EFFECT OF PLANT GROWTH REGULATORS, BRANCH BENDING AND TRUNK GIRDLING ON GROWTH, FLOWERING AND FRUITING OF PEAR (*Pyrus communis* L.) cv. FLEMISH BEAUTY

THESIS

by

NANAK DEV

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in

HORTICULTURE

(Pomology)

1985

COLLEGE OF HORTICULTURE
Dr Yashwant Singh Parmar University of Horticulture and Forestry
Nauni, Solan 173 230 (H.P.) INDIA

2002

To
Mummy & Papa
to
whom I shall be
indebted whole life

Dr. N. Sharma
Associate Professor

Department of Pomology
College of Horticulture
Dr YS Parmar University of
Horticulture and Forestry,
Nauni, Solan (HP) 173 230 India

CERTIFICATE-I

This is to certify that the thesis entitled **"Effect of plant growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of pear (*Pyrus communis* L.) cv. Flemish Beauty"**, submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (Pomology)** to Dr Yashwant Singh Parmar University of Horticulture & Forestry, Solan (H.P.) is a record of bonafide research work carried out by **Mr Nanak Dev (H-2000-2-M)** under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of research work have been fully acknowledged.

Place: Nauni-Solan

Dated: 18 December, 2002

(N. Sharma)
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled **"Effect of plant growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of pear (*Pyrus communis* L.) cv. Flemish Beauty"**, submitted by **Mr Nanak Dev (H-2000-2-M)** to Dr.Y.S.Parmar University of Horticulture and Forestry, Solan (H.P.), in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE in HORTICULTURE (Pomology)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the External Examiner.

(**N. Sharma**)
Chairman
Advisory Committee

External Examiner

Professor & Head
Department Pomology

Dean
College of Horticulture

Acknowledgements

It is The Almighty, who bestowed me power, courage and will to meet the ups and downs of life. I courteously bow before Him.

With a profound personal regards, I take this opportunity to express my deep sense of heartfelt gratitude and regards to my esteemed teacher and Chairman Dr. N. Sharma, Associate Professor, Department of Pomology, Dr. YS. Parmar University of Horticulture and Forestry, Nauni-Solan, HP. for his expert guidance, suggestions, constructive criticism and constant encouragement during the entire period of study.

I extend my heartiest thanks to the worthy members of my Advisory Committee Dr. KK. Jindal (Director of Research), Dr. DR. Gautam (Professor, Dept. of Pomology) and Dr(Mrs) Anju Thakur (Associate Prof., Dept. of Basic Sciences) for their valuable suggestions.

My cordial thanks are due to all staff and field members of the Department of Pomology for their cooperation and assistance.

I will remain indebted to my parents especially my beloved mother Ms. Dev Bhagati Negi, father Shri KC. Negi, Bhaiya and Bhabhiji for their continuous, support and genial blessings.

Words seems to be too less to express regards to my Chachaji (GL. Negi) for his care taking guidance and encouragement.

I would like to acknowledge the company of my classmates Narendra, Amitabh, Gopal, Rahul, Pramod, Ved Prakash, Neena, Parul, Reshma and Vandana for their help and cooperation.

My cordial thanks are due to seniors who helped me one way or other while preparing this manuscript especially Dr. Rana, Dr. Reddy, Chuni Lal, Sunil, Naveen, Faizan, Arvind, Abhishek, Vinod, Anjana, Hardev Negi and Girish.

I am yet to find suitable words to acknowledge the company of my friends Vidya Negi, Sanjay Negi, Kailash Negi, Ajeet Negi and Arvind Negi.

I am highly thankful to Mr Asha Ram for his painstaking efforts for timely typing this manuscript.

Needless to say errors and omissions are mine.

Nanak 18/12/2002

(Nanak Dev)

Place: Nauni, Solan

Date: 18th December, 2002

Contents

List of Tables

List of Illustrations

Chapter-1
INTRODUCTION

INTRODUCTION

The soft fleshed European pears (*Pyrus communis* L.) are relished for their melting texture, delectable flavour and aroma. In Himachal Pradesh, pears were introduced by British colonists in the later part of 19^{th} century and since then it became tradition to grow pears as intercrop in apple orchards. In the recent years, pear cultivation has picked up especially due to increasing problems in apple industry and demand for its fresh fruits in the markets. Pear now ranks next only to apple in importance in the temperate fruit cultivation and Himachal Pradesh currently produces 7556 tonnes of pears annually from a cultivated area of 7549 hectares (Anonymous, 2002). Though, pear production has registered remarkable growth, there exist a lot of gap between area and production. Low productivity may probably be due to lesser emphasis on the development of production technologies for pear in comparison with apple and partly due to the reason that a sizable proportion of new orchards are still under non-bearing stage.

Though European pears are mainly grown in the high hills, where a number of early, mid and late season cultivars namely Early China, Bartlett, Beurre Hardy, Clapp's Favourite, Dr. Jules Guyot, Doyenne du Comice, Flemish Beauty, Laxton Superb, Conference, Max Red Bartlett and Starking Delicious have been successful, there also exists a good scope for the cultivation of some cultivars in the mid hills. Cultivar Flemish Beauty produces attractive fruits with excellent quality characteristics in the mid hills, but is late bearing and often exhibits erratic flowering, low fruit set and production.

Since early return from early production has become one of the most important factor contributing to orchard profitability, there is a need to generate changes in method of production that will be aimed at radical increase in pear productivity. Horticulturist have claimed that bending of shoots towards horizontal position reduce growth and stimulate flower bud formation in apple and pear (Mullins and Rogers, 1971; Sharma and Jindal, 1992a; Ito *et al.*, 1999). Techniques like ringing or girdling that involves removing a bark or making cut around the tree trunk may in some cases reduces shoot growth and promote flowering (Ingels, 2000). Exogenous plant growth regulators have been reported to regulate or manipulate growth and flowering of young trees, improving fruit set, thinning fruitlets, delaying fruit abscission and improving fruit quality in pome fruits (Miller, 1988). Keeping these points in view, the present study was therefore undertaken to investigate the influence of plant growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of Flemish Beauty pear with the following objectives:

1. To study the effect of paclobutrazol, branch bending and trunk girdling on vegetative growth and spur formation in pear trees.

2. To study the effect of growths regulators on fruit set, fruit quality and return bloom.

Chapter-2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

A review of current status of knowledge pertaining to the present investigations on the "Effect of growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of pear (*Pyrus communis* L.) cv. Flemish Beauty" is presented under suitable headings:

2.1 Effect on vegetative growth

Modern system of pear culture is concerned with methods of controlling growth and cropping of relatively young trees. In the bearing trees, vegetative growth must be balanced with flowering. However, maintenance of a delicate balance between the vegetative and reproductive processes is a major challenge in tree fruit production (Bukovac, 1981).

Exogenous application of different plant growth regulators and practices like trunk girdling and branch bending affect vegetative growth in pears and the current status of relevant information is reviewed as under:

2.1.1 Gibberellins

Gibberellin is commonly regarded to be the main plant hormone responsible for stem elongation (Graebe, 1987). Furthermore, exogenous applications of gibberellin have been reported to promote extension shoot growth in fruit trees. Teskey and Rajput (1977) observed that gibberellic acid (GA_3) applied at 10 or 100 ppm enhanced shoot growth and number of leaves in Bartlett pear.

Taylor (1978) reported that combined application of GA_{4+7} also increased shoot extension growth in young Golden Delicious apples. Baisai *et al.* (1988) recorded increased shoot growth following the application of 'Promalin' (GA_{4+7}+BA) in Golden Delicious apple trees. Poniedzialek *et al.* (1990) observed that application of a mixture of GA_3 + kinetin, each at 0.5 per cent to the buds of pear cv. Conference in the autumn after leaf fall, though slightly increased the number of shoots growing from the treated buds but significantly increased the shoot length. Pharis *et al.* (1990) showed the involvement of gibberellin in shoot extension and induction of flowering in apple. Xin *et al.* (1994) also reported that foliar application of GA_3 increased shoot growth in apple significantly. Grochowska *et al.* (1995) observed increased shoot elongation in apple trees by applying gibberellic acid (GA_3) at 5 or 10 mg/tree.

2.1.2 Cytokinins

Cytokinins reduce apical dominance and thus affect the development of lateral buds. Among various regulators from cytokinin class having hormonal or hormone like effects, benzyl adenine has been reported to be the most effective in promoting the elongation of shoots (Quinlan, 1980 and Cody *et al.*, 1985). Forshey (1982) showed that foliar spray of BA at 500 ppm stimulated primary and secondary branching and shoot growth in young apple trees. Rates for successful branching of pear are however, lower than for apple (VanOosten and Wertheim, 1981). Elfving (1984) further reported that BA application either alone or in combination with GA_{4+7} effectively increased the lateral shoot growth in apple. Unrath and Shaltout (1985) reported that application of BA at 250 to 500 ppm in combination with a suitable surfactant produced more consistent and effective response. Miller and Eldridge (1986) observed that application of BA at 500 ppm was more effective in breaking buds than pruning. Greene and Autio (1990) observed that BA stimulated lateral branching on young apple trees at a concentration of

100 mg/l. They found that BA reduced shoot length indirectly through intershoot competition.

Unrath (1989) reported that BA treatment altered the tree form in apple from a highly vigorous, upright trees with long terminal growth to a spreading, moderately vigorous and more productive form. Hrotko *et al.* (2000) reported that Paturyl 10WSC containing 10 per cent BA when applied to one year old apple trees on Malling-26 and MM-106 rootstocks significantly increased the number of shoots and their total length over the control.

2.1.3 Paclobutrazol

Paclobutrazol (2R, 3R+2S, 3S)-1-(4-chlorophenyl)-4, 4-dimethyl-2-(1,2,4-triazol-1-yl) pentan-3-ol also known as PP_{333} is a triazol compound having plant growth regulating properties. It is a potent inhibitor of gibberellin biosynthesis (Burden *et al.*, 1987) and has been extensively tested as a vegetative growth controlling agent on deciduous tree fruits including apple and pear (Miller, 1988).

In pome fruit, first observation on the effect of paclobutrazol was made by Quinlan (1980), who found that its foliar application at 1000-3000 ppm three weeks after full bloom to four year old Bramley's Seedling apple trees reduced shoot growth as effectively as standard dose of daminozide. Stinchcombe *et al.* (1984) reported that application of paclobutrazol and daminozide, each at 4 g/tree as foliar sprays on mature Michelin apple trees resulted in reduced shoot growth during the year of treatment, but only paclobutrazol reduced shoot growth in the subsequent years. They further observed that soil application of 1 g paclobutrazol per tree also reduced the mean shoot extension growth for upto two years. Foliar application caused greatest growth inhibition during the year of treatment in apple (Tukey, 1981). Paclobutrazol when applied as a soil spray at 20 g per tree of 16 years old d'Anjou pear in autumn however, produced no obvious effect on growth in the following year but decreased shoot growth in the subsequent years (Raese and Burts, 1983). In trials with mature Beurre Hardy and Doyenne du Comice pear trees on Quince A rootstocks, VanKricken and Lindenbergh (1984) compared the effect of chlormequat (CCC) and PP_{333} and observed that PP_{333} was more effective to suppress the growth of one year old shoots, especially with Comice. Jaumien *et al.* (1986) compared the effect of CCC, PP_{333} and daminozide all at 1000 or 2000 ppm on pear cultivars Clapp's Favourite and Beurre Hardy. They observed that CCC had the greatest and daminozide had least influence on shoot growth reduction, whereas, the influence of PP_{333} was in the intermediate range. However, concentration did not make any difference. Bonomo and Neri (1986) applied paclobutrazol at 500 ppm (4 treatments) and 1000 ppm (3 treatments) to Doyenne du Comice and Max Red Bartlett pear trees on dates starting from 10 days after petal fall and finishing in early October. In the second year a single June spray of 250 or 500 ppm was applied to both the cvs. and the third year only Comice was treated. Paclobutrazol applied at all dates had strong growth inhibiting effect on both cultivars. Stan *et al.* (1986) reported that the application of paclobutrazol at 1000 ppm, one month after full bloom to four-year-old Beurre Hardy pear trees reduced the amount of pruned wood by 60 per cent for the next 3 years.The spring shoot growth, internodal length and secondary growth of Yali pear were significantly inhibited by foliar application of paclobutrazol at 62.5, 125 or 250 ppm and soil application at 39, 78 or 155 mg/cm^2 trunk cross sectional area (Huang and Shen, 1987).

Huang and Cao (1989) found that under nursery conditions the intensity of shoot growth inhibited in apple trees had a significant correlation with concentration of paclobutrazol applied at 125 to 2000 mg/l. Noma *et al.* (1989) reported that treatments of paclobutrazol at 125 and 250 ppm applied five times at 2, 4, 5, 6 and 10 weeks after full bloom reduced shoot growth in the year of application in Japanese pear cvs. 'Kousui' and 'Shinsui'. Salem *et al.* (1990) reported that paclobutrazol applied either through foliage or soil at 1000 or 2000 ppm, significantly reduced shoot growth and internodal length of LeConte pear. Paclobutrazol reduced terminal shoot growth of Chilli pear (*P.*

bretschneideri) when applied at 250 to 2000 mg per litre of water (Ju *et al.*, 1993). Steffens *et al.* (1993) reported that paclobutrazol at 500 or 1000 ppm reduced shoot length and trunk cross sectional area of Gala apple when applied as foliar spray at 2, 4 and 6 weeks after full bloom.

Bist and Rai (1994) reported that late fall application of paclobutrazol as trunk soil line pour at 250 ppm to Gola pear reduced tree growth and increased number of spurs up to 2-3 years. However, its foliar application at post-bloom stage reduced shoot extension growth only for one year. Khurshid *et al.* (1997) reported that vegetative growth of Oregon Spur Delicious apple trees on MM-106 rootstocks was significantly reduced by the soil application of paclobutrazol.

2.1.4 Branch bending

Horticulturists have claimed that bending down the branches of apple trees reduce vegetative growth but similar reports on pears are lacking. Tromp (1970) while working on geotropic behaviour of individual shoot reported that growth of apple shoot in horizontal position was considerably less than that of vertical shoot and growth reduction was generally in proportionate to the degree of bending towards the horizontal position. Similarly, Hamzakheyl *et al.* (1976) reported that reduction of shoot growth was proportion to the degree of banding towards the horizontal in apple cv. Oregon Spur Delicious. In another study, orientation of Starking Delicious apple shoots and seedlings towards horizontal position markedly reduced terminal shoot growth (Myers and Ferree, 1983).

Sharma and Jindal (1992b) observed reduction in linear shoot growth, internodal length and radial growth of trunk in Royal Delicious apple with the orientation of trees at 30^{o}, 45^{o} and 60^{o} angles from the soil surface. Ito *et al.* (1999) reported that shoot growth of Japanese pears reduced significantly by bending of branches towards horizontal position.

2.1.5 Trunk girdling

Several reports indicate that ringing or girdling can reduce growth in different fruit trees. In apple cvs. McIntosh and Mutsu two types of girdling techniques significantly reduced trunk cross-sectional area, average shoot length and average number of shoots (Hoying *et al.*, 1992). Similarly, Skogerbo (1992) observed that girdling of trunk of apple cv. Lobo on MM-106 rootstock performed at full bloom reduced vegetative growth.

TianHong *et al.* (1996) reported that girdling + paclobutrazol treatment reduced vegetative growth of Red Fuji apple more effectively than treatment of girdling alone. In another study, XueCai *et al.* (1997) observed that trunk ringing and cultar application restricted vegetative growth and increased fruit production in Nagano Fuji apple. Ringing and bark inversion significantly reduced the radial growth of trunk below the treatment while, trunk girth above the treatments varied with cultivars in apple (Arakawa *et al.*, 1997).

Fumuro (1998) observed that girdling of trunk during the early shoot elongation period of tree growth in persimmon had dwarfing effect due to reduction of dry matter production attributable to the smaller number and areas of leaves and by inhibition of root functions, such as nutrient absorption and accumulation. Ilha *et al.* (1999) reported that trunk girdling of Japanese plum reduced tree vigour and vegetative growth in Southern Brazil. In an experiment on vigorous Bartlett pear trees, different methods of trunk girdling, namely double 'C' ring girdling, spiral ring girdling, complete ring girdling and goellotine girdling when employed about 6 weeks after full bloom reduced pruning weights by 30 to 40 pr cent (Ingels, 2000).

2.2 Effect on leaf area and chlorophyll content

2.2.1 Gibberellins

Ahmad (1998) observed that pre-bloom application of gibberellic acid at 20 or 30 ppm resulted in significantly increased average leaf area in pear cv. Flemish Beauty. Similarly, Sharma (2001) reported that GA_3 at 10, 20 and 40 ppm when applied at silver tip to green tip stage increased the leaf area of apple cv. Starking Delicious. Rana (2001) also observed that leaf area of strawberry increased significantly with GA_3 application at 25, 50 and 100 ppm. On the contrary GA_3 treatment to lemon (*Citrus jambhiri* Lush) caused 38 per cent reduction in leaf area and 43 per cent reduction in leaf biomass (Yu and Yelenosky, 1998). In another study, spray of gibberellic acid in combination with kinetin had no influence on leaf area of Royal Delicious apple trees (Singh, 1995).

Curry and Williams (1983) observed that pre-bloom and full bloom applications of 'Promalin' or gibberellin (A_3) both at 25 ppm increased leaf area in apple cv. Delicious. McLaughlin and Greene (1984) reported that GA_{4+7} when applied alone could not influence leaf area, however, application of the mixture of GA_{4+7} + BA increased leaf size of apple cv. Golden Delicious. Pal (1997) observed that application of 'Promalin' at 75 to 60 ppm had no significant effect on the leaf area of Starking Delicious apple.

2.2.2 Cytokinins

Engels and Ebert (1988) observed that application of benzyl adenine containing formulation 'Promalin' at 50 or 100 ppm on strawberry plants increased the total and individual leaf area over the untreated control. A dose of 100 ppm had a greater effect than 50 ppm. Pipattanawong *et al.* (1996) observed that number of leaves and petiole length increased when BA at 50 ppm or BA + GA_3 each at 50 ppm were applied on Miyoshi, Eurei and Summer Berry cvs. of strawberry, however, leaf area remained unaffected. Thukral *et al.* (1994) reported that a mixture of GA_3 + BA at 25 ppm when applied twice before anthesis to lemon (*Citris limon* Burm) significantly increased leaf area. However, Ahmad (1998) reported that application of kinetin at 20, 30 or 40 ppm during flowering period reduced the leaf area of pear cv. Flemish Beauty.

Rana (2001) reported that application of BA at 25, 50 and 100 ppm and 'Promalin' at 50 and 100 ppm significantly increased the leaf area of strawberry over the control. In a recent study, a lower dose of BA (5 ppm) applied to Starking Delicious apple trees at silver to green tip stage increased average leaf area over control (Sharma, 2001).

2.2.3 Paclobutrazol

The effect of paclobutrazol on various morphological characteristics of leaves have been investigated. In pear, Bonomo and Neri (1986) applied paclobutrazol at 500 ppm and 1000 ppm ten days after petal fall as foliage spray to Doyenne du Comice and Max Red Bartlett cultivars and observed markedly reduced individual leaf area in Comice pear even two years after the treatments, however, total chlorophyll content and leaf specific weight increased in both cultivars. Huang and Shen (1987) reported that paclobutrazol application to the soil or foliage at 1.0 to 1.5 mg a.i. per seedling of pear (*Pyrus betulaefolia*), reduced fresh and dry weight of leaves and leaf area. Salem *et al.* (1990) observed reduced leaf area and number of leaves per shoot in LeConte pear with the application of paclobutrazol at 1000 or 2000 ppm at 2, 4 and 6 weeks after full bloom.

Kim *et al.* (1990) found increased leaf thickness, its chlorophyll contents and photosynthetic activity with the treatments of paclobutrazol at 4 or 8 lit/ha of apple cv. Fuji plantation. However, application of this compound reduced the average leaf area. Hao *et al.* (1991) observed that foliar application of paclobutrazol at 1000 ppm, 21 and

36 days after full bloom resulted in increased leaf thickness and its chlorophyll b content from 1:33 to 1.86 mg/g of fresh weight in Delicious apple.

