The effect of timing and pruning regimes on the yield and quality of *Ozothamnus hookeri* 'Sussex Silver' for the cut foliage trade

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DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Master of Science is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work. I authorise Waterford Institute of Technology to lend or photocopy this thesis in whole or part to other institutions or individuals for the purposes of scholarly research.

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LIST OF ABBREVIATIONS

EU	European Union
UK	United Kingdom
ECE	European Commission for Europe
STS	Silver thiosulfate
1-MCP	1-methylcycpropene

CONTENTS

1. ABSTRACT

Ozothamnus spp. are globally important plants in the cut foliage industry. Highly regarded for its grey foliage, *Ozothamnus hookeri* 'Sussex Silver' is grown commercially in Ireland for domestic and European markets. Much is known about *Ozothamnus* spp. yield potential in Australian climates. However more research is required to fully understand the potential of this cut foliage crop when grown in Ireland's temperate climate. This study investigates the effects of pruning timings and regimes on the stem and spray yield of *Ozothamnus hookeri* 'Sussex Silver' on young and mature plantations grown in the South East of Ireland. The effect of tip-pruning on the type of stems produced, and the impact of rejuvenation pruning on a mature *O.hookeri* 'Sussex Silver' plantation were also examined. *Ozothamnus hookeri* 'Sussex Silver' plants were pruned in March or June using three pruning regimes: 'hard pruning' to 200 mm, 'light pruning' to 500 mm, or tip-pruning which involved removal of the top 5cm of each stem. Yields of saleable stems and sprays were calculated for each plant and results indicated that higher yields of saleable single stems and sprays are obtained when *O. hookeri* 'Sussex Silver' was pruned in March rather than in June, regardless of whether it was pruned to 200 mm or 500 mm. Upon comparing younger and mature *O. hookeri* 'Sussex Silver' plantations, it was found that the younger plantation produced almost twice as many saleable stems as the mature plantation showing that the age of *O. hookeri* 'Sussex Silver' plants may impact yield. Interestingly, tip pruning did not consistently produce more sprays than single stems and rejuvenation pruning did not produce any harvestable stems in the subsequent year. These results suggest that *O. hookeri* 'Sussex Silver' is a commercially viable product, which could be grown successfully in Ireland; however, growers need to be aware that a managed pruning regime on younger plantations is required to obtain maximum yield from this cut foliage plant.

2. INTRODUCTION

Cut foliage is vegetation used as a singular source of decoration in an arrangement and also in association with flowers in bouquets (Whelton, 2013a; Forrest, 1991).

There are presently over 20 growers of cut foliage in Ireland covering an area of approximately 200 hectares located mainly in Kerry and Wexford and smaller units of production in Dublin, Wicklow, Meath and Waterford (O'Mahony, 2011). The main cultivated species grown are *Eucalyptus* spp., *Pittosporum* spp., *Prunus* spp., *Viburnum* spp., *Brachyglottis* spp., and *Rosmarinus* spp. (Whelton, 2013a). There are over 25 hectares of *Ozothamnus hookeri* 'Sussex Silver' grown in Ireland, primarily in Wexford. According to O'Mahony (2011) new species will have to be introduced on a regular basis to meet growing demand for Irish cut foliage and Teagasc and Bord Bia are currently trialing many of these new to Ireland, cut foliage crops (Whelton, 2013a).

Plants from the *Ozothamnus* genus are grown in Ireland and sold as cut foliage crops for the Irish market and for export. Anecdotal evidence from Irish growers suggests that pruning can affect the length of extension growth produced by plants from which foliage material can be harvested each year; previous research on other cut foliage crops supports these observations. At present, there is no known research which investigates the effect of pruning regimes or plantation age on the yield of *O. hookeri* 'Sussex Silver' in Ireland; thus, this study seeks to contribute to fill that gap in knowledge.

Specifically, the aim of this research, conducted between 2011 and 2014, was to develop a pruning regime which is suitable for the Irish climate for *Ozothamnus hookeri* 'Sussex Silver' by examining the effects of varying pruning timings and regimes on yield of stems and sprays. The

effect of tip-pruning in August on the type of stems produced and the impact of rejuvenation pruning on an existing mature *Ozothamnus hookeri* ‘Sussex Silver’ plantation were also investigated.

3. LITERATURE REVIEW

Floriculture is the cultivation and marketing of flowering, foliage, and bedding plants (Bord Bia, 2003). In 2006, the world floriculture market was worth US$60 billion with production growing at a rate of 8-19% per year (Anon, 2006).

Cut foliage is a term used to describe 'plant material of tropical and temperate origin to create design structure and to cover the base of containers and oasis in flower arrangements, floral tributes and bouquets' (Forrest, 2002). Cut foliage used in this way can be harvested from a wide variety of trees, shrubs and herbaceous perennials.

Europe is one of the largest consumers of cut foliage in the world and since the 1970s, many cut foliage genera, such as *Eucalyptus* and *Pittosporum* have been grown in Ireland (Whelton, 2013d). Costello (2007) reports that the European Union (EU) market for cut flowers and foliage was worth €12 billion; 8-10% of which accounts for foliage.

The market for cut flowers and ornamental foliage has increased in the last decade due to an increase in consumption of cut flowers (Bord Bia, 2003) but also because of the introduction of new species of foliage (O'Mahony, 2011). According to Jim Costello there is a demand for high quality, Irish grown foliage in Europe; since 2001, the purchase of fresh cut flowers and wreaths in Ireland has increased by 9% (Bord Bia, 2010). However, according to Bord Bia (2010) the incidence of buying fresh flowers in Ireland has declined from 16% in 2005, to 13% in 2009 showing that the market can be variable. Costello (2007) states that Ireland has a reputation for producing quality green foliage and 'naturalness' is an increasing requirement in the foliage sector. This trend for natural products has resulted in a greater demand for foliage, especially of wild and woodland species such as *Ilex* (Whelton, 2006). Consumers and florists are also seeking

new and unusual foliage, such as *Melicytus* and *Correa* some of which cannot be grown successfully in other countries (Anon, 2006). Cut foliage is a useful winter crop when other crops are not being harvested and also provides employment at that time of the year (Stamps, 1999; Josiah *et al.*, 2004).

Ozothamnus spp. are grown and sold in Ireland as cut foliage crops, including species such as *O. rosmarinifolius*, and *O. hookeri*. This study was undertaken as there is no known research available to Irish growers which examine the effects of pruning regimes on the yield of *O. hookeri* 'Sussex Silver'. Research carried out in other countries, such as in Australia, have been used as guidance into site preparation and planting densities of *O. hookeri*. Recommendations by Beal *et al.* (2001) which examined pruning techniques, and harvesting procedures elucidated by Greer and Dole (2009) were taken into account when designing this study. The pruning lengths selected for use in this study for *O. hookeri* 'Sussex Silver' were selected following consultation with Cut Foliage Adviser Andy Whelton (Teagasc) who through experience found that these pruning treatments had a positive effect on yield. Grading of harvested stems was carried out *in situ* using criteria set out by The Economic Commission for Europe (Table 3.4) so that only stems of sufficient quality were classified as 'saleable stems'.

3.1. **Cut flower and foliage production in Ireland**

Cut foliage is grown and processed commercially in the south of Ireland, including Limerick, Waterford and Wexford with additional production in Dublin (Bord Bia, 2003).

According to personal conversations with Andy Whelton (Teagasc) there are presently over 20 growers of cut foliage in Ireland covering an area of approximately 200 hectares with over 25 hectares of *Ozothamnus hookeri* 'Sussex Silver'. In recent times, the cut foliage industry has employed the equivalent of 40 full-time, and 100 part-time labour units, with nearly 200 hectares of cut foliage grown mainly in Kerry and Wexford (O'Mahony, 2011). To date, cut foliage has been grown mainly by agricultural enterprises as opposed to growers being specialist producers where 2-3 ha can provide maintenance, harvesting and processing work for one person working full-time (Costello *et al.*, 2007).

The demand for cut foliage is not a new phenomenon and research into the cut foliage industry has been carried out in Ireland since the late 1960s (Gilsenan, 1969; An Foras Taluntais, 1971). Research on the hardiness of *Eucalyptus* and its potential for use in the industry has been carried out in the 1970s at Teagasc's Kinsealy Research Centre. According to conversations with Jim Costello of Forest Produce Ltd, *Eucalyptus* foliage has been produced commercially in Ireland since the early 1990s. In addition, trials were carried out by Forrest (2002) in University College Dublin to develop a cropping programme for *Eucalyptus* and *Pittosporum.*

3.2. **Reasons for growing cut foliage in Ireland**

The cut foliage industry is growing at a rate of 10% per annum (O'Mahony, 2011) and there are many reasons for developing the cut foliage industry in Ireland. For instance, Ireland's proximity to the European market is a major advantage to cut foliage production. In addition, climatic

conditions in the south of Ireland give growers an advantage over growers in Northern Europe as Ireland's temperate climate allows the growth of many plants that are not hardy therefore are not suitable to grow in colder regions of Europe (Robinson, 1996). In addition, Irish crops do not need irrigation or shading and this potentially cuts down on the initial capital investment required to establish a cut foliage crop.

3.3. **Barriers to growing cut foliage in Ireland**

There are some barriers to growing and marketing cut foliage from Ireland. For example, producers in Ireland have intense international competition from other growers of cut foliage such as from Italy, North and South America, Israel, and Sri Lanka (O'Mahony, 2011). Specialised horticultural skills in growing and harvesting cut foliage are also required. According to Whelton (2006) there is limited return on investment for three years but this can vary with the crop grown. For example, *Ozothamnus* can be harvested after two years. Another barrier to production of cut foliage is that land must be committed to the cut foliage crop for 4-10+ years depending on the species (Bord Bia, 2003). For example, *Eucalyptus* can continue to be cropped for 12-15 years.

3.4. **Cut foliage and Irish climate**

Ireland's climate is generally suitable for growing many genera of cut foliage plants (Robinson, 1996) as typically, Ireland does not have extremes of temperature experienced by other countries at similar latitude. Normally, Ireland's mild winter allows for harvesting to take place from autumn to the end of spring (Murphy *et al.,* 1999). However despite Ireland's temperate climate, sites for foliage production must be chosen carefully. For example, locations in the south and south-west of Ireland are suitable for growing a range of tender and exotic plants whereas

successful growth of those plants is less likely in the northern half of the country; the favorable climatic conditions in the south, and south-west (mild, wet, winter temperatures averaging 4 - 7 °C, and summers averaging 14 - 17 °C) and high humidity all year round suit a whole range of exotic, naturalised and wild flora (Keane, 1992).

However, the very low temperatures of 2010 (minimum low of -12 °C) and 2011 proved an exception to this generally mild weather pattern. Foliage ready for market can be damaged by winter frosts with some tender species such as *Eucalyptus* and *Pittosporum* susceptible to lethal damage, as witnessed in many areas of Ireland following the winter of 2010.

Many crops that have potential for production in Ireland are tender, frost-susceptible species even if recent cold winters have been very destructive to some existing cut foliage plantations; of the 200 ha of cut foliage established in the past 8 years over half has been killed following the severe weather events in early and late 2010. According to Whelton (Teagasc), this represents losses of approximately 8 million stems worth over €2 million in export sales (personal correspondence). For example a plantation of *Ozothamnus* 'Silver Jubilee' was killed at Kilmore Quay, Co. Wexford in 2010. This crop of *Ozothamnus* has been replaced by the hardier *Ozothamnus* 'Sussex Silver'. If recent low winter temperatures reoccur then site location and species selection will need to be re-examined.

3.5. **Suppliers of cut foliage and cut flowers**

There are many suppliers of cut foliage worldwide. As seen in Table 3.1, the principal suppliers of cut flowers and foliage are the Netherlands who provide 50% of the total global production of cut foliage and flowers, followed by the United States of America, Latin America, Africa and

Asia (Parker, 2011b). Collectively, the members of the EU are the largest market in the world for cut flowers and foliage (Parker, 2011b; Parker, 2011c).

Table 3.1: World suppliers of exported cut flowers and foliage: 2011 (Parker, 2011b).

Exporters	Rank	Value (000US$)	% of World	Cumulative %
Netherlands	1	3,649,537	50.32	50.32
Colombia	2	858,701	11.84	62.16
Ecuador	3	405,120	5.59	67.75
Kenya	4	387,959	5.35	73.10
Israel	5	191,538	2.64	75.74
Italy	6	177,679	2.45	78.19
United States	7	147,646	2.04	80.22
Costa Rica	8	125,174	1.73	81.95
China	9	92,809	1.28	83.23
Canada	10	85,828	1.18	84.41
South Africa	17	50,993	0.70	91.02
Australia	28	23,507	0.32	96.67
South Korea	29	22,812	0.31	96.98
Other	36	124,351	1.71	100.00
Total		**7,252,594**	**100.00**	**100.00**

3.5.1. European Union (EU)

The EU uses over 50% of the world's production of cut flowers and foliage. As seen in Table 3.2, there is an especially strong demand in Germany, the Netherlands, the United Kingdom (UK), Switzerland, Italy and France (Gollnow, 2002). However, according to the Flower Council of Holland (Lim-Camacho, 2006), in recent years there is a trend consistent with decreasing demand in Switzerland, Germany, France and the United States but an increasing demand for

flowers and foliage in the UK and Ireland. Germany is still one of the biggest and most influential buyers of cut foliage and cut flowers in the EU, with the UK the second largest importer of flower products (Gollnow, 2002). In 2009, the value of the cut flower industry in the UK was more than £2 billion (Plasmeijer and Yanai, 2009).

Table 3.2: Target markets for imported cut flowers and foliage: 2011 (Parker, 2011b).

Target Market	Rank	Value (000US$)	% of World	Cumulative%
Germany	1	1,235,615	17.04	17.04
United States	2	1,135,853	15.66	32.70
United Kingdom	3	1,109,489	15.30	48.00
Netherlands	4	826,976	11.40	59.40
France	5	618,040	8.52	67.92
Japan	6	305,095	4.21	72.13
Italy	7	255,661	3.53	75.65
Switzerland	8	214,372	2.96	78.61
Belgium	9	204,938	2.83	81.43
Russia	10	199,880	2.76	84.19
Ireland	18	52,580	0.72	94.75
Australia	35	9,024	0.12	98.97
Other	36	74,591	1.03	100.00
Total		**7,252,594**	**100.00**	**100.00**

In Europe there are two main markets for Irish cut foliage; the floristry market and wholesale companies who sell on pre-packed bunches of flowers to supermarkets and other retail outlets (Forrest, 2002). The cut foliage sector in Europe is worth €1.1 billion. In 2009, €289 million worth of cut foliage was exported from Europe and €389 million was imported (O'Mahony, 2011).

The main suppliers of cut foliage originate in Italy, France, Israel, North and South America, and Sri Lanka. The Netherlands are the leading importer of cut flower and foliage and serves as a

gateway to the EU market (DIPP, 2009). Total imports to the Netherlands increased from €77.35 million to €87.53 million between 2004-2008 (DIPP, 2009); with exports valued at approximately €1.8 billion or almost 55% of the world market (ESSD, 2004). This decreased to 50% of the world market in 2011 (Parker, 2011b). While Europe is a large producer of cut foliage and flowers, it is also one of the biggest floriculture importers, including from non-European countries (Laws, 2005).

3.5.2. Australia

In Australia production of cut flowers and foliage is part of the agricultural sector, mainly in the temperate regions of Victoria, New South Wales, Queensland and Tasmania. The main products supplied include traditional flowers and foliage (72%), tropical flowers (22%), tropical foliage (4%), native flowers (2%) (Arthy and Bransgrove, 2003). In 2002, approximately 90% of the flowers and foliage produced in Australia was for the domestic market (Gollnow, 2002). In 2006-2007, exports of Australian cut flowers and foliage were valued at €9.5 million, with imports valued at €8.7 million (Shannon, 2009). In 2009 approximately 5.6% of flowers and foliage was exported (Shannon, 2009). The gross value of cut flowers and foliage in the State of Queensland alone is valued at €50 million for 2009-2010 (Anon, 2011). Japan is Australia's main market, followed by USA and The Netherlands (Parker, 2011c), while Australia's main competitors of cut flowers and foliage are Israel, USA, South Africa and South America (Gollnow, 2002). Some of the main cut foliage crops grown in Australia include *Ozothamnus diosmifolius* (Riceflower), *Anigozanthos* spp. (*Kangaroo Paw*), *Ceratopetalum gummiferum* (Christmas Bush) and *Protea* spp. (Parker. 2011), while the main cut flowers grown are *Rosa* spp. (roses), *Gerbera* spp., *Dianthus* (carnations) and *Dendranthemum* spp. (chrysanthemums) (Shannon, 2009). *Ozothamnus* species are grown in Ireland for their foliage, whereas,

Ozothamnus spp. are grown in Australia for their flowers where they are sold as filler plants, mainly into the Japanese and United States market (Ellis, 2007).

3.6. **Current quality standards in the cut foliage industry**

To maximize profits, the grower of cut foliage requires plants that are fast growing and produce numerous stems each year. Stems can be manipulated through pruning, including pollarding and coppicing techniques and should preferably have a long stem, ranging from 0.6-3m (Greer and Dole, 2009). The florist requires material that is easy to use and available when needed. Long vase-life is very important and this can be improved by good production habits, and floral preservatives (Gast, 1997). In general species suitable for cut foliage should combine good ornamental value with the ability to retain flowers, foliage and/or fruit characteristics well.

