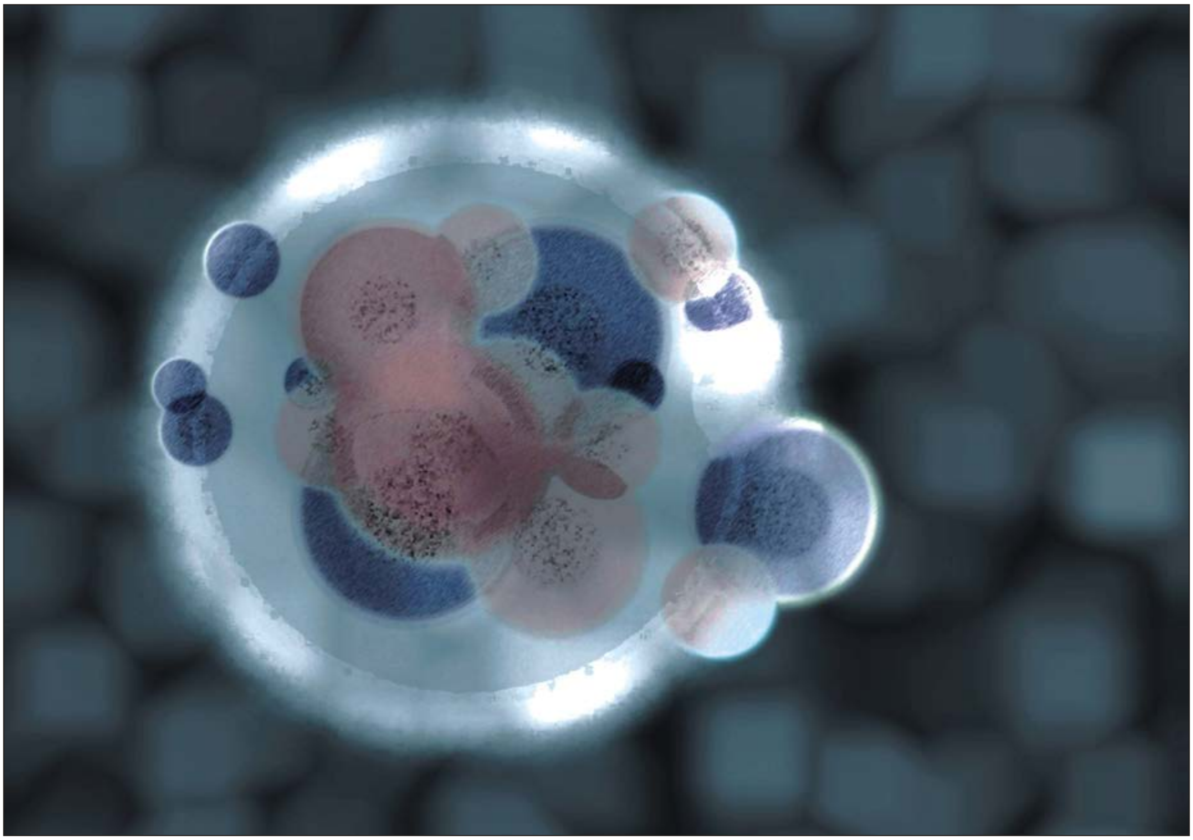

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Use of Gibberellins to Improve Fruit Set in Pears After Frost Damage

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Abstract: The objectives of this study were to investigate the effect of applied bioregulators on fruit set after this frost in April 2002, growth, yield and the incidence of *Pseudomonas syringae* and the understanding of the underlying mechanisms of fruit set by applying bioregulators shortly after full bloom at the Klein-Altendorf experimental station near Bonn, Germany with the following results. The best fruit set was achieved with both GA_3 and GA_3 plus 0.5l GA_{4+7} sprayed at 12 mL ha^{-1} which increased initial fruit set by 78 and 77%, respectively as compared to unsprayed control with 32% while it was GA_3 (105%) followed by the combination of GA_3, Promalin and Azolon (100%) after June drop. The second-best fruit set was in GA_3 plus 0.25l of GA_{4+7} and Azolon sprayed at 12 mL ha^{-1}. Azolon reduced fruit set before and after June drop. Repeat applications of the treatments did not generally improve the results of fruit set after June drop. It is concluded that GA_3 or combined with GA_{4+7}, successfully improved fruit set, shoot growth, reduced the incidence of *Pseudomonas syringae* and rescued the yield showing that the mechanism is via development of parthenocarpic fruit.

