

Impact of Chemical Thinning Agents on Pear (*Pyrus communis* L.) Fruit size and Crop Load Management

Chemical thinning involves the application of plant growth regulators to reduce crop load and improve fruit size at harvest. 'Forelle', the second most widely planted pear cultivar in South Africa, is characterized by a relatively small average fruit size, making early fruitlet thinning essential for achieving commercially acceptable fruit size. Previous studies have demonstrated that 6-benzyladenine (6-BA), 1-naphthylacetic acid (1-NAA), and abscisic acid (S-ABA) can be effective chemical thinners in pears and may enhance the size of the remaining fruit. During the 2019/20 season, the effectiveness of 1-NAA, 6-BA, and S-ABA was evaluated on 'Forelle' pears in the Ceres production region. Treatments were applied at the 8–12 mm fruitlet diameter stage. The concentrations tested were 1.6 mL/10 L for 1-NAA, 75 mL/10 L for 6-BA, and 15 g/10 L for S-ABA, each applied at varying spray volumes. Results showed that chemical thinning did not significantly reduce crop load or improve fruit size during the 2019/20 season. No significant differences were observed among treatments, and none of the chemical applications increased overall fruit yield. Although S-ABA at 15 g/10 L showed slight potential relative to the other treatments, its effect was not significantly different from the untreated control. Further research is therefore required to identify effective thinning strategies for 'Forelle' pears.

Keywords: Pear fruit thinning, S-Abscisic acid (S-ABA), 1-Naphthylacetic acid (1-NAA), and 6-Benzyladenine (6-BA), Post-bloom stage.

Introduction

Pear (*Pyrus communis* L.) production is an important component of global temperate fruit agriculture, contributing significantly to fresh fruit markets and export industries (Byers, 2003). The pear industry in South Africa only European pears produced, with its well-balanced mix of production and markets, continues to expand slowly with total production rising by about 2 percent per year (Belrose Inc., 2015). South Africa produces 3% of the global pear output, and pears make up 16% of the local deciduous fruit industry (Blanckenberg, 2015). The main production areas are Ceres, where 38% is cultivated, followed by the Langkloof 14% and Wolseley/Tulbagh 12% (Table 1) (HORTGRO, 2021). The total area planted to pears is 12 850 ha (HORTGRO, 2021).

Table 1. Main Pear Production Areas in SA

DISTRICTS	NR OF TREES	AREA IN HECTARES
CERES	6 690 394	4 734
GROENLAND	2 639 832	1 672
LANGKLOOF EAST	2139 525	1 621
WOLSELEY/TULBAGH	2 057 173	1 429

VILLIERSDORP/VYEBOOM	1 838 351	1 228
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1 Source HORTGRO tree census, 2021

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3 The agriculture play a vital role to develop the economy of the country and
4 agrees that agriculture is main food source for the growing population
5 (Paschalidis *et al.*, 2021). The major fruit production in Greece is derived from
6 permanent tree crops (Cultivated areas of tree plantations and their production)
7 and is comprised of olives (mainly oil producing), citrus (oranges, tangerines,
8 lemons), stone fruits (peaches, apricots, cherries) and pome fruits (apples, pears)
9 (Ordoudi *et al.*, 2018). For the moment, most of the nectarines existing on the
10 Romanian markets come from Greece, Turkey and other countries (Măguran,
11 2013). Fruits and vegetables constitute an important sector in the agricultural
12 production of Greece holding very important share (about 39%) in the domestic
13 agricultural economy, estimated at around 10 billion EUR (Ordoudi *et al.*, 2018).

14 The major cultivars grown (Table 2) are Packham's Triumph (33%), Forelle
15 (26%) and Bon Chrétien (22%) with other important cultivars Abate Fétel (6%),
16 Rosemarie (4%), Beurré Bosc (2%), Cheeky (2%), Doyenné du Comice (1%),
17 Flamingo (1%) and Golden Russet Bosc (1%) ((Blanckenberg, 2015). In order
18 to keep the South African pear culture competitive, it is necessary to develop
19 unique, acclimatised and profitable varieties. There has been a shift in production
20 towards blushed or bi coloured cultivars with Forelle being the most important
21 of these (Theron *et al.*, 2008).

22
23 **Table 2.** Pears: Area planted per cultivar (in Hectare) in South Africa.

Pear Cultivars	2019	2020	2021
PACKHAM'S TRIUMPH	4275	4 354	4 232
FORELLE	3 361	3 515	3 518
ABATE FETEL	2 329	2 275	2 200
WILLIAMS BON CHRETIEN	744	720	700
ROSEMARIE	510	589	598
CHEEKY	526	560	568
CELINA	208	217	226
FLAMINGO	145	137	136
BEURRE BOSCH	130	111	110
DOYENNE DU COMICE	130	115	109
CLAPP'S FAVOURITE	102	102	104
GOLDEN RUSSET BOSCH	88	96	91
OTHER	126	121	151
Total Season	12 674	12 913	12 743

24 Source: HORTGRO tree census, 2021

25

1 Among the commercially important pear cultivars, Forelle pear is highly
 2 valued for its distinctive appearance colour, eating quality, and export potential
 3 (Table 3). Pears are produced for food consumption, and consistently good eating
 4 quality is a prerequisite for consumer satisfaction and for encouraging loyalty to
 5 a pear cultivar (Blanckenberg *et al.*, 2016). Pears contain a range of vitamins and
 6 minerals that help strengthen the immune system (Simionca Mărcășan *et al.*,
 7 2023).

