FRUIT SIZE IMPROVEMENT OF 'ROYAL GALA' APPLES

By

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

SUMMARY

Fruit size improvement of 'Royal Gala' apples.

The effect of foliar application of triadimenol (a triazole), Promalin®, or scoring branches on fruit set, fruit size and fruit quality of 'Royal Gala' apples were evaluated. Four treatments were tested, viz., (a) an unsprayed control, (b) triadimenol sprayed on 6 March 1997 (one month after harvest) and then every two weeks for 8 weeks until leaf drop, as well as at mouse ear and full bloom, (c) as treatment b, plus Promalin® two weeks after full bloom, and (d) Promalin® two weeks after full bloom. Four scoring treatments were tested, viz., (a) a control, (b) scoring at full bloom, (c) scoring two weeks after full bloom, and (d) scoring four weeks after full bloom. Promalin® application two weeks after full bloom improved fruit size without any detrimental effects on fruit quality. This application was in addition to the standard commercial applications of Promalin® as part of the chemical thinning program. The possible negative effect of the GA_{4+7} on return bloom was however not determined. The scoring treatments were not severe enough to influence growth and development significantly and should be investigated again in the future.

The influence of bearing position on apple flower and subsequent fruit quality was evaluated. At full bloom in the 1997/98 season, ten flower clusters from the following bearing positions were collected and evaluated: (a) dorsal spurs, (b) ventral spurs, (c) terminal on bourse shoot, (d) terminal on long shoot, and (e) lateral on long shoots. The same bearing positions were used, one week after full bloom, for the 1998/99 season. The flowering pattern was monitored for both seasons and just prior to harvest in both

seasons the length and diameter of the fruit were measured as well as the length of the bourse shoot that had developed from the same bud. Fruit thinning by hand was done in 1997 by thinning to the largest fruit per cluster, but no thinning was done in the 1998 season. The results obtained in the morphological analysis of the flower cluster of 'Royal Gala' were not very consistent. In general, the dorsal spurs appeared to be the better quality flowers and the "king" flower is believed to be the best quality flower in the cluster as far as the receptacle dimensions are concerned. When fruit were harvested, no fruit on long shoots, either in the terminal or lateral positions, were found. Even though the percentage of these positions were low at bloom, this indicates a low set potential and possibly poor flower quality of these bearing positions in 'Royal Gala'. The size of the fruit at harvest in 1998/99, did not correlate well with the parameters measured at bloom. The correlation coefficients between bourse shoot length and fruit size were significant, but relatively small. We found a positive correlation between developed seed number and fruit dimensions.

Thinning and heading pruning cuts affect fruit size and yield of 'Royal Gala' apple trees. During the 1997 winter trees were pruned as follows: (a) control with no further pruning, (b) thinning cuts of only entire secondary branches (branches that were thicker than half of the trunk diameter were removed at the point of attachment to the trunk), (c) thinning cuts of secondary branches and tertiary fruiting units (positioned on branches), (d) thinning of spurs only, without removal of branches or fruiting units, and (e) thinning cuts of branches and tertiary fruiting units combined with heading back of fruiting units into the spurs leaving four bud on the fruiting units. Treatments (b) through (e), were

conducted at light or heavy pruning intensities, i.e., by leaving 300 or 150 reproductive buds/tree, respectively. Pruning was followed up by hand thinning of fruitlets to one fruit per cluster. All pruning treatments increased fruit size, primarily because of a indirect fruit thinning effect except the combined thinning and heading treatments where a direct effect resulted in the largest apples without having a negative effect on yield. In winter 1998 trees were pruned as follows: (a) control with no further pruning, (b) heavy thinning of secondary branches and fruiting units leaving 250 reproductive buds/tree, (c) light thinning of secondary branches and fruiting units leaving 400 reproductive buds/tree, (d) heavy thinning of secondary branches and fruiting units combined with heading back into the spurs of the remaining fruiting units leaving 250 reproductive buds/tree, and (e) light thinning of secondary branches and fruiting units combined with heading back into the spurs of the remaining fruiting units leaving 400 reproductive buds/tree. In 1998/99 season the advantage of pruning on fruit size were not observed.

Lastly, the effect of artificial extinction (removal) of flower clusters on fruit size and quality of 'Royal Gala' apples were evaluated. Individual branches were pruned as follows: (a) control, (b) 25 % removal of fruiting spurs, (c) 50 % removal of fruiting spurs, (d) 75 % removal of fruiting spurs to test for any possible enhancements of fruit size. No subsequent hand thinning of fruitlets was done. Thinning by artificial extinction methods of the fruit buds did not influence fruit size, colour, seed set or seed development. No significant differences were found between fruit number, but with 50% and 75% bud removal fewer fruit were counted. In these data the absence of any significant fruit size improvement may be due to the lack of subsequent hand thinning of fruitlets.

OPSOMMING

Vruggrootte verbetering van 'Royal Gala' appels

Die effek van blaarbespuiting van triadimenol en Promalin® asook ringelering op vrugset, vruggrootte en vrugkwaliteit is geëvalueer. Vier behandelings is toegepas nl: (a) onbehandelde kontrole, (b) triadimenol op 6 Maart 1997 en dan elke twee weke tot en met blaarval asook met "muis oor" en volblom, (c) soos behandeling b, plus Promalin® twee weke na volblom, en (d) Promalin® twee weke na volblom. Vier ringelering behandelings is ook toegepas nl: (a) geen ringelering (kontrole), (b) tydens volblom, (c) twee weke na volblom, en (d) vier weke na volblom. Promalin® bespuiting twee weke na volblom verbeter vruggrootte sonder enige nadelige effekte op vrugkwaliteit. Dit moet ingedagte gehou word dat hierdie behandeling van Promalin® was addisioneel toegevoeg tot die standard kommersiele gebruik van Promalin® wat deel vorm van die chemiese uitdun program. Die moontlike negatiewe effek van GA_{4+7} op blominisiasie is nie bepaal nie. Die ringelering behandelings was nie straf genoeg nie en dit het nie die groei en ontwikkeling betekenisvol beïnvloed nie en sal in die toekoms weer geëvalueer moet word.

Verder is die invloed van draposisies op die appel blomkwaliteit en die daaropvolgende vrugkwaliteit geëvalueer. Met vol blom in die 1997/98 seisoen is tien blom trosse van die volgende draposisies versamel en geëvalueer: (a) dorsale spore, (b) ventrale spore, (c) terminaal op beurslote, (d) terminaal op langlote, en (e) lateraal op langlote. Dieselfde

draposisies is versamel, een week na volblom, vir die 1998/99 seisoen. Die blompatroon is gemonitor gedurende beide seisoene. Net voor oes is die vruglengte en - deursnee gemeet as ook die lengte van die beurslote wat van dieselfde knop ontwikkel het as die vrugte. Vruguitdinning met die hand tot die grootste vrug per tros was gedoen in die 1997/98 seisoen, maar nie in die 1998/99 seisoen nie. Die resultate wat gekry is met die morfologiese analise van die blom trosse was nie baie konsekwent nie. In die algemeen vertoon die dorsale spore die beste kwaliteit blomme en die "koning" blomme het die grootste blombodems. Met die oes van die vrugte is geen vrugte op lang lote, hetsy in die terminale of laterale posisies gevind nie. Al was die persentasie van die posisies laag met volblom dui dit op lae setpotensiaal en moontlik ook op 'n lae blom kwaliteit van hierdie draposisies vir 'Royal Gala" appels. Die grootte van die vrugte van die 1998/99 oes korreleer nie goed met die parameters wat tydens blom gemeet is nie. Ongelukkig is die vrugte vir die 1998/99 seisoen nie gedurende die na-blom staduim uitgedun nie, wat daartoe bygedra het dat dit moeilik is om afleidings te maak. Die korrelasiekoeffisient tussen die beurslootlengte en vruggrootte was betekenisvol maar redelik klein. 'n Positiewe korrelasie tussen die aantal goed ontwikkelde sade en vrugdimensie is gevind.

Die effek van uitdun en terugsnysnitte op vruggrootte en opbrengs van 'Royal Gala' is ook geëvalueer. Gedurende die 1997 winter is die bome op die volgende manier gesnoei: (a) geen snoei (kontrole), (b) uitdunsnitte van hele sekondêre takke (takke wat dikker was as die helfde van die stam se deursnee by die punt van aanhegting aan die stam), (c) uitdunsnitte van sekondêre takke en tersiêre vrugdraende takke, (d) uitdun van spore alleen sonder om enige takke te verwyder, en (e) uitdunsnitte van sekondêre takke en

tersiêre vrugdraende takke gekombineerd met terugsnysnitte van vrugdraende takke in die spoor sisteem in tot net vier spore per tak oorbly. Vir behandelings (b) tot (e) was die behandelings opgedeel in 'n ligte en 'n strawwe uitduning van knoppe deur onderskeidelik uit te dun tot 300 en 150 reproduktiewe knoppe/boom. Die snoei was opgevolg deur handuitdunning tot een vrug per tros. Alle snoeibehandelings verbeter vruggrootte, primêr as gevolg van 'n indirekte vruguitdunnings, effek behalwe die behandeling met uitdunsnitte van sekondere takke en tersiêre vrugdraende takke gekombineerd met terugsnysnitte van vrugdraende takke. In hierdie behandeling is daar 'n direkte effek op vruggrootte sonder om 'n negatiewe effek op die oes opbrengs te he. In die winter van 1998 is die bome soos volg gesnoei: (a) geen snoei (kontrole), (b) strawwe uitdun snitte van hele sekondêre takke en vrugdraende takke tot op 250 reproduktiewe knoppe/boom, (c) ligteuitdun snitte van hele sekondêre takke en vrugdraende takke tot op 400 reproduktiewe knoppe/boom, (d) strawwe uitdunsnitte van sekondêre takke en tersiêre vrugdraende takke gekombineerd met terugsnysnitte van vrugdraende takke tot in die spoorsisteem tot op 250 reproduktiewe knoppe/boom, en (e) ligte uitdunsnitte van sekondêre takke en tersiêre vrugdraende takke gekombineerd met terugsnysnitte van vrugdraende takke tot in die spoorsisteem tot op 400 reproduktiewe knoppe/boom. Geen handuitdunning is gedurende die seisoen gedoen nie. In die 1998/99 seisoen is geen voordeel van snoei op vruggrootte waargeneem nie. Snoei moet dus opgevolg word deur handuitdunning van vruggies.

Laastens is daar na die effek van kunsmatige uitdun van blomtrosse op vruggrootte van 'Royal Gala' appels gekyk. Individuele takke is soos volg gesnoei: (a) kontrole, (b) 25 %

verwydering van spore, (c) 50 % verwydering van spore, en (d) 75 % verwydering van spore. Geen opvolg handuitdunning is gedoen nie. Die uitdun tegniek het nie die vruggrootte, - kleur of die hoeveelheid en ontwikkeling van saad beïnvloed nie. Met die 50 % en 75 % verwydering is daar soos verwag minder vrugte geoes. Die rede dat geen vruggrootte verbetering gevind is nie kan moontlik daaraan toegeskryf word dat geen opvolg handuitdunning toegepas is nie.

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CONTENTS

LITERATURE REVIEW:

1. Introduction

The aim of this literature review is to consider all the processes occurring in the apple tree during reproductive bud development and how it influences bud development, bud quality and therefore fruit quality. Fruit size is determined from the start at reproductive bud induction and throughout its development (Faust, 1989). Therefore, it is important that reproductive bud development occurs under optimal conditions.

Flowering in fruit trees can be divided into two major developmental processes, occurring in two successive growing seasons. These developmental processes are the initiation and development of the reproductive buds during the summer and autumn of one season and the flowering process itself occurring during spring the next season (Faust, 1989).

For reproductive buds to be initiated, the tree must receive a signal or signals and subsequently meristems undergo complex histological and morphological changes to become reproductive buds. After initiation, the differentiation of buds occurs. The reproductive bud differentiation process coincides with, and is influenced by the other activities occurring in the tree. Therefore, it is an extremely complicated process. Environmental conditions should be conducive to this activity (Faust, 1989).

2. Internal control of reproductive bud induction and differentiation.

2.1 General features of reproductive bud induction and initiation.

The beginning of flower formation is often referred to as induction (Luckwill, 1974). It is followed by initiation of the growing point and, later, by differentiation of flower primordia. Each of these processes is distinct and requires specific internal and external conditions to proceed. Induction of flower buds is a qualitative change that according to some is governed by hormonal balance (Luckwill, 1974) and according to others is brought about by changed distribution of nutrients inside the apical meristem (Williams, 1981). The end result is that strategically located parts of the meristem are programmed to form flowers.

The physiological details of this process are intricate and complex. Induction can also be viewed as a process during which previously repressed information is being translated to form a new structure, namely, the flower bud (Buban and Faust, 1982). In essence, induction is the ceasing of repression of genes responsible for flower bud development, and in this sense "induction" is synonymous with "de-repression" of a special set of genes. Subsequent to the induction, the differentiation of the reproductive bud begins. This process includes histological and morphological changes in the apex resulting in the development of the flower primordia and later the distinguishable parts of the complete flower (Buban and Faust, 1982). According to Buban and Faust (1982), Becker (1964) found that these activities require mitotic activity; consequently, differentiation can be considered partly as a special-purpose cell division. As differentiation also requires that growth and development occur inside the buds, many characteristics of growth in general are also applicable to this process

Bernier (1970) divided the combined reproductive bud induction and differentiation processes into three main stages. (a) When the stimulus triggering flower initiation reaches the apical meristem, RNA and proteins essential for flower initiation are synthesised, (b) by the mitotic cycle when the nuclei divide, and (c) by the morphogenetic cycle when the flower primordia develop.

It is generally accepted that before the differentiation of the flower bud the mitotic activity increases in the apical meristem (Thomas, 1963; Gifford *et al.*, 1971). However, in plants placed under flower-inductive conditions an increased nucleic acid synthesis cannot always be detected before cell division. Taking into consideration several factors from which the cell division activity may be determined, one must proceed cautiously. The mitotic index may signify the change in the cell cycle, but it does not necessarily show the true cell division activity (Gifford *et al.*, 1971).

During cell division, nucleic acid metabolism is important. Under flower inductive conditions, synthesis of nucleic acids increases (Gifford and Nitsch, 1970), but different zones of tissues within the growing point may differ in synthetic activity. There are questions about the need for nucleic acid synthesis for the induction process itself. The synthesis of DNA is not an obligate condition for photoperiodic flower induction (Ullmann *et al.,* 1971), and the increase of RNA-synthesis may be required only to activate the growth processes accompanying differentiation (Seidlova, 1972). Teltscherova (1973) concluded that the growth phenomena occurring under inductive

circumstances cannot be separated from flower induction itself. Thus, the stimulation of nucleic acid synthesis and flower induction may not be directly connected. The structure of the vegetative apical meristem and the reproductive growing point is in many cases similar or almost identical. The major differences between the vegetative and the reproductive apical meristem are: a shortening of the plastrochron, an increase in mitotic activity in certain meristematic tissues, an increased size and RNA-content of the nucleoli in the meristematic cells. More differences are an increased stratification of the growing point; the zonation, characteristic of the vegetative growing point is less distinct; and the shape of the growing point is changed (Gifford *et al.*, 1971). Finally, the characteristic morphology of the flower primordium (inflorescence) takes shape.

2.2 The formation of reproductive buds in apple trees.

2.2.1 Cytochemical changes in the growing point.

Cytochemical changes, as indicators of the reproductive bud differentiation are important in induced buds of apples. The first of these changes is the increased synthesis of DNA and RNA. Cytophotometric determination of the histone, the DNA, and the DNA + RNA levels of the nuclei in terminal buds of spurs of bearing and nonbearing 'Jonathan' trees have shown a good correlation with differentiation (Buban and Simon, 1978). The nucleic acid level is lower and the histone level is higher in the nuclei of cells in the growing point of spur buds when fruit is present than when it is absent. The cytochemical features of the growing point change again when histologically differing structures are recognisable in the reproductive growing point (Buban and Simon, 1978).

Base analogs of nucleic acids inhibited flower bud differentiation in apple, further pointing to the involvement of nucleic acids in the process (Buban, 1969). Although changes in histones correlate well with flower differentiation in apples (Buban and Hesemann 1975), histone changes have frequently given inconclusive results in other plants (Knox and Evans, 1966).

2.2.2. The Histological differentiation of the growing point.

Soon after cytochemical changes start, histological differentiation begins and proceeds during the following 8 to 10 months. Changes in the structure of the apex during the histological differentiation were described by Faust, (1989)

The tunica, as one of the distinct zones within the vegetative apical meristem, is separated into two layers. The top layer consists in all cases of two rows of cells (dermatogen and subdermatogen), whereas the second accessory tunica layer may have from one to four rows of cells. The corpus (the central meristem) is located under the tunica. The corpus is connected with the pith rib meristem (Buban and Faust, 1982).

When the vegetative apex receives the signal to differentiate into a flower bud, a sequence of events occurs. Mitotic activity becomes general in the entire apex, changing the histological structure of the apex. The central meristem now is located directly under the subdermatogen. Changes follow in the flower meristem, which is morphologically distinguishable. Subsequently, the shaping of the flower primordium proceeds. The entire development (the vegetative bud, then the appearance of the reproductive growing

point, followed first by the reproductive meristem and then by the flower primordium) is the result of the progressive transformation of the vegetative growing point (Buban and Faust, 1982). Buban and Faust (1982) said that according to Hilkenbaumer and Buchloh (1954), the key step for histological differentiation occurs in the tunica. The first visible sign of differentiation is when the flat apical meristem assumes a dome shape. About 8 to 14 days are required from the beginning of histological differentiation to the appearance of the reproductive meristem. The subsequent development of the reproductive meristem is relatively rapid. By leaf drop all parts of the flowers are present in a large percentage of reproductive buds (Faust, 1989).

2.2.3 The morphological differentiation of the flower primordia.

According to Buban and Faust (1982), the diameter of the terminal flower primordium ("king") is approximately 700 to 780μm at the beginning of December (Northern Hemisphere). The increase from October to December in these buds was 23% to 36%. The diameter of lateral-flower primordia were less, ranging from 550 to 570μm. The increase from October to December in these buds was 23% to 26%. During the winter, the morphological differentiation and the increase in diameter both continued, but at a slower rate compared to that occurring from October to December. By mid-February the terminal flower primorduim increased by an additional 16 to 17 %, the lateral primordia by 6 to 18 %. Toward spring, the growth accelerated. By the time of bud burst the diameter of the terminal flower primordia was more than 1900μm and that of the lateral primordia nearly 1400μm (Buban *et al.*, 1979). Faust (1989) confirmed this. He said that

buds continue to develop during the winter. According to him, apple buds increase in sizes 20 to 25 % during the winter months.

At the moment of bud burst there is still a significant difference in the maturity of the terminal and lateral flowers. The delayed development of the lateral flowers explains their later bloom, which may be attributed to correlative inhibition (Buban and Faust, 1982).

3. The sequential development of reproductive buds.

The first sign of reproductive bud initiation is when the meristem within the bud swells and rises on its axis (Huang, 1996). This is defined as initial stage I. Next, a new protuberance (bract primordium) appears on the crown, with phyllotaxy order of 2/5. The first lateral flower primordium is then observed in the axial of the bract primordium, and at the same time an upper protuberance (bract) is detected. This implies that the flower bud differentiation has entered into the initial stage II. When two lateral flower primordia are present, the lower one is always larger than the upper one, indicating that the second lateral flower primordium is differentiated acropetally. In addition, a new bract primordium forms in the uppermost position. When three lateral flower primordia are seen, without exception, the middle one is the largest, clearly indicating that the third lateral flower primordium differentiate basipetally from the first lateral primordium.