Key words: Frost damage, fruit set, plant growth regulators, parthenocarpic, shoot growth, disease

INTRODUCTION

In dormant flower buds of fruit trees, freezing injury is initiated within the bud scales and the tissues subtending the developing floral organs. Formation of ice crystals within the bud axis and scales result in the formation of a water potential gradient within the bud tissues (Ashworth, 1982). Freezing injury can occur in plants only after thawing of the ice crystals within the plasma membranes.

Water is withdrawn from the developing floral organs and pedicel region and migrate to the growing ice crystals within the bud axis and scales. In the dormant flower buds water inside them supercool as a result of structural, morphological and physiological mechanisms. As flower buds break their dormancy and resumed development in the spring, their capacity to deep supercool is lost (Ashworth, 1982) and cold hardiness progressively diminishes (Proebsting, 1963). Eventually, the open flower viz., ovary completely lose their capacity to survive subfreezing temperatures and are killed as soon as ice formation is initiated.

Freeze damage affects many fruit crops in the temperate world. Some degree of crop damage (i.e., fruit loss) occurs almost every year in some location. Because of its relatively big size, pears need fewer flowers to set fruit to attain fair to excellent commercial yields compared to small fruits. Therefore a mild freeze that only slightly damages flowers can result in economic losses. A means of reducing pear fruit losses due to freeze injury would have immediate impact.

Four categories of parthenocapy exist. Pear is categorised as vegetative or-facultative parthenocarpic and can be induced by exogenous gibberellins (Honeyborne, 1996). In pears it has been reported that the king flower pedicels left *in situ* on the tree after removal of pear flowers of the facultative parthenocarpic variety Conference sprayed at blossoming with GA_3, expand into fruit-like structures (Goldwin, 1978). Inomata *et al.* (1992) observed that the type of parthenocarpy in pears especially Conference is different from that of other fruits since the presence of ovule is not essential for hormone-induced parthenocarpic development.

The objectives of this study were to investigate the effect of bioregulators on fruit set, growth, yield and the incidence of *Pseudomonas syringae*. The hypothesis was that gibberellins can improve growth and fruit set and hence yield of pears after a frost damage at flowering.

MATERIALS AND METHODS

Study area, pears and their cultivation: The studies were conducted at the Klein Altendorf Experimental Station of the University of Bonn, Germany in April 2002. The station receives an average monthly rainfall of 615 mm and average daily temperatures of 41° celcius and the soil temperatures are on average 11.7° celcius and the soil type is luvisol on sandy loams with a pH of 6.8-6.9. The study was carried out on Pear trees cv. Alexander Lucas on Quince rootstocks. The pears had been planted in 1987 at a spacing of 3.5×1.5 m in single rows.

Treatments: Frost occurred on the days 26th March and 27th March when the temperatures were -2.5 and -3.5°C, respectively and on 8th, 9th and 19th April 2002 when the temperatures were -1.7, -2.0 and -1.5°C, respectively. Bioregulators showed in Table 1 were applied on a clear, still day with a water dosage of 600 L ha^{-1}, at full blossom (BBCH stage 63) to whole trees on 7th April 2002. The weather at the time of spraying, i.e., 11 AM-1PM German time, was: temperature of 10°C for 3 h, relative humidity of 42% for 3 h and maximum wind speed between 1-4 m sec^{-1}.

Due to the occurrence of another frost damage after the first spraying a repeat application was conducted on 12th April 2002. The spraying was also done on a clear, sunny day. The weather was temperature of 18°C for 2 h, wind speed of 4 m sec^{-1} and a relative humidity of 60%. for 2 h.

Fruit set and yield: Fruit set was determined on two uniform branches on selected pear trees one month after the application of the gibberellin analogues, while the second count was determined after June drop and also expressed per 100 blossoms. Fruit yield per tree was done by weighing the fruits in a weighing scale (Mettler Instrument Corp., Toledo, Klein, Germany).

Incidence of *Pseudomonas syringae*: The incidence of *Pseudomonas syringae* was monitored and related to the performance of the treatments. Rating of the disease among the experimental trees was done visually on a scale of 10 to 100, where 10 represented least occurrence and 100 most occurrence and statistically processed.

Number of shoots: The number of shoots was counted for each experimental tree.

