Does gibberellin treatment inducing parthenocarpy affect development of fruits from fertilization in pear (*Pyrus communis* 'Conférence') ?

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Abstract

Pear (*Pyrus communis*) is the main fruit crop in Belgium and 'Conférence' accounts for 90% of the pear production. 'Conférence' is self-incompatible and thus requires cross-pollination to produce fruits by fertilization. Hives could be settled in the orchards to facilitate pollination and to allow a better fruit size production. However, blooming occurs early in the spring and climatically unfavorable conditions (frost, low temperatures, rain, etc.) could prevent the pollination by insects. To overcome this inconvenience, parthenocarpy induction by spraying gibberellins is a common practice in 'Conférence' orchards. However, whether gibberellin treatment affects fruit set and quality of fruits produced by fertilization has not been investigated. We therefore compared the impact of gibberellin spraying on the development of parthenocarpic fruits and fruits obtained by fertilization. Un-pollinated, open-pollinated and hand-pollinated flowers were sprayed or not with 10 mg L^{-1} GA4/7 at the balloon, full bloom and petal fall stages and the resulting fruit production and quality were assessed. Compatible hand-pollination increased fruit size and fruit weight by respectively 9 and 8% and decreased fruit length by 10% compared to parthenocarpic fruits whatever the gibberellin treatment. Treatment with GA4/7 increased the fruit set at harvest compared to untreated fruits. The time of GA4/7 spraying significantly affected fruit parameters and treatment was more efficient when applied at the balloon stage. Regarding fruits produced by fertilization, GA4/7 treatment decreased seed development by respectively 12, 13 and 36% when applied at the balloon, full bloom and petal fall stages compared to untreated fruits. Consequently, fruit size decreased by 2 and 5% and fruit weight by 8 and 13% when GA4/7 was sprayed at full bloom and petal fall stages compared to untreated fruits. However, treatment at the balloon stage did not affect fruit size and weight. Thus, our results showed that GA4/7 treatment negatively affect the development of fruits from fertilized flowers, depending on the timing of spraying.

Keywords: fruit production, hormonal treatment, *Rosaceae*, pollination, self-incompatibility

INTRODUCTION

Pear (*Pyrus communis* L.) is currently the main fruit crop in Belgium and 'Conférence' accounts for more than 90% of the production. As most pear cultivars, 'Conférence' is self-incompatible and requires inter-cultivar cross-pollination to produce fruits by fertilization (Jacquemart et al., 2006; Quinet and Jacquemart, 2015). Self-incompatibility is genetically determined and two cultivars must differ by their *S*-genotypes to be compatible (Claessen et al., 2019; Quinet et al., 2019a). To ensure cross-pollination, compatible pollinizer trees are planted in addition to the main cultivar and pollinators such as honeybees or bumblebees are introduced in the orchards (Quinet and Jacquemart, 2017). However, pear flowers are less attractive for pollinators as compared to other fruit trees such as apples (Quinet et al., 2016; Smessaert et al., 2019), explaining why introduction of pollinizer trees and beehives are less common in pear orchards than in apple orchards in Belgium (Smessaert et al., 2018, 2019). Moreover, blooming occurs early in the spring and climatically unfavorable conditions (frost, low temperatures, rain, etc.) could prevent the pollination by insects. Production of seedless fruits resulting from parthenocarpy naturally occurs in 'Conférence' (Quinet and Jacquemart,

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2015). Stimulating parthenocarpy by gibberellin application is a common practice in 'Conférence' orchards (Quinet and Jacquemart, 2015; Smessaert et al., 2020). Although gibberellin application may increase fruit set, it may also negatively affect size and shape of fruits (Quinet and Jacquemart, 2015; Quinet et al., 2019b; Smessaert et al., 2020; Vercammen et al., 2011). Indeed, compatible pollination and seed development increase 'Conférence' fruit size and quality (Quinet and Jacquemart, 2017; Warnier, 2000). However, the impact of gibberellin application on fruits from fertilization has not been analyzed or only to a limited extent. In this work, we compared the effect of gibberellin application on the development of parthenocarpic fruits and fruits from fertilization. Moreover, we investigated whether the timing of gibberellin application could affect fruit set and fruit development of both types of fruits.

MATERIALS AND METHODS

This study was carried out on 'Conférence' pear trees in a 0.6 ha orchard of the CEF (Centre Fruitier Wallon) in Wasseiges, Belgium (50°37'58"N; 5°0'57"E). 'Conférence' on Quince C was planted at 3.4×1.3 m (2,262 trees ha^{-1}) in 1995. 'Concorde', 'Triomphe de Vienne' and 'Doyenné du Comice' were present as pollinizer cultivars in the row at a ratio of 1 pollinizer tree per each 16 'Conférence' trees. All cultural management practices were the same as accorded to commercial production except that no thinning was performed on the analyzed trees. One honeybee hive was placed in the orchard during the flowering period to improve insect pollination.

