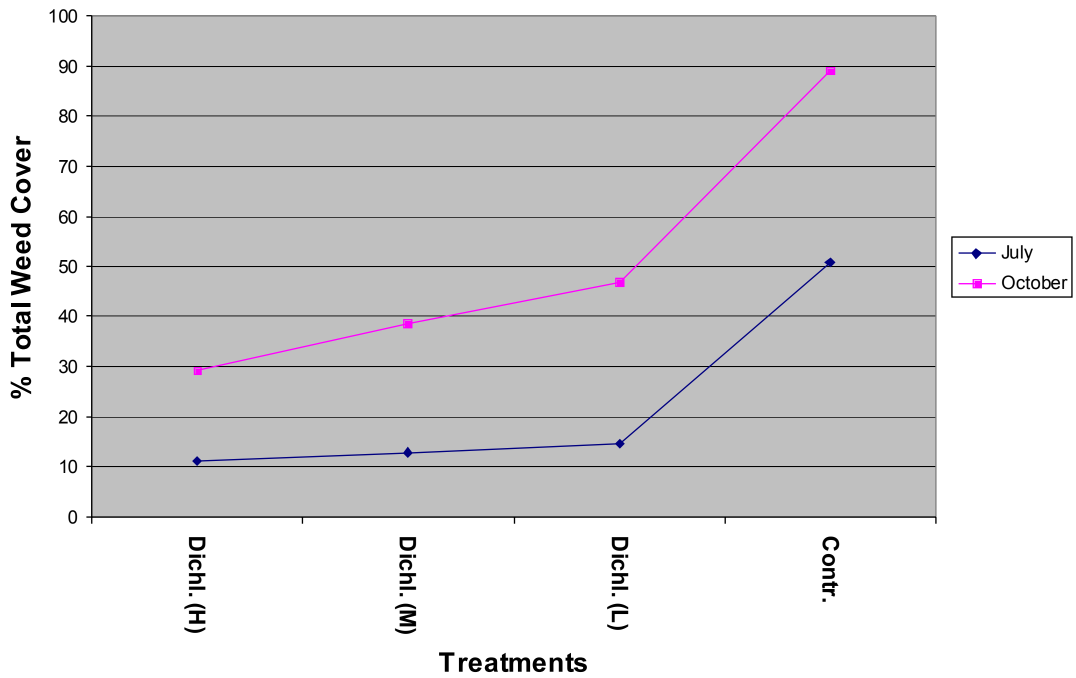
(July and October 1998)

Treatment	**(Conc.)**	**Tr. No.**	**% Weed Cover ***	
			July	**Oct**
Dichlobenil	**(high)**	3	11.0 ^{a}	29.3 ^{a}
Dichlobenil	**(med)**	2	12.7 ^{a}	38.6 ^{b}
Dichlobenil	**(low)**	1	14.5 ^{a}	46.8 ^{b}
Control	**-**	4	50.8 ^{b}	89.3 ^{c}

* Values followed by the same letter are not significantly different at P = 0.05

Non parametric analysis indicated no significant difference in total weed control efficacy between the three herbicide treatments up to July. Treatment of *Erica* plants with the high rate of **dichlobenil** was marginally the most efficient treatment. The high rate treatment was found to be significantly better than both the low and medium treatments by October, indicating possible longer residual activity at higher concentrations. All four treatments were found to be significantly better in controlling all categories of weeds than the control as would be expected. A comparison of treatments is presented graphically for July and October in Figure 15.

Figure 15: Comparison of Total Weed Cover in *Erica* Plots by Treatment



4.4.5 Comparison of Existing Control System with Dichlobenil Treatment

The weed control system used during the trials for *Erica* as well as other foliage species described previously includes an application of simazine as an overall spray with up to **two** spot applications of glyphosate per season. This system costs up to €400 per hectare for one season. In comparison, a single application of dichlobenil is has been previously costed in the *Pittosporum* trials at approximately €674 per hectare for one season. This is assuming application of dichlobenil using a motorised applicator.

If application costs over three seasons are compared, the difference between the current weed control systems (€ 1200 per hectare) and treatment with dichlobenil (€2023) is more substantial.

4.4.5 Discussion – *Erica veichii*

4.4.5.1 Safety and Efficacy of Treatments Applied in Trials

Herbicide trials were carried out to test the safety and efficacy of **dichlobenil** (4% w/w) and **hexazinone** applications and on *Erica veichii*. The trials were carried out on a 3-year-old crop of *Erica veichii* on 5th April, 1998. Three rates of dichlobenil were used in the trial: 60, 80 and 120 kg/ha respectively.

Results confirm that **hexazinone** is not safe on *Erica* species and its application resulted on total plant mortality. **Dichlobenil** was found safe to apply even at higher than recommended levels on *Erica veichii* in these trial situations on a commercial crop. Analysis of herbicide efficacy indicated that no significant difference between application rates up to July 1998. The higher rate application appeared to have a longer residual effect, being found more effective up to October of that year. In contrast to the treated plots, the control plots had almost 90% weed cover by October 1998.

Existing weed control treatments in *Erica* crops incorporated an overall application of simazine as a residual herbicide prior to the onset of weed growth to control annual weeds. A spot treatment of glyphosate at is used sporadically during the growing season. Spot treatment with glyphosate carries a risk of crop damage. This has occurred in the past due to lack of attention by operators during application, inexperience or drift of the herbicide onto the foliage even in conditions of light winds. The use of dichlobenil according to label specifications may provide a safer alternative to the above treatment. However the cost of herbicide in particular is at issue.

4.4.5.2 Use of Approved Herbicides and Label Specifications

The efficacy of dichlobenil in controlling a range of annual and perennial weeds has been shown in this trial. However, there are safety implications associated with the use of the dichlobenil on *Erica species*. Manufacturers specify a maximum rate of application of 10 g/m^2 (at 4% concentration) for sensitive species. The product label for dichlobenil does not recommended its use on Golden varieties of *Erica*. While treatment of *Erica veichii* was found safe under these trial situations growers are advised to follow the product recommendations at all times.