This is followed by the sepal primordia differentiating at the top of the crown (sepal stage). At this stage the 5-sepal lamella do not occur simultaneously, they occur

sequentially according to the phyllotaxy order, and thus they are not equal in size at the beginning of this stage. Later in this stage, they reach the same size forming a cup-shaped "king" flower. During the following stage, 5 petal primordia are formed to the inside of the sepal (petal stage). Following the petal stage the stamen primordia appear as a ring beneath and alternating in pairs with the petal primordia (stamen stage). Next, the second ring of stamen primordia differentiate beneath and alternating in pairs with the pair of stamen primordia of the first ring. Finally, the centre of the meristem becomes concave and 5 protuberances (carpel) are revealed. Reproductive bud differentiation slows down for the winter in this form. Each lateral flower primordium first differentiates two bracts on either side, and then differentiate in the same manner as the "king" flower (Huang, 1996).

Huang and Cheng, (1984) earlier showed that the rate of progress of each stage is inconsistent especially under unfavourable conditions. Development could stagnate at a certain stage for an extended period. Therefore, it is difficult to determine exactly how much time is required to complete a given stage. Huang (1996), collected buds of 'Golden Spur' in Wenatchee, USA in 1983, a year with favourable weather for reproductive bud initiation, resulting in a very large percentage of buds being reproductive. Results showed that the reproductive bud initiation started the 7^{th} week after spur growth terminated. The rate of progress was highly uniform. This data allowed them to find the approximate minimum time required for each developmental stage, which was as follows: 1 week for the first lateral flower primordium, 1 week each

for sepal and petal primordia and 2 weeks each for stamen and carpel primordia under favourable conditions (Huang, 1996).

Floral organs develope slowly from March to August (Southern Hemisphere) and pollen sacs are only formed in the anthers at the end of this period in 'Starking Delicious' (Bergh, 1985a). Development accelerates during September and ovules form three weeks before full bloom. The carpels rapidly increase in length and fuse with the receptacle at their dorsal ends. The inner and outer integuments of the ovule develope and the filaments of anthers lengthen rapidly during the last three weeks before bloom.

4. Node length and plastrochron length.

In order for the vegetative bud to receive the inductive stimulus and undergo the preceding changes, it must be at a certain stage (Faust, 1989). The apple reproductive bud is a shortened axis, bearing typically 21 leaf formations. At the base of the shoot, there are nine bud scales followed by three transition leaves, six true leaves, and three bracts. Only after a certain critical node number has been reached does flower induction begin first in the shoot apex itself and then in the axils of three bracts and the upper true leaves. In apple, the critical node number required before flower initiation commences is about 20 for 'Cox's Orange Pippin' and 16 for 'Golden Delicious'.

Fulford (1966) first suggested that flower initiation in apple is related to the length of the plastochron, the average time interval between the initiation of the successive leaf primordia. Fulford contended that flowers do not form if the plastochron is longer than

seven days. Abbott (1970) stated that, in apples, flower formation occurs only once a critical number of nodes have been formed on the bud axis, and if the critical node number is not reached by the end of the growing season, the bud will remain vegetative. He observed that flower initiation in cv. Cox's Orange Pippin commenced only after about 20 nodes had been formed within the bud. Luckwill (1974) established the plastochron theory for flower bud induction. He emphasised that an apex with 6 nodes at the beginning of the season must grow for about 100 days to attain the 20-node stage for flower induction to commence. When the plastochron is longer than 9 days, the bud does not reach this stage of being receptive to flower induction. While a very short plastochron may result in the buds growing out as vegetative shoots in the current season.

Huang (1996) cast doubt on this hypothesis, as the progress of node formation in vegetative and reproductive buds before the start of morphogenesis of the flowers is similar for both types of buds. The difference in node number between reproductive and vegetative buds occurred only after the beginning of flower bud induction. Luckwill and Silva (1979), Buban and Faust (1982) and Faust (1989) also recognised that, (before the first visible sign of flower initiation) there is no difference in the rate of node production in buds whether they become reproductive or remain vegetative. The additional nodes are produced in the floral apex only after the flower morphogenesis has begun i.e., the differences in the node number between the reproductive and vegetative buds occurs only during the initial stages of the reproductive bud development. According to Huang (1996), Mehri *et al.* (1994) traced the spur bud development with electron microscope and vinyl polysiloxane techniques and found that the last true leaf primordium occurred

synchronously with the doming of the central zone of the bud apex. These primordia differentiate on the dome were the bracts, and form the base of which floral primordia differentiate further.

Although daminozide (2, 2-dimethylhydrazide) promotes and gibberellic acid (GA_3) inhibits reproductive bud formation, neither GA_3 nor daminozide has any significant effect on the rate of node production or on the so called critical number of nodes (Huang, 1996). This is supported by Luckwill and Silva (1979), who found that GA_3 inhibits flowering of apple buds without any effects on the rate of node production in the buds. Based on the results obtained from most experiments it seems likely that there really exist a critical number of nodes necessary for flower induction. But it should be emphasised that the critical number of nodes was not an absolute value, but only a mean value. The frequency distribution of node number varied greatly in both vegetative and reproductive buds, with variation between the maximum and minimum number as high as ten (Huang, 1996).

5. The site of reproductive bud initiation.

In apples, flower bud initiation occurs terminally on short, bearing shoots (spurs) and in axillary buds of elongated shoots (Milutinovic, 1974). Reproductive bud development on elongated shoots is not characteristic of all the cultivars, nor does it occur in every year. The shoot vigour, expressed in length, and the position of the bud on the shoot are important factors in reproductive bud differentiation. Flower initiation occurs most often laterally in the middle of long shoots. Buds developing at longer internodes are less

likely to differentiate flowers than buds developing at shorter internodes (Jackson and Sweet 1972).

According to Buban and Faust (1982), Zeller (1962) found that some of the flower primordia initiated laterally on the elongated shoots never reach full development, with up to 60 % never developing. The development of these flower buds on one-year-old shoots start late, the flower primordia are incomplete, and they frequently have no pistil primordia when trees become endodormant. Such flowers are smaller at bloom, pollen development is reduced, set potential is low and part of the seed does not develop after fertilisation. Ecological factors must also be taken into consideration. For instance in cool climates where initiation on spurs is in June (Northern Hemisphere) and much later in lateral bud on long shoots, lateral buds never complete their development. In more moderate climates, there is time for the development of reproductive buds on laterals because the growing season is much longer. In most apple growing areas, the flowers on the one-year-old, elongated shoots have significance only when the earlier-opening flowers of the spurs suffer frost damage (Buban and Faust 1982).

Lee *et al.* (1994) found that the most valuable flowers of 'Rome Beauty' apple trees develop in the terminal position on spurs and short shoots. They reported that spur terminal flower buds begin blooming earlier, blossom for a longer period of time, and produce many more blossoms than lateral buds on one-year-old shoots. This allows spur flowers to attract bees first and for a longer time. The result is better pollination, as shown by seed count in the fruit. Milutinovic (1974) also found well-developed apple

clusters in the terminal buds of elongated shoots, but their frequency of occurrence is low. The quality of the spur buds differs with age. The buds on younger spurs are more advanced and of good quality while the flowers borne on the older, shorter spurs may have irregular ovaries more frequently (Milutinovic, 1974).

6. Reproductive bud position and orientation.

Reproductive bud position on a fruiting branch determines the development of the bud (Deckers, 1999). The reproductive spurs on the upper side of the fruiting branch are superior to those buds on the spurs on the lower side of the same branch. This preferential development of structures on the upper side is not only true for reproductive buds, but also for the development of shoots and bourse shoots. This results in higher fruit weight for fruit produced on buds in the upright position (Rom and Barritt, 1990).

Rom (1992) found that vegetative and fruiting spurs orientated vertically down on the underside of horizontal limbs had fewer leaves, smaller leaf area, smaller leaves, less specific leaf weight and thinner terminal buds than spurs pointing up. Spurs pointed vertically down, set a greater percentage of fruit than spurs of other orientations, but the fruit were significantly smaller than fruit from spurs orientated vertically up and horizontally.

7. The time and period of reproductive bud initiation and differentiation.

The time interval between the beginning and final stages of reproductive bud differentiation is relatively long and varies with cultivars. Tromp (1968) reported that initiation of reproductive buds is possible in late summer on nonbearing trees, whereas bearing trees initiate flowers earlier, i.e., before the predominance of the inhibiting effect of fruit. Initiation starts only after shoot growth ceasation (Abdulkadyrov *et al.*, 1972).

Where initiation occurs relatively late in the season the fruit buds are physiologically "young" (Abbott, 1970). On opening they give rise to clusters with an elongated bourse, large spur leaves and a reduced number of flowers with long stalks which show only a poor ability to set fruit. By contrast, early initiation results in physiologically "old" flower buds producing compact clusters with small primary leaves and almost sessile flowers which set well. Wertheim *et al.* (1976) described "young" buds as having larger primary leaves, long bourse shoots, fewer flowers and poor fruit set. Fruit that set in such clusters are oblong and of average size, with longer stalks. These clusters also bloom late, and the flowers have fewer stamens and ovules. "Mature" buds have bloom better. The primary leaves are fewer and smaller, fruit set and size is good and optimal yields are obtained. "Old" buds produce compact clusters with small primary leaves, their fruit set is low and the resulting fruit are relatively small and flat with short stalks.

8. Cultural practices affecting reproductive bud initiation and development and fruit quality.

8.1 The influence of the nutritional status of the tree.

One theory states that the ratio between the carbohydrates and nitrogen (C:N ratio) in the tree, will determine whether reproductive buds or vegetative buds will develop (Tromp, 1976). When carbohydrates dominate reproductive buds will form. The values are relative. At an optimal C/N value the tree is in physiological balance, which implies that the vegetative growth and flower formation is in balance (Tromp, 1976).

Trees that receive nitrogen fertilisation during spring seem to have larger buds at the end of the growing season. However, autumn application of N greatly accelerates the development of reproductive buds, by March (Northern Hemisphere). Apparently, autumn application of nitrogen stimulates buds that are underdeveloped (Buban *et al.*, 1979). Without additional nitrogen or with spring applied N, the early developmental stages of reproductive bud differentiation are the same. The effect of spring/summer-applied N shows in October (Northern Hemisphere) when the development of stamens commences. Usually the later developmental stages, the differentiation of pistils, and formation of pollen tetrads do not take place without a sufficient quantity of nitrogen. According to Faust (1989) it is possible that the early phases of reproductive bud development are governed by hormonal events, whereas the later development of the buds depend on availability of carbohydrates and nitrogen.

Rootstocks play an important role in uptake of nutrients, thus rootstock effects on flowering may be due to differences among rootstocks in phosphorus (P) uptake from the soil or differences in distribution within the tree. Uptake of P by roots is positively related to rootstock vigor (Bukovac *et al.,* 1958). Phosphorus application increases flowering the following year (Taylor and Nichols, 1990). Hirst and Ferree (1995b) found that rootstock effects on spur leaf P concentration were small in magnitude and inconsistent from year to year. They also found that other minerals (for example Ca, Mg, Mn, and B) were affected by rootstock with stable relationship across years, however, no correlation of mineral status with rootstock vigour and productivity were apparent. Although previous studies have shown that rootstocks differ in their ability to absorb and translocate P (Jones, 1976), Hirst and Ferree (1995b) suggest that rootstocks do not affect the amount of P at the site of flower formation, the bud apical meristem. A role for P in the mechanism of rootstock control of flowering cannot be ruled out, but a direct role seems unlikely.

8.2 The influence of leaves

Mature leaves are required for flower initiation and they are also a major source of cytokinins. Leaves provide photosynthate to the surrounding fruit and tissues that may, in turn, promote flowering (McLaughlin & Greene, 1991). Hansen, (1969) showned that 190 to 230cm^2 of leaf area was required for reproductive bud initiation to occur on 'Golden Delicious'. Delaying and reducing leaf expansion may be a factor in inhibiting reproductive bud formation by lowering the amount of hormones or photosynthates available for growth of the bourse shoot bud (McLaughlin & Greene, 1991).

8.3 The influence of fruit and previous season's crop on bud development.

Cultivars with a biennial bearing habit produce few reproductive buds in heavy cropping years (Luckwill, 1970), and the number of reproductive buds decrease as crop load increases (Abbott, 1984). The earlier fruit are picked in a heavy cropping year, the better the yield in the subsequent year (Williams *et al.,* 1980). This was initially attributed to insufficient nutrients remaining for bud development after fruit demands have been satisfied, but later defoliation experiments showed inhibition of bud development to be hormonal rather than nutritional (Fulford, 1966). Chan and Cain (1967) found that parthenocarpic fruit did not inhibit bud development, whereas seeded fruit did, and concluded that the effect of fruit on return bloom was caused by the seeds and was hormonally regulated.

The effect of seed produced hormones of the fruits on reproductive bud formation was also investigated. Endogenous auxin appears to have an indirect, but favourable, effect on reproductive bud initiation at the beginning of the growing season (Buban & Faust, 1982). Auxin in the young developing seeds, less than 4 weeks old, attract more nutrients to the spurs. Auxin functions in the intensively developing shoot tip in the same way. This is important because the early, fast development of the leaf primordia, and of young leaves early in the season, is a prerequisite for reproductive bud initiation (Buban & Faust, 1982). Ethylene also promotes flower bud formation, and exogenous growth regulators having similar effect to auxin are believed to act through promoting ethylene. Thus auxin could act in either way, depending on the concentration produced or sprayed.

Gibberellins were reported to inhibit the first stages of reproductive bud initiation (Luckwill, 1970). The most important GA's that diffuse from the seeds into the spur tissue are GA_4 and GA_7 and both are produced by the seeds of annual and biennial cultivars, but it is not known what amount of the individual GA's are produced (McLaughlin & Greene, 1991). There is strong evidence that it is GA_7 rather than GA_4 that inhibits reproductive bud formation (Tromp, 1982). GA's translocated from the seed starting from the 3rd to 4th week after full bloom counteract the favourable auxin effect and decrease reproductive bud formation. GA's also increase growth excessively, which, in addition to their direct effect, decreases reproductive bud initiation indirectly (Buban and Faust, 1982).

Buszard and Schwabe (1995) found that while leaf number and area and flower number per spur clusters were not significantly affected by prior crop load, pedicel length, peduncle length, and receptacle diameter were all smaller on the previously heavily cropped trees. The number of flower clusters per tree was 2.5-fold greater and the final yield (fruits per tree) was nearly double on defruited trees compared to those previously heavily cropped. Initial percentage fruit set on defruited trees was about 3.5 times that on heavily cropped trees, but final percentage fruit set was about 30% greater on previously heavily cropped trees. This was probably related to increased fruit drop on defruited trees, where competition between developing fruit was much greater than on the previously heavily cropped trees.

Previous crop load also influences the effective pollination period (EPP). The EPP was ten days for flowers from defruited trees and barely six days for the previously heavily cropped trees. Heavy cropping results in smaller flowers the following season and reduced initial fruit set, due to the reduced EPP. There were striking differences between flower characteristics and fruit set associated with cropping history. Flowers of previously defruited trees are most receptive to pollen at anthesis, as evidenced by their good fruit set. In contrast, fruit set of flowers on previously heavily cropped trees was poor at anthesis, with their best response to pollination 3 days after anthesis. The stigmata of flowers on defruited trees were covered with fully expanded papillae at anthesis and were carried on a thick style, while the papillae from flowers from previously heavily cropped trees were unexpanded at anthesis and styles were thinner (Buszard and Schwabe, 1995). It may be that papillae must be fully expanded to allow the hydration and germination of pollen grains deposited on the stigma, and that the expansion of papillae from flowers of previously heavily cropped trees is delayed sufficiently to result in a substantial reduction in the initial fruit set and EPP. The results of this study provide evidence that floral morphology, EPP and initial fruit set of apple is influenced by the previous crop load (Buszard and Schwabe, 1995).

Bergh (1985b) investigated the effect of crop load of the previous season on cell number and size of the cortical region of flower primordia, flowers, fruit and fruit size in 'Starking Delicious' apples in South Africa. A heavy crop during the previous season resulted in a decrease in cell number of the cortical tissue at the base of the developing

flowers and fruit and therefore it reduced fruit size. Lower cell numbers were evident when mature fruit of similar size were compared.

A maximum of 25 to 26 divisions occur in developing apple flower primordia, starting at the initiation of the flower primordium and ending 35 to 50 days after anthesis (Smith, 1950). Twenty to 21 of these divisions apparently occur during the pre-anthesis period. Bergh (1985b) found that 19.9 and 19.3 pre-anthesis divisions occurred in the flower primordia from heavily cropped trees and 20.5 and 19.7 in lightly cropped trees. The difference in cell number at anthesis in flowers from previously heavily and normal cropped trees could possibly be due to a difference in the number of cells participating in the formation of the floral primordia. This in turn could be due to competitive correlative effects of a nutritional or hormonal nature, or both. Cell number appears to be a major factor determining fruit size. Goffinet *et al.* (1995) found that fruit size and weight decreases as thinning was delayed and unthinned trees had the smallest fruit. Within a thinning treatment, fruit size is positively correlated with cortex cell number, not with cell size or proportion of intercellular spaces. Unthinned trees have smaller fruit with fewer cells than did larger fruit from thinned trees, and fruit from trees thinned near bloom are larger with more cells than those from trees thinned later. In 'Empire' apples, fruit thinning appears to increase fruit size by allowing remaining fruits to continue cell division under less competition during the first weeks after bloom, and not by extending the cell division period, increasing cell size or increasing the proportion of intercellular spaces (Goffinet *et al.*, 1995).

Cell division during the post anthesis period is unaffected by different cropping levels of the previous season (Bergh, 1985b). Since differences in cell number are present at anthesis and earlier, the difference in final cell number must be due to the effect of the crop of the previous season. Fruit with fewer cells compensate for this by increasing cell size. However, compensation is insufficient to produce fruit of the desired uniform size. Bain and Robertson (1951) also indicated that cell number is a more important component determining final fruit size. Bergh (1985b) indicates that the reduction in cell number caused by a heavy crop will persist during the following seasons and consequently reduce fruit size.

8.4. The influence of vegetative growth and rootstocks.

A negative relationship between vegetative growth and flower initiation is commonly recognised, and factors that induce early cessation of shoot growth often lead to increased reproductive bud formation (Forshey, 1989). Hirst and Ferree (1995a) suggested early termination of shoot growth leads to increased flower initiation. Abbott (1970) also noted that flower initiation occurs only after shoot growth has ceased. It is widely accepted that dwarfing rootstocks induce shoot growth cessation earlier in the season than trees growing on more vigorous rootstocks, thus, resulting in the initiation of more flowers (Hirst and Ferree, 1995a).

8.5 The influence of chemical application.

The possibility of using chemical growth regulators to improve production has been of interest to horticulturist for many years. Triazoles represent one such group of

compounds. The most obvious plant growth response to triazole treatment is reduced shoot elongation. The growth-retarding properties of the triazoles are largely attributed to interference with gibberellin biosynthesis (Davis *et al.,* 1988). Triazole induced growth inhibition can be reversed by the application of GA_3, thus indicating that they do not block the activity of either existing endogenous or exogenous GA_3 (Lever, 1986) but only reduces gibberellin biosynthesis (Davis *et al.,* 1988). The effect of triazoles on the reproductive development of woody perennial fruit crops show an increased number of reproductive buds in apples (Lever, 1986) in some studies, but not in others (Elfving and Procter, 1986). Foliarly applied triadimefon (a triazole) on apples increased fruit set, but it is not clear if this was due to a direct plant growth regulator effect or due indirectly to the fungicidal properties of the compound (Strydom and Honeyborne, 1981).