3.6.1. *Ozothamnus* as a global cut foliage crop

Ozothamnus is a genus of plants found in Australia, New Zealand and New Caledonia and a member of the Asteraceae family. This genus includes evergreen shrubs or perennials, with small, slightly aromatic, linear leaves and tiny white flower heads, which may be solitary, or in showy terminal corymbs (Ellis, 2007). There are over 56 species in the *Ozothamnus* genus including many used in the cut foliage industry, such as *O. rosmarinifolius, O. diosmifolius, O. ledifolius, O. hookeri* and *O. rosmarinifolius*. Forty-eight of these species are grown in Australia where they are grown for their flowers as well as the foliage (Irons, 2009). *Ozothamnus* has many common names including Rice Flower, White Dogwood, Pill Flower and Sago Bush (Gollnow *et al*, 2010). *Ozothamnus*, *Cassinia* and *Helichrysum* are closely related genera with some confusion over their taxonomy, although *Ozothamnus* is now regarded as a genus in its own right (Schilling, 2005; Irons, 2009).

Due to their hardiness and long vase life, two varieties of *Ozothamnus* are used in cut foliage production in Ireland: *O. rosmarinifolius* ‘Silver Jubilee’ and *O. hookeri* ‘Sussex Silver’.

Ozothamnus rosmarinifolius 'Silver Jubilee' (Figure 3.1) is a small, upright evergreen shrub with narrow, silvery-grey leaves and compact clusters of crimson buds opening into small, scented white flower heads in summer. In Ireland it is fast growing and can grow up to 3m high (Irons, 2009), doing best in a south or west facing aspect and tolerates well drained soils (Fletcher, 1996). *Ozothamnus rosmarinifolius* will tolerate soil that is waterlogged in winter and can withstand short periods of flooding in summer (Irons, 2009). *Ozothamnus rosmarinifolius* is not hardy (McIndoe, 2005; Schilling, 2005) but can survive temperatures as low as -5˚C (Anon, 2012).

Figure 3.1: *Ozothamnus rosmarinifolius* ‘Silver Jubilee’

Ozothamnus hookeri ‘Sussex Silver’ (Figure 3.2) is a fast growing, evergreen shrub with cord-like white stems and silvery leaves. In Ireland a small white flower is produced in summer. *Ozothamnus hookeri* likes well-draining, moderately fertile soil and requires little water in full sun. It can grow up to 2 m high and 2 m wide in 3 years and is hardy and easily propagated (Schilling, 2005). *Ozothamnus hookeri* is hardier in poorer soils and its hardiness is one of the

main reasons it has become the preferred cut foliage crop over *O. rosmarinifolius* 'Silver Jubilee' in the cut foliage trade in Ireland (Anon, 2001).

Figure 3.2: *Ozothamnus hookeri* 'Sussex Silver'

Ozothamnus diosmifolius (Figure 3.3) (commonly known as Riceflower) is widely grown in Australia as a cultivated plant. It is less hardy in Ireland and England and grown only in the mildest parts of Britain (Irons, 2009). *Ozothamnus diosmifolius* is an upright shrub, which can grow to 2-5 m in height, and its unique selling point is its flowers, which can be white or pink. *Ozothamnus diosmifolius* is grown in a wide range of climates and soil types in Australia, with rainfall ranging from <1000mm to >2000mm per annum but higher growth rates were observed in warmer climates (Ellis, 2007). Mature *O. diosmifolius* can tolerate minimum temperatures of -2˚C up to a maximum of 30˚C although they perform poorer in lower temperatures (Evan, 1999). *O. diosmifolius* prefers an acidic soil, with a pH between 5.0 and 6.0 (Ellis, 2007). The main harvest period in Australia is September and October with smaller quantities cut in August, November and December (Beal and Turnbull, 1998). The flowering season for *O. diosmifolius* in Australia is from September to January but it can be influenced by variety, age of the plants and

location (Beal *et al*, 2001). Environmental factors such as short days and low temperatures can also affect timing of flowering (Beal *et al*, 2001; Harevy *et al*, 2001). The absence of cool winters can result in poor flowering in *O. diosmifolius* and other species such as *O. rosmarinifolius* (Beal and Turnbull, 1998).

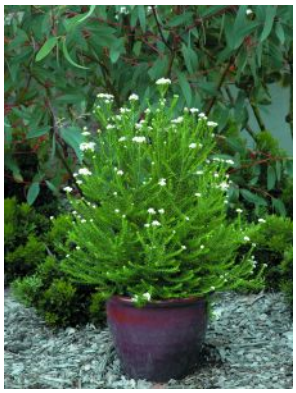

Figure 3.3: *Ozothamnus diosmifolius*

3.6.2. *Ozothamnus* propagation

Ozothamnus can be raised from cuttings with planting out taking place in late spring or early summer which gives the plant roots time to establish before winter (Stevens, 1998). However the success of this *Ozothamnus* propagation method depends on the species in use (Slater and Allen, 1994; Beal *et al.,* 1996) and some trials have shown that stem cuttings of *Ozothamnus* can produce roots within 5-8 weeks (Beal *et al.,* 1996). The influence of planting density on the success of *Ozothamnus* can be variable but generally, *Ozothamnus* planting density is from 2250-5000 plants per hectare but depends on the species in use (Beal *et al*. 1996). For example, trials carried out in Australia using *Ozothamnus* had planting densities of 3333-5000 plants per hectare (Fletcher, 1996) and results of that study recommended planting on mounded sites, approximately 2m wide, with 4m between rows and an intra-row spacing varying from 0.5 to 1.0 m but exact spacing depended on plant species (Beal, and Turnbull, 1998). Further trials by

Cynthia Carson at Redlands Research Facility, Australia tested high density planting of *O. diosmifolius* (8000 plants per hectare) and found that this higher density plant regime encouraged upright growth of long stems and gave a higher yield per hectare in the first years of production (personal correspondence). According to personal email correspondence with Carson, plantations of *O.diosmifolius* were destroyed and the same species replanted after 5 years. This differs to plantations of *Ozothamnus* spp. in Ireland, which are grown and harvested for 10-12 years. Beds were raised 10-15 cm to help with drainage and were narrow enough to allow for weeding and harvesting of the crop. Steven (1998) recommended that row widths should allow for growth and also be compatible with spraying or mulch laying equipment. Carson's work at Redlands Research Centre is comparable with existing plantations of *O. hookeri 'Sussex Silver'* in Ireland, which are planted 1 m apart with 1.2 m between rows (Whelton, 2013b), which equates to a density of 8,333 plants per hectare. This suggests that establishment of plantations in Ireland were based on the establishment of plantations in Australia; therefore extension growth rate may be comparable.

3.6.3. Weed, pest and disease control

Weeds can compete with woody plants for water, light and nutrients therefore the site must be cleared of perennial weeds prior to planting and the establishment of an annual weed control programme is essential. A systemic herbicide will move throughout a plant after being applied to the leaf surfaces; soil acting residual herbicides will kill the weed seedling before or after it emerges (Adams *et al.,* 1999*).* Systemic herbicides can clear the site initially and the use of further weed control measures, such as the use of residual herbicides will be necessary for the first few years after planting. According to personal correspondence with Andy Whelton (Teagasc), Flexidor® (12.1% isoxaben) in combination with Butisan (43.1% w/w metazachlor) or

Stomp® Aqua (455g/l pendimethalin) has been observed to work well in plantations already grown in Ireland. A follow-up treatment of residual herbicides, such as Flexidor or Kerb (500 g/l propyzamide), may be required in the following spring (Whelton, 2006). Some weeds are resistant to these chemicals and so further use of systemic or contact herbicides (such as Glysophate (360g/l glysophate) and Basta (18.0% glufosinate ammonium) may be required. A common bed preparation system in use is comprised of a raised bed covered with plastic mulch, which controls weeds and reduces water loss through evaporation (Stevens, 1998). A typical American production system uses evenly spaced plants in rows with strips of grass between the rows; the grass strip is generally 1.2-1.5 m wide but can depend on the machinery used to mow the lawn (Greer and Dole, 2009). Anecdotal evidence from existing Irish growers of cut foliage suggests that black horticultural plastic as a mulch has been used with varying degrees of success in Ireland as the plastic can easily be damaged allowing weeds to grow in its place.

The most common diseases that affect *Ozothamnus* in Australia include *Phytophthora* rot, wood rot, and root-knot nematodes. Diseases and pests such as these have resulted in plant losses of up to 20 % per year (Fletcher, 1996). Severity of pest and disease can depend on the site location and plant species (Beal *et al.*, 1996). According to Beal *et al.* (2001), pest and disease monitoring along with strategic spraying can help reduce losses especially when used in conjunction with weekly inspections up until harvesting. There is no treatment for *Phytophthora* however; improved drainage by planting on raised beds can help reduce development of *Phytophthora* diseases (Greenwood, 1997). Wood rots and nematodes can also be prevented by planting in well-drained soils and by buying healthy plant stock. In most cases, Australian plantations of *O. diosmifolius* are generally destroyed after 5 years, thus reducing any ongoing problems with such diseases (Beal *et al.*, 2001). As *Ozothamnus* is not widely grown as a cut foliage crop in Europe,

there is currently no recorded evidence of pest and disease damage to this cut foliage species in European production sites.

3.6.4. Pruning

While there is some research on pruning *Eucalytpus* and *Pittosporum* for cut foliage production (Wirthensohn and Sedgley 1996; Murphy *et al.*, 1999; Forrest, 2002), little research has been carried out on *Ozothamnus*. Correct pruning is essential to maintain the juvenile foliage of *Eucalyptus* used for cut foliage (Preece and Read, 1993; Wirthensohn and Sedgley 1996) however this type of pruning for juvenile foliage is not required for *Ozothamnus*. Research by Josiah *et al.* (2004) on pruning of a variety of woody crops in Nebraska showed some shrubs responded well to cutting to ground level each winter but this depended on the species. For example, severe pruning of *Eucalyptus* can result in plant losses of up to 30% and pruning in the first growing season is not recommended as this allows the plant to increase biomass and carbohydrate reserves thus being more resistant when hard pruned (Murphy *et al.*, 1999).

Successful pruning requires a good knowledge of species habit and response to pruning (Adams *et al.*, 1999) as poor pruning can reduce the number, length or quality of stems (Greer and Dole, 2009). There are many reasons for pruning but in the commercial production of cut foliage, pruning is used to remove unproductive wood, to control the size of shrubs, and to encourage new growth. The aim of pruning *O. hookeri* 'Sussex Silver', or other cut foliage plants with similar growth habit to *Ozothamnus*, is to reduce congestion and encourage the production of longer and more numerous stems which have a higher sale value (Greer and Dole, 2009).

The evidence for pruning effect on *Ozothamnus* is contradictory; it has been shown that *Ozothamnus* grown for ornamental purposes requires little pruning even if it can tolerate hard

pruning (Brickell, 1996). However other studies suggest that *O. rosmarinifolius* needs to be pruned heavily from an early age as plants become leggy and may need replacing after 3 years (Irons, 2009). Many shrubs that are pruned hard respond by producing stems that are vigorous, long and straight (Greer and Dole, 2009), which are desirable characteristics to the cut foliage grower. Pruning can also allow for better light penetration and air circulation which can result in a stronger, healthier plant (Preece and Read, 1993). Pruning of *O. diosmifolius* is carried out at the time of harvesting (Beal *et al.*, 2001), which, in Australia, occurs when flowers are present but not open. *Ozothamnus hookeri* does not require flowers when harvesting so pruning could potentially take place before or after flowering. Again, this must be established for each species as pruning shrubs before flowering can result in the loss of flowers from what would have been saleable stems (Brickell, 1996).

Pruning can also impact on plant productivity; the removal of shoots by pruning reduces the overall leaf surface area of the plant and so, could significantly reduce the photosynthetic capability of the plant leading to poorer plant growth (Montagu *et al*. 2002). For example, Preece and Read (1993) recommend the removal of no more than one-third of the growth each year as additional loss of plant tissue can weaken the plant. Pruning does, however, stimulate improved utilisation of carbohydrates and, consequently, promotes vegetative growth (Fraser, 1966). In general, the harder the pruning the more vigorous the regrowth will be; but this can depend on the plant species (Brickell, 1996; Ingram *et al.*, 2002). Designing a pruning regime for cut foliage crops requires an understanding of the influence of plant growth regulators on apical and lateral growth (Ingram *et al.*, 2002); according to Cline (2006) the main growing shoot of a plant can inhibit the growth of shoots below it. The plant growth regulator, auxin, is synthesized in the apical meristems and is subsequently released and transported down the main stem where it

inhibits lateral buds growth. Therefore, the primary growing point of an unpruned stem is at the top or apical meristem and removal of the stem tip where the apical meristem is located decreases endogenous auxin levels, allowing the lateral meristems to grow to produce side branches and hence a bushier stem (Ingram *et al.,* 2002). Auxins, along with the hormone gibberellin, also control stem extension growth (Adam *et al.,* 1999). Therefore, pruning methods directly influence numbers and length of stems produced for harvesting (Greer and Dole, 2009).

In Australia treatment of *Ozothamnus* is different as it is a plant grown for a short time whereas in Ireland they are grown and harvested for 10-12 years (Whelton, 2013b). In Australia, the process of harvesting *O. diosmifolius* is conveniently used as a pruning method; the crop is harvested, and therefore pruned, by selecting and removing individual mature stems or by cutting back the whole plant where individual saleable stems are choosen from harvested biomass after the harvesting process is complete. In this situation, varieties were selected for uniform harvest maturity on all branches, so that significant losses did not occur during grading. In young plants, lateral branches close to the ground were removed to reduce the spread of fungal diseases (Beal *et al.,* 2001). Some lower branches were retained on the plant to feed the weakened root system until the plant regrew. According to personal email correspondence with Cynthia Carson of the Redlands Research Centre in Australia these lower branches were subsequently removed and discarded if not of saleable quality. Although plants can live for 10 years or more, Carson acknowledged that *O. diosmifolius* is treated as a 'short turn around' crop since plants are replaced after 5 years. Hard pruning, especially in the second and third year of plant growth, can cause greater plant stress and poor regrowth (Beal *et al.*, 2001). Beal *et al.* (2001) suggest that cutting into previous years wood of *O. diosmifolius* should also be avoided because of poor regrowth. Older, overgrown shrubs can respond to renewal pruning but the plants response to

this type of hard pruning depends on the species of plant and its condition and age (Carpenter and Dana, 2001). There is very little research on the effects the age of the cut foliage plantation have on the plants' ability to produce regrowth following rejuvenation pruning. Rejuvenation pruning is carried out to control the size of the shrub and encourage new growth (MacDonald, 1999).

Removal of the top section of new growth using a thumb and forefinger is called 'pinching out'. According to Carson of the Redlands Research Centre, Australia, when planted, young plants of *O. diosmifolius* are pinched out to encourage auxillary branching (personal correspondence). Timing of flowering in young plants can be delayed by 1-2 weeks and this can result in harvesting (and therefore pruning), being delayed as it takes more time for the plant to produce new growth which will hold the new flower buds. Site location and species in use can also affect the timing of the pruning (Beal *et al.*, 2001). Pruning regimes of *Ozothamnus* in Australia is well understood while at present there is no formal pruning regime for *Ozothamnus* grown in Ireland and the only action which could be termed 'pruning' is the removal of stems when harvesting.

3.7. **Harvest of cut foliage**

Postharvest handling involves both harvesting and handling of the product so that it can be brought from the field to the consumer in a way that preserves the foliage or flower at optimum quality. When, how, and where foliage is to be harvested depends on the crop in use and the location of the market (Faragher *et al.* 2002).

It is important for the producer to know the crop growth characteristics as each plant species has its own optimum harvest stage and plant material will stay fresh for longer if harvested at the correct stage of development (Nowak and Rudnicki, 1990). In general, the best time of the day to

harvest is the coolest part of the day when there is no surface water from dew or rain on the plants (Gast, 1997). Harvesting should be avoided during the hottest hours of the day (11 – 3pm) as plants will lose large amounts of water (Greer and Dole, 2009). In addition, cutting stems at temperatures above 25˚C should be avoided as leaf blackening can occur when stems are subsequently placed in cold storage (Faragher *et al.*, 2002).

Seasonal timing of harvesting varies depending on the genus at hand but factors such as flowering time, dormancy of the plants and customer demands can influence when plants are cut (Greer and Dole, 2009).

In Europe, quality standards dictate that stems must be cut to scale shown in Table 3.3.

Table 3.3: Economic Commission for Europe Stem Length Scale of cut foliage (Economic Commission for Europe, 1994).

Code Number	Length (cm)
5	5-10
10	10-15
15	15-20
20	20-30
30	30-40
40	40-50
50	50-60
60	60-80
80	80-100
100	100-120
120	>120

The length of stem cut depends on the crop species but most cut foliage grown in Ireland is harvested when stems have achieved a length of at least 45-60 cm (Costello, 2011). Stems can be cut at an angle or straight across (Faragher *et al.*, 2002) but must have a clean cut to prevent crushing of the xylem which would block the flow of water up the stem (Gast, 1997). Flowers or foliage with high sap content require treatment immediately after harvesting to prevent sap blocking the xylem; Gast (1997) recommends that such stems are dipped in boiling water for 10 seconds immediately after harvest. Foliage in Ireland is pruned by hand using secateurs and this is followed by a grading procedure, which is carried out, on site before being transported to the storage shed. According to personal correspondence with Whelton (Teagasc) an experienced harvester can cut up to 2000 stems in one day.

