A STUDY OF THE EFFECTS OF PRUNING AND DEHEADING ON THE FLOWERING BEHAVIOUR OF *LEUCOSPERMUM* CV. SCARLET RIBBON AND *LEUCOSPERMUM* SAXOSUM

By

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The undersigned certify that they have read, and recommended to the Department of Crop Science for acceptance, the thesis entitled:

A study of the effects of pruning and deheading on the flowering behaviour of *Leucospermum cv.* Scarlet Ribbon and *Leucospermum* Saxosum

Submitted by **GAUDENCIA TICHAIDZA MAHENGA** in partial fulfillment of the requirements of the degree of Master of Philosophy (Horticulture).

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ABSTRACT

Leucospermum plants have a relatively short flowering period and peak flowering periods often coincide with low prices on the export market. Two field trials were therefore carried out at Pinfields farm Ruwa, Zimbabwe from 2002 to 2004 to investigate the effect of two cultural practices, pruning and deheading, on the flowering behaviour of two *Leucospermum* cultivars: Scarlet Ribbon and Saxosum. The first trial investigated the effect of pruning and deheading two different aged plants (2½-3years 'old' and 1-1½ 'young') of Scarlet Ribbon. The second experiment compared the response to pruning and deheading of two cultivars, Scarlet Ribbon and Saxosum, on flowering time. Measurements taken in all experiments included the period from pruning to harvesting, the extension to harvest time after deheading of the primary inflorescence, length of harvested flowering stems, inflorescence diameter of harvested flowering stems, grading of stems and losses in harvest due to pruning and deheading. Pruning of plants was carried out at different times from January to July, including the control treatment (normal farmer practice) for both experiments. Deheading of the primary inflorescence bud was at 0-5 mm, 6-10 mm, and 15-20 mm and was compared with a control (disbudding all but the primary bud). Pruning and deheading treatments significantly ($P<0.05$) extended harvest time for all the experiments. The extension to harvest varied with pruning time, deheading diameter, age of plants and cultivar. Pruning early (Jan/Feb) and deheading early in the induced reproductive phase resulted in a longer extension to harvest time compared to late pruning (May/Jun and Jun/July). Old plants had a shorter extension to harvest time compared to young plants. Harvesting of flowering stems post pruning was earlier for old plants by 2 weeks compared to young plants of Scarlet Ribbon. The significant ($P<0.05$) age x deheading diameter interaction resulted in long stems for old plants for all the deheading diameter treatments. Quality and quantity of stems and earnings from old plants were higher than for young plants. Pruning and deheading old plants of Scarlet Ribbon resulted in the least losses (10%) with regards to harvested stems compared to young plants (12.5%). Results indicate the ability of old plants with more plant matter to effectively resume growth and development to the flowering stage due to more assimilates facilitating this compared to young plants. When the two cultivars were compared, Scarlet Ribbon had a longer extension to harvest time than Saxosum. The result was similar when comparing the extension to harvest after deheading. The effects of pruning and deheading are cultivar specific as was demonstrated in this study. Although in Zimbabwe both Scarlet Ribbon and Saxosum are regarded as early flowering in the industry, Saxosum was harvested much earlier by 2.4 weeks than Scarlet Ribbon. Flowering and harvest period for Saxosum was shorter (5 months) compared to Scarlet Ribbon (7 months). In addition, a difference in flower head complexity resulted in early flowering for Saxosum. Saxosum is naturally multiheaded thus exerting less apical dominance through correlative inhibition of the secondary bud. The secondary bud resumed growth and flowered earlier than Scarlet Ribbon, which produces solitary inflorescence naturally. Scarlet Ribbon produced longer stems than Saxosum. The significant ($P<0.05$) cultivar x pruning time interaction showed a reduction in stem length for Saxosum. There was no significant difference to the inflorescence diameter of harvested stems for both cultivars. Losses in harvest were high for Saxosum (16.7%) than for Scarlet Ribbon (12.5%) when the plants were deheaded at 6-10 mm. Deheading late in the season from late July to September at a diameter of 15-20 mm produced the highest losses. Deheading resulted in different quality stems for the two cultivars however, the stems were of marketable quality. Scarlet Ribbon produced more flowering stems of higher quality and correspondingly high earnings compared to Saxosum. Scarlet Ribbon had the most favourable response to pruning and deheading on flowering time compared to Saxosum. It is therefore recommended that pruning be done early (Jan/Feb and Mar/Apr) and deheading at 0-20 mm diameters up to mid July as harvest period can be extended up to November for

Scarlet Ribbon with good quality stems, earnings and minimal losses in the Ruwa farming area. Old plants respond better to pruning and deheading than young plants.

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CHAPTER 1

1.0 INTRODUCTION

Members of the *Proteaceae* family are commonly referred to as proteas. The family originates mainly in southern continents (Leonhardt and Criley, 1999). The main centres of occurrence are Africa, especially South Africa and Australia with a few outliers present in South America and New Zealand (Salinger, 1985). The *Proteaceae* family comprises of over 60 genera (Leonhardt and Criley, 1999). However plants from about 12 genera are grown or used for cutflowers or foliage (Salinger, 1985). Proteas are always woody and perennial. A unique characteristic of the family is the presence of proteoid roots. These are dense clusters of hairy rootlets that form a 2-5 cm thick mat at the soil surface (Leonhardt and Criley, 1999). This is essential for efficient nutrient uptake from soils with low nutrients where the *Proteaceae* evolved.

The family comprises some of the most beautiful and exotic looking flowers in the world. From a floral point of view the attraction is often in the bracts and coloured leaves, which surround the flowers (Salinger, 1985). The flowers have a relatively longer vase life compared to other cutflowers like roses. They also dry well and dried flowers provide an alternative outlet when there is a glut of fresh flowers on the market and for poorer quality material (Salinger, 1985).

Protea growing in Zimbabwe began in the early 1970s. The high level of interest in protea growing resulted in the formation of the Zimbabwe Protea Association (ZPA) in 1983. The ZPA represents the grower's interests with regards to the Horticultural Promotion Council (HPC), Government policies and Reserve Bank Regulations, research and general simulation/support of the industry (Percival, 2004). Commercial production of *Proteaceae* is mainly confined to the Eastern Highlands, Harare, Karoi, Norton, Darwendale, Makondi, Vumba (Zimflora, 2003). The flowers are grown as cutflowers mainly for export to the United Kingdom, Holland, Germany, Switzerland, France, Austria, Japan and the United States of America (Zimflora, 2003). Protea production not only creates employment, but also earns foreign currency for the country.

In deciding which proteas to grow, many growers in Zimbabwe have found that some cultivars 'choose' them (with respect to soil types and prevailing microclimate) rather than the other way round (Archer, 2000). The genera grown in Zimbabwe include mainly *Leucadendron*, *Leucospermum* (commonly known as pincushions), *Protea* and others. *Leucadendron* are grown for their attractive foliage and fruiting heads, while *Protea* and *Leucospermum* are grown for their flowers (Webb, 1997). A survey carried out by the ZPA indicated that, *Leucadendron* comprised 46%, *Leucospermum* 27%, *Protea* 10% and others (17%) of the protea produced in Zimbabwe (ZPA survey, 2003).

While protea growers in parts of the world like Australia and New Zealand concentrate on a single cultivar, Zimbabwean growers tend to grow at least three different cultivars from the genera indicated, as a hedge against changing market trends (Archer, 2000). The genera are grown from rooted cuttings, as seedlings of *Leucospermum* and *Protea* are variable and will not produce the consistent quality that the market demands (Archer, 2000). Cultivars are usually selected from the South African genera although some have been sourced from Australia and New Zealand.

The *Leucospermum* genus, which is grown commercially from rooted stem cuttings, is popular amongst Zimbabwean growers due to its widespread availability. In addition, the genus has a wide variety of species giving a wide choice to farmers. *Leucospermum* are evergreen woody perennials with growth habits that range from small trees to spreading shrubs to prostrate ground covers (Leonhardt and Criley, 1999). Although the genus is popular amongst growers, one of the problems in the marketing of the *Leucospermum* crop is the relatively short flowering duration (Jacobs and Honeyborne, 1978) in comparison to other cutflowers like marigolds and poppies (Ireland, 2008).

In Zimbabwe, the main flowering period for these cut flowers is from April to October with a peak in August/September (Archer, 2000) depending on cultivar and growing area. These flowering periods present problems, as the cultivars are at peak production during summer months in most of Europe. During those periods, there is a wide variety of locally produced non protea flowers at cheap prices resulting in a glut on the market and therefore a decrease in selling price not only for *Leucospermum* but of all cut flowers. Because of this, flowering in *Leucospermum* has been studied and manipulated to enable prediction and control of the process to produce flowering stems during the off-season period. If the flowering period of *Leucospermum* could be delayed or if the plants were made to flower earlier, the harvest could be spread over several more months. This would increase profitability, as production would be targeted for off peak production in niche markets.

Control of flowering comprises of both stimulation and prevention of inflorescence development (Wellensiek, 1961). Certain cultural practices in the production of pincushions have been employed to delay flowering. Pruning and deheading are some of the practices that could be employed to achieve this. Pruning entails the cutting back of both flowering and non-flowering shoots (pruning and harvesting are usually synonymous because a substantial amount of plant matter is removed during harvesting) and timely pruning strongly influences flowering time (Gollnow, 1995). Deheading involves physically removing the primary bud by hand or by use of chemicals such as ethephon. The initial or primary flower head inhibits the development of other buds into flowers (Jacobs and Honeyborne, 1978). The removal of the primary bud promotes the development of secondary buds into flowers.

The cut flower harvesting period can be delayed by deactivation of the primary inflorescence bud (Brits, 1986). The term deheading has at times been confused with disbudding. The latter refers to the removal of surplus lateral buds and is carried out several times a month depending on the cultivar (Kroll, 1995). Deheading has been successful in delaying flowering of *Leucospermum cv*. Golden Star in South Africa (Jacobs and Honey-borne, 1978). By removing the primary flower head, one or more buds situated proximally to the primary flower head is released from inhibition and develops into an inflorescence much later than the primary inflorescence, which develops and flowers earlier (Jacobs and Honeyborne, 1978).

An understanding of flower induction, initiation and development is necessary to determine if flowering over a longer period can be achieved. It is envisaged that by combining these cultural practices, the flowering period can be manipulated to suit the grower's needs. While attempting to manipulate the flowering time, the quality of the flowers has to conform to the prevailing market requirements for it to be profitable. Cultural practices therefore provide opportunities to manipulate the timing of flowering, providing an opportunity for farmers to increase their earnings by selling flowers during the off-season period.

1.1 Aim of Study

The overall aim of this study was to investigate the feasibility of using cultural practices such as pruning and deheading to manipulate the timing of flowering to off-season periods, thereby increasing earnings from the sale of flowers.

1.1.1 Specific Objectives

- To determine whether age of plant affects the flowering response to pruning and deheading of *L* cv. Scarlet Ribbon.
- To investigate the response to pruning and deheading of *L* cv. Scarlet Ribbon and *L*. Saxosum on the flowering time.

1.2 Hypotheses

The hypotheses tested were as follows:

- Age of plant affects the flowering response to pruning and deheading in *L* cv. Scarlet Ribbon and quality of harvested stems.
- *L* cv. Scarlet Ribbon and *L*. Saxosum cutlivars respond differently to pruning and deheading.

CHAPTER 2

LITERATURE REVIEW

2.1 Characteristics of the *Leucospermum* Genus

Leucospermum species are evergreen woody perennials with growth habits that range from small trees to spreading shrubs to prostrate ground cover (Leonhardt and Criley, 1999). In Zimbabwe, the main *Leucospermum* harvested for export are *L. glabrum x tottum cv Scarlet Ribbon*, *L. saxosum*, *L. lineare 'Diadem' x glabrum cv Tango, L. cordifolium 'Yellow Bird' x patersonii cv High Gold* and *L. lineare*. Rouke (1972) and Jacobs (1985) describe the inflorescence as a capitulum that develops from an axillary rather than a terminal bud, but that appears to rise distally.

The inflorescence may be solitary, as in *L cordifolium* and *L vestitum*, or in clusters (conflorescences) as in *L tottum* and *L mundii* (Leonhardt and Criley, 1999). The attraction of the flower heads lies in the colour of the extended styles and the coloured perianth segments at their base (Salinger, 1985). The perianth curls back to display a prominent style; the striking appearance of the whole inflorescence of open flowers resembles a pincushion (Leonhardt and Criley, 1999).

Leucospermum plants grow vegetatively during spring and summer. Reproductive development commences in autumn after shoot extension growth has terminated and the inflorescences develop during winter (Jacobs *et al*., 1986). Naturally the stems are short and curved. Horticulturists have developed management practices to improve stem length and straightness for their use as cut flowers (Leonhardt and Criley, 1999). *Leucospermum* grown in Zimbabwe are available in the following main colours: orange, red salmon pink and yellow and the flowering time is between April and October with a peak in August/ September (Archer, 2000).

2.2 Establishing a *Leucospermum* Plantation

The only micro-climatic barrier to establishing a successful plantation in Zimbabwe is a locality prone to severe frosts. In areas that are frost prone, the grower should attempt to establish the plantation in spring rather than in autumn to enable as much growth as possible before the frosts can be expected (Archer, 2000). Mature plants can tolerate slight frosts of short duration. *Leucospermum*, like other proteas, are generally very drought tolerant but it is vital that the soil is kept wet in the first weeks of establishment. In very hot areas, the metabolism of the plants is speeded up and while plants come into bearing sooner, their reproductive life is usually reduced (Archer, 2000).

2.3 Propagation and Growing *Leucospermum*

Although *Leucospermum* species can be grown from seed or cuttings, propagation of commercial cultivars of *Leucospermum* is by using rooted stem cuttings (Leonhardt and Criley, 1999). While cuttings can be rooted at almost any physiological stage of development, a preferred cutting is the recently matured new growth, known as a semi-hardwood cutting (Malan, 1992). Cutting material is normally gathered after shoot growth terminates in autumn. Cultivars are usually selected from the South African genera, which include *Leucospermum*, *Leucadendron*, *Protea* and others, although some like *Waratah*, *Telopea* and *Banksia* have been sourced from Australia and New Zealand. The advantage of using vegetatively propagated plant material is that there could be saleable flowers after the first year (Parvin, 1979) thereby maximizing returns for the grower. In comparison, seedlings tend to grow slowly and will produce a flower from the second year onwards. In addition, seedlings are variable and will not produce the consistent quality that the market demands (Archer, 2000).

Although *Leucospermum* and other proteas can be grown on flat ground, they perform best when planted on ridges. The advantages of using ridges according to Archer (2000) are:

i) ridges are constructed using topsoil and effectively provide the plant with a double layer of topsoil and consequently extra nutrients.

ii) the protea roots are in well-aerated soil.

iii) water drainage is enhanced

2.4 Flower Initiation and Development in *Leucospermum*

Plants grow and flower at different periods of time in response to the environment in fieldproduced *Protea* (Dupee and Goodwin, 1990). The process of flowering requires the vegetative meristem (buds) to change into a reproductive meristem (Saupe, 2002). The transition to flowering is one of the major changes that a plant makes during its life cycle. The transition must take place at a time that will ensure maximal reproductive success. To meet these needs a plant is able to interpret important endogenous and environmental cues, such as changes in plant hormones levels, and seasonable temperature and photoperiod changes (Wikipedia, 2008).

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The process of flowering in the *Protea* genus is dependent on a number of factors, which influence the growth, and development of root systems, vegetative shoots and flowering stems (Dupee and Goodwin, 1990). In *Leucospermum*, flowering is dependent on photoperiodic changes. *Leucospermum* are short day plants. Evidence for the short day requirements of *Leucospermum* for flower initiation come from experiments using artificial lighting (Malan and Jacobs, 1987; Malan and Jacobs, 1990). Long days were simulated by continuous incandescent lighting or night breaks and prevented flowering. The short day response is quantitative and the critical daylength and number of inductive days needed for flower initiation varies between species.

The inflorescence develops from a distal axillary bud, but appears to be borne terminally. Floret differentiation is normally completed by early winter, and a rapid enlargement phase follows leading to anthesis in late winter or early spring (Crily *et al.*, 1990). The development of the inflorescence was divided into four stages (Napier *et al*., 1986):

i) during the pre-floret stage peduncular bracts are formed and dry mass accumulation is low;

ii) the growth rate remains slow during the floret initiation stage; basal florets develop first;

iii) the floret differentiation phase lasts about two months during which a rapid accumulation in dry mass occurs;

iv) organ development is completed in the floret enlargement phase, and the rapid increase in dry mass continues to anthesis.

2.4.1 Development of the Secondary Inflorescence

The developing primary inflorescence correlatively inhibits other axillary buds from developing (Jacobs 1983, 1985). The degree of inhibition of the axillary buds depends on its position on the shoot. The first 6-10 axillary buds immediately below the developing inflorescence are only partially inhibited since they develop to about 5mm in diameter. Floret differentiation in these buds has progressed to the stage where the perianth initials are visible.

They are buds referred to as secondary flower buds. Buds lower down on the flowering shoot show no signs of development and are apparently inhibited (Jacobs *et al*., 1986).

The increasing suppression of axillary bud development and the resulting decrease in morphological development of inhibited buds further away from the most dominant axillary position suggests a dominance gradient. The longer the distance from the primary inflorescence, the stronger the dominance (Malan *et al*., 1994). It seems that it is not the IAA concentration of a single organ or its inherent ability to export IAA, which is responsible for the inhibition (Malan *et al*., 1994). IAA apparently diffuses from all developing buds. As active meristems are the source of plant growth substances (Salisbury and Marinos, 1985), and the buds closer to the primary inflorescence are physiologically more active, the level of IAA moving basipetally in the shoot may be higher further down the shoot. Thus it may rather be the total amount of IAA moving in the shoot (Lim and Tamas, 1989), which is possibly related to the IAA transport ability of the shoot (Brenner *et al*., 1987), that determines the extent of auto inhibition of IAA export from the inhibited organ (Bangerth, 1989; Malan *et al*., 1994).

2.5 Importance of Quality in Protea Flowers

Growing proteas is a long-term investment and potential growers need to take various factors into consideration before embarking on such a venture. In cutflower production, not only is the number of flowers produced per hectare or per square metre important, but also the quality of the flowers and the time of harvest (Hettasch *et al*., 1997). The productive life of a protea plant can vary from three to fifteen years or more with seven to ten years being the average (Archer, 2000). It is imperative therefore to lay down a good foundation from establishing the plants to harvesting and marketing them. Returns per hectare will vary considerably depending on the age of plants, planting densities, management skills and market trends (Archer, 2000).

Proteas grown for export to the European cutflower market must be cultivated with emphasis on quality and time of production (Gerber *et al*., 1995). Salinger (1985) has laid down the following criteria for marketable *Proteaceae*, which growers have to take into consideration when producing these flowers:

- Long straight stems
- Clear bright colours
- Prominent terminal blooms
- Good packing and travelling properties
- Good lasting ability with colour retention and market appeal.

In Zimbabwe growers tend to follow these general criteria, although the exporting company provides extra guidelines which growers use when preparing their produce for export, as listed in Appendix A.

2.6 Basic Principles of Pruning

Pruning is one of the most important cultural practices for maintaining woody plants, including ornamental trees and shrubs, fruits and nuts (Wade and Westerfield, 1999). Pruning involves the selective removal of specific plant parts for the benefit of the entire plant. While pruning usually involves the removal of branches it can include removal of roots, seedpods, or flower buds (Evans, 2003). It involves both art and science: art in making the pruning cuts properly and science in knowing how and when to prune for maximum benefits (Wade and Westerfield, 1999).

2.6.1 Plant Responses to Pruning

Pruning is an invigorating process for the plant and a basic understanding of how a plant responds to pruning is essential for one to achieve the desired objective. The terminal vegetative bud on a shoot produces a hormone (auxin) that inhibits the development of lateral buds alongside the shoot. When the terminal vegetative bud is removed, the lateral buds near the cut become active and grow (Evans, 2003). Wade and Westerfield, (1999) also report that by removing the apex, pruning temporarily interrupts apical dominance and stimulates the growth of lateral buds into shoots.

Pruning also reduces the size of the above ground portion of the plant in relation to the root system. As a result, the undisturbed root system services a smaller number of shoots and buds. The relative uptake of water and nutrients by the remaining shoots and buds increases, and a flush of growth (re-growth) occurs (Wade and Westerfield, 1999). The effects of pruning in plants will differ according to species, growth habit and desired effect by the grower. Johnson (2006) reports that the best blooms are usually produced on vigorous plants and when camellias are pruned, growth is more vigorous and blooms are often larger.

2.6.2 Types of Pruning

Five basic techniques are used for pruning shrubs: pinching, heading back, thinning, renewal pruning and shearing (Evans, 2003). Some plants require more than one method, but good pruning is usually a combination of several methods (Evans, 2003). The types of pruning are briefly described as follows:

Pinching - this involves the removal of the terminal portion of a succulent, green shoot before it becomes woody and firm. This type of pruning is common in roses and chrysanthemums.

Heading back – this involves removing the terminal portion of a woody branch by cutting it back to a healthy bud or branch. This type of pruning is practiced in proteas. Heading back will stimulate shoot growth below the cut thus making the plant denser (Evans, 2003).

Thinning – this is the least conspicuous method of pruning and results in a more open plant without stimulating excessive new growth. Plants pruned by the thinning method include crape myrtle (*Lagerstroemia indica*), magnolia (*Magnolia cylindrica*), viburnum (*Virburnum dentutum*), spirea (*Spiraea japonica*), smoketree (*Cotinus obovatus*) and lilac (*Syringa vulgaris*) (Evans, 2003).

Renewal Pruning (rejuvenation) – this method entails removing the oldest branches of a shrub by pruning them near the ground, leaving only the younger, more vigorous branches which may also be cut back. Examples of plants pruned this way include abelia (*Abelia chinesis*), deutzia (*Deutzia crenata*), forsythia (*Forsythia onata*), mockorange (*Philadelphus delavayi*), spirea, weigela and lignotuberous varieties of protea (Evans, 2003).

Shearing – this involves cutting the terminal of most shoots with shearing of hedge clippers. This method should not be used on foundation plants but should be restricted to creating a formal hedge (Evans, 2003).

2.7 Pruning of *Proteaceae*

Pruning in all *Proteaceae* is essential for optimum growth and flower yield. Pruning entails the cutting back of both flowering and non-flowering shoots and is done using sharp secateurs. The secateurs must be disinfected regularly with a biocide such as sodium hypochlorite to avoid transmission of diseases (Webb, 1997). Several fungi can cause dieback from pruning wounds as such, pruning during wet weather should be avoided to minimise the risk of infection (Gollnow, 1995).

Pruning of *Proteaceae* breaks apical dominance, resulting in growth of vegetative shoots from lateral buds, which elongate by successive growth flushes (Gerber *et al.*, 1995). Many of the *Proteaceae* benefit markedly from a regular yearly prune (Matthews, 1993). As listed by Oertel and Oertel, (2001), there are reasons why pruning is essential in protea production. These include:

- To lengthen the productive lifespan by cutting back from time to time.
- To adjust the shape of the bush to provide more or better flower- yielding branches
- To remove diseased branches before the infection spreads to other parts of that plant or other bushes.