Foliar applications of paclobutrazol (1-(4-chlorophenyl)-4,4-dimethyl-2- (1,2,4- triazol-1-yl) pentan-3-ol) by Strydom and Honeyborne (1986) in autumn increased fruit set and fruit size and reduced vegetative growth of 'Songold' plums. Olivier *et al.* (1990) reported that autumn application of paclobutrazol on 'Songold' plums caused a significant increase in the dry weight of flower buds and flowers had larger ovaries. Apparently paclobutrazol altered the dry matter allocation in favor of reproductive bud development in plums, thus causing "stronger" buds which yielded heavier flowers that opened earlier. Paclobutrazol induced changes in dry matter allocation might account for the reported increase in fruit set and size by Strydom and Honeyborne (1986). Autumn applications of chlormequat (CCC) to 'Doyenne du Comice' pear trees improved flower bud quality in terms of average dry weight and flower number per bud and increased the

set potential of flowers. Autumn chlormequat application apparently caused a shift in dry matter allocation to the development of reproductive buds (Theron *et al.*, 1998). The heavier a reproductive bud and the more flowers in a bud, the better the quality of the flowers (Buszard and Schwabe, 1995). Total shoot growth was significantly reduced following chlormequat application. This was due to shorter shoots, because the number of shoots were not significantly reduced (Theron *et al.*, 1998). Due to the reduction in vigour, more and earlier reproductive bud initiation resulted in a higher blossom density, with an increase in fruit set and production the following season (Nicotra, 1982). Triadimefon application before full bloom to 'Starking Delicious' apple trees significantly increased the number of seeds per fruit, reduced the number of seedless fruit, altered seed distribution of seeds with more fruit having 4 to 7 seeds and increased the number of loculi containing two seeds (Jacobs *et al.*, 1990). Chlormequat application also increased the seed number in pear fruit.

Gibberellin (GA) inhibits flowering in pear trees (Dennis *et al.*, 1970). Chlormequat, triadimefon and paclobutrazol (all triazoles) reduce GA levels in plants. A reduction in GA levels should decrease the plastrochron, which should result in more rapid development and differentiation of reproductive buds (Buszard and Schwabe, 1995). Autumn gibberellic acid sprays delay the differentiation of reproductive buds in stone fruit (Corgan and Widmoyer, 1971). The inhibition of the biosynthesis of gibberellins by paclobutrazol might account for the increased rate of reproductive bud development found in treated 'Songold' plums (Olivier *et al.*, 1990). Effects of the triazoles on fruit size have been somewhat inconsistent (Davis *et al.*, 1988). Triazoles have little effect on

net photosynthetic rates but influence it in several indirect ways. Triazoles reduce leaf expansion, and thereby may reduce the amount of photosynthetic surface, but it may also delay the onset of leaf senescence thereby prolonging the period of photosynthetic activity for a given leaf (Sankhla *et al.,* 1985). Curry and Williams (1983) found that high concentrations of paclobutrazol result in a reduction of leaf size as well as smaller, flattened fruit with shorter pedicels. Experiments with both GA_3 and Promalin® (Benzyladenine + gibberellin A_{4+7}) increased pedicel length on paclobutrazol treated fruits. When applied to paclobutrazol treated trees at pre-pink stage both treatments significantly increased fruit diameter and fruit length (Curry and Williams, 1983). GA_3 and Promalin® increased leaf size on paclobutrazol treated trees and thereby increase photosynthetic leaf area of supporting spurs. Promalin® causes fruit thinning, which may also lead to larger fruit (Curry and Williams, 1983).

8.6 Influence of girdling and scoring.

Girdling and scoring have been used for centuries to either hasten flower initiation or increase fruit set in apples. Girdling involves the complete removal of a cylinder of bark, including the phloem, around the branch or trunk of a woody plant. The width of the girdle can vary, depending on the desired response, but is usually kept narrow to allow sufficient wound healing to take place. Girdling inhibits primary and secondary growth. Dann *et al.* (1984) found that lateral growth and secondary thickening were decreased by 50% in girdled peach trees. The balance between reproductive and vegetative growth shifted towards reproductive growth, but vegetative growth was normal at times of minimum fruit growth. The total leaf area is reduced due to a smaller average leaf size,

as well as a decrease in the number of leaves (Noel, 1970). Cambium activity above and beneath the girdle is temporarily suspended. A thick callus layer is then formed above the girdle, which grows over the girdle wound (Dann *et al.,* 1985). The vascular transport pathways are usually restored after a few weeks, and the basipetal transport of assimilates is resumed within the season of girdling. Flowering in apple trees is generally increased when the trees have been girdle during the previous season (Dennis and Edgerton, 1966). The increase in flowering can be attributed to higher carbohydrate levels in the branches, as well as changes in endogenous plant growth regulators, such as decreases in gibberellin levels. The accumulation of carbohydrates above the girdle (Noel, 1970) must be responsible for the stimulation of fruit growth, because vegetative growth is inhibited and the other major competing sink such as the roots, is cut off from the supply of assimilates. Greene (1937) reported that the spurs, fruits and leaves of girdled apple trees contained higher concentrations of sugar and starch. Girdling disrupts the balance of endogenous growth regulators in the plant. Beneath the girdle, the IAA concentration decreases by 75% and remains low. An increase in IAA concentration in the bark above the girdle was reported for apple trees (Kuzina *et al.,* 1987). Auxins are synthesised in shoot tips and young leaves and are transported basipetally to the roots during the growing season (Kuzina *et al.,* 1987). Girdling appears to stop this transport. Girdling also disrupts the transport of gibberellin through the plant. The GA concentration is also much reduced in the slower growing shoots on girdled peach trees. This could be attributed to a reduced allocation of root produced gibberellins to the shoots because of the disruption of the basipetal auxin signal (Wand, 1990). Girdling reduces the levels of cytokinins in the shoot tips of peach trees which could be related to

reduced shoot growth. The reduced shoot growth can also be due to a lack of an auxin signal from the shoots (Wand, 1990).

8.7. The influence of pruning and thinning.

Pruning could improve light distribution within the tree canopy and improve spur quality (Barritt and Rom, 1987). Barritt and Rom (1987) found that spur pruning without improving light interception by spurs had no real advantage.

Rom (1992) stated that reducing spur bud number may reduce local competition among flower clusters for assimilates and nutrients and additional bourse shoot leaf area and shoot leaf area may enhance fruit growth. Thinning apples to increase fruit size has become a common practice and Goffinet *et al.* (1995) found that fruit size and mass decreased as thinning was prolonged and unthinned trees had the smallest fruit in 'Empire' apple trees.

Pruning trials on 'Packham's Triumph' pear trees by Saunders *et al.* (1991) show that heading back into the spurred 2-years-old wood increased fruit set. Heading also decreased the number of new shoots per shoot unit. Apart from reducing shoot number, heading affected the relative position of the new shoots to the developing fruits by reducing the distance between the fruit on the spurred 2-year-old wood and the shoot sinks remaining on the shoot units. The increase in fruit set resulting from heading in winter decreased when heading was delayed until after anthesis. Heading failed to improve fruit set when it was delayed until 3 weeks after anthesis or later. It would

appear that the inhibition of subordinate fruitlets by distal shoot sinks had already started at anthesis before shoot growth was even visible. Small sinks have a low demand for assimilates (Bangerth, 1989). Heading increased the set of seedless fruit. Apparently seedless fruits are subordinate to distal shoots while seeded fruits are not (Saunders *et al.*, 1991).

Work done by Lauri and Terouanne (1999) showed that an artificial reduction in the number of inflorescences per branch may stimulate fruit set of the remaining inflorescences revealing a physiological adjustment of that branch. The practical interests of inflorescence removal on one-year-old wood are twofold; first, it decreases the number of small-sized fruit; secondly, it tends to increase the development to fruitful inflorescences, at least over the first years of the lateral growth (Lauri and Terouanne, 1999).

9. The influence of climate on reproductive bud development.

9.1. Light.

Distinction needs to be made between day length and the amount of light the tree receives. In most fruit trees, day length has no role in reproductive bud initiation, but the amount of available light reaching the tree is important (Tromp, 1976).

When a tree receives less than 30 percent full sunlight, poor reproductive bud initiation and development, occurs. Approximately 30 to 50 percent of full sunlight is necessary for maximum photosynthesis by the leaves. Limiting light (sunlight) by shading within a

tree canopy reduces photosynthesis, thereby reducing carbohydrates available for growth. Under reduced carbohydrates supply within a fruit tree, shoot growth, root growth, and mineral uptake are reduced, and reproductive bud development, fruit set, and fruit growth are minimised. Shading trees to 25 percent of full sun reduces yield approximately 50 percent compared to the non-shaded trees. More important were the effects of shade the following year. Shading reduced the initiation and development of reproductive buds (Tromp, 1976). The year following shading treatments, trees that had received less than full sunlight had fewer reproductive buds, reduced fruit set and smaller fruit. Thus, the tree has a "memory", and the detrimental effects of shading is carried over to the next season.

Any period of shading reduces spur leaf efficiency (specific leaf weight). Leaves, which are shaded, lose leaf nitrogen and lose some chlorophyll. Light within the tree canopy controls distribution of mineral elements and carbohydrates. Well-exposed portions of the tree will have leaves with high levels of nitrogen, while shaded portions have lower levels. Good light distribution within the canopy will result in more uniform distribution of nitrogen and other elements (Barritt and Rom, 1989). Early in the season, spur leaves are the first leaves to appear on the tree. Fruiting spur leaves provide the carbohydrate necessary for initial fruit growth, cell division, and fruit set. After 20 to 40 days after bloom, the spur leaves are inadequate to maintain fruit growth rate, and bourse shoot leaves and long shoot leaves are important for maintained fruit growth. Leaves on long shoots produce carbohydrates in excess of that needed by fruits. These carbohydrates are then used for additional shoot and leaf growth, root development, and storage

carbohydrates necessary to maintain respiratory needs of the tree during the dormant season and to tolerate stresses. Vegetative spur leaves also contribute to fruit growth during the middle of the growing season and are important in reproductive bud development for the following season. Shading of these leaves during the critical periods of the year will result in reductions in yield and growth activity in the current and succeeding season (Barritt and Rom, 1989).

Low light levels can reduce fruit growth and set, and increase shoot extension (Byers *et al.,* 1985). Bepete and Lakso (1998) found that the growing shoot tip has priority over the fruit for assimilates, especially under limiting light conditions early in the season when fruit numbers and fruit cell division are establishing the crop potential.

9.2. Temperature.

Tromp *et al.* (1976) found that temperature influences a number of physiological processes in the tree (for example photosynthesis, hormone production, and the up-take of nutrients) that are all related to reproductive bud initiation and development.

Abbott *et al.* (1974) reported that daily temperature fluctuation around a mean of 14.5°C favours reproductive bud initiation as compared with a constant 14.5°C. Tromp (1976) compared two temperatures (24 and 17°C) and found that reproductive bud initiation is stimulated at the lower temperature when applied from full bloom, but it is reduced when the temperature was raised from 17 to 24°C seven weeks before harvest. Later, Tromp (1980) suggested that the first 4 to 5 weeks after full bloom are of especially great

importance for reproductive bud initiation. In contrast, Luckwill (1974) is of the opinion that the temperature during the summer also affects flower initiation. Recently, Verheij (1996), in an extensive study on reproductive bud initiation and development in apple, found that different cultivars do not respond similarly to temperature with respect to flowering. Some early studies by Fulford (1966) on morphogenesis of flower buds in apple showed that this process is closely related to the plastrochron. The relationship between temperature on the one hand and plastrochron length and node number on the other hand is not clear. Fulford (1966) stated that the plastrochron was not affected, but Verheij (1996) found that the plastrochron was shortened at higher temperatures.

The enhancement of flowering in apple with increasing temperature as found in an experiment by Zhu *et al.* (1997) conflicts with data of Tromp (1976) and Verheij (1996), implying that reproductive bud initiation and development was favoured at lower temperatures. The data of Zhu *et al.* (1997) do not comply, with the widely accepted concept of an antagonism between vegetative growth and reproductive bud initiation and development in fruit trees. These conflicting results may be brought into line when we assume that an increase in temperature directly favours reproductive bud initiation and development, but at the same time inhibits flowering via stimulation of shoot growth. The ultimate result depends on the relative importance of these two effects, which will probably not be the same in all situations and for all cultivars. As a consequence, flowering is stimulated by increasing temperature when applied for the whole season, as well as when applied six or seven weeks after bloom. Zhu *et al.* (1997) suggested that at higher temperatures during the period in which new flowers are initiated, will result in

later initiation of parts of the clusters and, consequently, a decline in cluster quality. Abbott (1970) showed that reproductive buds of apple initiated late in the season contained clusters with a reduced numbers of flowers.

9.3. Water stress.

Water stress seems to have a positive influence on bud initiation but it is not clear whether this is a direct influence on reproductive bud initiation and development or an indirect effect via a reduction in shoot growth (Tromp *et al.,* 1976).

Conclusion

Many factors contribute to reproductive bud development and fruit quality. Some of the most important factors are the flower bud position, density, and orientation. It is therefore important to give attention to these factors to improve fruit size and quality. Fruit size is determined from the start at reproductive bud induction and throughout its development, therefore is it important that reproductive bud development occurs under optimal conditions.

The reproductive bud differentiation process is an extremely complex process, which can be markedly influenced by different cultural practices that affecte reproductive bud initiation, development and fruit quality.

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PAPER 1: THE EFFECT OF TRIADIMENOL, PROMALIN AND SCORING ON FRUIT SIZE OF 'ROYAL GALA'

ABSTRACT

The effect of foliar application of triadimenol (a triazole), Promalin®, or scoring branches on fruit set, fruit size and fruit quality of 'Royal Gala' apples were evaluated. Four treatments were tested, viz., (a) an unsprayed control, (b) triadimenol sprayed on 6 March 1997 and then every two weeks until leaf drop, as well as at mouse ear and full bloom, (c) as treatment b, plus Promalin® two weeks after full bloom, and (d) Promalin® two weeks after full bloom. Four scoring treatments were tested, viz., (a) a control, (b) scoring at full bloom, (c) scoring two weeks after full bloom, and (d) scoring four weeks after full bloom. Promalin® application two weeks after full bloom improved fruit size without any detrimental effects on fruit quality. This application was in addition to the standard commercial applications of Promalin® as part of the chemical thinning program. The possible negative effect of the GA_{4+7} on return bloom was however not determined. The scoring treatments were not severe enough to influence growth and development significantly and should be investigated again in the future.

INTRODUCTION

'Royal Gala' is a small-fruited variety especially in South Africa where the problem is exacerbated by the relative warm winters experienced in most apple production areas (Greybe, 1997). It is therefore important to use all possible production practices that could improve fruit size. Improving reproductive bud differentiation, resulting in better

quality flowers with a potential to yield larger fruit has been achieved by chemical application of gibberellin (GA) biosynthesis inhibitors (Olivier *et al.*, 1990; Theron *et al.*, 1998). Foliar applications of the triazole, paclobutrazol in autumn, increased fruit set and fruit size while limiting vegetative growth of 'Songold' plums (Strydom and Honeyborne, 1986). Olivier *et al.* (1990) reported that autumn application of paclobutrazol significantly increased the dry weight of the reproductive buds and flowers by increasing the dimensions of the ovary and its parts. Apparently paclobutrazol altered the dry matter allocation in favor of reproductive bud development in plums, thus causing 'stronger' buds, which yielded heavier flowers that opened earlier. Paclobutrazol induced changes in dry matter allocation might account for the reported increase in fruit set and size (Strydom & Honeyborne, 1986). Autumn chlormequat application to 'Doyenne du Comice' pear trees apparently caused a shift in dry matter allocation to the development of reproductive buds, enhancing their development and improving fruit size (Theron *et al.*, 1998). Chlormequat, triadimefon and paclobutrazol (all triazoles) reduce GA levels in plants. A reduction in GA levels should decrease the plastochron, which should result in more rapid development and differentiation of reproductive buds (Buszard & Schwabe, 1995). When applying GA_3 and Promalin® (Benzyladenine + gibberellin A_{4+7}) to paclobutrazol treated 'Delicious' apple trees at pre-pink stage, both treatments significantly increased pedicel length, fruit diameter and fruit length (Curry & Williams, 1983). It also improved leaf size on paclobutrazol treated trees, thereby increasing photosynthetic leaf area of supporting spurs. Promalin® has also been shown to cause fruit thinning, when applied early during bloom, which improves fruit size (Curry & Williams, 1983).

Another possible manipulation to improve fruit size is scoring. Scoring involves a clean cut made into the phloem, therefore inhibiting cambium activity above and beneath the cut temporarily. A callus layer is then formed above the scoring ring, which grows over the wound (Dann *et al.*, 1985). The vascular transport pathways are usually restored after a few weeks, and the basipetal transport of assimilates is resumed within the same season. Greene (1937) found that final fruit set is increased following girdling in apples. The accumulation of carbohydrates above the cut and the inhibition of the movement of cytokinins and other growth hormones and substances in the phloem must be responsible for the stimulation of fruit growth. The stimulation of fruit growth is also due to the inhibition of vegetative growth and the other major competing sink, the roots (Noel, 1970).

This paper report on the effect of foliar application of triadimenol (a triazole) and Promalin®, and scoring on fruit set, fruit size and fruit quality of 'Royal Gala' apples.

MATERIAL AND METHODS

Plant material:

Trials were conducted on 8th leaf 'Royal Gala' trees on M793 rootstocks at Molteno Estate, in the Elgin area (Western Cape, South Africa, 34°10'S, 19°00 'E, 300 m.a.s.l.). This area has a Mediterranean climate with cold, wet winters and dry, warm summers. (Schultze, 1974). Trees were planted in 1989 in a North – South row direction, with a

spacing of 2m by 4.5m. Full bloom was on 8 October 1997. Standard commercial practices for thinning, fertilisation, irrigation and other orchard practices were followed.

Treatments and experimental design:

Chemical application trial: Four treatments were used, viz., (a) an unsprayed control, (b) triadimenol [1-(4-chlorophenoxy)-3,3-dimethyl-1- (1,2,4-triazol-1-yl)-2-butanol] at 100 $mg.l^{-1}$ on 6 March 1997 and then every two weeks until leaf drop, as well as at mouse ear and full bloom, (c) as treatment b, plus Promalin® at 25 $mg.l^{-1}$ two weeks after full bloom, and (d) Promalin® at 25 $mg.l^{-1}$ two weeks after full bloom. No wetting agents were used with the foliar application. High volume foliar application took place on the following dates: 6 March 1997, 19 March 1997, 2 April 1997, 16 April 1997 (leaf drop), 25 September 1997 (mouse ear), 8 October 1997 (full bloom) and 22 October 1997 (Promalin®). A randomised completed block design was used, with 10 blocks and 3 trees per plot.

Scoring trial: Four treatments were used, viz., (a) a control, (b) scoring at full bloom, (c) scoring two weeks after full bloom, and (d) scoring four weeks after full bloom. Two scaffold branches of similar circumferences were selected per tree. Scoring was done by cutting the bark with a hacksaw blade down to the secondary xylem and around the full circumference of the branch. Scoring was done near the base of the branches. A randomised completed block design, with 10 blocks and single tree plots was used.

Data collected:

Chemical application trial: Two branches from the middle tree (of the 3 tree/plot) were tagged. At full bloom all flower clusters were counted on these branches. The fruit set per branch was determined by counting the number of fruit at harvest and expressed as a percentage of the number of flower clusters. Fruit were harvest at the second commercial harvest date (4 February 1998). Total yield was measured by weighing all fruit harvested per tree in the orchard. All fruit from the tagged branches were brought to our laboratory and the following parameters recorded: (a) Number of fruit, (b) Fruit weight, length and diameter, (c) Seed number and weight per fruit, (d) Seed colour – using a Hortec seed colours chart (Hortec, P.O. Box 1231,Stellenbosch, 7600), (1 represents a white colour and 5 the dark brown seed colour), (e) Best colour side and worst colour side per fruit - using the Hortec colour chart no. A 42 (1 represents the red colour until 12 for the yellow/green colour).

Scoring trial: The fruit set per branch was determined by counting the number of fruit at harvest and expressed as a percentage of the number of flower clusters. All fruit from the tagged branches were brought to our laboratory and the parameters recorded as in the chemical application trials.

Statistical analysis:

The General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) was used to analyse the data (SAS Institute., 1990).