8
 9 **Table 3.** *Utilisation of pears in South Africa for 2006/2007*

Crop utilization	Volume (tons)	%
Fresh consumption (local)	57,931	17
Fresh consumption (export)	162,360	47
Processed	118,780	34
Dried	8,592	2
Total	347,763	100

10 Source: (Theron *et al.*, 2008).

11
 12 Pear fruit quality and yield are strongly influenced by orchard management
 13 practices such as pruning, irrigation, fertilisation, pest control, and thinning.
 14 Among these practices, crop load management through fruit thinning is
 15 considered essential to ensure marketable fruit size, uniformity, and consistent
 16 annual production (Byers, 2003).

17 Forelle pear (*Pyrus communis* L. cv. Forelle) is a commercially important
 18 cultivar, widely grown in South Africa and valued for its attractive red blush,
 19 distinctive flavour, and suitability for export. However, Forelle is known to be
 20 prone to heavy fruit set, which can lead to excessive crop load, reduced fruit size,
 21 delayed maturity, and irregular bearing if not properly managed (Webster, 2002).
 22 Excessive fruit load increases competition among fruitlets for carbohydrates and
 23 nutrients, resulting in small fruits with poor colour development and lower
 24 commercial value (Bound, 2021).

25 Fruit thinning can be achieved manually or chemically. Manual thinning is
 26 labour-intensive, costly, and often inconsistent due to variable labour
 27 availability. As a result, chemical thinning has become a widely adopted practice
 28 in many commercial orchards, particularly where labour shortages and
 29 increasing production costs affect farm profitability (Dennis, 2000). Chemical
 30 thinning agents influence fruit set and abscission through hormonal regulation
 31 and carbohydrate balance within the tree. The effectiveness of thinning
 32 chemicals depends on cultivar, timing, environmental conditions, and tree
 33 physiological status (Greene, 2002).

34 The main produced pears cultivars in South Africa are Packham's Triumph,
 35 Forelle, William Bon Chretien, Rosemarie, Cheeky, Celina, Flamingo, Beurre
 36 Bosc, Doyenne Du Comice, Clapp's Favourite, Golden Russet Bosc and Abate
 37 Fetel (Muziri *et al.*, 2016).

38 South Africa is ranked sixth in the world in terms of European pear
 39 production, after China, the USA, Argentina, Turkey, and Italy, but is ranked
 40 fourth in terms of export after Argentina, the Netherlands, and Belgium
 41 (Musacchi, S., 2023). The pear industry is the third largest in the South African

1 fruit industry after citrus and apples. It is important in terms of size, fresh export,
2 and economic impact (Sawant *et al.*, 2023). The ‘Forelle’ is the most profitable
3 pear cultivar planted in South Africa; however, it remains a challenge to achieve
4 regular high yields with good fruit size (Dreyer, 2013)

5 This chapter reviews literature on chemical thinning in pears, focusing
6 specifically on S-abscisic acid (S-ABA), 1-naphthylacetic acid (NAA), and 6-
7 benzyladenine (6-BA). The review highlights mechanisms of action, effects on
8 yield and fruit quality, and the relevance of these chemicals to Forelle pear
9 production under South African conditions.

10 11 12 **Importance of Crop Load Management in Pear Production**

13
14 Crop load refers to the number of fruits carried by a tree relative to its leaf
15 area or tree size. Pear trees are particularly sensitive to crop load because
16 excessive fruit numbers reduce the size and quality of individual fruits. Crop
17 load management ensures that the tree allocates sufficient resources to the
18 remaining fruits, resulting in improved fruit size, better sugar accumulation,
19 enhanced colour development, and improved firmness (Robinson and Lakso,
20 2011). Excessive crop load has been linked to delayed fruit maturity, lower
21 soluble solids content (SSC), reduced storage life, and increased incidence of
22 physiological disorders (Wertheim, 2000). In addition, heavy cropping can
23 reduce flower bud formation for the following season, resulting in biennial
24 bearing, a phenomenon where the tree alternates between high-yield and low-
25 yield years (Webster, 2002).

26 This irregular production creates challenges for orchard planning and
27 reduces long-term profitability (Byers, 2003). Proper thinning reduces the risk
28 of biennial bearing by promoting balanced vegetative and reproductive growth.
29 By lowering fruit numbers early in the season, the tree maintains adequate
30 carbohydrate reserves for flower initiation and bud development (Byers, 2003).
31 Therefore, thinning is not only important for fruit quality but also critical for
32 long-term orchard sustainability (Byers, 2003).