The degree and severity of pruning will vary according to the age of the plant and with the species (Matthews, 1993). The time of pruning depends on the grower's choices and preferences. Pruning should be carried out at times that best complement the growth characteristics and flowering trends desired (Wade and Westerfield, 1999). The following are some reasons listed by Oertel and Oertel (2001) as the best times to prune:

- just before the plant undergoes its growth spurt;
- as part of cutting the flowers (harvesting the flowers);

- during the early stages of budding, when the number of buds present is reduced by removal of those that look weak and have short stems;
- anytime when there is disease encroachment or should there be a trend the farmer does not want to continue.

Pruning in the different protea genera will differ and can be manipulated to attain certain effects that the grower may desire. In the genus *Protea* for instance, pruning has been done at different times of the year to achieve various objectives. Pruning *Protea cv.* Carnival in spring induced a biennial bearing pattern while pruning in autumn induced an annual bearing pattern (Hettasch *et al*., 1997). *Leucadendron* are normally tip pruned to promote side shoot development, as is the case with some *Protea* (Gollnow, 1995). Work done in Israel by Wolfson *et al*. (2001) showed that soft pinching (removal of the terminal portion of a succulent, shoot before it becomes woody and firm) of *Leucadendron* cv. Safari Sunset stems enhanced branching and increased the number of export quality stems per plant. However, the timing of pinching is crucial for obtaining large numbers and best quality of the cut branches.

In *Leucospermum*, both manual and chemical pruning can be used as a practical means of extending the harvesting period (Brits, 1986). The standard for pruning *Leucospermum* after each flowering season in South Africa is to leave a maximum of six bearers in year one, 12 to 16 bearers in year two and not > 20 to 24 in subsequent years (Blomerus *et al*., 1998). In Zimbabwe, growers leave up to 50 bearers in some cultivars. It is recommended that farmers prune a third of the foliage of the plant at a time as severe pruning usually affects subsequent plant growth and flowering may be restricted for one or two years (Webb, 1997) and may even kill the plant if done too hard (Gollnow 1995).

2.7.1 Pruning Plants With Lignotubers

Some protea species have a large swelling of the trunk/root just under or at the soil surface called a lignotuber (Oertel, 2001). This is common in the *Protea* genus and in some species in the *Leucospermum* genus. The lignotuber acts as an underground trunk and is an adaptation to surviving fire or severe physical damage. The lignotuber has dormant buds that shoot after fire or drastic pruning of the plant (Oertel, 2001). Plants with lignotubers have a longer life span than those without and should be treated differently when pruning. Heavy pruning, which is removing all the branches by pruning them off at ground level every 5-20 years, will rejuvenate any plant species with a lignotuber (Protea Atlas Project, 2002). In these plants, flowers should be cut with as long a stem as possible (right down to the root stock) in order to stimulate new buds to grow (Protea Atlas Project, 2002).

2.8 Principles of Deheading and Disbudding

Bud removal on plants can either be through deheading or disbudding. Deheading involves physically removing the primary bud by hand or by use of chemicals such as ethephon (Jacobs and Honeyborne, 1978). Disbudding refers to the removal of surplus lateral buds and is carried out several times a month depending on the cultivar (Kroll, 1995). In addition the timing of bud removal is critical, as deheading and disbudding too early or late in a season will not delay flowering time.

The bud removal type used depends on the plant species and desired effect. The removal of flower buds concentrates the plant's energy on the development of fewer flowers (Virginia Camellia Society, 2004). In most cut flowers, both deheading and disbudding are practiced. In pot chrysanthemums (Yoder Brothers Inc, 2006) and roses (Sagers, 2006), disbudding is done to improve the size and quality of the flower. All lateral buds are removed and only the terminal bud is allowed to remain and develop on each stem. On trees and some bushes, disbudding is most suitable. In young avocado trees pinching and disbudding is generally necessary to suppress the extension of the shoots that interfere with the uniformity of growth and regularity in the formation of the future tree (Smakel, 2006).

2.8.1 Deheading in *Leucospermum*

After shoot growth cessation, a number of distal axillary buds start developing. One of these buds develops faster, attains dominance over others and develops into a solitary inflorescence. This solitary inflorescence is referred to as the primary inflorescence (Malan *et al*., 1994). Three to eight buds surrounding, but mostly below, the primary inflorescence develop to the floret initiation phase and are referred to as secondary inflorescences. When these buds reach about 5mm in diameter, their development stops, due to correlative inhibition by the primary inflorescence (Malan *et al.*, 1994). However, upon removal of the primary flower head, one or more buds situated proximally to the primary flower head is released from inhibition and develops into an inflorescence much later than the primary inflorescence which develops and flowers earlier (Jacobs and Honeyborne, 1978).

The degree of inhibition of an axillary buds depends on its position on the shoot (Jacobs *et al*., 1986). It is this aspect that forms the basis of delaying flowering by removal of the primary inflorescence. If the first flower to develop is removed, a second will take its place. Development of the secondary bud is slower initially, however upon deheading, the secondary bud then leads to production of an inflorescence at a much later time. By removing flower buds (deheading) before normal flowering, it is possible to delay flowering in *Leucospermum* by up to two months without weakening the plant (Protea Atlas Project, 2002).

The characteristic of being able to produce multiple flowers does present the opportunity to better distribute the flowering season or work load, of a specific variety (Malan and le Roux, 1996). The farmer can plan for the best time to disbud, with regards to prices on the market as well as managing produce at peak periods. Normally, the first flower to develop will prevent further flowers from developing, but on very strong shoots, more than one flower will often develop. This is natural in species like *L. erubescense* and *L. saxosum* and flowers are marketed with more than one inflorescence (Malan and le Roux, 1996)

Growers in Zimbabwe tend to concentrate on the development and flowering of the primary bud and will disbud the secondary and any other buds that may develop to get a saleable stem. Deheading the primary buds and leaving the secondary buds could extend flowering in pincushions. However, late treatment can cause loss of yield through poor resumption of secondary bud development (Brits, 1986).

2.8.2 Methods of Deheading

Deheading has normally been done manually; however, this is considered too laborious for commercial practice (Brits, 1977). As such, research has been carried out to find a suitable chemical pruning agent. Work done by Brits (1977) on *L. cordifolium* showed that ethephon sprayed at concentrations ranging from 250-2000 mg/l on primary buds resulted in the abrupt cessation in development of the primary bud with visible enlargement of secondary buds six weeks after spraying. The period of delay in flowering of the secondary buds depended on the stage of primary bud development at which ethephon was applied.

Research has also been carried out to try and delay flowering using growth regulators. Dupee and Godwin (1990) carried out trials using Grocel GA_3, cytokinin, benzyl aminopurine, bonzi and Pro-Gibb. The primary buds of some stems were removed while some of the stems were left to flower naturally. The growth regulators were sprayed on *Leucospermum cordifolium* shoots with single dominant flower buds. Dupee and Goodwin (1990) observed that although both cytokinin and ProGibb applied to flower buds extended flowering duration by one to three weeks, and disbudding the primary bud resulted in the most consistent delay in flowering by two to three weeks, but was less effective as the spring temperature increased.

2.8.3 Factors to Consider When Deheading *Leucospermum*

Malan and le Roux (1996) have listed some factors to consider when deheading *Leucospermum* species:

- Not all cultivars respond similarly to the deheading treatment and early cultivars respond better.
- If a shoot bears two buds of similar size at the time of deheading, the treatment will not be effective unless both buds are removed.
- Deheading too late will result in at least 20% crop loss as a result of shoot growth instead of flower development.
- Weak shoots do not respond well to deheading, as they tend not to form the secondary flower even if disbudded early.

In pot chrysanthemums, late deheading reduces flower size, slows down the crop and may lessen the intensity of flower colour (Yoder Brothers Inc, 2006).

CHAPTER 3

GENERAL MATERIALS AND METHODS

3.1 Characteristics of Research Site

The study was carried out from 2002 to 2004 at Pinfields, a commercial farm in Ruwa, which is about 40 km east of Harare. Ruwa lies in Natural Region IIa at an altitude of 1585 m above sea level and the area receives a mean annual rainfall of 700-1050 mm, which mainly falls during summer (October-March). The soil type on the farm is sandy loam derived from granite. The soil is classified according to the South African Binomial Soil classification system (MacVicar and Co-workers, 1991) as having a hutton ortchic A-horizon with a clay content of less than 5% and a red apedal B-horizon with a clay content of 25%. Prior to growing *Leucospermum* cultivars, the farmer practiced a tobacco and Katambora Rhodes grass rotation for over 20 years after which the land lay fallow for two years.

Weather conditions over the study period are as shown in Fig 3.1 and 3.2. The highest temperature for the study period was 29.6^{o}C and was recorded in November 2003 while the lowest temperature was 5.4^{o}C, which was recorded in July 2003 (Fig 3.1). Fig 3.2 shows the monthly rainfall totals and monthly relative humidity for the study period. Season 1 had (474.2 mm) a lower rainfall total than season 2 (737.2 mm). The highest monthly total was 274.4 mm, which was recorded in March 2003. Rainfall occurred during the hot summer months. Relative humidity was also high during the summer and low in winter. High relative humidity was recorded in months with high monthly rainfall totals for each year (Fig 3.2).

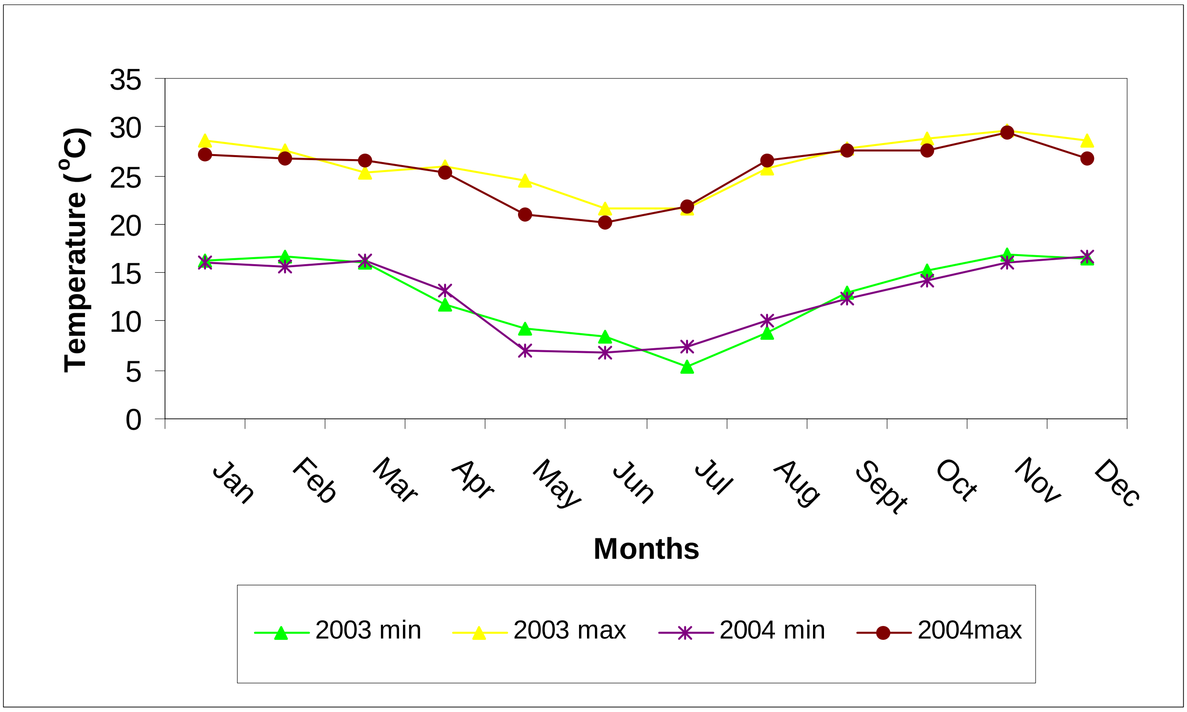


Fig 3.1 Mean monthly max and min temperature for Pinfields farm, Ruwa, Zimbabwe for the 2003 & 2004 production periods. (Source: Department of Meteorological Services Harare, 2005)

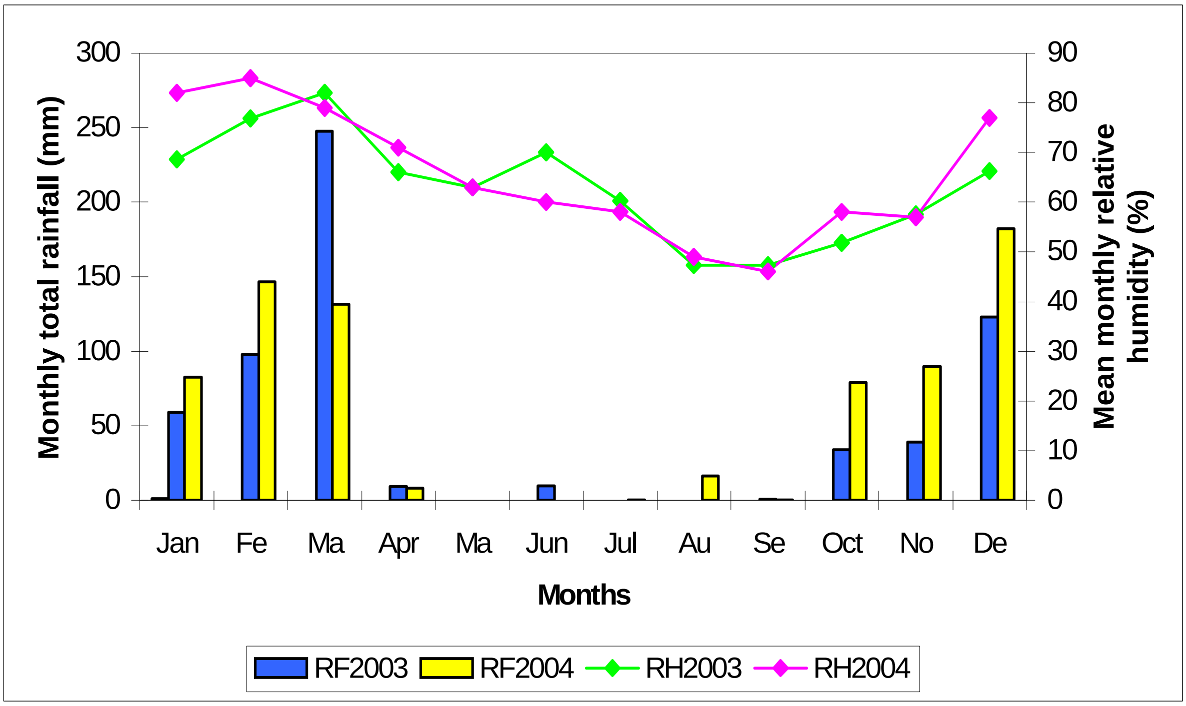


Fig 3.2 Total monthly rainfall and mean monthly relative humidity for Pinfields farm, Ruwa, Zimbabwe for the 2003 & 2004 production periods. (Source: Department of Meteorological Services Harare, 2005)

3.2 Description of Cultivars Used in the Study

The cultivars used in the study were selected on the basis that they were readily available for the trials on the farm and are among the top five of *Leucospermum* grown in the country.

Leucospermum cv. Scarlet Ribbon

Leucospermum cv. Scarlet Ribbon (common name Scarlet Ribbon) is a Southern African hybrid whose parentage is *L. glubrum* x *L. tottum*. It is an early flowering cultivar, which produces flowers that are pink salmon in colour and stems are marketed with a solitary inflorescence. The natural flowering time is April-October with peak production in June. Production of flowers in the first and second year is 5-8 stem per plant and 15-20 stems per plant respectively (Zimflora, 2003).

Leucospermum saxosum cv Saxosum

Leucospermum saxosum is a *Leucospermum* species indigenous to Zimbabwe and is grown as a cultivar. It is also early flowering, producing orange-red flowers. This cultivar tends to be multiheaded (i.e. produces 3-4 heads per stem) and this is acceptable on the market. The natural flowering time is April-September and peak period is June-July. Production of flowers in the first and second year is 2-5 stems per plant and about 15 stems per plant respectively (Zimflora, 2003).

Production figures and peak flowering periods depend on management practices carried out and also on growing area.

3.3 Experimental Procedures

At the commencement of the trials, the plants were already established in plantations on the farm. The plants were grown under drip irrigation at a plant spacing of 0.75 m within row and 1.8 m between rows. Selection and pegging of plants from the established plantations was based on uniformity in plant rows (i.e. healthy plants and no missing gaps within rows). Eight plants/bushes were used for each pruning treatment and two plants as borders between treatments. Complete single rows were borders between the blocks. When pruning began, the pruning date was noted. A third of the primary shoots were pruned per plant (normal farmer practice). Five stumps were labelled on the pruned plants and from these, new secondary lateral shoots grew.

The regrowth of the pruned plants occurred for over a year and shoot growth was monitored and recorded. Two plants in each pruning treatment (time of pruning) were used for the sub-treatments (deheading) the following year. Three vigorous and straight lateral shoots per stump were randomly selected and used for each of the deheading treatments. This involved removing the primary inflorescence, at the specified deheading diameter on each stem, and leaving one secondary bud (Fig 3.3). The different deheading diameter treatments were obtained by measuring the diameter using string and tape measure. All other buds were also removed and the date of deheading of the primary inflorescence was noted. For the control treatment, all buds except the primary inflorescence were removed

Potentially, 15 harvestable stems could be obtained per plant if the pruning and deheading were carried out successfully. However, some pruned and deheaded stems could fail to produce a flowering stem due to continued vegetative growth at the expense of floral growth, or abortion of the secondary flower buds could occur. The fertilizer applications, irrigation scheduling, and pest and weed control were carried out by the farmer as per recommendations and guidelines of the Zimbabwe Protea Association hand book (Archer, 2000).

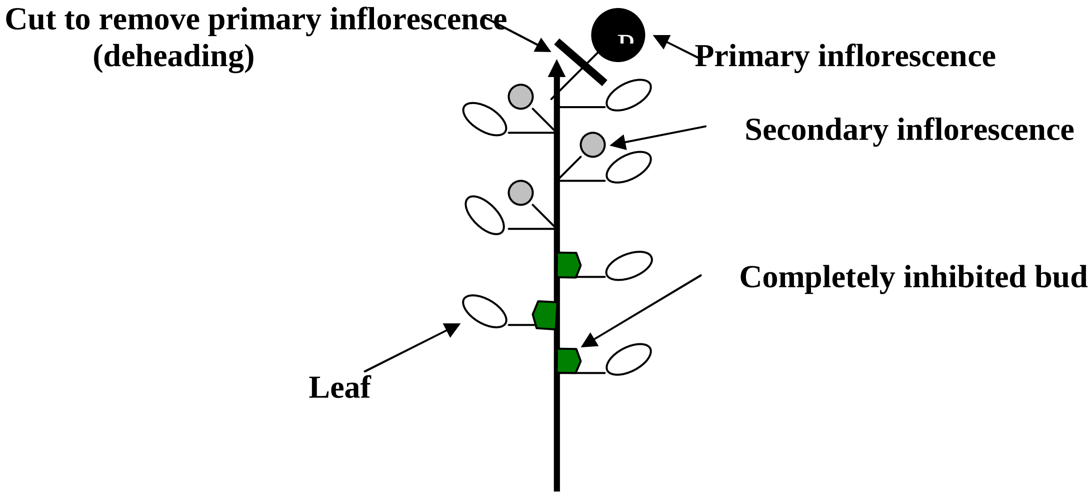


Fig 3.3 Schematic presentation of *Leucospermum* cv. Scarlet Ribbon shoot. The developmental stage represented is the onset of reproductive growth. Shoot growth has stopped, primary inflorescence is developing, and secondary flower buds are visible (Adapted from Jacobs, 1983)

3.4 Measurements

Secondary shoot growth and growth rate

Growth measurements of secondary shoots commenced three months after pruning until shoot growth cessation. Some shoots from early pruned plants (Jan/Feb) developed floral buds during the reproductive phase in the first year of growth. The buds were removed as the stems were too short (<10 cm) to be marketable and shoot growth measurements continued. Shoot growth was determined by measuring the length of the longest shoot from the base to the apex using a tape measure. This was done monthly per plant per pruning treatment. The increase in growth per month was calculated by subtracting the shoot length of the previous measurement date from current shoot length.

Flowering time

The number of days post- pruning to harvesting was recorded for each pruning treatment as well as the number of days it took for the secondary inflorescence to flower after deheading.

Harvesting

When the flowering stems reached the commercially harvestable stage, they were harvested. This involved picking and counting the number of flowering stems that exceeded 30cm in length and counting secondary stems that failed to flower per treatment. This was done weekly until the entire crop was harvested. The percentage crop loss (for secondary shoots that failed to produce an inflorescence after deheading) for each treatment was calculated using the following formula:

$$\text{Crop loss} = (x / n) \times 100\%$$

Whereby x = number of deheaded stems that failed to flower

n = total number of stems harvested (those that flowered and those that failed)

Quality of flowers

Quality of stems was determined through a grading system. The grading of the harvested stems was carried out at the packing shed. The stems were graded according to the Zimflora Co-op Ltd Recommended standards for export (Appendix A). Zimflora Co-op Ltd is a marketing company that exports 95% of *Proteaceae* grown in Zimbabwe. The farmer exports flowers through this marketing company. For the purposes of this study, the stems were then assigned grades according to the stem length on a 1-5 scale whereby:

Range of Length (cm)	Grade
70+	1
60 - 69	2
50 - 59	3
40 - 49	4
30 - 39	5

Harvested stems were also grouped and classified according to the range of the stem length. The diameter of inflorescence was measured using a tape measure during grading of the stems for each treatment.

CHAPTER 4

EFFECT OF AGE OF PLANT, PRUNING AND DEHEADING ON FLOWERING OF *LEUCOSPERMUM CV.* SCARLET RIBBON

4.1 Introduction

The vegetative and reproductive growth of *Leucospermum* follows a seasonal sequence. The plants grow vegetatively during late spring and summer (November to March in the Southern Hemisphere) and reproductive growth commences in autumn after shoot extension growth has terminated (Malan and Jacobs, 1990). In South Africa, the flower heads eventually develop in winter (Jacobs *et al*., 1986). In Zimbabwe, *Leucospermum* grow vegetatively from late spring to summer and produce flowers from winter to late spring.

The timing of pruning is important as it strongly influences flowering time (Gollnow, 1995) whereby plants can be manipulated to flower at a particular time. Over time and with an understanding of the flowering pattern through field observations of a particular crop, growers eventually develop a pruning pattern depending on their choices and preferences.

The degree and severity of pruning will vary according to the age of the plant and with the species (Matthews, 1993). Depending on cultivar, new plants are normally pruned 4-6 weeks after planting and establishment (Gollnow, 1995). This encourages branching of the plants (Archer, 2000). On mature bushes, harvesting is the main pruning operation. Any additional pruning or general cleaning up should be done as close as possible to the beginning of the vegetative growth phase (Gollnow, 1995). In Zimbabwe, growers normally prune a third of the plant at a time. The pruning is mainly carried out during harvesting of flowers as a lot of plant matter is removed in the form of flowering stems. At the end of the flowering season the bushes are cleaned and shaped up to promote growth of long vertical stems for the next season.