Despite the findings in other trials within this project, manufacturer's recommendations require that plants be established for two years prior to treatment which is particular for this chemical. There is the potential for damage through local overdosing without appropriate levels of experience and training by the operator as the product has a granular formulation. Application of dichlobenil is generally recommended in late winter or early spring, and is at its most effective when applied prior to germination of weeds and their seedlings (Duphar, 1996).

4.4.5.3 Cost of Weed Treatments

A comparison of indicative costs suggests that overall treatment with dichlobenil may be unattractive and cost prohibitive (being in excess of € 2000 over three seasons). However, due to the wide range of weeds controlled by the chemical, it may however have a role as a once off treatment in situations of problematic weed development in this type of crop.

4.4.6 Conclusions: *Erica veichii*

Trials on selected herbicides applied in plots of 3-year-old *Erica veichii* indicate that residual herbicides may be incorporated into weed control regimes for the crop. Recommendations for weed control within established *Erica veichii* crops include the following:

- Avoid the use of Hexazinone in *Erica* crops
- One of the following herbicides or mixtures may be appropriate, according to availability and the presence of particular weed types. Apply early in the season either post-planting or prior to the onset of grass and annual weed growth. Use recommended rates according to manufacturer's specifications. Rates may vary according to the brand and concentration of chemicals and are therefore not specified here:
    - **Simazine**
    - **Propyzamide + Simazine**
    - **Isoxaben**
    - **Dichlobenil (as once off or partial treatment)**
- Use of dichlobenil over a number of seasons appears cost prohibitive.
- During the growing season, repeat or alternative applications of residual herbicides or mixtures may improve grass and annual weed control if required. In general it is important to apply these products to young weeds before they become too large and established.
- Directed sprays of broad-spectrum herbicides such as **glyphosate** should only be used to clear large established weeds if required. Application of dichlobenil could be considered as an alternative and may reduce or avoid the necessity for such a treatment.

4.5 The Effects of Herbicide Application on Two *Hypericum* Cultivars

4.5.1 Survival and *Hypericum* Health Rating

4.5.1.1 Hypericum androsaemnum ' Senario'

A visual examination of plots containing *Hypericum androsaemum* 'Senario' was carried out 6 weeks after treatment on 5th June 1998. The examination indicated that plant health had been adversely affected by application of dichlobenil. This was particularly apparent on *Hypericum* plants treated with dichlobenil (dry granules) at both 80 kg and 120 kg per hectare (Plate 18), although damage was also observed at a rate of 60 kg/ha.

Damage levels were visually estimated six weeks after herbicide application based on the health rating system previously described. Table 36 presents an estimate of the proportion of plants in each health rating category for the three dichlobenil treatments in question.

Table 36: Estimate of % of 'Senario' Plants in Health Categories by Treatment

Treatment	Health Rating Category (% damage per category)					
	1 (0-5%)	**2 (6-35%)**	**3 (36-65%)**	**4 (66-95%)**	**5 (96-99%)**	6 (100%)
Dichlobenil (low)	0	61	35	4	0	**0**
Dichlobenil (mod)	0	18	53	29	0	**0**
Dichlobenil (high)	**0**	**0**	**10**	**79**	**11**	**0**

The high rate of application resulted in 79% of plants in category 4 and 11% of plants in category 5. Both of these categories represent serious and unacceptable plant damage. Over half the plants which receive the moderate rate of dichlobenil had a health rating of 3 with damage levels between 36 and 65%. A further 29 % were more seriously damaged. The majority of plants which received the low herbicide application had a health rating of either 2 or 3 which is still unacceptable.

Visual examination on 12th July 1999 indicated that some plant failures had occurred. Analysis of survival rates is presented in Table 37.

Table 37: Survival rates for 'Senario' Trials

Tr. no.	Herbicides Mixed	Herbicide Rate(s)	% Plant Survival
	Control	----	100 [a]
1	Dichlobenil	60 kg	99 [a]
2	Dichlobenil	80 kg	96 [b]
3	Dichlobenil	120 kg	92 [c]

[*] Values followed by the same letter are not significantly different at P = 0.05

This analysis indicates a significant lower survival rate for both the moderate and high dichlobenil applications. Many of the surviving plants showed symptoms of stunting, most likely as a result of observed damage to the foliage and leading shoots of this *Hypericum* variety. Analysis of heights or weed cover was not undertaken in this trial because of the extent of the damage. The herbicide treatments and in particular their timing was deemed unsuitable due to the unacceptable damage levels observed (Plate 20).

Plate 20: Comparison of Damage to *Hypericum androsaemum* ' Senario'

Dichlobenil at 120 kg/ha

Dichlobenil at 80 kg/ha

Dichlobenil at 60 kg/ha

4.5.1.2 Hypericum androacenum 'Excellent Flair'

A visual examination of all plots containing *Hypericum androsaemum* 'Excellent Flair' was carried out 12 weeks after treatment in May 1999. This examination indicated that plant health had not been affected by application of dichlobenil. Plant heights for all treatments and the control taken in June of that year were later compared which supported this observation.

4.5.2 Effects on 'Excellent Flair' Height Growth

The heights of *Hypericum androsaemum* 'Excellent Flair' plants in each of the trial plots were recorded on 10th June 1999. The recorded results were found to be normally distributed and treatments were compared using Analysis of Variance.

Table 38: Comparing 'Excellent Flair' Mean Heights for June 1999

Treatment	(Conc.)	Tr. No.	Mean Ht. June * (cm)
Dichlobenil	**(low)**	2	72.9 [a]
Dichlobenil	**(med)**	3	72.2 [a]
Control	**-**	5	72.2 [a]
Propyzamide + Simazine **	**(med)**	1	71.3 [a]
Dichlobenil	**(high)**	4	70.6 [a]

* Values followed by the same letter are not significantly different at P = 0.05

** Followed by a spot application of glyphosate to control perennial weed growth in March 1999.

Analysis of heights for June (Table 38) indicated no significant difference in **Hypericum** growth between the control treatment and the 4 treatments applied in the trials.