33 34 **Fruit Set and Natural Abscission in Pear Trees**

35
36 Fruit set is defined as the proportion of flowers that develop into fruits after
37 pollination and fertilisation. Pear trees often produce a large number of flowers
38 and can set fruit excessively under favourable pollination and climatic
39 conditions. Following fruit set, a natural fruit drop occurs, usually in two phases:
40 the initial post-bloom drop and the June drop, where weaker fruitlets are abscised
41 due to hormonal changes and limited carbohydrate supply (Bangerth, 2000).

42 Abscission is controlled by the abscission zone (AZ), which is located at the
43 base of the fruitlet stem. Abscission occurs when cell separation processes are
44 activated, leading to fruitlet detachment. The activation of abscission is
45 influenced by the balance of plant hormones such as auxins, cytokinins,
46 ethylene, and abscisic acid (Taylor and Whitelaw, 2001). When carbohydrate

1 supply becomes limited, fruitlets with weaker sink strength produce lower levels
2 of auxin, which increases the sensitivity of the abscission zone to ethylene,
3 promoting fruit drop (Bangerth, 2000).

4 The natural abscission process is often insufficient to reduce crop load to
5 commercially optimal levels, particularly in cultivars such as Forelle that tend to
6 set heavily. As a result, chemical thinning is required to reduce fruit number and
7 improve fruit quality.

10 **Thinning Methods**

12 *Hand thinning*

14 Manual thinning is carried out by removing excess fruitlets by hand,
15 typically several weeks after bloom. This method is highly effective and allows
16 the grower to selectively remove damaged or poorly positioned fruits. However,
17 manual thinning is expensive and requires significant labour input, making it less
18 feasible for large-scale commercial operations (Dennis, 2000). Hand-thinning is
19 one of the most accurate methods of reducing excessive crop loads of either
20 flowers or fruitlets (Kirstein, 2015). In apples and European pear, hand-thinning
21 is normally commenced later in the season once the danger of spring frosts is
22 over and growers can see what has set on the trees (Webster, 2002). Early hand
23 thinning at blossom time is difficult to achieve accurately, as it is not known
24 which flowers will set fruit; retained flowers may not have been pollinated,
25 resulting in later abscission (Bound, 2021).

27 *Mechanical thinning*

29 Mechanical thinning uses physical tools such as trunk shakers or rotating
30 devices to remove flowers or fruitlets. While this method reduces labour costs,
31 it may cause damage to tree structures and can result in inconsistent thinning
32 (Greene, 2002). Two main challenges exist for the mechanical thinning of pome
33 fruit. The first of these is the extent of leaf area present during bloom, as
34 considerable damage to foliage could be detrimental (Greene & Costa, 2013).
35 Mechanical thinning has developed to such an extent that it is now used
36 commercially for thinning of pome fruit (Greene & Costa, 2013; Costa *et al.*,
37 2017). Apples have been used as the model crop in most of the research done
38 with mechanical string thinners, but extrapolations can be made to pears given
39 that they are both pome fruits (Kirstein, 2015).

41 *Chemical thinning*

43 Chemical thinning involves applying plant growth regulators (PGRs) that
44 promote fruit abscission by altering hormone balance or disrupting carbohydrate
45 distribution. Chemical thinning is widely used in modern fruit production due to
46 its efficiency and reduced labour requirement. However, its effectiveness is

1 influenced by environmental conditions such as temperature, light intensity, and
2 humidity, as well as application timing and concentration (Wertheim, 2000).
3 Chemical thinning is practised in most tree fruit-growing areas in the world. It
4 is the easiest practice and is a cost-effective way to reduce crop load on heavily
5 cropping trees (Greene, 2012). Fruit trees without chemical thinning result in
6 excessive fruits of small size, and excessive growth causes substantial limb
7 breakage from heavy crops (Stover *et al.*, 2001).
8 The latest time of thinning (15 d after PH) also had a negative impact on yield at
9 first harvest and on total yield, fruit FW, and delayed fruit ripening compared to
10 thinning during, and 15 d before PH (Drogoudi *et al.*, 2009).

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12

13 **Chemical Thinning and Plant Hormonal Regulation**

14

15 Chemical thinning is standard industry practice for crop load management
16 of fruits per tree, applied during the bloom and/or post-bloom periods, followed
17 up with hand thinning. Chemical thinning uses caustic materials or synthetic
18 hormonal growth regulators to reduce the number of flowers and/or fruit on the
19 tree (Bound, 2021). Plant growth regulators influence fruit retention and
20 abscission through complex interactions. The major hormones involved in fruit
21 set regulation include auxins, cytokinins, ethylene, and abscisic acid. Auxins are
22 produced in developing seeds and young fruitlets and are transported through the
23 pedicel, inhibiting abscission by maintaining abscission zone inactivity
24 (Bangerth, 2000).