Lin *et al.* (1993) reported that application of paclobutrazol increased leaf chlorophyll content in Shinseiki pear (*Pyrus serotina*). In another study, four-year-old trees of apple cv. Aki Fuji on *Malus micromolus* rootstock while, in their second year of fruiting that had been given two soil applications of paclobutrazol, first at 1.5 g a.i. in spring followed by second at 0.75 g a.i. in October recorded significantly higher photosynthetic rates than those of untreated trees (Huang *et al.*, 1995).

2.2.4 Branch bending

Orientation of branches in relation to gravity has been reported to influence photosynthetic production. Blinovski (1970) recorded increased leaf surface area per unit of shoot length when shoots were trained horizontally in apple. Further, chlorophyll contents in leaves on horizontal shoots were greater and more uniform throughout the growing season than in leaves from upright shoots. Myers and Ferree (1983) reported that orientation of young apple trees in a non-vertical position and summer pruning delayed a decline in net photosynthesis exhibited by vertical unpruned trees. However, non-vertical orientation of trees decreased the average leaf size on subsequent shoot growth. Sharma *et al.* (1991) reported that vertical trees produced larger leaves as compared to trees oriented at 30^{o}, 45^{o} and 60^{o} angles from the soil surface in apple cv. Royal Delicious. However, reports about similar work on pear are still lacking.

2.2.5 Trunk girdling

There are few reports to suggest that trunk girdling influences leaf characteristics and photosynthetic production in different fruit trees. In Thompson Seedless grapes, trunk girdling reduced stomatal conductance and CO_2 assimilates in vines but increased leaf weight per unit area by 17 per cent (Harrell and Williams, 1987). Roper and Williams (1989) observed greater accumulation of carbohydrates in girdled vines of Thompson Seedless grapes. Girdling increased the specific leaf area, stomatal resistance and internal CO_2 concentration in apple (Schechter *et al.*, 1994). Peng and Rabe (1996) however, reported that summer trunk girdling significantly reduced chlorophyll content and leaf area in Mikowase satsuma mandarin.

2.3 Effect on spur formation and flowering

2.3.1 Gibberellins

It has been reported that exogenous application of gibberellins influences flowering in pome fruits. VanKricken and Lindenbergh (1984) observed that application of gibberellic acid greatly reduced flower bud number in Comice pear. Similarly, Knight and Browning (1986) reported that GA_3 at 11 mg/l inhibited the flower initiation in Conference pear.

Singh and Chadha (1990) reported that GA_3 application at 25 to 75 ppm during bloom period on apple cv. Delicious reduced the percentage of flowering in following year over the control. Looney *et al.* (1985) suggested that specific gibberellins like GA_4 and C-3 epimer of GA_4 may however, promote flowering in apple. It increased number of spurs in Golden Delicious apple during off year when applied 4-5 weeks after anthesis. On the contrary, McLaughlin and Greene (1991) observed reduction in flower bud formation by GA_{4+7} application in apple. Greene (1993a) observed that GA_4 and GA_7 when applied alone inhibited return bloom in Red Spur Delicious apple.

2.3.2 Cytokinins

Information about the effects of benzyl adenine on flowering in pears is not available, however, its application has been reported to promote flowering process in apple. Unrath (1989) found that BA application to the drip point at 300 ppm when new growth was 2-3 cm long increased floral initiation by 82 per cent in Delicious apple trees. Elfving (1989) applied BA at the concentrations of 50, 100 and 150 ppm on 23rd May to apple trees (cv. Idared on MM-106) and observed equal increase in return bloom at all concentrations.

Elfving and Clive (1993) applied benzyl adenine at 50, 100 and 150 ppm to mature Empire apple trees and observed that higher concentrations (100 and 150 ppm) markedly thinned young fruitlets and increased the return bloom. Greene (1993b) found a direct relationship between the number of fruit thinned from spurs with BA spray and return bloom in apple. Wismer *et al.* (1995) also reported that application of BA to mature Empire apple trees increased the return bloom.

In another study, return flowering of Braeborn apple was enhanced by the late application of 6-BA (McArtney *et al.*, 1995). However, Greene (1995) reported that thidiazuron which is a phenyl urea compound and shows cytokinin like activity, did not influence return bloom when applied at 10 to 50 mg/l during full bloom in apple. More recently, Buban and Lakatos (1997) have reported that post bloom application of BA at 40-50 ppm increased return bloom and yield in Golden Delicious and Well Spur apples.

2.3.3 Paclobutrazol

Increased flowering may accompany the growth retarding effect of paclobutrazol (Lever, 1986; Volz and Knight, 1986). VanKricken and Lindenbergh (1984) observed that paclobutrazol not only suppressed shoot growth but also enhanced the number of flower buds in Comice pear.

Aldini and Cobianchi (1986) reported that paclobutrazol applied as a soil drench or as a foliage spray at 0.9 kg/ha increased the number of flower clusters in pear cv.General Leclerc. Huang and Shen (1987) reported that paclobutrazol applied through soil or foliage at 1.0 or 1.5 mg a.i. per seedling increased return bloom and decreased shoot growth in pear (*Pyrus betulaefolia*). Noma *et al.* (1989) observed increased number of flower bud with the application of paclobutrazol at 125 and 250 ppm in Japanese pear cvs. Kousui and Shinsui. Foliar application of paclobutrazol at 250-2000 ppm to young Williams pear, 20 days after petal fall reduced shoot growth by 20-30 per cent and increased flower bud differentiation in the following year (Sansavini *et al.*, 1988).

Dheim and Browning (1988) reported that localized application of paclobutrazol on the shoot tips of Doyenne du Comice and Conference pear was more effective treatment for increasing the flower bud differentiation than the treatments of its over all spray and shoot tipping by hand. Browning *et al.* (1992) observed that much less of paclobutrazol is required to promote flowering than to inhibit shoot growth in pear cv. Doyenne du Comice. Bist and Rai (1994) reported that application of paclobutrazol at 125 or 250 ppm either as trunk/soil line drench or as three sequential foliar sprays resulted in increased number of spurs in Oriental pears (*Pyrus pyrifolia* Burm).

Rakngan *et al.* (1995) reported that foliage application of paclobutrazol at 1000 ppm suppressed vegetative growth and promoted flower bud differentiation in axillary buds of elongating shoots of Japanese pears under green house conditions.

2.3.4 Branch bending

It has been long claimed by horticulturists that bending of branches towards horizontal position stimulate flower bud formation in apple (Carlson, 1968). When upright branches of apple trees were tied in a horizontal position there was a change in the pattern of growth of lateral shoots. The buds on the upper side of the stem produced mainly shoots but buds on the underside remained dormant or grew into spurs (Mullins and Rogers, 1971). Devyatov and Kazalov (1972) observed that in the 'palmate' trained apple trees the oblique position of the main shoot caused apical branching while, a horizontal position of the secondary shoots resulted in better spur formation.

Adamov (1973) studied the effect of branch inclination on bud development in certain apple cultivars and found that in bend branches, the number of flower buds increased with the angle of orientation. Greene and Lord (1978) observed that limb spreading increased the number of flower buds per centimeter limb circumference in Rich-a-Red Delicious apple.

Shoots of apple cv. Oregon Spur Delicious trained at an angle of 30^{o} from vertical in the first year and bent to 60^{o} in the next year had the greatest reduction in shoot growth and more flowering on the upper and middle shoots (Hamzakheyl *et al.*, 1976). Banno *et al.* (1985) observed that in pear (*P. serotina*) cv. 'Shinsui' branch bending or daminozide increased flower bud formation. Rom and Barritt (1990) reported that spur development of Delicious apple is influenced by position of shoot on the tree, wood age, strain and pruning. In a study on the orientation of apple trees in relation to gravity, non-vertical trees produced more number of spurs, total flower clusters and had higher bloom density compared with vertically grown trees (Sharma and Jindal, 1992a; Sharma and Jindal, 1992b).

Raolin *et al.* (1999) observed an increase in the number of fruit spurs by bending the branches of young apple trees to 70^{o} to 80^{o} from vertical in early April. Ito *et al.* (1999) reported that floral development of lateral buds was accelerated in Japanese pear [*Pyrus pyrifolia* (Burm.) Nak.] when vertical shoots were bent towards 45^{o} in late June.

2.3.5 Trunk girdling

Ringing or girdling of trunk has been reported to promote flower formation in different fruit crops. Sharma *et al.* (1976) reported that in mango cvs. Bombai, Hemsagar, Zardalu and Langra, emergence of inflorescence was earlier on the branches given ringing and scoring treatments. They suggested that such effect was probably due to the accumulation of carbohydrates above the cut portion of the treated branches. Guo *et al.* (1988) reported that trunk girdling induced 76 per cent of three years old and 82 per cent of four years old seedlings of apple cvs. Qin Guan and Rall x Starkrimson Delicious to flower for first time and increased the average number of flower clusters per tree by five times compared to control. They suggested that higher flower production can be stimulated with girdling treatments on the trees which have completed juvenile phase. Trunk girdling and root pruning of cv. Lobo on MM 106 rootstock when performed at full bloom reduced growth and enhanced flowering by 110 per cent and 55 per cent, respectively (Skogerbo, 1992). Similarly, XueCai *et al.* (1997) reported that trunk girdling increased flower production on five to seven year old Nagano Fuji apple. Kondratenko *et al.* (1998) observed that the girdling stimulated the initiation of generative organs in apple cv. Florin on a seedling rootstock.

Arakawa *et al.* (1997) reported that ringing and bark inversion significantly increased flowering in the following spring in Megumi cv. of apple. TianHong *et al.* (1996) reported that treatments combination of trunk girdling + foliar application of paclobutrazol increased flower bud formation in apple trees.

2.4 Effect on fruit set

2.4.1 Gibberellins

Several gibberellins effectively increased fruit set in pome fruits as reported by various workers (Dennis and Edgerton, 1962; Modlibowska, 1967 and Williams and Letham, 1969). GA_3 or GA_{4+7} promoted fruit set and stimulated the development of parthenocarpic fruits in pear (Gil *et al.*, 1972). Nyeki *et al.* (1977) applied GA_3 at 5 to 200 ppm during flowering on five varieties of pear and obtained increased fruit set with 10 to 50 ppm concentrations. Flick and Hermann (1978) reported that following the spring damage spray of GA_3 at 12 ppm at full bloom and petal fall stages increased fruit set in pear cv. Passe Crassane. Marcelle (1984) obtained increased initial fruit set with the application of GA_3 in Doyenne du Comice pear, however, the number of well developed seeds per fruit decreased. Knight and Browning (1986) reported that application of GA_3 at 11 ppm during flowering induced parthenocarpic fruit development in Conference pear.

Kazakova (1978) reported that gibberellins treatment at postgamic phase had favourable effect on fruit set in pear and apple cultivars which are prone to self fertilization, while, its application at pre-gamic phase had no effect on fruit set. Herrero (1984) applied 10 ppm GA_3 at three different stages of flower development on Agua de Aranjuez pears and observed parthenocarpic fruit set with all the treatments. He further reported that treatments at balloon and anthesis stages resulted in higher set than petal fall stage, while, the latter treatment produced fruits similar to seeded fruits.

A diluted spray of GA_3 or GA_{4+7} at 15 or 25 ppm during flowering on pears increased fruit set particularly in those cultivars which have strong tendency towards natural parthenocarpy (Tromp and Werthein, 1980). In another study, spray of GA_{4+7} at bloom increased the number of fruits/cm limb circumference in apple cv. Golden Delicious (McLaughlin and Greene, 1984). Wertheim and Bootsma (1992) observed increased fruit set in Doyenne du Comice and Conference pears following the treatments of GA_3 and GA_{4+7} at 15 or 5 mg/l applied alone or in different combinations during or shortly after flowering. Treatments given at the later stages however, did not affect fruit set in both cultivars.

Deckers (1994) reported that application of Pro-gibb plus (GA_3), Regulex (GA_{4+7}) or Promalin (GA_{4+7} + BA) during flowering at 10 g a.i./ha increased fruit set in Conference pear. Honeyborne (1996) reported that spray of Progibb, Fenzib [GA_3 +

phenothiol (MCPA - thioethyl)] or Promalin at 30-40 per cent flowering stage on pear cultivar Forelle significantly increased fruit set over the control. However, application of these bioregulators at petal fall stage failed to affect fruit set. Further, the number of seeds per fruit were significantly lower in treated fruits than in control and a large proportion (>80%) of treated fruits were parthenocarpic. In a 2 years trial on trees of pear cv. Conference on Quince Adams rootstocks, different treatments of gibberellins were applied at full bloom and it was observed that application of GA_3 at 10 g a.i. per ha increased fruit set in both years (Deckers *et al.*, 1997).

2.4.2 Cytokinins

Some studies indicated that application of cytokinins have a promotive effect on fruit set in pome fruits. Fruit set response to exogenous application of GA_3 as a single bioregulator treatment in apple cv. Cox's Orange Pippin is limited. It has been reported that spraying a mixture of GA_3+BA and 2-naphthoxy acetic acid at 40 per cent bloom increased fruit set of destyled flowers in this cultivar (Jonkers, 1978). The treatment did not increase fruit set of open-pollinated flowers. Marcelle (1984) applied BA (10 or 20 ppm) and GA_3 (10 or 20 ppm) either alone or in various combinations on shoots bearing a limited number of flower clusters in Doyenne du Comice pear and observed that GA_3 alone or in mixture with BA appreciably increased the initial fruit set although, after the June drop no significant difference could be found between the treatments. He further reported that the effect of GA_3 on the reduction of well developed seeds was reversed by BA.

Bangerth and Schroder (1994) reported that cytokinin-CPPU and GA_3 had a positive synergistic effect on parthenocarpic fruit set when sprayed at the end of petal fall stage in apple cultivars Golden Delicious and Jona Gold.

2.5 Effect on fruit yield

2.5.1 Gibberellins

Lower production is often a major limiting factor in pear cultivation. There are reports that improved fruit yield can be obtained with the use of different chemicals. The application of GA_3 has been reported to increase fruit size and yield in pears (Modic and Turk, 1978; Wertheim and Bootsma, 1992). Buban and Borka (1979) observed that under unfavourable conditions at flowering, application of GA_3 at 20 ppm improved fruit yield in pear cv. Bosc. However, under favourable conditions for fruit set GA_3 did not increase yield. Cristoferi *et al.* (1981) reported that application of GA_3 at 30 to 40 per cent bloom increased yield from 4.8 to 11.6 kg per tree in 10-year-old Comice pear. Gil *et al.* (1983) reported that treatment of 50 ppm GA_3 when applied during flowering period with 1 or 2 additional spray later to pear cv. Packham gave yield of 20.07 and 30.02 kg per tree, respectively compared with 7.29 kg per tree in untreated control.

Singh and Chadha (1990) observed that bloom application of GA_3 at 50 ppm ensured a higher fruit set, reduced fruit drop, higher yield and yield efficiency in Delicious apple. Singh *et al.* (1994) reported that application of GA_3 at 20 ppm or 40 ppm at full bloom increased fruit yield in LeConte pear.

2.5.2 Cytokinins

Various reports suggest that the influence of cytokinin on fruit yield varies greatly with its concentration and time of application. Marcelle (1984) reported that bloom application of BA alone at 10 or 20 ppm or in combination with 10 ppm GA_3 increased the initial fruit set in Doyenne du Comice, however, after June drop no significant difference could be found between the treatments. Elfving and Clive (1993) reported that post bloom application of BA at 100 and 150 ppm caused a drastic fruit thinning and consequently decreased yield in apple cv. Empire, however, BA at 50 ppm slightly increased yield as compared to control. McArtney *et al.* (1995) applied 100 ppm BA at 10.2, 15.4 and 19.6 mm fruit diameter stages to Jona Gold apples and observed increased yield efficiency with the early and late application and decreased yield efficiency with mid application. Buban and Lakatos (1997) observed that BA at 40 and 50 ppm when applied at 9.1 to 12.0 mm fruit diameter stage caused fruitlet thinning and reduction of yield in Golden Li 85-50 and well Spur Delicious apples.

2.6 Effect on fruit quality

2.6.1 Gibberellins

The effect of the application of Gibberellic acid during flowering on fruit size and fruit quality varied with cultivar to cultivar in pears (Modic and Kodric, 1978). Treating pear cultivars Beurre Bosc, Conference and Packham's Triumph with GA_3 or GA_{4+7} at 25 ppm during bloom period affected fruit shape only slightly (Modic and Turk, 1978). In another study, application of GA_3 at 10-50 ppm during full bloom, to the trees of pear cvs. Arabitka, Beurre Bosc, Clapp's Favourite, Blou Morceau and Teli Esperes did not affect fruit size, but at higher rate (60-200 ppm) reduced fruit size due to excessive fruiting (Byoro *et al.*, 1978). Martin and Nishijima (1978) observed that a single treatment of GA_3, GA_3+$CaCl_2$ or gibberellin GA_{45} on the flowers of caged cross fertile Winter Nellis produced parthenocarpic fruits, which were significantly smaller than those of open pollinated controls. Similarly, Knight (1980) reported that Conference pear trees treated with GA produced a crop of small and misshapen fruits.

Following spring frost in Leningard, GA_3 at 0.1 per cent applied during flowering to the trees of pear cvs. Beurre d'Hardenpont, Cure and Beurre Bosc stimulated the development of parthenocarpic fruits, but had no effect on fruit quality (Burlak and Scherbatko, 1980). Cristoferi *et al.* (1981) also observed that application of GA_3 at pink bud and 30-40 per cent bloom stages did not affect fruit shape in Comice pear. However, in Switzerland, application of GA_3 at 9 ppm to frost damaged William pears, lead to the formation of elongated parthenocarpic fruits (Pfammater *et al.*, 1984). Similarly, Herrero (1984) noted elongated fruits with the spray of 10 ppm GA_3 at full bloom in Agua de Aranjuaz pear. Herrero (1989) observed that late treatment of 10 ppm GA_3 applied at petal fall stage produced higher yield of well shaped fruits in pear cv. Agua de Aranzuez as compared to early treatment applied at bloom.

In a study carried out on the effect of pollination and gibberellins on fruit set, physiological drop, growth and maturation in pear cv. LeLectier, spray of GA_3 at 200 ppm when applied one day before pollination resulted in longer fruits with a protruding calyx (Yamada *et al.*, 1991). However, fruit weight and fruit diameters were higher in cross pollinated than GA_3 treated non-pollinated pears. Singh *et al.* (1994) reported that GA_3 at 20-40 ppm, when applied at full bloom did not influence fruit size and weight of LeConte pear. Deckers (1994) however, observed adverse effect on fruit size and shape with the spray of 10 ppm GA_3 (Pro-gibb Plus) during flowering in Conference pears. Ahmad (1998) reported that preharvest sprays of GA_3 at 20, 30 and 40 ppm significantly increased fruit weight and fruit volume, decreased TSS and increased acidity in Flemish Beauty pear. Higazi *et al.* (1993) reported that GA_3 at 50-100 ppm, when applied 60 days after fruit set increased fruit acidity and reduced TSS and TSS:acid ratio in LeConte pear. Sharma (1998) reported that spray of GA_3 + Kinetin increased fruit firmness, acidity and total sugars in apple cv. Vance Delicious.

Sharma (2001) observed that GA_3 applied alone at 10, 20 and 40 ppm at silver tip and green tip stages decreased TSS and total sugar contents of fruits, but when applied in combination with BA and NAA, TSS was increased in apple cv. Starking Delicious.

2.6.2 Cytokinins

The 6-benzyladenine, a cytokinin when applied alone or in combination with gibberellins near blossom time, alter fruit shape in apples (Williams and Stahley, 1969; Stembridge and Morrell, 1972). Studies in North Carolina first indicated the effectiveness of the bioregulator mixture of BA + GA_{4+7} applied at 25 ppm between full bloom and petal fall in improving the fruit shape in apple (Unrath, 1974). Similar observations have been reported in several lateral studies (Greene, 1980; Edgerton and Williams, 1981; McLaughlin and Greene, 1984). However, cytokinins induced alteration in size and shape of fruits has been less studied in pears compared to apples. Rai and Bist (1991) observed that foliar application of Promalin at 250 ppm to 4-year old *Pyrus pyrifolia* cv. Gola trees resulted in the production of better quality fruits. Similarly, Deckers (1994) obtained higher yield of better sized fruits with the application of `Promalin' at 0.6 litres/ha during green bud to full bloom stage in pear cv. Durondeau. In contrast, Honeyborne (1996) observed smaller fruit size following the spray of `Promalin' at 30-40 per cent flowering in pear cv. Forelle.