Plate 21: Comparison of Hypericum Treatments

Dichlobenil at 60 kg/ha | Propyzamide + Simazine followed by directed spray of Glyphosate

4.5.3 The Effect of Herbicide Treatment on ‘Excellent Flair’ Weed Cover

4.5.3.1 Grasses and Annual Broadleaf Weeds in Trial

Table 39 presents results for data on cover of grasses and annual broadleaved weeds as a percentage of overall plot area for *Hypericum androsaemum* ‘Excellent Flair’ plots measured in June 1999. Analysis indicates that the four treatments restricted grass and annual weed development below 2% up to June 1999. There was no significant difference in efficacy between these 4 treatments. However all 4 treatments were found to be significantly better that the control in restricting these weed categories.

Table 39: % Grass and Annual Cover for *Hypericum* Treatments (June, 1999)

Treatment	(Conc.)	Tr. No.	% Weed Cover *
Dichlobenil	(high)	4	0.1 [a]
Propyzamide + Simazine**	(med)	1	0.6 [a]
Dichlobenil	(med)	3	1.0 [a]
Dichlobenil	(low)	2	1.3 [a]
Control	-	5	39.5 [b]

* Values followed by the same letter are not significantly different at P = 0.05

** Followed by a spot application of glyphosate to control perennial weed growth in March 1999.

4.5.3.2 Total Weed Cover for Hypericum androacenum 'Excellent Flair'

Tables 40 presents data on total weed cover of as a percentage of overall plot area for *Hypericum androsaemum* 'Excellent Flair' herbicide treatments measured for June 1999. The Mann-Whitney test was used to determine significant differences between treatments as these data sets were not normally distributed.

Table 40: % Total Weed Cover for 'Excellent Flair' Treatments (June, 1999)

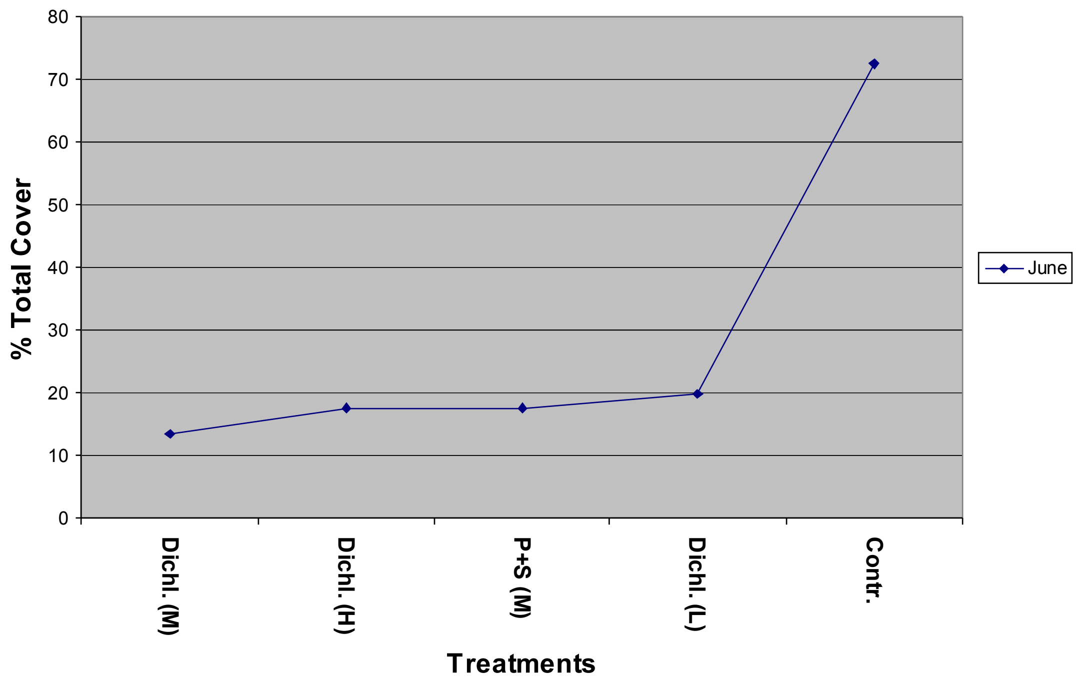
Treatment	(Conc.)	Tr. No.	% Weed Cover*
Dichlobenil	(med)	3	13.5 [a]
Dichlobenil	(high)	4	17.5 [a]
Propyzamide + Simazine	(med)	1	17.6 [a]
Dichlobenil	(low)	2	19.8 [a]
Control	-	5	72.5 [b]

* Values followed by the same letter are not significantly different at P = 0.05

Analysis indicated no significant difference in total weed control efficacy between the 4 herbicide treatments. Treatment of plants with the medium rate of **dichlobenil** was found to be the most effective treatment, maintaining slightly lower weed control than even the high rate of the same chemical.

This was due to the random occurrence of Creeping Buttercup as the main perennial weed species in plots treated with **dichlobenil** as confirmed in field plot data (Plate 21). All four treatments were found to be significantly better in controlling all categories of weeds than the control as would be expected. A comparison of treatments is shown graphically in Figure 16

Figure 16: Comparing Total Weed Cover in 'Excellent Flair' Plots by Treatment



4.5.4 Discussion – Hypericum

4.5.4.1 Safety and Efficacy of Treatments Applied in Trials

Herbicide trials were carried out to test the safety and efficacy of **dichlobenil** (4% w/w) applications and their timing on two cultivars of *Hypericum androsaemum*. The initial trial on an established crop of **'Senario'** cultivar was laid down on 25th April 1998. Three rates of dichlobenil were used in the trial: 60, 80 and 120 kg/ha respectively. Analysis of results clearly indicates that there is the potential for considerable damage when dichlobenil is applied to this cultivar at this time of the season. The plots were treated to investigate the herbicide effects during the period when a new season's growth of weeds is commencing and also when soft new shoots were extending.