RESULTS AND DISCUSSION

Chemical application trial: No significant differences were found in fruit set between the control and chemical application or between any of the chemical treatments (Table 1). Unfortunately the dimensions of the flower buds, clusters and flowers were not determined in this trial, so it is unknown whether the autumn application of triadimenol had the same effect on dry mass allocation in favour of reproductive buds of 'Royal Gala' as triadimefon had in the case of 'Starking Delicious' (Jacobs *et al.*, 1990). Generally, a late application (2 weeks after full bloom) of Promalin® does not influence fruit set (Honeyborne, 1988).

Fruit size was improved by a Promalin® application two weeks after full bloom as can be seen in fruit length ($P = 0.0107$), fruit diameter ($P = 0.0152$) and fruit weight ($P = 0.0242$) (Table 2). This improvement in average fruit size almost resulted in a significant improvement in yield efficiency. Using the number of fruit per tagged branch, from which the fruit sample was collected, as a covariate further accentuated the improvement in fruit size. The triadimenol applications had no effect on fruit size or yield efficiency.

No significant differences occurred in the average number of seeds per fruit or in the average weight of the seeds indicating that the improved fruit size resulting from the Promalin® application was not due to improved fertilisation or a reduction in embrio abortion (Table 3). The Promalin® application significantly delayed maturity as can be seen from the less advanced seed colour. If the same trend were to be observed in other maturity parameters it could indicate that fruit from Promalin® treated trees could be

harvested slightly later, resulting in a further improvement in fruit size. Unfortunately no other maturity parameters were measured (Table 3).

Scoring trial: Scoring scaffold branches at full bloom, or two or four weeks after full bloom did not improve fruit set on these branches (Table 4). Also fruit size, in terms of fruit length, diameter or weight was not influenced (Table 5). Scoring did not improve seed set or seed development (Table 6). Neither did it advance maturity as indicated by seed colour, nor did it improve fruit colour (Table 6). It was thought that scoring would reduce vegetative shoot development on scored branches, resulting in an improvement in fruit size and colour, however, shoot length was not determined. It is clear from this data that the scoring treatment was probably not severe enough to interrupt basipetal transport long enough in order to affect shoot growth and fruit development.

In conclusion, Promalin® application two weeks after full bloom improved fruit size without any detrimental effects on fruit quality. It must be remembered that this application was in addition to the standard commercial applications of Promalin® as part of the chemical thinning program. The possible negative effect of the GA_{4+7} on return bloom was however not determined. The scoring treatments were not severe enough to influence growth and development significantly and should be investigated again in the future.

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Table 1. The effect of a foliar application of triadimenol and/or Promalin® (GA_{4+7} + benzyladenine) on fruit set (number of fruit as percentage of number of flower clusters) of 8th leaf 'Royal Gala' trees on M793 rootstock.

Treatments	Percentage fruit set
(1) Control	47.2 a [Z]
(2) Triadimenol until leaf drop + mouse ear and full bloom	48.0 a
(3) As (2) plus Promalin® two weeks after full bloom.	50.8 a
(4) Promalin two weeks after full bloom	47.1 a
Significance level:	*0.9298*

[Z] Mean separation by LSD (5%).

Table 2. The effect of a foliar application of triadimenol and/or Promalin® (GA_{4+7} plus benzyladenine) on fruit size and yield efficiency of 8th leaf 'Royal Gala' trees on M793 rootstock using fruit number as a covariant.

Treatments	Fruit length (mm)	Fruit diameter (mm)	Fruit weight (g)	Yield (kg.cm stem circumference)
(1) Control.	56.5 ab [Z]	61.2 b	111.4 a	0.984 a
(2) Triadimenol until leaf drop + mouse ear and full bloom.	55.5 b	62.3 ab	111.7 a	0.948 a
(3) As (2) plus Promalin® two weeks after full bloom.	57.5 ab	63.8 a	120.9 a	1.054 a
(4) Promalin two weeks after full bloom.	58.3 a	63.5 a	120.6 a	1.141 a
Significance level :				
Treatment	*0.0452*	*0.0657*	*0.1529*	*0.3893*
Contrast: Promalin vs Rest of treatments.	*0.0107*	*0.0152*	*0.0242*	*0.1261*
Covariant : Fruit number	*0.2194*	*0.1714*	*0.4249*	
Treatment	*0.0308*	*0.0661*	*0.1387*	
Contrast: Promalin vs Rest of treatments.	*0.0088*	*0.0116*	*0.0216*	

[Z] Mean separation by LSD (5%).

Table 3. The effect of a foliar application of triadimenol and/or Promalin® (GA_{4+7} plus benzyladenine) on locule number per fruit, seed development and fruit colour development of 8th leaf 'Royal Gala' trees on M793 rootstock.

Treatments	Total seed number	Average seed weight (g)	Average seed colour (Hortec colour chart)	Best coloured side of fruit (colour chart no. A 42)	Worst coloured side of fruit (colour chart no. A 42)
(1) Control.	4.49 a	0.21 a	5.13 a	4.2 a	6.9 a
(2) Triadimenol until leaf drop + mouse ear and full bloom.	4.57 a	0.24 a	5.18 a	4.6 a	7.4 a
(3) As (2) plus Promalin® two weeks after full bloom.	4.35 a	0.21 a	4.68 b	4.0 a	6.3 a
(4) Promalin two weeks after full bloom.	4.00 a	0.24 a	4.65 b	4.3 a	6.7 a
Significance level :					
Treatment	*0.4852*	*0.5810*	*0.0020*	*0.7197*	*0.4008*
Contrasts: Promalin vs Rest of treatments	*0.2036*	*0.8541*	*0.0002*	*0.4824*	*0.1884*

[z] Mean separation by LSD (5%).

Table 4. The effect of scoring at different times from full bloom on fruit set (number of fruit as percentage of number of flower clusters) of 8th leaf 'Royal Gala' trees on M793 rootstock.

Treatments	Percentage fruit set
Control	37.9 a [z]
Score at full bloom	39.6 a
Two weeks after full bloom	37.3 a
Four weeks after full bloom	41.7 a
Significance level	
Treatment	*0.8316*
Contrasts:	
Control vs scoring	*0.7026*
Scoring linear	*0.6924*
Scoring quadratic	*0.4592*

[w] Mean separation by LSD (5%).

Table 5. The effect of scoring at different times from full bloom on fruit size of 8th leaf 'Royal Gala trees on M973 rootstock.

Treatments	Fruit length (mm)	Fruit diameter (mm)	Mean fruit mass (g)
Control	59.49 a [z]	64.66 a	127.88 a
Score at full bloom	61.82 a	65.62 a	133.64 a
Two weeks after full bloom	59.86 a	64.58 a	128.32 a
Four weeks after full bloom	60.43 a	64.85 a	128.67 a
Significance level	*0.2278*	*0.7480*	*0.7623*
Contrasts:			
Control vs scoring	*0.2146*	*0.6816*	*0.6448*
Scoring linear	*0.2442*	*0.4699*	*0.4230*
Scoring quadratic	*0.2202*	*0.4782*	*0.5973*
Covariant : Fruit number	*0.5177*	*0.9733*	*0.6957*
Treatment	*0.2562*	*0.7719*	*0.7443*
Contrasts:			
Control vs scoring	*0.2646*	*0.7334*	*0.7444*
Scoring linear	*0.1692*	*0.4259*	*0.3148*
Scoring quadratic	*0.3513*	*0.5765*	*0.8108*

[z] Mean separation by LSD (5%).

Table 6. The effect of scoring at different times from full bloom on seed development and fruit colour development of 8th leaf 'Royal Gala trees on M973 rootstock.

Treatments	Total seed number	Average seed weight (g)	Average seed colour (Hortec colour chart)	Best coloured side of fruit (colour chart no. A 42)	Worst coloured side of fruit (colour chart no. A 42)
Control	4.02 a [z]	0.21 a	5.08 a	4.88 a	7.13 a
Score at full bloom	4.08 a	0.22 a	5.30 a	5.64 a	8.11 a
Two weeks after full bloom	3.92 a	0.21 a	5.21 a	5.13 a	7.57 a
Four weeks after full bloom	3.71 a	0.21 a	5.27 a	4.68 a	7.12 a
Significance level	*0.5864*	*0.8776*	*0.6467*	*0.3403*	*0.3629*
Contrasts:					
Control vs scoring	*0.6314*	*0.8753*	*0.2415*	*0.5525*	*0.3713*
Scoring linear	*0.2008*	*0.4445*	*0.8715*	*0.0879*	*0.1262*
Scoring quadratic	*0.9138*	*0.8245*	*0.6458*	*0.9419*	*0.9287*

[z] Mean separation by LSD (5%).

PAPER 2: THE INFLUENCE OF BEARING POSITION ON APPLE FLOWER QUALITY AND SUBSEQUENT FRUIT QUALITY

ABSTRACT

At full bloom in the 1997/98 season, ten flower clusters from the following bearing positions were collected and evaluated: (a) dorsal spurs, (b) ventral spurs, (c) terminal on bourse shoot, (d) terminal on long shoot, and (e) lateral on long shoots. The same bearing positions were used, one week after full bloom, for the 1998/99 season. The flowering pattern was monitored for both seasons and just prior to harvest in both seasons the length and diameter of the fruit were measured as well as the length of the bourse shoot that had developed from the same bud. Fruit thinning by hand was done in 1997 by thinning to the largest fruit in the cluster, but no thinning was done in the 1998 season. The results obtained in the morphological analysis of the flower cluster of 'Royal Gala' were not very consistent. In general, the dorsal spurs appeared to be the better quality flowers and the "king" flower is believed to be the best quality flower in the cluster as far as the receptacle dimensions are concerned. When fruit were harvested, no fruit on lateral on long shoots, and terminal on bourse shoot positions, were found. Even though the percentage of these positions were low at bloom, this indicates a low set potential and possibly low flower quality of these bearing positions in 'Royal Gala'. The size of the fruit at harvest in 1998/99, did not correlate well with the parameters measured at bloom. Unfortunately fruit were not thinned during the post bloom period and this made deductions more difficult. The correlation coefficients between bourse shoot length and

fruit size were significant, but relatively small. We found a positive correlation between full seed number and fruit dimensions with an increase in seed number per fruit.

INTRODUCTION

Fruit size is one of the most important factors that determine the profitability of apple production. Many factors influence fruit size in apples, one of which is reproductive bud quality (Deckers, 1999).

According to Deckers (1999), reproductive bud quality can be determined by evaluating the following characteristics. The number of leaves per reproductive bud is an important quality criterium. The presence of a bourse shoot at the base of a flower cluster increases the leaf area and the photosynthetic capacity significantly. The length of the flower pedicle is important as flowers with short pedicles have a reduced fruit set capacity. The length and diameter of a flower bud can also be a good indication of reproductive bud quality. Another characteristic used to determine reproductive bud quality is cell number. Pre-anthesis cell division accounts for between 20 and 21 of the total 25 to 26 divisions that eventually take place during flower bud differentiation, bloom and fruit differentiation (Smith, 1950). As fruit size is a function of the number of cells and their size, this is a very important characteristic determining eventual fruit size (Tukey & Young, 1942), therefore an apple developing from a flower with a greater number of cells at bloom has the potential to become larger in size by harvest (Tukey, 1974).

The reproductive bud quality is however, influenced by the wood age and bearing position at which the bud develops. Robbie and Atkinson (1994) found that the capacity of 'Cox Orange Pippin' apple flowers on young wood to set fruit was considerably less than that on older wood. Flower clusters on young wood typically have smaller leaf areas and mean flower weights as well as fewer flowers than those on older wood. In apple, reproductive bud initiation occurs terminally on short, bearing shoots (spurs) and in axillary buds of elongated shoots. The best quality flowers of most apple cultivars develop in the terminal bud of the spurs (Milutinovic, 1974). Lee *et al.* (1994) reported that for 'Rome Beauty' apples, spur terminal reproductive buds began blooming earlier and blossom for a longer period of time than lateral buds. This allows spur flowers to attract bees first and for a longer time. The result is better pollination, as shown by seed count in the fruit.

Fruit size will be influenced by seed number (Deckers, 1999). It is well known that more seeds mean better fruit size and shape. Seed are a major source of hormones required for fruit development by creating a powerful physiological sink, which enables fruit to withstand the fruit-shoot competition more effectively (Luckwill, 1948; 1970).

This paper reports on the effect of bearing position of the reproductive bud quality in 'Royal Gala' apple, and on the correlation between fruit size, and seed number and bourse shoot length.

MATERIAL AND METHODS

Plant material:

The trials were conducted at Kromfontein, Koue Bokkeveld (Western Cape, South Africa). The 'Royal Gala' trees on M793 rootstocks were planted in a north-south row direction in 1991, with a tree spacing of 4m by 1.5m and trained as free-standing central leader trees. 'Hillierri crab' (*Malus scheideckeri*) trees were used as pollinators. During the winter of 1997, light penetration was improved in trees by removing up to three of the most vigorous branches with a thinning cut from the trunk. In both the 1997/98 and 1998/99 season the same orchard was used, but different trees.

Methodology:

At full bloom, 10 October 1997, ten flower clusters from the following bearing positions were collected at random from the trees: (a) dorsal spurs, (b) ventral spurs, (c) terminal on bourse shoot, (d) terminal on long shoot, and (e) lateral on long shoots. The same bearing positions were used on 17 October 1998, one week after full bloom, for the 1998/99 season. Fruit thinning by hand was done ≈ 40 days after full bloom in 1997 by thinning to the largest fruit in the cluster, but no thinning was done in the 1998 season. All clusters were placed in FAA (90ml 50% ethanol, 5ml acetic acid and 5ml formaldehyde) and brought to our laboratory for evaluation.

Data collected:

Morphological analysis of clusters:

Data were collected in the same way for both the 1997/98 and 1998/99 seasons. Five flower clusters per bearing position were dissected and the number and surface area of the foliage leaves were determined. Leaf surface was determine by using a 'H.P. ScanJet 4c' scanner. The "king" and one lateral flower per cluster were further analysed and the following parameters determined: (a) The length and diameter of the pedicle, (b) the length and diameter of the receptacle, (c) the number of styles and locules, (d) the number of ovules per flower, and (e) the length of the ovule. Ovule length was measured using a graded eyepiece on a 'Kyowa Optical model' (SDZ – PL) light microscope.

Cell number:

The remaining five flower clusters for each bearing position were used to determine cell number. The "king" and lateral flowers were sectioned longitudinally through the center. These cross sections were made to include the tissue between the two adjacent carpels and the area across the petal vascular bundle, core line and cortex to the epidermal layer (Plate 1). Dissected flowers were dehydrated in an alcohol and alcohol-acetone series, critically dried and prepared for the scanning electron microscope (SEM) as described by Diaz *et al.* (1981). Photographs of the complete longitudinal sections and a section of the developing cortical region adjacent to the developing carpel primordium, were used to determine the average representative number of cells and cell sizes per flower. The average cell diameter and total number of cells in the base of the flower were calculated according to the formula of Smith (1950).

Cortex cell number = (volume of flower receptacle – volume of core of the flower receptacle) / volume of average cortex cell (Plate 1).

Where volume = $4/3 \prod r^2h$

Flowering pattern:

The flowering pattern was monitored, by regularly counting the number of flower clusters that reached anthesis at the different bearing positions on two tagged branches per tree. In both seasons data were recorded from the beginning of bloom, which started at 26 September 1997 and 29 September 1998, respectively. Counts were made every second or third day. Thirty trees in 1997 were monitored and 50 trees in the 1998 season.

Fruit characteristics at harvest:

One thousand six hundred fruit were selected randomly from 30 trees one week before harvest (26 January 1997) in the 1997/98 season. The length and diameter of the fruit were measured as well as the length of the bourse shoot that had developed from the same bud. In the 1998/99 season, fruit were tagged at three different bearing positions (dorsal and ventral spurs, and terminal on long shoots). At harvest (1 February 1999), these fruit were brought to our laboratory after having measured the bourse shoot length. In the laboratory the fruit length, diameter and weight, and seed number and weight were determined.

Data analysis:

The General Linear Models (GLM) and Correlation (CORR) procedures of the Statistical Analysis System (SAS) were used to analyse the data (SAS Institute., 1990).

RESULTS

The 1997/98 data on cluster morphology and flowering pattern:

A significant difference existed between the pedicel length and diameter with bearing position (Table 1). Spurs borne at dorsal positions differed significantly from those at ventral positions and terminally on long shoots. The pedicel length and diameter of the "king" flowers was significantly shorter and thinner than that of the lateral flower. Spurs in dorsal positions differed significantly in receptacle length from those in terminal positions on bourse shoots. Spurs in dorsal positions also differed significantly in receptacle diameter from those in terminal positions on bourse shoots and long shoots. The "king" flowers had a significantly longer receptacle than the lateral flower (Table 1). No significant differences were found between bearing positions in the number of styles, ovules and the length of ovules of flowers (Table 2). Lateral flowers had significantly more styles and therefore, locules than the "king" flowers. "King" flowers contained significantly more ovules per flower than lateral flowers, but they were similar in size (Table 2). Flower clusters on dorsal spurs had a significantly higher total leaf area than any other bearing position (Table 3). This was followed by the terminal position on bourse shoots and long shoots. The clusters on dorsal spurs also contained on average more foliage leaves than the other bearing positions. However, their average leaf area per

leaf was still the highest, although only significantly higher than those from the ventral spurs and the lateral buds on long shoots.

There were no significant differences in cell number per flower between different bearing positions or between flower positions in the cluster (Table 4). However, the flowers borne in clusters on dorsal spurs contained on average almost 3 million cells compared to the 2.1 million in the next best bearing position ($P = 0.1290$). The "king" flowers contained more cells than lateral flowers, except for clusters borne on long shoots.

While monitoring the flowering pattern it was found that approximately 75 % of all flower clusters were borne on dorsal spurs, 15 % were on ventral spurs and 8 % terminal on bourse shoots. Very few flower clusters were found on long shoots (Fig. 1A). It is clear from Fig. 2a that when the first observations were made the few flower clusters borne on long shoots were mostly open. The dorsal and ventral spurs were 32 % open and the terminal clusters on bourse shoots only 20 %. The peak observed on 1 October 1997 in the opening of clusters on long shoots is negligible when bearing in mind how few clusters were present in these positions (Fig. 2a). From Fig. 2b it is clear that the clusters on bourse shoot were slightly later in opening than those on spurs.

The 1998/99 data on cluster morphology and flowering pattern:

No differences were found between bearing positions for pedicel length, but the pedicel diameter of spurs borne on dorsal positions differed significantly from spurs on ventral positions and those on laterally on long shoots (Table 5). The pedicel length of the

"king" flower was significant shorter than that of the lateral flower (Table 5). The receptacles of dorsal spurs are significantly longer than the rest of the bearing positions. Dorsal spurs had flowers with significantly thicker receptacles than the terminal positions on bourse shoots and long shoots and the lateral position on long shoots. The "king" flowers had significantly longer receptacles than the lateral flowers (Table 5). No significant differences were found between bearing positions in the number of styles, ovules and the length of ovules of flowers (Table 6). The terminal clusters on bourse shoots and long shoots exhibited the highest total leaf area, followed by the ventral and dorsal spurs (Table 7). The clusters in the terminal position on long shoots contained on average more foliage leaves than the other bearing positions, but it only differed significantly from clusters on ventral spurs. A significant difference was found between bearing positions in average leaf area per leaf. The clusters in the lateral position on long shoots had significantly smaller average leaf area than the other bearing positions.

Cell number per flower could not be determined for the 1998/99 season, due to damage to flowers. While monitoring the flowering pattern it was found that approximate 70 % of all open flower clusters were borne on dorsal spurs, 16 % were on ventral spur and 12 % in the terminal position on bourse shoots. Very few flower clusters were found on long shoots (Fig. 1b). The peak observed on 5 October 1998 in the opening of clusters on long shoots is negligible when bearing in mind how few clusters were present in these positions (Fig. 3a). From Fig. 3b it is clear that the buds on dorsal and ventral spurs, and those in the terminal position on bourse shoots displayed the same opening pattern.

