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Alleviation of frost damage to pear flowers by application of gibberellin

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Abstract

Adverse effects of gibberellin applications on pear trees after frost such as small fruit size, abnormal fruit shape and poor return bloom are often attributed both to the sole use of GA_3 and its overdose. It is unclear whether protection against spring frosts before flower opening is more efficient when GA is applied directly after frost, i.e. before flower opening, or at full bloom or both. In April 2003, early spring frosts at Klein-Altendorf near Bonn, Germany damaged ca. 88% flowers of the early flowering cv. Alexander Lucas, 64% of cv. Conference and ca. 25% of flowers of the later flowering cv. Comice pears. Hence, the objective of the present work was to investigate the optimum timing of the application of low doses of the combined GA_3 and GA_{4+7} to improve parthenocarpic fruit set in pears, while maximising fruit quality and size for trees affected by a severe spring frost before full bloom. Return bloom was also considered and quantified. Frost-affected pear trees were treated with gibberellin $GA_3 + GA_{4+7}$, either immediately after the frost, at the white bud stage, or at full bloom or both to improve parthenocarpic set. Early flowering cv. Alexander Lucas pear was most affected by the early spring frost, but lost only 25% of fruitlets at June drop, irrespective of GA treatment. June drop was, however, severe in the two other cultivars least affected by frost, i.e. by 33% in cv. 'Conference' and 55% in cv. Comice. Both initial and final fruit set were significantly increased by a combined application of $GA_3 + GA_{4+7}$ at full bloom, without affecting return bloom, but June drop was also enhanced by GA application. The largest positive effect of GA application on fruit yield, an additional 2 kg of fruit per tree equivalent to € 1200/ha, was apparent with the cv. Alexander Lucas, i.e. the cultivar most affected by frost. There was no loss in fruit quality viz fruit size after any of the GA applications with any of the pear cultivars examined and no increase in abnormally-shaped, elongated fruit.

Introduction

Parthenocarpy, i.e. fruit set without pollination or fertilisation, is common in banana, fig, grape, persimmon, pineapple, and pear. In a fertilised fruitlet, the seeds naturally synthesize gibberellins, which enable fruit set (Luckwill et al. 1969). Luckwill (1961) first applied exogenous 'gibberellic acid', later identified as GA_3, to overcome frost damage in flowering pear. This application induced and stimulated the natural tendency of pear to set parthenocarpic unseeded fruits, thereby ensuring a harvest despite frost. Luckwill (1960) and Modlibowska (1961) concomitantly showed that gibberellic acid can induce parthenocarpic fruit set in pears when applied to flowers in which pollination had been prevented by excision of the styles due to spring frost.

Adverse effects of exogenous gibberellins such as small fruit size (Browning 1990; Honeyhome 1996), reduced fruit quality (elongated fruit with protuberant calyx; Luckwill 1961) and poor return bloom (Wertheim and Bootsma 1992; Greene 2000) are now attributed both to the use of GA_3 alone and to higher concentration (> 100 ppm; Wertheim and Bootsma 1992). The discovery of other physiologically active gibberellins led to the identification of GA_4 and GA_7 (Dennis and Nitsch 1966). Using a mixture of GA_3, GA_4 and GA_7 containing smaller doses of each gibberellin has resulted in fruit set in the year of application as well as the subsequent year. However, it remains unclear, if exogenous GA show better efficacy when applied directly after frost, i.e. before flower opening, or at full bloom, or before and at full bloom.

In April 2003, the opportunity to evaluate early GA application arose when a spring frost occurred before flowering. The objective of the present work was to investigate the optimum timing of the application of new lower doses of the combined GA_3 and GA_{4+7}. The overall objective remains to improve parthenocarpic pear fruit set of trees exposed to a spring frost before full bloom, while ensuring good fruit size, yield and quality, along with return bloom. Three pear cultivars with different flowering times were selected.