In Ireland and Australia harvesting of *Ozothamnus* stems occurs between September and May but timing depends on variety, location and plant age (Beal *et al.*, 2001). Harvesting of *O. diosmifolius* starts when 50% of the flower buds have reached full size (match-head size) but have not broken open at the top. If timing is incorrect and the stems are picked too early, the flower head will wilt (Halevy *et al.*, 2000). If the stems mature together mechanical pruners can be used to give a 'once-over' prune. If stems mature slowly, individual stems can be cut when mature and so grading can be done on site (Faragher *et al.*, 2002). The importance of optimising harvesting to complement flowering timing does not apply to the harvesting of *O. hookeri* in Ireland as retention of flowers is not desirable for this species. Stems of *O. hookeri 'Sussex* Silver' are harvested in lengths of 45-60 cm from September to May, bunched into groups of ten and then their cut stems are stood in water until packed and transported (Whelton, 2006). The term 'handling' constitutes the remaining tasks that are required to prepare the crop for the market. If proper care is not taken after the plant has been harvested, it can lead to wilting of the

crop, bruising, accumulation of ethylene, and fluctuations in temperature during storage all of which can contribute to a reduction in product quality (Faragher *et al.*, 2002). However, cold storage, consistent use of floral preservatives, careful handling and good sanitation practices solve many of these issues (Gast, 1997).

3.7.1. Handling of cut foliage

Handling foliage after harvesting requires foliage to be graded, bunched, hydrated, packed and cold stored before delivery to market. Some of these tasks are performed in the field and some are carried out in the packing shed. In Ireland, all grading is generally done in the field. Bundles are then transported to the storage shed and held in cold storage (4˚C) until they are placed onto Danish trolleys for shipping to their destination. In Australia, grading and bunching can be done in the field or in the packing shed and stems are either placed in water, or handled dry, and air cooled once they reach storage (Faragher *et al.*, 2002).

Stems are cut and placed in water, or harvest solution, which, depending on the plant material in use, could be acidified (pH 3.5) tepid water, citric acid or floral preservative (Gast, 1997). Care is taken not to bruise plant material and full containers are then placed in a cool place or refrigerated. *Ozothamnus diosmifolius* requires rapid cooling which can reduce leaf blackening (Faragher *et al.*, 2002).

3.7.2. Grading of cut foliage

Grading usually involves sorting flowers or foliage according to the specific requirements laid down by the buyer. While the grading the quality of flowers in international trade is evaluated on the basis of shape, colour, freshness, stem length and general health, standards for cut foliage apply to leaves, branches with or without fruit and other ornamental parts. The general

requirements regarding freshness and uniformity are similar to those for cut flowers (Greer and Dole, 2009). Europe and Australia have set officially recognized standards while others countries, such as America, have not set standards (Armitage, 2003). Grading can be based on stem length, stem thickness, freedom from defects or pests or diseases (Armitage, 2003; Faragher *et al.*, 2009). Most foliage in America is not graded (Armitage, 2003) due to such diverse market outlets; compliance with grading is voluntary. For example, in Florida standards for over 40 cut flowers are compiled in the publication 'Cut flower minimum guidelines and standards' (Gonzalez, 2009) but these standards are incomplete and do not include foliage plants such as *Ozothamnus* (Gollnow, 2010). In contrast to the situation in the rest of the world, in the US, the grower decides on grading.

Australian-grown *O. diosmifolius* is sold as five stems in a bunch or by weight and stems are usually 50 cm or longer (Faragher *et al.*, 2002). Standards for *Ozothamnus* are set out in the 'Australian standards for fresh cut flowers: as adapted by the Flower Export Council of Australia' (Beal *et al.*, 2001). This document states that all foliage at the top of stems should be fresh, clean and green. The stem must be strong, straight and derived from current season's wood. The plant must also be true to type, of uniform colour with a consistent stem diameter of ± 10 %. In Australia, lower stem leaves of *O. diosmifolius* may need to be stripped, especially if they are to be stored in water, often resulting in the removal of 25% to 50% of the leaves (Faragher *et al.*, 2002). Only stems that are ready to go to market are harvested. Proper evaluation and grading of foliage is essential as this is what determines the price a grower receives from the wholesaler (Nowak and Rudnicki, 1990).

As shown in Table 3.4, European grading standards for both cut flowers and foliage are set by the United Nations Economic Commission for Europe (ECE) (Economic Commission for

Europe, 1994). Most flowers and foliage sold in Western Europe are distributed through auctions located in the Netherlands.

Table 3.4: The Economic Commission for Europe classification of flowers and foliage (Economic Commission for Europe, 1994).

Classes	Requirement for Flowers
Extra Class	Flowers of best quality, free from extraneous matter, properly developed, with strong, rigid stems, fully characteristic of a given species or cultivar. 3% of flowers with slight faults allowed.
First Class	Requirements as above but with good quality of flowers and stem rigidity. 5% of flowers with slight faults allowed.
Second Class	Flowers not accepted in higher classes but satisfying minimal requirements and useful for decoration. 10% of flowers with slight faults allowed.

Current regulations devised by Economic Commission for Europe (1994) states that bundles must consist of 5, 10, 15, or multiples of 10, stems. The ECE standard for cut foliage also allows for quality and size tolerances of ±10 %.

The product should be able to withstand transport and handling and arrive at its destination in satisfactory condition (ECE, 1994). In Ireland, foliage is graded based on stem strength and stem length. Bunching also needs to be carried out to meet customer requirements. A standard number of flowers or foliage per bunch is determined; the minimum is usually 10 per bunch but this can depend on the plant material (Gast, 1997). Differences in longevity of cultivars of cut flowers or foliage can depend on stem diameter, stem rigidity, plant anatomy and physiology but varies

from plant to plant; Armitage (2003) states that longevity starts with the choice of cultivar to be grown but also depends on postharvest handling techniques.

3.7.3. Post-harvest treatment of cut foliage

Although it was not in the scope of this study it is useful to explore the treatment of cut foliage after harvesting. Postharvest treatment can take a variety of forms but is important as plant life can be extended depending on the treatment used. For example, the life of plant material can be extended by 3-4 times if stored at 0 - 10 °C (Greer and Dole, 2009). Cooling can reduce aging and water loss (Faragher *et al.* 2002). Forced air-cooling can be used. This involves the blowing of air through perforated storage boxes using a fan to cool foliage to a temperature of around 4°C (Armitage, 2003). The low temperature slows down the rate of respiration of the plant thus enhancing their shelf-life (Gast, 1997). Most cut stems harvested in Ireland are stored at 4˚C (Costello, 2011), which is similar to storage temperatures used in other countries; Nowak and Rudnicki (1990) recommend temperatures between 2˚C and 4˚C and Faragher *et al.,* (2002) recommend cooling *O. diosmifolius* to 2˚C and 4˚C within three hours of harvest.

3.7.4. Ethylene

Postharvest longevity of some plant species can be shortened by exposure to ethylene (Macnish, 2000). Ethylene is a naturally occurring plant growth regulator, which triggers ripening of plant material; it can cause flowers to drop prematurely and is produced by diseased or decaying organisms or when plants are wounded (Pollock and Griffiths, 2005). To avoid the effects of ethylene build-up, flowers and foliage should be stored in cool, well-ventilated areas away from aging flowers or ripening fruit (Armitage, 2003). Some plant species are more sensitive to the

effects of ethylene than others with *O. diosmifolius* having a slight sensitivity; especially from the ethylene the plant produces naturally (Faragher *et al.*, 2002).

Protection from the effects of ethylene can be achieved by preventing the pollination of flowers, protecting plants from pest and diseases, harvesting at the optimum time, and preventing injury to plant material. Flowers or foliage should also be kept cool as soon as possible after harvesting. There are many chemicals available to help inhibit the effects of ethylene, the most common being silver thiosulfate (STS) (Armitage, 2003) and 1-methylcycpropene (1-MCP) (Faragher *et al.*, 2002).

3.7.5. Vase life

Unpublished work from Dr. Sarka Spinarova of the Geisenheim Research Centre Department of Ornamental Crops in Germany, states that vase life of cut foliage is affected by water uptake, the carbohydrate reserves of the plant material, and exposure to, and production of ethylene. Plants with higher carbohydrate reserves will have a longer vaselife; therefore when growing, plants should be well fertilised and exposed to adequate sunlight to ensure an adequate reservoir of stored carbohydrate. However, finding a balance between fertilisier application and sun exposure to ensure adequate carbohydrate, is difficult. Spinarova noted that having plants growing in full sun is probably more crucial than using high fertilisers whereas Stamp (1985) noted that growing plants in full sun can adversely affect vase life of some species; studies carried out by Stamp (1985) found that *Pittosporum* stems produced under 70% shade had a longer vase life than those produced under 50% shade. These contrasting research results show that postharvest care varies between species and therefore must be optimised experimentally for each species of cut foliage. In addition to shade problems, the effect of drought on plants such as *Ozothamnus* can cause leaf

drop and wilting before harvesting (Faragher *et al.*, 2002). Harvesting at the optimum time, the storage procedures followed, and postharvest hydration also have important impacts on foliage vase life (Jones, 2001).

Rehydration of cut foliage material may be essential, depending on the crop harvested and the conditions under which they are harvested and stored. According to conversations with Jim Costello of Forest Produce, freshly harvested material is generally placed immediately in water to restore turgidity, although it is noted by Faragher *et al.* (2002) that the impact of this technique can be limited as some crops are handled dry until they reach the packing shed. Rehydration can be achieved by using a hydrating solution which is generally made up of water and citric acid (Faragher *et al.*, 2002), or a floral preservative, which can often contain a germicide, sugar, hydrating solutions and a wedding agent with a pH of approximately 3.5 (Gast,1997; Greer and Dole, 2009). Germicides are used to control bacteria and mould, which can produce ethylene (Gast, 1997) while sugar is a carbohydrate source for the plant (Greer and Dole, 2009). Spinarova of the Geisenheim Research Centre Department of Ornamental Crops in Germany noted that sugars can reduce the uptake of water and that, once hydrated, sugars could be added after a few hours (personal correspondence). This finding was backed up by studies carried out by Withensohn and Sedgley (1996) using *Eucalyptus*; it was found that using too high sugar concentrations damaged *Eucalyptus* foliage, causing browning of the foliage.

Foliage stems are often 'pulsed' to extend their shelf life. Pulsing is the temporary immersion in a higher temperature solution. Pulsing solutions contain sugars, such as sucrose or glucose, silver compounds such as Silver Thiosulphate (STS) and a germicide. According to Gast (1997), 2% sucrose is the standard amount in preservatives. To treat or pulse foliage, stems are placed in solution for 20 minutes at 65˚C (Gast, 1997), although Greer and Dole (2009) suggest anywhere

between a few seconds to eight hours. There are commercial preservatives available such as Floralife, Fleur Ami, Florissant, RVB and Vitabric, which are available in America and Europe (Costello, 2011; Greer and Dole, 2009). Nowak and Rudnicki (1990) also recommend the use of ethylene inhibitors such as Aminoethoxyvinyl glycine, Methoxyvinyl glycine and Aminoacetic acid to increase vaselife. Kerr (2007) recommended the use of Chrysal RVB Clear on *Eucalyptus* and then storage of the stems at 3˚C.

While there is little research on the vase life of *O. hookeri* 'Sussex Silver', studies in Australia have shown that *O. diosmifolius* has a long vase life of 10 days when held in 0% or 2% sucrose solution with 50ppm chlorine (Beal *et al.*, 1996).

Ozothamnus spp. are grown and sold in Ireland as cut foliage crops. This study was undertaken as there is no known research available to Irish growers which examines the effects of pruning regimes on the yield of *O. hookeri* 'Sussex Silver'. Research carried out in other countries, such as in Australia, have been used as guidance into site preparation and planting densities of *O. hookeri*. Recommendations by Beal *et al.* (2001), who examined pruning techniques, and harvesting procedures elucidated by Greer and Dole (2009) were taken into account when designing this study. The pruning lengths selected for use in this study for *O. hookeri* 'Sussex Silver' were selected following consultation with Cut Foliage Adviser Andy Whelton (Teagasc) who, through experience, found that these pruning treatments had a positive effect on yield. Grading of harvested stems was carried out *in situ* using criteria set out by The Economic Commission for Europe (Table 3.4) so that only stems of sufficient quality were classified as 'saleable stems'.

4. METHODOLOGY

4.1. **Introduction**

The aim of this research conducted between 2011 and 2014 was to develop a pruning regime suitable in the Irish climate for *Ozothamnus hookeri* 'Sussex Silver' by examining the effects of different pruning times and types on the yield of cut foliage. Rejuvenation pruning of an existing mature *O. hookeri 'Sussex Silver'* plantation was also examined. To achieve these aims, three different pruning regimes (200mm, 500mm and pruning of the tips) were carried out at three different times of the year (March, June and August). Three different sites in Ireland were used for this study. In addition to establish if pruning in consecutive years is beneficial, the pruning treatments were repeated on half of the plants on one of the sites (Site 1) the following year.

4.2. **Establishment of the sites in Kildalton College and Kilmore Quay**

Field trials were established in plantations at three sites in the South East of Ireland. The three sites used in the study had *O. hookeri 'Sussex Silver'* plantations of varying ages, ranging from newly planted, to a plantation that was 4 years old up to a plantation which was 9 years old at the start of this study. The sites for growing *Ozothamnus* were chosen because they all get full sun throughout the day, are free from frost pockets, and the soil is free draining.

4.2.1. Site 1 – Kildalton College, Co. Kilkenny.

Site 1 was located at Kildalton College, Piltown, Co. Kilkenny (Ordnance Survey grid reference 52°21'16"N, 7°19'42"W). On Site 1, the impact of pruning on a newly established *O. hookeri* 'Sussex Silver' plantation was examined. Prior to planting this cut foliage crop, this particular

location in Kildalton was used for growing vegetables. The Kildalton College plantation was southerly in aspect and was gently sloping with a grey-brown podzolic soil (Collins and Verling, 1976). Shelter was provided on all sides by an *Alnus sp.* tree shelterbelt. Soil tests were carried out on the site before planting in early 2011. Soil sampling was carried out using a soil corer to a depth of 100mm, using recommended industry standard (Schoeneberger *et al.*, 2012). The soil samples were analysed off site at Teagasc Johnstown Castle, Co. Wexford. The results showed an average pH of 6.93 and as shown in Whelton (2013b), this was deemed to be an appropriate pH for growing *Ozothamnus*. The phosphorous and potassium content was tested and was found to be at acceptable levels of 9.23 mg l^{-1} and 131 mg l^{-1}, respectively. However a feed of 18:6:12 (nitrogen:potassium:phosphorus) was applied at a rate of 2.6 kg per hectare before planting to ensure adequate levels of micro nutrients in the soil after plantation establishment, thus ensuring optimum growth.

4.2.2. Site 2 and 3 – Kilmore Quay, Co. Wexford.

Site 2 was located at Kilmore Quay, Co. Wexford (Ordnance Survey grid reference (52°11’8”N, 6°34’29”W). Research at this site examined the impact of different pruning regimes on a plantation, which was 4 years old. The sandy soil in the Wexford site was not tested for comparison as this was a mature plantation at the start of the study. A feed of 7N:6P:17K was applied at 2.7 kg ha^{-1} to site 2 at Wexford at the establishment stage. The crop had received no formal pruning before the start of this study however; it had been previously harvested for sale into the EU market between November and March, in 2010 and 2011 when the plants were 2 and 3 years old, respectively.

Site 3 was located at an adjacent site to Site 2 in Kilmore Quay, Co. Wexford. The sandy soil in this site was not tested for comparison as this was a mature plantation at the start of the study. A feed of 7N:6P:17K was applied at 2.7 kg ha^{-1} to site 3 at the establishment stage. Research at this site examined the potential of rejuvenation pruning on a plantation which was 9 years old (planted in 2003). Prior to the start of this study, the managers of Site 3 had considered rejuvenation pruning to be a way of increasing yields and the commercial life of the plantation therefore, the plants located in Site 3 were initially harvested when they were 1 year old and then once per year afterwards. Apart from the harvesting process, no separate formal pruning regime had been carried out on these plants.

Site 2 and 3 in Kilmore Quay were located on flat sites with shelter provided from mixed hedgerows on all sides. The soil was free draining, sandy soil.

4.3. **Preparation and establishment of Site 1 in Kildalton College**

Site 1 in Kildalton College was prepared and planted in June 2011. Before planting, annual and perennial weeds were cleared by spraying the site with Roundup® (360g/l glysophate) a broad-spectrum systemic herbicide. To aid drainage, the soil was also ripped, ploughed and harrowed. To further aid drainage, a bed ridge was raised to 20 cm (width 1 m) using a disc tiller. Aisles of approximately 1.2 m wide were left between each row to allow for adequate space between plants and to accommodate spraying and mowing machinery. Lawn was sown in the aisles to suppress weed growth and to provide a clean surface when harvesting. This grass area was mowed on a weekly basis between August and October in year 1, and between April and October in year 2.

The raised beds at the Kildalton College site were then covered by MyPex®, a geotextile groundcover material which suppresses weed growth and reduces water loss through evaporation. Liner plants of *O. hookeri* 'Sussex Silver' were sourced from Noel Howlin (Howlin Nursery, Co. Wexford). The plants were planted through the MyPex® in rows at a spacing of 1.2 m between plants. Two hundred of these *O. hookeri* 'Sussex Silver' plants were planted in site 1 in early June 2011 by the author and students of Kildalton College. As shown in the planting diagram in Figure 4.1, Kildalton College site had 5 rows with 40 plants in each row. These were divided into 5 blocks labelled A – E, each block had 40 plants (5 by 8 plants), with 10 treatment and 4 replicates. The experimental design was based on a randomised block design. By putting these experimental units that are as similar as possible together in the same block and by assigning all treatments into each block separately, variation among blocks can be measured and removed from experimental error. No formative pruning was carried out on the plants once planted. A weed control regime was initiated and repeated throughout the time period this study took place; the residual herbicide Stomp®Aqua (455g/litre pendimethalin) and contact herbicide, Basta® (18.0% Glufosinate ammonium) were used for weed control. Stomp®Aqua was applied in July, 2011 and again in May, 2012 at a rate of 2.9 l ha^{-1}. Basta® was applied at a rate of 3.0 l ha^{-1} a further five times at regular intervals between July, 2011 and December, 2013. Care was taken not to spray herbicides near the *Ozothamnus* plants. A protective measure taken to reduce herbivore attack included the placing of a rabbit proof fence around the perimeter of the Kildalton College site. It was found that the plants at the Kildalton site had achieved sufficient growth for harvesting 18 months after planting.