Fruit characteristics at harvest (both seasons):

During the 1997/98 season, fruit were not harvested according to bearing position. During the 1988/99 season this was done, but no significant difference were found in average fruit size between fruit from dorsal spurs, ventral spurs and fruit borne terminally on long shoots (Table 8). No fruit were found on bourse shoots or in the lateral position on long shoots. No significant difference was found with bearing positions for seed weight (Table 9). Fruit borne on dorsal and ventral spurs, contained significantly more seeds than those borne in the terminal position on long shoots. Clusters on ventral spurs set significantly more fruit per cluster than the dorsal spur's clusters and those in the terminal position on long shoots.

There was a positive correlation between bourse shoot length and fruit size in the 1997/98 season (Fig. 4). Although the correlations are significant the R-values are relatively low, 0.2255 and 0.1883 for fruit length and diameter, respectively. Data collected on the correlation between full seed number and fruit length, diameter and weight shows a significant increase in fruit dimensions with an increase in seed number per fruit (Fig. 5). Here the correlation coefficients are much higher, 0.2837 for fruit length, 0.3350 for fruit diameter and 0.3332 for fruit weight. There is also a positive correlation between bourse shoot length and fruit size in the 1998/99 season (Fig. 6). However, the correlations coefficients were slightly lower than in the previous season. Data collected on the relationship between full seed number and fruit length, diameter and weight show a significant increase in fruit dimensions with an increase in seed number per fruit (Fig. 7).

DISCUSSION AND CONCLUSION

The results obtained in the morphological analysis of the flower cluster of 'Royal Gala' varied. In general, the length and diameter of the pedicel of the flowers borne in clusters on dorsal spurs appeared to be longer and wider. Also the receptacle length and diameter were greater. This is usually seen as an indication of better quality flowers (Deckers, 1999; Rom 1992). On the other hand, the "king" flower is believed to be the best quality flower in the cluster (Bangerth, 1989), but it consistently had a shorter and thinner pedicel than the lateral flower in the cluster. However, as far as the receptacle dimensions are concerned the "king" flower was bigger. The "king" flower also contained more ovules per flower during season one, which might indicate better quality. The dimensions of all flowers were bigger in the second season due to the clusters being sampled slightly later during bloom.

During the first season, the dorsal spur clusters on average had more and larger foliage leaves, resulting in a larger total leaf area per cluster in this position. However, this was not repeated in the second season. The fact that in the second season the clusters in the terminal positions on the long shoots displayed a larger leaf area could be due to the earlier opening of these clusters. All clusters were collected on the same date. The importance of not making assumptions on only one year's results in woody perennials is again clearly visible from this study. Conclusions made the first year did not necessary hold true the following year.

When fruit were harvested, no fruit on lateral on long shoots, and terminal on bourse shoot positions, were found. Even though the percentage of these positions were low at bloom, this indicates a low set potential and possibly low flower quality of these bearing positions in 'Royal Gala'.

The size of the fruit at harvest in 1999, did not correlate well with the parameters measured at bloom. Unfortunately fruit were not thinned during the post bloom period and this made deductions more difficult. The effect of the difference between the "king" and lateral flower was not determined at harvest.

The correlation coefficients between bourse shoot length and fruit size were significant, but relatively small. It is generally assumed that bourse shoot length is positively correlated to flower bud quality (Abbott, 1960), but with 'Royal Gala' the positive correlation with fruit size was relatively small. The positive correlation between seed number and fruit size has been reported previously for other cultivars (Williams, 1979). With 'Royal Gala' we also found a positive correlation between well developed seed number and fruit dimensions with an increase in seed number per fruit.

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Table1: Effect of bearing position and position in clusters on flower dimensions of 'Royal Gala' at full bloom in the 1997/98 season.

Bearing Position	Pedicel length (mm)	Pedicel diameter (mm)	Receptacle length (mm)	Receptacle diameter (mm)
Bearing Position				
Dorsal Spurs	24.1 a [Z]	1.6 a	5.1 a	3.5 a
Ventral Spurs	20.2 b	1.5 ab	4.8 ab	3.4 ab
Terminal on bourse shoot	20.9 ab	1.5 ab	4.7 b	3.3 b
Terminal on long shoot	18.5 b	1.4 c	4.8 ab	3.3 b
Lateral on long shoot	21.5 ab	1.5 ab	4.8 ab	3.4 ab
Position in cluster				
"King" flower	18.5 b	1.5 b	5.0 a	3.4 a
Lateral flower	23.7 a	1.6 a	4.6 b	3.3 a
Significance level :				
Bearing position (B)	*0.0205*	*0.0039*	*0.2770*	*0.0849*
Position in cluster (P)	*0.0001*	*0.0024*	*0.0023*	*0.1086*
*B * P*	*0.6702*	*0.6434*	*0.8108*	*0.4753*

[Z] Mean separation by LSD (5%)

Table 2: Effect of bearing position and position in clusters on the average number of styles, ovules and ovule length of flowers of 'Royal Gala' at full bloom in the 1997/98 season.

Bearing Position	Average number of styles	Average ovule number per flower	Average length of ovules (mm)
Bearing Position			
Dorsal Spurs	5.0 a [Z]	11.1 a	0.9 a
Ventral Spurs	5.0 a	12.1 a	0.9 a
Terminal on bourse shoot	5.0 a	11.3 a	0.8 a
Terminal on long shoot	5.2 a	11.0 a	0.9 a
Lateral on long shoot	5.2 a	11.3 a	0.9 a
Position in cluster			
"King" flower	5.0 b	11.7 a	0.9 a
Lateral flower	5.2 a	11.0 b	0.9 a
Significance level :			
Bearing position (B)	*0.1130*	*0.3269*	*0.6246*
Position in cluster (P)	*0.0262*	*0.0489*	*0.1045*
B * P	*0.1130*	*0.1092*	*0.2199*

[Z] Mean separation by LSD (5%)

Table 3: Effect of bearing position on leaf development in the cluster of 'Royal Gala' at full bloom in the 1997/98 season.

Bearing Position	Total leaf area (mm^2)	Average leaf number	Average leaf area per leaf (mm^2)
Bearing Position			
Dorsal Spurs	9915 a [Z]	9.3 a	1072 a
Ventral Spurs	5782 c	7.2 b	793 c
Terminal on bourse shoot	7186 cb	7.9 b	917 abc
Terminal on long shoot	7739 b	8.0 b	967 ab
Lateral on long shoot	6643 cb	7.8 b	857 bc
Significance level :	*0.0001*	*0.0247*	*0.0165*

[Z] Mean separation by LSD (5%)

Table 4: Effect of bearing positions and positions in clusters on cell number of 'Royal Gala' flowers at full bloom in the 1997/98 season.

Bearing Position	Cell number per flower	Average cell number per bearing position
Bearing Position:		
Dorsal Spurs		
"King" flower	3412683.7	2934162.5
Lateral flower	2455640.6	
Ventral Spurs		
"King" flower	2806147.7	2073343.4
Lateral flower	1340539.1	
Terminal on bourse shoot		
"King" flower	2346297.2	2128802.8
Lateral flower	1911308.5	
Terminal on long shoot		
"King" flower	1288747.5	1439791.6
Lateral flower	1590835.7	
Lateral on long shoot		
"King" flower	2007510.8	2152466.8
Lateral flower	2297422.9	
Significance level:		
Bearing position (B)	0.1290	
Position in cluster (P)	0.2301	
*B * P*	0.3863	

Table 5: Effect of bearing position and positions in clusters on flower dimensions of 'Royal Gala' one week after full bloom in the 1998/99 season.

Bearing Position	Pedicel length (mm)	Pedicel diameter (mm)	Receptacle length (mm)	Receptacle diameter (mm)
Bearing Position				
Dorsal Spurs	26.4 a [Z]	1.8 a	7.9 a	6.4 a
Ventral Spurs	24.9 a	1.6 b	6.9 b	5.7 ab
Terminal on bourse shoot	25.4 a	1.7 ab	6.7 bc	5.5 b
Terminal on long shoot	24.8 a	1.8 a	6.3 c	4.9 b
Lateral on long shoot	27.5 a	1.7 ab	6.3 c	5.3 b
Position in cluster				
"King" flower	22.7 b	1.7 a	7.0 a	5.7 a
Lateral flower	28.7 a	1.7 a	6.6 b	5.5 a
Significance level :				
Bearing position (B)	*0.2650*	*0.0648*	*0.0001*	*0.0122*
Position in cluster (P)	*0.0001*	*0.1598*	*0.0436*	*0.4289*
B * P	*0.8305*	*0.2005*	*0.2610*	*0.7148*

[Z] Mean separation by LSD (5%)

Table 6: Effect of bearing position and positions in clusters on the average number of styles, ovules and ovule length of flowers of 'Royal Gala' one week after full bloom in the 1998/99 season.

Bearing Position	Average number of styles	Average ovule number per flower	Average length of ovules (mm)
Bearing Position			
Dorsal Spurs	5.3 a [Z]	10.5 a	1.63 a
Ventral Spurs	5.3 a	10.8 a	1.73 a
Terminal on bourse shoot	5.3 a	10.4 a	1.80 a
Terminal on long shoot	5.3 a	10.8 a	1.62 a
Lateral on long shoot	5.7 a	11.5 a	1.48 a
Position in cluster			
"King" flower	5.2 a	10.6 a	1.69 a
Lateral flower	5.5 a	10.9 a	1.61 a
Significance level :			
Bearing position (B)	*0.5445*	*0.4019*	*0.4811*
Position in cluster (P)	*0.1300*	*0.4028*	*0.4717*
B * P	*0.6079*	*0.9139*	*0.7002*

[Z] Mean separation by LSD (5%)

Table 7: Effect of bearing position on leaf development in the cluster of 'Royal Gala' one week after full bloom in the 1998/99 season.

Bearing Position	Total leaf area (mm^2)	Average leaf number	Average leaf area per leaf (mm^2)
Bearing Position			
Dorsal Spurs	9685 ab [Z]	9.4 ab	1040 ab
Ventral Spurs	9937 ab	8.8 b	1145 a
Terminal on bourse shoot	12762 a	10.0 ab	1262 a
Terminal on long shoot	12504 a	11.4 a	1095 a
Lateral on long shoot	8319 b	10.0 ab	824 b
Significance level :	*0.0765*	*0.2875*	*0.0104*

[Z] Mean separation by LSD (5%)

Table.8: The effect of bearing position on fruit length, diameter and weight of mature fruit for the 1998/99 season.

Bearing Position	Number of fruit used for evaluation	Average fruit length (mm)	Average fruit diameter (mm)	Average fruit weight (g)
Bearing Position :				
Dorsal Spurs	400	48.8 a [Z]	55.8 a	79.6 a
Ventral Spurs	400	48.7 a	55.8 a	80.6 a
Terminal on long shoots	57	48.6 a	55.6 a	77.9 a
Significance level :		0.9214	0.9112	0.4230

[Z] *Mean separation by LSD (5%)*

Table 9: The effect of bearing position on seed weight and number of mature fruit and the number of fruit per cluster on the different bearing positions for the 1998/99 season.

Bearing Position	Seed weight (g)	Seed number	Fruit number per cluster
Bearing Position :			
Dorsal Spurs	0.47 a [z]	6.5 a	3.3 b
Ventral Spurs	0.35 a	6.5 a	3.6 a
Terminal on long shoots	0.31 a	5.7 b	3.3 b
Significance level :	*0.5784*	*0.0443*	*0.0003*

[z] Mean separation by LSD (5%)

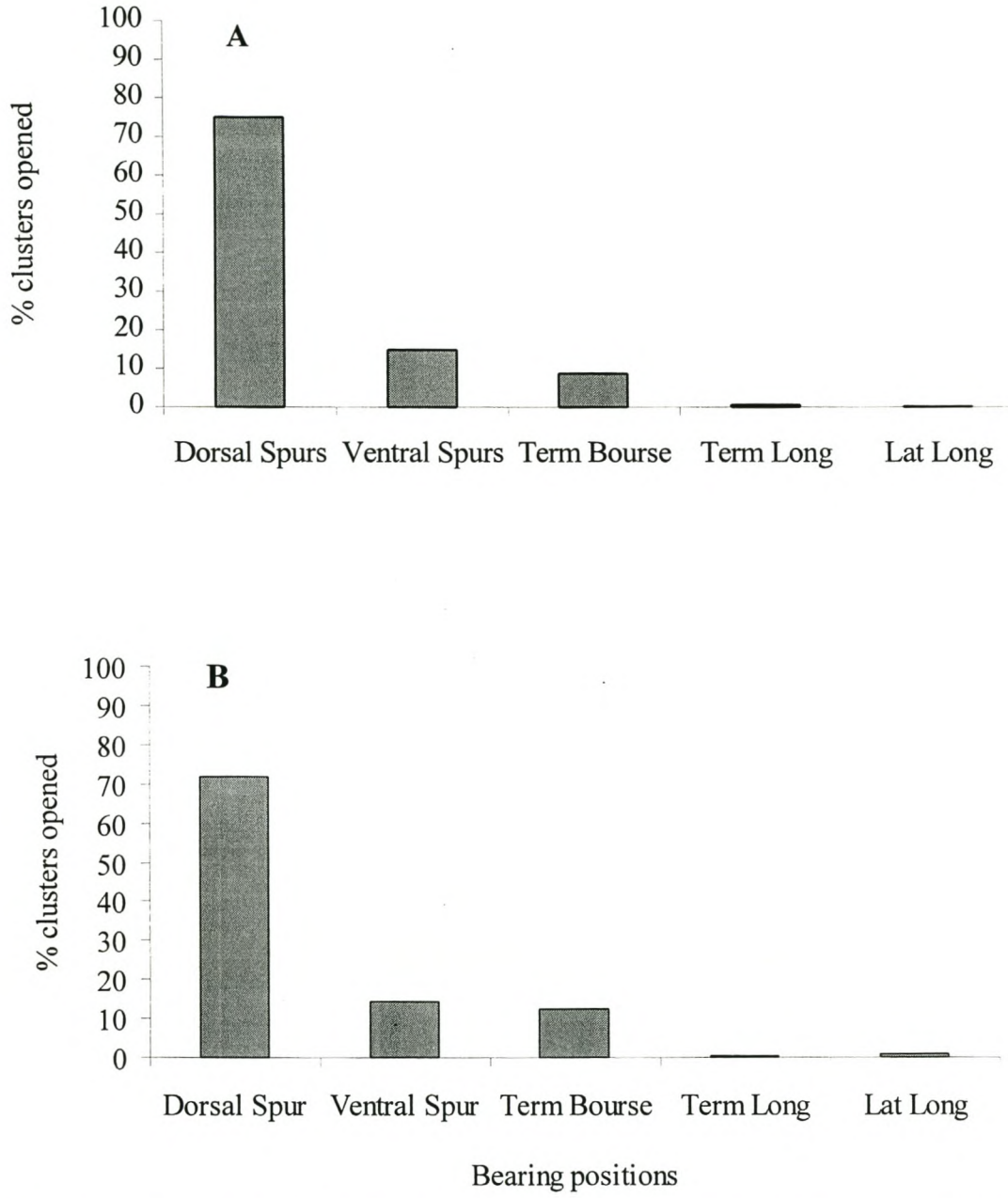

Fig. 1. Percentage of flower clusters borne at the different bearing positions on scaffold branches of 8th leaf 'Royal Gala' trees in the 1997/98 (A) season and 1998/99 (B) season.

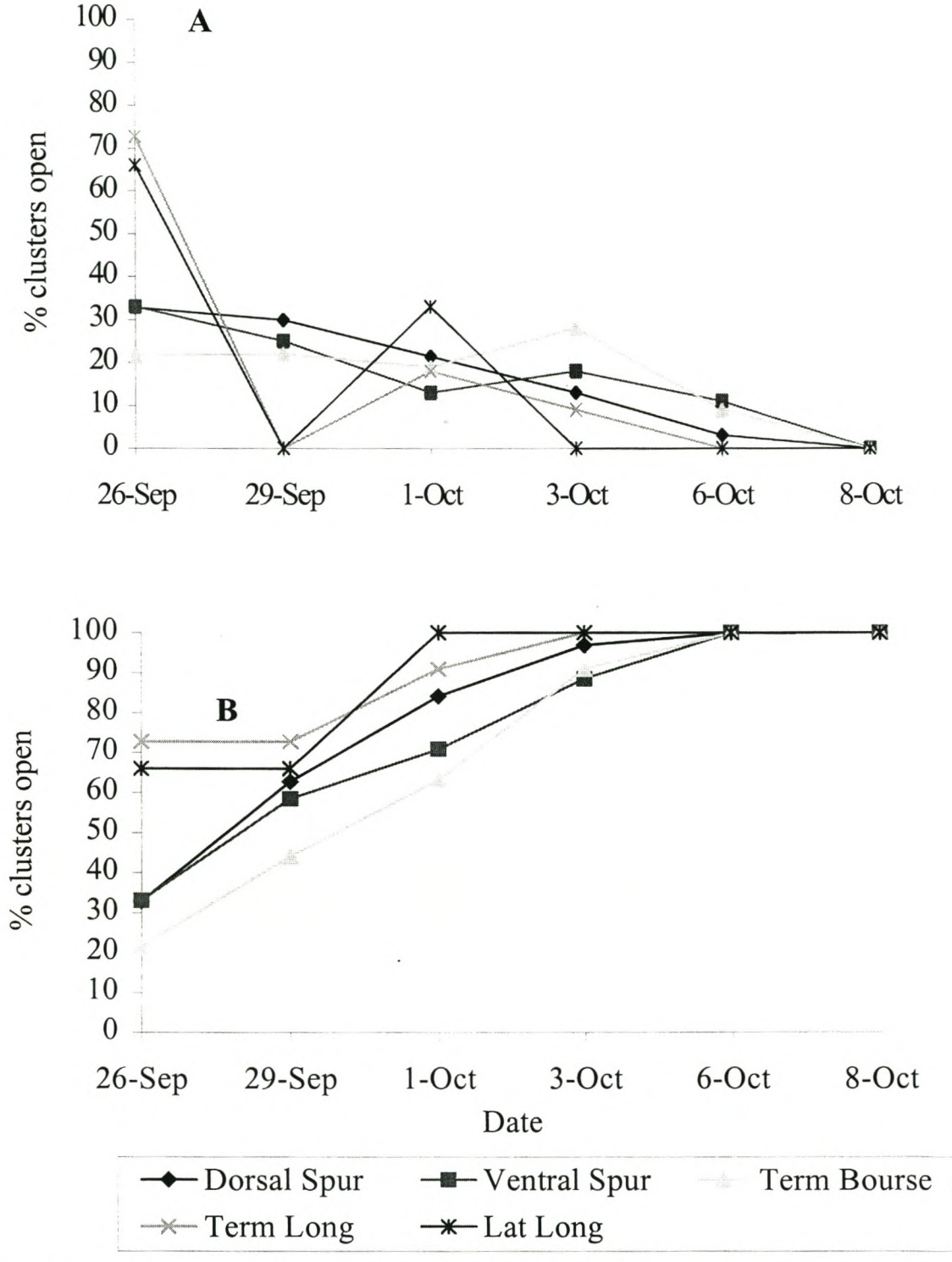

Fig. 2. The 1997 flower pattern of the percentage flower clusters opened on different bearing positions over time. The percentages flower clusters which opened over time (A) and the cumulative percentages flower clusters which opened over time (B).