25 Cytokinins stimulate cell division and enhance sink strength, affecting fruit
26 growth and competition among fruitlets (Greene, 2002). Ethylene is a key
27 hormone promoting abscission, as it induces cell wall degrading enzymes in the
28 abscission zone (Taylor and Whitelaw, 2001). Abscisic acid is associated with
29 stress responses and promotes abscission indirectly through interactions with
30 ethylene and carbohydrate limitation (Zhang *et al.*, 2009). Chemical thinning
31 agents manipulate these hormonal pathways to encourage fruit drop at specific
32 developmental stages. The success of chemical thinning depends on applying the
33 chemical during the period when fruitlets are sensitive to abscission, generally
34 between petal fall and early fruitlet development (Dennis, 2000).

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37 **S-Abscisic Acid (S-ABA) as a Chemical Thinner**

38

39 *Role of abscisic acid in plant physiology*

40

41 Abscisic acid (S-ABA) is a naturally occurring plant hormone that regulates
42 physiological processes such as stomatal closure, seed dormancy, senescence,
43 and stress responses. S-ABA levels increase under drought, high temperature,
44 and other stress conditions, helping plants reduce water loss and survive
45 unfavourable environments (Davies, 2010).

46

1 *Mechanism of S-ABA in fruit thinning*

2

3 S-ABA is the biologically active form of S-ABA used commercially. In fruit
4 thinning, S-ABA is believed to promote fruitlet abscission by reducing
5 photosynthesis and increasing ethylene sensitivity in fruitlets, resulting in
6 accelerated abscission zone activation (Zhang *et al.*, 2009). ABA can also reduce
7 carbohydrate availability by inducing partial stomatal closure, limiting carbon
8 assimilation, and increasing competition between fruitlets (Greene, 2002).
9 Subsequent studies have revealed that the application of S-ABA causes the
10 abscission of flowers and young developing fruit of several plants in the apple
11 tree (Greene *et al.*, 2011). The mechanism of S-ABA-induced thinning in apples
12 is unknown. S-ABA influences many physiological events in the plant
13 (Mupambi *et al.*, 2018). Each thinning compound has strengths and weaknesses
14 and the use of an individual thinner. The low fruit set is one of Brazil's most
15 important factors responsible for the pear scenario (Pasa *et al.*, 2017). S-ABA
16 has the potential to influence the carbohydrate status within a plant by closing
17 stomates, thus reducing photosynthesis during the time the stomates are closed
18 (Cline *et al.*, 2017).

19

20 *Effects of S-ABA on fruit yield and quality*

21

22 Studies have shown that ABA-based products can reduce fruit set and
23 increase fruit size when applied during early fruitlet development. Improved
24 fruit size is mainly due to reduced crop load and increased carbohydrate
25 availability to remaining fruits (Byers, 2003). However, thinning responses can
26 vary depending on environmental stress and cultivar sensitivity, meaning dosage
27 and timing must be optimised for specific orchard conditions. In pears, research
28 on S-ABA thinning is limited compared to apples. Some trials suggest that S-
29 ABA has potential as a mild thinning agent with fewer negative side effects
30 compared to more aggressive chemicals (Greene, 2002). This highlights the
31 importance of conducting cultivar-specific research, particularly for Forelle
32 pears under South African production conditions. The most effective time to
33 apply S-ABA chemical thinner is when the fruitlets diameter is 7-9 mm and 11-
34 13 mm (Greene, 2012). The time of application depends on the producers and to
35 cultivar. Chemical thinning on plums would reduce hand thinning substantially,
36 but currently, chemical thinners available for stone fruit thinning are limited
37 (Theron *et al.*, 2017).

38 Exogenously application of S-ABA during early fruit development
39 stimulates fruit abscission in apples and pears (Cline *et al.*, 2017). Reduction in
40 the number of fruits to a more favorable leaf-to-fruit ratio allows high-quality
41 fruit to be produced in the current year and improves bloom the following season
42 (Greene, 2012).

43 Application of S-ABA at 400 mg/L at veraison improved berry colour and
44 was the most effective in the pedo-climatic conditions of Puglia (Ferrara *et al.*,
45 2015). Thus, high quality and high yield can be achieved by minimizing the
46 wastage and maximizing the supply of carbohydrates and mineral nutrients to

1 the developing fruit (Sidhu *et al.*, 2014). However, inadequate or untimely
2 thinning practices can lead to production problems, such as a biennial bearing
3 pattern resulting in fluctuating production (Sidhu *et al.*, 2022).

4 The lowest S-ABA concentration (350 mg L⁻¹) caused an excessive
5 reduction of the number of fruits per tree; 500 and 750 mg L⁻¹. In 'Bartlett' pear,
6 a reduced crop load, as petals fell when S-ABA at 500 mg L⁻¹ was applied at
7 full bloom, and when fruit were 10 mm diameter (Giovanaz *et al.*, 2015). Fruit
8 thinning resulted when ABA was applied at 500 mg·L⁻¹ to 'Bartlett' pears
9 between full bloom and the 10 mm stage of fruit development (Greene, 2012).
10 more intense thinning observed at the more advanced developmental stages. In
11 'Autumn Rose Fuji' apple, a greater thinning was observed with increasing ABA
12 rates (0, 50, 150, 300, and 1000 mg L⁻¹) applied in 2008 (Giovanaz *et al.*, 2015).
13 Applications of 300 mg L⁻¹ of S-ABA significantly reduced the total number of
14 fruits per branch and total number of fruiting sites per branch compared with the
15 untreated control (Cline *et al.*, 2017).