Previous work has concentrated on the influence of pruning on shoot growth (Malan and Jacobs, 1994) and the extension of harvesting period in *Leucospermum* by means of manual and chemical pruning methods (Brits, 1986). There is very little documented work on the effects of pruning different aged plants of *Leucospermum*. This experiment was therefore carried out to determine whether or not age of the plant affects the response to pruning and deheading on flowering time of Scarlet Ribbon. It was hypothesized that age of plant will affect the flowering response to pruning and deheading in Scarlet Ribbon.

4.2 Materials and Methods

4.2.1 Treatments and Experimental Design

The experimental design was a 2 x 4 x 4 factorial in a split-split plot design arranged in a randomized complete block design with 3 replications. The age of the plant was the main plot factor (**factor A**) with two levels: plants aged 2½-3 years old ('old' plants) and 1-1½ years old ('young' plants) (net plot size of 24 plants). The ages of the plants used in the trial were based on availability on the farm. Pruning period was the sub-plot factor **(factor B)** with four levels including normal farmer practice as the control (net plot size of eight plants) and these are listed as follows:

Factor B	**Pruning period**
1	End January - beginning February
2	End March - beginning April
3	End May - beginning June
4	Control (farmer practice June-July)

The pruning of plants was carried out as described in section 3.3.

The deheading diameter was the sub-sub- plot factor (**factor A**) with four levels including a control (net plot size of two plants) and these are listed as follows:

Factor C	**Deheading diameter**
1.	0-5 mm
2.	6-10 mm
3.	15-20 mm
4.	Control (farmer practice: disbud all but primary bud).

Deheading of the primary inflorescence was carried out as described in 3.3.

4.2.2 Measurements

Measurements and records taken were as described in section 3.4.

4.2.3 Data Analysis

The experiment was analysed as a 2 x 4 x 4 factorial in a split-split-plot design (age of plant x pruning time x deheading diameter) using the GenStat Statistical Package (2002). Means were separated using the Fisher's Least Significant Difference (LSD) when $P<0.05$. Analysis of variance (ANOVA) was carried out for growth rates, stem quality and losses. Data for losses was checked for normality to see if it required transformation and it did not.

4.3 Results

4.3.1 Shoot Growth of Old and Young Plants of Scarlet Ribbon

The growth of the secondary shoot was slow to begin with during the winter months (May-July) for all the pruning treatments and plant ages. However it rapidly increased during the warm summer months (Fig 4.1). Plants pruned early from Jan to Apr produced longer secondary shoots (55-70 cm) compared to plants pruned later from May to Jul (30-50 cm) for both plant ages. The Jan to Jun pruning treatments resulted in a mean sprouting delay of about three months, but longer (four months) for the Jun/Jul treatments for both plant ages.

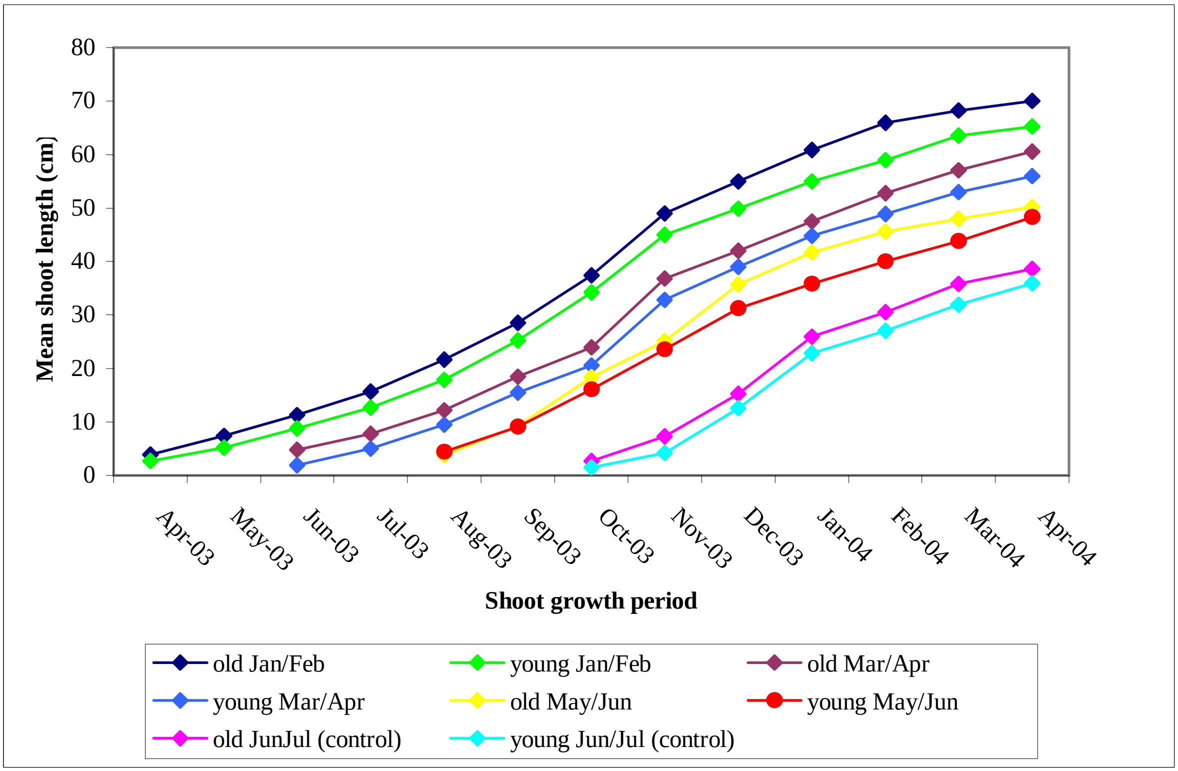


Fig 4.1 Mean monthly stem length of old and young plants of Scarlet Ribbon following pruning on four different dates as indicated

4.3.2 Comparison of Shoot Growth Rates of Old and Young Plants following pruning

Tables 4.1-4.4 show growth rates for the two plant ages of Scarlet Ribbon at four different pruning times. Where growth rate was significantly different ($P<0.05$), the old plants had a higher growth rate than the young plants for all the pruning treatments. Growth rate was not significantly different ($P>0.05$) between the two plant ages from July – Sept 2003 (Tables 4.1 and 4.2) and Nov-03 (Table 4.3) and May 2004. Growth rate was slow from winter to spring and rapidly increased during the hot summer months before gradually declining as winter approached the following year. (Tables 4.1-4.4)

Table 4.1 Growth rates for old and young plants pruned Jan/Feb

	Growth rate/ month (cm)										
Age	**Jul-03**	**Aug-03**	**Sep-03**	**Oct-03**	**Nov-03**	**Dec-03**	**Jan-04**	**Feb-04**	**Mar-04**	**Apr-04**	**May-04**
Old plants	3.6a[1]	3.9a	5.2a	7.4a	9.0a	8.2a	6.6a	5.7a	5.2a	4.7a	4.2a
Young plants	3.3a	3.6a	4.7a	5.9b	7.1b	6.5b	5.7b	4.0b	4.0b	3.7a	2.8a
P value	0.48	0.51	0.13	0.02	0. 05	0.04	0.02	0.02	0.03	0.26	0.09
SED	0.27	0.35	0.19	0.21	0.40	0.35	0.12	0.20	1.00	0.64	0.47
LSD$_{0.05}$	NS	NS	NS	0.80	1.86	1.50	0.52	0.87	0.87	NS	NS

Means followed by the same letter in a column[1] are not significantly different at P<0.05

Table 4.2 Growth rates for old and young plants pruned Mar/Apr

	Growth rate/ month (cm)								
Age	**Sep-03**	**Oct-03**	**Nov-03**	**Dec-03**	**Jan-04**	**Feb-04**	**Mar-04**	**Apr-04**	**May-04**
Old plants	3.9a[1]	5.3a	8.7a	8.6a	7.6a	7.0a	6.4a	5.6a	4.0a
Youn	3.7a	3.3b	5.8b	5.3b	4.1b	5.0b	4.6b	3.3b	3.3b
P value	0.07	0.03	0.04	0.01	0.05	0.04	0.02	0.05	0.27
SED	0.06	0.35	0.60	0.35	0.84	0.50	0.27	0.50	0.64
LSD$_{0.05}$	NS	1.49	2.59	1.50	3.62	2.14	1.15	2.20	NS

Means followed by the same letter in a column[1] are not significantly different at P<0.05

Table 4.3 Growth rates for old and young plants pruned May/Jun

	Growth rate/ month (cm)						
Age	**Nov-03**	**Dec-03**	**Jan-04**	**Feb-04**	**Mar-04**	**Apr-04**	**May-04**
Old plants	6.5a[1]	9.8a	8.0a	6.9a	5.9a	4.5a	3.7a
Young plants	5.9a	7.5b	5.5b	5.1b	3.8b	3.6b	3.2a
P value	0.20	0.02	0.02	0.01	0.01	0.04	0.19
SED	0.38	0.31	0.35	0.15	0.15	0.17	0.20
LSD$_{0.05}$	NS	1.30	1.52	0.66	0.66	0.77	NS

Means followed by the same letter in a column[1] are not significantly different at P<0.05

Table 4.4 Growth rates for old and young plants pruned Jun/Jul(control)

	Growth rate/ month (cm)				
Age	**Jan-04**	**Feb-04**	**Mar-04**	**Apr-04**	**May-04**
Old plants	6.8a[1]	6.5a	5.7a	4.6a	3.7a
Young plants	5.4b	4.5b	3.9b	2.9b	2.6a
P value	0.00	0.00	0.02	0.00	0.09
SED	0.15	0.07	0.20	0.20	0.36
LSD$_{0.05}$	0.63	0.29	1.00	0.87	NS

Means followed by the same letter in a column[1] are not significantly different at P<0.05

4.3.3 Harvest Dates and Duration of Harvest Period of Old and Young Plants

Harvesting of flowering stems for Scarlet Ribbon commenced in May 2004 albeit at different dates and was spread over six months (up to October 2004) for both plant ages. Harvesting of old plants commenced on the 16th of May 2004, while harvesting of young plants began on the 30th of May 2004.

4.3.4 Effect of Age of Plant, Pruning Time and Deheading Diameter on Days to Harvest Flowering Stems

Plant age (P<.001), pruning time (P<.001) and deheading diameter had a significant effect (P<0.05) on days to harvest flowering stems after pruning. There was a significant (P<0.05) pruning time x deheading diameter interaction on days to harvest flowering stems after pruning (Appendix B22).

The old plants produced flowering stems earlier by 44.5 days than the young plants as reflected by the number of days to harvest from the time of pruning (Table 4.5)

Table 4.5 Effect of age of plant on date of harvest of flowering stems after pruning

Age of plants	Days to harvesting after pruning
Old plants	436.8b
Young plants	481.3a
P value	<.001
SED	1.29
$LSD_{0.05}$	5.53

Means followed by the same letter are not significantly different at P<0.05

There was a significant (P<0.05) pruning time x deheading diameter interaction on date of harvest of flowering stems after pruning (see Appendix C1). However, their effects cannot be considered separately as they are confounded within the significant (P<0.007) interaction on date of harvest of flowering stems after pruning. The interaction is seen (Fig 4.2) in the differential inconsistent effects of deheading plants at different pruning times. The interaction resulted in a significant reduction in the number of days to harvest flowering stems for the control pruning time (June/Jul, normal farmer practice) for all the deheaded treatments. The control disbudding treatment had significantly the least number of days to harvest (308.8 days) for the same pruning time. There was an increase in the number of days to harvest for the Jan/Feb pruning time with the 0-5mm deheading treatment, resulting in the most number of days to harvest (602.1 days). There was no significant difference when a large deheading diameter was used while the control disbudding treatment had the least number of days to harvest for the same pruning time (Fig 4.2). For the Mar/Apr and May/Jun pruning times, there was no significant difference in the number of days to harvest when deheading was done from 0-20 mm. However, the control disbudding treatment had significantly the least number of days to harvest flowering stems for both pruning times (Fig 4.2).

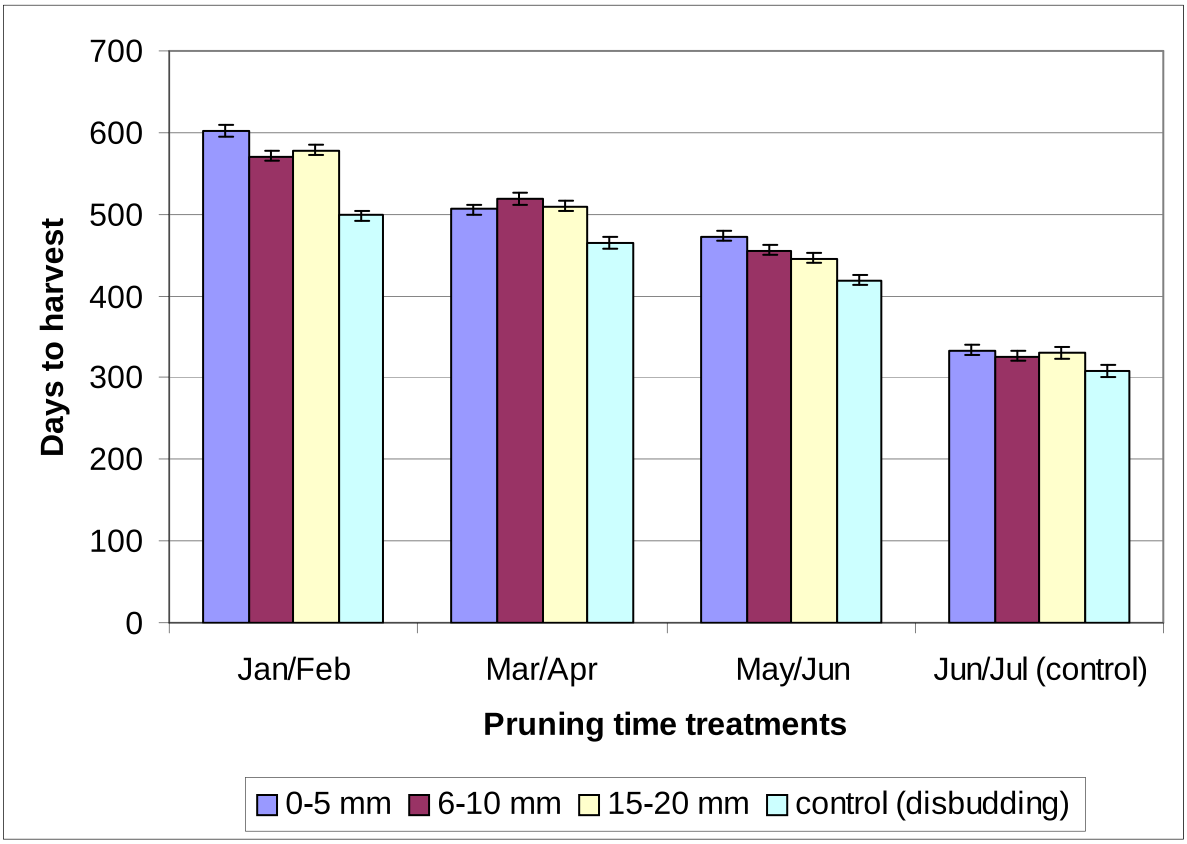


Fig 4.2 Interaction between pruning time and deheading diameter on days to harvest flowering stems after pruning (bars indicate SED at P<0.05)

4.3.5 Effect of Age of Plant, Pruning Time and Deheading Diameter on Days to Harvest Following Deheading of the Primary Inflorescence

The age of plants ($P<.001$) and pruning time ($P<0.007$) had a significant effect on days to harvest following deheading of the primary inflorescence while the deheading diameter did not have a significant effect. There were no significant interactions on days to harvest flowering stems following deheading of the primary inflorescence (Appendix B23).

The young plants took a longer time (by 14.8 days) for flowering stems to reach harvestable stage following deheading of the primary inflorescence compared to the old plants as shown in Table 4.6.

Table 4.6 Effect of age of plants on days to harvest following deheading of the primary Inflorescence

Age of plants	Number of days to harvest
Old plants	86.5b
Young plants	101.3a
P value	<.001
SED	0.46
$LSD_{0.05}$	1.98

Means followed by the same letter are not significant at P<0.05

The effect of pruning time on days to harvest flowering stems following deheading was significant (P<0.007). The Jan/Feb pruning time had the most number of days to harvest flowering stems while the control pruning treatment (Jun/Jul, normal farmer practice) produced the least number of days as shown in Fig 4.3. The number of days to harvest flowering stems was not significantly different for the Mar/Apr and May/Jun pruning treatments (Fig 4.3).

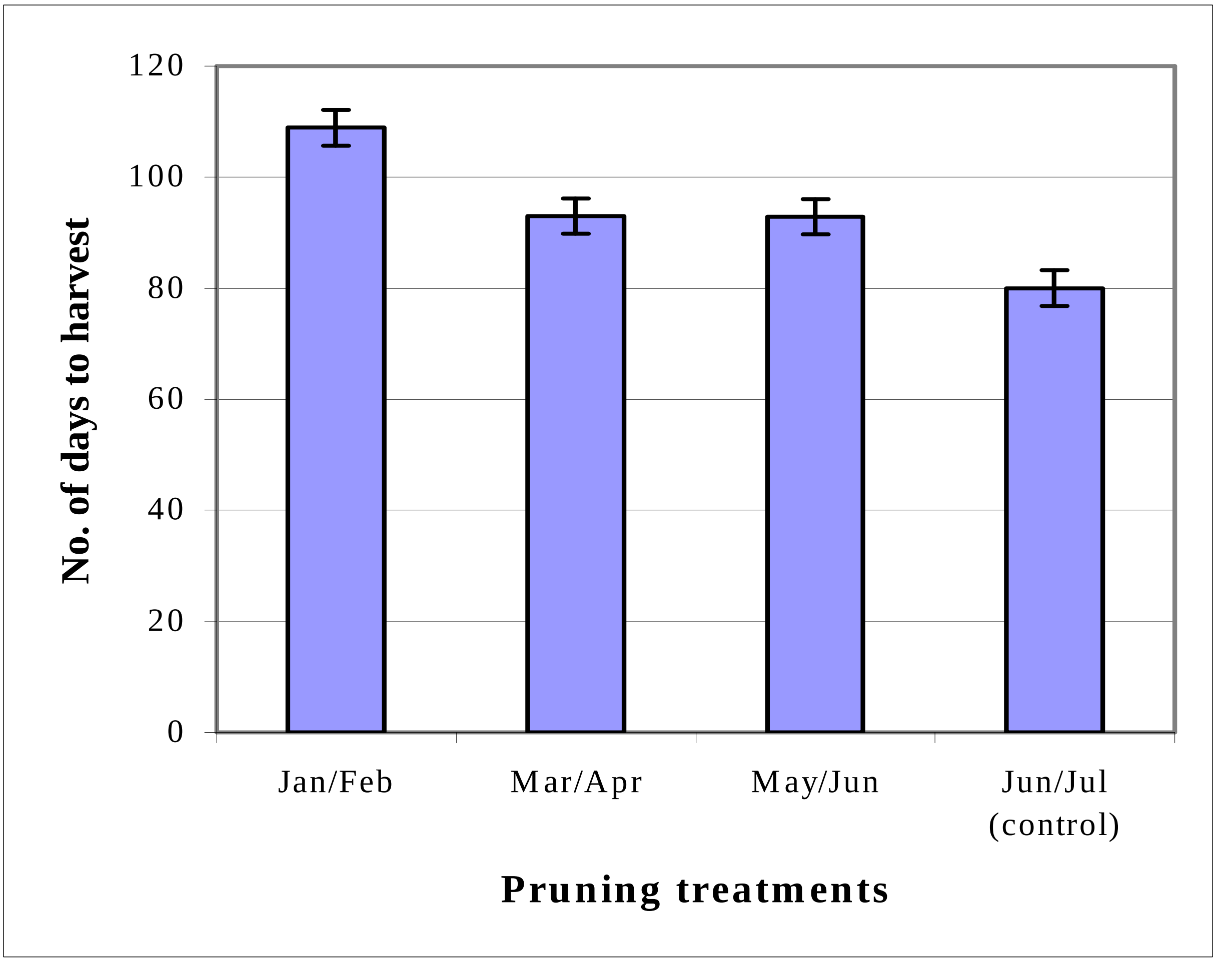


Fig 4.3 Effect of pruning time on days to harvest following deheading of the primary inflorescence (bars indicate SED at P<0.05)

4.3.6 Effect of Age of Plant, Pruning Time and Deheading Diameter on the Length of Harvested Flowering Stems

The effect of age of plants ($P<0.02$), pruning time ($P<0.01$) and deheading diameter ($P<.001$) on length of flowering stems was significant. There was a significant ($P<0.05$) age of plant x deheading diameter interaction on the length of flowering stems (Appendix B24).

Effect of pruning time on stem length was significant ($P<0.01$). The Jun/Jul (control), normal farmer practice) treatment produced the longest stems with the shortest flowering stems being harvested from the May/Jun pruning time as shown in Fig 4.4. Length of flowering stems declined as pruning was deferred except for the control (normal farmer practice) treatment.

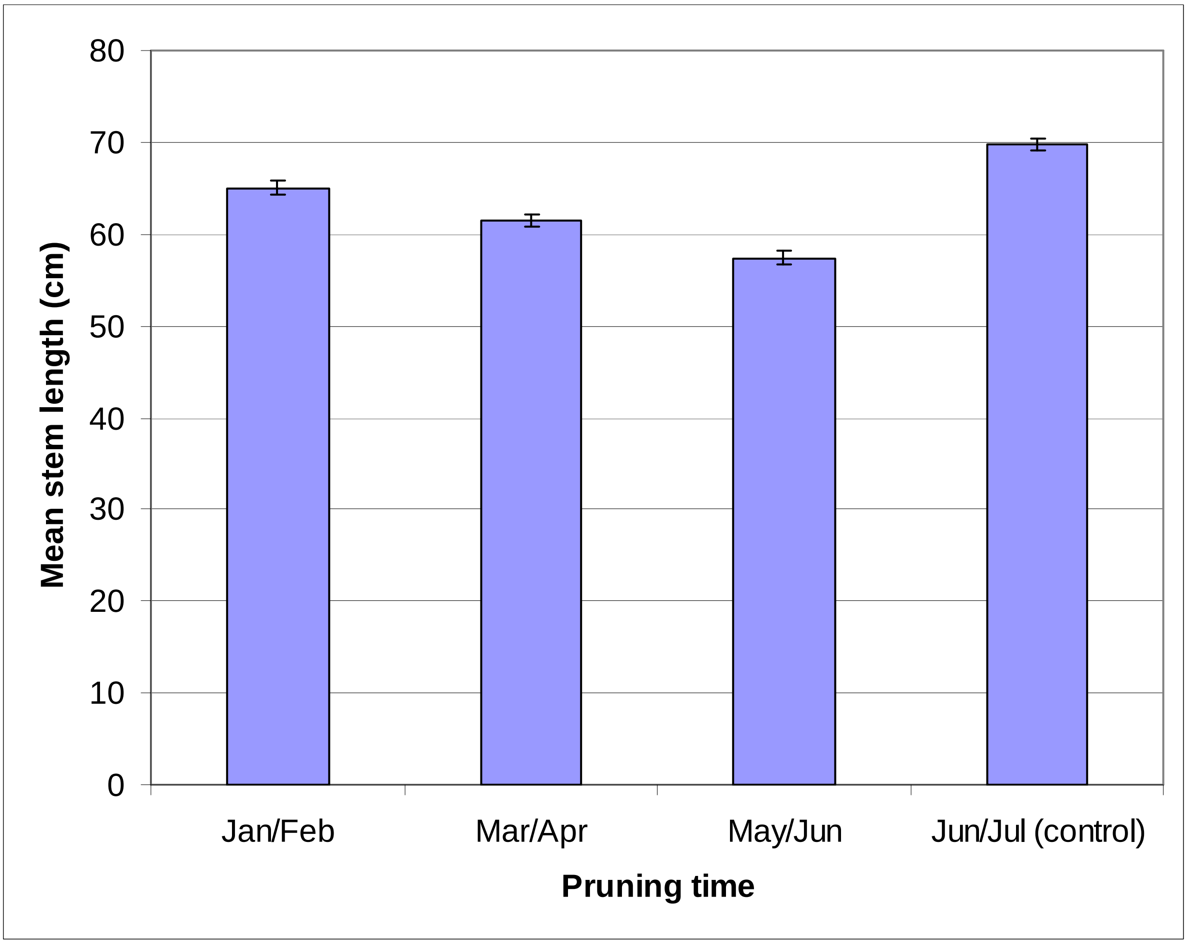


Fig 4.4 Effect of pruning time on length of flowering stems (bars indicate SED at P<0.05

The age of plants (P<0.02) and deheading diameter (P<.001) had a significant effect on length of flowering stems. However, their effects cannot be considered separately as they are confounded within the significant (P<0.01) age of plant x deheading diameter interaction on length of flowering stems. The interaction is seen (Fig 4.5) in the differential effect of deheading old and young plants at different diameters. The interaction resulted in a decrease in stem length as the size of the deheaded primary bud increased from 0-5 mm to 15-20 mm. The situation was different for the control treatment (removal of all bud the primary bud). Stem length increased significantly for both plant ages (Fig 4.5).