As a follow up to the **'Senario'** trial, dichlobenil was applied to plots of an '**Excellent Flair'** cultivar on 10th February 1999. Treatments included the same low, moderate and high rates of dichlobenil. A further treatment consisting of a mixture of **propyzamide + simazine** at recommended rates, combined with a follow-up **directed spray of glyphosate** (on 15th April, 1999) was added to this trial. Results from the 'Excellent Flair' trials indicated no damage from dichlobenil even at the high rates of application. Visual examination of plant condition combined with analysis of plant heights in June, 1999 indicated no effect of herbicide treatments on crop plants.

Application of dichlobenil is generally recommended in late winter or early spring, and is at its most effective when applied prior to germination of weeds and their seedlings (Duphar, 1996). The fact that dichlobenil is prone to volatilisation in warm weather may partially explain why damage arose to new *Hypericum* growth in initial 'Senario' trial. The 'Senario' cultivar was also observed to be less vigorous in its general growth than 'Excellent Flair'cultivar and therefore may be more susceptible to herbicide damage.

Herbicide efficacies were examined within the 'Excellent Flair' plots in June 1999.

All three rates of **dichlobenil** applied on 10th February were shown to be very effective in controlling grass and annual weeds up to June of that year, maintaining plots virtually free of these weeds types. There was also no significant difference between these treatments and the combination of **propyzamide + simazine** combined with the directed spray of **glyphosate** (in April). In contrast to these treatments, almost 40% of the control plots were found to be covered with grass and annual weeds by June 1999.

A similar pattern emerged when data on total weed cover was analysed for June 1999. All four treatments were found to be significantly better than the control (70% covered) in maintaining total weed cover below 20% up to June of that year. The fact that the moderate rate of dichlobenil was found to be marginally better than the control is explained by the random development of Buttercup and Spearworth which are resistant to dichlobenil. Though the trial was not continued beyond June 1999 due to time constraints on this project, it is anticipated that the high rates of dichlobenil would have a longer persistence in the soil and maintain total weed cover lower for longer into the growing season as already found in the *Erica* trials.

Current weed control treatments in *Hypericum* crops are similar to those of other foliage crops described previously. Damage due to spot treatment has occurred periodically in the past, similar to experience in other crops. The addition of

propyzamide to the simazine application in this trial has been shown to be safe on the crop and is known to broaden the range of weeds controlled. Such weeds include Knotgrass, Cleavers, Broadleaved Dock and Creeping Buttercup. Increasing the level of weed control using safe residuals will invariably reduce the potential for damage by spot applications of glyphosate.

The efficacy of dichlobenil in controlling a range of annual and perennial weeds has been shown in this trial. However, there are safety implications associated with the use of the dichlobenil on *Hypericum*. Manufacturers of this herbicide advise caution when treating young broadleaf ornamentals such as *Hypericum* (Duphar, 1996). It also specifies a maximum rate of application of 10 g/m^2 (at 4% concentration) for sensitive species. There is the potential for damage through local overdosing without appropriate levels of experience and training by the operator. This trial also showed the potential for damage on at least one cultivar with application when soft new growth is forming.

4.5.4.2 Cost of Treatments

As with the *Erica* trials, use of **dichlobenil** as an overall treatment over three years may be cost prohibitive and may be more suited to limited or once-off usage where problem weeds develop in existing crops. The use of propyzamide in mixture with simazine appears to be a more cost effective treatment. However, crop safety is an important issue that cannot be costed in these terms and dichlobenil may therefore have a role in future control regimes.

4.5.5 Conclusions: *Hypericum*

Trials on selected herbicides applied in plots of 3-year-old *Hypericum* indicate that **approved** residual herbicides can be used either individually or in mixture to broaden the range of grasses and broadleaf weeds controlled. These may be incorporated into weed control regimes for the crop.

Recommendations for weed control within established *Hypericum* crops include the following:

- One of the following herbicides or mixtures may be appropriate, according to availability and the presence of particular weed types. Apply early in the season either post-planting or prior to the onset of grass and annual weed growth. Use recommended rates according to manufacturer's specifications. Rates may vary according to the brand and concentration of chemicals and are therefore not specified here:
    - **Simazine**
    - **Propyzamide + Simazine**
    - **Dichlobenil (**for limited usage**)**
- During the growing season, repeat or alternative applications of residual herbicides or mixtures may improve grass and annual weed control if required. In general it is important to apply these products to young weeds before they become too large and established. Applications can only be considered if allowed and recommended by manufacturers.
- Directed sprays of broad-spectrum herbicides such as **glyphosate** should only be used to clear large established weeds if required.

- Application of dichlobenil could be considered as an alternative with limited usage but not over a number of years due to high chemical cost.
- Volatilisation of dichlobenil can occur during the growing season, early application is vital.

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4.6 Polythene Mulch

Systems of foliage crop production are continually evolving. Since the trials in this project were carried out, recent developments include the production of some foliage crops under (UV- stabilised) polythene as a means of controlling weed development and also retaining soil moisture (Whelton, 2004, pers comm). This system is referred to as 'Strawberry Mulch' in the trade. While the use of polythene is established in general horticulture, it has not been previously adopted in cut foliage crops in Ireland. New planting sites are first prepared in the normal way by chemical treatment of vegetation, ploughing, rotavation and the use of a levelling bar. The plastic-laying machine uses shears to raise a ridge about 10 cm high prior to the polythene being placed. Seedlings of foliage species are then planted manually through the polythene. This system is illustrated in Plate 22.

Plate 22: Establishment of Foliage Crops using Polythene Mulch

Polythene mulch (Guage 50) is now being used in trial situations and in the establishment of some foliage crops (Plate 23). As this is a relatively new weed control technique, the industry is on a learning curve as to its efficacy and durability.