18 **1-Naphthyl-Acetic Acid (1-NAA) as a Chemical Thinner**

20 *Role of 1-NAA in plant physiology*

21
22 1-NAA is a synthetic auxin widely used in horticulture for thinning and
23 growth regulation. Although auxins naturally inhibit abscission, synthetic auxins
24 applied externally can induce thinning when applied at certain concentrations
25 and developmental stages (Dennis, 2000). 1-NAA has been used for decades as
26 an effective thinner in apples and pears (Fruk *et al.*, 2017). The mechanism of
27 action of NAA is based on the stimulation of ethylene synthesis taking place in
28 fruitlet tissue. It has also been ascertained that the natural drop of fruitlets is
29 always connected with an increase in ethylene synthesis and evolution
30 (Pesteanu, 2015).

32 *Mechanism of action of 1-NAA chemical thinner*

33
34 1-NAA induces thinning by disrupting normal auxin transport and altering
35 hormonal balance in fruitlets. This disruption can reduce the sink strength of
36 developing fruitlets and increase ethylene production, triggering abscission
37 (Bangerth, 2000). 1-NAA may also reduce photosynthesis and carbohydrate
38 availability, increase fruitlet competition and promote selective abscission of
39 weaker fruitlets (Wertheim, 2000). 1-NAA is known to stimulate ethylene
40 synthesis in plants. Applications of 1-NAA or other synthetic auxins delayed
41 apple fruit abscission even though fruit ethylene production and fruit softening
42 were increased at ripening time (Hudina & Štampar, 2009). According to Milic
43 *et al.* (2017). 1-NAA acts as a thinning agent by reducing the polar auxin
44 transport from lateral fruits in the cluster.

45 1-NAA application causes the inhibition of tree photosynthesis, which leads
46 to a short and vigorous stress at the time of ongoing fruit cell division (Milic *et*

1 *al.*, 2017). 1-NAA functions by reducing the amount of energy available to
 2 developing fruit either by interference with photosynthesis or by the reduced
 3 translocation of metabolites, including photosynthates, from leaves to fruit
 4 (Hudina & Štampar, 2009). Post-bloom application of 1-NAA is cultivar-specific
 5 and may show unwanted side effects, in addition to causing fruit abscission. The
 6 explanation of different responses among cultivars can be directly associated
 7 with their different sensitivities to 1-NAA (Garriz *et al.* 2002). Weather
 8 conditions are strongly involved in the effect of chemical thinners. Leaf uptake
 9 of 1-NAA increases with temperature and is better at low light intensities and
 10 high humidity (Hudina & Štampar., 2009).

11

12 *1-NAA Effects on fruit yield*

13

14 1-NAA thinning often results in reduced fruit number and increased average
 15 fruit weight. Fruit size improvement is a major advantage of 1-NAA application,
 16 especially in cultivars prone to excessive set. However, excessive application
 17 may lead to over-thinning and yield reduction, which can negatively affect farm
 18 profitability (Greene, 2002). 1-NAA has also been reported to increase the risk
 19 of pygmy fruit formation or irregular fruit shape in certain cultivars, although
 20 responses vary widely (Dennis, 2000). In pears, 1-NAA thinning can be
 21 effective, but sensitivity differs among cultivars. Environmental factors such as
 22 high temperatures can increase 1-NAA activity and lead to excessive thinning,
 23 emphasising the need for careful calibration (Wertheim, 2000).

24 No thinning effect was observed in ‘Hosui’ by following application of 7.5
 25 and 15 mg L⁻¹ at 14 dAFB and observed a lack of thinning effect with 8 mg
 26 L⁻¹ 1-NAA applied at 9-mm fruitlet diameter to the cultivars ‘Hosui’ and
 27 ‘Shinko’ (Bound, 2022). Abscission of immature fruits occurs frequently,
 28 varying in magnitude every year depending on fruit set, climatic conditions
 29 during flowering, nutritional status, carbohydrate availability, plant hormonal
 30 balance, or any combination of these factors (Sebek, 2016).

31 Sebek (2016) states that the effectiveness of chemical thinning on the variety
 32 Golden Delicious with the compounds based on 1-NAA does not depend directly
 33 on the concentration of 1-NAA. 1-NAA applied at 20 mg/L at the 5 mm fruitlet
 34 diameter stage was ineffective as a thinner. 1-NAA applied at rates of 10 to 20
 35 mg/L at 8–10 mm fruitlet diameter had no significant thinning effect on
 36 ‘Conference’ pears over three years of trials in Spain (Bound, 2021).

37

38

39 **6-Benzyl-Adenine (6-BA) as a Chemical Thinner**

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41 *Role of 6-BA in plant physiology*

42

43 Cytokinins are plant hormones involved in cell division, growth regulation,
 44 and sink strength enhancement. They play a key role during early fruit
 45 development by promoting cell division, which contributes to final fruit size
 46 (Greene, 2002).