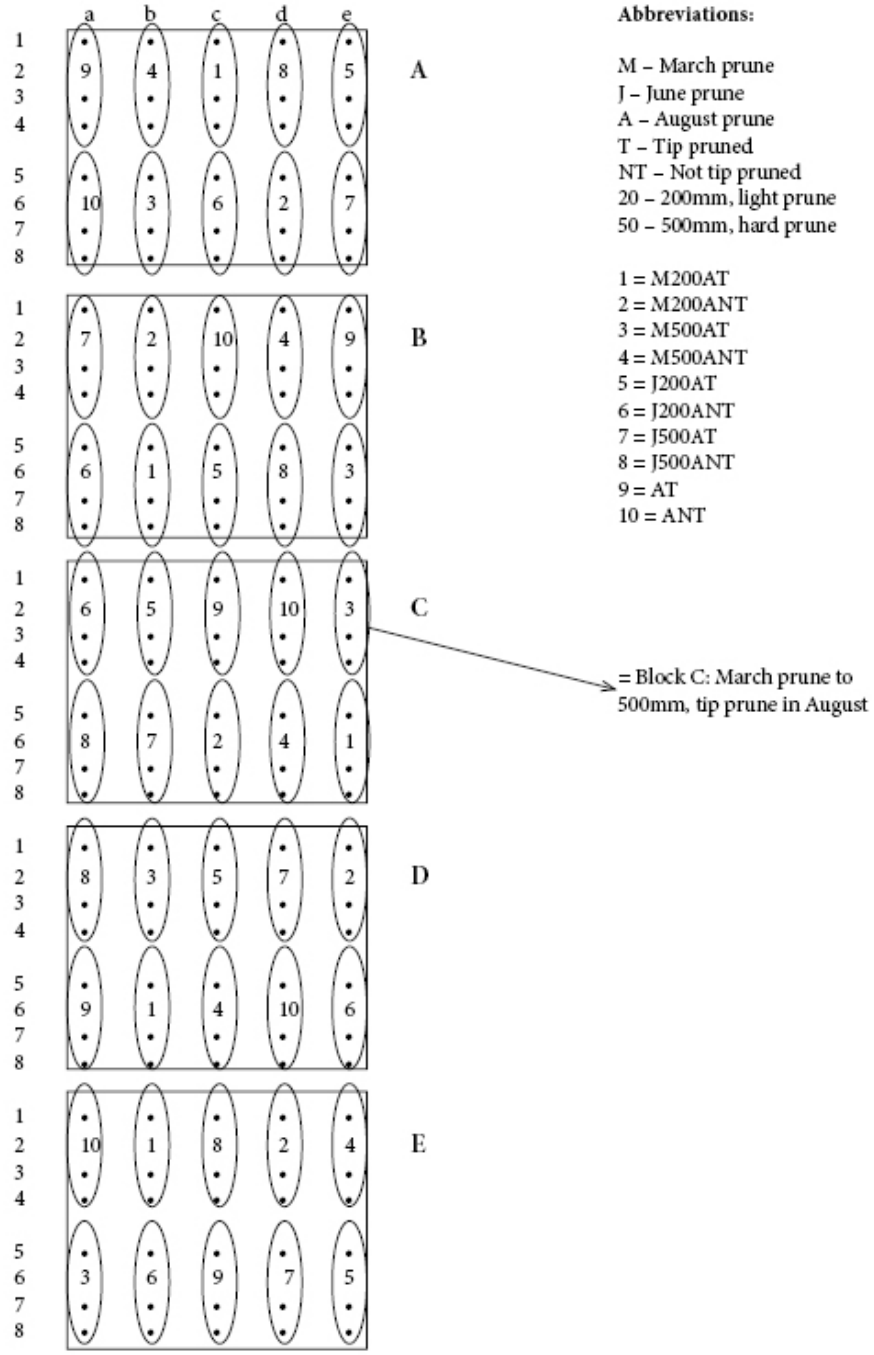

Figure 4.1: Site Layout for Site 1 at Kildalton College, County Kilkenny showing a plantation of *Ozothamnus hookeri* 'Sussex Silver', with 4 plants per treatment per block in a randomised design.

4.4. **Preparation and establishment of Site 2 in Kilmore Quay.**

Site 2 in Kilmore Quay was a 1.2 ha site with approximately 3500 *O. hookeri* 'Sussex Silver' plants already *in situ*, which were 4 years old at the start of this study. Previous to the crop used in this study, a plantation of *O. rosmarinifolius* 'Silver Jubilee' was planted in this site. However, this variety was killed by cold winter temperatures in 2007 and was therefore replaced with the hardier variety *O. hookeri* 'Sussex Silver' the following year. Site 2 in Kilmore Quay was set up as follows. First, all cold-weather-damaged *O. rosmarinifolius* 'Silver Jubilee' plants were removed using a digger. Annual and perennial weeds were then killed using Roundup® (360g/l glysophate) at a rate of 4.0 l ha^{-1} and the soil was ripped, ploughed and harrowed to reduce compaction. A feed of 7N:6P:17K was applied at 2.7 kg $ha^{-1.}$ To further help with drainage, a disc tiller was used to raise the planting ridges and aisles of approximately 1.5 m wide were left between each row for ease of access when spraying and harvesting. Black polythene plastic was laid down to prevent weed growth and the liner *O. hookeri* 'Sussex Silver' plants were sown through the black plastic at a spacing of 1.5 m. These plants were sourced and planted from the same nursery as those planted in Kildalton. As shown in the planting diagram in Figure 4.2, Kilmore Quay site 2 consisted of 4 rows with 50 plants in each row. There were 5 blocks, labelled A-E with 10 replicates in each block. Experimental design was based on a randomised block design, similar to the Kilkenny site, to reduce experimental error.

The aisles were kept clear of weeds by spraying with Roundup® (360g/l glysophate) mixed with Grazon® 90 (240 g/l Triclopyr) twice a year, at a rate of 1.5 l ha^{-1} and 4 l ha^{-1}, respectively. Care was taken not to spray herbicide near the *Ozothamnus* plants.

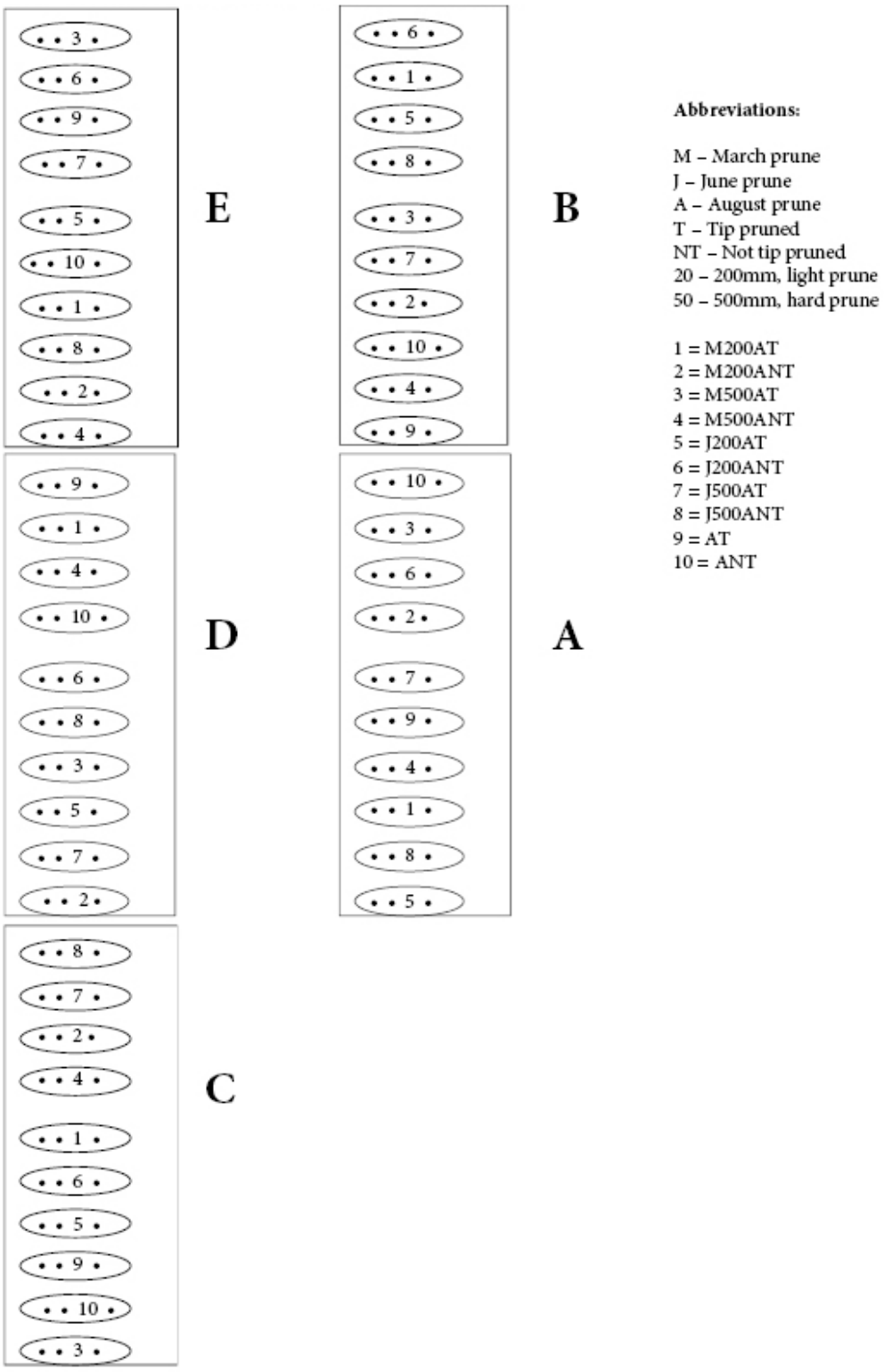

Figure 4.2: Site layout map for Site 2 Kilmore Quay, Co. Wexford showing a plantation of *Ozothamnus hookeri* 'Sussex Silver', with 4 plants per treatment per block in a randomised design.

4.5. **Preparation and establishment of Site 3 in Kilmore Quay.**

Site 3 in Kilmore Quay was a 1.8 ha site of mature *O. hookeri* 'Sussex Silver' plants which were 9 years old at the start of this study. The plants had been harvested for selling for the previous five years. However apart from the harvesting, no formal pruning regime had been carried out. Corn was grown previously on this site. The *O. hookeri* plants had been sourced and planted by the same grower as the previous two sites in liners through black plastic at a spacing of 1.5m with a further 1.5m left between rows. When the O. *hookeri* plants at Site 3 were first planted, Roundup® (360g/l glysophate) had been used to control weeds between the rows. However, once plants were established, weed control between rows was not required as the plants had grown sufficiently wide to suppress the growth of weeds. Perennial grasses, broad-leaved weeds and annual weeds on the perimeter of the plantation were controlled on an ongoing basis using Roundup® applied at a rate of 1.5 l ha^{-1}. At the start of this study, it was noticed that this crop of *O. hookeri* at site 3 in Kilmore Quay had become congested and had a reduced stem length compared to the plants on site 2 in Kilmore Quay. As shown in Figure 4.3, Kilmore Quay site 3 consisted of 3000 plants with 1.5 m between plants and 1.5 m between rows. This site was set up using 4 blocks consisting of 20 plants (4 plants wide by 5 plants), labelled A, B, C and D. Experimental design was based on a randomised block design, similar to site 1 and site 2, to remove experimental error.

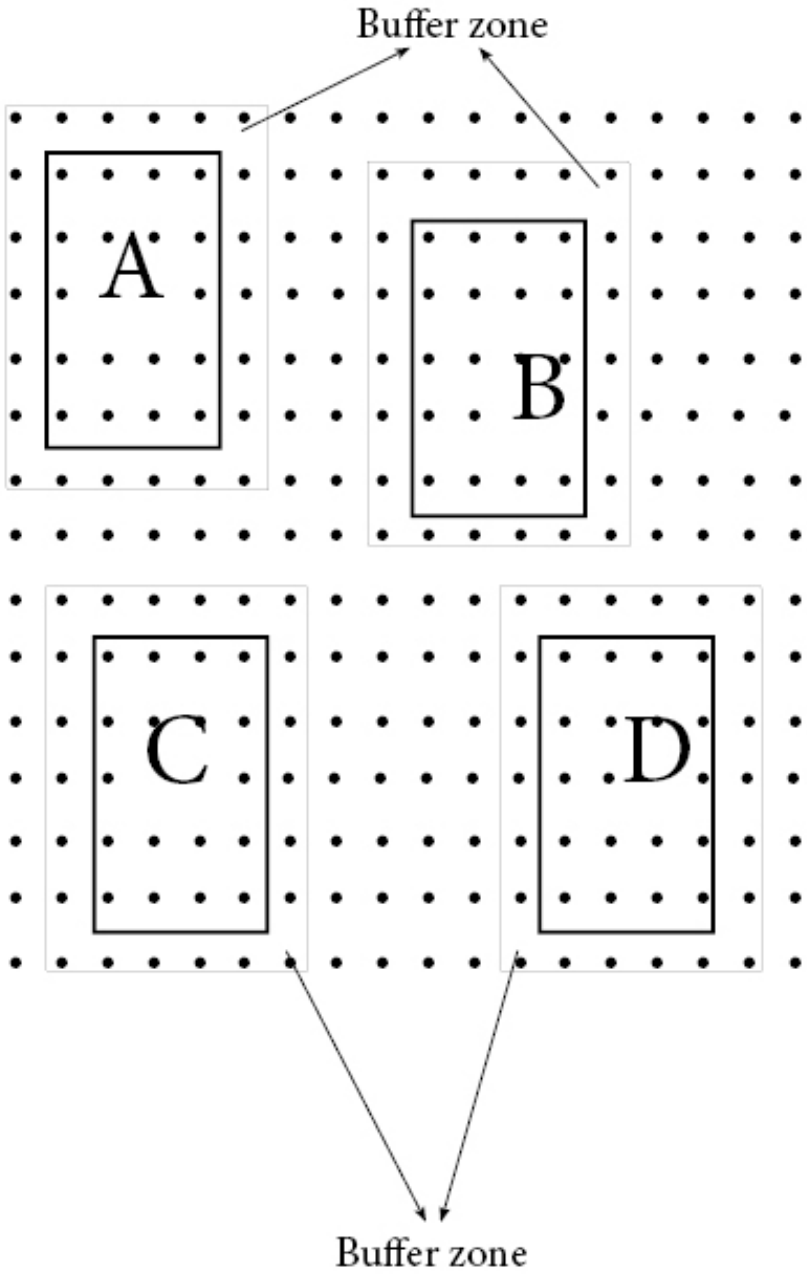

Figure 4.3: Site layout map for Site 3 Kilmore Quay, Co. Wexford showing a plantation of *Ozothamnus hookeri* 'Sussex Silver', with 20 plants per block (A-D) in a randomised design.

4.6. **Pruning treatments used in this study**

'Soft pruning' to 500 mm and 'hard pruning' to 200 mm was carried out in Site 1 and Site 2 in March and June of the first year of the study. 'Hard pruning' is explained as pruning until stems of 200 mm in length remain on the plant and 'soft pruning' refers to stems of 500 mm in length left on the plant after pruning. Tip pruning, which involved the removal of the top 5cm of each stem, was carried out in August of year 1. Site 1 and 2 consisted of 10 pruning treatments carried out on 200 *O. hookeri* 'Sussex Silver' plants. The timing of the pruning treatments were chosen to examine the effects of pruning at three different times of the year, as a function of the type of pruning. To determine if there was an effect on the yield of marketable cut foliage due to timing of the pruning, plants were pruned while in their pre-flowering stage in March and they were also pruned post flowering, in June.

The severity of rejuvenating pruning was examined in Site 3 to determine if this affected overall yield. This involved pruning the stems of these mature 9-year-old plants to 1000mm height.

4.6.1. Pruning regime carried out on Site 1 in the first year of the study

Pruning was carried out at the Kilkenny site in the first (2012) and second year (2013) of the study. For ease of understanding, the pruning times and pruning regimes are outlined in Table 4.1. Half of the plants were tip-pruned in August. Of the 40 control plants used, 20 were left untip-pruned (negative control) and the other 20 were tip-pruned (positive control).

Number of Plants	**80 plants**				**80 plants**				**40 plants**	
Month of treatment	**March**				**June**				**N/A (Control Plants)**	
Number Pruned Hard (to 200 mm) or Soft (to 500 mm)	40 pruned to 200mm		40 pruned to 500mm		40 pruned to 200mm		40 pruned to 500mm		Not pruned in March or June	
Tip-pruning details	20 tip-pruned in August	20 not tip-pruned at all	20 tip-pruned in August	20 not tip-pruned at all	20 tip-pruned in August	20 not tip-pruned at all	20 tip-pruned in August	20 not tip-pruned at all	20 tip-pruned in August	20 control plants- no pruning

Table 4.4: Pruning treatments of *Ozothamnus hookeri 'Sussex Silver'* at Site 1 at Kildalton College, Co. Kilkenny.

The table details the pruning treatments carried out on Site 1 in year 1 of the experiment.