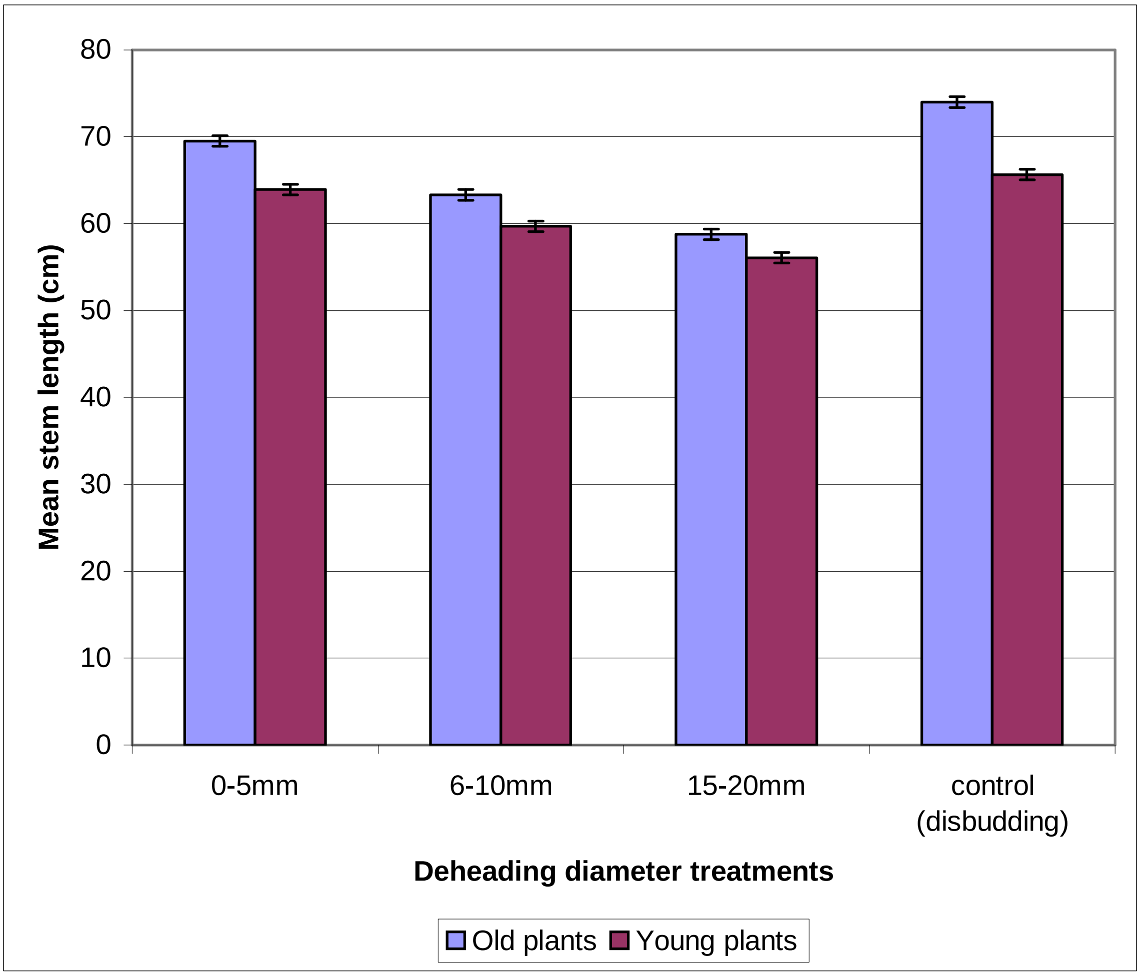


Fig 4.5 Interaction of age of plants and deheading diameter on the length of flowering stems (bars indicate SED at P<0.05)

4.3.7 Effect of Age of Plants, Pruning Time and Deheading Diameter on Inflorescence Diameter of Harvested Flowering Stems

The effect of age of plants and pruning time on inflorescence diameter of flowering stems was not significant while the effect of deheading diameter was significant (P<.001). There were no significant interactions treatment effects on the inflorescence diameter of flowering stems (Appendix B25).

The control treatment (removing all but the primary inflorescence) produced the largest flower head while the 6-10 mm deheading diameter resulted in the smallest flower head (Fig 4.6)

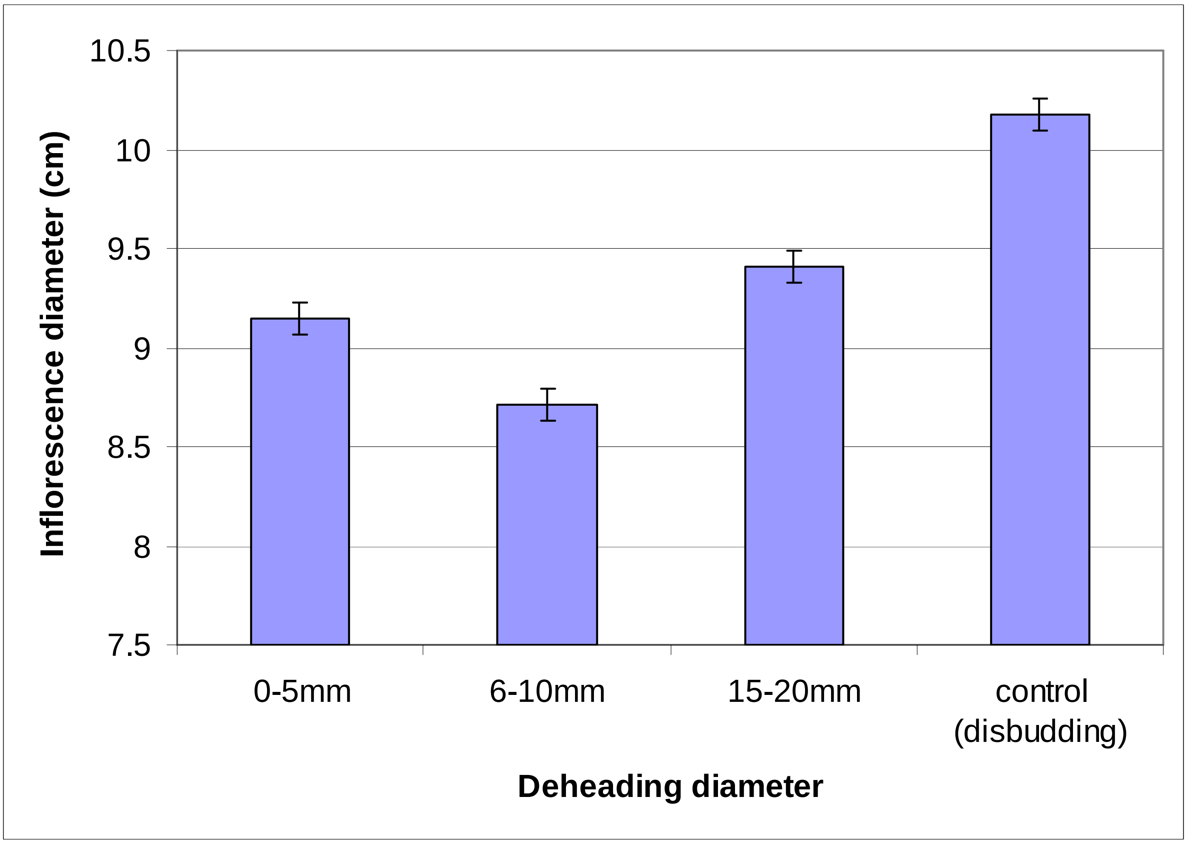


Fig 4.6 Effect of deheading diameter on inflorescence diameter of flowering stems (bars indicate SED at $P<0.05$)

4.3.8 Quality of Harvested Stems for Old and Young Plants of Scarlet Ribbon

The quality of harvested flowering stems for old and young plants of Scarlet Ribbon are shown in Table 4.7. The old plants generally had higher quality stems compared to the young plants. When considering the pruning treatments, the Jan/Feb pruning time had a high percentage of good quality stems (Grade 1-3) for the old plants compared to the young plants for the same pruning time. The young plants had high percentage stems mostly in grade 3 for the Mar/Apr, May/Jun and Jun/Jul (control). The young plants also had high percentage stems in the lower grades (grade 4 and 5) compared to the old plants as shown in Table 4.7.

Table 4.7 Quality of harvested stems for old and young plants of Scarlet Ribbon

Pruning Treatment	No. of stems	Percentage of total Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Old plants						
Jan/Feb	150	27.8±3.6	28.9±2.7	31.9±1.2	11.2±4.3	*
Mar/Apr	111	25.9±0.9	25.8±1.3	30.6±4.1	17.9±1.3	*
May/Jun	71	24.0±2.4	29.4±3.8	29.3±8.2	17.4±3.5	2.2±3.9
Jun/Jul (control)	83	20.3±2.9	21.7±2.9	19.3±5.8	15.0±5.0	6.7±7.6
Mean	**103.8**	**18.1±4.0**	**22.0±4.1**	**25.8±5.0**	**17.8±1.3**	**1.3±2.3**
Young plants						
Jan/Feb	110	18.2±3.3	21.8±5.0	16.5±5.8	10.6±4.7	12.7±3.1
Mar/Apr	90	19.0±3.3	18.0±5.7	20.7±7.6	21.8±3.8	13.7±4.1
May/Jun	70	11.3±0.6	18.9±0.9	11.3±0.6	21.9±1.2	10.4±0.7
Jun/Jul (control)	66	16.9±2.2	18.8±3.0	28.3±4.9	10.8±5.2	12.6±2.9
Mean	**84**	**16.4±1.3**	**19.4±2.2**	**19.2±3.0**	**16.3±1.9**	**12.4±1.4**

Values are mean ± S.E of 24 plants per pruning treatment (* no value recorded)

4.3.9 Crop Loss Due to Deheading of the Primary Bud for Old and Young Scarlet Ribbon Plants.

In old plants the highest crop losses were obtained from the May/Jun pruning time (10%) at a deheading diameter of 0-5 mm while the least losses were from the Mar/Apr (3.8%) at a deheading diameter of 0-5 mm (Table 4.8). For the young plants, the highest crop losses were from the Jan/Feb pruning time (12.5%), at 15-20 mm deheading diameter while the least losses were from the Mar/Apr pruning time (5.7%) at a deheading diameter of 0-5 mm (Table 4.8). Generally the older plants had less crop losses compared to the young plants. The control pruning time (Jun/Jul) had no losses due to deheading because a different treatment was applied whereby all other secondary buds were removed and the primary inflorescence was left to develop and flower.

Table 4.8 Crop losses due to deheading for old and young plants of Scarlet Ribbon

Pruning Time	Deheading date		Deheading diameter	Stems Harvested		% crop loss	
	Old	**Young**		**Old**	**Young**	**Old**	**Young**
Jan/Feb	6/08/04	26/07/04	0-5 mm	35	25	5.7±2.9	8±2.9
		24/07/04	15-20 mm	*	24	*	12.5±4.2
Mar/Apr	6/07/04	31/07/04	0-5 mm	35	23	3.8±1.6	5.7±2.5
	26/07/04	24/08/04	6-10 mm	28	21	7.4±3.7	9.5±2.2
May/Jun	6/09/04	24/07/04	0-5 mm	20	21	10.0±2.0	6.3±2.8
		28/08/04	6-10 mm	*	17	*	11.8±2.9

Values are mean ± S.E of 24 plants per pruning treatment (* no value recorded)

4.3.10 Comparison of Distribution of Harvested Flowering Stems and Monthly Gross Average Prices for Old and Young plants of Scarlet Ribbon

The best price for Scarlet Ribbon in 2004 occurred in May (Euro 0.738 per stem). However, very few stems were harvested during that period. Good prices were also obtained in the months of January, November and December. The lowest price was in March (Euro 0.275 per stem). Peak production was from June- August for both plant ages (Fig 4.7 a & b) when prices were declining. However, more stems were harvested from the older plants than the younger plants. The harvest period for both plant ages was mostly spread over 6 months from May 2004 to October 2004 (Fig 4.9 a & b)

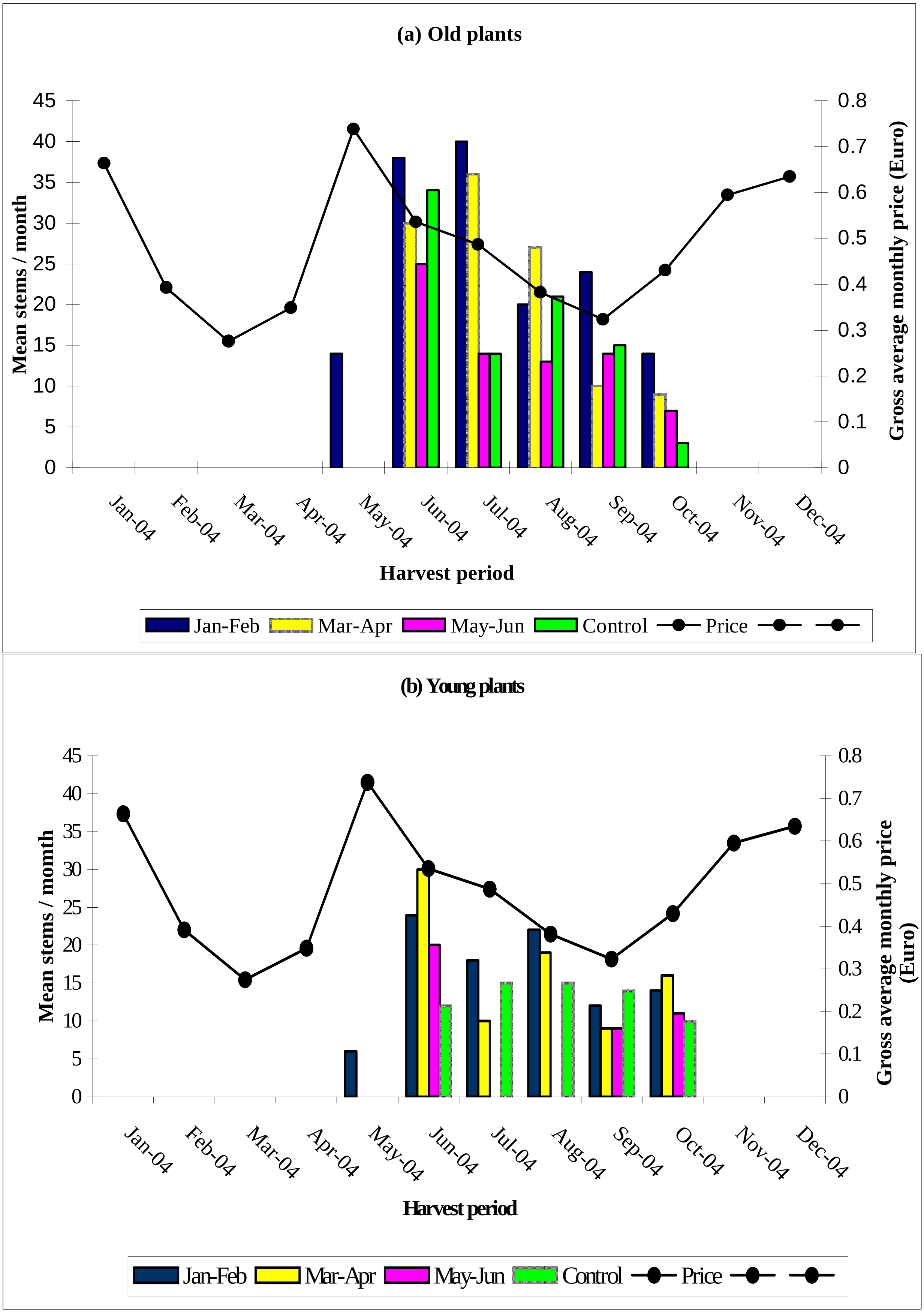


Fig 4.7 Distribution of flowering stems and corresponding monthly gross average prices for old and young plants of Scarlet Ribbon. Values are means from 24 plants per pruning treatment (Source of prices: Zimflora Pvt Ltd, 2005)

4.3.11 Mean Stem Counts and Earnings for Old and Young Plants of Scarlet Ribbon

Earnings of plant both ages are shown in Table 4.10. The Jan/Feb pruning treatment produced the most number of stems and correspondingly high earnings in both plant ages. The May/Jun pruning time resulted the least number of stems and earnings for the old plants while the May/Jun and Jun/Jul (control) pruning treatments produced the least number of stems and earnings for the young plants. In general, the old plants produced the most stems and corresponding earnings for all the pruning treatments compared to the young plants (Table 4.10)

Table 4.10 Mean stem counts and earnings for old and young plants of Scarlet Ribbon

	Old plants		**Young plants**	
Pruning time	**Mean Stem counts**	**Mean Earnings (Euro)**	**Mean Stem counts**	**Mean Earnings (Euro)**
Jan/Feb	50.0 ± 2.0	32.7	36.7 ± 4.2	23.8
Mar/Apr	37.0 ± 2.7	22.8	30.0 ± 2.0	19.7
May/Jun	23.7 ± 2.1	15.4	24.3 ± 1.1	15.8
Jun/Jul (control)	27.7 ± 2.1	18.5	22.0 ± 2.0	15.2
Mean	**34.6 ± 0.3**	**22.4**	**28.2 ± 1.3**	**18.6**

Values are mean ± S.E of 24 plants per pruning treatment

4.4 Discussion

Vegetative growth of Scarlet Ribbon occurred during the hot summer months (September - February) when growth rate was relatively high, while reproductive growth occurred during the cold winter months (May - July) when growth rate was low. This was observed for both the old and young plants, reinforcing observations by Jacobs (1983) on the growth patterns of *Leucospermum*.

Pruning and deheading were effective cultural practices in extending the time of harvest of flowering stems of both old and young plants of Scarlet Ribbon. Flowering for old plants commenced two weeks earlier than young plants and this was attributed to the plant structures of the respective plant ages. Although a third of the plant for each age group was pruned, the old plants had a bigger and more developed plant structure. This facilitated the quick growth of the new shoots as more assimilates were channelled to the secondary shoots and subsequently to the developing inflorescence during the reproductive phase. The results obtained are also supported by Wade and Westerfield (1999) who report that a pruned plant re-grows to restore a balance between the shoot and root system. Their work on pruning of shrubs showed that pruning a young plant will stimulate vigorous shoot growth and will delay the development of flowers.

The interaction of the two cultural practices resulted in a much longer by 293 days (Jan/Feb pruning time and deheading at 0-5 mm compared to Jun/Jul pruning time with a disbudding control) time from pruning to harvest the flowering stems compared to the normal farmer practice. This was because plants pruned early (Jan to Apr) had a much longer growth cycle and therefore a longer time to grow and produce long flowering stems compared to plants pruned later (May to July). The reduction in number of days to harvest flowering stems for the Jun/Jul (control, normal farmer practice) pruning treatment, was attributed to the fact that the inflorescence produced was from the primary inflorescence of which there were no interruptions to growth due to deheading. In comparison, the other pruning treatments produced an inflorescence from a secondary bud as deheading had been done. The period between growth and harvesting is thus shorter for the control disbudding treatment. When deheading was carried out, harvesting for old plants earlier for by 14.8 days than young plants. This was also a result of differences in the respective plant structures. Growth and development of younger plants with a less complex plant structure (with regards to branching and root density) continues for a longer period than old plants with a more complex plant structure. This agrees with observations by Jacobs (1985)

The earlier the plant is pruned the longer the stem. This is because the time taken for the secondary shoot to grow up to flowering and consequently harvesting is longer for plants pruned early (Jan/Feb) compared to plants pruned later (May/Jul). The 0-5 mm and control deheading treatments resulted in the longest stems as shown by the interaction between the age of plants and deheading diameter on length of harvested stems. This can be explained by the fact that the 0-5 mm inflorescence is obtained early enough to facilitate the rapid resumption of growth of the secondary bud, which consequently flowers with the flower stalk elongating to its maximum length under the induced reproductive phase. In comparison, there is a period of waiting for the larger primary buds (6-10 mm and 15-20 mm) to be deheaded.

Growth of stems from the control disbudding treatment (normal farmer practise) was not interrupted by deheading and therefore the primary inflorescence develops fast, giving rise to a longer stem, compared to the deheaded stems which undergo a ‘stop’ ‘start’ process. Another aspect to this result is that because of the small size of the bud deheaded at 0-5 mm there is less influence of its apical dominance on secondary buds such that when deheading is done, there is rapid response in resumption of growth of the remaining secondary bud. Consequently there is a longer time for the flower stalk to grow and elongate to its maximum length compared to deheading at larger diameters (6-10 mm and 15-20 mm) where apical dominance is stronger.

Old plants had longer stems than young plants in all the deheaded treatments. Due to the physical nature of old plants, the response to the pruning process is stronger compared to the young plants. This was due to the fact that old plants had a more established architecture, allowing it to absorb high nutrient levels in addition to its high photosynthetic capacity, which allows it to produce high levels of photo assimilates. These were then supplied to the meristematic regions to facilitate the rapid growth of the stems as reported by Saupe (2002) compared to young plants with smaller plant structures.