Greene (1993b) observed that cytokinin increased fruit L/D ratio, fruit weight, flesh firmness and TSS contents of apples when applied between full bloom to 18 days after full bloom. Wismer *et al.* (1995) found that post bloom application of BA effectively increased fruit size and soluble solid contents in Empire apples. Ahmad (1998) observed that treatments of kinetin at 20, 30 and 40 ppm when applied 15 days after full bloom increased TSS and sugar contents in Flemish Beauty pears.

Chapter-3

MATERIALS & METHODS

2.6.2 Cytokinins

The 6-benzyladenine, a cytokinin when applied alone or in combination with gibberellins near blossom time, alter fruit shape in apples (Williams and Stahley, 1969; Stembridge and Morrell, 1972). Studies in North Carolina first indicated the effectiveness of the bioregulator mixture of BA + GA_{4+7} applied at 25 ppm between full bloom and petal fall in improving the fruit shape in apple (Unrath, 1974). Similar observations have been reported in several lateral studies (Greene, 1980; Edgerton and Williams, 1981; McLaughlin and Greene, 1984). However, cytokinins induced alteration in size and shape of fruits has been less studied in pears compared to apples. Rai and Bist (1991) observed that foliar application of Promalin at 250 ppm to 4-year old *Pyrus pyrifolia* cv. Gola trees resulted in the production of better quality fruits. Similarly, Deckers (1994) obtained higher yield of better sized fruits with the application of `Promalin' at 0.6 litres/ha during green bud to full bloom stage in pear cv. Durondeau. In contrast, Honeyborne (1996) observed smaller fruit size following the spray of `Promalin' at 30-40 per cent flowering in pear cv. Forelle.

Greene (1993b) observed that cytokinin increased fruit L/D ratio, fruit weight, flesh firmness and TSS contents of apples when applied between full bloom to 18 days after full bloom. Wismer *et al.* (1995) found that post bloom application of BA effectively increased fruit size and soluble solid contents in Empire apples. Ahmad (1998) observed that treatments of kinetin at 20, 30 and 40 ppm when applied 15 days after full bloom increased TSS and sugar contents in Flemish Beauty pears.

Chapter-3

MATERIALS & METHODS

MATERIALS AND METHODS

The present investigations entitled "Effect of plant growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of pear (*Pyrus communis* L.) cv. Flemish Beauty", were carried out in the Experimental Orchard of the Department of Pomology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) during the years 2001 and 2002. These studies comprised of two experiments, one each on young and bearing trees.

3.1 Experiment-I: Effect of paclobutrazol, branch bending and trunk girdling on vegetative growth and flowering/spur formation in young trees of pear cv. Flemish Beauty.

3.1.1 Plant materials and treatments

This experiment was undertaken on six-year-old plantation of pear cultivar Flemish Beauty established on Kainth (*Pyrus pashia* Bush.) seedling rootstocks at 1x3 m spacing and trained as central leaders. For the present study, forty trees were selected on the basis of their uniform vigour and were given the treatments described in Table 1.

All the treatments were given at bud break stage on 23rd March 2001, with four replicate trees. The experiment was laid out in a simple randomized block design. Experimental trees were kept under uniform cultural practices during the entire course of investigation.

Table 1. Description of paclobutrazol, branch bending and girdling treatments applied to young trees of Flemish Beauty pear

Treatments	Concentration/method
T_1: Paclobutrazol (PP_{333})	500 ppm
T_2: Paclobutrazol (PP_{333})	1000 ppm
T_3: Paclobutrazol (PP_{333})	1500 ppm
T_4: Branch bending	Horizontal position
T_5: Trunk girdling	Double "C"
T_6: Branch bending + Paclobutrazol (PP_{333})	Horizontal position + 500 ppm
T_7: Branch bending + Paclobutrazol (PP_{333})	Horizontal position + 1000 ppm
T_8: Trunk girdling + Paclobutrazol (PP_{333})	Double "C" + 500 ppm
T_9: Trunk girdling + Paclobutrazol (PP_{333})	Double "C" + 1000 ppm
T_{10}: Control	

3.1.2 Preparation of spray material and method of application

Paclobutrazol solutions were prepared by diluting the appropriate quantities of the commercial compound (Cultar, ICI) in water. With the addition of 0.1 per cent Tween-20, two litres of solution per treatment was applied to the aerial parts of trees with a hand sprayer. The spray was started with lower concentration treatment and before starting the spray with next higher concentration, the sprayer was rinsed with small quantity of the spray solution. The spraying operation was performed during morning hours on a clear and calm day to run off.

3.1.3 Branch bending

In bending treatments, the branches on trees were spread towards horizontal position by tying them with thread to the wooden pegs inserted all around in the soil.

These branches were maintained in horizontal position throughout the growing season during 2001. In the subsequent year i.e. 2002, branches were allowed to grow naturally without bending.

3.1.4 Girdling

Double 'C' method of trunk girdling as suggested by Ingels (2000) was employed. It was carried out by making two overlapping cuts with a sharp grafting knife just over halfway around the trunk. The two cuts were separated vertically by 5 cm, where, the first cut was made about 15 cm above the graft union (Plate 1).

3.1.5 Observations recorded

The observations on vegetative and reproductive traits of experimental trees were recorded for two years i.e. 2001 and 2002.

3.1.5.1 Shoot growth: The observations on the extension growth of 10 randomly selected shoots from all over the tree periphery were recorded at 15 days interval from bud break stage till the end of growing period. The values were averaged and expressed in centimeter.

3.1.5.2 Shoot diameter: The diameter of the 10 randomly selected shoots from each experimental tree was taken at the end of growing season and expressed in millimeter.

3.1.5.3 Trunk diameter: The trunk diameter of each experimental tree was measured 10 cm above the graft union at the beginning and end of growing season with the help of digital vernier calliper and expressed in per cent increase.

3.1.5.4 Internodal length: The internodal length of 10 current seasons shoots selected at random on each experimental tree was calculated by dividing their length with total number of internodes at the end of growing season and expressed in centimeter.

3.1.5.5 Tree height and spread measurement: Total height and spread of each experimental tree were measured at the beginning and end of growing season and per cent increase in average height and spread was calculated in each year. The observations on tree height and spread were used to calculate tree volume as per formulae (Westwood, 1978) given below:

1) For the tree which was taller than its width:

$$\text{Tree volume} = \frac{4}{3} \pi a b^2$$

2) For the tree which was wider than its height:

$$\text{Tree volume} = \frac{4}{3} \pi a^2 b$$

where,

π = 3.1428
a = 1/2 of major axis
b = 1/2 of minor axis

The increase in tree volume over the growing season was expressed in percentage.

3.1.5.6 Average leaf area: Ten fully growing leaves were randomly selected from all over the periphery of the tree. Their area was measured with the help of automatic leaf area meter (Li-COR 3100) and expressed as average leaf area in square centimeter.

Plate 1. Trunk girdling - Double "C"

3.1.5.7 Chlorophyll content: Ten representative leaves were detached from each experimental tree in the morning hours, immediately placed in ice box and brought to the laboratory. The samples were then kept in a refrigerator at subzero temperature to avoid degradation of chlorophyll pigments.

A) Extraction

Leaves from each sample were washed and chopped into fine pieces. One gram of chopped material was taken in a mortar and pestle and the extraction of chlorophyll was carried out in 80 per cent acetone as per method described by Sestak *et al.* (1971). A small quantity of $CaCO_3$ and acid washed sand were also added to prevent degradation of pigments and to enhance maceration. The extract was filtered through Buchner funnel using Whatman No.1 filter paper. The residues were washed with excess of acetone until it was colourless. All these operations were carried out in subdued light.

B) Estimation

The filtrate of each extraction was pooled and volume made to 25 ml with 80 per cent acetone. The absorbance was recorded with Spectronic-20 colorimeter at 645 and 663 nm wave length. A blank was also run for zero calibration. The total chlorophyll was calculated by using the following formulae:

$$\text{Chlorophyll (a)} = 12.7\ A_{663} - 2.69\ A_{645}$$

$$\text{Chlorophyll (b)} = 22.9\ A_{645} - 4.68\ A_{663}$$

$$\text{Total chlorophyll (a+b)} = 8.02\ A_{663} + 20.20\ A_{645}$$

The results were expressed in milligrams of total chlorophyll per gram of fresh weight.

3.1.5.8 Number of shoots and spurs: Total number of shoots more than five centimeter in length and shoots lesser than five centimeter (spur like) were counted separately and expressed as number of shoots and number of spur like short shoots per tree basis respectively.

3.1.5.9 Spur density: It was calculated by dividing the total number of spur like short shoots by tree volume and expressed as number of spur/m^3 tree volume.

3.2 Experiment-II: Effect of gibberellic acid and benzyl adenine on fruit set and fruit quality in pear cv. Flemish Beauty

3.2.1 Plant material and treatments

This experiment was carried out using uniform bearing trees of Flemish Beauty pear on Kainth rootstocks spaced at 5x5 m. On these trees, uniform limbs were selected prior to bloom and each treatment was applied on one limb. The experiment was laid out in a randomized block design with three replicated limbs per treatment. Experimental trees were kept under uniform cultural practices during the entire course of study. The details of different treatments are given in Table 2.

3.2.2 Preparation of spray material and method of application

The required quantities of each growth regulator were accurately weighed on an electronic digital balance (Mettler BB-240). Gibberellic acid and benzyl adenine were first dissolved in a small quantity of acetone and ethanol respectively and their final volume was made up to three litres with water. In order to decrease surface tension and to facilitate absorption of droplets, 0.1 per cent Tween-20 was added to each solution before use. The solutions of different treatments were applied to respective randomly assigned limbs to run off at the time of full bloom with a hand sprayer. Spraying was carried out during morning hours on a cloudless and windless day.

Table 2. Description of gibberellic acid and benzyl adenine treatments applied to bearing Flemish Beauty pear

Treatments	Concentration (ppm)
T_1: Gibberellic acid (GA_3)	10
T_2: Gibberellic acid (GA_3)	20
T_3: Gibberellic acid (GA_3)	30
T_4: Benzyl adenine (BA)	5
T_5: Benzyl adenine (BA)	10
T_6: Benzyl adenine (BA)	15
T_7: Gibberellic acid (GA_3)+Benzyl adenine (BA)	10+5
T_8: Gibberellic acid (GA_3)+Benzyl adenine (BA)	10+10
T_9: Gibberellic acid (GA_3)+Benzyl adenine (BA)	20+5
T_{10}:Gibberellic acid (GA_3)+Benzyl adenine (BA)	20+10
T_{11}:Control	Water spray

3.2.3 Observations recorded

3.2.3.1 Shoot growth: Ten shoots were randomly selected from all over the treated limbs and their length was measured with a meter scale at the end of the growing season and expressed in centimeter.

3.2.3.2 Internodal length: The internodal length of the selected current season's shoots from each limb was worked out as per procedure followed in experiment-I.

3.2.3.3 Average leaf area: Ten fully developed and mature leaves were randomly selected from each treated limb during the first week of July and their average area was estimated as per method followed in experiment-I.

3.2.3.4 Fruit set: Fruit set on the treated limbs was recorded 30 days after full bloom. It was calculated in percentage as per the method suggested by Westwood (1978).

$$\text{Fruit set(\%)} = \frac{\text{Total number of fruit set}}{\text{Total number of flower clusters}} \times 100$$

3.2.3.5 Fruit retention: The total number of fruits retained on the treated limbs were counted at the time of harvest and the percentage of fruit retention was calculated by using the following formula:

$$\text{Fruit retention(\%)} = \frac{\text{Total number of fruit retained}}{\text{Total number of fruit set}} \times 100$$

3.2.3.6 Fruit count: The total number of fruits from each treated limb were counted at harvest and expressed as number of fruits per cm^2 limb cross sectional area.

3.2.3.7 Yield efficiency: At harvest all the fruits from each replication were weighed and production expressed as kg per cm^2 limb cross sectional area.

3.2.3.8 Return bloom: The number of flower clusters on each treated limb were counted at bloom time in 2001 and 2002 and expressed as number of flower clusters per cm^2 limb cross sectional area. The difference in the number of flower clusters between these two years gave the measure of return bloom. The results were expressed as per cent increase or decrease in return bloom.

3.2.3.9 Fruit size: The length and diameter of ten randomly selected fruits from each replication were measured with the help of a Digimatic Calliper (Mitutoyo, Japan). The values were averaged and expressed in millimeter.

3.2.3.10 Fruit shape index: The fruit shape index in terms of length/diameter ratio was calculated by dividing the fruit length with fruit diameter.

3.2.3.11 Fruit weight: Ten fruits were weighed on a top-pan balance. Subsequently, average fruit weight was calculated and expressed in gram per fruit.

3.2.3.12 Fruit volume: It was determined by water displacement method using a measuring cylinder of 2000 ml capacity. The measure of volume was averaged and expressed in cubic centimeter (cc) per fruit.

3.2.3.13 Number of seeds: Five fruits were sampled from each replication and total number of seeds were counted by cutting the fruits. The results were expressed as number of seeds per fruit.

3.2.3.14 Fruit firmness: The fruit firmness was measured with Effegi Panetrometer-Ft 327, which recorded the pressure required to force a plunger of 8 mm in diameter into the peeled flesh of fruit. The results were expressed in Newton (N).

Where, Newton (N) = Force in kg x 9.807.

3.2.3.15 Total soluble solids (TSS): The total soluble solids content in fruits were determined with Erma hand refractometer (0-32^{O}Brix) by putting a drop of juice on its prism. Before use it was calibrated with distilled water. The total soluble solids were expressed as percentage of fresh juice.

3.2.3.16 Titratable acidity: Twenty five gram of fresh fruit was taken, homogenised thoroughly with distilled water in a Wareing blender and volume was made to 250 ml. The contents were then filtered through Whatman No.1 filter paper. Ten ml of the extract was titrated against 0.1N NaOH solution using phenolphthalein as an indicator. The appearance of light pink colour indicated the end point. The total titratable acidity was calculated in terms of Malic acid on the basis of one ml of 0.1N NaOH equivalent to 0.0067 g of anhydrous acid (A.O.A.C., 1980). The results were expressed as per cent of fresh weight of the fruit pulp. The remaining extract was kept for estimation of sugars.

3.2.3.17 Reducing sugar: To the remaining filtrate, 10 ml of saturated lead acetate was added and contents were shaken and filtered. Ten ml of potassium oxalate was later added to the filtrate in order to precipitate the excess of lead acetate and contents were again filtered. The volume was made to 250 ml with distilled water. Out of this solution, 50ml was kept for determining total sugars. To determine reducing sugar, boiling mixture containing 5 ml each of Fehling A and B solutions was titrated against the remaining unhydrolysed pulp solution using methylene blue as an indicator. The titration was carried till the colour of solution became brick red and the results were expressed as per cent of reducing sugar (A.O.A.C., 1980).

3.2.3.18 Total sugar: The remaining 50 ml deleaded and clarified solution was hydrolysed by adding few drops of concentrated hydrochloric acid and the contents were allowed to stand for overnight. The excess of hydrochloric acid was then neutralised with saturated sodium hydroxide solution. The total sugar was estimated by titerating the boiling mixture containing 5 ml each of Fehling A and B solutions against hydrolysed pulp solution using methylene blue as indicator, till the appearance of brick red colour. The values were expressed in per cent on fresh pulp weight basis.

3.2.3.19 Non-reducing sugars: The non-reducing sugar was calculated by subtracting reducing sugar from total sugar and multiplying the difference by a standard factor 0.95 (A.O.A.C., 1980). The results were expressed as per cent non-reducing sugars.

3.2.3.20 Ascorbic acid: Ascorbic acid was determined as per A.O.A.C. (1980) method using the following reagent and procedure:

Reagents

A) Extraction solution

Fifteen gram of metaphosphoric acid pellets were dissolved in a mixture of 40 ml of glacial acetic acid and 200ml of water and the volume was made upto 500ml with distilled water. The solution was filtered rapidly through filter paper and stored in refrigerator.

B) Ascorbic acid standard solution

One hundred milligram of analytical grade ascorbic acid (reference standard) was accurately weighed on an electronic balance and dissolved in a small quantity of extraction solution. The contents were transferred to 100 ml volumetric flask and the final volume was made upto 100 ml with extraction solution. The stock solution was diluted upto 20 times before use with metaphosphoric acid extraction solution so that it would consume less dye.

C) Indophenol standard solution

The dye was prepared by dissolving 50 mg of 2,6-dichlorophenol indophenol and 42 mg of sodium bicarbonate in distilled water and volume made up to 200 ml.

Procedure

Five gram of fruit pulp was homogenized in 10 to 15 ml extraction solution and the volume was made up to 50 ml in a volumetric flask. Five ml of clarified extract was titrated against indophenol dye. The freshly prepared dye was standardized against known concentration of ascorbic acid. The appearance of rose pink colour indicated the end point which persisted for atleast 15 seconds. Titre reading was noted and the content of ascorbic acid in mg per 100 g (mg/100 g) was calculated by the following formula:

$$\text{Ascorbic acid (mg/100 g)} = \text{Dye factor} \times \frac{\text{Titre reading} \times \text{Volume made}}{\text{Weight of fruit taken} \times \text{Volume taken for estimation}} \times 100$$

Chapter-4
EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

The results of the present investigations on the "Effect of plant growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of pear (*Pyrus communis* L.) cv. Flemish Beauty" are presented experiment wise under different headings:

4.1 Effect of paclobutrazol, branch bending and trunk girdling on vegetative growth and spur formation in young trees of pear cv. Flemish Beauty

4.1.1 Shoot growth

The data pertaining to the effect of different treatments on shoot extension growth are presented in Tables 3a, 3b and depicted in Figures 1a, 1b.

During the year 2001, various treatments exhibited a marked influence on shoot growth (Table 3a; Fig.1a). The maximum mean shoot growth (27.34 cm) was found in control (T_{10}) and the minimum (10.93 cm) in trees given 1500 ppm PP_{333} treatment (T_3), thus exhibiting 60 per cent reduction in growth as compared to control. Treatments of trunk girdling + 1000 ppm PP_{333} (T_9), branch bending + 1000 ppm PP_{333} (T_7), trunk girdling + 500 ppm PP_{333} (T_8) and 1000 ppm PP_{333} (T_2) accounted for 50.87, 45.94, 36.32 and 32.40 per cent reduction in mean shoot growth respectively as compared to control.

During 2002, different treatments reduced shoot growth significantly though not as drastically as in the previous year (Table 3b and Fig.1b). The maximum mean shoot growth (23.71 cm) was observed in untreated control trees (T_{10}), while minimum (17.87 cm) was recorded in trees given 1500 ppm PP_{333} treatment, which registered 24.63 per cent growth reduction in comparison to control. Treatments of trunk girdling + 1000 ppm PP_{333} (T_9), branch bending + 1000 ppm PP_{333} (T_7), trunk girdling + 500 ppm PP_{333} (T_8), 1000 ppm PP_{333} (T_2) and branch bending + 500 ppm (T_6) reduced shoot growth by 19.52, 17.33, 14.34, 13.70 and 12.53 per cent, respectively compared to control. However, application of PP_{333} at 500 ppm (T_1) did not influence shoot growth significantly.

It is evident from Figures 1a and 1b that differences in shoot extension growth of trees under different treatments became apparent just 15 days (D_1) after bud break and these differences increased as the growth period progressed. At the end of growing period, total shoot length was maximum (32.70 cm in 2001 and 26.53 cm in 2002) in control and minimum (12.49 cm in 2001 and 20.89 cm in 2002) in trees given 1500 ppm PP_{333} treatment. Trees under other treatments except 500 ppm PP_{333} (T_1) and branch bending (T_4) during 2002 also produced significantly shorter shoots than control.

Periodical shoot extension growth also showed significant variations in both years. In 2001, greatest increase in shoot length occurred at D_3 (between 30-45 days of bud break) followed by D_2 and D_1 intervals. However, no significant growth occurred after 90 days of bud break. In 2002, greatest increase in shoot length was observed at D_2 (between 15 to 30 days of bud break) followed by D_1 and D_3 intervals in the decreasing order. Shoot length increment after D5 (75 days of bud break) interval was non-significant.