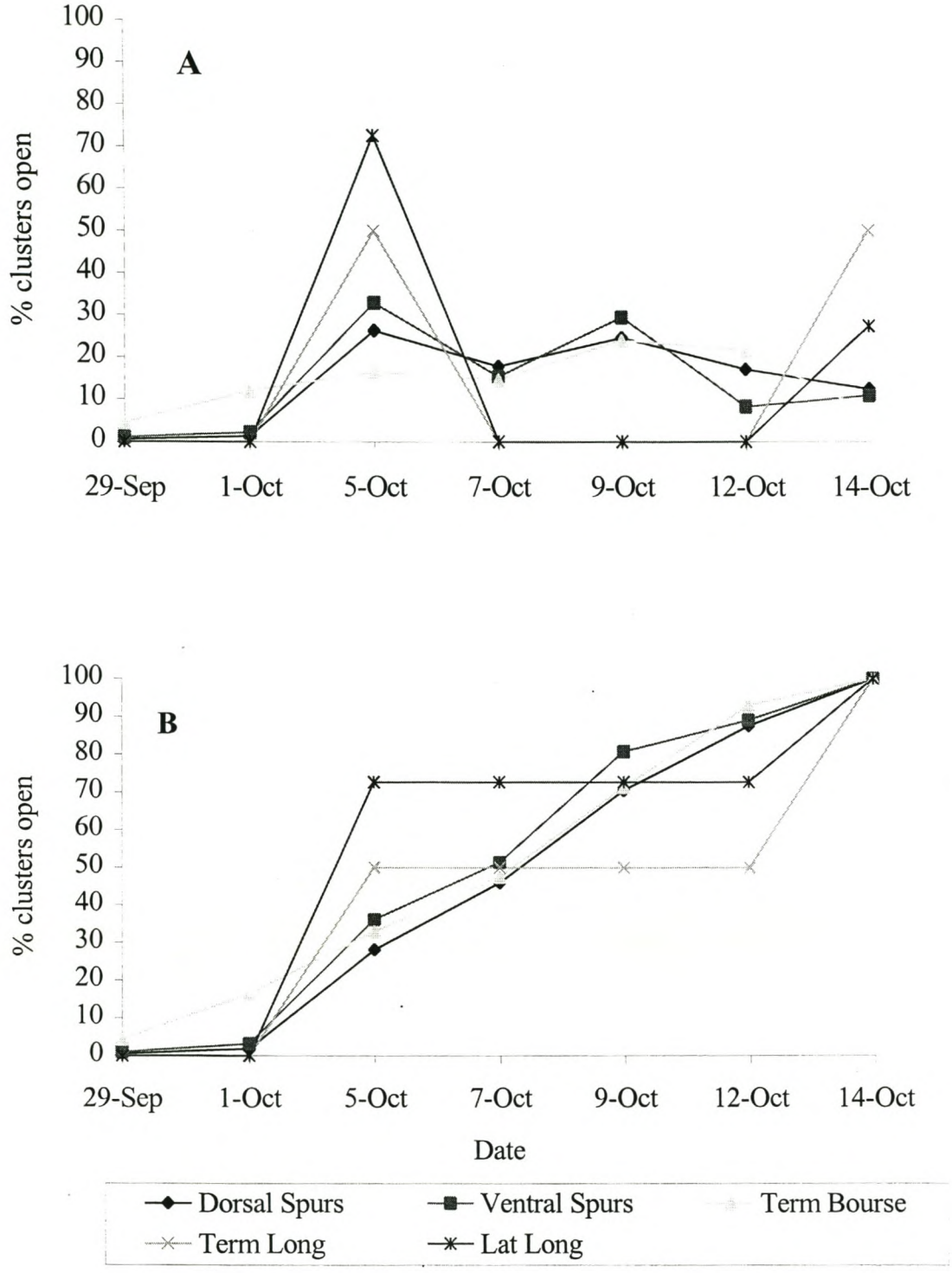

Fig. 3. The 1998 flowering pattern for the different bearing positions over time. The percentages flower clusters which were open at a given time (A) and the cumulative percentages flower clusters which opened over time (B).

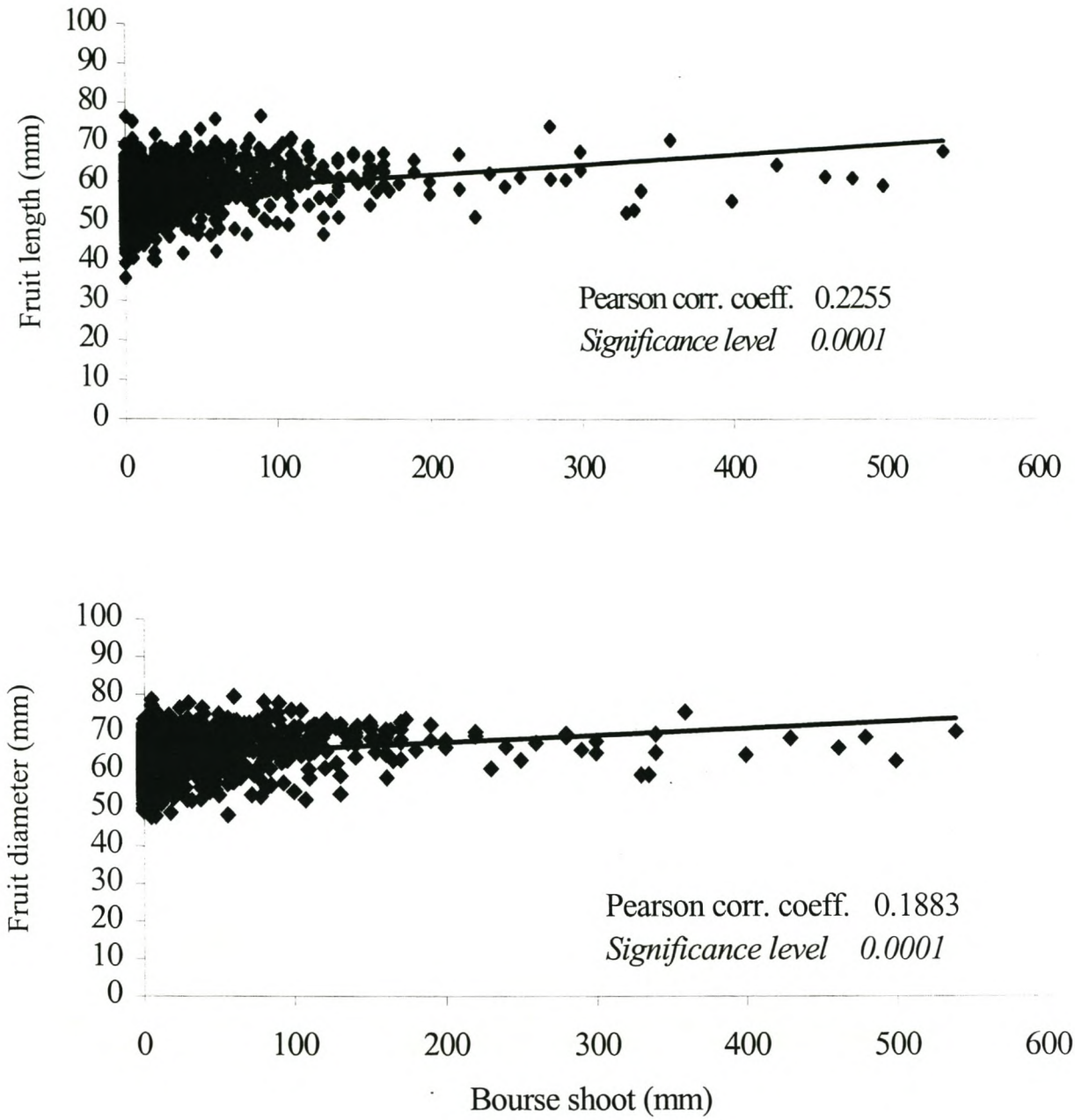

Fig. 4. The correlation between the bourse shoot length and fruit length and diameter as measured one week before harvest in the 1997/98 season.

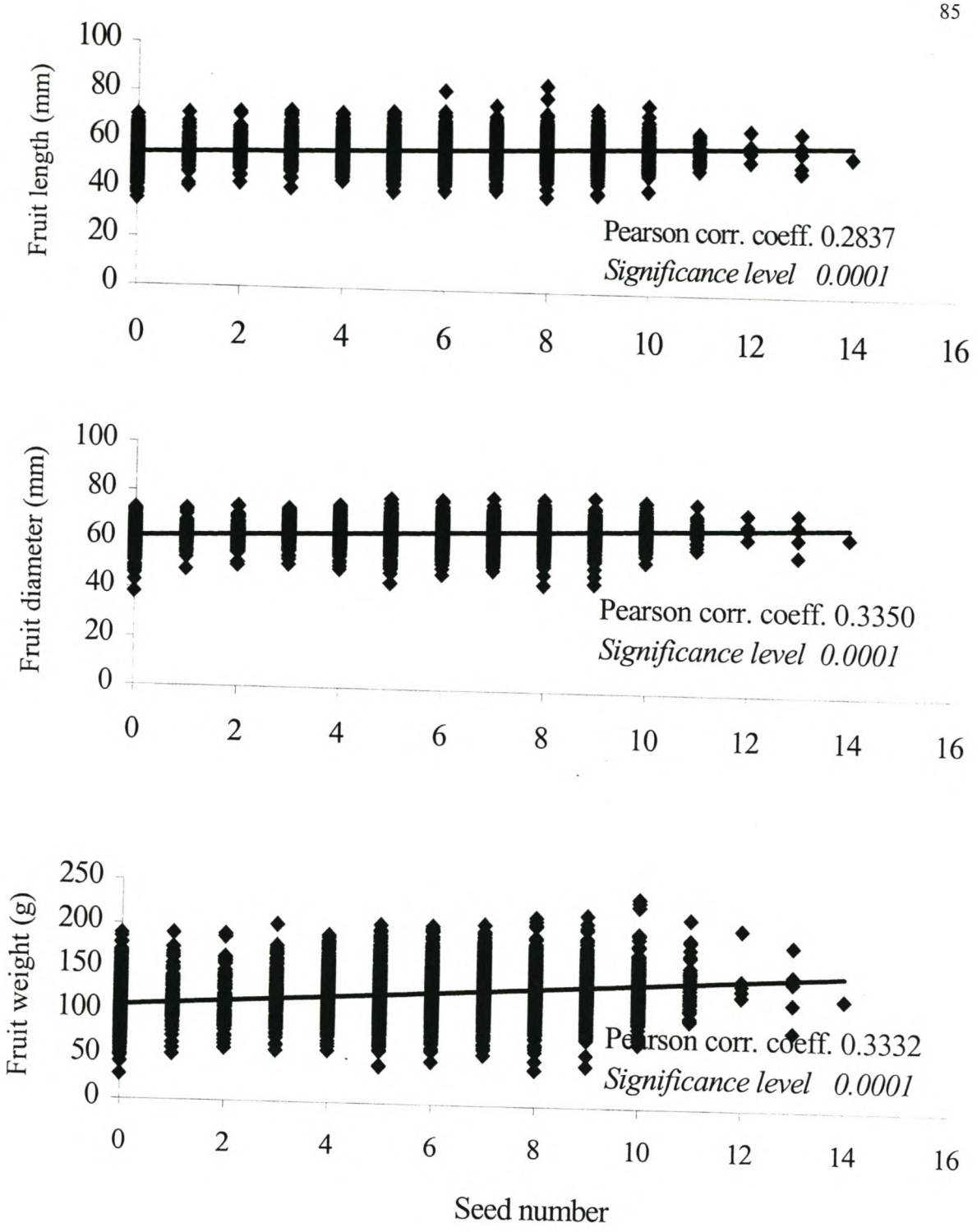

Fig. 5. The correlation between seed number in the fruit, and fruit length, diameter and weight for the 1997/98 season.

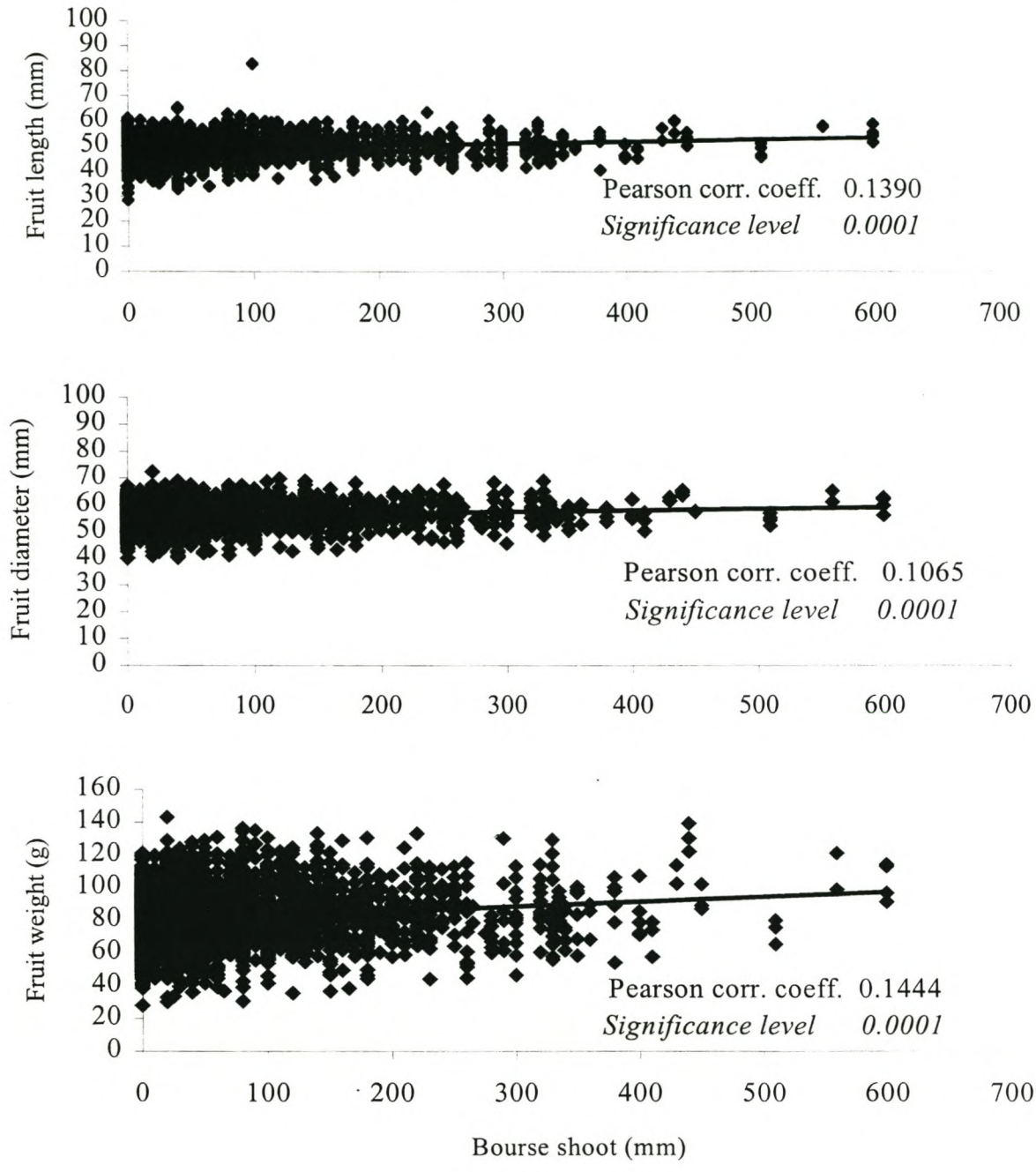

Fig. 6. The correlation between the bourse shoot length and fruit length, diameter and weight as measured at harvest for the 1998/99 season.

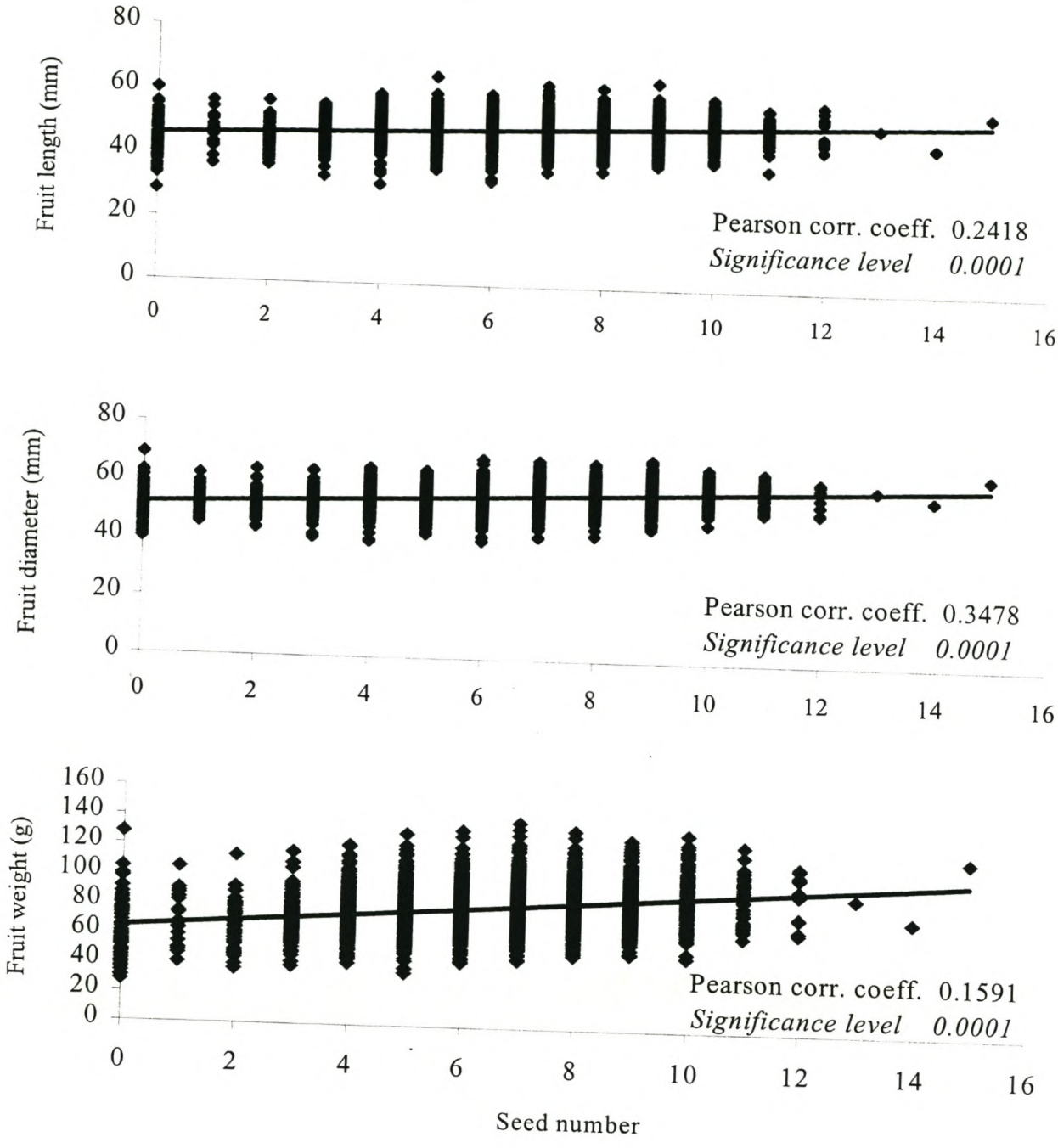

Fig. 7. The correlation between seed number in the fruit, and fruit length, diameter and weight for the 1998/99 season.