The deheading diameter treatments affected the size of the inflorescence of harvested stems. Malan and le Roux (1996) suggested disbudding the primary bud at 10 – 15 mm to obtain optimum results when deheading. In this study, deheading a large primary bud (15-20 mm) resulted in a large inflorescence while deheading at a small diameter produced small inflorescence. This was linked to the time of deheading. When deheading was carried out early during the induced reproductive state, environmental conditions (short days and low temperatures) favoured deheading at a larger diameter than at a smaller diameter

The quality of the stems is very important to a grower. This is because the longer the stems, the better price the grower obtains, especially at peak production when there is a glut. Therefore cultural practices that enable the grower to obtain long stems are favourable. Stem length becomes less important at off peak production periods as prices are normally favourable. Quality of stems in *Leucospermum* improves with age of plant after the first harvest and continues until the plant reaches maximum production (Archer, 2002). This was confirmed in this study as old plants had high quality stems compared to young plants. It has also been observed in the field that the first flowers are borne on the longest stems (Jacobs, 1983). Old plants had longer stems especially in the Jan/Feb pruning treatment and consequently a higher grade, which were harvested early.

Crop losses due to deheading were higher in young plants compared to the old plants. This can be attributed to the size of the plant structures at the respective plant ages. Old plants have larger structures and make and absorb enough nutrients and assimilates to support the resumption of growth of the secondary inflorescence after deheading. Deheading late (late July- August) using large deheading diameters (6-10 mm & 15-20 mm) resulted in high crop losses especially for young plants. These results are in accordance with those reported by Jacobs and Honeyborne (1978). Their work showed that late treatment (deheading) (August onwards) could cause loss of yield through poor resumption of secondary bud development. In addition, Malan and le Roux (1996) observed that disbudding too late (mid to late August) would result in at least 20% crop loss as a result of shoot growth instead of flower development.

Deheading when temperatures begin to rise in spring seemed to have detrimental effects on floral development of the secondary inflorescence as reflected by the higher crop loss figures for both plant ages. This agrees with Jacobs and Honeyborne (1979) who report that the developmental period of the secondary flower buds becomes shorter the later the primary inflorescence is removed due to the rising temperatures of spring and summer. Deheading early during the induced reproductive state gives the secondary bud a better chance of developing and consequently flowering, as shown by the proportion of flowers harvested from deheaded plants harvested after the peak flowering period.

From the results, the older plants had a higher number of stems harvested per pruning treatment compared to the younger plants. This can be explained by the way that pruning is carried out. The grower normally prunes a third of the plant at a time. Considering the plant ages in this study, an older bush will have more stems prior to pruning than a younger bush. When pruning is then done, the proportion of secondary stems that grow and develop into flowering stems will be much higher in older plants than in younger plants. Production figures of Scarlet Ribbon at different ages (Zimflora, 2003) also support this. In addition, the results obtained can be attributed to the fact that older plants have a bigger plant structure that facilitated and supported reproductive growth of more stems compared to the younger plants.

With regards to total earnings, the prevailing price at the market and the quality of the harvested stems determine the final price. In old plants, the May/Jun pruning time produced the least number of harvested stems and the least earnings. This result was a combination of two factors: fewer stems, low prices on the market and low quality of stems. The Jan/Feb pruning time produced the best results with regards to the quality of stems harvested and earnings.

CHAPTER 5

EFFECT OF CULTIVAR, PRUNING AND DEHEADING ON FLOWERING OF *LEUCOSPERMUM CV.* SCARLET RIBBON AND *L.* SAXOSUM

5.1 Introduction

The time of flowering varies with the species and type of planting material chosen (Gollnow, 1995). Plants grown from cuttings will flower earlier than those grown from seed. In addition, different crop management factors like irrigation, pruning and disbudding/deheading as well as the use of fertilizers have an impact on the subsequent time of flowering (Archer, 2000).

Growers in Zimbabwe have a wide range of *Leucospermum* cultivars to choose from and normally consider colour and flowering time when selecting cultivars to grow. In this study, the response of two different cultivars, Scarlet Ribbon and Saxosum to pruning and deheading on flowering time were investigated. Suitability of these two cultivars to pruning and deheading will enable growers to select the best cultivars so as to maximize gains. It was hypothesized that cultivar, pruning and deheading will affect flowering time in Scarlet Ribbon and Saxosum.

5.2 Treatments and Experimental Design

5.2.1 Effect of Cultivar on Response to Pruning and Deheading of Scarlet Ribbon and Saxosum

The experimental design was a 2 x 4 x 4 factorial in a split-split plot arranged in a randomized complete block design with 3 replications**.** Cultivar was the main plot factor (**factor A**) with two levels: Scarlet Ribbon and Saxosum (net plot size of 24 plants). The pruning time was the sub plot factor (**factor B**) with four levels including normal farmer practice as the control (net plot size of eight plants) and these are listed as follows:

Factor B	**Pruning period**
1	End January - beginning February
2	End March - beginning April
3	End May - beginning June
4	Jun/Jul (Control farmer practice)

The pruning of plants was carried out as described in section 3.3.

The deheading diameter was the sub-sub- plot factor (**factor C**) with four levels including a control (net plot size of two plants) and these are listed as follows:

Factor C	**Deheading diameters**
5.	0-5 mm
6.	6-10 mm
7.	15-20 mm
8.	Control (farmer practice: disbud all but primary bud).

Deheading of the primary inflorescence was carried out as described in section 3.3.

5.2.2 Measurements

Measurements were carried out as described in section 3.4.

5.2.3 Data Analysis

The experiment was analysed as a 2 x 4 x 4 factorial in a split-split-plot design (age of plant x pruning time x deheading diameter) using the GenStat Statistical Package (2002). Means were separated using the Fisher's Least Significant Difference (LSD) when $P<0.05$. Analysis of variance (ANOVA) was carried out for growth rates, stem quality and losses. Data for losses was checked for normality to see if it required transformation and it did not.

5.3 Results

5.3.1 Shoot Growth for Scarlet Ribbon and Saxosum

The growth of the secondary shoots for Scarlet Ribbon and Saxosum for all pruning times was slow during the winter months (May-July). However it rapidly increased during the warm summer months (Fig 5.1). Pruning early (Jan/Feb and Mar/Apr) produced longer secondary shoots than pruning in winter when shorter stems were obtained. This was similar for both cultivars (Fig 5.1).

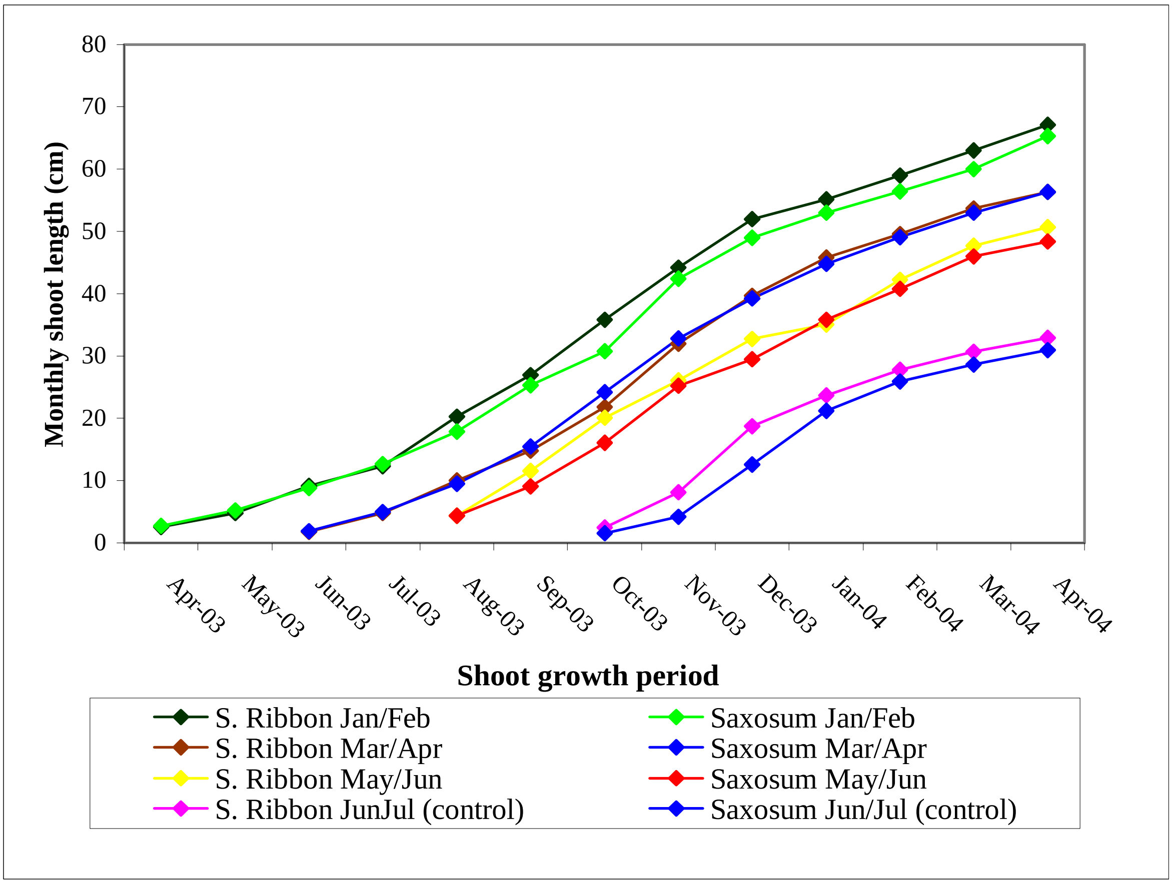


Fig 5.1 Monthly shoot growth curves for Scarlet Ribbon and Saxosum following pruning on four different dates as indicated

5.3.2 Comparison of Growth Rates per Pruning Treatment for Scarlet Ribbon and Saxosum

Tables 5.1-5.4 show the growth rates for Scarlet Ribbon and Saxosum per pruning time. Where growth rate was significantly different (P<0.05), Saxosum generally had a higher growth rate compared to Scarlet Ribbon for the different pruning times. Growth rate was not significantly different for the two cultivars from July to September 2003 (where applicable) and towards autumn April to May 2004 for each pruning. Growth rate measurements declined as pruning time was deferred during the year for both cultivars. The hot summer months resulted in a general increase in growth rate for Scarlet Ribbon and Saxosum which, gradually declined as winter approached (Table 5.1-5.4)

Table 5.1 Growth rate for Scarlet Ribbon and Saxosum pruned Jan/Feb

	Growth rate/ month (cm)										
Cultivar	**Jul-03**	**Aug-03**	**Sep-03**	**Oct-03**	**Nov-03**	**Dec-03**	**Jan-04**	**Feb-04**	**Mar-04**	**Apr-04**	**May-04**
S. Ribbon	3.0a	3.6a	4.7a	5.0b	6.4b	6.5b	5.4a	5.2a	5.2a	3.7a	2.8a
Saxosum	3.9a	5.6a	7.5a	9.2a	8.2a	7.9a	6.6a	4.7a	4.0a	3.6a	2.7a
P value	0.24	0.10	0.06	0.04	0.01	0.00	0.12	0.20	0.50	0.95	0.90
SED	0.32	0.69	0.73	0.87	0.15	0.07	0.40	0.27	0.33	0.50	0.61
$LSD_{0.05}$	NS	NS	NS	3.76	0.66	0.30	NS	NS	NS	NS	NS

Means followed by the same letter on a column are not significantly different at P<0.05

Table 5.2 Growth rate for Scarlet Ribbon and Saxosum pruned Mar/Apr

	Growth rate/ month (cm)								
Cultivar	**Sep-03**	**Oct-03**	**Nov-03**	**Dec-03**	**Jan-04**	**Feb-04**	**Mar-04**	**Apr-04**	**May-04**
S. Ribbon	3.7a	3.3b	4.5b	6.0b	5.6b	5.0b	4.6b	3.3a	3.3a
Saxosum	4.2a	5.7a	7.0a	7.7a	6.5a	6.1a	5.6a	4.0a	3.7a
P value	0.24	0.00	<.001	0.05	0.05	0.05	0.05	0.21	0.39
SED	0.30	0.27	0.03	0.39	0.22	0.26	0.22	0.58	0.39
$LSD_{0.05}$	NS	1.17	0.10	1.69	0.94	1.10	0.94	NS	NS

Means followed by the same letter on a column are not significantly different at P<0.05

Table 5.3 Growth rate for Scarlet Ribbon and Saxosum pruned May/Jun

	Growth rate/ month (cm)						
Cultivar	**Nov-03**	**Dec-03**	**Jan-04**	**Feb-04**	**Mar-04**	**Apr-04**	**May-04**
S.Ribbon	7.0a	7.0b	5.5b	4.8b	4.2b	4.0a	3.6a
Saxosum	7.9a	8.6a	8.0a	5.9a	4.9a	4.0a	3.6a
P value	0.30	0.04	0.03	0.05	0.05	0.86	0.53
SED	0.61	0.30	0.47	0.29	0.16	0.05	0.09
$LSD_{0.05}$	NS	1.28	2.00	1.23	0.70	NS	NS

Means followed by the same letter on a column are not significantly different at P<0.05

Table 5.4 Growth rate for Scarlet Ribbon and Saxosum pruned Jun/Jul (control)

	Growth rate/ month (cm)				
Cultivar	**Jan-04**	**Feb-04**	**Mar-04**	**Apr-04**	**May-04**
S. Ribbon	4.6b	3.3b	3.0b	2.9b	2.4a
Saxosum	5.3a	5.0a	4.0a	2.0a	2.0a
P value	0.00	0.01	0.03	0.14	0.29
SED	0.03	0.17	0.20	0.32	0.20
$LSD_{0.05}$	0.14	0.75	0.87	NS	NS

Means followed by the same letter on a column are not significantly different at P<0.05

5.3.3 Harvest date and Duration for Scarlet Ribbon and Saxosum

Harvesting of flowering stems for Scarlet Ribbon and Saxosum commenced in May 2004, although at different times. Scarlet Ribbon was harvested from the 29th of May and harvesting was spread over seven months (May to November 2004). Saxosum was harvested from the 12th of May 2004 and the harvest was spread over five months (May-September 2004). Harvesting of Saxosum was earlier by 2.4 weeks compared to Scarlet Ribbon.

5.3.4 Effect of Cultivar, Pruning Time and Deheading Diameter on Days to Harvest Flowering Stems after Pruning

The effect of cultivar (P<0.001), pruning time (P<.001) and deheading diameter (P<.001) on the days to harvest flowering stems after pruning was significant. There were significant (P<0.05) cultivar x pruning time, and pruning time x deheading diameter interactions on the days to harvesting after pruning (Appendix B42).

The cultivar (P<0.001) and pruning time (P<.001) had a significant effect on days to harvest flowering stems after pruning. However their effects are confounded within the significant (P<0.002) cultivar x pruning time interaction on days to harvest the flowering stems after pruning. The interaction is seen (Fig 5.2) in the differential effect of pruning two different cultivars at different times. The interaction resulted in a reduction in the number of days to harvest flowering stems as pruning was deferred. For all the pruning times, Saxosum was harvested much earlier compared to Scarlet Ribbon. For instance, for the Jan/Feb pruning time, Saxosum was harvested earlier by 132.1days than Scarlet Ribbon as shown by the number of days from pruning to harvesting (Fig 5.2).

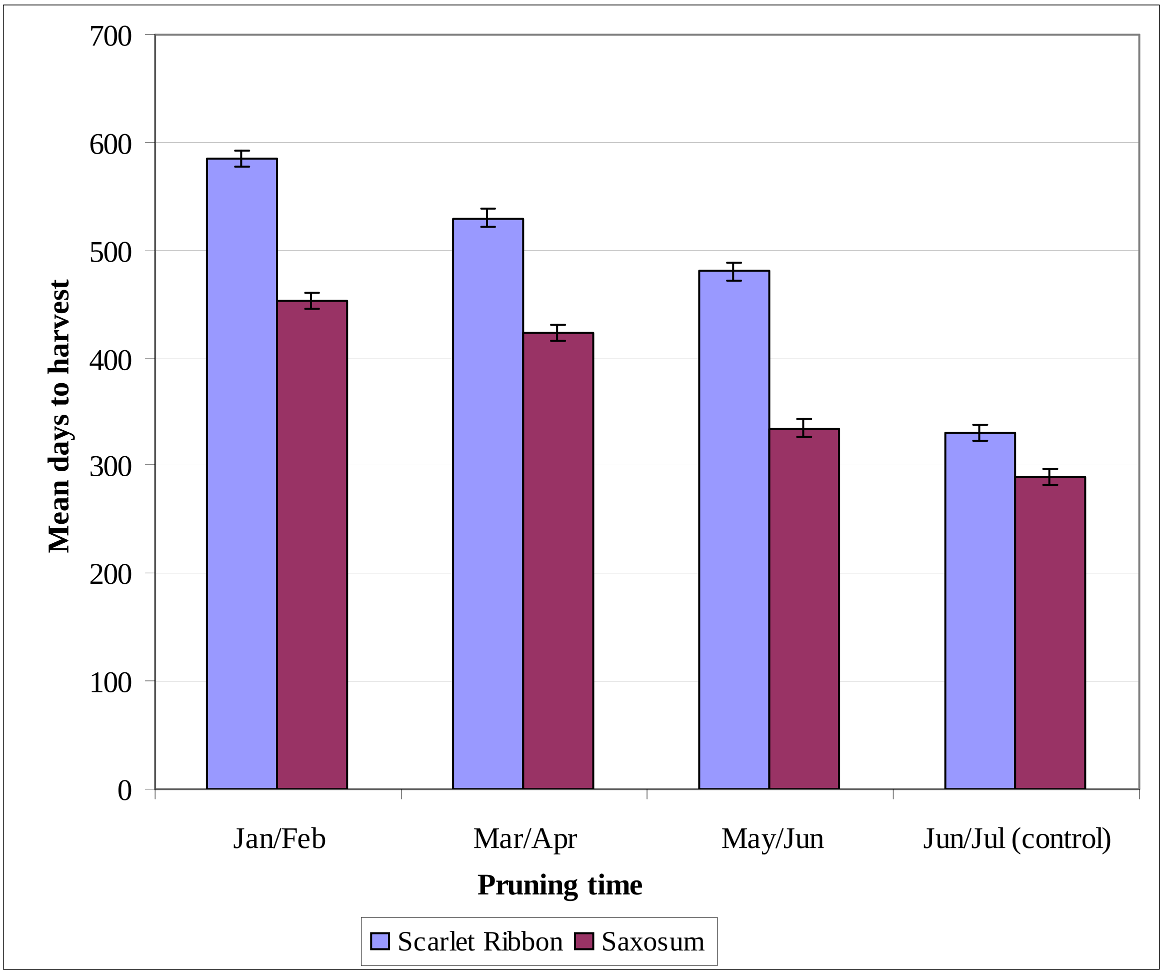


Fig 5.2 Interaction between cultivar and pruning days to harvest following pruning (bars indicate SED at P<0.05)

The effect of pruning time (P<.001) and deheading diameter (P<.001) on time taken to harvest the flowering stems after pruning was significant. However, their effects cannot be considered separately as they are confounded within the significant (P<0.009) pruning x deheading diameter interaction on days to harvest flowering stems following pruning. The interaction is seen (Fig 5.3) when the plants were pruned and deheaded at different deheading diameters. The interaction resulted in no consistent trend. The Jan/Feb pruning time resulted in the most number of days (560.8 days for the 0-5 mm deheading treatment) to harvest after pruning for each of the deheaded treatments including the control (disbudding) compared to the Mar/Apr, May/Jun and Jun/Jul pruning times. Although the number of days to harvest declined from the Mar/Apr and May/Jun pruning times, there was no significant difference between the deheaded treatments for both pruning times. The exception was for the control (dibudding) treatment where the number of days to harvest was significantly lower. The normal farmer practice pruning time (control, Jun/Jul) resulted in the least number of days to harvest flowering stems following pruning for all the deheading treatments. The control (disbudding) treatment for the same pruning period significantly had the least number of days to harvest (290.5 days) (Fig 5.3).

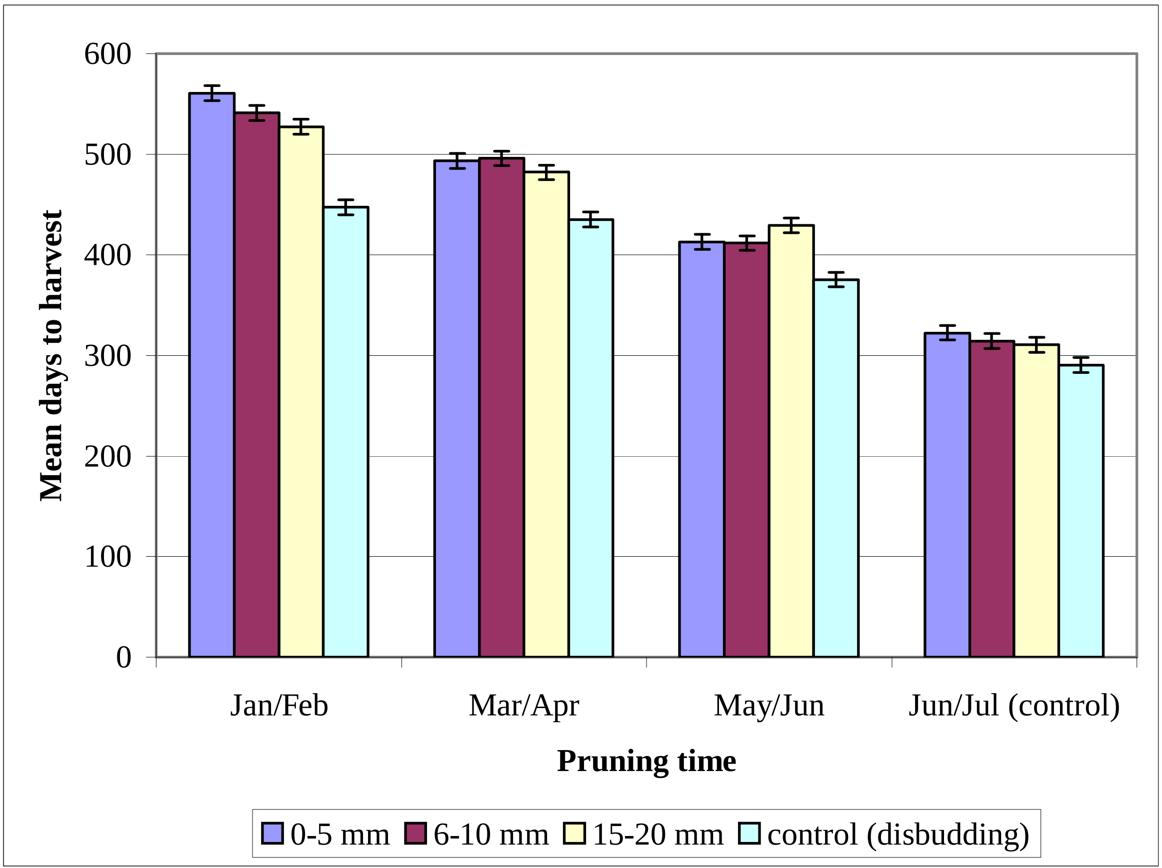


Fig 5.3 Interaction between pruning time and deheading diameter on days to harvest Flowering stems following pruning (bars indicate SED at P<0.05)

5.3.5 Effect of Cultivar, Pruning Time and Deheading Diameter on Days to Harvest Following Deheading of the Primary Inflorescence

The different cultivars ($P<0.02$) and pruning time ($P<0.006$) had a significant effect on days of harvest following deheading while the deheading diameter did not have a significant effect (Appendix B43).