Table 3a: Effect of paclobutrazol, branch bending and trunk girdling on shoot growth (cm) of Flemish Beauty pear (2001)

Treatment	Days after bud break										
	15 (D_1)	30 (D_2)	45 (D_3)	60 (D_4)	75 (D_5)	90 (D_6)	105 (D_7)	120 (D_8)	135 (D_9)	150 (D_{10})	Mean
T_1: PP_{333} 500 ppm	5.42	13.42	21.68	23.00	24.34	25.08	25.11	25.15	25.15	25.15	21.35
T_2: PP_{333} 1000 ppm	5.34	10.00	19.27	21.09	21.25	21.43	21.50	21.62	21.62	21.62	18.48
T_3: PP_{333} 1500 ppm	4.62	7.50	10.75	11.89	12.33	12.37	12.39	12.49	12.49	12.49	10.93
T_4: Branch bending	6.00	14.46	23.74	24.87	25.31	26.00	26.39	26.43	26.44	26.44	22.61
T_5: Trunk girdling	5.62	12.17	20.50	21.69	22.47	22.50	22.55	22.57	22.57	22.57	19.52
T_6: Branch bending + PP_{333} 500 ppm	4.88	12.17	20.21	21.31	21.79	22.11	22.48	22.50	22.50	22.50	19.25
T_7: Branch bending + PP_{333} 1000 ppm	4.85	11.35	15.01	16.18	16.37	16.79	16.82	16.83	16.83	16.83	14.78
T_8: Trunk girdling + PP_{333} 500 ppm	5.12	11.25	14.45	18.78	19.77	20.76	20.80	21.05	21.05	21.05	17.41
T_9: Trunk girdling + PP_{333} 1000 ppm	4.40	7.36	13.33	14.37	15.07	15.87	15.93	15.99	15.99	15.99	13.43
T_{10}: Control	7.76	18.36	26.18	28.29	29.90	32.19	32.66	32.69	32.70	32.70	27.34
Mean	5.40	11.81	18.51	20.14	20.86	21.51	21.66	21.73	21.73	21.73	

$CD_{0.05}$

Treatments (T) = 0.51
Days (D) = 0.51
TxD = 1.61

Table 3b: Effect of paclobutrazol, branch bending and trunk girdling on shoot growth (cm) of Flemish Beauty pear (2002)

Treatment	Days after bud break										
	15 (D_1)	30 (D_2)	45 (D_3)	60 (D_4)	75 (D_5)	90 (D_6)	105 (D_7)	120 (D_8)	135 (D_9)	150 (D_{10})	Mean
T_1: PP_{333} 500 ppm	8.08	20.15	24.01	25.24	25.64	25.85	26.11	26.18	26.18	26.18	23.36
T_2: PP_{333} 1000 ppm	6.62	16.21	20.58	22.49	22.57	23.02	23.20	23.31	23.31	23.31	20.46
T_3: PP_{333} 1500 ppm	5.08	12.67	18.72	19.11	19.76	20.15	20.60	20.89	20.89	20.89	17.87
T_4: Branch bending	7.74	19.78	23.96	25.17	25.59	25.96	26.02	26.05	26.05	26.05	23.24
T_5: Trunk girdling	6.93	16.40	22.36	24.41	25.02	25.14	25.21	25.23	25.23	25.23	21.12
T_6: Branch bending + PP_{333} 500 ppm	6.54	16.95	20.68	22.72	23.08	23.42	23.47	23.50	23.50	23.50	20.74
T_7: Branch bending + PP_{333} 1000 ppm	6.45	15.72	19.65	21.56	21.92	21.99	22.17	22.20	22.20	22.20	19.60
T_8: Trunk girdling + PP_{333} 500 ppm	6.21	15.82	21.18	22.19	22.64	22.88	22.98	23.05	23.05	23.05	20.31
T_9: Trunk girdling + PP_{333} 1000 ppm	5.82	15.18	19.28	20.12	21.04	21.60	21.93	21.96	21.96	21.96	19.08
T_{10}: Control	8.43	20.75	24.25	25.61	25.95	26.10	26.47	26.52	26.53	26.53	23.71
Mean	6.79	16.96	21.47	22.86	23.32	23.61	23.82	23.89	23.89	23.89	

$CD_{0.05}$

Treatments (T) = 0.41
Days (D) = 0.41
TxD = 1.28

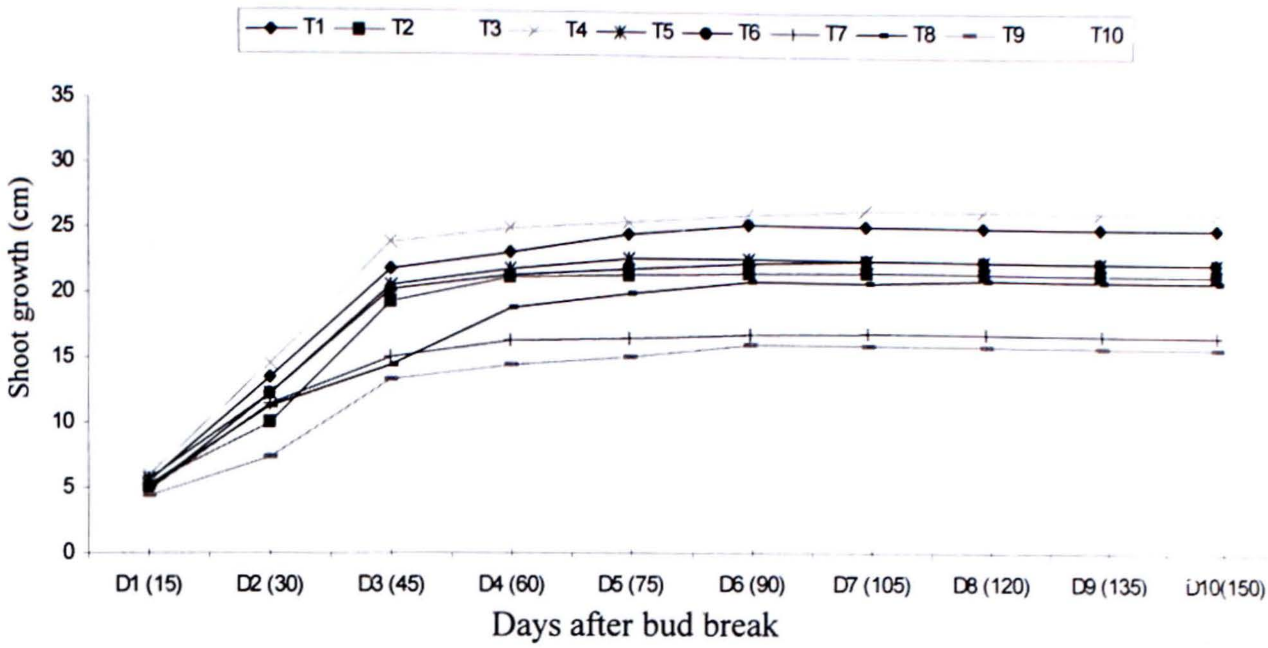

Fig.1a: Effect of paclobutrazol, branch bending and trunk girdling on shoot growth of Flemish Beauty pear (2001)

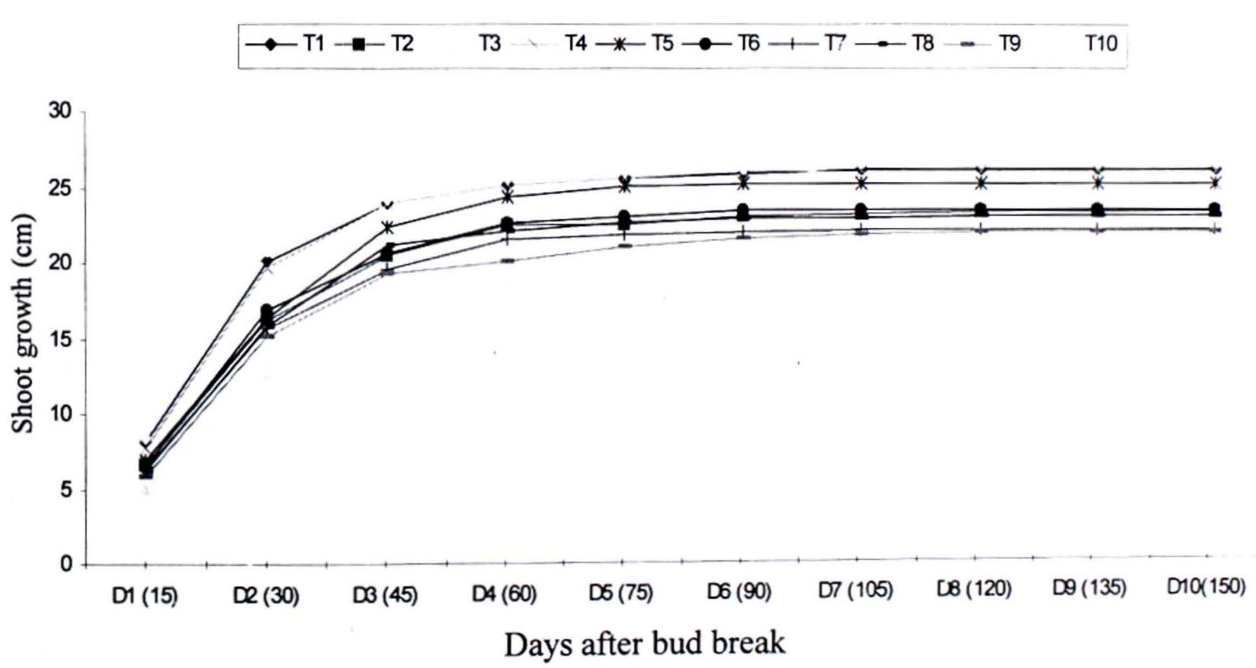

Fig.1b: Effect of paclobutrazol, branch bending and trunk girdling on shoot growth of Flemish Beauty pear (2002)

4.1.2 Internodal length

The data in Table 4 reveal that different treatments reduced the internodal length of annual shoots significantly as compared to control. During 2001, shortest internodal length (1.01 cm) was found in the shoots of trees given 1500 ppm PP_{333} (T_3) spray followed by the treatments of trunk girdling + 1000 ppm PP_{333}, branch bending + 1000 ppm PP_{333}, trunk girdling + 500 ppm PP_{333} and PP_{333} 1000 ppm in the increasing order. The maximum internodal length (2.40 cm) was found in untreated control.

During 2002, though the treatment of 1500 ppm PP_{333} produced shoots with shortest internodal length (1.90 cm) yet, reduction with this treatment was not as drastic as recorded in 2001. Trees given treatments of 1000 ppm PP_{333} (T_2), trunk girdling + 1000 ppm PP_{333} (T_9), branch bending + 1000 ppm PP_{333} (T_7), trunk girdling + 500 ppm PP_{333} (T_8) also produced shoots with decreased internodal length. However, average length of shoot internodes on trees given treatments of 500 ppm PP_{333} (T_1), branch bending (T_4), trunk girdling (T_5) and branch bending + 500 ppm PP_{333} (T_6) was statistically at par with control (2.32 cm).

4.1.3 Shoot diameter

It is evident from data (Table 4) that none of the treatments could exert a significant influence on shoot diameter during both the years.

4.1.4 Trunk diameter

The data in respect of annual increase in trunk diameter have been presented in Table 5.

It is evident from the data that during 2001, all treatments significantly decreased the growth of trunk diameter as compared to control. Annual increment in trunk diameter was lowest (3.11%) in trees treated with 1500 ppm PP_{333} which was however, statistically at par with trees given trunk girdling + 1000 ppm PP_{333} (4.60%) treatment. Treatments of branch bending + 1000 ppm PP_{333} (T_7), branch bending + 500 ppm PP_{333} (T_6) and 1000 ppm PP_{333} (T_2) recorded 5.06, 5.41 and 5.54 per cent annual increase in trunk diameter respectively. Untreated control trees registered 14.3 per cent increase in trunk diameter.

During the year 2002, the effect of different treatments on trunk diameter was however, non-significant.

4.1.5 Tree height and spread

The observation on average height and spread of trees are given in Table 5. It is clear from the data that average tree height was significantly decreased by all the treatments in both years as compared to control. The lowest increase (2.40% in 2001 and 3.80% in 2002) in height was observed in trees treated with 1500 ppm PP_{333}, followed by trees given trunk girdling + 1000 ppm PP_{333} (T_9) and branch bending + 1000 ppm PP_{333} (T_7) treatments in the increasing order. The highest increase (7.31% in 2001 and 6.98% in 2002) in height was observed in untreated control trees.

The perusal of data in Table 5 reveal that average tree spread was significantly decreased by various treatments. During 2001, application of PP_{333} at 1500 ppm resulted in lowest increase in average tree spread, closely followed by treatment of trunk girdling + 1000 ppm PP_{333}. Treatments of PP_{333} 1000 ppm alone, branch bending + 1000 ppm PP_{333} and trunk girdling + 500 ppm PP_{333} also significantly reduced per cent increase in average tree spread compared to control. In 2002, treatments of 1500 ppm PP_{333},

Table 4: Effect of paclobutrazol, branch bending and trunk girdling on internodal length and shoot diameter of Flemish Beauty pear

Treatment	Internodal length (cm)		Shoot diameter (mm)	
	2001	2002	2001	2002
T_1: PP_{333} 500 ppm	2.02	2.22	4.99	5.00
T_2: PP_{333} 1000 ppm	1.80	2.07	5.00	4.98
T_3: PP_{333} 1500 ppm	1.01	1.90	5.00	5.01
T_4: Branch bending	2.10	2.21	5.07	5.12
T_5: Trunk girdling	1.91	2.20	5.11	4.88
T_6: Branch bending + PP_{333} 500 ppm	1.85	2.18	5.03	4.89
T_7: Branch bending + PP_{333} 1000 ppm	1.55	2.00	5.01	4.99
T_8: Trunk girdling + PP_{333} 500 ppm	1.73	2.10	5.04	4.99
T_9: Trunk girdling + PP_{333} 1000 ppm	1.50	1.98	5.01	4.82
T_{10}: Control	2.40	2.32	5.10	5.12
$CD_{0.05}$	0.20	0.16	NS	NS

Table 5: Effect of paclobutrazol, branch bending and trunk girdling on trunk diameter, height, spread and volume of tree in Flemish Beauty pear

Treatment	Trunk diameter (% increase)		Tree height (% increase)		Tree spread (% increase)		Tree volume (% increase)	
	2001	2002	2001	2002	2001	2002	2001	2002
T_1: PP_{333} 500 ppm	7.14	11.66	4.41	5.50	5.82	6.78	15.06	17.02
T_2: PP_{333} 1000 ppm	5.54	11.06	3.25	4.01	5.26	6.18	13.23	16.02
T_3: PP_{333} 1500 ppm	3.11	10.06	2.40	3.80	3.87	4.10	8.64	14.01
T_4: Branch bending	12.26	12.07	5.17	5.60	6.00	7.10	15.51	16.21
T_5: Trunk girdling	8.83	12.00	4.47	5.55	5.87	6.98	15.19	16.16
T_6: Branch bending + PP_{333} 500 ppm	5.41	11.19	3.27	4.08	5.70	6.50	13.29	16.00
T_7. Branch bending + PP_{333} 1000 ppm	5.06	11.05	2.73	4.00	4.42	5.10	11.64	15.91
T_8: Trunk girdling + PP_{333} 500 ppm	7.14	11.00	3.18	4.10	4.58	5.30	12.77	15.99
T_9: Trunk girdling + PP_{333} 1000 ppm	4.60	10.98	2.72	3.97	3.98	5.00	10.30	15.77
T_{10}: Control	14.30	12.42	7.31	6.98	6.76	7.01	17.84	17.28
$CD_{0.05}$	1.53	NS	1.50	1.07	1.45	1.27	3.24	0.66

branch bending + 1000 ppm PP_{333}, trunk girdling + 500 ppm PP_{333} and trunk girdling + 1000 ppm PP_{333} caused significantly lower increase in tree spread in comparison with control. However, the lowest increased (4.1%) in average spread was found in trees treated with 1500 ppm PP_{333}.

4.1.6 Tree volume

Data in Table 5 reveal that different treatments exerted a significant influence on the tree volume.

During the year 2001, annual increase in tree volume was lowest (8.64%) with the application of 1500 ppm PP_{333}, followed by trunk girdling + 1000 ppm PP_{333}, branch bending + 1000 ppm PP_{333} treatments in the increasing order. Other treatments except 500 ppm PP_{333}, branch bending and trunk girdling also reduced annual increase in tree volume significantly compared to control.

During 2002, treatment of 1500 ppm PP_{333} increased tree volume by 14.01 per cent as compared to 17.28 per cent in control. Other treatments except 500 ppm PP_{333} (T_1) also reduced per cent increase in tree volume significantly in comparison with control.

4.1.7 Average leaf area

The observations on average leaf area are given in Table 6.

It is evident from the data (Table 6) that all treatments except branch bending (T_4) in 2002 reduced average leaf area significantly when compared with control. Average leaf area in control trees was 21.92 cm^2 and 21.59 cm^2 in the year 2001 and 2002 respectively. Application of 1500 ppm PP_{333} (T_3) decreased individual leaf size to 17.33 cm^2 in 2001 and 19.00 cm^2 in 2002 and thus recorded 20.94 and 12.0 per cent reduction, respectively compared to control.

4.1.8 Chlorophyll content

Total chlorophyll content in leaves from trees under different treatments are given in Table 6.

The data show that application of 1500 ppm PP_{333} (T_3) significantly increased total chlorophyll content of leaf over the control in both years. Chlorophyll contents in the leaves of trees given 1500 ppm PP_{333} spray were 3.19 mg/g fresh weight and 2.96 mg/g fresh weight during the years 2001 and 2002 respectively. Leaves of untreated control trees had lowest chlorophyll content (2.18 mg/g and 2.21 mg/g fresh weight in 2001 and 2002, respectively). The effect of other treatments on leaf chlorophyll content was however, non-significant.

4.1.9 Number of shoots

The observations on the number of shoots per tree are shown in Table 7.

The data reveal that during 2001, all treatments significantly reduced the number of shoots that grew more than five centimeter in length when compared with control. Highest number of shoots (57.75) were observed in control trees and lowest (23.50) in trees treated with 1500 ppm PP_{333}. Trees given trunk girdling + 1000 ppm PP_{333} (T_9), trunk girdling + 500 ppm PP_{333} (T_8), 1000 ppm PP_{333} (T_2), branch bending + 1000 ppm PP_{333} (T_7) treatments produced 26.50, 29.50, 31.50 and 32.75 shoots per tree respectively.

Table 6: Effect of paclobutrazol, branch bending and trunk girdling on average leaf area and total chlorophyll in Flemish Beauty pear

Treatment	Average leaf area (cm^2)		Total chlorophyll (mg/g fresh wt.)	
	2001	2002	2001	2002
T_1: PP_{333} 500 ppm	18.20	20.07	2.56	2.36
T_2: PP_{333} 1000 ppm	17.80	19.87	2.85	2.39
T_3: PP_{333} 1500 ppm	17.33	19.00	3.19	2.96
T_4: Branch bending	20.70	21.55	2.36	2.30
T_5: Trunk girdling	19.45	20.90	2.26	2.29
T_6: Branch bending + PP_{333} 500 ppm	17.81	20.00	2.53	2.43
T_7: Branch bending + PP_{333} 1000 ppm	17.50	19.50	2.72	2.48
T_8: Trunk girdling + PP_{333} 500 ppm	18.02	19.99	2.47	2.38
T_9: Trunk girdling + PP_{333} 1000 ppm	17.50	19.17	2.60	2.41
T_{10}: Control	21.92	21.59	2.18	2.21
$CD_{0.05}$	1.08	1.15	0.82	0.50

Table 7: Effect of paclobutrazol, branch bending and trunk girdling on number of shoots, short spur like shoots and spur density in Flemish Beauty pear

Treatment	No. of shoots (>5 cm)/tree		No. of spur-like shoots (<5 cm)/ tree		Spur density (No. of spur/m^3 tree volume)	
	2001	2002	2001	2002	2001	2002
T_1: PP_{333} 500 ppm	36.50	40.75	70.50	64.25	5.28	4.55
T_2: PP_{333} 1000 ppm	31.50	39.50	79.50	66.50	5.90	4.93
T_3: PP_{333} 1500 ppm	23.50	36.75	94.50	74.25	7.34	5.10
T_4: Branch bending	45.25	41.50	64.75	62.50	4.72	4.24
T_5: Trunk girdling	41.50	41.25	68.50	63.75	5.13	4.53
T_6: Branch bending + PP_{333} 500 ppm	34.75	40.75	76.25	65.25	5.68	4.86
T_7: Branch bending + PP_{333} 1000 ppm	32.75	38.25	79.25	65.75	6.04	4.94
T_8: Trunk girdling + PP_{333} 500 ppm	29.50	40.25	82.50	70.75	6.66	5.02
T_9: Trunk girdling + PP_{333} 1000 ppm	26.50	37.50	86.50	72.50	7.06	5.06
T_{10}: Control	57.75	42.50	44.25	61.50	3.37	4.19
$CD_{0.05}$	2.35	1.50	3.54	1.80	1.11	0.70

Similarly during 2002, the highest number of shoots (42.50) were found in untreated control trees and lowest (36.75) in trees given 1500 ppm PP_{333} treatment. Other treatments except branch bending (T_4) and trunk girdling (T_5) also recorded significantly lesser number of shoots than control.