Materials and methods

Seventeen-year-old pear trees of cvs Alexander Lucas, Conference and Comice on quince C rootstock, planted at a spacing of 3.6 × 1.5 m, were exposed to four frosts between 5th and 10th April 2003 at white flower bud stage (BBCH scale 54 for A. Lucas and BBCH 57 for Conference and Comice) at Klein-Altendorf Fruit Research Station of Bonn University, Germany. All three pear cvs were treated with a gibberellin combination of 4 g a.i./ha GA_3 (40 g /ha $GIBB_3$) and 5 g a.i./ha GA_{4+7} (500 ml/ha GIBB Plus) before (8 April 2003) and at flowering (16 April 2003). The first gibberellin treatment before flowering was applied after two frost events down to −6.7 °C which was followed by a further frost of similar severity (Table 1).

Data assessment on the pear trees and statistical analysis

Thirty-two pear trees were selected for uniformity of size and blossom with eight trees per gibberellin treatment. Two horizontal, central branches on each of the thirty-two pear trees of each cultivar were chosen at random for initial and final fruit set counts. Return bloom was assessed in May 2004 on eight entire trees using a scale of 1–9 with 1 being a poor and 9 a strong bloom. Data were subjected to a one-factorial analysis of variance, and significant differences were determined as LSD at the 5% level based on Duncan's *t*-test.

Results

Aborted pear flowers due to spring frost

Frost damage in April 2003, when averaged over the lower (< 1 m) and upper (> 1 m) tree, amounted to 88% of the flower pistils for the cv. Alexander Lucas, 64% for 'Conference' and 25% for 'Comice' all on quince C rootstock (Figure 1). Therefore, particular attention was drawn to cv. Alexander Lucas due to the large amount of frost damage for which the induction of parthenocarpic fruit set would be most beneficial. While frost

Table 1. Gibberellin treatments on cv. Alexander Lucas, Conference and Comice pears.

Treatment	Application date	Flower stage*
Before flowering	8 April 2003 before beginning of flowering	BBCH 57 – 59
Before and at full bloom	8 + 16 April: 1 + 10 days later at the beginning of flowering (30–40% open flowers)	BBCH 57 – 59 + BBCH 63 – 65
At full bloom	16 April at the beginning of flowering (40% open flowers)	BBCH 63 – 65
Control	n/a	n/a

n/a – not applicable, * flower stages refer to cv. Alexander Lucas pears.

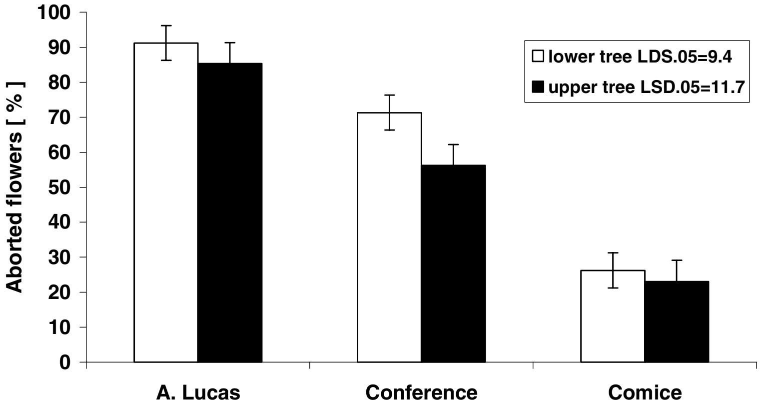

Figure 1. Effect of a late spring frost in April 2003 upon the number of aborted flowers in pear cvs Alexander Lucas, Conference and Comice recorded on 20 April 2003.

damage significantly differed between the three pear cultivars used. No statistical differences were observed in the pre-bloom frost damage between the upper (> 1 m) and lower (< 1 m) canopy for the cvs Alexander Lucas and Comice (Figure 1). However, only for 'Conference' were flowers on the lower part of the tree more severely affected by the late spring frost than in the upper 1 m (Figure 1).

The number of flowers remaining on the pear trees was inversely related to the frost damage (Figure 1).