There was a significant ($P<0.001$) cultivar x pruning time interaction on days to harvest flowering stems following deheading of the primary inflorescence. However their effects cannot be considered separately as they are confounded within the significant cultivar x pruning time interaction on days to harvest flowering stems following deheading of the primary inflorescence. The interaction is seen (Fig 5.4) in the differential effect of pruning Scarlet Ribbon and Saxosum at different times during the year. There was no significant difference in number of days to harvest for the Jan/Feb and Mar/Apr for Scarlet Ribbon while for Saxosum, the Mar/Apr, May/Jun and Jun/Jul (control) were not significantly different. For each of the pruning times, the number of days to harvest time following deheading was more for Scarlet Ribbon particularly the Mar/Apr pruning time (37.3 days) compared Saxosum (Fig 5.4)

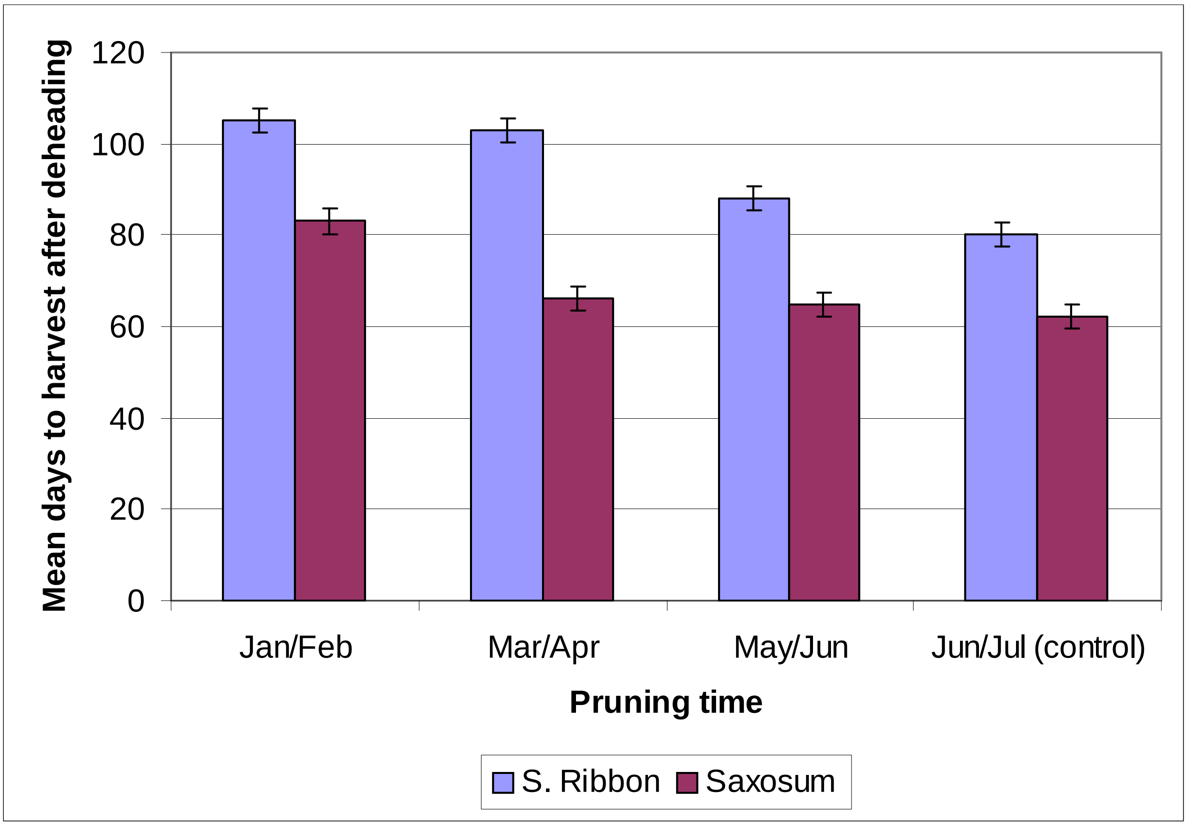


Fig 5.4 Interaction between cultivar and pruning time on days to harvest flowering stems following deheading (bars indicate SED at P<0.05)

5.3.6 Effect of Cultivar, Pruning Time and Deheading Diameter on Length of Flowering Stems

The effects of cultivar ($P<0.03$), pruning time ($P<0.001$) and deheading diameter ($P<.001$) were significant on the length of flowering stems (Appendix B44). There was a significant ($P<0.05$) cultivar x pruning time interaction.

The deheading diameter had a significant ($P<0.05$) effect on length of flowering stems. The control disbudding treatment produced the longest flowering stems followed by the 0-5 mm deheading diameter. The 15-20 mm deheading diameter resulted in the shortest stems. Length of stems declined as deheading diameter was increased while it increased for the control (disbudding treatment) (Fig 5.5).

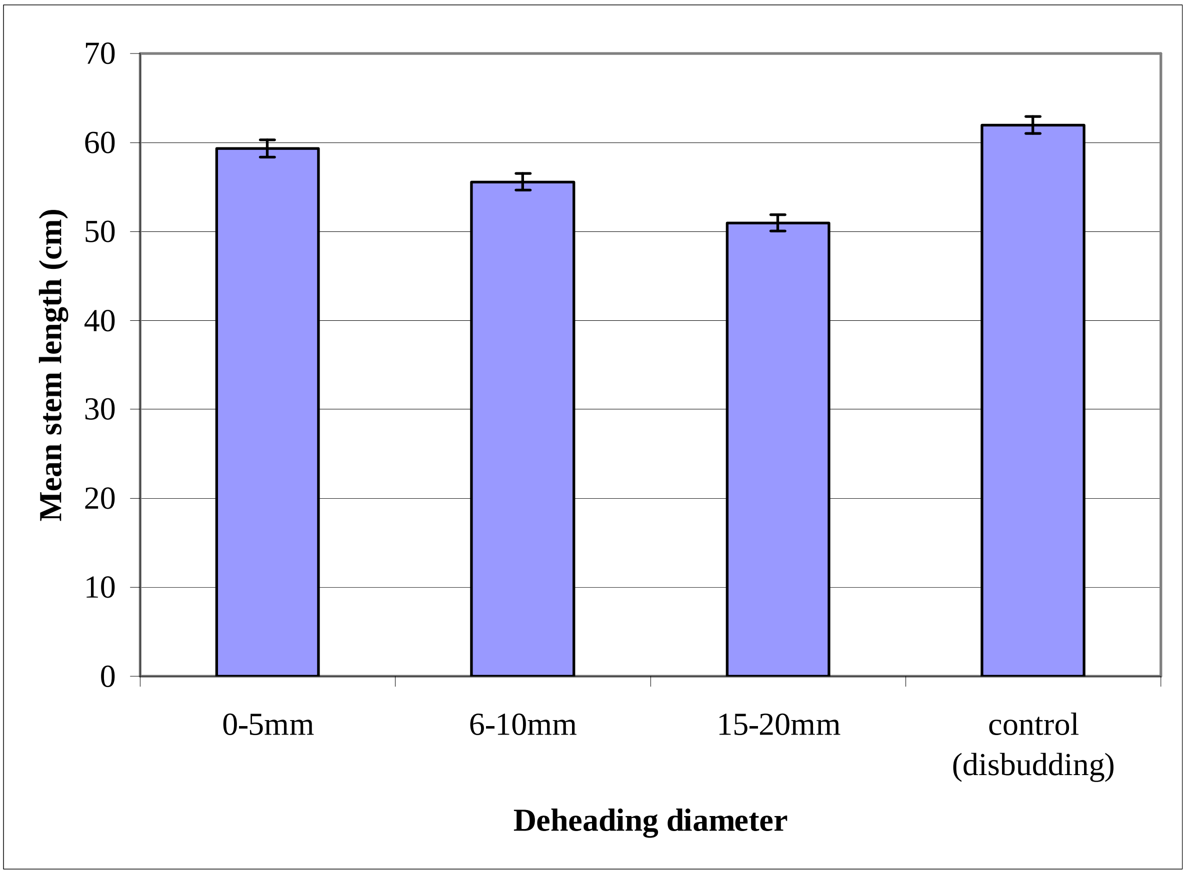


Fig 5.5 Effect of deheading diameter on length of flowering stems (bars indicate SED at P<0.05)

There was a significant (P<0.04) cultivar x pruning time interaction on length of flowering. However their effects cannot be considered separately as they are confounded within the significant (P<0.04) cultivar x pruning time of effects on length of flowering stems. The interaction is seen (Fig 5.6) in the inconsistent differential effects of pruning Scarlet Ribbon and Saxosum at different times of the year. Plants pruned from the Mar/Apr and May/Jun pruning times, resulted in a reduction in stem length and which was not significantly different for Scarlet Ribbon while stem length increased significantly for the Jan/Feb and control (Jun/Jul) pruning times for Scarlet Ribbon. With Saxosum, there was a gradual decline in stem length from the Jan/Feb to May/Jun pruning times, which then increased for the Jun/Jul (control) pruning time. For each pruning time, Scarlet Ribbon produced the longest stems compared to Saxosum (Fig 5.6).

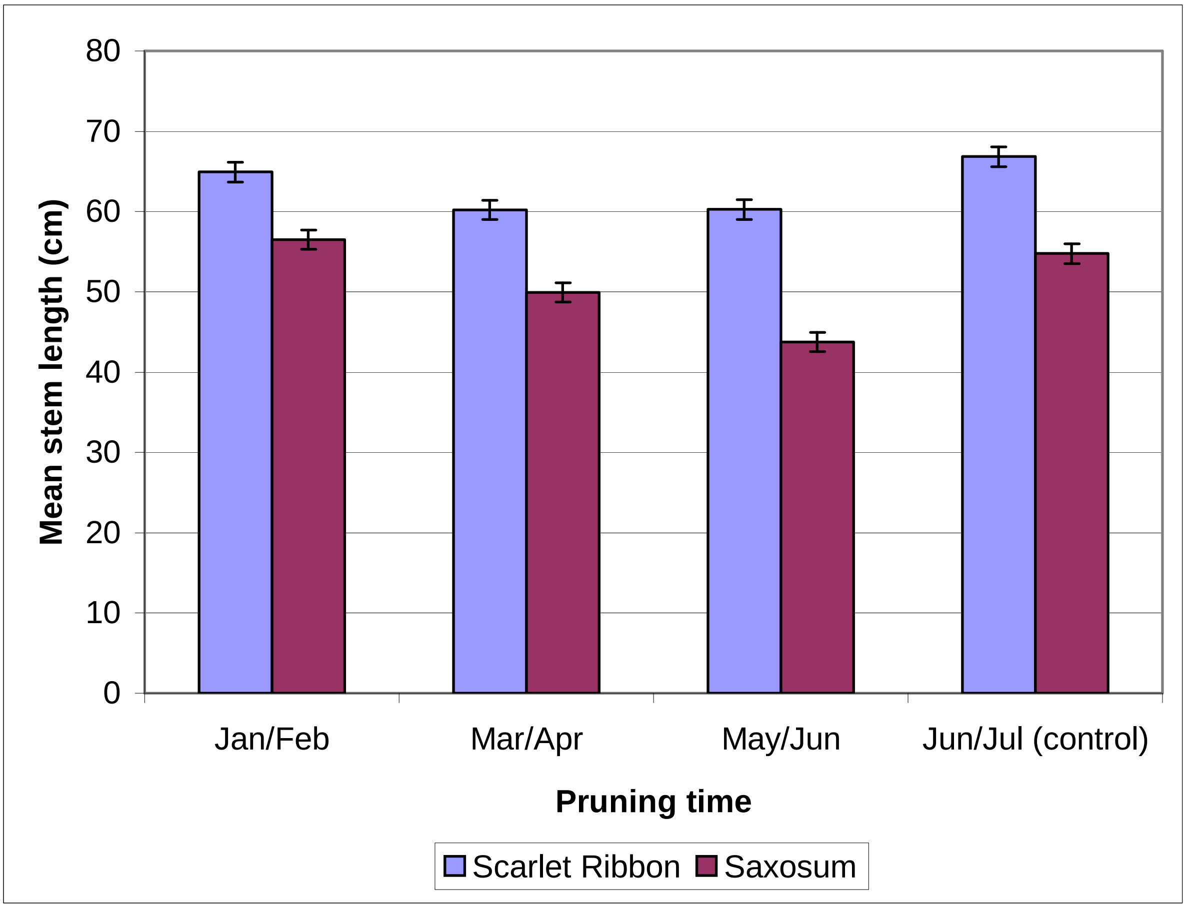


Fig 5 .6 Interaction between cultivar and pruning time on length of flowering stems (bars indicate SED at P<0.05)

5.3.7 Effect of Cultivar, Pruning Time and Deheading Diameter Inflorescence Diameter of Harvested Flowering Stems

The effects of cultivar, pruning time and deheading diameter on the inflorescence diameter of harvested flowering stem were not significant. There were also no significant interactions of treatments effects on inflorescence diameter of harvested flowering stems (Appendix B45).

5.3.8 Quality of Harvested Flowering Stems of Scarlet Ribbon and Saxosum

The quality of harvested stems for Scarlet Ribbon and Saxosum is illustrated in Table 5.5 and 5.6 respectively. Scarlet Ribbon produced more high quality stems compared to Saxosum. Scarlet Ribbon had more high quality stems, in the Grade 1 and 2 ranges, for the all the pruning times including the control treatment. Saxosum had a higher percentage of lower quality stems (Grade 3, 4 & 5) than Scarlet Ribbon (Table 5.5).

Table 5.5 Quality of harvested flowering stems for Scarlet Ribbon and Saxosum

Pruning Treatment	No. of stems	Percentage of total Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Scarlet Ribbon						
Jan/Feb	110	18.2 ±3.3	21.8±5.0	28.3±4.9	10.6±4.7	12.7±8.1
Mar/Apr	90	19.0±8.3	18.0±5.7	20.7±7.6	21.8±3.8	13.7±6.1
May/Jun	70	36.9±2.2	18.8±3.0	16.5±5.8	10.8±5.2	12.6±2.9
Jun/Jul (control)	66	26.7±7.6	18.3±2.9	21.7±2.9	13.3±5.8	10.0±5.0
Mean	**84**	**25.2±3.0**	**19.2±1.4**	**21.8±2.0**	**14.1±0.8**	**12.3±2.2**
Saxosum						
Jan/Feb	78	5.0±5.0	20.0±5.0	30.3±1.4	21.7±7.6	5.0±5.0
Mar/Apr	70	8.3±2.9	8.3±2.9	31.7±7.6	23.3±2.3	25.0±5.0
May/Jun	50	7.7±6.8	6.1±2.8	24.0±1.8	35.9±0.9	20.8±2.9
Jun/Jul (control)	46	20.7±5.0	13.3±7.6	21.7±7.6	26.7±7.6	15.0±5.0
Mean	**61**	**10.0±1.6**	**11.9±2.3**	**26.9±3.6**	**26.9±3.8**	**16.5±1.1**

Values are mean ± S.E of 24 plants per pruning treatment

5.3.9 Crop Loss Due to Deheading of the Primary Inflorescence for Scarlet Ribbon and Saxosum

Crop losses occurred in both Scarlet Ribbon and Saxosum, due to deheading of the primary inflorescence. The growth and development of the secondary inflorescence after deheading was not successful, instead vegetative shoots developed as shown in Plate 5.1. From the results, Saxosum generally had higher crop losses than Scarlet Ribbon. The highest crop losses for Scarlet Ribbon were 12.5% from the Jan/Feb pruning time and deheaded at 15-20 mm in late August and 11.8% from the May/Jun pruning time deheaded at 6-10 mm in late August. For Saxosum, the Mar/Apr pruning time deheaded at 6-10 mm had the highest losses of 16.7%, which was deheaded in late July (Table 5.7).

Table 5.7 Crop losses due to deheading for Scarlet Ribbon and Saxosum plants

Pruning Time	Deheading date		Deheading diameter	Stems Harvested		% crop loss	
	Scarlet	**Saxosum**		**Scarlet**	**Saxosum**	**Scarlet**	**Saxosum**
Jan/Feb	26/07/04	27/07/04	0-5 mm	25	17	8±1.9	7.9±3.4
	24/08/04		15-20 mm	24	*	12.5±4.2	*
Mar/Apr	31/07/04		0-5 mm	23	*	5.7±2.5	*
	24/08/04	24/08/04	6-10 mm	21	12	9.5±2.2	16.7±2.9
May/Jun	24/07/04		0-5 mm	21	*	6.3±2.8	*
	28/08/04	27/07/04	6-10 mm	17	14	11.8±2.9	14.3±7.2
		27/08/04	15-20 mm	*	14	*	14.3±7.2

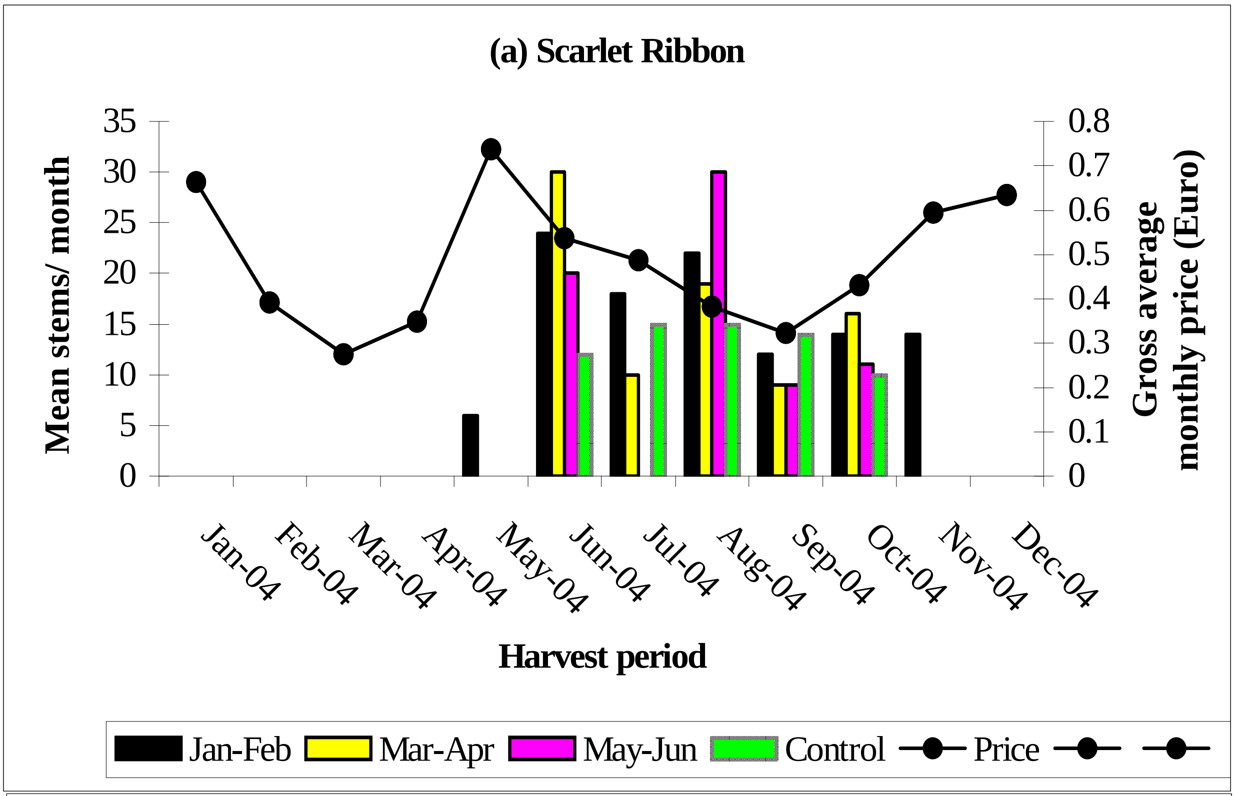
Values are mean ± S.E of 24 plants per pruning treatment (* no value recorded)

Plate 5.1: A secondary stem of *L*. Saxosum that was deheaded late showing several vegetative shoots indicated by the arrows instead of producing a secondary inflorescence

5.3.10 Comparison of Distribution of Harvested Flowering Stems and Monthly Gross Average Prices for Scarlet Ribbon and Saxosum

Flowering and harvesting for Scarlet Ribbon and Saxosum commenced in May 2004. More stems were harvested in May for Saxosum compared to Scarlet Ribbon (Fig 5.7a & b). Peak production for Scarlet Ribbon occurred in June and August when prices were declining. For

Saxosum, peak production occurred in May. This coincided with the best price of Euro 0.777 representing a (Euro 0.551) difference in price gain on the lowest price (Euro 0.226 in September) for the harvest period. The harvest period for Scarlet Ribbon was spread over seven months (May- November) while for Saxosum it was shorter, over five months (May-September) (Fig 5.7a & b).



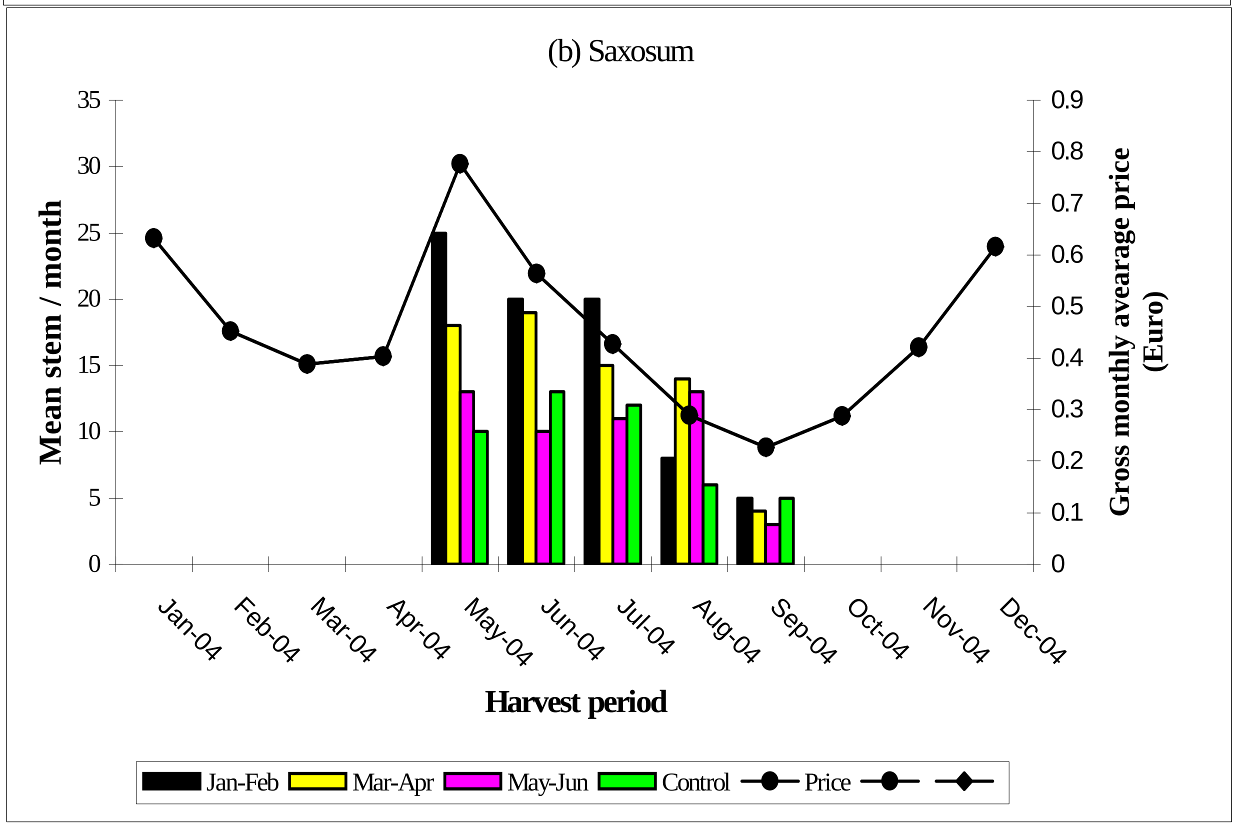


Fig 5.7 Distribution of Flowering Stems and Corresponding Gross Monthly Average Prices for Scarlet Ribbon and Saxosum. Values are means from 24 plants per pruning treatment (Source of prices: Zimflora Pvt Ltd, 2005)

5.3.11 Mean Stem Counts and Earnings of Scarlet Ribbon and Saxosum

A comparison of the two cultivars showed that more flowering stems were harvested from Scarlet Ribbon than Saxosum for the entire pruning times including the control. Earnings from Scarlet Ribbon were also higher than for Saxosum (Table 5.8). The Jan/Feb pruning time resulted in the highest number of stems and corresponding earnings for both cultivars. Pruning later during the year (May/Jun) and the control treatment produced the least number of stems and corresponding earnings for both cultivars (Table 5.8).