4.1.10 Number of spur-like short shoots

The data on number of short shoots which were spur like are presented in Table 7.

It is evident from the data that all treatments significantly increased the number of spur-like shoots that were lesser than five centimeter in length over the control. During 2001, the highest number of short shoots (94.50) were found in trees given 1500 ppm PP_{333} treatment followed by trees subjected to trunk girdling + 1000 ppm PP_{333} (86.50), trunk girdling + 500 ppm PP_{333} (82.50), 1000 ppm PP_{333} (79.50), branch bending + 1000 ppm PP_{333} (79.25) and branch bending + 500 ppm PP_{333} (76.25) treatments in the decreasing order. Whereas, lowest number of short shoots (44.25) were found in control trees.

During 2002, the number of short shoots were highest (74.25) in trees treated with 1500 ppm PP_{333} closely followed by trees given trunk girdling + 1000 ppm PP_{333} (72.50) treatment. Average number of short shoots per tree were lowest (61.50) in control.

The perusal of data in Table 7 however, reveal that during 2002, the number of short shoots decreased under different treatment and increased in control over the year 2001.

4.1.11 Spur density

The data in Table 7 clearly indicate that spur density computed on the basis of number of spurs (short shoots) per cubic meter tree volume was significantly increased by different treatments.

In 2001, all treatments increased spur density significantly over the control. The highest spur density (7.34/m^3 tree volume) was found in trees treated with 1500 ppm PP_{333} and lowest (3.37/m^3 tree volume) in untreated control. In 2002, significantly higher spur density was found in trees given treatments of 1000 ppm PP_{333}, 1500 ppm PP_{333}, branch bending + 1000 ppm PP_{333}, trunk girdling + 500 ppm PP_{333} and trunk girdling + 1000 ppm PP_{333} than untreated control trees.

4.2 Effect of gibberellic acid and benzyl adenine on fruit set and fruit quality in pear cv. Flemish Beauty

4.2.1 Shoot growth

The data on shoot extension growth of bearing pear trees as influenced by different treatments of growth regulators are presented in Table 8.

It is clear from the data that GA_3 applied alone or in various combination with BA significantly increased shoot extension growth over the control. During 2001, longest annual shoots (35.29 cm) were produced with the treatment of GA_3 at 30 ppm (T_3) followed by treatments of 20 ppm GA_3 + 10 ppm BA (T_{10}), 20 ppm GA_3 + 5 ppm BA (T_9) in the decreasing order. Average shoot length on limbs treated with BA alone did not differ significantly with control (22.27 cm).

Table 8: Effect of bloom spray of growth regulators on shoot extension growth, internodal length and leaf area of Flemish Beauty pear

Treatment	Shoot growth (cm)		Internodal length (cm)		Leaf area (cm^2)	
	2001	2002	2001	2002	2001	2002
T_1: GA_3 10 ppm	30.17	28.66	2.37	2.31	22.01	21.67
T_2: GA_3 20 ppm	31.67	30.17	2.47	2.39	22.50	22.70
T_3: GA_3 30 ppm	35.29	34.07	2.65	2.60	23.93	23.16
T_4: BA 5 ppm	23.18	24.32	2.15	2.12	20.94	20.00
T_5: BA 10 ppm	21.31	21.72	2.10	2.10	21.03	20.17
T_6: BA 15 ppm	20.17	20.97	2.00	2.01	21.59	21.66
T_7: GA_3 10 ppm + BA 5 ppm	25.23	24.01	2.20	2.21	21.89	21.87
T_8: GA_3 10 ppm + BA 10 ppm	27 13	26.67	2.25	2.22	22.06	22.10
T_9: GA_3 20 ppm + BA 5 ppm	29.49	29.07	2.33	2.31	22.90	22.80
T_{10}: GA_3 20 ppm + BA 10 ppm	32.29	31.18	2.40	2.38	23.03	23.11
T_{11}: Control	22.27	22.59	2.01	2.02	20.02	19.98
$CD_{0.05}$	3.19	4.07	0.16	0.13	1.74	1.70

Similarly in 2002, longest annual shoots (34.07 cm) were produced on limbs sprayed with 30 ppm GA_3. Other treatments of GA_3 alone or in combination with BA except 10 ppm GA_3+5 ppm BA (T_7) also produced significantly longer shoots than control (22.59 cm). However, none of the BA treatment when applied alone could influence shoot extension growth significantly.

4.2.2 Internodal length

The data on internodal length of annual shoots are given in Table 8.

During the year 2001, internodal length was maximum (2.65 cm) in shoots on the limbs treated with 30 ppm GA_3. Other treatments of GA_3 whether given alone or in combination with BA also increased internodal length significantly over the control. However, internodal length remained unaffected when BA was applied alone.

During 2002, shoots on limbs treated with 30 ppm GA_3 had longest (2.60 cm) internodal length. Other treatments of GA_3 (10 and 20 ppm) and GA_3 + BA combinations also increased internodal length significantly over the control. Benzyl adenine when applied alone did not influence internodal length.

4.2.3 Leaf area

The perusal of data presented in Table 8 reveal that different treatments exerted a significant influence on average leaf area.

During 2001, maximum average leaf area (23.93 cm^2) was observed with the application of 30 ppm GA_3 (T_3) followed by 20 ppm GA_3 + 10 ppm BA (T_{10}) and 20 ppm GA_3 + 5 ppm BA (T_9) treatments. Other treatments of GA_3 or GA_3 + BA mixture also increased the area of individual leaf significantly over the control (20.02 cm^2). Benzyl adenine when applied alone did not influence the leaf area.

In the year 2002, the largest average leaf area (23.16 cm^2) was found on limbs sprayed with 30 ppm GA_3 (T_3) closely followed by 20 ppm GA_3 + 10 ppm BA (23.11 cm^2) and 20 ppm GA_3 + 5 ppm BA (22.80 cm^2) treatments in the decreasing order. Application of BA at different concentrations had no obvious effect on leaf area.

4.2.4 Fruit set

It is clear from the data (Table 9) that GA_3 and BA when applied alone or in different combinations at bloom significantly increased per cent fruit set over the control. In the year 2001, highest fruit set (36.18%) was observed on limbs sprayed with a combination of 20 ppm GA_3 + 10 ppm BA (T_{10}), followed by 20 ppm GA_3 + 5 ppm BA (T_9), 10 ppm GA_3 + 10 ppm BA (T_8) and 10 ppm BA (T_5) treatments in the decreasing order. Other treatments except 10 ppm GA_3 (T_1) also increased per cent fruit set significantly over the control (30.18%).

In the year 2002, there was a marked increase in fruit set on limbs sprayed with different combinations of GA_3 and BA. Limbs sprayed with the combined treatments of 20 ppm GA_3 + 10 ppm BA, 20 ppm GA_3 + 5 ppm BA and 10 ppm GA_3 + 10 ppm BA registered 18.52, 18.41, 17.45 per cent fruit set respectively. Gibberellic acid when applied alone at different concentrations and BA at 5 ppm also increased fruit set significantly over the control. In general, fruit set was low (12.6 to 18.52%) in 2002.

Table 9: Effect of bloom spray of growth regulators on fruit set and fruit retention in Flemish Beauty pear

Treatment	Fruit set (%)		Fruit retention (%)	
	2001	2002	2001	2002
T_1: GA_3 10 ppm	32.04	15.21	62.29	61.67
T_2: GA_3 20 ppm	32.70	15.27	59.96	60.63
T_3: GA_3 30 ppm	33.29	15.90	57.19	56.17
T_4: BA 5 ppm	32.94	14 70	63.18	63.97
T_5: BA 10 ppm	33.85	14.11	62.17	61.01
T_6: BA 15 ppm	32.44	13.88	61.11	60.33
T_7: GA_3 10 ppm + BA 5 ppm	33.75	17.36	63.01	62.09
T_8: GA_3 10 ppm + BA 10 ppm	34.98	17.45	64.20	67.17
T_9: GA_3 20 ppm + BA 5 ppm	35.11	18.41	67.11	68.08
T_{10}: GA_3 20 ppm + BA 10 ppm	36.18	18.52	68.19	68.17
T_{11}: Control	30.18	12.60	64.27	62.07
$CD_{0.05}$	1.90	1.84	3.32	3.55

4.2.5 Fruit retention

The perusal data (Table 9) reveal that different treatments exerted a significant influence on per cent fruit retention at harvest. During the year 2001, GA_3 applied at 20 or 30 ppm decreased fruit retention significantly compared to control. On the contrary, application of the combination of 20 ppm GA_3 + 10 ppm BA resulted in significantly increased fruit retention over the control.

During the year 2002, treatments of 20 ppm GA_3 + 10 ppm BA, 20 ppm GA_3 + 5 ppm BA and 10 ppm GA_3 + 10 ppm BA significantly increased per cent fruit retention over the control (62.07%). Whereas, application of GA_3 at 30 ppm decreased the per cent fruit retention. Benzyl adenine when applied alone at 5 or 10 or 15 ppm however, did not influence fruit retention.

4.2.6 Number of fruits

The data on the number of fruits/cm^2 limb cross section area have been presented in Table 10.

During the year 2001, all the combined treatments of GA_3 + BA significantly increased the number of fruits computed on the basis of per centimeter square limb cross sectional area in comparison to control. The maximum number of fruits (1.15/cm^2 LCSA) were obtained from limbs treated with 20 ppm GA_3 + 10 ppm BA and minimum (0.80/cm^2 LCSA) in control. Effect of GA_3 and BA when applied alone on the number of fruits/cm^2 LCSA was non-significant.

In 2002, significantly higher number of fruits/cm^2 LCSA were obtained from limbs treated with all GA_3 + BA combinations and BA at 5 or 10 ppm than control.

4.2.7 Yield efficiency

The data (Table 10) reveal that different treatments had a significant influence on yield efficiency (kg/cm^2 LCSA).

All the treatments of GA_3 + BA combination increased yield efficiency when compared with control in both years. However, GA_3 when applied alone reduced the yield efficiency in 2002.

4.2.8 Return bloom

The data presented in Table 10 show that there was a significant influence of different treatments on return bloom. Increased return bloom was observed with the application of 10 ppm BA (+16.25%) and 15 ppm BA (+21.78%). On the contrary, application of GA_3 alone at different concentrations decreased the return bloom. However, combined application of GA_3 + BA had no significant influence on return bloom.

4.2.9 Fruit size

The observations on length and diameter of fruits are shown in Table 11.

It is evident from the data that fruit length was significantly influenced by different treatments. During 2001, limbs sprayed with the different combinations of GA_3 + BA and 15 ppm BA (T_6) produced longer fruits than control. Maximum fruit length

Table 10: Effect of bloom spray of growth regulators on number of fruits, yield efficiency and return bloom in Flemish Beauty pear

Treatment	Number of fruits/cm^2 LCSA*		Yield efficiency (kg/cm^2 LCSA*)		Return bloom (% increase or decrease)
	2001	2002	2001	2002	
T_1: GA_3 10 ppm	0.83	0.72	0.13	0.08	-14.73
T_2: GA_3 20 ppm	0.83	0.66	0.13	0.08	-15.86
T_3: GA_3 30 ppm	0.85	0.65	0.13	0.07	-16.09
T_4: BA 5 ppm	0.94	0.89	0.15	0.11	9.97
T_5: BA 10 ppm	0.92	0.86	0.15	0.10	16.25
T_6: BA 15 ppm	0.90	0.82	0.14	0.10	21.78
T_7: GA_3 10 ppm + BA 5 ppm	1.02	0.99	0.17	0.13	6.67
T_8: GA_3 10 ppm + BA 10 ppm	1.08	1.04	0.18	0.14	5.41
T_9: GA_3 20 ppm + BA 5 ppm	1.08	1.04	0.19	0.14	5.04
T_{10}: GA_3 20 ppm + BA 10 ppm	1.15	1.06	0.20	0.14	4.76
T_{11}: Control	0.80	0.71	0.13	0.10	3.80
$CD_{0.05}$	0.16	0.12	0.03	0.01	12.15

LCSA*: Limb cross-sectional area

Table 11: Effect of bloom spray of growth regulators on fruit size and fruit shape index in Flemish Beauty pear

Treatment	Fruit length (mm)		Fruit diameter (mm)		Length/diameter ratio (L:D)	
	2001	2002	2001	2002	2001	2002
T_1: GA_3 10 ppm	71.32	58.83	63.03	51.66	1.13	1.06
T_2: GA_3 20 ppm	70.71	54.73	62.71	51.60	1.12	1.06
T_3: GA_3 30 ppm	69.95	54.87	61.77	50.64	1.12	1.08
T_4: BA 5 ppm	69.24	53.64	64.15	52.43	1.08	1.02
T_5: BA 10 ppm	71.27	53.63	64.17	52.51	1.11	1.02
T_6: BA 15 ppm	72.56	53.62	64.57	52.34	1.12	1.02
T_7: GA_3 10 ppm + BA 5 ppm	72.73	58.08	64.31	53.73	1.13	1.07
T_8: GA_3 10 ppm + BA 10 ppm	72.83	58.97	65.20	53.80	1.12	1.10
T_9: GA_3 20 ppm + BA 5 ppm	74.11	58.81	65.80	53.96	1.13	1.09
T_{10}: GA_3 20 ppm + BA 10 ppm	78.21	59.35	65.31	53.93	1.17	1.10
T_{11}: Control	68.66	53.50	64.76	53.09	1.06	1.01
$CD_{0.05}$	2.76	1.96	1.40	1.43	0.04	0.04

(78.21 mm) was observed in limbs treated with 20 ppm GA_3 + 10 ppm BA (T_{10}), followed by 20 ppm GA_3 + 5 ppm BA (T_9), 10 ppm GA_3 + 10 ppm BA (T_8), 10 ppm GA_3 + 5 ppm BA (T_7) and 15 ppm BA (T_6) treatments in the decreasing order. During 2002, limbs treated with GA_3 + BA combinations and GA_3 at 10 ppm produced significantly longer fruits than control.

The data in Table 11 reveal that application of GA_3 at 10 or 20 or 30 ppm during 2001 and at 20 or 30 ppm during 2002 decreased average fruit diameter significantly as compared to control. Average diameter of fruits from limbs treated with BA either alone or in combination with GA_3 remained unaffected.

4.2.10 Fruit shape index (L/D ratio)

The data in Table 11 reveal that fruit length/diameter ratio increased significantly with the application of GA_3 alone or in combination with BA during both years. During 2001, highest length/diameter ratio (1:1.17) was obtained with the application of 20 ppm GA_3 + 10 ppm BA (T_{10}), closely followed by treatments of 10 ppm GA_3 (T_1), 10 ppm GA_3 + 5 ppm BA (T_7) and 20 ppm GA_3 + 5 ppm BA (T_9). Other treatments except BA at 5 ppm (T_4) also increased fruit length/diameter ratio significantly compared to control.

During 2002, highest length/diameter ratio (1.10:1) was found in fruits from limbs treated with 10 ppm GA_3 + 10 ppm BA (T_8) and 20 ppm GA_3 + 10 ppm BA (T_{10}) and and lowest in fruits from untreated control limbs (1:1.01). However, BA applied alone had no significant influence on fruit shape index.

4.2.11 Fruit weight

The observations on average fruit weight are given in Table 12.

The data reveal that different treatments had a significant influence on average fruit weight during both the years. During 2001, fruits from limbs treated with 20 ppm GA_3 + 10 ppm BA had maximum fruit weight (174.89 g), which was significantly higher than control (161.15 g). Application of 20 ppm GA_3 + 5 ppm BA, 10 ppm GA_3 + 10 ppm BA, GA_3 10 ppm + BA 5 ppm and 15 ppm BA also increased fruit weight significantly. However, application of GA_3 at 20 or 30 ppm and BA at 5 or 10 ppm decreased the fruit weight.

During 2002, combined application of GA_3 + BA increased the fruit weight, whereas GA_3 and BA when applied alone decreased the fruit weight significantly compared to control.

4.2.12 Fruit volume

It is clear from the data in Table 12 that different treatments had a marked effect on average fruit volume. Application of all GA_3 + BA combinations resulted in significantly increased fruit volume over the control in 2001. However, GA_3 applied at 20 or 30 ppm and BA at 5 or 10 ppm decreased the average fruit volume.

Similarly during 2002, fruit volume was increased significantly with the spray of 20 ppm GA_3 + 10 ppm BA, 20 ppm GA_3 + 5 ppm BA, 10 ppm GA_3 + 10 ppm BA and 10 ppm GA_3 + 5 ppm BA as compared to control. Gibberellic acid when applied alone however, decreased fruit volume linearly with the increasing concentration. The effect of BA when applied alone was not consistent.

Table 12: Effect of bloom spray of growth regulators on fruit weight and fruit volume in Flemish Beauty pear

Treatment	Fruit weight (g)		Fruit volume (cc)	
	2001	2002	2001	2002
T_1: GA_3 10 ppm	160.61	118.69	163.57	121.71
T_2: GA_3 20 ppm	153.44	116.64	156.98	119.89
T_3: GA_3 30 ppm	151.44	110.21	154.76	113.83
T_4: BA 5 ppm	158.11	122.29	162.01	125.82
T_5: BA 10 ppm	159.33	122.47	163.02	126.15
T_6: BA 15 ppm	163.28	121.47	166.91	124.71
T_7: GA_3 10 ppm + BA 5 ppm	166.41	128.73	169.73	132.20
T_8: GA_3 10 ppm + BA 10 ppm	167.17	135.59	171.14	138.64
T_9: GA_3 20 ppm + BA 5 ppm	172.39	136.47	175.80	139.97
T_{10}: GA_3 20 ppm + BA 10 ppm	174.89	136.56	178.06	140.04
T_{11}: Control	161.15	124.65	165.24	127.90
$CD_{0.05}$	1.81	1.19	2.21	1.95

4.2.13 Seed number

Average number of seeds per fruit were significantly influenced by gibberellic acid treatments during both the years (Table 13). Fruits from control limbs contained 4.50 and 3.57 seeds per fruit in the year 2001 and 2002 respectively, which were statistically at par with the seed content in fruits from limbs treated with BA alone or in various combinations with GA_3. However, GA_3 applied alone reduced average seed count per fruit. Average number of seeds in fruits from limbs treated with GA_3 at 10, 20 and 30 ppm were 2.75, 2.50 and 1.90 respectively during 2001 and 2.70, 2.70 and 1.80 during 2002. Therefore, seed content in fruits decreased linearly with the increasing concentration of applied GA_3.

4.2.14 Flesh firmness

The data in Table 13 show that none of the treatments could influence flesh firmness of fruits in 2001. Whereas during 2002, flesh firmness was increased when GA_3 and BA were applied alone or in different combinations. The maximum flesh firmness (84.87 N) was found in fruits from limbs treated with 30 ppm GA_3, followed by 20 ppm GA_3 treatment. Fruits from other treatments except 20 ppm GA_3 + 10 ppm BA also registered significantly higher flesh firmness than control (80.21 N).

4.2.15 Total soluble solids

The data presented in Table 14 reveal that BA applied alone or in different combinations with GA_3 increased total soluble solids in fruits. During 2001, fruits from limbs treated with 15 ppm BA had maximum total soluble solid (13.66%) content which was however, statistically at par with the TSS content of fruits from limbs treated with 10 ppm BA (T_5), 10 ppm GA_3 + 10 ppm BA (T_8), 20 ppm GA_3 + 5 ppm BA (T_9) and 20 ppm GA_3 + 10 ppm BA (T_{10}). Application of GA_3 at 30 ppm (T_3) however, decreased total soluble solids significantly compared to control (12.07%). Application of GA_3 at 10 or 20 ppm did not influence total soluble solids in fruits.