1 *Mechanism of 6-BA in thinning*

2
3 6-BA is a synthetic cytokinin used as a thinning agent, particularly in pome
4 fruits. It is believed to thin fruitlets by altering the balance between cytokinins
5 and auxins, disrupting hormonal signals that support fruit retention (Iglesias *et*
6 *al.*, 2007). In addition, 6-BA may increase competition among fruitlets by
7 stimulating growth of certain fruits, causing weaker fruitlets to abscise
8 (Robinson and Lakso, 2011). Application of 6-BA stimulated ethylene
9 production in both leaves and fruit, but ethylene could not explain 6-BA's mode
10 of action (Costa *et al.*, 2018). 6-BA applications can significantly reduce seed
11 numbers even if only fruit were treated and no thinning occurred (Cline *et al.*,
12 2017). 6-BA may thin fruit by increasing dark respiration and decreasing net
13 photosynthesis. Overall, the mode of action of BA as a chemical thinner remains
14 unclear (Stern, 2015). Mechanisms of 6-BA, based on enhancing the intensified
15 competition among fruits and between fruit and vegetative growth (Chabikwa,
16 2008). 6-BA inhibited net photosynthesis of apple leaves and reduced the
17 carbohydrates available to developing fruit. 6-BA stimulated vegetative growth.
18 6-BA reduce the auxin export of fruit and increases ethylene production in both
19 leaves and fruits (Bound, 2022).

20 21 *6-BA effects on the yield of Forelle pears*

22
23 6-BA is widely associated with increased fruit size, as it stimulates cell
24 division during early development. Studies in apples show that 6-BA improves
25 fruit size and uniformity while reducing crop load (Iglesias *et al.*, 2007). Pear
26 studies are less common, but available research suggests similar potential
27 benefits, including improved fruit size and quality. However, the thinning
28 response of 6-BA can be inconsistent, especially when applied under low
29 temperatures or low sunlight conditions. The compound is often more effective
30 when applied during active fruit growth and favourable metabolic conditions
31 (Greene, 2002). Reported that 200–250 mg/L was effective in reducing fruit set
32 and crop load, as well as the amount of follow-up hand thinning, across multiple
33 cultivars studied; the cost of hand thinning was reduced by up to 50%, saving
34 growers up to USD 2000 per acre (Bound, 2022).

35 6-BA has been reported to thin several pear cultivars, including Clara Frijs,
36 Packham's Triumph and Conference (Greene, 2012). Concentrations of 100 to
37 150 mg/L 6-BA were the most effective at application timings from 11 to 26
38 dAFB. Different levels of thinning according to rate and application time of 6-
39 BA on 'Williams' pear in Argentina, recommending doses equal to or higher than
40 150 mg/L (Bound, 2022). 6-BA applications were made when maximum cell
41 division in pear fruit occurs (Curitti *et al.*, 2010).

42 In Argentina and the USA, confirm the effectiveness of 6-BA application
43 rates of 100 and 125 mg/L on cv. 'Williams' in reducing crop load and increasing
44 the yield per hectare of large fruit (Bound, 2022). Studies on 'Williams' pear in
45 Argentina examining the timing of application of 150 mg/L BA from petal fall

1 (PF) to 28 days after petal fall (dAPF) found significant fruit thinning between
2 4 and 16 dAPF when fruit diameters were between 9 and 19 mm (Bound, 2021).

5 **Environmental and Physiological Factors Affecting Chemical Thinning**

7 The success of chemical thinning is strongly influenced by external
8 environmental conditions and internal tree physiology. Temperature plays a
9 major role, as higher temperatures accelerate metabolic activity and increase
10 chemical absorption, often resulting in stronger thinning responses (Dennis,
11 2000). Light intensity affects carbohydrate availability, and cloudy conditions
12 can reduce photosynthesis, increasing fruitlet sensitivity to thinning chemicals
13 (Robinson and Lakso, 2011). Tree vigour also influences thinning effectiveness.
14 Vigorous trees often have higher carbohydrate reserves and may show reduced
15 thinning response compared to weak trees. Additionally, orchard practices such
16 as pruning intensity, irrigation scheduling, and fertilisation affect tree balance
17 and fruit retention (Wertheim, 2000).

18 Optimal application timing is referred to fruit diameter, it is subject to
19 suitable temperature conditions because lower levels of thinning were achieved
20 when temperature was low (Bregoli *et al.*, 2007). Therefore, it is recommended
21 to give priority to temperature (18°C or higher) rather than precise fruit size at
22 the time of application (Maas, 2005). Temperature may affect the absorption of
23 the thinning compound (Dussi, 2010). Most of the 6-BA uptake takes place in
24 the initial 8 hours after application (Li *et al.*, 2005) and 6-BA penetration into
25 leaves was linear with increase in temperature from 15 to 35°C. Absorption into
26 leaves is via the abaxial surface rather than the adaxial surface (Cortens & Cline,
27 2019).