Table 5.8 Mean stem counts and earnings for Scarlet Ribbon and Saxosum

	Scarlet Ribbon		**Saxosum**	
Pruning time	**Mean Stem counts**	**Mean Earnings (Euro)**	**Mean Stem counts**	**Mean Earnings (Euro)**
Jan/Feb	36.7 ± 4.2	24.9	26.0 ± 1.7	18.5
Mar/Apr	30.0 ± 2.0	19.8	24.3 ± 1.2	16.3
May/Jun	24.3 ± 1.1	17.8	16.7 ± 0.6	12.8
Jun/Jul (control)	22.0 ± 2.0	16.9	14.7 ± 2.5	12.3
Mean	**28.2 ± 1.3**	**22.4**	**20.4 ± 0.8**	**15.0**

Values are mean ± S.E of 24 plants per pruning treatment

5.4 Discussion

Results in this study showed that growth of secondary shoots for both pincushions after pruning followed a similar pattern albeit at different rates. The growth of secondary shoots was slow to begin with during the colder winter months (May-August) in the first year of growth. The plants were in the induced reproductive state and vegetative growth was minimal. As the induced state was gradually lost with the approach of summer, the growth rate of secondary shoots was rapid for both cultivars. The high temperatures and occurrence of rainfall during this period facilitated the rapid growth of the secondary shoots.

In this study, the farmer planted rooted cuttings of Scarlet Ribbon and Saxosum cutlivars and the cultivars commenced flowering at different times, thus confirming observations by Gollnow (1995) that time of flowering varies with the species and type of planting material chosen. Although both cultivars are naturally early flowering, Saxosum was harvested much earlier, by 2.4 weeks, than Scarlet Ribbon. The result could be attributed to differences in cultivar in terms of genetic make up. In addition, Saxosum is a lignotuber (has a large swelling of the trunk/root just under or at the soil surface) plant. The lignotuber has dormant buds that shoot after fire or drastic pruning of the plant as reported by Oertel (2001). Pruning plants with such a characteristic results in rapid rejuvenation growth and consequently flowering hence, the early harvesting date for Saxosum.

A similar result was also obtained when the cultivars were deheaded. The period between deheading and harvesting was significantly shorter for Saxosum than for Scarlet Ribbon. In addition to producing solitary inflorescence, Saxosum tends to produce 3-4 flower heads on a single stem and is marketed as such. The ability to do so suggests less apical dominance exerted on the secondary buds, which are inhibited correlatively. This then meant that after deheading, resumption of growth and development of the secondary inflorescence occurred rapidly compared to Scarlet Ribbon, which produces solitary inflorescences. In addition, Scarlet Ribbon has naturally a bigger flower head with more styles and therefore it took a longer period to develop after deheading compared to Saxosum.

The flowering time of early flowering *Leucospermum* cultivars can be delayed more than those of late flowering cultivars (Malan and le Roux, 1996). This is because, the flowering stems are produced early during the induced reproductive phase therefore enabling the deheading process to be successful as the resulting secondary inflorescence has ample time to grow and develop before the induced state starts to decline. This was observed in this study with regards to Scarlet Ribbon as harvesting commenced in May up to November. The situation was different for Saxosum, which is also early flowering, as flowering period was shorter from May to September.

Plants pruned late during the Jun/July (control, normal farmer practice) and disbudded produced the least number of days to harvesting compared to the other pruning times which were deheaded as shown by the interaction between pruning time and deheading diameter on time to harvest flowering. This can be explained by that, pruning early results in a longer growth cycle up to the point of flowering. The deheaded plants produced a flowering stem from a secondary bud while for the control (disbudding treatment), the inflorescence was from the primary bud. On *Leucospermum* plants, the primary bud develops and attains apical dominance over other axillary buds on the stem and develops into a solitary inflorescence as reported by Malan *et al* (1994). Shue- Lockham, (1965) also reported that dormant buds respond to a flower stimulus provided the flower stimulus was forced down by means of decapitation and disbudding. On deheaded plants, the primary bud was removed and by doing this, the correlative inhibition of the primary inflorescence was removed. The secondary buds then grew and eventually flowered at a later time, as was the case in this study.

From the results obtained in this study, Scarlet Ribbon produced longer stems than Saxosum. According to Jacobs (1980), the change from vegetative to reproductive growth takes place during a relatively short period for long shoots. The shoots would therefore produce an inflorescence and flower early. In this study, Saxosum produced shorter stems for all the pruning times and was harvested much earlier compared to Scarlet Ribbon. This clearly demonstrates that observations by Jacobs (1980) are for species with similar genetic composition.

The quality of stems harvested varied for the two cultivars as Scarlet Ribbon produced stems of higher quality and also had higher earnings compared to Saxosum. The results demonstrate the difference in response to pruning and deheading treatments due to cultivar differences. Saxosum produced a higher percentage of low quality stems (although they were acceptable for marketing) and this showed that it does not respond well to pruning and deheading treatments compared to Scarlet Ribbon. The extended harvest period (up to November) for Scarlet Ribbon was an advantage as prices on the market were increasing and this coincided with the off- peak period. The short harvest period was only beneficial to the farmer at the beginning of the harvest period when prices were high. Had the harvest period also extended to November, the farmer would have taken advantage of the rising prices.

Both cultivars had crop losses due to failure to produce an inflorescence by the deheaded secondary stems. However crop losses were higher for Saxosum than for Scarlet Ribbon. The losses were from stems deheaded late into the season. Losses occurred in later pruning times and deheading using a medium deheading diameter late (late August) for Saxosum. Deheading late when spring temperatures were increasing caused the deheading process to be less effective, as reported by Dupee and Goodwin (1990). In addition, Brits (1977) reports that earlier flowering plants show a greater tendency towards massive vegetative bud break. This could explain the short flowering period for Saxosum, which was harvested earlier (with regards to the proportion of stems harvested), than Scarlet Ribbon. Deheading should therefore be carried out up to mid July for the 0-20 mm deheading diameters to minimize losses.

The pruning and deheading treatments in both cultivars did not affect the size of flower heads. The reason for this could be that although the deheading process delayed flowering time, the deheading diameter range used in the study (0-20 mm) could have been too small to make a significant difference on the size of inflorescence for the deheaded stems of the two cultivars.

CHAPTER 6

GENERAL DISCUSSION

The *Leucospermum* genus is popular amongst Zimbabwean growers due to availability and a large variety of species from which to choose. Scarlet Ribbon and Saxosum were selected for this study because they are among the top five grown in the country and because they were readily available at the trial site. The flowering nature of this genus is well understood in the industry worldwide and a lot of research has been conducted to try and manipulate the flowering time to maximize benefits.

One of the problems in the marketing of the *Leucospermum* crop is the relatively short flowering duration (Jacobs and Honeyborne, 1978). In this study, two cultural practices, pruning and deheading, were employed to extend or delay the flowering time of Scarlet Ribbon and Saxosum.

The growth pattern of *Leucospermum* plants was determined by monitoring the growth rates of plants after pruning. The *Leucospermum* plants grew vegetatively during spring and summer and reproductive development commenced in autumn to winter after shoot extension growth had terminated. The growth pattern was similar for different aged plants but old plants had a higher growth rate than young plants of Scarlet Ribbon. The pattern was also similar when two cultivars were compared, but Saxosum had a higher growth rate than Scarlet Ribbon.

The transition from the vegetative to reproductive buds is usually triggered by an environmental signal, such as photoperiod and temperature (Saupe, 2002). Results obtained reinforce the fact that *Leucospermum* require short days for flower initiation as reproductive growth occurred as day length was shortening signalling the beginning of winter.

The effect of pruning varies with plants, growth characteristics, flowering and other objectives desired. For instance in tomatoes, the main benefits of pruning have been shown to be larger fruit size (Manyard, 2000). In this study, the benefits of pruning and deheading were an overall extension to the harvest time. The period of extension varied according to the time of pruning, age of plant and cultivar. The earlier pruning was carried out the longer the extension time to harvest. The old plants produced a short time to harvesting compared to the young plants and Saxosum was harvested much earlier than Scarlet Ribbon.

Deheading involved physically removing the primary inflorescence of the secondary stems at different diameters by hand. The effect was an extension to flowering time due to the later development of the secondary inflorescence. The period of delay to harvest after deheading of the primary inflorescence also varied with age of plants as old plants were harvested much earlier than young plants of Scarlet Ribbon. This could be linked to the fact that old plants have more plant matter and energy to facilitate the resumption of growth of the secondary inflorescence more rapidly than young plants. On comparing the two cultivars (Scarlet Ribbon and Saxosum), the extension to harvest after deheading was longer for Scarlet Ribbon than for Saxosum. This could be a result of differences in species composition as well as differences in flower head complexity between the two cultivars.

The length of harvested stems is important as it contributes to quality and subsequently pricing on the market and because of this, growers always strive to attain long stems in the industry. In this study, the early pruning as well as the control treatment with no deheading (normal farmer practice) produced the longest stems at harvest compared to other pruning times, which were deheaded. This was also observed when different aged plants of Scarlet Ribbon were pruned and deheaded. The pruning and deheading cultural practices appeared to be interrupting the normal growth and development of plant stems of the *Leucospermum* by introducing a ‘stop’ and ‘start’ response with regards to vegetative and reproductive growth. This was specifically apparent for plants pruned early (pre-winter). Scarlet Ribbon produced longer stems at harvest than Saxosum when the two cultivars were compared, a result related to differences in species with regards to genetic make up. Saxosum is a lignotuber plant while Scarlet Ribbon is not.

The inflorescence produced from the normal farmer practice was of a significantly larger size compared to the secondary inflorescence produced from the deheaded stems for Scarlet Ribbon. Because the resulting primary inflorescence is a product of the disbudding of all axillary (secondary) buds, the plant’s energy is concentrated on the production of a solitary inflorescence, as observed by the Virginia Camellia Society (2004) on work done on camellias. Malan and le Roux (1996) suggested deheading the primary inflorescence at a diameter of 10-15 mm to obtain good results. In this study, deheading the primary inflorescence at a small diameter resulted in a small sized secondary inflorescence, while deheading larger primary buds early during the induced state produced a larger secondary inflorescence. The different deheading diameters did not affect the size of the secondary inflorescence for the pruned and deheaded plants of the cultivars Scarlet Ribbon and Saxosum. This could be due to small range diameter (0-20mm) of primary inflorescence deheaded.

Time of pruning varies with plant species. It is recommended to prune at times that best complement the growth characteristics, flowering and other objectives desired (Wade and Westerfield, 1999). In this study pruning early (pre-winter) resulted in an extended period to harvesting compared to the normal farmer practice as reported by Archer (2000). This was evident when different ages of Scarlet Ribbon were pruned, and when Scarlet Ribbon and Saxosum were compared.

The quality of stems contributes to the final price of flowers on the market. Brits (1986) reports of a reduction in quality of *Leucospermum* pruned and deheaded by chemical and manual means, though acceptable for marketing. In this study, pruning and deheading resulted in both high and low quality flowers. Young plants of Scarlet Ribbon produced higher quality flowers compared to older plants. Flower stems harvested from Scarlet Ribbon were of superior quality than stems harvested from Saxosum when the two cultivars were compared. Although the flowering stems had different quality grades, they were acceptable for marketing.

Losses in harvest were also incurred in both trials due to pruning and deheading. The losses were a result of the treated secondary stems failing to produce a secondary inflorescence. This was mainly due to poor or non-resumption of the secondary bud development after deheading of the primary inflorescence. The cause of this was mainly deheading late in the season as reported by Jacobs and Honeyborne (1978) and Malan and le Roux (1996). In addition the increasing temperatures in spring made deheading less effective as observed by Dupee and Goodwin (1990). As the induced state was declining, the secondary buds either aborted or turned vegetative.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

The conclusions derived from this study were:

- Pruning and deheading are effective tools in manipulating flowering time in *Leucospermum.* The effects differed with time of pruning and deheading diameter used, age of plants and cultivar.
- Pruning early during the year (Jan/Feb and Mar/Apr) and deheading early during the induced reproductive phase produced the longest extension to harvest compared to the normal farmer practice with regards to number of days to harvest after pruning. This was common in old and young plants
- Although old were harvested earlier (by two weeks) than young plants, they respond better to pruning and deheading compared to young plants with regards to quality and quantity of stems harvested. The old plants also had more stems harvested of good quality and correspondingly higher earnings especially from plans pruned early (Jan/Feb). Losses to harvest due to deheading were minimal compared to young plants.
- Scarlet Ribbon proved to be the better cultivar to prune and dehead because the extension to harvest was longer and its harvest was spread over several months (seven) thus taking advantage of good prices on the market especially from September to November (off-peak period). Saxosum on the other hand was harvested early however extension to harvest period was short and harvest period was over five months. More flowering stems and correspondingly high earnings were obtained from Scarlet Ribbon with minimum losses to harvest due to deheading compared to Saxosum.

Recommendations to growers:

- Pruning and deheading are recommended to extend harvest time of *Leucospermum.* However the success of these cultural practices is highly dependent on the grower's requirements and preferences with regards to peak flowering periods and prices on the market. Pruning early Jan/Feb and Mar/Apr and deheading at 0-20 mm diameters up to mid July will result in extended harvest period up to November for Scarlet Ribbon with good quality stems, earnings and minimal losses in the Ruwa farming area
- It is recommended that pruning and deheading only be carried out by growers with large plantations and cultivating more than one *Leucospermum* cultivar so as to minimise risk of incurring losses should prices on the markets fluctuate unfavourably.

Recommendations for further research:

- Although deheading resulted in a delay to flowering time, the deheading diameter range used in this study was small (0-20 mm). Further work is recommended using larger deheading diameters to see if further delays can be achieved.
- The study was carried out at only one site, therefore it is recommended to carry out the study in other growing areas in Zimbabwe like the Eastern Highlands and Karoi, which have different weather conditions to Ruwa, to find the effect of growing environment while pruning and deheading *Leucospermum.*

REFERENCES

Archer, D. 2000. Zimbabwe Protea Association: Guidelines for Commercial Protea Growers. 4th Edition. Zimbabwe Protea Association, Harare. 2-25.

Bangerth, F. 1989. Dominance among fruits/sinks and the search for correlative signal. *Physiology of Plants* **76**, 608-614.

Blomerus, L. M., Brits, G. J & Littlejohn, G. M. 1998. 'High Gold', a Yellow, Vigorous *Leucospermum*. *Horticultural Science* **33** (6): 1094-1095.

Brenner, M.L., Wolley, D.J., Sjut, V & Salerno, D., 1987. Analysis of apical dominance in relation to IAA transport. *Horticultural Science* **22**(5) 833-835.

Brits, G. J.1977. Manipulation of flowering time in *Leucospermum Cordifolium* with Ethephon. *Agroplantae* 9,127-130.

Brits, G. J. 1986. Extension of harvesting period in *Leucospermum* by means of manual and chemical pruning methods. *Acta Horticulturae* **185**, 237-240.

Criley, R. A., Parvin, P. E & Lekawata, S.1990. Flower development in *Leucospermum* 'Vlam'. *Acta Horticulturae*. **264**, 61-70.

Dupee, S.A and Goodwin, P.B.1990. Effect of temperature, daylength and growth regulators on flowering in Protea, Telopea and Leucospermum. *Acta Horticulturae* 264: 79-86.

Department of Meteorological Services Harare. 2005.

Evans, E. 2003. Pruning Shrubs. Consumer Horticulture NC State University.

GenStat Release 6.1 Copyright 2002, Lawes Agricultural Trust (Rothamsted `Experimental Station).

Gerber, A. I., Greenfield, E. J., Theron, K. I & Jacobs, G. 1995. Pruning of *Protea cv. Carnival* to optimize economic biomass production. *Acta Horticulturae*. **387**, 99-105.

Gollnow, B.1995. Growing proteas commercially. Agfacts- Department of Agriculture, New South Wales H9.1.19. 1-10.

Hettasch, H. B., Gerber, A.I & Theron, K.l. 1997. Pruning Protea Cultivar Carnival for biennial crops of improved yield and quality. Proceedings of fourth Int Protea Symposium. *ACTA Horticulturae* **453**: 127-130.

Ireland, K. 2008. Kathy Ireland flower profiles. Viewed 23 July 2008. www.kathyirelandworldwide.com

Jacobs, G.1980. Aspects of flower initiation and development of pincushion *Leucospermum* cv. Red Sunset. Crop Production 9:175-177.

Jacobs, G.1983. Flower initiation and development in *Leucodendron* cv. Safari Sunset. *Journal of the American Society for Horticultural Science*. 108 (1): 32-35.

Jacobs, G.1985. *Leucospermum.* In: A.H Helevy (ed), Handbook of flowering. CRC Press, Boca Raton, FL. 283-286p.

Jacobs, G. and Honeyborne, G. E, 1978. Delaying the flowering time of *Leucospermum* cv, Golden star by deheading. *Agroplantae* **10**, 13-15.

Jacobs, G. and Honeyborne, G. E, 1979. The relationship between heat accumulation and the flowering date of *Leucospermum* cv, Golden star. *Agroplantae* **11**, 83-85.

Jacobs, G., Napier. D. N. and Malan D. G. 1986. Prospects of delaying flowering time of *Leucospermum*. *Acta Horticulturae*. **185**, 61-65.

Kroll, R. 1995. Cutflowers. The Tropical Agriculturalist. Macmillan Education Ltd London and Basingstoke. 9- 86p.

Johnson, T. 2006. Camellias: Care & Culture. American Camellia Society. 100 Massee Lane-Fort Valley, Georgia 31030.

Leonhardt, K. W and Criley, R. A. 1999. Proteaceae floral crops: Cultivar development and underexploited uses. In: Janick (ed.), Perspectives on new crops and new uses. ASHS Press, Alexandria, VA. 410-430p.

Lim, R. and Tamas, I. M. 1989. The transport of radio-labelled indoleacetic acid and its conjugates in nodal stem segments of *Phaseolus vulgaris* L. *Pl. Growth Regul*. **8**, 151-164

MacVicar, C.N & Co-workers.1991. Soil classification- A binomial System for South Africa. Second edition, Directorate of Agricultural Information, Private Bag X 144, Pretoria, 0001.

Malan, D.G. 1992. Propagation of Proteaceae. *Acta Horticulturae.* 316:27-34.

Malan, D.G and Jacobs, G. 1987. The influence of photoperiod on flower induction of *Leucospermum* cv. Red Sunset. Protea News 6:12-13

Malan, D.G and Jacobs, G. 1990. Effect of photoperiod and shoot decapitation on flowering of *Leucospermum* ‘Red Sunset’. *Journal of the American Society for Horticultural Science* 15 (1): 131-135

Malan, D.G., Cuting, J.G.M. and Jacobs, G. 1994. Correlative inhibition of inflorescence development in *Leucospermum* ‘Red Sunset’. *Journal of the Southern African Society for Horticultural Science*. 4 (1): 26-31

Malan, D.G and Jacobs, G. 1994. Influence of daylength irrigation and pruning on shoot growth of *Leucospermum* ‘Red Sunset’. *Journal of the Southern African Society for Horticultural Science*. 4 (1): 24-25

Malan, D.G. and le Roux, R.D. 1996. Disbudding of *Leucospermum* for better crop distribution. SAPPEX NEWS. Issue **90**. June 1996 Newsletter. 103-14.

Matthews, L.J.1993. Proteas of the world. Timber Press, Portland, Oregon 97225, U.S.A in association with David Bateman Ltd, Glenfield, Auckland New Zealand.

Maynard, E.T. 2000. Fresh Market Tomato Cultivar and Pruning Evaluation for Northern Indianan. Dept. of Horticulture, Purdue University North Central, Westville, IN 46391.

Napier, D.R., Jacobs, G., Van Staden, J and Forsyth, C. 1986. Cytokinins and Flower

devlopment in Leucospermum. *Journal of the American Society for Horticultural Science.* 111(5):776-780.

Napier, D.R. and Jacobs, G.1989. Growth regulators and shading reduce flowering *Leucospermum* cv. Red Sunset. *Horticultural Science*. 24 (6): 966-968

Oertel, C. and Oertel, J. 2001. Pruning proteas. The Fijnbosch Farme Trust. Cape Town, South Africa. www.holani.net:

Rourke, J. P.1972. Taxonomic studies on *Leucospermum* R. BR. *Southern African Botany* (Suppl.) **8**,1-194.

Parvin, P.E. 1979. The Art and Science of growing Proteas- Current Recommendations. Protea Workshop proceedings. Miscellaneous Publication **176** University of Hawaii at Manoa. Hawaii.

Percival, K. 2004. ZPA Survey 2003. Zimbabwe Protea Association Newsletter July 2004 Supplement, 1-5.

Protea Atlas Project. 2002. Growing Proteas Criteria. Viewed 8 October 2002. www.protea.worldonline.co.za.

Salinger, J. P. 1985. Commercial flower growing. Buttersworth Horticultural books. 216-239p.

Salisbury, F.B. and Marinos, N.G. 1985. The ecological role of plant growth substances. P707-766. In: R.P. Pharis and D..M. Reid (eds) Hormonal regulation and development III: Environmental Effects. *Encyclopedia of plant Physiology*, new series Vol II. Springer-Verlag, Tokyo.

Saupe, S.G. 2002. Plant Physiology: Flowering. College of St Benedict/ St John's University, Biology Department, Collegeville, M.N.

Sagers, L.A. 2006. Roses. Viewed 6 July 2006. www.larrysagers.com.

Smakel, H.J. 2006. Pruning By Pinching and Disbudding. California Avocado Association Yearbook 1929 14:135-136.

Shue-Lockham. 1965. The Movement of the flower stimulus in Xantium. Department of Horticulture, Purdue University, Lafayette, Indiana Amer. Jour. Bot. 52: 924-928.