Statistical analysis: The treatments were laid out in a completely randomised block design comprising 9 tree replicates per treatment. The first and second application were tested for interactions and none found for the initial fruit count Statistical analysis was done by SPSS version 9.0 (SPSS Inc., USA). The two-factorial experiment was treatment x date of application. Analysis of variance and separation of means was done using the LSD at the 5% level based on Duncan's t-test. Statistical analysis for the first fruit set counts (before June drop) showed no significant interaction with the second date of treatment so the two sets of data were pooled and analysed together. The reverse happened for the fruitlet counts after June drop when there were significant differences between the two application dates. Final fruit set data was subsequently analysed separately.

Table 1: Treatments and concentrations

Treatments	Concentration (mL ha^{-1})
GA_3 + 0.5l GA_{4+7}	12
GA_3	10
GA_3 + 0.25 mL/GA_{4+7}	10
Azolon (26% N) (old formulation)	120
GA_3 + 0.5l GA_{4+7} + Azolon	12
GA_3 + Azolon	12
GA_3 + Promalin + Azolon	12
Unsprayed control	N/a

RESULTS

The freeze damage to the flower was estimated at 46% after the last frost in April. The flower parts were seriously damaged. For some trees the flower petals and sepals were damaged but not the ovary.

The treatments were applied on two different dates necessitated by the recurrence of frosts after the previous application of the treatments.

The T_1 had the largest number of fruit lets which was not significantly different from T_2 and T_7 but significantly different from all the other treatments. Azolon had the least number of fruit lets (Table 2). The repeat applications did not generally improve fruit set, save for T_4, T_5 and T_6. On the first date of application, the treatments with the largest number of fruit lets were T_7 and T_2 and there was no significant difference between them. However, they had significantly larger number of fruit lets than all other treatments (Table 3). A part from T_1 all the other treatments had very few fruit lets. On the repeat application the treatments with larger number of fruit lets were T_1, T_2, T_4, T_5 and T_7 (Table 3) but there were no significant differences between them.

On the first application T_1 and T_7 had significantly higher fruit yields than the unsprayed controls while T_4, T_5 and T_6 were not significantly different from the unsprayed controls in yields (Table 3). The decreasing order of yields among the treatments was T_1, T_3, T_2, T_7 on the first application. On the repeat applications the yield trends in decreasing order were: T_1, T_2, T_3 and T_7 (Table 4). Most of the treatments in the repeat application were significantly different from each other.

All the treatments significantly reduced the occurrence of *Pseudomonas Syringae* as compared to the unsprayed controls T_1 had the best disease control which was significantly higher than all the rest of the chemical treatments which had similar disease control level (Table 5).

The treatments which had significantly greater shoot growth as compared to the unsprayed controls were T_1, T_7 and T_4, on the first application. In the repeat application

Table 2: Effect of treatments on the initial fruit set of pears at Klein Aldendorf Station, near Bonn, in the year 2002

Treatments	No. of fruit lets in first and repeat application
GA_3 + GA_{4+7}	77.00
GA_3	58.00
GA_3 + Promalin	40.00
Azolon	22.00
GA_3 + GA_{4+7} + Azolon	61.00
GA_3 + Azolon	50.00
GA_3 + Promalin + Azolon	74.00
Unsprayed control	32.00
LSD ($p \leq 0.05$)	28.32

Table 3: Effect of date of application of treatments on the number of fruits of pears after Jnne drop at Klein Altendorf Station, near Bonn, in the year 2002

	No. of fruit lets	
Treatments	First application	Repeat application
GA_3 + GA_{4+7}	68.00	69.00
GA_3	108.00	80.00
GA_3 + Promalin	30.00	22.00
Azolon	10.00	60.00
GA_3 + GA_{4+7} + Azolon	22.00	60.00
GA_3 + Azolon	20.00	56.00
GA_3 + Azolon + Promalin	100.00	80.00
Unsprayed control	05.00	10.00
LSD ($p \leq 0.05$)	25.69	27.10

Table 4: Effect of treatments on yield per tree (kg) of pears at Klein Altendorf Station near Bonn, in the year 2002

	Yield	
Treatments	First application	Repeat application
GA_3 + GA_{4+7}	6.40	1.30
GA_3	4.40	6.80
GA_3 + Promalin	5.00	5.60
Azolon	0.50	0.60
GA_3 + GA_{4+7} + Azolon	0.70	0.80
GA_3 + Promalin + Azolon	2.00	2.70
GA_3 + Azolon	0.50	0.70
Unsprayed control	0.40	0.30
LSD ($p \leq 0.05$)	0.42	0.40

Table 5: Effect of treatments on disease occurrence of pears at Klein Altendorf Station near Bonn, in the year 2002

	Mean disease occurrence	
Treatments	First application	Repeat application
GA_3 + GA_{4+7}	0.80	1.00
GA_3	2.80	3.50
GA_3 + Promalin	3.50	3.20
Azolon	3.70	4.90
GA_3 + GA_{4+7} + Azolon	3.30	3.40
GA_3 + Promalin + Azolon	2.40	3.60
GA_3 + Azolon	3.40	3.30
Unsprayed control	6.30	8.00
LSD ($p \leq 0.05$)	1.02	1.06

all the treatments a part from T_1 and T_3 had significantly greater shoot growth than the unsprayed controls (Table 6). Repeat application of the treatments improved shoot growth some what.