During 2002, treatments of BA at 10 or 15 ppm and all combined treatments except 10 ppm GA_3 + 5 ppm BA (T_7) significantly increased total soluble solid in fruits over the control. In contrast, GA_3 applied at 30 ppm decreased soluble solids in fruits.

4.2.16 Acidity

The data in Table 14 indicate that titratable acidity in fruits was significantly influenced by different treatments. Gibberellic acid applied alone or in combination with BA increased titratable acids in fruits during both the years. The maximum acidity (0.52% in 2001 and 0.50% in 2002) was observed in fruits from limbs treated with 30 ppm GA_3 and the minimum in control (0.30% in 2001 and 0.33% in 2002). Application of BA at all concentrations in 2001 and at 15 ppm in 2002 also increased acidity in fruits.

4.2.17 Total sugar

The observations on total sugar in pear fruits as influenced by growth regulator treatments are shown in Table 15.

It is evident from the data that different treatments had a marked influence on the accumulation of total sugar in fruits. In 2001, the maximum total sugar (9.76%) was found in fruits from limbs sprayed with 15 ppm BA. Application of 10 ppm BA (T_5) and 20 ppm GA_3 + 10 ppm BA (T_{10}) also increased total sugar in fruits significantly over the control. GA_3 applied alone at different concentrations and other treatments did not influence the accumulation of total sugar in fruits.

Table 13: Effect of bloom spray of growth regulators on number of seeds and flesh firmness in Flemish Beauty pear

Treatment	Number of seed/fruit		Flesh firmness (N)	
	2001	2002	2001	2002
T_1: GA_3 10 ppm	2.75	2.70	81.79	83.79
T_2: GA_3 20 ppm	2.50	2.70	83.03	84.58
T_3: GA_3 30 ppm	1.90	1.80	83.12	84.87
T_4: BA 5 ppm	4.40	3.40	81.61	83.64
T_5: BA 10 ppm	3.90	3.44	81.29	83.29
T_6: BA 15 ppm	3.80	3.38	82.05	82.79
T_7: GA_3 10 ppm + BA 5 ppm	4.00	3.35	81.37	82.50
T_8: GA_3 10 ppm + BA 10 ppm	4.33	3.40	81.17	82.77
T_9: GA_3 20 ppm + BA 5 ppm	4.20	3.39	80.26	81.49
T_{10}: GA_3 20 ppm + BA 10 ppm	4.45	3.26	80.31	80.48
T_{11}: Control	4.50	3.57	80.92	80.21
$CD_{0.05}$	0.67	0.53	NS	1.04

Table 14: Effect of bloom spray of growth regulators on total soluble solids and titratable acidity in Flemish Beauty pear

Treatment	TSS (%)		Titratable acidity (%)	
	2001	2002	2001	2002
T_1: GA_3 10 ppm	12.01	12.11	0.41	0.42
T_2: GA_3 20 ppm	11.95	11.79	0.44	0.47
T_3: GA_3 30 ppm	11.50	11.21	0.52	0.50
T_4: BA 5 ppm	12.93	12.54	0.37	0.37
T_5: BA 10 ppm	13.47	12.99	0.39	0.38
T_6: BA 15 ppm	13.66	13.35	0.40	0.40
T_7: GA_3 10 ppm + BA 5 ppm	12.50	12.35	0.41	0.41
T_8: GA_3 10 ppm + BA 10 ppm	13.13	13.00	0.43	0.42
T_9: GA_3 20 ppm + BA 5 ppm	13.23	13.12	0.44	0.43
T_{10}: GA_3 20 ppm + BA 10 ppm	13.31	13.30	0.40	0.40
T_{11}: Control	12.07	12.27	0.30	0.33
$CD_{0.05}$	0.53	0.69	0.04	0.06

Table 15: Effect of bloom spray of growth regulators on total sugar, reducing sugar and non-reducing sugar in Flemish Beauty pear

Treatment	Total sugar (%)		Reducing sugar (%)		Non-reducing sugar (%)	
	2001	2002	2001	2002	2001	2002
T_1: GA_3 10 ppm	8.49	8.05	6.93	6.60	1.48	1.37
T_2: GA_3 20 ppm	8.44	7.86	6.91	6.44	1.44	1.34
T_3: GA_3 30 ppm	8.30	7.52	6.60	6.13	1.61	1.32
T_4: BA 5 ppm	8.88	8.60	7.10	7.18	1.69	1.34
T_5: BA 10 ppm	9.61	9.07	7.49	7.38	2.01	1.61
T_6: BA 15 ppm	9.76	9.27	7.60	7.46	2.04	1.71
T_7: GA_3 10 ppm + BA 5 ppm	8.57	8.30	7.03	7.03	1.45	1.21
T_8: GA_3 10 ppm + BA 10 ppm	8.72	8.35	7.15	6.84	1.49	1.43
T_9: GA_3 20 ppm + BA 5 ppm	8.87	8.44	7.26	6.98	1.52	1.38
T_{10}: GA_3 20 ppm + BA 10 ppm	9.09	8.78	7.34	7.16	1.66	1.53
T_{11}: Control	8.39	8.20	6.69	6.65	1.60	1.47
$CD_{0.05}$	0.55	0.27	0.21	0.28	0.10	0.14

Table 16: Effect of bloom spray of growth regulators on ascorbic acid content of fruits in Flemish Beauty pear

Treatment	Ascorbic acid (mg/100 g fruit pulp)	
	2001	2002
T_1: GA_3 10 ppm	3.52	3.42
T_2: GA_3 20 ppm	3.68	3.50
T_3: GA_3 30 ppm	3.75	3.61
T_4: BA 5 ppm	3.18	3.10
T_5: BA 10 ppm	3.38	3.20
T_6: BA 15 ppm	3.28	3.30
T_7: GA_3 10 ppm + BA 5 ppm	3.64	3.45
T_8: GA_3 10 ppm + BA 10 ppm	3.73	3.61
T_9: GA_3 20 ppm + BA 5 ppm	3.81	3.58
T_{10}: GA_3 20 ppm + BA 10 ppm	3.84	3.82
T_{11}: Control	3.20	3.08
$CD_{0.05}$	0.25	0.28

In 2002, BA applied alone at 5 or 10 or 15 ppm significantly increased total sugar in fruits compared to control and this effect was more pronounced at higher concentrations (10 or 15 ppm). Application of 20 ppm GA_3 + 10 ppm BA (T_{10}) also increased total sugar in fruits. In contrast, GA_3 applied alone at higher concentrations (20 or 30 ppm) decreased total sugar in fruits.

4.2.18 Reducing sugar

The bloom application of growth regulators significantly increased reducing sugar in pear fruits (Table 15). During 2001, the maximum accumulation (7.60%) of reducing sugar occurred in fruits from limbs treated with 15 ppm BA, followed by 10 ppm BA treatment. Other treatments except 30 ppm GA_3 (T_3) also increased reducing sugar in fruits.

Similarly in 2002, there was a significant increase in reducing sugar content of fruits with the application of BA at 5, 10 or 15 ppm and GA_3 + BA combinations at 10 ppm + 5 ppm (T_7), 20 ppm + 5 ppm (T_9) and 20 ppm + 10 ppm (T_{10}). However, application of GA_3 at higher concentration (T_3) decreased reducing sugar in fruits.

4.2.19 Non-reducing sugar

The data in Table 15 reveal that different treatments had a marked influence on non-reducing sugar content in fruits.

In 2001, application of BA at 10 or 15 ppm significantly increased non-reducing sugar in fruits. On the contrary, treatments of 10 ppm GA_3, 20 ppm GA_3, 10 ppm GA_3 + 5 ppm BA and 10 ppm GA_3 + 10 ppm BA decreased non-reducing sugar in fruits. In 2002, BA applied at 15 ppm significantly increased non-reducing sugar in fruits over the control. Whereas, combined spray of 10 ppm GA_3 + 5 ppm BA decreased non-reducing sugar in fruits. GA_3 applied alone did not influence non-reducing sugar in fruits.

4.2.20 Ascorbic acid

The observations on ascorbic acid content in fruits are given in Table 16.

In 2001, the maximum ascorbic acid (3.84 mg/100 g) was found in fruits from limbs treated with 20 ppm GA_3 + 10 ppm BA, followed by 20 ppm GA_3 + 5 ppm BA, 10 ppm GA_3 + 10 ppm BA treatments in the decreasing order. GA_3 applied alone at all concentrations and 10 ppm GA_3 + 5 ppm BA treatment also increased ascorbic acid in fruits significantly compared to control (3.20 mg/100 g). In 2002, ascorbic acid was highest (3.82 mg/100 g) in fruits from limbs treated with 20 ppm GA_3 + 10 ppm BA combination and lowest (3.08 mg/100 g) in control. Other treatments except that of BA alone also increased ascorbic acid content in fruits significantly compared to control.

Chapter-5
DISCUSSION

DISCUSSION

The results of the present investigations on the "Effect of plant growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of pear (*P. communis* L.) cv. Flemish Beauty" are discussed as under:

5.1 Effect of paclobutrazol, branch bending and trunk girdling on vegetative growth and spur formation in young tree of pear cv. Flemish Beauty

5.1.1 Shoot growth

The experiment on young pear trees clearly demonstrate that shoot extension growth was significantly reduced with the application of PP_{333} at various concentrations. Paclobutrazol at 1000 ppm and 1500 ppm retarded shoot growth in both years, but the response was more pronounced during the year of application of treatments. Paclobutrazol applied at 500 ppm however, retarded shoot growth only in 2001. These results confirm earlier reports (Jaumien *et al.*, 1986; Stan *et al.*, 1986) that PP_{333} applied as foliar spray effectively control shoot growth in pear. It has been reported that PP_{333} is catabolized slowly in the trees (Davis and Curry, 1991) and the effect of a single application may last for 2-3 years or more depending upon its concentration (Tukey, 1981; Tukey, 1983). Present findings are also in agreement with those of Tukey (1981), who reported that foliar application of PP_{333} caused greatest inhibition during the year of treatment.

Different treatments of girdling retarded shoot growth however, girdling + PP_{333} application caused greater reduction than girdling alone. These findings are in agreement with those of Ingels (2000), who reported that double 'C' ring girdling caused reduction in vegetative growth in pear. XueCai *et al.* (1997) has reported that growth control was greater with the combine treatment of trunk girdling + cultar application than girdling alone in apple.

Treatment of branch bendings alone retarded shoot growth only during 2001, however, combination of branch bending + PP_{333} caused significant growth controlling effect in both years compared to control. Horizontal spreading of branches has been reported to reduce shoot growth in Japanese pear (Ito *et al.*, 1999). Increased reduction with combined treatments of bending + PP_{333} compared to bending or PP_{333} alone at respective concentration suggests synergistic effect of branch bending and PP_{333}.

The present investigation revealed that internode elongation in shoots was reduced with different treatments of PP_{333}, branch bending and trunk girdling whether given alone or in different combinations (Table 4). The internodal length decreased proportionally with the decreasing annual shoot length (Table 3a, 3b) under different treatments. There are reports (Salem *et al.*, 1990; Davis and Curry, 1991) to suggest that reduction in shoot growth by PP_{333} occurs primarily as a consequence of reduced internode elongation. Sharma and Jindal (1992a) observed reduced internode elongation in shoots in trees planted at 30^o, 45^o and 60^o angles from the soil surface.

5.1.2 Trunk diameter, tree height and spread and tree volume

Present investigation revealed that different treatments of PP_{333}, branch bending and trunk girdling significantly decreased annual increment in trunk diameter than control in 2001, when these treatments also caused greater reduction in shoot growth (Table 3a, 3b) and leaf area (Table 6). Decreased radial growth of trunk has been reported with trunk girdling (Hoying *et al.*, 1992), trunk girdling + PP_{333} (TianHong *et al.*, 1996) and tree bending (Sharma and Jindal, 1992a) treatments.

In this experiment annual increase in tree height was significantly reduced by all the treatments when compared with control (Table 5). Treatments of PP_{333} alone at 1500 ppm, PP_{333} at both concentrations in combination with trunk girdling and 1000 ppm PP_{333} + branch bending also caused a significantly lesser increase in average tree spread. It seems that lower increase in the height and spread of treated trees resulted from retarded shoot growth (Table 3a, 3b). In the present experiment, this lower increase in height and spread of trees under different treatments consequently resulted in reduced tree volume. Fletcher and Hofstra (1988) also reported that application of paclobutrazol resulted in reduced tree height and more compact trees.

5.1.3 Leaf area and chlorophyll content

The results of the present investigation revealed that application of PP_{333} significantly reduced leaf area compared to control in both years. These results agree with the earlier findings (Huang and Shen, 1987; Salem *et al.*, 1990) that PP_{333} reduced leaf area in pears.

Girdling alone or in combination with PP_{333} significantly reduced leaf area compared to control in both years. These results confirm the similar findings of Peng and Rabe (1996) in mandarin. Branch bending + PP_{333} treatments also decreased leaf area. Sharma *et al.* (1991) reported that orientation of apple trees in oligogeotropic position reduced average leaf size.

Paclobutrazol application at 1500 ppm significantly increased chlorophyll content in leaves over the control. It has been earlier reported that foliage of trees treated with PP_{333} contain more chlorophyll (Kim *et al.*, 1990; Lin *et al.*, 1993).

5.1.4 Number of shoots and spur density

During the course of present investigation all treatments reduced the number of shoots compared to control. Lowest number of shoots were observed in trees sprayed with 1500 ppm PP_{333}, followed by trees given treatments of trunk girdling + 1000 ppm PP_{333} (T_9), trunk girdling + 500 ppm PP_{333} (T_8), branch bending + 1000 ppm PP_{333} (T_7), 1000 ppm PP_{333} in the increasing order. In contrast, treated trees produced considerably more number of spur like short shoots compared to untreated control (Table 7). These findings confirm earlier reports (Huang and Shen, 1987; Browning *et al.*, 1992; Rakngan *et al.*, 1995) that application of PP_{333} suppressed the growth of shoots and increased the flower bud in apple and pear. It has also been reported that flower bud formation increased by girdling of trunk (Skogerbo, 1992; TianHong *et al.*, 1996) and horizontally bending of shoots (Raolin *et al.*, 1999; Ito *et al.*, 1999).

In the present study, trees treated with 1500 ppm PP_{333} showed highest spur density (Table 7). Other treatments that produced higher number of spur like short shoots also significantly increased spur density over the control. Decreased tree volume (Table 5) and increased spur like shoots (Table 7) suggest higher spur density in treated trees than untreated control.

5.2 Effect of gibberellic acid and benzyl adenine on fruit set and fruit quality in pear cv. Flemish Beauty

5.2.1 Shoot growth

In this study it was observed that GA_3 applied alone or in different combinations with BA significantly increased shoot growth and internode elongation over the control (Table 8). The maximum increase in shoot growth and internodal length was recorded with the application of 30 ppm GA_3 (T_3), closely followed by 20 ppm GA_3 + 10 ppm

BA (T_{10}) treatment. In this study, annual shoot length increased proportionally with an increase in internodal length following the application of different GA_3 treatments. These results confirm that application of gibberllic acid as foliar spray enhance shoot growth in pome fruits (Xin *et al.*, 1994; Grochowska *et al.*, 1995).

5.2.2 Leaf area

The present results revealed that application of GA_3 alone at various concentrations or in combination with BA significantly increased average leaf area compared to control. Maximum leaf area was observed with the application of 30 ppm GA_3 in both years. The increase in leaf area with the application of GA_3 has earlier been observed in apple (Xin *et al.*, 1994), pear (Ahmad, 1998) and strawberry (Rana, 2001). Whereas, McLaughlin and Greene (1984) reported that GA_{4+7} when applied alone did not influence leaf area but combination of GA_{4+7} + BA increased leaf area in apple. Since growth in developing leaves is due to cell division, cell enlargement and differentiation, thus the increase in leaf size may be the result of the effect of growth regulators on cell division and cell enlargement.

5.2.3 Fruit set

The present experiment illustrates the benefit of combining the two growth regulators in the production of pear. The results (Table 9) clearly showed that GA_3 and BA were more effective in promoting fruit set when used in different combinations than alone. These findings have further established that increase in fruit set can be accomplished with bloom spray of GA_3 (Marcelle, 1984; Knight and Browning, 1986), BA or GA_3 + BA (Marcelle, 1984).

5.2.4 Fruit retention

During the course of present study, application of the various mixtures of GA_3 + BA significantly increased fruit retention (Table 9) and consequently number of fruits per cm^2 limb cross sectional area (Table 10) over the control. However, GA_3 applied alone at higher concentrations decreased fruit retention. Application of GA_3 may have stimulated fruit drop by reducing the number of well developed seed (Table 13). It has been reported that overwhelming factor in control of fruit retention is intra-tree competition, which favours fruits with many seeds (Buszard and Schwabe, 1988). In the present study, on equal seed number basis GA_3 + BA mixtures increased fruit retention.

5.2.5 Yield efficiency

Bloom spray of all GA_3 + BA mixtures significantly increased yield efficiency when compared with control. Highest yield efficiency (0.20 kg/cm^2 limb cross sectional area in 2001 and 0.14 kg/cm^2 limb cross sectional area in 2002) was obtained with the application of 20 ppm GA_3 + 10 ppm BA. Higher yield efficiency under GA_3 + BA treatments may be attributed to increased fruit set, fruit retention (Table 9) and fruit size (Table 12).

It seems that reduction in yield efficiency under the treatments of GA_3 alone in 2002 may be the result of decreased return bloom (Table 10).

5.2.6 Return bloom

In this experiment, application of BA at 10 and 15 ppm significantly increased return bloom as compared to control. On the contrary, GA_3 applied alone decreased the return bloom. Combined application of GA_3 + BA however, did not influence return bloom. Luckwill (1969) proposed that flowering may be controlled by a balance between gibberellins and cytokinins. He suggested that gibberellins produced in shoots must be reduced substantially while, cytokinins are still high to stimulate partially the development of lateral buds into flower.

Present results are in agreement with the findings of McLaughlin and Greene (1984) who reported that bloom application of BA increased return bloom in apple. Exogenous application of GA_3 has been reported to inhibit flowering in pear (VanKricken and Lindenbergh, 1984; Knight and Browning, 1986).

5.2.7 Fruit size and L/D ratio

In this experiment, combined application of GA_3 + BA significantly increased fruit length without affecting fruit diameter relative to control. BA applied alone at 15 ppm in 2001 and GA_3 at 10 ppm in 2002 also increased fruit length. Exogenous gibberellis and cytokinins when applied alone or in combination often produce longer fruits (Pfammater *et al.*, 1984; Herrero, 1984; McLaughlin and Greene, 1984). However, it was observed that GA_3 applied alone at various concentrations significantly decreased fruit diameter (Table 11). In the present investigation, application of GA_3 alone had a detrimental effect on seed development (Table 13), which may have affected fruit diameter. In some reports GA_3 decreased fruit diameter is concert with lesser number of seeds since, seeds had been said to produce growth promoting substances e.g. auxin, gibberellin and cytokinin (Cawthon and Morris, 1982; Ryugo, 1988 and Hasegawa and Nakajima, 1990).

The results revealed that GA_3 applied alone or in combination with BA significantly increased the length/diameter ratio of fruits. It has been earlier demonstrated that use of gibberellin and cytokinin can alter fruit shape (Curry and Williams, 1983; Eccher, 1986).

5.2.8 Fruit weight and volume

Combined application of GA_3 and BA during the course of present experiment significantly increased average fruit weight and volume in comparison with control. However, when GA_3 was applied alone particularly at higher concentrations decreased fruit weight and volume. BA applied alone at various concentrations also had adverse effect on fruit weight and volume. Increased fruit weight and volume with the combined spray of GA_3 + BA may probably be due to increase in fruit length (Table 11), whereas, decreased fruit weight and volume under the treatments of GA_3 alone can be attributed to decrease in fruit diameter. Looney (1979) also observed increase in fruit weight with the combined spray of BA + GA_{4+7} at petal fall in apple. Present results confirm the findings of Yamada *et al.* (1991) that bloom application of GA_3 decreased fruit weight in Le Lectier pear.