The first pruning was carried out on the Kilkenny site on the 14th March 2012 and 26th June 2012, 9 and 12 months, respectively, after the plantation was established. Bamboo canes of 200 mm and 500 mm in length were used to measure the height of stem to leave uncut on each plant. Sharp secateurs were used to prune each plant.

Tip-pruning was carried out on the 14th August 2012. This involved removing 5cm from the tip of half of all stems on the *Ozothamnus* plants. Half of these tip-pruned plants were previously pruned to 200mm or 500mm or belonged to the control 'no-prune' group. Any stem that was less than 50 cm or in flower was not tip-pruned as these would not be of marketable standard for harvesting in August therefore tip pruning was deemed unnecessary. Secateurs were used to prune each plant which was carried out after 1 year of growth on Site 1. Replications of the different pruning treatments shown in Figure 4.1 were carried out on 4 adjacent plants.

4.6.2. Pruning on site 1 in second year of the study

In 2013 the treatments were repeated on half of plants from each treatment number on Site 1. For ease of understanding, Table 4.2 details both the first and second year pruning treatments. As seen in Table 4.2, on the 27th March 2013 a second pruning on half the plants was carried out in the second year of the study; some plants were not pruned in year 2; they therefore only received 1 prune during the first year. Pruning again involved the use of a clean secateurs and a 200 mm cane to give a 'hard prune' and a 500 mm cane to give a 'soft prune'.

80 plants- March 2012				80 plants – June 2012				40 plants 2012	
40 plants: Hard pruned to 200mm		40 plants: Light pruned to 500mm		40 plants: Hard pruned to 200mm		40 plants: Light pruned to 500mm		Not pruned in March or June	
20 plants tip pruned in August	20 plants not tip pruned	20 plants tip pruned in August	20 plants not tip pruned	20 plants tip pruned in August	20 plants not tip pruned	20 plants tip pruned in August	20 plants not tip pruned	20 plants tip pruned in August	20 control plants- no pruning
Treatment no.1	Treatment no. 2	Treatment no. 3	Treatment no. 4	Treatment no. 5	Treatment no.6	Treatment no. 7	Treatment no. 8	Treatment no. 9	Treatment no.10
80 plants – March 2013				**80 plants – June 2013**				**40 plants 2013**	
20 plants: Hard pruned to 200mm		**20 plants: no pruning**		**20 plants: Light pruned to 500mm**		**20 plants: no pruning**		**80 plants: no pruning**	**Not pruned in March or June**
10 plants tip pruned in August	**10 plants not tip pruned**	**10 plants tip pruned in August**	**10 plants not tip pruned**	**10 plants tip pruned in August**	**10 plants not tip pruned**	**10 plants tip pruned in August**	**10 plants not tip pruned**	**80 plants not tip pruned**	**10 plants tip pruned in August**	**10 plants not tip pruned**	**20 control plants- no pruning**

Table 4.2: Pruning treatments of *Ozothamnus hookeri 'Sussex Silver'* at Site 1 at Kildalton College, Co. Kilkenny. The table details the pruning treatments carried out on Site 1 in year 2 of the experiment.

4.6.3. Pruning regime carried out on site 2 in year 1 of the study

Pruning was carried out on site 2 at Kilmore Quay, Co. Wexford in year 1 of the study only. This was done on the 30th March 2012 and 28th June 2012. Tip-pruning was carried out on the 17th August 2012. These treatments were not repeated in the 2nd year of the study.

The previously used criterion for tip-pruning was to remove 5cm from the tips of all stems longer than 50cm and from the stems that had not flowered. In year 1, plants that had been pruned to 200 mm in March and June on Site 2 had not produced sufficient extension growth by the 14th and 17th August to meet the previously used tip-pruning criteria. These plants where not, therefore, tip-pruned in August. Plants on site 2 in Kilmore quay, Co. Wexford were not pruned in year 2 (2013) of the study.

4.6.4. Pruning regime carried out on site 3

Pruning on site 3 at Kilmore Quay, Co. Wexford was carried out in year 1 of the study only. This plantation was used to examine the effects of rejuvenation pruning on mature plants. These plants were hard pruned by chainsaw to a height of 1000 mm. There were over 3000 plants in this plantation, the majority being *Ozothamnus* 'Sussex Silver'. The aim of pruning at site 3 was to encourage lateral branching with the final aim of increasing the number and quality of marketable stems that can be harvested. Plants in blocks of 20 (4 x 5) were pruned to a height of 1 m on May 1st 2013. A buffer zone of pruned plants was left around this block. This block was replicated in 4 other sections of the plantation. This hard pruning was not repeated in year 2 of the study.

4.7. **Harvesting carried out during the study**

Harvesting was carried out after inspection of all sites to ensure there was sufficient extension growth to get the maximum number of marketable stems. A cool day was chosen to reduce moisture loss and prevent stems drying out. Stems were cut clean using sharp secateurs to minimise the entry of pathogens into the plants.

4.7.1. Harvesting at site 1 in year 1 of the study

Harvesting was carried out on site 1 Kildalton College, Kilkenny from the 10th to the 14th December 2012. All potentially marketable stems longer than 55 cm were harvested and graded. Very thin stems (Figure 4.5) <5mm were not harvested as they were not of sufficient size to be sold. Saleable stems were reasonably well branched and bushy towards the top third of the stem. As seen in Figure 4., harvested stems were deemed to have optimum characteristics for the market when they were strong and straight and uniform in colour keeping in mind that the quality and size tolerance of ±10% according to the Economic Commission of Europe. Throughout the harvesting process it was ensured that foliage was kept fresh and clean by placing in containers immediately after harvesting.

4.7.2. Harvesting at site 1 in year 2 of the study

Harvesting of all plants was carried out December the 3rd to the 5th 2013 and numbers of marketable stems graded, counted and recorded as per year 1.

4.7.3. Harvesting of site 2 in year 1 of the study

At Site 2 in Kilmore Quay, Co. Wexford harvesting was carried out between the 17th to 19th December 2012 only, as per Table 4.3. Similar to harvesting at site 1, all potentially marketable

stems in excess of 55 cm were harvested and graded. Very thin stems that were <5mm were not harvested as they were not of sufficient size to be sold. Saleable stems were strong and straight with reasonably well branched and bushy towards the top third of the stem. All harvested foliage was kept fresh and clean by placing in containers immediately after cutting from the plant. Plants were not harvested from site 2 in year 2 of the study.

Number of Plants	**80 plants**				**80 plants**				**40 plants**	
Month of treatment	**March**				**June**				**N/A (Control Plants)**	
Number Pruned Hard (to 200 mm) or Soft (to 500 mm)	40 pruned to 200mm		40 pruned to 500mm		40 pruned to 200mm		40 pruned to 500mm		Not pruned in March or June	
Tip-pruning details	20 tip-pruned in August	20 not tip-pruned at all	20 tip-pruned in August	20 not tip-pruned at all	20 tip-pruned in August	20 not tip-pruned at all	20 tip-pruned in August	20 not tip-pruned at all	20 tip-pruned in August	20 control plants- no pruning

Table 4.3: Table Pruning treatments of *Ozothamnus hookeri 'Sussex Silver'* at Site 2 in Kilmore Quay, Co. Wexford.

The table details the pruning treatments carried out on Site 2 in year 1of the experiment.

4.7.4. Harvesting of site 3 for year 1 and 2

Hard pruned plants on Site 3 in Kilmore Quay were not harvested as there was insufficient growth to produce marketable stems.

4.8. **Grading**

Harvested stems were graded according to length as follows: 55 – 65 cm, and >66 cm. These were further subdivided into groups of single stems or sprays. As shown in Figure 4.4, a single stem was characterised as unbranched and a spray was characterised as having three or more branches. The number of stems obtained at harvest time for each plant was recorded and the plant on site at time of harvest and the plant number, length and harvest time were also recorded for each plant. Un-marketable stems as shown in Figure 4.5 that were less than 55cm, damaged or had curved foliage were not recorded. The pruning lengths used in this study for *O. hookeri* 'Sussex Silver' were selected following consultation with Cut Foliage Adviser Andy Whelton (Teagasc) who through experience found that these pruning treatments had a positive effect on yield. Grading of harvested stems was carried out *in situ* using criteria set out by The Economic Commission for Europe (Table 3.4) so that only stems of sufficient quality were classified as 'saleable stems'.

Figure 4.4: Marketable cut foliage stems 55mm - 65mm single stems and sprays (A), and cut foliage stems >66mm single stems and sprays (B).

Figure 4.5: Unmarketable cut foliage stems – too curved/too thin

4.9. **Data storage and statistical analysis**

Data collected from this study were recorded using Microsoft Excel. Statistical analysis to determine significance was carried out using Single Factor or two way ANOVA with post-hoc t-test (two-tailed t-test assuming equal variances). Microsoft Excel software was used to carry out these tests where the significance was determined at a confidence interval of 95 %. Results are significant where '(P<0.05)' is included in the text. A Bonfferoni correction was used to adjust the significance thus avoiding errors when making many comparisons.

5. RESULTS

To investigate if timing and type of pruning has an effect on the yield of *Ozothamnus hookeri* 'Sussex silver', pruning to 200 mm and 500 mm was carried in March and June of year 1 and saleable stems were subsequently harvested in December of year 1. The effect the age of the plantation had on yields was also examined. The total number of saleable stems harvested from the Kilkenny site after a 2-year pruning regime was explored along with the effects that tip pruning in August had on the type of stems produced. The following sections detail the results of these experiments.

5.1. **Evaluation of pruning regime on year 1 harvest**

To determine what pruning regime and pruning timing would result in the highest yield of saleable stems of *O.hookeri* 'Sussex Silver', plants in the Kilkenny site and the Wexford site were pruned to a height of 200 mm or 500 mm in March or June and harvested in December of the same year.

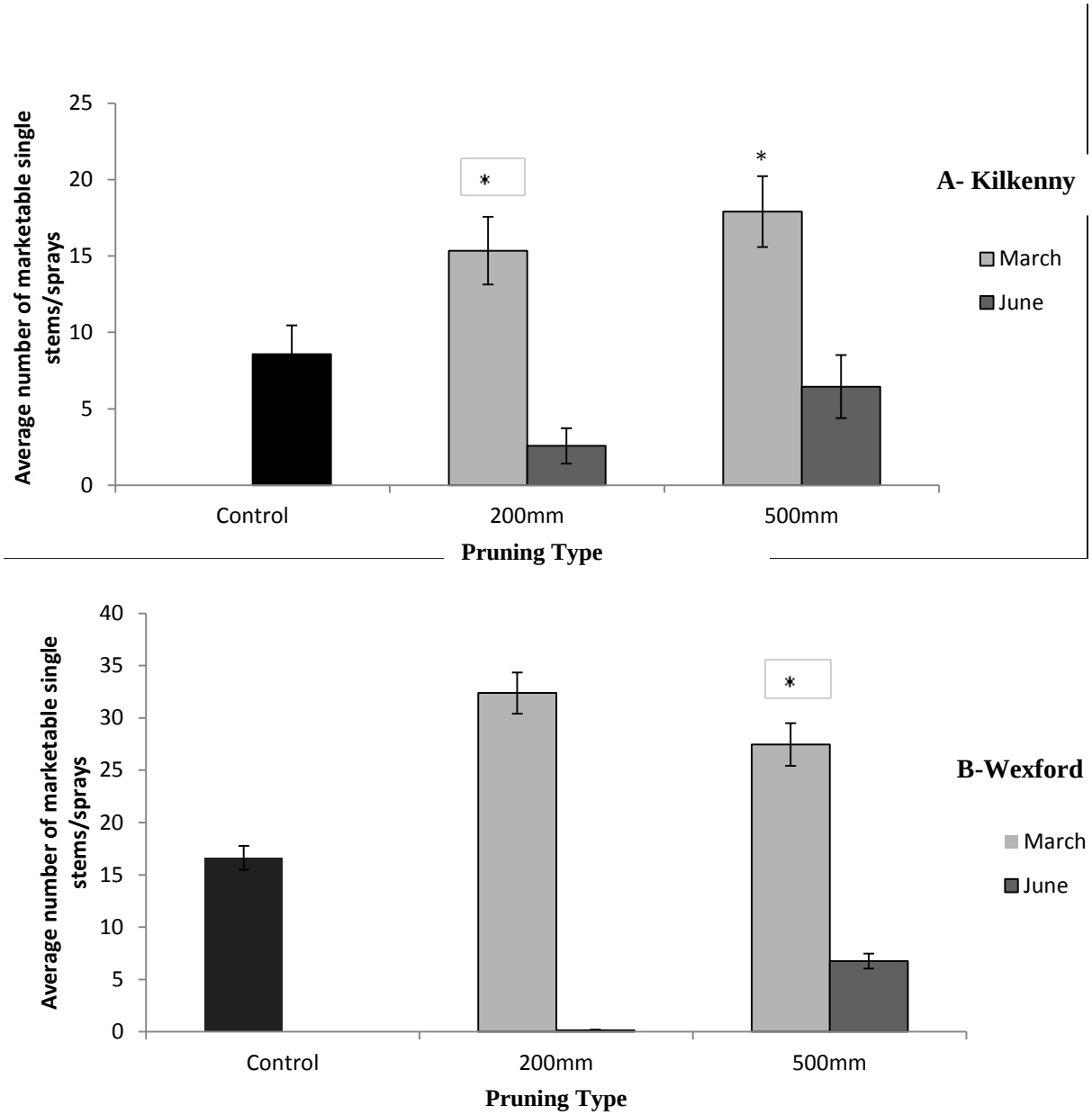

Figure 5.1: The average number of harvested saleable *Ozothamnus hookeri* 'Sussex Silver' single stems or sprays obtained after pruning to 200mm or 500 mm in March or June of year 1 in Kilkenny (A) and Wexford (B). The single stems / sprays shown on these charts were harvested in December of year 1.

The control groups received no pruning during year 1 (n=20). Treatment plants were hard pruned to 200mm (n=40) or light pruned to 500mm (n=40). Single Factor ANOVA (Table 5.1) analysed the variation among and between data groups and post-hoc t-tests examined significant differences between control and 200mm or 500mm, and the significant difference between the 200mm and 500mm. The asterisk signifies significance; in Kilkenny in March, a 200mm and a 500mm prune produced a significantly higher yield of saleable stems ($P<0.05$) compared to the control. Conversely, in Wexford in March only a 500mm prune produced a significantly higher yield of saleable stems compared to the control. Analysis of Kilkenny and Wexford site data in June showed that 200mm and 500mm prunes produced a statistically lower yield of saleable stems compared to the control.

Table 5.1: Single-factor ANOVA of yield of marketable single stems/sprays harvested from two sites (Wexford and Kilkenny) subjected to a pruning regime in year 1 of the study.

		Kilkenny			Wexford		
	df	**SS**	**F**	***P-value***	**SS**	**F**	***P-value***
March	2	5191	20.8	0.00000001917*	1858	5.039	0.008*
June	2	5500	113	0.0000000000000*	740	3.027	0.0523

(* denotes significance at the 5% level)

Figure 5.1A and B shows the effect of pruning to 200 mm or 500 mm in March or June. When *O.hookeri* 'Sussex Silver' plants were pruned to 200 mm in Site 1 in Kilkenny an average of 15.35 saleable stems were harvested from March pruning compared to 2.58 stems from June pruning. *O.hookeri* 'Sussex Silver' plants pruned to 500 mm gave an average of 17.9 saleable stems in March and 6.45 saleable stems in June. This harvesting of more saleable stems from March pruning than June pruning is mirrored for 200 mm and 500 mm pruning on site 2 in Wexford. The control group, which received no pruning, gave an average of 8.58 saleable stems in Kilkenny and an average of 17 stems in Wexford. This 'no prune' group of plants in Site 2 in Wexford gave less saleable stems than March pruning but more saleable stems than June pruning.

5.2. **Evaluation of the effects of the age of the plantation on the number of harvested saleable stems**

In order to investigate the effects the age of a plantation can have on the yield of saleable stems of *O. hookeri* 'Sussex Silver' the average yield of harvested stems obtained per plant from site 1 in Kilkenny were compared with Site 2 in Wexford. The plantation of *O. hookeri* 'Sussex Silver' in the Kilkenny site was 2 years old and the plantation at the Wexford site was 4 years old at the time of the study. Pruning on both sites involved cutting back *O.hookeri* 'Sussex Silver' plants to 200 mm or 500 mm in March or June followed by harvesting the following December.