While trials are still ongoing it is anticipated that the polythene will withstand photo-degradation and have a persistence of 3 to 4 years (Whelton, 2004, pers. comm.). This would provide sufficient time for perennial foliage species such as *Pittosporum* or *Erica* to be well established without competition from weeds species. Polythene mulch also provides the benefit of moisture retention in the soil.

Plate 23: Polythene Mulch under Trial in a Range of Foliage Species

Estimated Cost of Polythene Mulch System

The establishment of new foliage crops using a polythene mulch has a one-off cost of **€500 per hectare** (Whelton, 2004. pers comm.). Control of weeds in between the rows of foliage plants would be required during each season either by herbicide application or mechanical mowing. The latter is costed as the equivalent of one overall application of simazine and 0.5 spot treatment equivalent of glyphosate per season (€138).

While the beneficial aspects of the mulch system are clear at this early stage in its application, possible negative environmental aspects such as dispersal of the polythene following degradation have not been fully investigated. This may also carry a 'cleanup' cost to growers in the future.

5.0 General Discussion

This study carried out in commercial crops has established that a wide range of weed species compete in foliage crops in the southwest of Ireland. A range of grass, annual and perennial weed species were found to proliferate within the trial areas. Kelly, (1997) described the variation in life cycle and growth pattern between different weed species in the southwest of Ireland and the need to vary control treatments as a result.

Couch Grass for example which was found on all trial sites is a persistent weed that is difficult to eradicate since plant fragments are capable of forming a new plant. One plant of Ragworth, another weed species common to these trials, is capable of producing fifty thousand seed (Uí Chonchubhair and Ó Conchuir, 1995). Willowherb, a further species common in trial plots, produces a mass of wind blown seed (Atwood 1996). Creeping Buttercup spreads rapidly by seed which germinate most of the year and also by means of fast-growing, rooting stolons (Uí Chonchubhair and Ó Conchuir, 1995). It is essential to prevent seeding and by implication, new generations of such weed species. Those species outlined above are mere examples of weed pests identified that pose a serious challenge to growers in a relatively new, emerging industry.

5.1 Effective Strategies

There is consensus among many authors on the most effective strategy in establishing new foliage crops. This involves the elimination of both annual and perennial weeds with a systemic herbicide prior to planting. The key to good weed control post planting is to minimize the development of new weeds and prevent their spread through seeding (Willoughby and Clay, 1996; Kelly, 1997; Robinson, 1998.). Periodic spot application with a systemic herbicide is considered essential in order to control perennial weed species and prevent their seeding. This is achieved as a directed spray by manual application with a knapsack or spot sprayer. However, subsequent growth of grasses and annual broadleaf weeds from seed can be efficiently controlled by the application of residual herbicides. These should be applied before weed emergence and repeated (if necessary) during the season.

5.2 Existing Control Regimes

The above treatments have been an integral part of weed control regimes within the Kerry Foliage Industry since it commenced in 1993. Simazine has been one of the mainstay residual herbicides, being safe to apply as an overall treatment in most crops. Glyphosate has been used for both control of vegetation on new sites and as a spot treatment during the growing season. However, both the application cost and potential for damage to soft young foliage growth with glyphosate were issues that needed to be addressed. Since the trials in this project were completed, it has emerged that the use of simazine will be illegal from 31st December 2007 as a result of European directives (Pesticide Control Service, 2004). The availability of alternatives will be necessary in the future as such chemicals are phased out. Herbicides with different modes of action could also be rotated in order to prevent the build-up of resistant weeds (Robinson, 1989).

5.3 The Use of Residual Herbicides/Mixtures

Atwood (1996) describes the benefit of mixing residual herbicides in order to broaden the range of weeds controlled and to prolong the persistence of residual herbicide activity. This in turn would reduce the frequency and/or intensity of spot applications required.

One of the focal points of this current study was the identification and testing of such residual mixtures as well as individual herbicides with the potential to safely control a broad range of weeds. The incorporation of **propyzamide** in mixture with **simazine** would control more grass, annual and perennial weeds species than would simazine on its own (Atwood, 1995). Findings from this study indicate that **propyzamide** is safe and effective in mixture over a range of foliage crops. **Isoxaben** could also be substituted for simazine in crops such as *Paeony Roses*, *Pittosporum* and *Eucalyptus*, though it is relatively expensive compared to other herbicides screened. Herbicides were found to be safe at application rates and frequencies outside those recommended by manufacturers. Herbicides were also found to be safe following application to newly planted seedlings of *E. perreniana* and *E. moorei*.

5.4 Other Herbicides with Potential in Foliage Crops.

Other herbicides outside the normal range of chemicals generally used within ornamental species were found safe and effective within these trials. **Metazachlor** and **pendimethalin** were found satisfactory in *Paeony Rose*, *Pittosporum* and *Eucalyptus* crops. **Linuron** was found to be safe for *Paeony Roses* yet quite potent to weeds. Observations were also made of the potential of specific herbicides to treat specific problems in foliage. For example **metoxuron** which is recommended for use in carrots might be applied specifically to control Fat Hen in *Paeony Roses*. The further development and application of the findings of this study will have to take into consideration the total safety of these weed control systems in an increasingly regulated industry environment. Currently these issues are subject to vigorous investigations.

5.5 Herbicides Injurious to Crops

The physical appearance of foliage stems or branchlets supplied to a discerning market is paramount so crop safety is a priority. During the course of this study a number of herbicides tested were found to be injurious to crops when treated at specific rates and at specific times during the growing season. **Napropamide** was found to cause damage to *Pittosporum* when applied to established plants in April 1998. **Atrazine** was also found to be injurious to *Pittosporum* when applied at the same time. The latter herbicide resulted in reduce height growth of *E. perreniana* and *E. moorei* following a September application to newly planted seedlings. While *Eucalyptus* plants appeared to recover from damage in subsequent years, caution would have to be recommended towards **atrazine** use. Though not known during the course of this study, it has since emerged that the herbicide is due to be phased out by 2007, following the same path as simazine due to environmental concerns (Pesticide Control Service, 2004).