Table 6: Effect of date of application of treatments on the number of shoots of pears at Klein Altendorf Station in the year 2002

	No. of shoots	
Treatments	First application	Repeat application
GA_3 + GA_{4+7}	95.00	60.00
GA_3	105.00	80.00
GA_3 + Promalin	85.00	60.00
Azolon	55.00	80.00
GA_3 + GA_{4+7} + Azolon	45.00	70.00
GA_3 + Promalin + Azolon	40.00	72.00
GA_3 + Azolon	20.00	75.00
Unsprayed control	20.00	40.00
L. S. D. ($p \leq 0.05$)	28.95	25.30

DISCUSSION

The treatments with GA_3 alone or combined with GA_{4+7} and/or when combined with Azolon increased fruit set of the frost-damaged pears. The increase of fruit set in the freeze damaged pears by gibberellins, indicates that they promote set and development of parthenocarpic fruit confirming the categorisation of pear as a facultative vegetative parthenocarpic fruit (Honeyborne, 1996).

Repeat applications of the chemicals did not yield better results particularly GA_3 and GA_3 plus GA_{4+7} confirming the works of Werthein and Bootsma (1992) who observed no increase in fruit set of conference pears after 3 GA_3 applications, thereby minimising cost and chemicals. The treatments containing Azolon and Azolon alone were improved but still worse than GAs alone and more costly by the repeat applications.

Of particular interest is the fact that Azolon did not affect fruit set but in combination with the gibberellins fruit set increased many-fold showing that it is the gibberellins in the combinations which affect fruit set. Post freeze applications of GA_3 appear to prevent abscission of damaged pear flowers which later set fruit parthenocarpically (NeSmith *et al*., 1995).

The gibberellins increased the growth of the shoots which implies that the increase in fruit set may be due to many shoots manufacturing carbohydrates in their leaves which are then channelled for fruitlet formation. The fact that initial and final fruit sets were different among the treatments reflect their different degrees or abilities in retaining the fruits after setting and the interplay of various factors involved in fruit abscission in June.

The apparent close relationship between the effect of the gibberellins on the fruit set with disease occurrence indicate that the plant growth regulators increase vigour in the trees which make them fight off the disease or reduce their susceptibility to the disease. The treatments where fruit set was increased had low disease occurrence while it was worse in the treatments which had very low fruit set. It appears that gibberellins can reduce several types of stress even the ones caused by disease pathogens.

Fruit set is a physiological phenomenon that is a major factor in determining the fruit crop yield. The mechanisms of fruit set is speculative and is thought to involve hormones. This idea is based, in part, on observations in a variety of crops of parthenocarpic inducement and subsequent growth through the application of exogenous growth regulators, as observed with GA_3 in the present study, simulating seed development/increasing auxin synthesis, thereby altering sink-source relationships in favour of the fruitlet. Fruit set is controlled by plant growth regulator effects on translocation of photosynthates and nutrients into the ovary and or accessory tissue. If the primary role of plant growth regulators in inducing set is to create a mobilizing sink for assimilates, then treatments that induce fruit set should induce similar changes in assimilate accumulation and/or metabolism. Yet such a relationship has never been discovered at all from experimentation (Darnell and Martin, 1988). It is therefore necessary to continue with research into how gibberellins induce fruit set after freeze damage.

The present study provided corroborrative evidence that flowers that have suffered damage to the ovary, stigma, style, pollen or corolla following a freeze can be induced to set fruit with gibberellins.

CONCLUSIONS

The results of the present study showed that fruit set can be largely increased in pear after frost damage by application of either gibberellin, GA_3 or GA_{4+7}, promote growth of shoots reduce the incidence of *Pseudomonas syringae* and produce a reasonable harvest. This study showed, by repeated application, that a lower temperature (even frost) does not limit the expected rescue. Other issues to be researched on in future are) mechanism of gibberellin-driven freeze damage rescue, cultivar differences and timing of applications related to freeze events and rates.

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