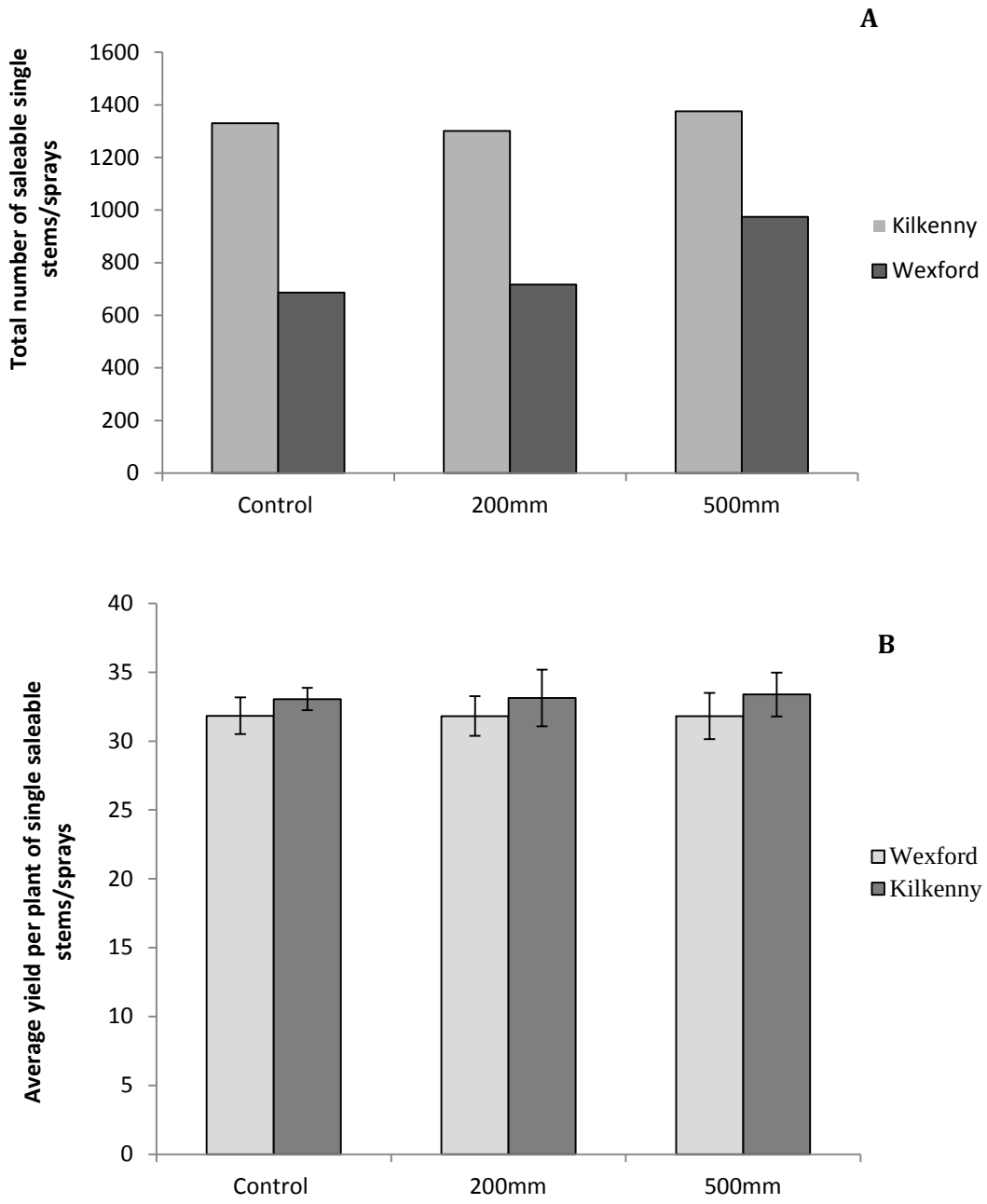

Figure 5.2A and B: The total number of harvested saleable single stems /sprays of *Ozothamnus hookeri* 'Sussex Silver', obtained per plant after pruning and harvest in year 1 in Kilkenny and Wexford (A) and the average number of single sprays obtained per plant on both sites (B).

At the time of harvest, plants in Kilkenny were 2.5 years old and plants in Wexford were 5 years old. In year 1 the control group received no pruning. Data plotted is the sum of plants (n=80) pruned to 200 mm in March and June, and plants (n=80) pruned to 500 mm in March and June. Where error bars are included, values are means ±SD. Analysis of data sought to determine if plantation age effected total yields of saleable stems/sprays. The data is deemed significant when the F value > F-crit and when P-value < 0.05.The yield data (Figure 5.2B) analysed here using ANOVA is not significantly different between and within data groups (Table 5.2). Post-hoc t-tests comparing the control to 200 mm or 500 mm did not show significantly high or low yields due to plantation age nor was there a significant difference between the yields obtained after 200 mm and 500 mm pruning on either site.

Table 5.2: Single-factor ANOVA of total yield of marketable single stems/sprays harvested per plant from two sites (Wexford and Kilkenny) subjected to a pruning regime in year 1 of the study.

	df	SS	F	F-crit	*P*-value
Kilkenny	2	35.75833	0.090351	3.03392	0.913642
Wexford	2	624.8083	1.772729	3.03392	0.172114

(* denotes significance at the 95% level however no significance detected here).

This data attempts to determine if plantation age effects yield. After year 1 Kilkenny site was 2.5 years whereas the Wexford site was 5 years old. Figure 5.2A shows that plants of *O. hookeri* 'Sussex Silver' in the control group which (not pruned) gave a total number of saleable stems of 1330 from site 1 in Kilkenny compared to 686 from site 2 in Wexford. There is a consistent result that *O. hookeri* 'Sussex Silver' plants in the younger Kilkenny site yielded a higher number of saleable stems than the older Wexford site the yield per plant. However this data has not proven to be statistically significant. When plants of *O. hookeri* 'Sussex Silver' were pruned to 200 mm, 1301 saleable stems were harvested from the Kilkenny site and 717 saleable stems were harvested from the Wexford site. This trend of yielding approximately double the number of total saleable stems from the Kilkenny site compared to the Wexford site is also mirrored when plants *O. hookeri* 'Sussex Silver' were pruned to 500mm.

5.3. **Average yield of saleable single/sprays harvested from Kilkenny after a 2 year pruning and harvesting regime.**

The effect of pruning on site 1 in Kilkenny in two subsequent years was examined. In order to give a clearer view of this effect the average number of saleable single / spray stems obtained per plant of *O. hookeri* 'Sussex Silver' harvested from Kilkenny site combining year 1 and year 2 results is shown in Figure 5.3.

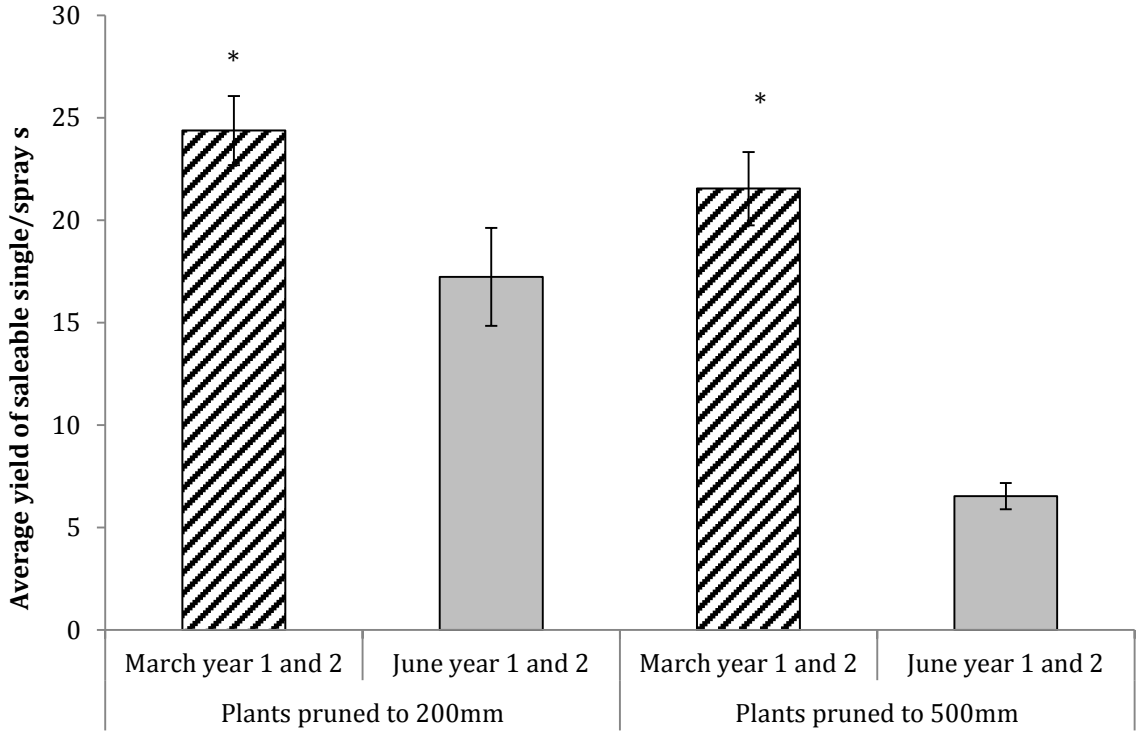

Figure 5.3: The average yield of harvested saleable single stems /sprays of *Ozothamnus hookeri* 'Sussex Silver' in March and June, year 1and year 2 at Site 1, Kilkenny.

In March of year 1 and year 2 plants were hard pruned to 200mm or light pruned to 500mm. In addition, in June of year 1 and 2 plants were hard pruned to 200mm or were light pruned to 500mm. Data analysis using two-way ANOVA with replication highlighted a significant difference between treatments (Table 5.3). The plants pruned to 200mm in March of year 1 and 2 produced a significantly higher yield of single stems/sprays per plant ($P<0.05$) compared to those pruned to 200 mm in June. However, when plants are pruned to 500mm in March of year 1 and 2, the average yield of single/stems sprays per plant is not significantly increased compared to those pruned to 200 mm in June. Further t-tests showed that pruning to 500 mm in march of year 1 and 2 significantly increased the yield of stems/sprays obtained per plant compared to those pruned to 500 mm in June of year 1 and 2 ($P<0.05$). (* denotes a significant higher average yield as elucidated above).

Table 5.3: Single-factor ANOVA of yield of marketable single stems/sprays harvested from Kilkenny site subjected to a pruning regime in year 1 and year 2 of the study.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	3739.142405	1	3739.142405	15.26148	0.0001148*	3.871435977
Columns (march/June)	9504.079114	1	9504.079114	38.79134	1.523E-09*	3.871435977
Interaction	1244.079114	1	1244.079114	5.077766	0.0249287*	3.871435977
Within	76441.62025	312	245.0051931			

(* denotes significance at the 95% level)

Figure 5.3 shows the total number of saleable stems of *O. hookeri* 'Sussex Silver' for year 1 and year 2. Plants pruned to 200 mm in March of year 1 and year 2 gave a yield of 24.38 saleable stems compared to 21.54 for plants pruned to 500 mm. *Ozothamnus hookeri* 'Sussex Silver' plants pruned to 200 mm in June gave a yield of 17.24 saleable stems compared to 6.54 stems for plants pruned to 500 mm in June.

5.4. **Comparison of 200 mm versus 500 mm pruning at different times of the year and over subsequent years in site 1 in Kilkenny.**

Figure 5.4 shows a comparison between *O. hookeri* 'Sussex Silver' plants pruned in year 1 only with those pruned in year 1 and year 2 of the experiment. This investigates if pruning in 2 subsequent years gives a higher yield of saleable stems than a once off pruning in year 1 only. Control plants of *O. hookeri* 'Sussex Silver' received no pruning.

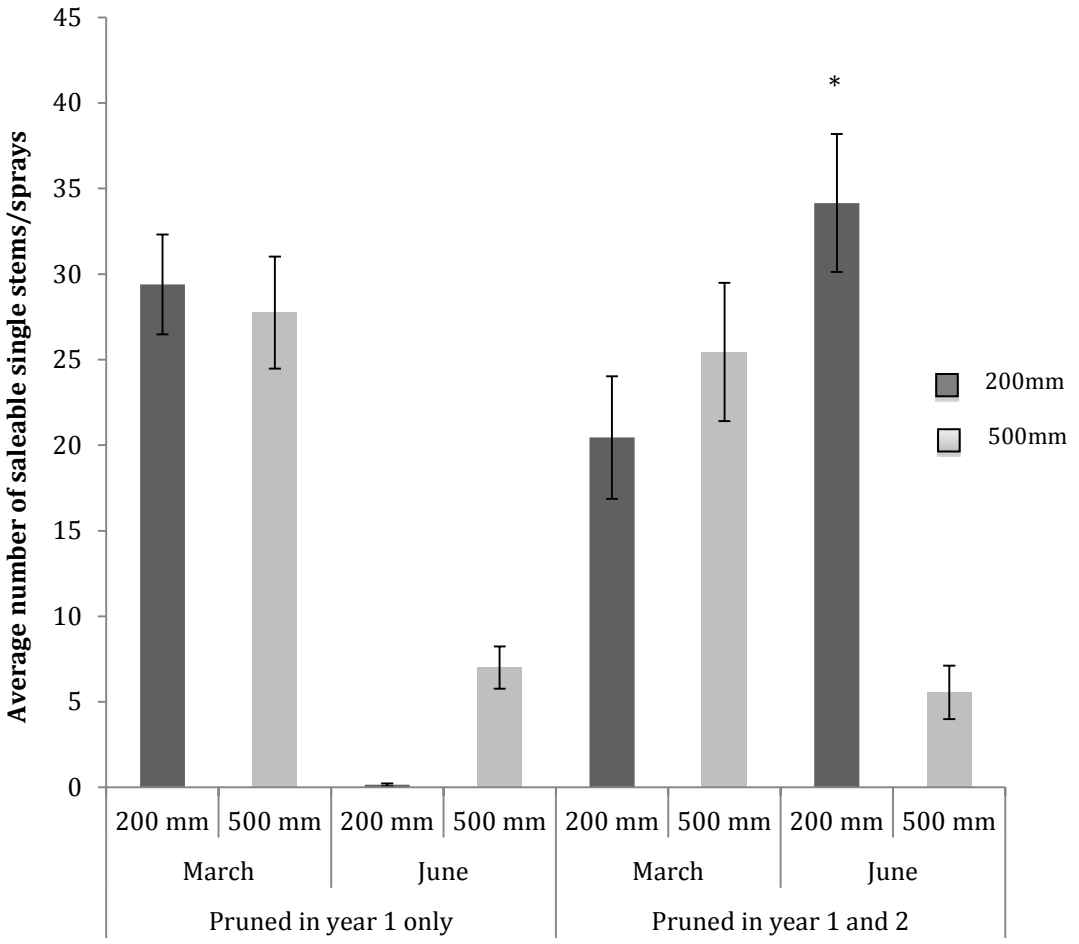

Figure 5.4: An overview of the average number of harvested saleable single stems /sprays of *Ozothamnus hookeri* 'Sussex Silver' pruned in March and June year 2 in Kilkenny and harvested in December. All plants were pruned in year 1.

'Pruned plants' were pruned to 200mm in year 1 and year 2 or 500mm in year 1 and year 2.

'Pruned in year 1 plants' were pruned to 200mm or 500mm in year 1 and not pruned in year 2.

Statistical analysis of the data showed that only plants which were pruned in year 1 and year 2 to 200 mm produces a significantly higher number of saleable stems ($P<0.05$) compared to all other treatments.

Values are means ±SD. (* denotes statistical significance as elucidated above).

Figure 5.4 shows that in site 1 in Kilkenny plants pruned in year 1 gave an average yield of 57.15 saleable stems of *O. hookeri* 'Sussex Silver' when pruned in March and 7.15 saleable stems when pruned in June of year 1. An average yield of 29.4 saleable stems was harvested from plants pruned to 200 mm in year 1 only and an average yield of 27.75 saleable stems when pruned to 500 mm. Plants of *O. hookeri* 'Sussex Silver' pruned in year 1 and year 2 of the experiment produced an average of 45.9 saleable stems when pruning in March and 39.7 saleable stems when pruned in June. An average yield of 54.6 saleable stems was achieved from *O. hookeri* 'Sussex Silver' plants pruned to 200 mm in year 1 and year 2, while plants pruned to 500 mm in year 1 and year 2 gave an average yield of 31 saleable stems.

5.5. **Tip pruning has no influence on the number of saleable stems but it does have an effect on the type of stem harvested**

Tip pruning was carried out on half of all *O. hookeri* 'Sussex Silver' plants (n=20) in August and the control group received no tip pruning (n=20) in site 1 in Kilkenny and in site 2 in Wexford. The purpose of tip pruning was to investigate its effects on the growth habit of stems harvested and whether it produced more sprays than single stems. A spray is defined as a stem with lateral shoots and a single stem has reduced lateral shoot growth. The total number of saleable *O. hookeri* 'Sussex Silver' stems was calculated following harvesting the following December. These plants were not previously pruned to 200mm or 500m but belonged to the control group, which received no pruning.