Linuron was another herbicide found to be injurious to seedlings of *E. perreniana* but found to be both safe and effective when used in mixture with **simazine** in *Paeony Rose*. **Dichlobenil** has potential for safe use in *Pittosporum* and *Eucalyptus* crops but was found to be injurious to one cultivar of *Hypericum androsaemum.* Both the timing of application and the type and vigour of crop plants were found to be important considerations with this chemical. The cost of dichlobenil was found to be considerably higher than that of other treatments tested in these trials, particularly if used over a three year rotation. It can have a role as a periodic treatment where difficult weeds arise and there is danger from glyphosate application.

5.6 Suitability of Other Control Systems

With the phasing out of certain chemicals imminent in the future, the search for alternative 'green' methods of controlling weeds will be an important issue. The use of polythene mulch is a recent development in the control of weeds for foliage crops in Ireland. A comparison of indicative costs indicates that this mulch system may be more economic than solely chemical control systems over the critical three year period during crop establishment. However, this system is still at an early stage of development in foliage crop husbandry. The rate of photo-degradation of the polythene and the possability of a 'cleanup' cost following such a process is yet to be determined. Further work on mulch development and how it is best incorporated into the establishment of young crops will be beneficial to the industry (Whelton, 2004, pers. comm.). For example current practice involves manual planting through the plastic after it being laid. The development of a system which could also offer mechanical planting of seedlings is being sought.

While polythene is an option for some species, it would not be suitable for herbaceous species such as *Paeony Roses*. It also cannot be physically applied where crops are already in place. Current foliage crops in the Kerry region extend to 65 hectares in area. The use of polythene may reduce the need for chemical control within some crop in the future but the requirement to prevent the development of weeds in the strips between the polythene rows will still exist. Residual herbicides are used to control weeds in these areas.

Observations made during the course of this study reveal how the development of *Polytrichum* species and their potential to exclude the development of problematic weed species. The moss species acted as natural mulch in this respect. Further investigation into promotion of the beneficial aspects of this process within foliage crops may be merited.

5.7 Limitations of the Study

Trial work carried out for this study was generally confined to one full growing season per crop due to time limitations on the project. Crop safety was monitored using visual examination of plant condition and height recordings following treatment. Ideally the progress of these crops could be followed over two or more growing seasons and possibly further control systems applied in order to build up a database of knowledge over the establishment cycle. Trials were carried out on commercial crops in all cases apart from those in *Eucalyptus* species. In most cases, the selection of herbicides for trial had to be somewhat tempered in view of the potential for damage in these commercial situations. The safety of herbicide use is probably best reflected in trial work on newly planted seedlings/tubers. This was not possible with all species and trials had to be restricted to established crops in the case of *Erica*, *Hypericum* and *Pittosporum* species. It was not possible either to fully explore the effect of timing of application on the safety and efficacy of crops due to limited trial areas and time limitations on the project. Perhaps there is further scope for work in this area for the future.

5.8 Challenge for Growers

The growing of foliage crops in the Kerry area is a relatively new enterprise that presents many challenges for growers. Control of weeds in young and established foliage crops is in itself one, if not the most challenging areas within the industry. Continued research and development of new control systems is essential. Market demand for new foliage species brings the requirement for expertise in their cultivation. This will bring further challenges for growers in the future. Research projects such as this will hopefully add to grower's knowledge and may be applied, refined and extended to new species as they come on stream.

5.9 General Conclusions

The study conducted investigated the range of weed pests that vigorously compete with selected cut foliage species in the Kerry region. It examined existing practice and focused on the development of weed control regimes for a number of important species within the foliage industry. It is anticipated that this will enhance the knowledge of growers and managers in controlling weed pests within some of the main foliage species. Conclusions on control regimes developed for individual foliage species have already been presented.

The following conclusions have been drawn based on the findings of this study:

- A wide range of grass, annual and perennial weeds compete with foliage crops.
- Existing control practice is dependent on the use of simazine early in the season to control annual weeds and the periodic use of spot applications of glyphosate to control difficult perennial weeds. Crop safety was sometimes at risk from the latter treatment
- Selected residual herbicides can broaden the range of weeds controlled by simazine without risk to the foliage crops.
- Selected residual herbicides can reduce the need for systemic spot applications
- Residuals such as **propyzamide** and **simazine** are suitable across a number of foliage species.
- Some treatments such as dichlobenil and isoxaben are safe but relatively expensive to use over a number of growing seasons.

- Other residuals herbicides such as **linuron**, **metazachlor** and **pendimethalin** have considerable potential on cultivated ornamental species.
- Significant differences were found between herbicides and herbicide mixtures available to growers. Significant differences were found in efficacy between herbicide concentrations. The more efficient herbicides and herbicide combinations can be applied as effective weed control options for growers of foliage crops.
- Some residual chemicals tested were unsuitable and injurious to foliage plants
- Alternative control systems such as the use of polythene mulch are still under trial but may be an economic alternative with new crops for certain species.

The results of this project have been communicated to growers and managers of cut foliage crops. Herbicides found safe and efficient such as propyzamide have been incorporated into weed control regimes since trials were completed. It is anticipated that finding from this study will enhance the knowledge of growers and managers in controlling weed pests within some of the main foliage crops. The development of new foliage species will also require continued evolution and refinement of control systems in future years.

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Appendices

Appendix 1

Details of Principal Soil Association No 15

Principal Soil — Association 15: Brown Podzolic

Topography:	Rolling
Slope:	8°
Altitude:	76 m O.D.
Drainage:	Well drained
Parent material:	Glacial drift composed of a mixture of sandstone, shaly sandstone and shale.