Effects of timing of the gibberellin application on initial fruit set before June drop

Both applications of the combined GA_3 and GA_{4+7}, i.e. (i) before as well as at full bloom and (ii) at full bloom only, significantly increased initial fruit set (Figures 2–4), irrespective of cultivar employed, confirming the high efficacy of the gibberellin application. However, the single application before full bloom showed the least effect which was presumably due to the lower sensitivity of the receptacle to gibberellin at this early stage. The LSDs given in each figure were calculated for each pear cultivar.

Effects of GA on final fruit set in pear after June drop

Final fruit set data for the cvs Alexander Lucas, Conference and Comice are similar to those obtained when measuring initial fruit set

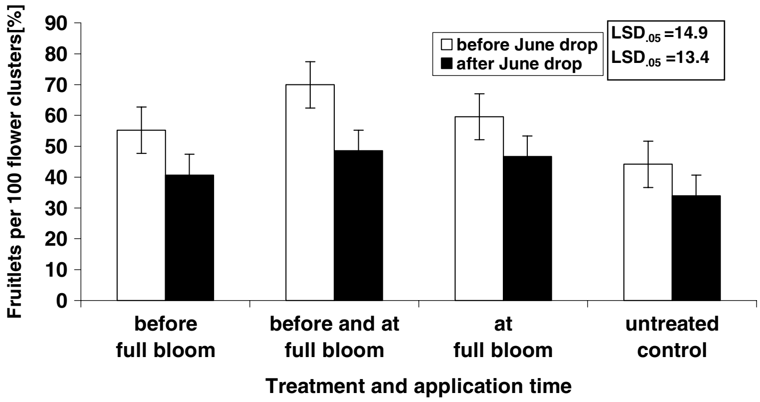

Figure 2. Effects of timing of gibberellin application on initial and final fruit set of pear cv. Alexander Lucas.

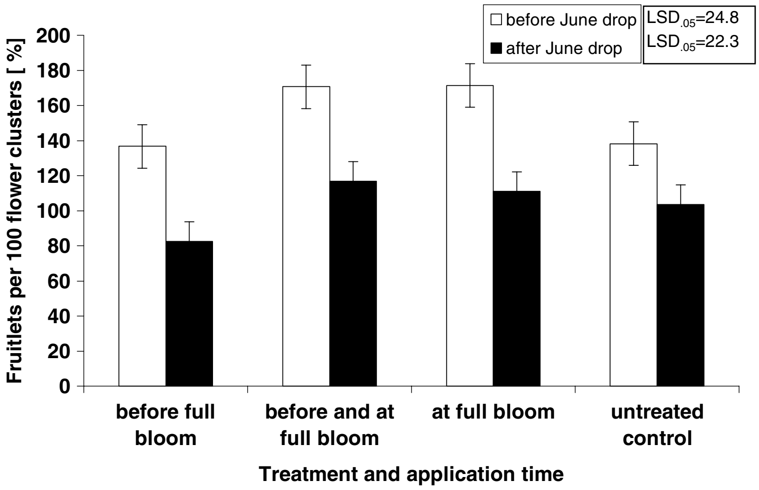

Figure 3. Effect of timing of GA application on initial and final fruit set of pear cv. Conference.

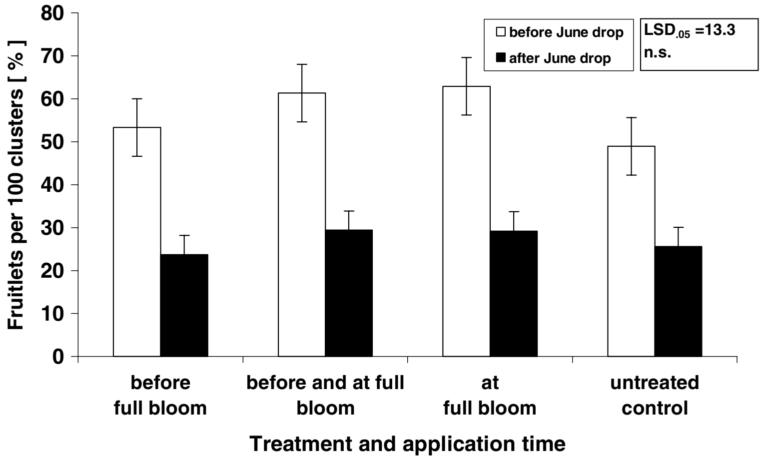

Figure 4. Effects of timing of GA application on initial and final fruit set of pear cv. Comice.