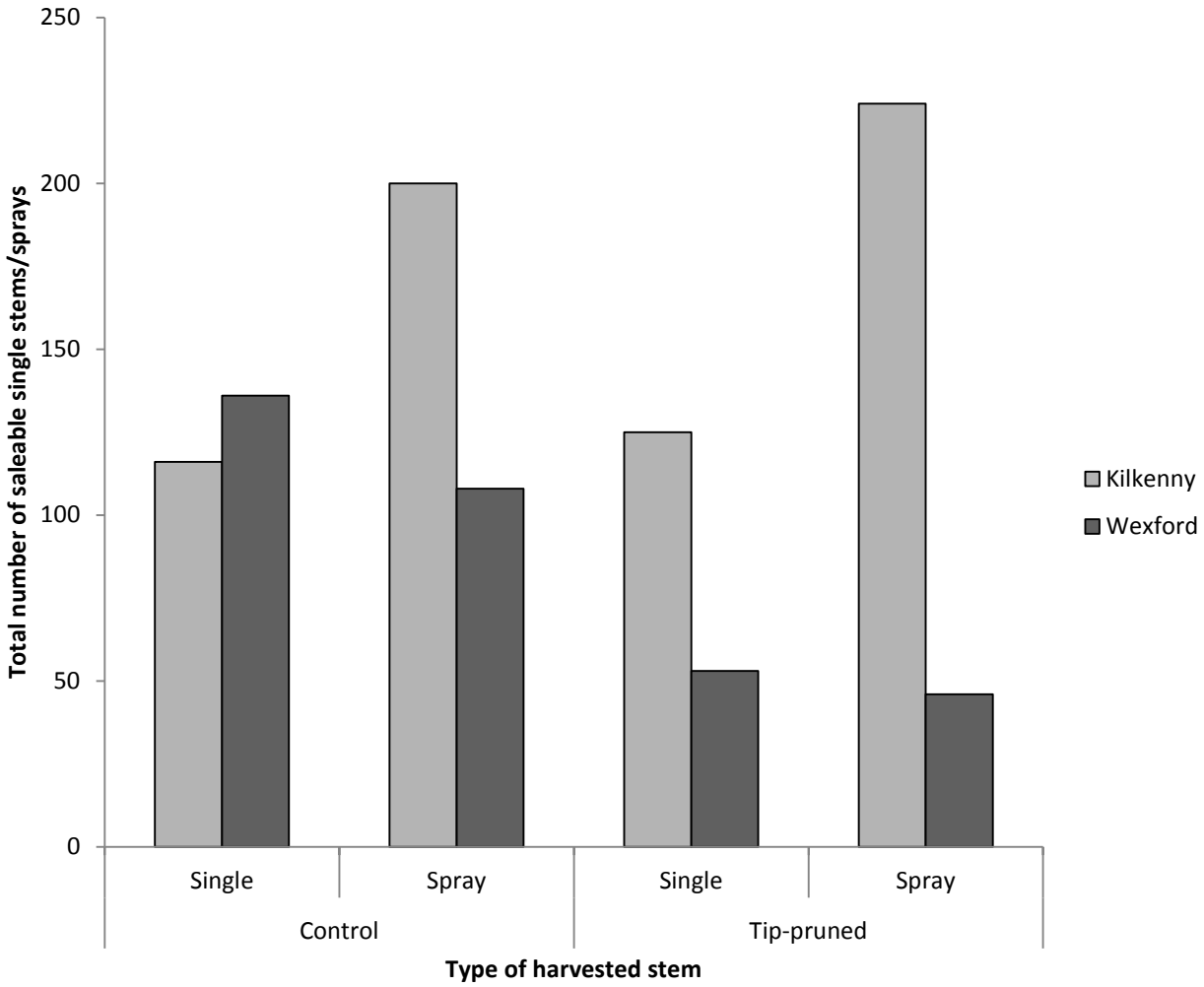

Figure 5.5: The total number of harvested saleable single stems or sprays of *Ozothamnus hookeri* 'Sussex Silver', tip pruned in August year 1 in Kilkenny and in Wexford. These single stems and sprays were harvested in December of year 1.

A single stem is defined as a stem with no lateral shoots while a spray is defined as a stem with lateral shoots.

The plants in this experiment were not previously pruned to 200 mm or 500 mm.

ANOVA and t-testing of the yield obtained per plant ruled out any statistical significant increase in saleable single stems or sprays after a tip-pruning treatment.

Figure 5.5 shows the results of tip pruning of *O. hookeri* 'Sussex Silver' plants and the total number of saleable spray stems and single stems harvested from site 1 in Kilkenny and site 2 in Wexford. On the Kilkenny site the control no tip pruning group produced 116 saleable single stems compared to 200 saleable spray stems. On the Wexford site the trend was opposite; 136 saleable single stems were harvested compared to 108 saleable spray stems on *O. hookeri* 'Sussex Silver' plants that were not tip pruned. For plants that were tip pruned, in the Kilkenny site 125 saleable single stems were harvested compared to 224 spray stems. Tip pruning produced almost a similar number of saleable single stems to sprays, with 53 stems to 46 stems respectively, harvested on the Wexford site. This shows that tip pruning does not consistently produce more saleable spray stems than single stems.

5.6. **Tip pruning produces more sprays than single stems.**

In order to investigate if tip pruning produced more saleable spray stems than single stems of *O.hookeri* 'Sussex Silver', half the plants in site 1 in Kilkenny and site 2 in Wexford were tip pruned (n=100) and half were not tip pruned (n=100) in August and harvested the following December. Tip pruning involved removing the top 5cm of all stems of *O.hookeri* 'Sussex Silver' that were >55 cm in length in August. A single stem is defined as a stem with reduced lateral shoot growth and a spray stem is defined as a stem with lateral shoot growth. A spray stem of *O. hookeri* 'Sussex Silver' is more desirable to the buyer of these plants.

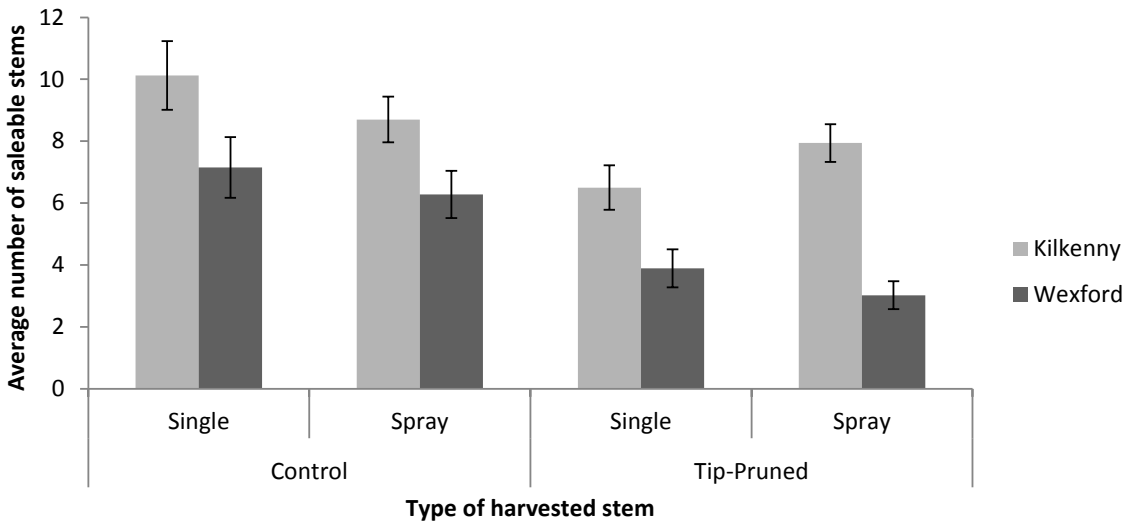

Figure 5.6: The average number of harvested saleable single stems or sprays of *Ozothamnus hookeri* 'Sussex Silver', tip pruned in August year 1 in Kilkenny and in Wexford. These single stems and sprays were harvested in December of year 1.

A single stem is defined as a stem with reduced lateral growth and a spray is defined as a stem with lateral shoots.

The tip-pruning treatment did not increase the average yield of sprays therefore; no significance testing was carried out.

Values are means ±SD.

On site 1 in Kilkenny, plants of *O. hookeri* 'Sussex Silver' that were not tip pruned produced an average of 10 saleable single stems compared to an average of 8.7 saleable spray stems for those plants which were tip pruned. On site 2 in Wexford, plants of *O. hookeri* 'Sussex Silver' that were not tip pruned produced an average of 7 saleable single stems compared to an average of 6 saleable spray stems. On *O. hookeri* 'Sussex Silver' plants that were tip pruned, an average of 6.5 saleable single stems were harvested from the Kilkenny site compared to 7.94 saleable sprays harvested on the same site. On the Wexford site, plants of *O. hookeri* 'Sussex Silver' that were tip pruned yielded 3.9 saleable single stems compared to 3 saleable spray stem on the same site. As shown on Figure 5.6, this does not show a consistent trend in relation to tip pruning and the production of more saleable spray stems than single stems.

5.7. **The effects of rejuvenation pruning on an existing mature *Ozothamnus hookeri* 'Sussex Silver' plantation were examined.**

Rejuvenation pruning involves cutting back all growth to near ground level or to a low framework. Rejuvenation pruning to 1000mm on May 1st 2013 was carried out at site 3 in Kilmore Quay, Wexford. The plants had not produced sufficient growth in the following December to warrant harvesting therefore the data is not presented here except to say that rejuvenation pruning of mature plantations will not produce single stems or sprays in time for harvesting later in that same year.

6. DISCUSSION

6.1. **Evaluation of pruning regime on year 1 harvest**

Results from site 1 in Kilkenny and site 2 in Wexford show that higher yields of saleable single stems and sprays are produced when *O. hookeri* 'Sussex Silver' is pruned in March rather than in June, regardless of whether they are pruned to 200 mm or 500 mm (Figure 5.1). A March pruning gave *O. hookeri* 'Sussex Silver' plants three additional months in which to put on growth. Therefore this may explain why there were less saleable stems harvested from plants pruned in June. *O. hookeri* 'Sussex Silver' flowers in June (Irons, 2009) so pruning in March is carried out before flowering. Stems of *O. hookeri* 'Sussex Silver' that have flowered, branch at the flowering node and this can result in the stem not reaching the desired length of 55cm. For example, like *O. hookeri* 'Sussex Silver', *Senecio greyii* belongs to the Asteraceae family and a native of New Zealand. Teagasc recommends pruning *Senecio greyii* before flowering as flowering diverts energy away from the development of strong stems desirable for cut foliage (Whelton, 2013a). Control, unpruned *O. hookeri* 'Sussex Silver' plants gave fewer saleable stems than the number obtained after a March pruning but gave more saleable stems than those which had been pruned in June. This result was mirrored on both sites suggesting that no pruning at all or limiting pruning of *O. hookeri* in March produces more saleable stems than pruning in June. In their fact sheet on cut foliage, Teagasc recommends pruning *Ozothamnus sp.* to within 400 mm – 500 mm of ground level annually after harvesting once plants are established (Whelton, 2013b). This method of pruning by Whelton (2013b) is similar to the findings of the research shown here using *O. hookeri* 'Sussex Silver'. As previously mentioned, *O. hookeri* 'Sussex Silver' is an evergreen shrub. Brickell (1996) advises not pruning evergreen shrubs too early in spring as new growth can be damaged by frost. There is very little information available on pruning *O. hookeri* 'Sussex

Silver' later in the summer and its effects on yields of cut foliage but the results from this research shows that this later pruning in June does not produce the highest yield of saleable stems if hard pruned to 200 mm. On the Kilkenny site, a 200 mm hard pruning carried out in March gave more saleable stems than pruning to 500 mm. This was mostly likely because there was sufficient time for plants to put on growth before harvesting. The need for adequate length of time for growth can be seen in results for light pruning in June to 500 mm which generated more saleable stems than hard pruning.

The results for June pruning are consistent on both sites; hard pruning to 200 mm produces fewer saleable stems than light pruning to 500mm (Figure 5.1). These results back up anecdotal evidence from observations made by growers of *O. hookeri* 'Sussex Silver' who found that pruning early in the year (March) gives a higher yield of saleable stems. However, pruning needs to be done before plants produce a flower because evidence suggests that flowering can take from the development of strong straight stems desirable for the cut foliage trade (Whelton, 2013a). Subsequent to these harvests, anecdotal evidence from several growers indicated that if plants are harvested too early subsequent regrowth could be subjected to high levels of frost, which will have an adverse effect on the health of the new soft stems. Studies by Kerr (2007) show that *Symphoricarpos* 'Magical Sweetheart' (a deciduous species) should be cut back in early spring and recommends not cutting these plants back too late as it results in a poorer harvest. Teagasc's recommendation for pruning *Eucalyptus* for cut foliage production is to prune at the end of the harvest season, in late February or March, and no later than mid-April before the onset of new growth (Whelton, 2013c). Kerr (2007) recommends not pruning *Eucalyptus sp*. in March to reduce the risk of low temperature winter damage to plants. Plants from this experiment were not damaged by frosts following March or June pruning however this is a possibility in future years where late frosts to occur

6.2. **The age of the plantation effects the number of saleable stems obtained after pruning**

One of the major findings of this study was that the age of *O. hookeri* 'Sussex Silver' impacts on the number of saleable stems obtained after pruning. For example, the younger plantation in site 1 in Kilkenny produced almost twice as many saleable stems as the older Wexford site. This indicates that the age of *O. hookeri* 'Sussex Silver' plants may impact on the crop yield. This was also seen in previous studies. For example, studies carried out in Australia recommend that *Ozothamnus diosmifolius* plants grown for cut foliage production be used for only 4-5 years and then discarded for younger plants (Beal *et al*, 2002). Presently in Ireland, plants of *O. hookeri* 'Sussex Silver' are grown and harvested for cut foliage for 10-15 years.

It is possible that the difference in the yield of saleable stems obtained from site 1 compared to site 2 could be due to the impact of factors other than the age of the plantations. In the study shown here, not all variables could be controlled effectively. Therefore, it is important to note that the effect of some variables was not investigated in this study and as a result, these represent some limitations to this study. For example, the Kilkenny site had a grey-podzol soil whereas the Wexford site had a sandy soil therefore, although the Wexford site may have had more efficient drainage, the Wexford plantation might also have had less access to micro nutrients. As well as the drainage issue, the fertiliser application regime was different on each site; a feed of 18N:6P:12K was applied at a rate of 2.6 kg ha^{-1} to Site 1 in Kilkenny before planting of the *Ozothamnus* crop while 7N:6P:17K was applied at 2.7 kg ha^{-1} to site 2 at Wexford also at the establishment stage. However, it is important to note that Kilkenny-based plants were 1.5 years old at the start of the study whereas the Wexford-based plants were 4 years old, a timeframe which also represents the time gap between when fertilisers were applied. It would have been possible to evaluate the soil condition and

nutrient availability at both sites by carrying out chemical analysis tests on the soil. As detailed in section 4.4, the Kilkenny site was tested but the Wexford was not tested as these were mature plantations at the start of the study. Soil sampling techniques, as outlined in the Methodology, could also impact negatively on the root systems of the established *O.hookeri* 'Sussex Silver' plants.

A further variable which was uncontrollable was the fact that the plantations were situated 60 km apart and the Wexford site was situated nearer to the coast. Even though both sites had a shelter belt installed to protect against the harshest weather elements, it is important to acknowledge that both plantations may have been exposed to very different climates.

6.3. **Average number of saleable single/sprays harvested from Kilkenny site after a 2-year pruning and harvesting regime.**

Figure 5.3 shows the average number of saleable stems of *O. hookeri* 'Sussex Silver' harvested following pruning in year 1 and year 2. Plants pruned to 200 mm in March of year 1 and 2 produced a higher yield of saleable stems per plant compared to those pruned to 200 mm in June. However, when plants are pruned to 500 mm in March of year 1 and 2, the average yield of saleable stems per plant is not increased compared to those pruned to 200 mm in June. No other research on the pruning of *Ozothamnus hookeri 'Sussex Silver'* in two subsequent years has been published. However, as *Ozothamnus diosmifolius* is pruned low to the ground by brush-cutter every year as part of the harvesting procedure in Australia (Carson 2012) and this does not impact negatively on yields of *O. diosmifolius* it would be interesting if the same results follow if *O. hookeri* was pruned the same way.

6.4. **Comparison of a 200 mm or 500 mm pruning regime at different times of the year, and over subsequent years.**

Figure 5.4 shows that in site 1 in Kilkenny, that plants of *O. hookeri* 'Sussex Silver' pruned in year 1 and year 2 produced a higher number of saleable stems compared to those pruned in year 1 only. Observations of the 9 year old plantation at site 3 in Kilmore Quay, Co. Wexford showed that unpruned plants become congested over time as a pruning regime would have removed older, less productive wood (Brickell, 1996). Irons (2009) observed that *O. rosmarinifolius* needs to be severely pruned back at an early age as plants become 'leggy' which may account for pruning in year 1 and year 2 of the study producing a higher yield of saleable single stems / sprays. Pruning also allows for better light penetration (Preese and Read, 1993), which is essential for growth of stems of *O.hookeri* 'Sussex Silver'.

6.5. **The influence of tip pruning on the production of single stems and spray stems**

Half the control group of *O. hookeri* 'Sussex Silver' plants from site 1 in Kilkenny and site 2 in Wexford were not tip pruned and half were tip pruned in August to investigate if tip pruning had an impact on production of more desirable spray stems than single stems. As these had not been previously pruned to 200 mm or 500 mm no previous pruning or harvesting had been carried out on this group. The results did not show a consistent return of sprays following tip pruning (Figure 5.5). However, on site 1 in Kilkenny more sprays were harvested than single stems following tip pruning in August. This was not consistent with site 2 in Wexford where more single stems were harvested following tip pruning in August. All these plants had not previously been pruned to 200 mm or 500mm. Little research on the effects of tip pruning on *Ozothamnus* spp. has occurred, however, the effect of tip pruning on other species has been examined. It has already been shown that the growing tip of a plant can inhibit the growth of shoots below due to apical dominance, and that pruning, which breaks this dominance, can encourage the growth of lateral branches (Macdonald, 1999). Tip pruning has been recommended for the growing of *Xanthostemon chrysanthus* for cut foliage production so as to encourage the growth of lateral shoots (Arthy and Bransgrove, 2003). According to personal conversations with Andy Whelton (Teagasc), spray stems of *O. hookeri* 'Sussex Silver' are more desirable than single stems to the end user but spray stems do not receive a higher financial return for the grower. Tip pruning is a labour intensive and time consuming undertaking therefore, tip pruning is not an economically worthwhile venture when Irish growers are cultivating *O. hookeri* 'Sussex Silver'.