Horizon	*Depth (cm)*	*Description*
A11	0-14	Gravelly loam; brown (10 YR 4/3); moderate fine granular; friable; abundant roots; arbitrary boundary to:
A12	14-29	Similar to A11.
A13	29-64	Similar to A11 but contains more gravel; plentiful roots; clear wavy boundary.
B2	64-86	Loam; yellowish red (5 YR 5/6); weak fine granular; very friable; sparse roots; gradual tonguing boundary to:
C	Below 86	Gravelly loam; light olive brown (2.5 YR 5/4) moist slightly firm in situ; no roots.

Analytical data

Hor.	Coarse sand %	Fine sand %	Silt %	Clay %	pH	CEC meq/100g	C%	N%	C/N	Free iron %
A11	28	23	35	14	5.5	19.0	3.3	0.32	10.3	1.7
A12	27	24	34	15	5.5	11.6	2.9	0.20	14.5	2.0
A13	27	21	37	15	5.4	12.0	2.2	0.16	—	2.1
B2	22	22	46	10	6.0	15.6	1.0	0.07	—	3.5
C	22	24	41	13	6.3	5.4	0.3	0.04	—	1.4

Appendix 2

Details of Principal Soil Association No. 34

Principal Soil — Association 34: Grey Brown Podzolic

Topography:	Gently undulating
Slope:	4°
Altitude:	122 m O.D.
Vegetation:	Old pasture *(Lolia-Cynosuretum,* typical Sub-ass., *Centaureo-Cynosuretum,* typical Sub-ass. or *Cent.-Cyn.,* Sub. ass. of *Galium verum)*
Drainage:	Well drained
Parent material:	Glacial drift predominantly of limestone composition but with a small proportion of sandstone, shale and volcanics; of Midlandian age.

Horizon	*Depth (cm)*	*Description*
A11	0-20	Gravelly loam; brown to dark-brown (7.5 YR 4/4); moderate, medium crumb structure; friable; abundant rooting; clear, smooth boundary to:
A12	20-37	Gravelly loam; brown to dark-brown (7.5 YR 4/4); moderate, medium crumb structure; friable; plentiful rooting; gradual, smooth boundary to:
B21	37-57	Gravelly loam; brown to dark-brown (7.5 YR 4/4); weak, medium sub-angular blocky structure; friable; plentiful rooting; clear, smooth boundary to:
B2t	57-100	Gravelly clay loam; brown to dark-brown (10 YR 4/3); weak, coarse sub-angular blocky structure; clay coatings on some ped faces and along vertical cracks; wet sticky; few, fine roots.
C	Below 100	Gravelly loam, white (10 YR 8/2) with streaks of yellowish brown (10 YR 6/4) massive friable, no roots, calcareous.

Analytical data

Horizon	Coarse sand %	Fine sand %	Silt %	Clay %	pH	CEC meq/100g	TEB meq/100g	Base sat. %	C%	N%	C/N	Free iron %
A11	23	23	33	21	5.5	15.5	10.0	65	3.1	0.34	9.1	1.8
A12	22	25	35	18	5.7	10.6	7.0	66	1.3	0.15	8.7	1.9
B21	20	22	33	25	6.6	12.9	—	Sat.	0.8	0.13	—	1.8
B2t	18	20	33	29	7.3	10.0	—	Sat.	0.2	0.08	—	2.1

Appendix 3: Progression of Weed Development (cm ^{2}) in a *Paeony* Plot (6.3 m^2)

following <u>repeated moderate applications</u> with Propyzamide + Simazine

	April	May	June	July	Aug	Sept	Oct
Annual Grasses							
Annual Meadow						42	200
Sub-Total	0	0	0	0	0	42	200
Perennial Grasses							
Cocksfoot							
Couchgrass			20	182	450	1025	2915
False Fox Sedge							
Meadow Foxtail							
Meadow Oat							
Narrow Leaved Meadow				24	104	280	1530
Rough Meadow							
Red Fescue							
Sheeps Fescue						25	145
Sub-Total	0	0	20	206	554	1330	4590
Annuals							
Chickweed							
Cleaver							
Common Mouse-ear							
Speedwell							
Fat Hen				28	243	615	702
Prickly Sowthistle						128	2784
Sub-Total	0	0	0	28	243	743	3486
Perennials							
Broadleaf Dock							
Burdock							
White clover							60
Creeping Buttercup			14	60	106	300	1420
Creeping Thistle				45	312	750	2570
Curled Dock							
Daisy							
Dandelion							
Dog Rose							
Field Bindweed					215	440	660
Lesser Celandine							
Groundsel						100	140
Nettle							40
Ragworth			20	76	185	365	1010
Soft Rush							180
Sorrell							
Adderstongue Spearworth							
Wavy Bittercress							
Wild Turnip					49	188	215
Willowherb					23	145	1480
Sub-Total	0	0	33	179	890	2279	7775
Grand Total	0	0	53	413	1685	4394	16051

Appendix 4: Progression of Weed Development (cm ²) in a *Paeony* Plot (6.3 m²)

following single <u>high rate of application</u> with Propyzamide + Simazine

	April	May	June	July	Aug	Sept	Oct
Annual Grasses							
Annual Meadow					51	153	287
SubTotal	0	0	0	0	51	153	287
Perennial Grasses							
Cocksfoot							
Couchgrass							
False Fox Sedge					127	349	859
Meadow Foxtail				127	394	734	1962
Meadow Oat							
Narrow Leaved Meadow				234	936	2053	3521
Rough Meadow							
Red Fescue							
Sheeps Fescue					98	267	436
Sub Total	0	0	0	361	1555	3403	6778
Annuals							
Chickweed							
Cleaver							
Common Mouse-ear							
Speedwell						278	312
Fat Hen							
Prickly Sowthistle					156	984	2165
Sub Total	0	0	0	0	156	1262	2477
Perennials							
Broadleaf Dock							
Burdock							
White clover							
Creeping Buttercup					638	2507	4724
Creeping Thistle				239	746	1197	2695
Curled Dock							
Daisy						74	156
Dandelion							
Dog Rose							
Field Bindweed					103	261	348
Lesser Celandine							
Groundsel					37	115	247
Nettle							
Ragworth				148	278	639	974
Soft Rush							
Sorrell							
Adderstongue Spearworth							
Wavy Bittercress							
Wild Turnip							
Willowherb					33	261	576
Sub Total	0	0	0	387	1835	5054	9720
Grand Total	0	0	0	748	3597	9872	19262