Virginia Camellia Society. 2004. Pruning and disbudding camellias. Camellia growing. Tips and culture. The garden Report: Questions and answers.

Wade, G.L. and Westerfield, R.R. 1999. Basic Principles of Pruning Woody Plants. The University of Georgia, Cooperative Extension. Learning for Life. Bulletin: 949.

Wallerstein, I. and Nissim, A. 1992. Control of growth and flowering in *Banksia Ashbyi*, *Leucospermum* Petersonii and *Leucadendron* “Safari Sunset”. *Acta Horticulturae* – 316.

Wikipedia, 2008. Flower. Wikipedia the free Encyclopedia. www.wikipedia.encyclopedia.htm.

Webb, M. 1997. Growing proteas. Plant Research and Development, Albany. Agriculture Western Austalia Farmnote.1-7.

Wellensiek, S.J. 1961. Theoretical backgrounds of flowering. In:(Eds) Advances in Horticultural Science and their applications. Proceedings of the XVth International Horticultural congress. Nice. Pergamon press Ltd, Oxford: 35-41.

Wolfson, D., Anav, D., Tamari, Y., Lahav, T. and Shlomo, E. 2001. Soft pinching for increasing the yield of *Leucadendron* 'Safari sunset'. *Acta Horticulturae,* **545**.ISHS 239-243.

Yoder Brothers Inc. 2006. Pot Mums/Fleurettes. Cultural Tips. Viewed 9 September 2006. www.yoder.com/grower/pot/tips/cultural asp.

Zimflora. 2003. Annual statistics 2002. Juliasdale: Zimflora Private Limited.

Zimflora. 2005. Annual statistics 2004. Juliasdale: Zimflora Private Limited.

APPENDICES

APPENDIX A : ZIMFLORA CO-OP LTD: Recommended standards for export schedule of definitions

The schedule of definitions is a guide, which growers have to follow when they prepare flowers for export with Zimflora. The definitions also indicate why a consignment may be rejected if any of the definitions indicated are present.

‘‘Blemishes’’ means any external defect which detrimentally affects the appearance of the fresh proteas and which is caused by extraneous factors such as hail, sun, wind, insects, mites, handling practises and transport;

"Clean" means free from visible spray residues, excessive dirt or foreign matter;

"Crooked flower stems" means a flower stem of which the curvature at the middle therefore deviates by more than 40mm from a straight line drawn from the base of the flower head to the point of the stem, or with more than one curvature, no matter how slight;

"Foreign matter" means any material that is not normally present in, on or between fresh proteas, excluding:-

(a) residues of agricultural remedies which are permissible in
proteas; and.
(b) non-toxic colourants which are used to colour fresh proteas;

"Immature bud" means a bud that has a hard point, shows no signs of opening, and therefore will not complete the full development process of opening of the flower head or inflorescence;

"Malformed " means that the shape of a fresh protea of any species is not typical of that species;

‘‘Overdeveloped bloom or inflorescence'' means a bloom of which the outer ring of individual florets has separated as a result of advanced maturity and which no longer forms a unit with the rest of the floret mass;

‘‘Sound’’ means that the fresh proteas are free from living insects and mites, diseases or any visible external or internal physiological disorders, which may detrimentally affect the quality and appearance of the fresh proteas;

‘‘Wilted’’ means that fresh proteas have lost their freshness, and that the leaves show signs of blackening.

APPENDIX B: ANOVA TABLES

Chapter 4 ANOVA Tables

B1: Growth rate in Oct-03 for old and young plants pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.03000	0.51500	7.92	
Age	1	3.37500	3.37500	51.92	0.019
Residual	2	0.13000	0.06500		
Total	5	4.53500			

B2: Growth rate in Nov-03 for old and young plants pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.6033	0.3017	1.07	
Age	1	5.2267	5.2267	18.56	0.050
Residual	2	0.5633	0.2817		
Total	5	6.3933			

B3: Growth rate in Dec-03 for old and young plants pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.1300	0.0650	0.35	
Age	1	4.3350	4.3350	23.43	0.040
Residual	2	0.3700	0.1850		
Total	5	4.8350			

B4: Growth rate in Jan-04 for old and young plants pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.46333	0.23167	10.69	
Age	1	1.30667	1.30667	60.31	0.016
Residual	2	0.04333	0.02167		
Total	5	1.81333			

B5: Growth rate in Feb-04 for old and young plants pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.30333	0.15167	1.86	
Age	1	4.16667	4.16667	51.02	0.019
Residual	2	0.16333	0.08167		
Total	5	4.63333			

B6: Growth rate in Mar-04 for old and young plants pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.96333	0.98167	15.92	
Age	1	1.70667	1.70667	27.68	0.034
Residual	2	0.12333	0.06167		
Total	5	3.79333			

B7: Growth rate in Oct-03 for old and young plants pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.9600	0.9800	5.44	
Age	1	6.0000	6.0000	33.33	0.029
Residual	2	0.3600	0.1800		
Total	5	8.3200			

B8: Growth rate in Nov-03 for old and young plants pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.823	0.912	0.86	
Age	1	18.027	18.027	16.98	0.054
Residual	2	2.123	1.062		
Total	5	21.973			

B9: Growth rate in Dec-03 for old and young plants pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.1233	0.5617	1.51	
Age	1	8.1667	8.1667	21.97	0.043
Residual	2	0.7433	0.3717		
Total	5	10.0333			

B10: Growth rate in Jan-04 for old and young plants pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.2033	0.6017	1.10	
Age	1	12.6150	12.6150	23.15	0.041
Residual	2	1.0900	0.5450		
Total	5	14.9083			

B11: Growth rate in Feb-04 for old and young plants pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.9100	0.4550	2.46	
Age	1	16.3350	16.3350	88.30	0.011
Residual	2	0.3700	0.1850		
Total	5	17.6150			

B12: Growth rate in Mar-04 for old and young plants pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.0533	0.0267	0.25	
Age	1	4.6817	4.6817	43.89	0.022
Residual	2	0.2133	0.1067		
Total	5	4.9483			

B13: Growth rate in Dec-03 for old and young plants pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.0933	0.0467	0.33	
Age	1	7.9350	7.9350	56.68	0.017
Residual	2	0.2800	0.1400		
Total	5	8.3083			

B14: Growth rate in Jan-04 for old and young plants pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.4133	0.2067	1.11	
Age	1	9.1267	9.1267	48.89	0.020
Residual	2	0.3733	0.1867		
Total	5	9.9133			

B15: Growth rate in Feb-04 for old and young plants pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.09000	0.04500	1.29	
Age	1	4.86000	4.86000	138.86	0.007
Residual	2	0.07000	0.03500		
Total	5	5.02000			

B16: Growth rate in Mar-04 for old and young plants pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.04333	0.02167	0.62	
Age	1	6.61500	6.61500	189.00	0.005
Residual	2	0.07000	0.03500		
Total	5	6.72833			

B17: Growth rate in Feb-04 for old and young plants pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.14333	0.07167	1.59	
Age	1	1.21500	1.21500	27.00	0.035
Residual	2	0.09000	0.04500		
Total	5	1.44833			

B18: Growth rate in Jan-04 for old and young plants pruned Jun/Jul

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.560000	0.780000	117.00	
Age	1	6.406667	6.406667	961.00	0.001
Residual	2	0.013333	0.006667		
Total	5	7.980000			

B19: Growth rate in Feb-04 for old and young plants pruned Jun/Jul

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.66333	0.33167	10.47	
Age	1	2.80167	2.80167	88.47	0.011
Residual	2	0.06333	0.03167		
Total	5	3.52833			

B20: Growth rate in Mar-04 for old and young plants pruned Jun/Jul

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.16000	0.08000	0.92	
Age	1	5.22667	5.22667	60.31	0.016
Residual	2	0.17333	0.08667		
Total	5	5.56000			

B21: Growth rate in Apr-04 for old and young plants pruned Jun/Jul

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.22333	0.61167	9.92	
Age	1	4.16667	4.16667	67.57	0.014
Residual	2	0.12333	0.06167		
Total	5	5.51333			

B22: Effect of age of plants, pruning time and deheading diameter on days to harvest after pruning

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	295.4	147.7	3.72	
Age	1	47477.5	47477.5	1195.82	<.001
Residual	2	79.4	39.7	0.02	
Prune	3	730978.6	243659.5	148.57	<.001
Age x prune	3	10724.4	3574.8	2.18	0.143
Residual	12	19679.8	1640.0	3.19	
Dehead	3	43871.0	14623.7	28.41	<.001
Age x dehead	3	2828.4	942.8	1.83	0.154
Prune x dehead	9	13671.2	1519.0	2.95	0.007
Age x prune x dehead	9	3316.1	368.5	0.72	0.692
Residual	48	24709.4	514.8		
Total	95	897631.2			

B23: Effect of age of plants, pruning time and deheading diameter on days to harvest following deheading of the primary inflorescence

Source	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep	2	1403.7	701.9	137.59	
Age	**1**	**5205.4**	**5205.4**	**1020.44**	**<.001**
Residual	2	10.2	5.1	0.01	
Prune	3	9563.7	3187.9	6.48	0.007
Age x prune	3	1928.2	642.7	1.31	0.317
Residual	12	5900.5	491.7	1.30	
Dehead	2(1)	444.6	222.3	0.59	0.562
Age x dehead	2(1)	850.6	425.3	1.12	0.338
Prune x dehead	6(3)	2739.7	456.6	1.20	0.330
Age x prune x dehead	6(3)	853.6	142.3	0.38	0.889
Residual	32(16)	2135.4	379.2		
Total	71(24)	35017.6			

B24: Effect of age of plants, pruning time and deheading diameter on length of flowering stems

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	274.646	137.323	10.90	
Age	1	615.094	615.094	48.84	0.020
Residual	2	25.188	12.594	0.56	
Prune	3	405.531	135.177	5.99	0.010
Age x prune	3	53.865	17.955	0.80	0.519
Residual	12	270.667	22.556	2.47	
Dehead	3	2181.115	727.038	79.77	<.001
Age x dehead	3	111.948	37.316	4.09	0.011
Prt x dehead	9	38.760	4.307	0.47	0.886
Age x prune x dehead	9	156.927	17.436	1.91	0.073
Residual	48	437.500	9.115		
Total	95	4571.240			

B25: Effect of age of plants, pruning time and deheading diameter on inflorescence diameter of flowering

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.2146	0.1073	0.74	
Age	1	0.0001	0.0001	0.00	0.983
Residual	2	0.2916	0.1458	0.26	
Prune	3	2.3186	0.7729	1.37	0.299
Age x prune	3	1.0819	0.3606	0.64	0.604
Residual	12	6.7640	0.5637	1.75	
Dehead	3	27.3343	9.1114	28.36	<.001
Age x dehead	3	2.3838	0.7946	2.47	0.073
Prune x dehead	9	4.9202	0.5467	1.70	0.115
Age x prune x dehea	9	3.0062	0.3340	1.04	0.423
Residual	48	15.4205	0.3213		
Total	95	63.7358			

Chapter 5 Anova Tables

B26: Growth rate in Oct-03 for S.Ribbon and Saxosum pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.878	0.939	0.82	
Age	1	24.685	24.685	21.54	0.043
Residual	2	2.292	1.146		
Total	5	28.854			

B27: Growth rate in Nov-03 for S.Ribbon and Saxosum pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.58333	0.29167	8.33	
Age	1	4.86000	4.86000	138.86	0.007
Residual	2	0.07000	0.03500		
Total	5	5.51333			

B28: Growth rate in for S.Ribbon and Saxosum pruned Jan/Feb

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.513633	0.256817	32.86	
Age	1	3.124817	3.124817	399.76	0.002
Residual	2	0.015633	0.007817		
Total	5	3.654083			

B29: Growth rate in Oct-03 for S.Ribbon and Saxosum pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	1.0233	0.5117	4.58	
Age	1	8.8817	8.8817	79.54	0.012
Residual	2	0.2233	0.1117		
Total	5	10.1283			

B30: Growth rate in Nov-03 for S.Ribbon and Saxosum pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.243333	0.121667	73.00	
Age	1	9.626667	9.626667	5776.00	<.001
Residual	2	0.003333	0.001667		
Total	5	9.873333			

B31: Growth rate in Dec-03 for S.Ribbon and Saxosum pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.2433	0.1217	0.53	
Age	1	4.5067	4.5067	19.45	0.048
Residual	2	0.4633	0.2317		
Total	5	5.2133			

B32: Growth rate in Jan-04 for S.Ribbon and Saxosum pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.06333	0.03167	0.44	
Age	1	1.12667	1.12667	15.72	0.051
Residual	2	0.14333	0.07167		
Total	5	1.33333			

B33: Growth rate in Feb-04 for S.Ribbon and Saxosum pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.2508	0.1254	1.25	
Age	1	1.7604	1.7604	17.53	0.053
Residual	2	0.2008	0.1004		
Total	5	2.2121			

B34: Growth rate in Mar-04 for S.Ribbon and Saxosum pruned Mar/Apr

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.37000	0.18500	2.58	
Age	1	1.30667	1.30667	18.23	0.051
Residual	2	0.14333	0.07167		
Total	5	1.82000			

B35: Growth rate in Dec-03 for S.Ribbon and Saxosum pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr
Rep	2	1.2900	0.6450	4.90	
Age	1	3.5267	3.5267	26.78	0.035
Residual	2	0.2633	0.1317		
Total	5	5.0800			

B36: Growth rate in Jan-04 for S.Ribbon and Saxosum pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.3433	0.1717	0.51	
Age	1	9.3750	9.3750	27.99	0.034
Residual	2	0.6700	0.3350		
Total	5	10.3883			

B37: Growth rate in Feb-04 for S.Ribbon and Saxosum pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.1033	0.0517	0.42	
Age	1	1.9267	1.9267	15.84	0.051
Residual	2	0.2433	0.1217		
Total	5	2.2733			

B38: Growth rate in Mar-04 for S.Ribbon and Saxosum pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.13463	0.06732	1.71	
Age	1	0.78482	0.78482	19.96	0.047
Residual	2	0.07863	0.03932		
Total	5	0.99808			

B39: Growth rate in Jan-04 for S.Ribbon and Saxosum pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.243333	0.121667	73.00	
Age	1	0.806667	0.806667	484.00	0.002
Residual	2	0.003333	0.001667		
Total	5	1.053333			

B40: Growth rate in Feb-04 for S.Ribbon and Saxosum pruned May/Jun

Source	d.f	s.s.	m.s.	v.r.	F pr.
Rep	2	0.12333	0.06167	1.37	
Age	1	4.33500	4.33500	96.33	0.010
Residual	2	0.09000	0.04500		
Total	5	4.54833			

B41: Growth rate in Mar-04 for S.Ribbon and Saxosum pruned May/Jun

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.02333	0.01167	0.19	
Age	1	1.92667	1.92667	31.24	0.031
Residual	2	0.12333	0.06167		
Total	5	2.07333			

B42: Effect of cultivar, pruning time and deheading diameter on days to harvest after pruning

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	515.3	257.6	0.67	
Cult	1	270750.5	270750.5	702.40	0.001
Residual	2	770.9	385.5	0.28	
Prune	3	603451.4	201150.5	144.60	<.001
Cult x prune	3	38799.5	12933.2	9.30	0.002
Residual	12	16693.5	1391.1	2.15	
Dehead	3	55075.0	18358.3	28.31	<.001
Cult x dehead	3	691.3	230.4	0.36	0.785
Prune x dehead	9	16577.8	1842.0	2.84	0.009
Cult x prune x dehead	9	4797.3	533.0	0.82	0.599
Residual	48	31121.6	648.4		
Total	95	1039244.2			

B43: Effect of cutivar, pruning time and deheading diameter on days to harvest following deheading of the primary inflorescence

Source	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Rep	2	432.7	216.4	0.65	
Cult	1	15224.6	15224.6	46.07	0.021
Residual	2	660.9	330.5	1.97	
Prune	3	3410.7	1136.9	6.77	0.006
Cult x prune	3	4952.7	1650.9	9.83	0.001
Residual	12	2014.7	167.9	0.23	
Dehead	2(1)	2323.5	1161.7	1.58	0.221
Cult x dehead	2(1)	588.3	294.1	0.40	0.673
Prune x dehead	6(3)	5563.9	927.3	1.26	0.302
Cult x prune x dhd	6(3)	3427.8	571.3	0.78	0.593
Residual	32(16)	23483.8	733.9		
Total	71(24)	55462.6			

B44: Effect of cultivar pruning time and deheading diameter on length of harvested flowering stems

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	24.40	12.20	0.14	
Cult	1	3151.04	3151.04	35.28	0.027
Residual	2	178.65	89.32	2.54	
Prune	3	1062.92	354.31	10.09	0.001
Cult x prune	3	408.88	136.29	3.88	0.038
Residual	12	421.46	35.12	3.30	
Dehead	3	1644.75	548.25	51.58	<.001
Cult x dehead	3	25.04	8.35	0.79	0.508
Prune x dehead	9	96.50	10.72	1.01	0.446
Cult x prune x dehead	9	42.04	4.67	0.44	0.907
Residual	48	510.17	10.63		
Total	95	7565.83			

B45: Effect of cultivar, pruning time and deheading diameter on inflorescence diameter of flowering stems

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	39.95	19.98	0.77	
Cult	1	84.06	84.06	3.26	0.213
Residual	2	51.58	25.79	1.33	
Prune	3	99.16	33.05	1.71	0.218
Cult x prune	3	77.91	25.97	1.34	0.307
Residual	12	232.03	19.34	0.91	
Dehead	3	44.09	14.70	0.69	0.560
Cult x dehead	3	58.72	19.57	0.93	0.436
Prune x dehead	9	192.26	21.36	1.01	0.445
Cult x prune x dehead	9	157.09	17.45	0.83	0.596
Residual	48	1015.20	21.15		
Total	95	2052.05			

APPENDIX C: TABLES OF MEANS

Chapter 4 Tables of Means

C1: Interaction between pruning time and deheading diameter on days to harvest flowering stems after pruning

	Deheading Diameter treatments			
Pruning Time	**0-5mm**	**6-10mm**	**15-20mm**	**Control**
Jan/Feb	601.2a	571.3a	578.3a	498.7a
Mar/Apr	505.8b	518.6b	509.6b	465.0b
May/Jun	473.5c	456.3c	446.0c	419.3c
Jun/Jul (control)	334.0d	326.3d	330.8d	308.8d
	P value	**SED**	**$LSD_{0.05}$**	
Pruning time	<.001	11.69	25.47	
Deheading diameter	<.001	6.55	13.17	
Pruning time x deheading	0.007	16.29	33.01	

Means followed by the same letter in a column[1] are not significantly different at P<0.05

C2: Effect of pruning time on days to harvest following deheading

Pruning time	**No. of days to harvest**
Jan/Feb	108.9a
Mar/Apr	93.0b
May/Jun	92.9b
Jun/Jul (control)	80.0c
P value	0.007
SED	6.40
$LSD_{0.05}$	12.05

Means followed by the same letter are not significantly different at P<0.05

C3: Effect of pruning time on length of flowering stems

Pruning time	Length of flowering stems (cm)
Jan/Feb	65.04d
Mar/Apr	61.50c
May/Jun	57.42b
Jun/Jul (control)	69.83a
P value	0.01
SED	1.37
LSD$_{0.05}$	2.99

Means followed by the same letter are not significantly different at P<0.05

C4: Interaction between age and deheading diameter on length of stems (cm)

	Deheading Diameter treatments			
Age of plants	**0-5mm**	**6-10mm**	**15-20mm**	**Control**
Old plants	69.50a[1]	63.33a	59.75a	74.00a
Young plants	63.92b	59.67b	56.08b	65.67b

	P value	SED	LSD$_{0.05}$
Age of plants	0.020	1.21	5.22
Deheading diameter	<.001	4.36	8.87
Age x Deheading diameter	0.011	1.29	2.70

Means followed by the same letter in a column[1] are not significantly different at P<0.05

C5: Effect of deheading diameter on inflorescence of flowering stems

Deheading diameter	Inflorescence diameter (cm)
0-5mm	9.15b
6-10mm	8.70c
15-20mm	9.40b
Control	10.18a
P value	<.001
SED	0.164
LSD$_{0.05}$	0.329

Means followed by the same letter are not significantly different at P<0.05

Chapter 5 Tables of means

C6: Interaction between cultivar and pruning time on days to harvest after pruning

	Pruning time treatments			
	Jan/Feb	**Mar/Apr**	**May/Jun**	**Jun/Jul (control)**
Cultivar				
Scarlet Ribbon	585.2a[1]	530.2a	479.8a	329.8a
Saxosum	453.1b	423.1b	334.9b	289.2b
	P value	**SED**	**$LSD_{0.05}$**	
Cultivar	0.01	4.01	17.24	
Pruning time	<.001	10.77	23.46	
Cultivar x pruning time	0.002	13.78	29.64	

Means followed by the same letter in a column[1] are not significantly different at P<0.05

C7: Interaction between pruning time and deheading diameter on days to harvest after pruning

	Deheading diameter treatments			
	0-5mm	**6-10mm**	**15-20mm**	**control**
Pruning time				
Jan/Feb	560.8a[1]	541.2a	527.3a	447.3a
Mar/Apr	493.3b	495.9b	482.1b	435.2a
May/Jun	412.8c	411.6c	429.5c	375.5 b
Jun/Jul (control)	322.5d	314.5d	310.5d	290.5c
	P value	**SED**	**$LSD_{0.05}$**	
Pruning time	<.001	10.77	23.46	
Deheading diameter	<.001	7.35	14.78	
Pruning x deheading	0.009	16.67	33.56	

Means followed by the same letter a column[1] are not significantly different at P<0.05

C8: Interaction between cultivar and pruning time on days to harvest following deheading of the primary inflorescence

	Pruning time treatments			
	Jan/Feb	Mar/Apr	May/Jun	Jun/Jul (control)
Cultivar				
Scarlet Ribbon	104.8a[1]	103.2a	87.6a	80.3a
Saxosum	82.7b	65.9b	64.7b	61.9b
	P value	**SED**	**$LSD_{0.05}$**	
Cultivar	0.021	3.71	15.97	
Pruning time	0.006	3.74	8.15	
Cultivar x pruning time	0.001	5.90	13.30	

Means followed by the same letter in a column[1] are not significantly different at P<0.05

C9: Effect of deheading diameter on length of flowering stems

Deheading diameter	**Length of flowering stems**
0-5mm	59.33b
6-10mm	55.58c
15-20mm	50.96d
Control	61.96a
P value	0.027
SED	0.94
$LSD_{0.05}$	1.89

Means followed by the same letter are not significantly different at P<0.05

C10: Interaction between cultivar and pruning time on length of harvested flowering stems

	Pruning time treatments			
	Jan/Feb	**Mar/Apr**	**May/Jun**	**Jun/Jul (control)**
Cultivar				
Scarlet Ribbon	65.58a[1]	61.17a	57.08a	66.92a
Saxosum	53.08b	50.00b	44.83b	57.00b
	P value	**SED**	**$LSD_{0.05}$**	
Cultivar	0.027	1.929	8.301	
Pruning time	0.001	1.711	3.272	
Cultivar x pruning time	0.038	2.848	6.611	

Means followed by the same letter in a column[1] are not significantly different at P<0.05