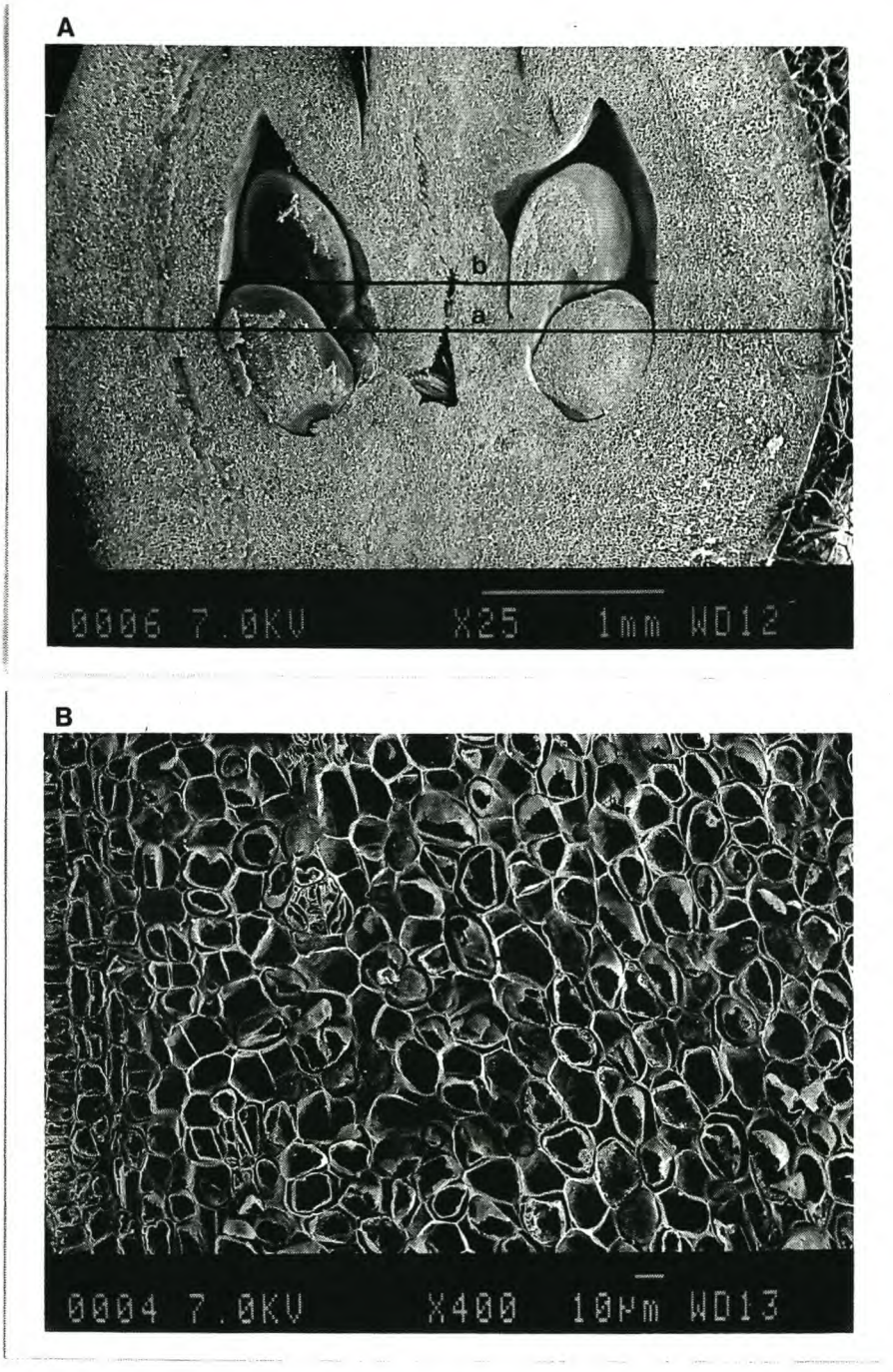

Plate 1. Scanning electron micro-graphs of the complete longitudinal sections (A) and a section of the developing cortical region (B) adjacent to the developing carpel primordium. The average representative number of cells and cell sizes per flower were determine by using the following variables: Plate 1A (a) receptacle length, (b) core length, and Plate 1B (c) cortex cell length.

PAPER 3: THINNING AND HEADING PRUNING CUTS AFFECT FRUIT SIZE AND YIELD OF 'ROYAL GALA' APPLE TREES.

ABSTRACT

During the 1997 winter 'Royal Gala'(*Malus domestica.* Borkh.) apple trees were pruned as follows: (a) control with no further pruning, (b) thinning cuts of only entire secondary branches (branches that were thicker than half of the trunk diameter were removed at the point of attachment with the trunk), (c) thinning cuts of secondary branches and tertiary fruiting units (positioned on branches), (d) thinning of spurs only, without removal of branches or fruiting units, and (e) thinning cuts of branches and tertiary fruiting units combined with heading back of fruiting units into the spurs leaving four buds per fruiting unit. Treatments (b) through (e), were conducted at light or heavy pruning intensities, i.e., by leaving 300 or 150 reproductive buds/tree, respectively. Pruning was followed up by hand thinning of fruitlets to one fruit per cluster ≈ 40 days after full bloom. All pruning treatments increased fruit size, primarily because of a indirect fruit thinning effect except the combined thinning and heading treatments where a direct effect resulted in the largest apples without negatively effecting yield. In the winter of 1998 trees were pruned as follows: (a) control with no further pruning, (b) heavy thinning of secondary branches and fruiting units leaving 250 reproductive buds/tree, (c) light thinning of secondary branches and fruiting units leaving 400 reproductive buds/tree, (d) heavy thinning of secondary branches and fruiting units combined with heading back into the spurs of the remaining fruiting units leaving 250 reproductive buds/tree, and (e) light thinning of secondary branches and fruiting units combined with heading back into the spurs of the remaining fruiting units leaving 400 reproductive buds/tree. No hand

thinning was done in this season. In 1998/99 season the advantage of pruning on fruit size were not observed. Pruning should be followed up by hand thinning of fruitlets.

INTRODUCTION

Fruit size is a problem with 'Royal Gala' apples under South Africa condition's, with poor prices realised for small apples. Pruning combined with fruit thinning is an important method of improving fruit size (Denne, 1960; Williams, 1985). According to Goffinet *et al.* (1995) fruit from 'Empire' apple trees thinned at bloom were the largest among their thinning treatments. As thinning was delayed after bloom, there was a linear decrease in size. McArtney *et al.* (1996) support this statement for 'Royal Gala' apples. Pruning trials on 'Packham's Triumph' pear trees by Saunders *et al.* (1991) show that heading back into the spurred 2-years-old wood increased fruit set. Heading also decreased the number of new shoots per shoot unit. Apart from reducing shoot number, heading affected the relative position of the new shoots to the developing fruits by reducing the distance between the fruit on the spurred 2-year-old wood and the shoot sinks remaining on the shoot units. The increase fruit set resulting from heading in winter decreased when heading was delayed until after anthesis. Heading failed to improve fruit set when it was delayed until 3 weeks after anthesis or later. It would appear that the inhibition of subordinate fruitlets by distal shoot sinks had already started at anthesis before shoot growth was even visible. Small sinks have a low demand for assimilates (Bangerth, 1989). Heading increased the set of seedless fruit. Apparently seedless fruits are subordinate to distal shoots while seeded fruits are not (Saunders *et al.*, 1991).

Much work has been done by Lauri *et al.* (1995) to classify various apple cultivars into their fruiting types. 'Royal Gala', with respect to lateral spur autonomy, is classified halfway between the autoregulatory varieties, like 'Granny Smith', and biennial-bearing varieties like 'Golden Delicious.' Flower buds that set fruit are found mainly on 2-year-old and older wood. 'Royal Gala' exhibits a tendency for alternation at the spur level, i.e., spurs that bear fruit tend not to bear the following year. Thus, 'Royal Gala' produces mostly on 2-year-old and older spurs, with many of these spurs in a vegetative or "resting" state.

Bourse-shoot development is known to have a detrimental effect on early set and a positive effect on fruit growth later in the season (Abbott, 1960). The ability of an individual inflorescence to set fruit is positively related to the number of leaves and flowers of the inflorescence and wood age. Apple fruit set increased with increasing numbers of leaves and flowers of inflorescence (Lauri and Terouanne, 1999). Inflorescence thinning by Lauri and Terouanne, (1999) showed that the stimulation of fruit set was essentially observed on inflorescences, with the lowest number of leaves and flowers. It, therefore, seems that inflorescence removal minimised fruit set differences between weak and strong inflorescences. Winter pruning involves inflorescence removal. The purpose of this study was to determine the effect of selective pruning cuts (thinning and heading cuts) and severity of thinning via pruning on fruit size of 'Royal Gala' apples. The objective was to improve fruit size without a loss in yield.

MATERIALS AND METHODS

1997/98

Site & plant material:

The trial was conducted on 'Royal Gala' apple trees planted in a commercial orchard at Kromfontein in the Koue Bokkeveld region of the Western Cape, South Africa (33°18' S, 19°20' E, altitude 930m). The 'Royal Gala' trees on M793 rootstock, were planted in a north-south row direction in 1991, spaced at 4m by 1.5m. The trees were trained to a central leader system with a dominant central trunk with inferior secondary branches. Light management was done in autumn to all the trees, by thinning no more than three of the most vigorous branches originating from the trunk. 'Hillierri crab' (*Malus scheideckeri*) apple trees were used as pollinators. Standard commercial practices for fertilisation, irrigation and other orchard practices were followed.

Treatments and experimental design:

The following pruning treatments where conducted on 21 August 1997. Treatment: (a) control with no further pruning, (b) thinning cuts of only entire secondary branches according to the 2:1 rule (branches that were thicker than half of the trunk diameter were removed at the point of attachment with the trunk) (Zahn, 1986), (c) thinning cuts of secondary branches and tertiary fruiting units (positioned on branches) according to the 2:1 rule, (d) thinning of spurs only, without removal of branches or fruiting units, and (e) thinning cuts of branches and tertiary fruiting units (2:1 rule) combined with heading back of fruiting units into the spurs leaving four buds per fruiting units. Treatments (b) through (e), were conducted at light or heavy pruning intensities, i.e., by leaving 300 or

150 reproductive buds/tree, respectively. The trial was laid out as a non-statistical trial. There were five rows (one treatment per row) with ≈ 30 trees per row. Six uniform trees where randomly selected from within each row; three were pruned lighter and three heavier. Fruit thinning was done by hand ≈ 40 days after full bloom leaving the largest fruit per cluster.

Data collected:

For the 1997/98 season data were collected from three tagged trees per pruning treatment/intensity combination. All the apples on the tagged trees were harvested (4 February 1998) and brought to our laboratory for evaluation. The trunk circumference of all the tagged trees was measured at harvest. The following parameters were recorded: (a) yield per tree (kg) and yield efficiency ($kg.cm^{-1}$), (b) fruit number, (c) fruit mass, length and diameter, (d) the most and least intense colour of the apples according to the Hortec colour chart no. A 42 (Hortec, P.O. Box 1231,Stellenbosch, 7600), and (e) seed number per fruit.

1998/99

Site & plant materials:

Different trees in the above orchard were used for the 1998/99 trails. Light pruning and management was conducted as in the previous year.

Treatments and experimental design:

With the results of the 1997/98 season in mind we conducted the following pruning treatments on 18 August 1998: (a) control with no further pruning, (b) heavy thinning of secondary branches and fruiting units according to the 2:1 rule leaving 250 reproductive buds/tree, (c) light thinning of secondary branches and fruiting units according to the 2:1 rule leaving 400 reproductive buds/tree, (d) heavy thinning of secondary branches and fruiting units according to the 2:1 rule combined with heading back into the spurs of the remaining fruiting units leaving 250 reproductive buds/tree, and (e) light thinning of secondary branches and fruiting units according to the 2:1 rule combined with heading back into the spurs of the remaining fruiting units leaving 400 reproductive buds/tree. In 1998/99 no further hand fruit thinning was conducted. The trial layout was a randomised complete block design with the treatments randomised in 10 blocks with single tree plots.

Data collected:

For the 1998/99 season all the apples from two previously tagged branches per tree were brought to our laboratory at harvest (1 February 1999). The remaining apples were harvested, counted and weighed from each tree. Trunk circumference was measured at harvest. On all apples in the sample, the following parameters were recorded: (a) average fruit weight, length and diameter, (b) the most and least intense colour of the apples according to the Hortec colour chart no. A 42, (Hortec, P.O. Box 1231,Stellenbosch, 7600), and (c) seed number per fruit. On the two tagged branches fruit number per cluster and the bourse shoot length per bearing cluster (see Paper 2) was recorded at harvest.

Statistical analysis:

The General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) was used to analyse the data for both years (SAS Institute., 1990).

RESULTS AND DISCUSSION

1997/98

Compared to the control, all the pruning treatments affected yield, yield efficiency, fruit number and average fruit weight significantly (Table 1). Pruning reduced fruit number or set. Yield and yield efficiency were reduced by pruning except for the combination of thinning with heading cuts (thinning plus heading). Fruit number was thus used as a covariant for yield and yield efficiency. After adjustment for fruit number only the combination of thinning with heading cuts differed from the control (Table 2). Heavy pruning appeared to reduce yield and yield efficiency more than light pruning, probably through an increased thinning effect (Tables 1 and 2).

All pruning treatments tended to improve fruit weight (Table 1). With the fruit weight means adjusted for fruit number we see that all pruning treatments, except for thinning plus heading, increased fruit size via a fruit thinning effect (Table 2). Thinning plus heading directly increased fruit size in addition to the fruit thinning effect (Table 2), largely via an increase in fruit length, but also via an increase in fruit diameter (Tables 3 and 4). Pruning did not affect fruit coloration (Tables 4). Parthenocarpic fruit set was not affected by heading as occurs with pears (Saunders *et al.,* 1991), and seed number per

fruit was not affected (Table 5 and 6). Thinning plus heading significantly increased fruit weight of both seeded and seedless fruit (Table 5 and 6).

1998/99

The pruning effects on yield, yield efficiency, fruit number and average fruit weight observed in 1997/98 were not observed in 1998/99, probably because of the lack of hand thinning of fruitlets (Table 7). In contrast with the 1997/98 findings, heavy thinning plus heading tended to reduce fruit number, yield, and yield efficiency, but also tended to produce smaller fruit (Table 7), even when means were adjusted for fruit number (Table 8). No significant differences were found between treatments for fruit length and diameter, colour, partenocarpic fruit set, seed number and the weight of seeded and seedless fruit (Table 9 and 10).

To explain the poor response of the heavy thinning and heading treatment, the data were analysed further. We observed less fruit set and a tendency for fruiting clusters to set more fruit per cluster (Table 11). There also tended to be more clusters with four or more fruit (Table 11 and Figure 1). The bourse shoots on the bearing clusters in this treatment tended to be longer and no correlation existed between the bourse shoot length and the total fruit weight (Table 11). In 1998/99 heavy thinning plus heading possibly resulted in increased fruit/fruit and fruit/shoot competition.

In 1997/98 all the pruning treatments combined with subsequent fruitlet thinning by hand increased fruit size, primarily because of an indirect fruit thinning effect. When thinning

was combined with heading an additional direct improvement on fruit size is observed without any negative effects on yield. With heading it is possible that the reproductive buds could be in a better position as observed by Saunders *et al.,* (1991). The advantages of thinning combined with heading on fruit size were not influenced by the intensity of pruning. Heavy pruning tends to reduce yield. In 1998/99 season where no hand thinning of fruitlets was done the advantages of pruning of fruit size were no longer evident. Pruning should be followed up by hand thinning of fruitlets.

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Table 1. Effect of pruning treatments on the yield and number of fruit on 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1997/98 season.

Pruning treatments	Yield (kg/tree)	Yield efficiency (kg/cm)	Fruit number	Average fruit weight (g)
Control (C)	23	0.85	206	114
Control (C)	18	0.66	162	115
Light thinning on trunk to 300 buds (Tl)	23	0.82	204	118
Heavy thinning on trunk to 150 buds (Th)	13	0.42	95	138
Light thinning on trunk + branches to 300 buds (Bl)	15	0.52	129	119
Heavy thinning on trunk + branches to 150 buds (Bh)	12	0.45	89	141
Light spur thinning to 300 buds (Sl)	21	0.72	163	131
Heavy spur thinning to 150 buds (Sl)	4	0.16	41	120
Light thinning and heading to 300 buds (Hl)	22	0.78	162	141
Heavy thinning and heading to 150 buds (Hh)	8.88	0.31	61	146
Pruning treatment	0.0029	0.0027	0.0019	0.0051
Contrast:				
Control vs. all other treatments	0.0335	0.0165	0.0053	0.0020
Tl vs. Th	0.0239	0.0210	0.0091	0.0320
Bl vs. Bh	0.5228	0.6715	0.2965	0.0262
Sl vs. Sh	0.0015	0.0019	0.0040	0.2227
Hl vs. Hh	0.0062	0.0067	0.0143	0.6110
Tl+Th vs. Bl+Bh	0.1704	0.2268	0.1468	0.7217
Control vs. Tl+Th+Bl+Bh	0.0978	0.0501	0.0280	0.0132
Control vs. Sl+Sh	0.0196	0.0107	0.0062	0.0769
Control vs. Hl+Hh	0.1094	0.0788	0.0132	0.0001

Table 2. Effect of pruning treatments on the yield and number of fruit on 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1997/98 season. Means have been adjusted for fruit number.

Pruning treatments	Yield (kg/tree)	Yield efficiency (kg/cm)	Average fruit weight (g)
Control (C)	14.9	0.54	119
Control (C)	14.9	0.53	117
Light thinning on trunk to 300 buds (Tl)	15.6	0.52	123
Heavy thinning on trunk to 150 buds (Th)	17.2	0.57	135
Light thinning on trunk + branches to 300 buds (Bl)	15.6	0.52	119
Heavy thinning on trunk + branches to 150 buds (Bh)	17.4	0.62	137
Light spur thinning to 300 buds (Sl)	17.5	0.59	134
Heavy spur thinning to 150 buds (Sl)	15.1	0.52	113
Light thinning and heading to 300 buds (Hl)	19.0	0.66	144
Heavy thinning and heading to 150 buds (Hh)	16.9	0.59	141
Number of fruit/tree	0.0001	0.0001	0.0035
Pruning treatment	0.0192	0.0430	0.0155
Contrast:			
Control vs. all other treatments	0.0225	0.2304	0.0452
Tl vs. Th	0.2373	0.3768	0.2544
Bl vs. Bh	0.1415	0.0386	0.0539
Sl vs. Sh	0.0988	0.1937	0.0670
Hl vs. Hh	0.1335	0.1796	0.7498
Tl+Th vs. Bl+Bh	0.8702	0.4582	0.8963
Control vs. Tl+Th+Bl+Bh	0.0587	0.5037	0.0929
Control vs. Sl+Sh	0.1666	0.6725	0.4725
Control vs. Hl+Hh	0.0035	0.0218	0.0034

Table 3 Effect of pruning treatments on fruit length, diameters and colour of 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1997/98 season.

Pruning Treatments	Average fruit length (mm)	Average fruit diameter (mm)	Best coloured side of fruit (colour chart no. A 42)	Worst coloured side of fruit (colour chart no. A 42)
Control (C)	56	62	6	9
Control (C)	56	63	7	9
Light thinning on trunk to 300 buds (Tl)	55	63	7	9
Heavy thinning on trunk to 150 buds (Th)	60	66	6	8
Light thinning on trunk + branches to 300 buds (Bl)	56	64	6	8
Heavy thinning on trunk + branches to 150 buds (Bh)	60	66	6	9
Light spur thinning to 300 buds (Sl)	58	65	6	8
Heavy spur thinning to 150 buds (Sl)	57	63	6	8
Light thinning and heading to 300 buds (Hl)	60	66	6	8
Heavy thinning and heading to 150 buds (Hh)	61	66	5	8
Pruning treatment	0.0119	0.0728	0.8203	0.3214
Contrast:				
Control vs. all other treatments	0.0256	0.0107	0.1960	0.0479
Tl vs. Th	0.0124	0.0962	0.5223	0.2487
Bl vs. Bh	0.0258	0.0977	0.5483	0.6227
Sl vs. Sh	0.2544	0.2464	0.4971	0.2732
Hl vs. Hh	0.5543	0.7312	0.4055	0.4062
Tl+Th vs. Bl+Bh	0.7168	0.7835	0.7875	0.9947
Control vs. Tl+Th+Bl+Bh	0.1484	0.0176	0.3501	0.2240
Control vs. Sl+Sh	0.2099	0.2255	0.2712	0.0281
Control vs. Hl+Hh	0.0013	0.0048	0.1650	0.0464

Table 4. Effect of pruning treatments on fruit length, diameters and colour of 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1997/98 season. Means have been adjusted for fruit number.