Appendix 5: Progression of Weed Development (cm ²) in a *Paeony* Plot following

repeated moderate applications with Linuron + Lenacil + Simazine

	April	May	June	July	Aug	Sept	Oct
Annual Grasses							
Annual Meadow							
Sub Total	0	0	0	0	0	0	0
Perennial Grasses							
Cocksfoot						27	159
Couchgrass							
False Fox Sedge			62	121	264	420	708
Meadow Foxtail							
Meadow Oat							
Narrow Leaved Meadow						41	250
Rough Meadow							
Red Fescue							
Sheeps Fescue							
Sub Total	0	0	62	121	264	488	1117
Annuals							
Chickweed							
Cleaver							
Common Mouse-ear			13	49	147	201	296
Speedwell							
Fat Hen			7	29	43	154	172
Prickly Sowthistle					978	4351	6189
Sub Total	0	0	20	78	1168	4706	6657
Perennials							
Broadleaf Dock							
Burdock							
White clover							90
Creeping Buttercup			58	73	117	164	650
Creeping Thistle			19	379	748	2100	3264
Curled Dock							
Daisy							
Dandelion							
Dog Rose							
Field Bindweed							
Lesser Celandine							
Groundsel							
Nettle							48
Ragworth						37	135
Soft Rush							
Sorrell							
Adderstongue Spearworth							
Wavy Bittercress							
Wild Turnip							
Willowherb						87	901
Sub Total	0	0	77	452	865	2388	5088
Grand Total	0	0	159	651	2297	7582	12862

Appendix 6: Progression of Weed Development (cm ²) in a *Paeony* Plot following a single <u>high rate of application</u> with Linuron + Lenacil + Simazine

	April	May	June	July	Aug	Sept	Oct
Annual Grasses							
Annual Meadow							
Sub Total	0	0	0	0	0	0	0
Perennial Grasses							
Cocksfoot				38	372	1648	3132
Couchgrass							
False Fox Sedge					125	397	607
Meadow Foxtail				27	264	594	1250
Meadow Oat							
Narrow Leaved Meadow			42	96	394	935	4294
Rough Meadow							
Red Fescue							
Sheeps Fescue						22	90
Sub Total	0	0	42	161	1155	3596	9373
Annuals							
Chickweed							
Cleaver							
Common Mouse-ear						36	104
Speedwell							
Fat Hen							
Prickly Sowthistle			43	167	321	788	2240
Sub Total	0	0	43	167	321	824	2344
Perennials							
Broadleaf Dock							
Burdock							
White clover					25	92	150
Creeping Buttercup				79	548	1897	4858
Creeping Thistle		31	161	342	976	1725	4010
Curled Dock							
Daisy							
Dandelion					126	228	432
Dog Rose							
Field Bindweed							
Lesser Celandine							
Groundsel							
Nettle					135	417	702
Ragworth							
Soft Rush							
Sorrell							
Adderstongue Spearworth							
Wavy Bittercress							
Wild Turnip							
Willowherb						33	126
Sub Total	0	31	161	421	1810	4392	10278
Grand Total	0	31	246	749	3286	8812	21995

Appendix 7: Progression of Weed Development (cm ²) in a *Paeony* Plot following single high rate of application with Linuron + Lenacil + Simazine

	April	May	June	July	Aug	Sept	Oct
Annual Grasses							
Annual Meadow						80	255
Sub Total	0	0	0	0	0	80	255
Perennial Grasses							
Cocksfoot							
Couchgrass							
False Fox Sedge							
Meadow Foxtail		21	298	363	412	489	979
Meadow Oat							
Narrow Leaved Meadow			164	249	301	332	2376
Rough Meadow						216	713
Red Fescue							
Sheeps Fescue							25
Sub Total	0	21	462	612	713	1037	4093
Annuals							
Chickweed							
Cleaver							
Common Mouse-ear			7	116	341	756	1558
Speedwell							146
Fat Hen							
Prickly Sowthistle					39	247	1903
Sub Total	0	0	7	116	380	1003	3607
Perennials							
Broadleaf Dock							
Burdock							
White clover			7	125	358	395	472
Creeping Buttercup			52	319	783	922	3569
Creeping Thistle			64	174	299	615	1897
Curled Dock							
Daisy							
Dandelion							
Dog Rose							
Field Bindweed							
Lesser Celandine							
Groundsel						13	85
Nettle						36	95
Ragworth			70	313	1438	2295	3902
Soft Rush							
Sorrell							
Adderstongue Spearworth							
Wavy Bittercress							
Wild Turnip							233
Willowherb						79	576
Sub Total	0	0	193	931	2878	4355	10829
Grand Total	0	21	662	1659	3971	6475	18784

Appendix 8: Calibration of Knapsack Sprayer (Robinson, 1997)

The amount of herbicide delivered by a knapsack sprayer depends on the nozzle size, operating pressure the walking speed of the operator. The output from the sprayer is altered if changes are made to the nozzle size, spraying pressure or walking speed. Calibration can be carried out as follows:

- Put 5 litres of water into a sprayer (without herbicide) and spray on a dry level surface at a normal walking pace and pressure until the sprayer is empty. A pressure control valve on the sprayer will facilitate constant pressure.
- The area of surface covered by 5 litres of water is measured in square metres (call this area 'A').
- Find out from the label, the dose of herbicide to be used in millilitres to (ml). Call the application dose 'B'.
- The amount of herbicide in ml to be added to 5 litres of water to treat 'A' square metres is 'A' multiplied by 'B' divided by 10,000 ie.

$$\frac{A \times B}{10{,}000}$$

- (10,000 m^2 in one hectare)