30 **Effects of Postbloom Chemical Thinners on Fruit Size**

32 *6-BA*

34 Fruit size is a primary commercial quality parameter for pears. Proper
35 thinning increases average fruit weight by reducing competition among fruitlets.
36 The remaining fruits receive a greater carbohydrate supply, allowing improved
37 cell division and expansion (Byers, 2003). 6-BA appears to have several
38 advantages over the other commonly used chemical thinners: it may increase
39 fruit size in addition to that attributed to reduced crop load, and it is unlikely to
40 have adverse effects on beneficial mite predators (Dennis, 2002). 6-BA is a
41 steadier and more effective compound for pears and apple fruit thinning because,
42 despite the reduction of yields, it increases fruit size and provides feedback
43 flowering (Sebek, 2016). Sebek (2016) reported that the use of 6-BA increases
44 the fruit size even in the absence of fruit thinning. Increasing the size of the fruit
45 6-BA is realized through stimulation of cell division (Tang *et al.*, 2025).

1 Application of 6-BA was the most effective when the central apple fruit was
2 10 mm in diameter (Sebek, 2016). 6-BA is more effective in thinning when
3 applied to the leaf, rather than to the fruit (Dennis, 2002). 6-BA increases in fruit
4 size (weight and diameter), and firmness caused by ABA were reversed (Greene,
5 2012). 6-BA increases fruit size indirectly by reducing competition among fruits
6 and directly by stimulating cell division within the fruit (Dreyer, 2013).
7 Penetration of BA into the fruit is considerably higher than penetration into the
8 leaves. Reported that 6-BA improved fruit size in apple because of an increased
9 cell division rate (Xie *et al.*, 2020). Effective concentrations of BA employed
10 cover a range of 50 to 200 mg/L and depend on the cultivars to be treated. The
11 best application time coincides with a fruitlet diameter of 8 to 12 mm (Curetti *et*
12 *al.*, 2010).

13 14 *1-NAA*

15
16 Fruitlet thinning is one of the most important management practices a
17 commercial grower is required to perform to produce high-quality pears (Hudina
18 and Štampar, 2009). Improvements in fruit size and total yield were also obtained
19 by using 1-NAA chemical thinner. The results suggest that this is the best form
20 of auxin to be used for fruit thinning and increasing the fruit size (Gonkiewicz
21 *et al.*, 2011). The timing of thinning strongly influences fruit development. Fruit
22 thinning at an early stage of fruit development improves fruit size and reduces
23 biennial bearing in apples (Hudina and Štampar, 2009). Fruit thinning at an early
24 stage of fruit development improves fruit size, colour and quality at harvest,
25 while increasing return bloom the following year and thus reducing biennial
26 bearing (Hudina and Štampar, 2010). Varying response among cultivars can be
27 directly associated with their differing sensitivities to 1-NAA. 1-NAA is known
28 to stimulate ethylene synthesis in plants (Hudina and Štampar, 2010). Chemical
29 thinning agents have been evaluated for their ability to reduce crop load earlier
30 and more cost-effectively than conventional hand-thinning, increasing fruit size
31 and on European pear cultivars (Theron *et al.*, 2010). 1-NAA application causes
32 the inhibition of tree photosynthesis, which leads to a short and vigorous stress
33 at the time of ongoing fruit cell division (Milic *et al.*, 2017).

34 35 *S-ABA*

36
37 The application of S-ABA chemical thinners to pears enhances the fruit
38 thinning, and the remaining fruit becomes bigger in size. S-ABA has also been
39 associated with increased ethylene production and abscission of peach when
40 treated at pit hardening. S-ABA significantly thinned 'Bartlett' pears (Arrington
41 *et al.*, 2014). For a given S-ABA dose, however, the rate of thinning varied
42 among years (Arrington *et al.*, 2014). Greene (2012) reported consistent thinning
43 when applying ABA to single limbs of mature 'Bartlett' pear trees at similar
44 concentrations. S-ABA application 300 mg L⁻¹ resulted in significant
45 reductions in fruit set, number of fruits, number of fruits per spur, crop load, and
46 improvement in fruit size, but decreased yield and crop value (Cline *et al.*, 2017).

1 According to Bound (2021), responses to S-ABA application differed by
2 region and year and reported inconsistent results over the three years of their
3 study on cvs. ‘Cold Snap™’ and ‘Bosc’, but did find that 300 mg/L had a
4 greater thinning effect and increased fruit size than 150 mg/L. Most presently
5 used commercial thinners thin insufficiently if applied just once; thus, sequential
6 application of thinners is appropriate to achieve the optimum final cropload
7 (Wertheim, 2000). Therefore, ABA may be useful as a thinner when applied at
8 different times (Greene, 2012). Bound (2022) reported that the S-ABA increased
9 fruit weight, flesh firmness, and soluble solids in ‘Bartlett’. The application of
10 S-ABA in pears is promising to increase the fruit thinning and improve the size
11 of the remaining fruit at harvest.