6.6. **The effects of rejuvenation pruning on an existing mature *Ozothamnus* plantation were examined.**

Rejuvenation pruning to 1000mm on May 1st 2013 was carried out at site 3 in Kilmore Quay, Wexford. None of the plants had produced sufficient growth in the following December for harvesting. This experiment was not repeated in year 2. Research by Josiah *et al.* (2004) on pruning a variety of woody crops showed shrubs responded well to cutting to ground each winter but this depended on the species in question. Pruning plants low to the ground is recommended for some plants produced for cut foliage, such as *Eucalyptus*, which are coppiced or pollarded to retain juvenile foliage. However, severe pruning can result in plant losses (Forrest, 2002). Forrest (2002) noted that a pruning regime had a major impact on yield of *Eucalyptus* but severity of pruning, inadequate root establishment before pruning, and poor soil conditions can result in plant losses. Kerr (2007) recommends leaving side branches on this low framework for photosynthetic purposes. Beal *et al.* (2001) advises that some branches should be left to ensure continued photosynthesis for plant regrowth. Beal *et al.* (2001) also mentions that hard pruning of *O. diosmifolius* can lead to greater plant stress and slow regrowth. Further research into the effects of rejuvenation pruning of *O. hookeri* 'Sussex Silver' in alternate years is required. It has already been shown that hard pruning to 200 mm in June resulted in no harvested saleable stems in site 1 in Kilkenny the following December (Figure 5.3). However in year 2 on the Kilkenny site, the highest yield was harvested from *Ozothamnus hookeri* 'Sussex Silver' pruned to 200 mm in June showing that sufficient time is required for this plant to put on necessary growth between hard pruning and harvesting. Further research would show whether this result is replicated for rejuvenation pruning.

7. CONCLUSIONS AND FURTHER RESEARCH

This two year study of pruning regimes for *Ozothamnus hookeri* 'Sussex Silver' has shown the effects of different pruning timings and regimes on the yield of this cut foliage crop. The effects of tip-pruning in August on the type of stems produced and the impact of rejuvenation pruning on an existing mature *O. hookeri* 'Sussex Silver' plantation were also investigated.

The results indicated that higher yields of saleable single stems and sprays are produced when *O. hookeri* 'Sussex Silver' is pruned in March rather than in June, regardless of whether they are pruned to 200 mm or 500 mm. The younger plantation at site 1 in Kildalton College, Co. Kilkenny produced almost twice as many saleable stems as the older plantation in Kilmore Quay, Co. Wexford which would suggest that the age of *O. hookeri* 'Sussex Silver' plants impacts on the crop yield. However, it is possible that the difference in the yield of saleable stems obtained from site 1 compared to site 2 could be due to the impact of factors other than the age of the plantations. Yields of saleable stems / sprays harvested in year 1 and year 2 in site 1 in Kilkenny indicated that plants of *O. hookeri* 'Sussex Silver' benefited from pruning to 200 mm or pruning in March in two subsequent years. In order to produce more spray stems than single stems, which are more desirable to the buyer, tip pruning of stems in August was carried out on both sites. Results indicate that tip pruning did not consistently produce more sprays than single stems in either site and as tip pruning is highly labour intensive, tip pruning is not a worthwhile pruning regime to consider. Rejuvenation pruning which involved pruning the *O. hookeri* 'Sussex Silver' plant to a very low framework resulted in no harvest in the year of the experiment due to insufficient growth produced between pruning in June and harvesting in December

however, further research would be required to see if this type of pruning is beneficial in subsequent years.

Pruning of *O. hookeri* 'Sussex Silver' to 200 mm or 500 mm in March and June was carried out in Site 1 in Kilkenny and site 2 in Wexford in year 1 of the experiment. Pruning on half the plants of *O. hookeri* 'Sussex Silver' was carried out in year 2 on the Kilkenny site only. It would be beneficial to repeat this experiment on pruning regimes and pruning timing on the two sites in two or more subsequent years for comparison of results. Figure 5.4 showed that hard pruning of *O. hookeri* 'Sussex Silver' to 200 mm in June resulted in very low yields the following December but a significant yield in year 2 harvesting. Further research into the consequences of carrying out a pruning regime on *O. hookeri* 'Sussex Silver' every second year could also be of interest to the grower. Observations, by the author, on site 3 in Kilmore Quay in Wexford on a 9 year old plantation showed that older plants appeared to produce shorter stems of *O. hookeri* 'Sussex Silver' and not as many long, straight stems as favoured by the buyers of cut foliage. This observation was supported by anecdotal evidence from growers. Rejuvenation pruning could make these shrubs viable again. However, pruning to 1000 mm in August on site 3 in Wexford resulted in no stems being suitable for harvesting that year. Further research into the yields achieved in year 2 following rejuvenation pruning would show whether these plants benefit from hard pruning or should be replaced after 4-5 years, as is the case with *Ozothamnus diosmofolius* in Australia. Any increase in yield in year 2 following rejuvenation pruning would need to be offset against a lost in yield in year 1. As can be seen from Figure 4.5 curved stems were rejected from harvesting, as they are not acceptable to the buyer. These curved stems occurred on the outside of the *Ozothamnus hookeri* 'Sussex Silver' shrub. Investigation into whether planting these

plants closer together would reduce the number of curved stems could help increase the number of saleable stems harvested.

8. REFERENCES

Adams C.R., Bamford K.M.,**Early M.P.** (1999). Principles of Horticulture. 3rd ed. Oxford: Butterworth Heinemann.

An Foras Taluntais (1971). Horticulture, Research report 1971. Dublin: An Foras Taluntais.

Anon (1993). World trade in cut flowers, cut foliage and ornamental plants 1991, International Floriculture Trade Statistics 1993. Essex: Pathfast Publishing.

Anon (2001). San Marcos Growers. Available: http://www.smgrowers.com/products/plants/plantdisplay.asp?plant_id=2495. [Accessed 15th September 2011].

Anon (2006). Floriculture: A sector study. Vol:112. Export-Import Bank of India: Quest.

Anon (2011). The State of Queensland Department of Employment, Economic Development and Innovation. Available: http://www.dpi.qld.gov.au/26_12286.htm. [Accessed 16 Sept 2011].

Anon (2012). *Ozothamnus rosmarinifolius*, Kerosene bush. Available at: http://www.burncoose.co.uk/site/plants.cfm?pl_id=3070 [Accessed 15 Aug 2012].

Armitage A. (2003). Specialty cut flowers: the production of annuals, perennials, bulbs, and woody plants for fresh and dried cut flowers. London: Timber Press.

Arthy, J. and Bransgrove, K. (2003). New Foliage and cut flower species – commercial potential. Brisbane: Rural Industries Research and Development Corporation.

Beal, P., Carson, C., Turnbull, L., Forsberg, L., Lewis, L. (1996). Development of *Ozothamnus diosmifolia* as a cut flower crop. First Australian New Crop Conference. Redlands Research Station, Cleveland, 1996, **2**: 107-108.

Beal, P. and Turnbull, L. (1998). Ozothamnus and Cassinia species with potential for commercialization. Australia. *Acta Horticulture* (ISHS) **454**:147-156.

Beal, P., Carson, C., Turnbull, L., Forsberg, L. (2001). Rice flower production guidelines for growers. Queensland Government, Department of Primary Industries.

Bord Bia (2003). Amenity Profile, Market Intelligence, Dublin: Bord Bia, Irish Food Board.

Bord Bia (2010). Garden market purchasing 2009-2010, growing the success of Irish food and horticulture. Dublin: Bord Bia, Irish Food Board.

Bonarriva, J. (2003). USITC. Industry and Trade Summary, cut flowers. Washington: U.S. Trade Commission.

Brickell (1996). The Royal Horticultural Society, Pruning and Training. London: Dorling Kindersley.

Carpenter, P and Dana, M. (2001) Pruning ornamental trees and shrubs, available: http://www.hort.purdue.edu/ext/ho-4.pdf [Accessed 30 April 2015]

Central Statistics Office (2012). Central Statistics Office database. Available: http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/saveselections.asp [Accessed 25 June 2012]

Cline, M. (1994). The role of hormones in apical dominance. New approaches to an old problem in plant development. *Physiologia Plantarum*, **90:** 230–237

Collier, P. Short, I. Dorgan, J. (2004). 'Markets for non-wood forest products', Dublin: Coford.

Collins, J.F. & Verling, J.M. (1976). Soils of Agricultural and Horticultural College Farm, Kildalton, Piltown. Dublin: University College Dublin.

Costello, A. Whelton, A., Walsh, P., Kelly, J., Costello, J., Kelly, P. (2007). 'Forest Foliage', Coford Connects, Processing/Products No.6, 1-4

Costello, J. (2011). Forest Produce [Online], available: http://www.forestproduce.ie. [Accessed 15 Sept 2011].

Crossman, T. (2005). A study of cut flower production in Africa and South America to fins a position of unique advantage for the UK cut flower industry. Harborough: Nuffield Farming Scholarship Trust.

DIPP (2009). Cut flowers and foliage, a survey of the market for cut flowers and foliage in Denmark. Denmark: The Danish International Development Assistance, 13-33.

Economic Commission for Europe (1994). UN/ECE standards for cut flowers and cut foliage. Germany: ECE.

Ellis, C. (2007). Farm Management Systems for the cut flower and foliage industry. Available at: http://www.rirdc.gov.au/publications. [Accessed 16 Aug 2012].

ESSD (2004). Structure and dynamics of the European market for horticulture products and opportunities for SSA Exporters. Final Report. Africa: Agricultural trade facilitation study in Sub-Saharan Africa.

Evan, D. (1999). Wildflower and native plants. Australia: Rural Industries Research and Development Corporation. Available at: http://www.rirdc.gov.au/publications. [Accessed 17 Aug 2012].

Faragher J., Slater, T., Joyce, D., Williamson, V. (2002). Postharvest Handling of Australian Flowers. Australia: Department of Natural Resources and Environment.

Fletcher, R. (1996). The Australian New Crop Newsletter. Volume 5, available: http://www.newcrops.uq.edu.au/newslett/ncnl5111.htm. [Accessed 15 Sept 2011].

Flora Export. (2011). Flora Export S.G Israel. Available at: http://flora-sg.com/catalog.htm [Accessed 11 Aug 2012].

Forrest, M. (1991). Post-harvest treatment of cut foliage, *Acta Horticulture*, **298**:255-262.

Forrest, M. (2002). The performance of a *Eucalyptus gunnii* cut foliage plantation over 7 years, *Irish Journal of Agricultural and Food Research*, **41**:235-245.

Fraser, H. (1966). The Gardener's guide to pruning. West Sussex: Littlehampton Book Services Ltd.

Gast, K.L.B. (1997). Postharvest handling of fresh cut flowers and plant material. Commercial specialty cut flower production. Kansas State University.

Geisler, M. (2012). Floriculture Profile. Available at: http://www.agmrc.org/commodities__products/specialty_crops/floriculture_profile.cfm. [Accessed 25th June 2012].

Gilsenan, B. (1969). Horticulture and Forestry Division, Research report 1969. Dublin: An Foras Taluntais, 19-20.

Greer, L. and Dole, J.M. (2009). 'Woody cut stems for growers and florists', London: Timber Press, Inc.

Gollnow, B. (2002). Exporting cut flowers. Available at: http://www.dpi.nsw.gov.au/agriculture/horticulture/floriculture/industry/export. [Accessed 16 Sept 2011].

Gollnow, B., Faragher, J., Worrell, R., Turton, L., Joyce, D. (2010). Quality specifications for Australian wildflowers and revised manual of postharvest treatments for wildflowers. Brisbane: Rural Industries Research and Development Corporation.

Gonzalez, G. (2009) Cut flower minimum guidelines and standards. Florida: Association of floral importers of Florida.

Greenwood, P. (1997). Pest and diseases, the complete guide to preventing, identifying and treating plant problems. London: The Royal Horticultural Society.

Halevy, A.H., Shlomo, E., Shvartz, M. (2001). Environmental factors affecting flowering of rice flower (*Ozothamnus diosmifolius*). *Scientia* Horticulture **87** 303-309.

Hassan, F. (2005). Postharvest studies on some important flower crops. Published doctoral thesis. Corvinus University of Budapest.

Ingram, D., Vince-Prue, D., Gregory, P. (2002). Science and the garden, the scientific basis of horticultural practice. Blackwell Science Ltd.

Irons, J. (2009). A survey of cultivated *Ozothamnus*. Royal Horticultural Society, December 2009, **8** (4).

Keane, T. (1992). Irish Farming, Weather and Environment. Dublin: AGMET Group.

Kerr, D. (2007). Eucalyptus as cut foliage. Antrim: College of Agriculture, Food and Rural Enterprise.

James, R. (2004). Plantation silviculture, high pruning. Australia: Encyclopedia of Forest Sciences.

Jones, R. (2001). The caring of cut flowers, 2nd ed. Australia: Landlinks Press.

Josiah, S., Brott, H., Brandle, J.R. (2004). Producing woody floral products in a alleycropping system in Nebraska. *Hort technology* **14** (2).

Laws, N., (2005). Floriculture International, 'UN data: 2001 floriculture imports'. Available at: http://www.adf.gov/documents/tropicalflowerexportmarketliberia1714.pdf. [Accessed 16 Aug 2012].

Lim-Camacho, L. (2006). Australian native flowers in the Japanese market. Australia: The University of Queensland.

MacDonald, B. (1999). Practical woody plant propagation for nursery growers. 6th ed. Hong Kong: Timber Press.

Macnish, A.J, Simons, D.H, Joyce, D. Faragher, J. (2000). Responses of native Australian cut flowers to treatment with 1-methylcyclopropene and ethylene, *Hort Science* **35**, (2), 254-255

Met Eireann, (2012). The Irish Meteorological Service. Available from : http://www.met.ie/climate-ireland/climate-of-ireland.asp. [Accessed: 25th June 2012].

McIndoe, A. (2005). The Horticulture Gardener's Guide. Boston: Horticulture Publications.

Montagu, K.D., Kearney, D.E., Smith, R.G.B. (2002). The Biology and silviculture of pruning planted eucalyptus for clear wood production. Forest Ecology and Management. **179**: 1-13.

Murphy, R.F., Whelton, A., Campion, J. (1999). Eucalyptus foliage production. Dublin: Teagasc Kinsealy Research Centre.

Ngone, A. (2001). Guidelines for exporters of cut flowers to the European markets. London: Commonwealth Secretariat.

Nowak, J. and Rudnicki, R.M. (1990). Postharvest Handling and storage of cut flowers, florist greens and potted plants. Portland: Timber Press Inc.

O'Mahony, J. (2011). Plan for the development of the Irish cut foliage sector. Available: http://www.teagasc.ie/search/index.asp?q=cut foliage. [Accessed 15th March 2012]

Parker, C. (2011a). Australian native cut flower industry. Available: http://www.members.tripod.com/cqnativeflowers/cutflowers.htm. [Accessed 15th September 2011]

Parker, P. (2011b). The 2011 Import and Export market for cut flowers and foliage in Europe. Singapore: ICON Group Ltd.

Parker, P. (2011c). The world market for cut flowers and foliage: A 2011 Global Trade perspective. Singapore: ICON Group Ltd.

Pasternak, D. (1986). Developments of arid zone crops for the Negev Desert of Israel. *Journal of Arid Environments*. **11** p.23-27.

Plasmeijer, J. Yanai, C, (2009). Cut flowers and ornamental plants. International Trade Centre, Vol.M06:12.

Pollock, M. Griffiths, M. (2005). Royal Horticultural Society's Illustrated Dictionary of Gardening, London: Dorling Kindersley Ltd.

Preece. J and Read, P. (1993). The biology of horticulture, an introductory textbook. Philadelphia: John Wiley and Sons.

Robinson, (1996). 'The cut foliage enterprise', Irish Farmers Journal, 20 Jan, 24-25.

Schilling, T. (2005). *Ozothamnus rosmarinifolius* and its hybrids. *The Plantsman*, **4**, (3): 142-145.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff (2012). Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Shannon, B. (2009). Sustainable production technologies for the cut flower industry. Department of Education, Employment and Workplace Relations, Australian Government.

Slater, A and Allen, A. (1994). Selection and evaluation of *Ozothamnus obcordatus* and *Chrysocephalum semipapposum* as cut flowers. Australia: Institute for Horticultural Development.

Stamps, R.H., (1987). Major Florida cut foliage crops classified according to floral design and landscape usage. Florida Agricultural Experiment Station Journal series no. 8517.

Stamps, R.H., (1999). 'Foliage'. Floraculture International, June 1999, 27-29.

Stevens, A. (1998). Field grown cut flowers, a practical guide and sourcebook. 2nd ed. Edgerton: Avators World.

The Royal Horticultural Society, (1997). New Encyclopaedia of plant and flowers. London: Dorling Kindersley Limited.

United States Department of Agriculture, (2012). Floriculture crops 2011 summary. Available at: http://usda01.library.cornell.edu/usda/current/FlorCrop/FlorCrop-05-31-2012.pdf [Accessed 10 Aug 2012].

University of Florida, (2006). Cut Foliage: Production and Postharvest. Available at: http://smallfarms.ifas.ufl.edu/crops/flowers_and_foliage/index.html. [Accessed: 13 Sept 2011].

Whelton, A. (2006). 'Outdoor cut foliage production' Fact Sheet no.27, Galway: Teagasc.

Whelton, A. (2013a) Cut foliage production fact sheet, available at: http://www.teagasc.ie/publications/2012/1153/CutFoliageProductionweb.pdf. [Accessed May 3rd 2015].

Whelton, A. (2013b) *Ozothamnus* Technical Notes, available at http://www.teagasc.ie/publications/2013/2963/Ozothamnus.pdf [Accessed 1 May 2015].

Whelton, A. (2013c) *Eucalyptus* fact sheet, available at: http://www.teagasc.ie/publications/2012/1154/EucalyptusCutFoliageFactsheet.pdf [Accessed 1st May 2015].

Whelton, A. (2013d) *Senecio* for cut foliage, available at:

http://www.teagasc.ie/publications/2013/2965/SenecioFactsheet.pdf [Accessed 1 May 2015].

Wirthensohn, M, and Sedgley, M. (1996). Production and postharvest treatment of cut stems of *Eucalyptus* L. Her. Foliage. *Hort Science* **31** (6): p.1007-1009.