(Figures 2–4). This indicates that both gibberellin treatments, i.e. (i) before as well as at full bloom and (ii) at full bloom only, significantly increased final fruit set for the cv. Alexander Lucas and, to a lesser extent, for cvs Conference and Comice. The positive effect of dual applications – before and at full bloom – was attributed largely to the full bloom application which gave the same efficacy as the two applications before and at full bloom (Figure 4).

The largest June fruit drop was observed for the cultivar least affected by frost, i.e. a 55% reduction for cv. Comice (Figure 4), followed by a 33% loss for the cv. Conference (Figure 3). Interestingly, around 25% fruitlets of the severely frost affected cv. Alexander Lucas were lost by June drop in the absence of any significant differences between GA-treated and un-treated control trees (Figure 2). This indicates an inverse correlation between frost damage and June drop, i.e. frost damaged pear cultivars were less prone to June drop. This can be explained by the tree's capacity to sustain only a maximum number of fruit due to carbon and other limitations.

Effects of GA on fruit yield, fruit size and fruit quality

Fruit yields were around 18 kg/tree in the most frost affected cv. Alexander Lucas (Figure 5), 20 kg/tree for the cv. Comice and up to 25 kg/tree for the cv. Conference (data not shown). All three applications of the combined GA_3 and GA_{4+7}, i.e. (i) before full bloom, (ii) before as well as at full bloom and (iii) at full bloom only, increased fruit yield by ca. 2 kg/tree with a financial net gain of ca. € 1200 /ha. Treated pears retained good fruit quality in terms of fruit weight and size (Figure 5) without any significant increase in small or abnormally shaped fruit (data not shown) and without adversely affecting return bloom (Figure 6). The most positive effect of the gibberellin application on fruit yield relative to the untreated control was observed in cv. Alexander Lucas, i.e. the cultivar most affected by frost, in line with the fruit set results.

Return bloom

Return bloom varied from 5.4 units for the cv. Alexander Lucas when gibberellins were applied before full bloom, 5.46 with the dual application to 6.1 units when applied at blossom. There were no statistically significant differences in return bloom

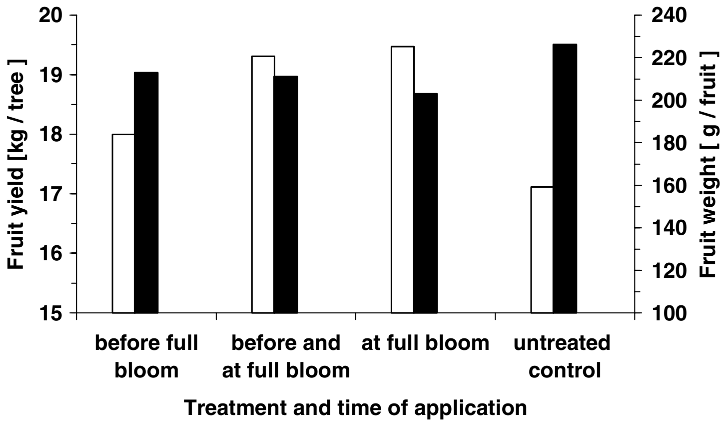

Figure 5. Fruit yield (left) and fruit weight (right columns) in cv. A. Lucas pears.