12
13

14 **Combination of 1-NAA and 6-BA chemical thinners on Pears**

15

16 The combination spraying of 6-BA and 1-NAA is sometimes recommended
17 to get a stronger thinning response or to use lower rates of each thinner
18 (Pesteanu, 2015). The combined use of thinning compounds may result in more
19 intensive thinning compared to a single application of plant regulators. The
20 combination of 1-NAA and 6-BA has the most excessive thinning impact on
21 ‘Empire’ (Šebek, 2015). According to Šebek (2015) reported that the combination
22 of 1-NAA and 6-BA has the most excessive thinning impact on ‘Empire’.
23 Applications of 150mgL⁻¹ of 6-BA, 1-NAA, significantly reduced total fruit
24 yield and number of fruits per tree but increased fruit weight compared with the
25 untreated control (Cline *et al.*, 2017).

26 With the cultivar ‘Summerred’, a combination of the two compounds, leads
27 to an increase in fruit size, and inhibits the development of the fruit in the cultivar
28 ‘Delicious Red Chief’ and the cultivar ‘Fuji’ (Šebek, 2016). In cultivar ‘Prima’
29 combined use of BA 60 ppm + NAA 5 ppm and 140 ppm 6-BA + NAA 5 ppm
30 influenced the increase of the number of fruits with a diameter >65 mm (Šebek,
31 2016). Šebek (2016) states that it is very difficult to adequately apply the process
32 of thinning in spur varieties such as ‘Red Delicious’. 6-BA + 1-NAA
33 combination to comply with the legal limits for pear and obtain a good thinning
34 effect. According to our findings, the 6-BA+1-NAA mixture could be a
35 promising option for ‘Conference’ and ‘Blanquilla’ orchards, allowing to
36 increase 1-NAA concentration while maintaining the 6-BA one. In conclusion
37 both bioregulators alone or in combination represent an interesting tool for fruit
38 thinning of ‘Conference’ and ‘Blanquilla’. However, further work is necessary
39 to pinpoint the effect as related to the different concentration of 6-BA and 1-
40 NAA (Asín *et al.*, 2009).

41
42

43 **Chemical Thinning in South African Pear Production**

44

45 South Africa is a major exporter of pears, with the Western Cape being the
46 primary production region. The export market demands high-quality pears with

1 good size, uniformity, and appearance. Chemical thinning is therefore an
2 important practice in South African pear orchards, particularly for cultivars such
3 as Forelle. Despite its importance, limited published research exists on chemical
4 thinning in South African pear cultivars. Many thinning recommendations are
5 based on apple research or adapted from international pear studies. Climatic
6 conditions in South Africa, such as warm spring temperatures and variable
7 rainfall, may influence thinning responses differently compared to European or
8 North American conditions. This creates uncertainty regarding the optimal use
9 of S-ABA, 1-NAA, and 6-BA for Forelle pears. The local research is required to
10 determine effective concentrations, application timing, and expected impacts on
11 yield and fruit size increase under South African orchard systems.
12
13

14 **Research Gaps and Justification for the Study**

15
16 Chemical thinning has been widely studied in apples, fewer studies focus
17 specifically on pears, and even fewer address Forelle pear thinning responses.
18 Research comparing the effectiveness of S-ABA, 1-NAA, and 6-BA under
19 similar orchard conditions is limited. Furthermore, there is inadequate
20 information regarding the combined effects of these chemicals on key fruit
21 quality parameters such as firmness, SSC, fruit size distribution, and colour
22 development. In South Africa, cultivar-specific recommendations are
23 particularly important due to the export-driven nature of the pear industry.
24 Forelle pears require consistent size and high-quality external appearance to
25 meet export standards. The limited scientific data on chemical thinning strategies
26 for Forelle pears highlights the need for research evaluating the performance of
27 these chemical thinners. This study, therefore, aims to assess the effects of S-
28 ABA, 1-NAA, and 6-BA on crop load reduction and fruit size of Forelle pears,
29 contributing valuable knowledge for both scientific understanding and practical
30 orchard management.

31 **Summary**

32

33 Fruit thinning is a critical orchard practice that improves fruit size, quality,
34 and consistent annual production. Chemical thinning offers a practical
35 alternative to manual thinning by reducing labour costs and improving thinning
36 efficiency. The effectiveness of chemical thinners is influenced by hormonal
37 regulation, environmental conditions, cultivar sensitivity, and tree physiological
38 status. S-abscisic acid promotes abscission through stress-related hormonal
39 responses and ethylene sensitivity. 1-NAA disrupts auxin transport and
40 carbohydrate balance, leading to fruitlet drop. 6-BA acts through cytokinin
41 pathways, influencing sink strength and fruitlet competition. All three chemicals
42 have potential to improve Forelle pear fruit quality by reducing crop load and
43 improving fruit development.

44 However, limited research exists on the comparative performance of these
45 chemicals in Forelle pears under South African conditions. The present study
46 addresses this gap by evaluating their effects on yield and fruit quality

1 parameters, contributing to improved thinning recommendations for commercial
2 Forelle pear production.

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