Pruning Treatments	Average fruit length (mm)	Average fruit diameter (mm)	Best coloured side of fruit (colour chart no. A 42)	Worst coloured side of fruit (colour chart no. A 42)
Control (C)	58	63	7	9
Control (C)	56	63	7	9
Light thinning on trunk to 300 buds (Tl)	56	64	7	9
Heavy thinning on trunk to 150 buds (Th)	59	66	6	8
Light thinning on trunk + branches to 300 buds (Bl)	56	64	6	9
Heavy thinning on trunk + branches to 150 buds (Bh)	59	66	6	9
Light spur thinning to 300 buds (Sl)	59	65	6	8
Heavy spur thinning to 150 buds (Sl)	55	62	5	8
Light thinning and heading to 300 buds (Hl)	60	66	6	8
Heavy thinning and heading to 150 buds (Hh)	60	65	5	8
Number of fruit/tree	0.0048	0.0191	0.2993	0.0144
Pruning treatment	0.0290	0.1264	0.9130	0.8119
Contrast:				
Control vs. all other treatments	0.2757	0.1488	0.2223	0.2653
Tl vs. Th	0.1461	0.5030	0.4835	0.6590
Bl vs. Bh	0.0537	0.1812	0.6206	0.4786
Sl vs. Sh	0.0663	0.0726	0.4672	0.7559
Hl vs. Hh	0.7647	0.6358	0.3883	0.8390
Tl+Th vs. Bl+Bh	0.8750	0.8296	0.7235	0.7444
Control vs. Tl+Th+Bl+Bh	0.5438	0.1167	0.3386	0.5332
Control vs. Sl+Sh	0.8500	0.8431	0.2849	0.1828
Control vs. Hl+Hh	0.0234	0.0600	0.1848	0.2130

Table 5. Effect of the pruning treatments on the % parthenocarpic fruit, mean seed number and mean seeded and seedless fruit mass on 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1997/98 season.

Pruning Treatments	% Parthenocarpic fruit	Average seed number	Average seeded fruit weight (g)	Average seedless fruit weight (g)
Control (C)	21	5.5	119	98
Control (C)	16	6.1	119	104
Light thinning on trunk to 300 buds (Tl)	13	6.3	120	100
Heavy thinning on trunk to 150 buds (Th)	6	6.7	142	107
Light thinning on trunk + branches to 300 buds (Bl)	16	5.5	124	109
Heavy thinning on trunk + branches to 150 buds (Bh)	7	5.9	145	106
Light spur thinning to 300 buds (Sl)	10	6.3	134	116
Heavy spur thinning to 150 buds (Sl)	10	5.6	128	77
Light thinning and heading to 300 buds (Hl)	14	6.0	145	133
Heavy thinning and heading to 150 buds (Hh)	5	5.7	151	112
Pruning treatment	0.2573	0.3237	0.0077	0.0471
Contrast:				
Control vs. all other treatments	0.0242	0.5352	0.0032	0.3080
Tl vs. Th	0.2508	0.4015	0.0246	0.4831
Bl vs. Bh	0.1441	0.4727	0.0300	0.7972
Sl vs. Sh	0.9108	0.1775	0.5311	0.0160
Hl vs. Hh	0.1874	0.5902	0.4835	0.0615
Tl+Th vs. Bl+Bh	0.6756	0.0344	0.6213	0.5836
Control vs. Tl+Th+Bl+Bh	0.0427	0.3723	0.0234	0.5225
Control vs. Sl+Sh	0.1181	0.7233	0.0744	0.6066
Control vs. Hl+Hh	0.0421	0.9559	0.0002	0.0093

Table 6. Effect of the pruning treatments on the % parthenocarpic fruit, mean seed number and mean seeded and seedless fruit mass on 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1997/98 season. Means have been adjusted for fruit number.

Pruning Treatments	% Parthenocarpic fruit	Average seed number	Average seeded fruit weight (g)	Average seedless fruit weight (g)
Control (C)	19	5.5	125	100
Control (C)	16	6.1	122	105
Light thinning on trunk to 300 buds (Tl)	12	6.3	127	101
Heavy thinning on trunk to 150 buds (Th)	7	6.7	139	106
Light thinning on trunk + branches to 300 buds (Bl)	16	5.5	123	109
Heavy thinning on trunk + branches to 150 buds (Bh)	8	5.9	141	105
Light spur thinning to 300 buds (Sl)	10	6.3	137	117
Heavy spur thinning to 150 buds (Sl)	11	5.6	120	76
Light thinning and heading to 300 buds (Hl)	13	6.0	148	134
Heavy thinning and heading to 150 buds (Hh)	7	5.7	145	110
Number of fruit/tree	0.0178	0.7153	0.0010	0.8029
Pruning treatment	0.7487	0.3653	0.0332	0.0583
Contrast:				
Control vs. all other treatments	0.1130	0.6845	0.0745	0.5297
Tl vs. Th	0.5440	0.5457	0.2461	0.7176
Bl vs. Bh	0.2090	0.5192	0.0625	0.7376
Sl vs. Sh	0.8962	0.2460	0.1331	0.0203
Hl vs. Hh	0.4279	0.5953	0.8003	0.0794
Tl+Th vs. Bl+Bh	0.5524	0.0447	0.9530	0.7033
Control vs. Tl+Th+Bl+Bh	0.1326	0.4855	0.1610	0.7134
Control vs. Sl+Sh	0.2487	0.8447	0.5262	0.5376
Control vs. Hl+Hh	0.1551	0.9711	0.0058	0.0412

Table 7. Effect of pruning treatments on the yield, number of fruit and average fruit weight on 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1998/99 season.

Pruning Treatments	Yield/ tree (kg)	Yield efficiency (kg/cm)	Average fruit number	Average fruit weight (g)
Control (C)	42	1.28	425	101
Heavy thinning on trunk + branches to 250 buds (Bh)	45	1.41	481	96
Light thinning on trunk + branches to 400 buds (Bl)	39	1.23	419	97
Heavy thinning and heading to 250 buds (Hh)	32	0.98	330	93
Light thinning and heading to 400 buds (Hl)	44	1.30	436	104
Treatment	0.1487	0.1069	0.2350	0.6510
Contrast :				
Control vs. all other treatments	0.5655	0.7024	0.8759	0.5528
(Bh) vs. (Bl)	0.3198	0.2515	0.3395	0.9143
(Hh) vs. (Hl)	0.0383	0.0473	0.1076	0.1643
Control vs. (Hh)+(Hl)	0.3483	0.3278	0.4639	0.6332

Table 8. Effect of pruning treatments on the yield, number of fruit and average fruit weight on 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1998/99 season. Means have been adjusted for fruit number.

Pruning Treatments	Yield/ tree (kg)	Yield efficiency (kg/cm)	Average fruit weight (g)
Control (C)	42.3	1.26	101.6
Heavy thinning on trunk + branches to 250 buds (Bh)	40.0	1.27	98.9
Light thinning on trunk + branches to 400 buds (Bl)	39.4	1.22	97.6
Heavy thinning and heading to 250 buds (Hh)	39.2	1.18	90.8
Light thinning and heading to 400 buds (Hl)	42.9	1.26	104.6
Number of fruit/tree	0.0001	0.0001	0.0996
Treatment	0.2756	0.6226	0.4038
Contrast :			
Control vs. all other treatments	0.2453	0.5505	0.5078
(Bh) vs. (Bl)	0.7755	0.4997	0.8550
(Hh) vs. (Hl)	0.0946	0.2026	0.0621
Control vs. (Hh)+(Hl)	0.4862	0.4435	0.5194

Table 9. Effect of pruning treatments on fruit length, diameters and colour of 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1998/99 season.

Pruning treatments	Average fruit length (mm)	Average fruit diameter (mm)	Best coloured side of fruit (colour chart no. A 42)	Worst coloured side of fruit (colour chart no. A 42)
Control (C)	48.9	56.0	10.9	11.7
Heavy thinning on trunk + branches to 250 buds (Bh)	48.2	55.4	10.6	11.7
Light thinning on trunk + branches to 400 buds (Bl)	49.0	55.9	10.5	11.5
Heavy thinning and heading to 250 buds (Hh)	48.9	55.7	10.9	11.7
Light thinning and heading to 400 buds (Hl)	51.3	58.1	10.1	11.4
Treatment	0.0827	0.1012	0.2255	0.4891
Contrast :				
Control vs. all other treatments	0.6322	0.7789	0.2621	0.3713
(Bh) vs. (Bl)	0.4799	0.6076	0.7471	0.3961
(Hh) vs. (Hl)	0.0421	0.0265	0.0406	0.1850
Control vs. (Hh)+(Hl)	0.2256	0.3611	0.2615	0.3394

Table 10. Effect of the pruning treatments on the % parthenocarpic fruit, average seed number and average seeded and seedless fruit weight of 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1998/99 season

Pruning Treatments	% Parthenocarpic fruit	Average seed number	Average seeded fruit weight (g)	Average seedless fruit weight (g)
Control (C)	3.02	6.66	81.3	30.4
Heavy thinning on trunk + branches to 250 buds (Bh)	1.55	6.55	80.1	27.1
Light thinning on trunk + branches to 400 buds (Bl)	3.74	6.67	82.9	43.9
Heavy thinning and heading to 250 buds (Hh)	4.40	6.29	77.1	33.7
Light thinning and heading to 400 buds (Hl)	2.31	6.57	90.4	47.9
Treatment	0.5965	0.5965	0.0978	0.5425
Contrast :				
Control vs. all other treatments	0.9886	0.4407	0.6090	0.4933
(Bh) vs. (Bl)	0.2574	0.6007	0.2346	0.2275
(Hh) vs. (Hl)	0.2783	0.2251	0.0380	0.3768
Control vs. (Hh)+(Hl)	0.8412	0.2495	0.2956	0.3861

Table 11. Effect of the pruning treatments on cluster characteristics and bourse shoots appearance and correlation with fruit mass of 'Royal Gala' apples at Kromfontein, Koue Bokkeveld for the 1998/99 season.

Pruning Treatments	% Clusters with fruit	Average fruit number per bearing cluster	Average number of clusters with 4 fruit and more	Average bourse shoot length per bearing cluster (cm)	Correlation between bourse shoot length and fruit weight	
					Pearson correlation coefficient	P > F
Control (C)	74.8	2.43	3.0	5.78	0.2358	0.0001
Heavy thinning on trunk + branches to 250 buds (Bh)	84.6	2.76	4.6	7.85	0.3174	0.0001
Light thinning on trunk + branches to 400 buds (Bl)	81.5	2.59	4.5	5.09	0.3137	0.0001
Heavy thinning and heading to 250 buds (Hh)	66.6	2.80	5.9	6.31	0.1236	0.0992
Light thinning and heading to 400 buds (Hl)	87.3	2.67	3.0	4.88	0.3032	0.0001
Treatment	0.1269	0.4717	0.3376	0.1861		
Contrast :						
Control vs. all other treatments	0.4488	0.1257	0.2434	0.8220		
(Bh) vs. (Bl)	0.7098	0.4726	0.9506	0.0420		
(Hh) vs. (Hl)	0.0197	0.5591	0.0775	0.2822		
Control vs. (Hh)+(Hl)	0.7775	0.1066	0.3025	0.8647		

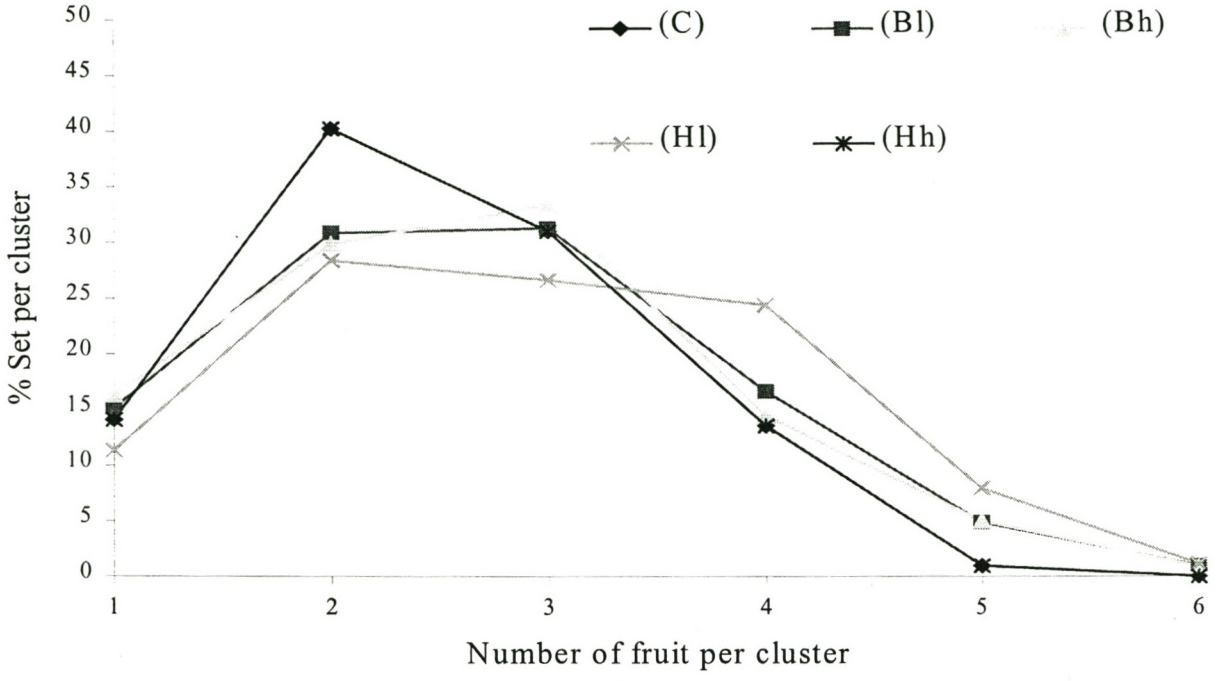

Figure 1. The relationship between the percentage clusters that set and the number of fruit per bearing cluster for the unthinned 1998/99 season.

PAPER 4: THE EFFECT OF ARTIFICIAL EXTINCTION OF FLOWER CLUSTERS ON FRUIT SIZE AND QUALITY OF 'ROYAL GALA' APPLES

ABSTRACT

Individual branches on 'Royal Gala' (*Malus domestica.* Borkh.) apple trees were pruned as follows: (a) control, (b) 25 % removal of fruiting spurs, (c) 50 % removal of fruiting spurs, (d) 75 % removal of fruiting spurs to test for any possible enhancements of fruit size. No subsequent hand thinning of fruitlets was done. Thinning by artificial extinction methods of the fruit buds did not influence fruit size, colour, seed set or seed development. No significant differences were found between fruit number, but with 50% and 75% bud removal fewer fruit were counted. In these data the absence of any significant fruit size improvement may be due to the lack of subsequent hand thinning of fruitlets.

INTRODUCTION

Fruit size is a problem in 'Royal Gala' apples under South Africa conditions, with poor prices realised for small apples. Work done by Lauri and Terouanne (1999) showed that an artificial reduction in the number of inflorescences per branch may stimulate fruit set of the remaining inflorescences revealing a physiological adjustment of that branch. The practical interests of inflorescence removal on one-year-old wood are twofold; first, it decreases the number of small-sized fruit; secondly, it tends to increase the development to fruitful inflorescences, at least over the first years of the lateral growth (Lauri and Terouanne, 1999). The aim of the present study was to test the potential of winter spur removal or "artificial extinction" to improve fruit size of the resultant apples.

MATERIALS AND METHODS

Site & plant material:

The trial was conducted on 'Royal Gala' trees in the Koue Bokkeveld at Kromfontein near Ceres in the Western Cape, South Africa (33°18' S 19°20' E, altitude 930m). The seven year old 'Royal Gala' trees on M793 rootstock were planted in a north-south row direction in 1991, with a tree spacing of 4m by 1.5m. Light management was done in autumn to all the trees, by thinning no more than three of the most vigorous branches originating from the trunk. 'Hillieri crab' (*Malus scheideckeri*) apple trees were used as pollinators.

Treatments and experimental design:

Ten trees were chosen at random. Four branches on each tree were tagged. The following treatments where conducted at the 18 August 1998. Treatment: (a) control with no further thinning on the tagged branch, (b) 25 % of fruiting spurs were removed, (c) 50 % of fruiting spurs were removed, and (d) 75 % of fruiting spurs were removed. No subsequent hand thinning of fruitlets was done. The trial was laid out as a randomised complete block design with single trees as blocks and single branches as plots.

Data collected:

All fruit from the tagged branches were brought to our laboratory and the following parameters were recorded: (a) fruit weight, length and diameter, (b) the best colour side and the worst colour side of the fruit according to the Hortec colour chart no. A 42

(Hortec, P.O. Box 1231,Stellenbosch, 7600), (c) seed number and weight per fruit, and (d) number of fruit per branch.

Statistical analysis:

The General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) was used to analyse the data (SAS Institute., 1990).

RESULTS AND CONCLUSION

Thinning by artificial extinction methods of the fruit buds did not influence fruit size (length, diameter or weight), colour, seed set or seed development (Tables 1 and 2). No significant differences were found in the number of fruit per branch, but with the 50% and 75% spur removal fewer fruit were counted. It was thought that thinning by artificial extinction would reduce the number of small-sized fruit resulting in an improvement in fruit size (Lauri and Terouanne, 1999). The lack of significant results may have been due to the lack of subsequent hand thinning of fruitlets.

REFERENCE

Lauri, P-E., & Terouanne, E., 1999. Effect of inflorescence removal on the fruit set of the remaining inflorescence and development of the laterals on one-year-old apple (*Malus domestica* Borkh.) branches. J. Hort. Science & Biotechnology. **74**: 110-117.

SAS Institute Inc., 1990. SAS/STAT User's Guide, Version 6 4th ed. Vol. 1 and 2, Cary, NC, USA.

Table 1. The effect of flower cluster removal on fruit size and fruit colour development on 'Royal Gala' apples at Kromfontein, Koue Bokkeveld.

Treatments	Average fruit length (mm)	Average fruit diameter (mm)	Average fruit weight (g)	Best coloured side of fruit (colour chart no. A42)	Worst coloured side of fruit (colour chart no. A42)
Control	49.3	58.2	79.6	10.7	11.7
Remove 25 % of flower clusters	49.6	56.2	82.3	10.4	11.6
Remove 50 % of flower clusters	49.7	55.9	84.5	10.7	11.4
Remove 75 % of flower clusters	49.3	56.6	82.4	10.8	11.7
Treatment	*0.9875*	*0.7073*	*0.8343*	*0.6966*	*0.9300*
Means adjusted for number of fruit/branch					
Control	49.3	58.2	79.6	10.7	11.7
Remove 25 % of flower clusters	49.6	56.2	82.	10.4	11.6
Remove 50 % of flower clusters	49.7	55.9	84.5	10.7	11.4
Remove 75 % of flower clusters	49.3	56.6	82.4	10.8	11.7
Fruit number	*0.3288*	*0.4850*	*0.2115*	*0.0601*	*0.1307*
Treatment	*0.9608*	*0.7441*	*0.7121*	*0.8261*	*0.9906*

Table 2. The effect of flower cluster removal on average seed number and weight and average fruit number on 'Royal Gala' apples at Kromfontein, Koue Bokkeveld.

Treatments	Average seed number per fruit	Average seed weight (g)	Average fruit number per treatment
Control	6.61	0.35	22.3
Remove 25 % of flower clusters	6.93	0.37	21.4
Remove 50 % of flower clusters	6.35	0.36	16.5
Remove 75 % of flower clusters	6.77	0.36	14.1
Treatment	*0.2557*	*0.8570*	*0.4594*
	Means adjusted for number of fruit/branch		
Control	6.61	0.35	
Remove 25 % of flower clusters	6.93	0.37	
Remove 50 % of flower clusters	6.35	0.36	
Remove 75 % of flower clusters	6.77	0.36	
Fruit number	*0.5390*	*0.5303*	
Treatment	*0.2307*	*0.8458*	