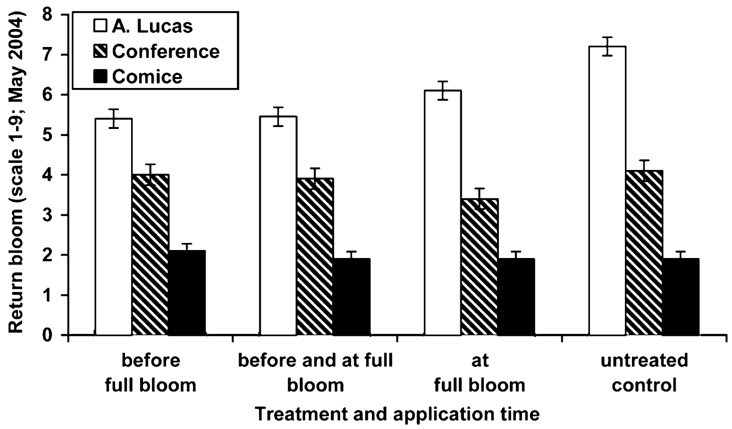

Figure 6. Return bloom on a 1 (poor) to 9 units (strong bloom) scale in May 2004 in pears cvs Alexander Lucas, Conference and Comice (n.s.).

between the three gibberellin treatments (Figure 6). These results were similar to those obtained with the other two cultivars which ranged from 3.4 to 4.1 for cv. Conference. In cv. Comice, the return bloom ranged from 1.9 in the control to 2.1 in the GA_3 and GA_{4+7} treatments applied before flowering (Figure 6).

Discussion

The positive effect of a combined application of GA_3 and GA_{4+7}, used directly after relatively severe frosts before full bloom, was to increase initial fruit set in three pear cultivars which is similar to the results of Luckwill (1960, 1961). In his work, GA_3 was applied to the pear cvs Bristol Cross, Laxtons Superb and Williams at Long Ashton after their ovules were affected by a mild frost of −2.8 °C at flowering. Luckwill (1961) also observed the least efficacy of the GA_3 when applied at the white-bud stage before full bloom as compared with the full bloom application, when mild frosts occurred at Bristol.

The combined application of GA_3 and GA_{4+7} was successful to overcome problems with return bloom (Figure 6). The positive effects on fruit set of both applications, before and at full bloom (Figures 2–4), was attributed exclusively to the latter application, which gave the same efficacy, and reflected the different magnitude in June fruit drop (Figures 2–4). The most promising effect of the combined $GA_3 + GA_{4+7}$ as a single application was apparent with the early flowering and the most frost affected cultivar Alexander Lucas, which gave a 35% and 37% increase in initial and final fruit set, respectively (Figure 2). Final fruit set of the less frost affected cultivars Conference and Comice increased by 7% or 14%, respectively.

Dual application of $GA_3 + GA_{4+7}$, before and at flowering, did not significantly improve fruit set (Figures 2–4). Final fruit set was increased in cv. Alexander Lucas by 43%, by 13% in 'Conference' and by 15% in 'Comice'. This confirms that gibberellin treatments before pollination increase fruit set of both self- or non-pollinated flowers of cv. Le Lectier by 30% (Yamada et al. 1991).

An application of 200 ppm GA_4 by Inomata et al. (1992) on flowers of Japanese pear, whose pistils and ovaries were affected by a −5 °C frost, increased fruit set. However, the high dosage of a single gibberellin decreased fruit size and increased abnormal calyx shape. In our work, the application of the combined GA_3 and GA_{4+7} achieved all five goals, improved fruit set and yield after a spring frost with a retention of good fruit size and quality as well as no loss of return bloom. An additional benefit of such a gibberellin application includes less bacterial *Pseudomonas* infection in wet weather conditions during flowering, as observed with gibberellin application after spring frosts in late March 2002 in Klein-Altendorf (Kunz and Blanke 2002, unpublished).

Conclusion

It is concluded that pear cultivars seriously affected by spring frost adapt by reducing their June drop and those less affected by frost enhance their June drop without exogenous gibberellins. However, initial and final fruit set as well as fruit yield can be significantly increased after an early spring frost prior to flowering by application of the combined GA_3(4 g) + GA_{4+7}(5 g a.i./ha) at reduced dose at blossom (30–40% petals open) yielding good fruit quality and fruit size as well as return bloom, in spite of increased June drop.

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