5.2.9 Number of seeds

Application of GA_3 caused reduction in the number of seeds per fruit, whereas, BA applied alone or in combination with GA_3 had no significant influence on seed development (Table 13). It has been earlier reported that bloom application of gibberellins reduce the number of well developed seeds in pear (Herrero, 1984; Marcelle, 1984; Honeyborne, 1996). Marcelle (1984) further reported that BA application before the gibberellin treatment could reverse the detrimental effect of GA on the seed development.

5.2.10 Flesh firmness

Treatments of GA_3 at higher concentrations increased flesh firmness in 2001, which seems to be associated with decrease in fruit diameter (Table 11). Perring and Jackson (1975) earlier reported that smaller fruits were more firm due to higher Ca content. Application of BA alone or in combination with GA_3 also increased flesh firmness in fruits. There are reports that cytokinin applied alone (Greene, 1993b) or in combination with gibberellin (Sharma, 1998) increased flesh firmness in apple.

5.2.11 Total soluble solids

The experimental results revealed that soluble solids in fruits increased with the application of BA alone or in combination with GA_3 (Table 14). The maximum soluble solids were found in fruits from limbs treated with 15 ppm BA. Similarly, it has been earlier reported that application of cytokinin caused an increase in soluble solids content in apples (Greene, 1993b; Wismer *et al.*, 1995) and pears (Ahmad, 1998).

In present study, the finding that GA_3 applied alone at higher concentrations decreased soluble solid in fruits is similar to those of Sharma (2001). Sharma (2001) further reported that combined application of GA_3 and BA however, increased TSS content in fruits.

5.2.12 Titratable acidity

Titratable acidity in fruits increased with the treatments of GA_3 applied alone or in combination with BA in both years (Table 14). Treatments of BA at all concentrations also increased acidity in fruits in 2001. These findings are in line with those of Ahmad (1998) for the effect of GA_3 and Sharma (1998) for gibberellin + cytokinin combinations.

5.2.13 Sugars

In this experiment, bloom application of BA at 15 ppm invariably increased total sugar, reducing sugar and non-reducing sugar in fruits (Table 15). On the contrary, application of GA_3 at various concentrations decreased sugar contents in fruits compared to control. Ahmad (1998) observed increased sugar content in fruits with the post bloom application of kinetin. Sharma (2001) found that GA_3 applied at different stages of flower bud opening caused an increase in the accumulation of sugar in apple.

5.2.14 Ascorbic acid

In the present investigation, GA_3 applied alone or in combination with BA significantly increased ascorbic acid content in fruits compared to control (Table 16). These findings are in conformity with those of Sharma (1998), who reported that exogenous application of gibberellin + cytokinin combination increased ascorbic acid content in fruits.

Chapter-6
SUMMARY & CONCLUSION

SUMMARY AND CONCLUSION

The salient findings of the present investigations on the "Effect of growth regulators, branch bending and trunk girdling on growth, flowering and fruiting of pear (*Pyrus communis* L.) cv. Flemish Beauty" are summarized below:

6.1 Treatments of PP_{333} alone at 1000 or 1500 ppm, trunk girdling +PP_{333} at 500 ppm or 1000 ppm, branch bending + PP_{333} at 500 ppm or 1000 ppm and trunk girdling alone significantly reduced shoot extension growth and internodal length as compared to control in both the years of study, but the effect was more pronounced during the year of application of these treatments. The maximum reduction in shoot growth and internodal length was found with the application of PP_{333} at 1500 ppm followed by trunk girdling + 1000 ppm PP_{333} treatment.

The trunk diameter was significantly influenced by all treatments. Trees treated with 1500 ppm PP_{333} showed lowest increase (3.11%) in trunk diameter. However, none of the treatments could exert a significant influence on shoot diameter. Annual increase in height, spread and volume of tree was lowest with the application of 1500 ppm PP_{333} followed by girdling + 1000 ppm PP_{333} treatment. Untreated control trees registered maximum increase in their height, spread and volume.

6.2 All the treatments except branch bending in 2002 significantly reduced average leaf area. However, application of PP_{333} at 1500 ppm significantly increased total chlorophyll content in leaf as compared to control in both years.

6.3 Different treatments exerted a considerable influence on the production of vegetative and reproductive shoots in both years, but the effect was more pronounced in the year of application of treatments. The number of shoots were lowest in trees treated with 1500 ppm PP_{333} and highest in untreated control. On the contrary, number of spur-like short shoots and spur density were highest in trees sprayed with 1500 ppm PP_{333} and lowest in untreated control. Trees given treatments of 1000 ppm PP_{333}, trunk girdling + PP_{333} at 500 or 1000 ppm, branch bending + 1000 ppm PP_{333} also showed significantly higher spur density in both years than control.

6.4 Application of GA_3 alone or in combination with BA significantly increased shoot elongation, internodal length and average leaf area as compared to control. Gibberellic acid applied at 30 ppm caused maximum increase in shoot growth, internodal length and leaf area.

6.5 Bloom application of growth regulators had a considerable influence on pear fruit production. Highest fruit set, fruit retention and yield efficiency were obtained with the combined application of 20 ppm GA_3 + 10 ppm BA. Application of growth regulators in other combinations also increased fruit set, fruit retention and yield efficiency. Gibberellic acid applied at 20 or 30 ppm though increased fruit set but decreased fruit retention.

6.6 Increased return bloom was observed consistently with the application of BA at 10 or 15 ppm. In contrast, application of GA_3 alone at different concentration decreased the return bloom.

6.7 Limbs sprayed with the different combinations of GA_3 + BA, 15 ppm BA in 2001 and 10 ppm GA_3 in 2002 produced longer fruits than control. Maximum fruit length was observed with the treatment of 20 ppm GA_3 + 10 ppm BA. Application of GA_3 at 20 or 30 ppm however, decreased fruit diameter significantly as compared to control. Fruit length/diameter ratio increased significantly with the application of GA_3 alone or in combination with BA.

Combined application of GA_3 + BA significantly increased weight and volume of fruit as compared to control. Gibberellic acid when applied alone however, decreased fruit weight, fruit volume and the number of seeds per fruits.

6.8 Application of GA_3 and BA alone or in different combinations increased flesh firmness of fruit in 2002.

6.9 Benzyl adenine applied alone at various concentrations increased soluble solids and sugar content in fruits. Maximum total soluble solids, total sugar, reducing sugar and non-reducing sugar were found in fruits from limbs treated with 15 ppm BA. Gibberellic acid applied alone at various concentrations decreased soluble solids and sugar contents in fruits. Titratable acidity in fruits increased significantly with the application of GA_3 alone at all concentrations, BA alone at 15 ppm and all the combinations of GA_3 + BA.

Ascorbic acid content in fruits increased considerably with the combined application of GA_3 + BA at various concentrations. GA_3 applied at 30 ppm also increased ascorbic acid content in fruit.

From these results, it may thus be inferred that the application of PP_{333} alone at 1500 ppm or PP_{333} at 1000 ppm in combination with trunk girdling can effectively control vegetative growth and increase spur formation in young pear trees. There seems to be a potential benefit of using combined application of GA_3 +BA in the pear fruit production. In the present study, GA_3 + BA when applied in small quantities at bloom enhanced fruit set, yield efficiency and fruit quality without adversely affecting flowering in Flemish Beauty pear.

REFERENCES

REFERENCES

A.O.A.C. 1980. Official methods of analysis of the Analytical Chemists, 13th ed. (W. Horwitz, ed.). *Association of Official Analytical Chemists,* **33**: 617-623.

Adamov, M.G. 1973. The effect of branch inclination on bud development in certain apple cultivars. *Shornik Nauchykh Rabot Vsesoyuzuyi Nauchno Issledo Vetelskii Institut Sadovostna imeni I.V. Michurina,* **17**: 97-100.

Ahmad, Mohd. 1998. Effect of plant bioregulators on growth, yield and quality of pear (cv. Flemish Beaty). Ph.D. Thesis. Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Aldini, A. and D. Cobianchi. 1986. Preliminary observations on the effects of paclobutrazol on pear. *Rivista-della-Ortoflorofrutticoltura-Italiana,* **70(6)**: 191-197.

Anonymous. 2002. Area and Production of Fruits in Himachal Pradesh. Directorate of Horticulture, H.P. Shimla-2.

Arakawa, O., K. Kanno, A. Kanetsuka, Y. Shiozaki, R.H. Rarritt and F. Kappel. 1997. Effect of girdling and bark inversion on tree growth and fruit quality of apple. *Acta Hortic.*, **451**: 579-585.

Baisai, R.; G. Costa and R. Baraldi. 1988. Effect of some growth regulators on vegetative growth and cropping in the apple cultivar Golden Delicious. *Societa Orticola Italiana,* 445-454.

Bangerth, F. and M. Schroder. 1994. Strong synergistic effect of gibberellins with the synthetic cytokinin N-(2-chloro-4-Pyridyl)-N-phenylurea on parthenocarpic fruit set and some other fruit characteristics of apple. *Plant growth regulation,* **15(3)**: 293-302.

Banno, K., S. Hayashi and K. Tanabe. 1985. Effect of SADH and shoot bending on flower bud formation, nutrient components and endogenous growth regulators in Japanese pear (*P. serotina* Rehd.). *J. Jap. Soc. Hort. Sci.*, **53(4)**: 365-376.

Bist, L.D. and N. Rai. 1994. Residual effect of paclobutrazol and promalin on tree shaping and productivity of 'Gola' pear. *Ind. J. Hort.*, **51(1)**: 41-48.

Blinovski, I.K. 1970. The effect of shoot angle on photosynthesis in apple. *DokL., Mork. Sel, Hoz. Aca. K.A. Timirjazev,* **158**: 135-141.

Bonomo, R. and D. Neri. 1986. The effect of paclobutrazol on pear. *Rivista-della-Ortoflorofrutticoltura-Italiana,* **70**: 6, 181-190.

Browning, G., Z. Singh; A. Kuden and P. Blake. 1992. Effect of (2RS, 3RS)-paclobutrazol on endogenous indole-3-acetic acid in shoot apices of pear cv. Doyenne du Comice. *J. Hort. Sci.*, **67(1)**: 129-135.

Buban, T. and G. Borka. 1979. Gibberellic acid treatments for increasing f ruit set in pear cv. Beurre Bosc. *Kertgazdasag,* **11(4)**: 21-27.

Buban, T. and T. Lakatos. 1997. Fruit thinning with benzyladenine in trees of hard to thin apple cultivars. *HortScience,* **29(3-4)**: 31-35.

Bukovac, M.J. 1981. Interrelationships between vegetative and reproductive development of fruit trees. *In*: "Tree Fruit Growth Regulators and Chemical Thinning" pp. 78-89. R.B. Tukey and M.W. Williams (*eds.*). Pullman, WA.

Burden, R.S., G.A. Carter; T. Clark; D.T. Cooker; A.H.B. Deas; P. Hedden; C.S. James and J.R. Lenton. 1987. Comparative activity of enantiomers of triadimenol and paclobutrazol as inhibitors of fungal growth and plant sterol and gibberellin biosynthesis. *Pesticide Science,* **21**: 253-267.

Burlak, V.A. and V.D. Scherbatko. 1980. Varietal response of pear to gibberellin treatment after flower damage by soring frost. *Byulleten-Vsesoyuznogo-Ordena-Levina-Instituta-Rastenienvodstvo-Imeni-N.I. Vavilona,* **103**: 19-22.

Buszard, J.I. Deborah and W.W. Schwabe. 1988. Effect of crop history on response of apple cv. Cox's Orange Pippin to a range of fruit setting treatments. *Acta Hortic.*, **293**: 353-356.

Byoro, F., J. Nyoki; M. Soltesz and Z. Tisza. 1978. Effect of treatments with gibberellic acid on fruit setting in pear. *Acta Hortic.*, **80**: 139-141.

Carlson, R.F. 1968. Bending and Knotting of trees. *Fruitlett,* **58**: 953.

Cawthon, D.C. and J.R. Morris. 1982. Relationship on seed number and berry development, fruit maturation, hormonal changes and uneven ripening of Concord grapes. *J. Amer. Soc. Hort. Sci.*, **107**: 1097-1104.

Cody, C.; F.E. Larsen and R. Fritts, Jr. 1985. Stimulation of lateral branch development in tree fruit nursery stock with GA_{4+7}+BA. *HortScience*, **20**: 758-759.

Cristoferi, G.; M. Meconcelli and B. Gchena. 1981. The chemical control of setting and fruiting in Comice pears. *Rivista-della-Ortoflorofruticoltura-Italiana*, **63(4)**: 309-318.

Curry, E.A. and M.W. Williams. 1983. Promalin or GA_3 increase pedicel and fruit length and leaf size of Delicious apples treated with paclobutrazol. *HortScience*, **18(7)**: 217-215.

Davis, T.D. and E.A. Curry. 1991. Chemical regulation of vegetative growth. *Crit. Rev. Plant Sci.*, **10**: 151-188.

Deckers, T. 1994. Comparison between GA_3, GA_{4+7} and promalin in fruit setting trials with pear. *Fruitteelt-nieuws*, 7: 7-16.

Deckers, T., E. Daemen and D. Vermeisen. 1997. Improvement of fruitfulness of young conference: Comparison of results achieved with GA_3 and GA_{4+7}. *Fruitteelt-nieuws*, **10(24)**: 7-10.

Dennis, F.G. (Jr) and L.F. Edgerton. 1962. Induction of parthenocarpy in the apple with gibberellin and effects of supplimentary auxin application. *Proc. Amer. Soc. Hort. Sci.*, **80**: 58-63.

Devyatov, A.S. and P.I. Kazalov. 1972. The effect of shoot bending on changes in the properties of apple buds. *Minsch, Belorrussion SSR, Nauka i Tokhnika Botenika Issled*, **14**: 107-117.

Dheim, M.A. and G. Browning. 1988. The mechanism of the effect of (2RS, 3RS)-paclobutrazol on flower initiation of pear cvs. Doyenne du Comice and Conference. *J. Hort. Sci.*, **63(3)**: 393-405.

Eccher, T. 1986. Russeting and shape of Golden Delicious apples related to endogenous GA content of fruitlets. *Acta Hortic.*, **179**: 767-770.

Edgerton, L.J. and M.W. Williams. 1981. Chemical thinning of apples. Proc. of Tree Fruit Short Course, Tree Fruit Growth Regulators and Chemical Thinning, 1981. pp. 141-172 [R.B. Tukey and M.W. Williams *eds.*]. Wash. Stat. Coop. Ext. Ser. Pullman.

Elfving, D.C. 1984. Factors affecting tree response to chemical branch induction treatments. *J. Amer. Soc. Hort. Sci.*, **109**: 476-481.

Elfving, D.C. 1989. N-(Phenyl methyl)-IH Purine-6-amine (BA) as a chemical thinner for Idared apple. *Acta Hortic.*, **239**: 357-363.

Elfving, D.C. and R.A. Clive. 1993. Benzyl adenine and other chemicals for thinning Empire apple trees. *J. Amer. Soc. Hort. Sci.*, **118**: 593-598.

Engels, B. and G. Ebert. 1988. Effect of combined application of GA_{4+7} and BA on photosynthesis, transpiration and leaf growth in strawberry cv. Korona. *Erwerbsobstbau*, **30(7)**: 183-185.

Fletcher, R.A. and G. Hofstra. 1988. Triazoles as potential plant growth protectants. In: Sterol synthesis inhibitors in plant protection. D. Berg and M. Plempel (*eds.*). Ellis Horwood Ltd., Cambridge, UK.

Flick, J.D. and L. Hermann. 1978. Effect of gibberellic acid on fruit set of Passe Crassane pear. *Acta Hortic.*, **80**: 143-147.

Forshey, C.G. 1982. Branching responses of young apple trees to applications of 6-benzylamino purine and gibberellin A_{4+7}. *J. Amer. Soc. Hort. Sci.*, **107**: 538-541.

Fumoro, M. 1998. Effect of trunk girdling during early shoot elongation period on tree growth, mineral absorption, water stress and root respiration in Japanese persimmon (*Diospyros kaki* L.) cv. Nishimurawase. *J. Jap. Soc. Hort. Sci.*, **67(2)**: 219-227.

Gil, G.F.; R. Gatti; C.H. Crisoto and S.R. Gatti. 1983. Fruit setting in Packham Triumph pear in Chile. *Cienciae-Investigacion-Agraria*, **10**: 53-62.

Gil, G.F.; W.H. Grings and G.C. Martin. 1972. Gibberellin induced parthenocarpy in Winter Nelis pear. *HortScience*, **7**: 559-561.

Graebe, J.E. 1987. Gibberellin biosynthesis and control. *Annu. Rev. Plant Physiol.*, **38**: 419-465.

Greene, D.W. 1980. Effect of silver nitrate, aminoethoxy vinylglycine and gibberellins A_{4+7} plus 6-benzyl-aminopurine on fruit shape and development of Delicious apples. *J. Amer. Soc. Hort. Sci.*, **105**: 717-720.

Greene, D.W. 1993a. Effect of GA_4 and GA_{4+7} on flower bud formation and russet development on apple. *J. Hort. Sci.*, **68**: 171-176.

Greene, D.W. 1993b. A comparison of several cytokinins on apple fruit set and quality. *Acta Hortic.*, **329**: 144-146.

Greene, D.W. 1995. Thidiazuron effects on fruit set, quality and return bloom of apples. *HortScience*, **30**: 1238-1240.

Greene, D.W. and W.J. Lord. 1978. Evaluation of scoring, limb spreading and growth regulators for flower bud initiation and fruit set on young "Delicious" apple trees. *J. Amer. Soc. Hort. Sci.*, **103(2)**: 208-210.

Greene, D.W. and W.R. Autio. 1990. Vegetative response of apple trees following benzyladenine and growth regulator sprays. *J. Amer. Soc. Hort. Sci.*, **115**: 400-404.

Grochowska, M.J.; M. Houden; A. Mika; H. Morgas and D. Chlebowska. 1995. High responsiveness of apple trees to single application of growth regulators to the root collar. *J. Fruit Orn. Plant Res.*, **3**: 91-101.

Guo, Z.N.; G.N. Guo and S.Z. Yan 1988. A study of shortening the juvenile phase of apple seedling. *Acta Hortic.*, **224**: 145-148.

Hamzakheyl, N.; D.C. Ferree and F.O. Hartman. 1976. Effect of lateral shoot orientation on growth and flowering of young apple trees. *HortScience,* **11(4)**: 393-395.

Hao, S.Q.; H. Yang and Z.M. Sun. 1991. Physiological changes induced by paclobutrazol in Delicious apple. *Fruit Sci. Rep.*, **18**: 163-172.

Harrell, D.C. and L.E. Williams. 1987. Net CO_2 assimilation rate of grapevine leaves in response to trunk girdling and gibberellic acid application. *Pl. Phy.*, **83(3)**: 457-459.

Hasegawa, K. and Y. Nakajima. 1990. Effect of bloom date, seediness, GA treatment and location of fruits in the foliar canopy on the fruit quality of persimmon (*Diospyros kaki* L.). *J. Japan Soc. Hort. Sci.*, **59(2)**: 263-270.

Herrero, M. 1984. Effect of time of GA_3 treatment on Agua de Aranjuez pear fruit set. *Acta Hortic.*, **149**: 211-216.

Herrero, M. 1989. Fruit shape as a response to the time of GA_3 treatment in "Agua de Aranjuez" pear. *Acta Hortic.*, **256**: 127-132.

Higazi, A.M., M.H. El-Hagah, S.Z. El-Nagar and A.A. Kassem. 1993. Physico-chemical characters of LeConte pear fruits in relation gibberellic acid effects. *Minufiya J. Agr. Res.*, **7**: 281-299.

Honeyborne, G.E. 1996. The effects of gibberellin containing growth regulators on fruit set and preharvest quality of Forelle pears. *Deci. Fr. Gr.*, **46(5)**: 166-172.

Hoying, S.A.; T.L. Robinson; M. Faust and S.S. Miller 1992. Effect of chain saw girdling and root pruning of apple trees. *Acta Hortic.*, **322**: 167-172.

Hrotko, K.; L. Magyar and Z. Bonay. 2000. Improved feathering on apple nursery trees by BA application. *Acta Hortic.*, **514**: 113-119.

Huang, H. and S.Cao 1989. Responses of some major deciduous fruit trees to foliar sprays of paclobutrazol. *Fruit Sci. Rep.*, **16**: 105-196.

Huang, W.D. and T.I. Shen. 1987. The effects of PP_{333} (paclobutrazol) on the growth of *Pyrus betulaefolia* Bge. and on the growth and fruiting of Yali pear (*Pyrus bretschneideri* cv. Yali). *Acta Hort. Sinica,* **14(4)**: 223-231.

Huang, W.D.; T. Shen; Z.H. Han and S. Lin 1995. Influence of paclobutrazol on photosynthesis and dry matter partitioning in the apple tree. *J. Pl. Nut.*, **18**: 901-910.

Ilha, L.L.H.; G.A.B. Marodin; E. Seibert and C.I.N. Barradas. 1999. Effect of thinning and of trunk girdling on growth, production and quality of Japanese plums. Pesquisq-*Agropecuaria-Brarileiria,* **34**: 2211-2217.

Ingles Chuck. 2000. Effect of trunk girdling of pear trees for vigour control. *ISHS. 8th International Pear Symposium* September 4-9, 2000, P. 200.

Ito Akiko; Hideaki Yaegaki; Hiroko Hayama; Shinnosuke Kusaka; Isomard Yamaguchi and Hirohito Yashioka. 1999. Bending shoots stimulats flowering and influences hormone levels in lateral buds of Japanese pear. *HortScience,* **34(7)**: 1224-1228.

Jaumien, F., M. Wiktorowicz and B. Osinska. 1986. Vegetative growth control and fruiting of young pear trees treated with CCC, SADH, PP_{333} (paclobutrazol) and mixture of these compounds with CEPA. *Acta Hortic.*, **179(1)**: 221-228.

Jonkers, H. 1978. Induction of parthenocarpy in apple and pear with mixtures of growth regulators. *Acta Hortic.*, **80**: 123-127.

Ju, Z.G.; Y.B. Yuan; C.L. Liu; H.Y. Dai and Z.J. Li. 1993. Effects of PP_{333} on phenolics synthesis and fruit growth of pears. *Acta Hort. Sinica,* **20(3)**: 216-220.

Kazakova, L.M. 1978. Effect ofgibberellin on fruit set in pear and apple. *Sb. Sinica,* **20**: 216-220.

Khurshid, T.; D.L. McNiel; M.C.T. Trought and G.D. Hill. 1997. The response of young "Braeburn" and "Oregon Spur Delicious" apple trees growing under an ultra-high density planting system to soil applied paclobutrazol: Effect on reproductive and vegetative growth. *Scientia Hortic.*, **72**: 11-24.

Kim, J.K.; K.Y. Kim; J.B. Kim and S.B. Kim. 1990. The effect of paclobutrazol on shoot growth, photosynthetic activity, leaf and fruit characteristics and flower bud formation in Fuji apples. *Res. Rep. Rural Dev. Admi. Hort.*, **32**:10-15.

Knight, J.N. 1980. Regulation of cropping and fruit quality of Conference pears by the use of gibberellic acid and thinning: The effect of hand thinning of blossom in conjunction with gibberellic acid application. *J. Hort. Sci.*, **55(1)**: 33-39.

Knight, J.N. and G. Browning. 1986. Regulation of Conference pear cropping with gibberellic acid and ethephon or paclobutrazol. *Acta Hortic.*, **179**: 337-342.

Kondratenko, P.V.; I.I. Tartachnjk and A.M. Silaena. 1998. Effect of girdling on the dynamics of assimilates in the leaves of apple. *Sadcvodstno-i-Vinogradradarstov*, **3**: 9-10.

Lever, B.G. 1986. "Cultar" - a technical overview. *Acta Hortic.*, **179**: 459-466.

Lin Hrinshan; Lin Jia; H. Singh; Chang Linsen; Lin Chinho; H.S. Lin; J.H. Lin; L.R. Chang and C.H. Lin. 1993. Effect of plant growth retardants on the vegetative growth habits of Shinseiki pears. *Bull. Taichung Distt.Agric. Improvement Station*, **59**: 51-59.

Looney, N.E. 1979. Some effects of gibberellins A(4+7) plus benzyladenine on fruit weight, shape, quality, Ca content and storage behaviour of 'Spartan' apple. *J. Amer. Soc. Hort. Sci.*, **104**: 389-391.

Looney, N.E.; R.P. Pharis and M. Noma. 1985. Promotion of flowering in apple trees with gibberellin A_4 and C-3 epi-gibberellin A_4. *Planta*, **165**: 292-294.

Luckwill, L.C. 1969. The control of growth and fruitfulness of apple trees. *In*: Physiology of tree crops. L.C. Luckwill and C.V. Cuttings (*eds.*). Academic Press, New York.

Marcelle, R.D. 1984. Effect of GA_3, BA and growth retardants on fruit set in the pear cultivar Doyenne du Comice. *Acta Hortic.*, **149**: 225-229.

Martin, G.C. and C. Nishijima. 1978. Fruit set and persistance of Winter Nellis pear following treatment with several gibberellins, cytek, abscisic acid and GA_3 plus $CaCl_2$. *HortScience*, **13(3)**: 255-256.

McArtney, S.J.; D.S. Turtin; S. Seymour; W. Cashmore and N.E. Looney. 1995. Benzyladenine and carbaryl effects on fruit thinning and the enhancement of return flowering of three apple cultivars. *J. Hort. Sci.*, **70(2)**: 287-296.

McLaughlin, J.M. and D.W. Greene. 1984. Effects of BA, GA_{4+7} and daminozide on fruit set, fruit quality, vegetative growth, flower initiation and flower quality of "Golden Delicious" apples. *J. Amer. Soc. Hort. Sci.*, **109**: 34-39.

McLaughlin, J.M. and D.W. Greene. 1991. Fruit and hormones influence flowering of apple : It effects hormones. *J. Amer. Soc. Hort. Sci.*, **116(3)**: 450-453.

Miller, S.S. 1988. Plant bioregulators in apple and pear culture. *Hort. Rev.*, **10**: 309-401.

Miller, S.S. and B.J. Eldridge. 1986. Use of 6-benzylamino purine and Promalin for improved canopy development in selected apple cultivars. *Scientia Hortic.*, **28**: 355-368.

Modic, D. and I. Kodric 1978. The effect of gibberellic acid on fruit development and yields in some pear varieties treated after spring frost. *Tugoslovensko-Vocarstvo,* **12**: 3-14.

Modic, D. and M. Turk. 1978. Effect of gibberellic acids on parthenocarpic fruit development in some pear cultivars. *Zbornik-Biotechniske-takultete-Univerzev-L-Jubljani-Kmetijstvo,* **31**: 75-81.

Modlibowska, I. 1967. Effect of GA on the cropping of Conference pears following the unfavourable conditions at bloom time. *Rpt. E. Malling Res. Sta.*, 79-83.

Mullins, M.G. and W.S. Rogers. 1971. Growth in horizontal apple shoot: Effect of stem orientation and bud position. *J. Hort. Sci.*, **108**: 634-638.

Myers, S.C. and D.C. Ferree. 1983. Influence of summer pruning and tree orientation on net photosynthesis, transpiration, shoot growth and dry weight distribution in young apple trees. *J. Amer. Soc. Hort. Sci.*, **108**: 4-9.

Noma, Y.; H. Ohara; S. Katou; Y. Murata and K. Nakamura. 1989. The effect of paclobutrazol on shoot growth and flower bud differentiation in two Japanese pear cultivars "Kousui" and "Shinsui" (*Pyrus serotina* Rehder var. Culta Rehder). *Technical Bulletin of Faculty of Horticulture, Chiba University,* **42**: 107-115.

Nyeki, J.; M. Soltesz and Z. Tisza 1977. Chemical regulation of fruit set in commercial pear plantations. *Ujabb-Kutatasi-eredmenyek-a-gyumolestermesztesben,* 89-109.

Pal, Sandip. 1997. Effect of plant bioregulators on fruit set, fruit growth, yield and quality of Starking Delicious apple. M.Sc. Thesis. Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Peng, Y.H. and E. Rabe. 1996. Effect of summer trunk girdling on fruit quality, maturation, yield, fruit size and tree peformance in "Mikowase" satsumas. *J. Hort. Sci.*, **71(4)**: 581-589.

Perring, M.A. and Jackson, C.H. 1975. The mineral composition of apples. Calcium concentration and bitter pit in relation to mean mass per apple. *J. Sci. Fd. Agr.*, **26(10)**: 1490-1502.

Pfammater, W.; J. Hurter; T. Umiker and H. Tanner. 1984. Does gibberellic acid lower the quality of Williams pear? *Revue-Suisse-de-Viticulture-d' Arboriculture-et d' Horticulture,* **16(2)**: 77-78.

Pharis, R.P.; L.T. Evans; R.W. King and L.N. Mander. 1990. Gibberellins and flower initiation/early differentiation -evidence for differences in structure and dose, relative to efficacy in shoot elongation. *Pl. Gr. Reg. Soc. Amer.*, 94-105.

Pipattanawong, N.; N. Frjishige; K. Yamane; Y. Ijiro and R. Ogata. 1996. Effect of growth regulators and fertilizers on runner production, flowering and growth in day nutral strawberries. *Jap. J. Trop. Agr.*, **40(3)**: 101-105.

Poniedzialek, W.; M. Malek and B. Michallik 1990. The effect of growth rgulators and propolis on the growth of pear shoots. *Zezyty Naukove Akademii Rolmiczej in H. Kollataja W. Krakawie, Ogrodnicktwo,* **18**: 49-57.

Quinlan, J.D. 1980. Recent developments in the chemical control of tree growth. *Acta Hortic.*, **114**: 144-151.

Raese, J.T. and E.C. Burts. 1983. Increased yield and suppression of shoot growth and mite populations of "d" Anjou pear trees with nitrogen and paclobutrazol. *HortScience,* **18**: 212-214.

Rai, N. and L.D. Bist. 1991. Effect of promolin, SADH and chlormequat on tree growth, flowering, fruit set, yield and fruit quality of "Gola" pear. *J. Hort. Sci.*, **66(4)**: 443-447.

Rakngan, J.; H. Gemma and S. Iwahori. 1995. Flower bud formation in Japanese pear trees under adverse climatic conditions and effects of some growth regulators. *Jap. J. Trop. Agri.*, **39(1)**: 1-6.

Rana, R.K. 2001. Studies on the influence of nitrogen fixers and plant bioregulators on growth, yield and fruit quality of strawberry cv. Chandler. Ph.D. Thesis. Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Raolin Guo; Jun Xia Yang; Jun Xiang Zhaw; Zhen Gad, Shu Zhi Hua; R.L. Guo; J.X. Yang, J.X. Zhao; Z. Gao and S.Z. Hua. 1999. Study on the effect of widening the growing angles of vigorous branches for fruit bud formation of young apple trees. *China Fruits,* **3**: 16-17.

Rom, G. Curt and Bruce Barritt. 1990. Spur development of Delicious apple as influenced by position, woodage, strain and pruning. *HortScience,* **25(12)**: 1578-1581.

Roper, T.R. and L.E. Williams. 1989. Net CO_2 assimilation and carbohydrate partitioning of grapevine leaves in response to trunk girdling and gibberellic acid application. *Plant. Phys.*, **89(4)**: 1136-1140.

Ryuge, K. 1988. Fruit culture: Science and art. John Wiley and Sons. Inc. New York. pp. 344.

Salem, A.T.; A.E. Kilany and A.D. Shaltout. 1990. Vegetative growth, yield and fruit quality of LeConte pear trees as affected by cultar treatments. *Bulletin of Faculty of Agriculture, University of Cairo,* **42**: 1353-1368.

Sansavini, S.; G. Cristoferi and P. Montalti. 1988. Effects of paclobutrazol on growth fruiting and carbohydrate metabolism in pear trees. *Ad. Hort. Sci.*, **2**: 52-57.

Schechter, I.; J.T.A. Proctor and D.C. Elfving. 1994. Apple fruit removal and limb girdling affect fruit and leaf characteristics. *J. Amer. Soc. Hort. Sci.*, **119(2)**: 157-162.

Sestak, Z.; J. Catschy and G.G. Ganier. 1971. Plant photosynthetic production. Manual of Methods. N.V. Publish., The Hague.

Sharma, Chuni Lal. 1998. Studies on the role of plant bioregulators on fruit set and yield in self incompatible apple cv. Vance Delicious. M.Sc. Thesis: Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Sharma, Girish. 2001. Effect of pre-bloom foliar application of nutrients and biorgulators on fruit set and yield in apple. M.Sc. Thesis. Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Sharma, N. and K.K. Jindal. 1992a. Growth, flowering, fruiting and yield efficiency in apple as influenced by tree orientation. *The Hort. J.*, **5(1)**: 9-14.

Sharma, N. and K.K. Jindal. 1992b. Effect of tree orientation on vegetative growth and spur formation in Royal Delicious apple. *Ind. J. Hort.*, **49(3)**: 227-230.

Sharma, N.; K.K. Jindal and J.S. Chauhan. 1991. Effect of tree orientation on photosynthetic production, transpiration and fruit quality in apple. *The Hort. J.*, **4(2)**: 1-4.

Sharma, R.K.; Ram Kumar and V.S. Chhonkar. 1976. A note on the effect of manuring and branch ringing on bearing of mango (*Mangifera indica* Linn.). *Ind. J. Hort.*, **33**: 137-138.

Singh, Ashok Kumar. 1995. Effect of plant bioregulators and nutrients on fruit set, maturity and yield in apple. M.Sc. Thesis, Dr. Y.S. Parmar University of Horticultue and Forstry, Nauni, Solan.

Singh, Jaswant; K.K. Sharma; S.S. Mann; Singh Raghbir; G.P.S. Grewal; J. Singh; R. Singh and D. Sugar. 1994. Effect of different chemicals on yield and fruit quality of LeConte pear. *Acta Hortic.*, **367**:210-213.

Singh, R.P. and T.R. Chadha. 1990. Effect of bloom spray of growth regulators on flowering and productivity of Delicious apples. *Ind. J. Hort.*, **47(4)**: 392-396.

Skogerbo, G. 1992. Effects of root pruning and trunk girdling on xylem cytokinin content of apple (*Malus* x *domestica* Borkh). *Norwegian J. Agr. Sci.*, **64**: 499-507.

Stan, S.; I. Popescu; M. Colorobai and M. Radulescum. 1986. Control of vegetative growth of fruit trees with cultar (Paclobutrazol). *Lucrarite Stiintifice ole Institutului de Pitesti,* **11**: 319-330.

Steffens, G.L.; F.W. Jacobs and M.E. Engelhaupt. 1993. Size, flowering and fruiting of maturing own rooted Gala apple trees treated with paclobutrazol sprays and trunk drenches. *Scientia Hortic.*, **56**: 13-21.

Stembridge, G.E. and G.Morrell. 1972. Effect of gibberellins and 6-benzyl-adenine on the shape and fruit set of "Delicious" apples. *J. Amer. Soc. Hort. Sci.*, **97**: 464-467.

Stinchcombe, G.R.; E. Copar, R.R. Williams and G. Arnold. 1984. The effects of paclobutrazol and daminozide on the growth and yield of cider apple trees. *J. Hort. Sci.*, **59**: 323-327.

Taylor, B.K. 1978. Effect of gibberellin sprays on fruit russet and tree performance of Golden Delicious apple. *J. Hort. Sci.*, **53**: 167-169.

Teskey, B.J.E. and C.B.S. Rajput. 1977. The response of Bertlett pears to certain growth regulators. *Fr. Var. J.*, **31**: 10-11.

Thukral, B.R., Ranvir Singh; K.K. Misra; H.R. Jaiswal and R. Singh. 1994. Effect of plant growth regulators on growth and mineral composition of leaves of lemon (*Citrus lemon* Burm.). *Ann. Agr. Res.*, **15(3)**: 306-309.

TianHong Li; WeiDong Huang; Zhao Quing; T.H. Li; W.D. Huang and Z.Q. Meng. 1996. Study on the mechanism of flower bud induction in apple tree. *Acta Phy. Sinica*, **22**: 251-257.

Tromp, J. 1970. Shoot orientation effect on growth and flower bud formation in apple. *Acta Bot. Neerl.*, **19**: 535-538.

Tromp, J. and S.J. Werthein. 1980. Synthetic growth regulators: Mode of action and application in fruit production. *Proc. 15th Colloq. Inter. Potash. Inst.*, 137-150.

Tukey, L.D. 1981. Growth and development in tree fruits. *In*: The Fruit Growth Regulators and Chemical Thinning. 1-45 [R.B. Tukey and M.W. Williams *eds*.]. *Proc. Pacific North West Tree Fruit Short Course Wash. State Coop. Ext. Ser., 1981, Pullam*.

Tukey, L.D. 1983. Vegetative control and fruiting on mature apple trees treated with PP_{333}. *Acta Hortic.*, **137**: 103-109.

Unrath, C.R. 1974. The commercial implication of gibberellin A_4, A_7 plus benzyl adenine for improving shape and yield of "Delicious" apples. *J. Amer. Soc. Hort. Sci.*, 99: 381-384.

Unrath, C.R. 1989. The influence of 6-benzyl-amino purine on growth, flowering and fruiting of young bearing apple trees following treatment as non-bearing trees. *Acta Hortic.*, **239**: 269-271.

Unrath, C.R. and A.D. Shaltout. 1985. Branch induction on young "Delicious" apple trees by application of growth regulators. *HortScience*, **20**: 230-231.

VanKricken, W. and C.M.J. Lindenbergh. 1984. Influencing flower bud formation in pears. *Fruitteelts*, **24**: 594-596.

VanOosten, H.J. and S.J. Wertheim. 1981. Experiences with the growth regulator M&B. 25, 105 in the fruit tree nursery. *De Fruitteelt*, **71**: 736-739.

Volz, R.K. and J.N. Knight. 1986. The use of regulators to increase precocity in apple trees. *J. Hort. Sci.*, **61**: 181-189.

Wertheim, S.M. and J.H. Bootsma. 1992. Gibberellin dosing can perhaps be lower. *Fruitteelt DenHaag*, **82**: 17, 14-16.

Westwood, M.N. 1978. Temperate Zone Pomology. San Francisco. W.H. Freeman and Company. pp. 220-228.

Williams, M.W. and D.S. Letham. 1969. Effect of gibberellins and cytokinins on development of parthenocarpic apples. *HortScience*, **4**: 215-216.

Williams, M.W. and E.A. Stahley. 1969. Effect of cytokinins and gibberellins on shape of delicious apple fruits. *J. Amer. Soc. Hort. Sci.*, **94**: 17-19.

Wismer, P.T., J.T.A. Proctor and D.C. Elfving. 1995. Benzyladenine affects cell division and cell size during apple fruit thinning. *J. Amer. Soc. Hort. Sci.*, **120**: 802-807.

Xin, P.G.; S.X. Xiang; P.G. Che; S.X. Xin and X.L. Chen. 1994. A study on distribution of PP_{333} in young trees and its growth inhibition effect and inhibition relieving with GA_3. *J. Shandong Agri. Uni.*, **25**: 1-8.

XueCai Wang; Rong Wu Zheng; X.C. Weng and R.W. Zheng. 1997. Study of the effect of girdling and applying cultar on the vigorous low fruited apple trees. *China Fruits*, **1**: 19-20.

Yamada, H., K. Nakajima, Y. Yamazawa and I. Kuroi. 1991. Effect of pollination and gibberellin treatments on fruit set and development of European pear (*Pyrus commuinis* L. var. Sativa DC) cv. LeLectier. *J. Jap. Soc. Hort.*, **60**: 267-273.

Yu, J.C.V. and G. Yelenosky. 1998. Biomass and photosynthesis rsponses of rough lemon (*Citrus jambhiri* Lush) to growth regulators. *Canadian J. Pl. Sci.*, **68**: 1, 261-266.

CURRICULUM VITAE

Name	:	Nanak Dev
Father's name	:	Shri Kapoor Chand
Date of birth	:	17.05.1976
Sex	:	Male
Marital status	:	Single
Nationality	:	Indian

Educational qualifications

Certificate/Degree	Percentage/ grade	Board/University	Year
10+2	Second	H.P. Board	1996
B.Sc.	First	UHF, Nauni-Solan	2000

Whether sponsored by some State/ Central Govt/Univ/SAARC : No

Scholarship/Stipend/Fellowship/ any other financial assistance received during study period:

B.Sc. - No
M.Sc. - University Stipend