Different pollination and gibberellin treatments were applied on three 'Conférence' trees per treatment (on 10 to 15 flower clusters on two-year-old wood per tree). Three pollination treatments (no pollination, open pollination, hand pollination) were combined with a gibberellin treatment (10 mg L^{-1} GA4/7) applied at balloon, full bloom, and petal fall flower developmental stages (Figure 1). These treatments were compared with two control treatments: intrinsic parthenocarpy (no pollination and no gibberellin) and fertilization (hand pollination and no gibberellin). Flower clusters were covered with exclusion bags during flowering to prevent visits by insects for the 'no pollination' and 'hand pollination' treatments. Open pollination consisted in freely pollinated flower clusters without exclusion bags. The hand pollination was realized on emasculated flowers to avoid self-pollination; flowers were hand pollinated twice with compatible pollen from 'Doyenné du Comice' and 'Triomphe de Vienne' (Quinet et al., 2019a). The gibberellin applications were made to the whole tree.

Figure 1. 'Conférence' pear flowers at different flowering stages: (A) balloon, (B) full bloom and (C) petal fall.

For each treatment, the number of flowers, initiated fruits (May) and fruits at harvest (September) were followed on 10-15 flower clusters per tree. At harvest, the resulting fruits were analyzed to determine their weight, size, length and the presence of seeds. Thirty fruits per treatment were measured at harvest (all fruits were analyzed when fewer fruits were produced). Statistical analyses were performed using mixed linear models to evaluate the effects of pollination treatments, gibberellin applications, timing of gibberellin applications and their interactions on the fruit parameters (the number of fruits per tree was set as random factor) and differences between means were scored for significance according to the Tukey's post hoc test. Comparisons between proportions were analyzed using chi-square tests. All analyses were performed using the SAS 9.3 system for windows.

RESULTS AND DISCUSSION

Combination of pollination and gibberellin affected fruit set at harvest

Initial fruit set was neither affected by pollination nor by gibberellin treatments (χ^2=5.95, p=0.54) and ranged between 86.1% and 100% (Figure 2A). However, fruit set at harvest differed among treatments (χ^2=31.08, p=0.0014, Figure 2B). Compatible hand pollination significantly increased fruit set at harvest in absence of gibberellin treatment. Gibberellin applications increased the final fruit set compared to intrinsic parthenocarpy even if the positive effect decreased with the flower developmental stage at application. Moreover, the pollination treatment affected the final fruit set when gibberellin was sprayed at the balloon stage (χ^2=9.45, p=0.009), showing a higher percentage for hand-pollinated flowers but such difference was no more significant when gibberellin was applied at full bloom (χ^2=0.23, p=0.89) or at petal fall (χ^2=39.67, p=0.49) stages. As a result, gibberellin treatment decreased the final fruit set of fruits from fertilization when applied after full bloom. Our results confirmed thus previous results showing the positive impact of fertilization and gibberellin applications on 'Conférence' fruit set, although this effect may depend on the year and on the environmental conditions (Quinet and Jacquemart, 2015; Smessaert et al., 2020; Vercammen and Gomand, 2008). It is known that the concentration and timing of gibberellin application vary with the chemical used and the pear cultivar to which it is applied (Theron, 2021). However, to our knowledge, no previous study has compared the effect of the timing of gibberellin applications on fruit set of fruits from fertilization in 'Conférence'. Our results showed that the time of application is important and can affect fruit drop. Gibberellin treatments are usually applied just before full bloom, at full bloom or after a frost event (Quinet and Jacquemart, 2015; Quinet et al., 2019b; Smessaert et al., 2020; Teng et al., 2018; Vercammen and Gomand, 2008). Although, Lordan et al. (2019) reported that gibberellin application after petal fall increased fruit set, with a positive relationship with the dose in Spain. Comparison of different application times is thus required to determine the best moment to apply gibberellin depending on the cultivar and the environmental conditions.

Combination of pollination and gibberellin affected fruit size and shape

In absence of gibberellin treatment, fruits from fertilization were larger (60.8±0.4 vs. 52.5±1.6 mm) and less elongated (99.2±1.5 vs. 103.3±4.3 mm) than parthenocarpic fruits (Figure 2C-F), confirming previous observations (Quinet and Jacquemart, 2015; Quinet et al., 2019b; Warnier, 2000). Fruits from fertilization and pathenocarpic fruits contained respectively 3.59±0.25 and 0.27±0.15 viable seeds, and 4.98±0.3 and 2.23±0.4 aborted seeds (Figure 2G-H). We previously observed that the number of viable seeds remained limited in 'Conférence' even after compatible cross-pollination (Quinet and Jacquemart, 2015, 2017). The gibberellin and pollination treatments affected most fruit parameters (Table 1) and an interaction between pollination and gibberellin treatments was observed for fruit weight, fruit length, fruit size and the number of viable seeds per fruit. Moreover, the timing of gibberellin application also affected significantly fruit parameters (Table 1). The weight and the size of gibberellin treated fruits ranged between values observed for parthenocarpic and control fruits from fertilization (Figure 2C, D). Fruit weight and size decreased when gibberellin was applied after full bloom compared to early treatments. Moreover, fruit size, but not fruit weight increased with compatible hand pollination compared to parthenocarpy (Figure 2C, D). As a result, gibberellin treatment increased fruit weight and size of parthenocarpic fruits mainly when applied at the balloon and full bloom stages while it decreased fruit weight and size of fruits from fertilization, mainly when applied at petal fall stage.

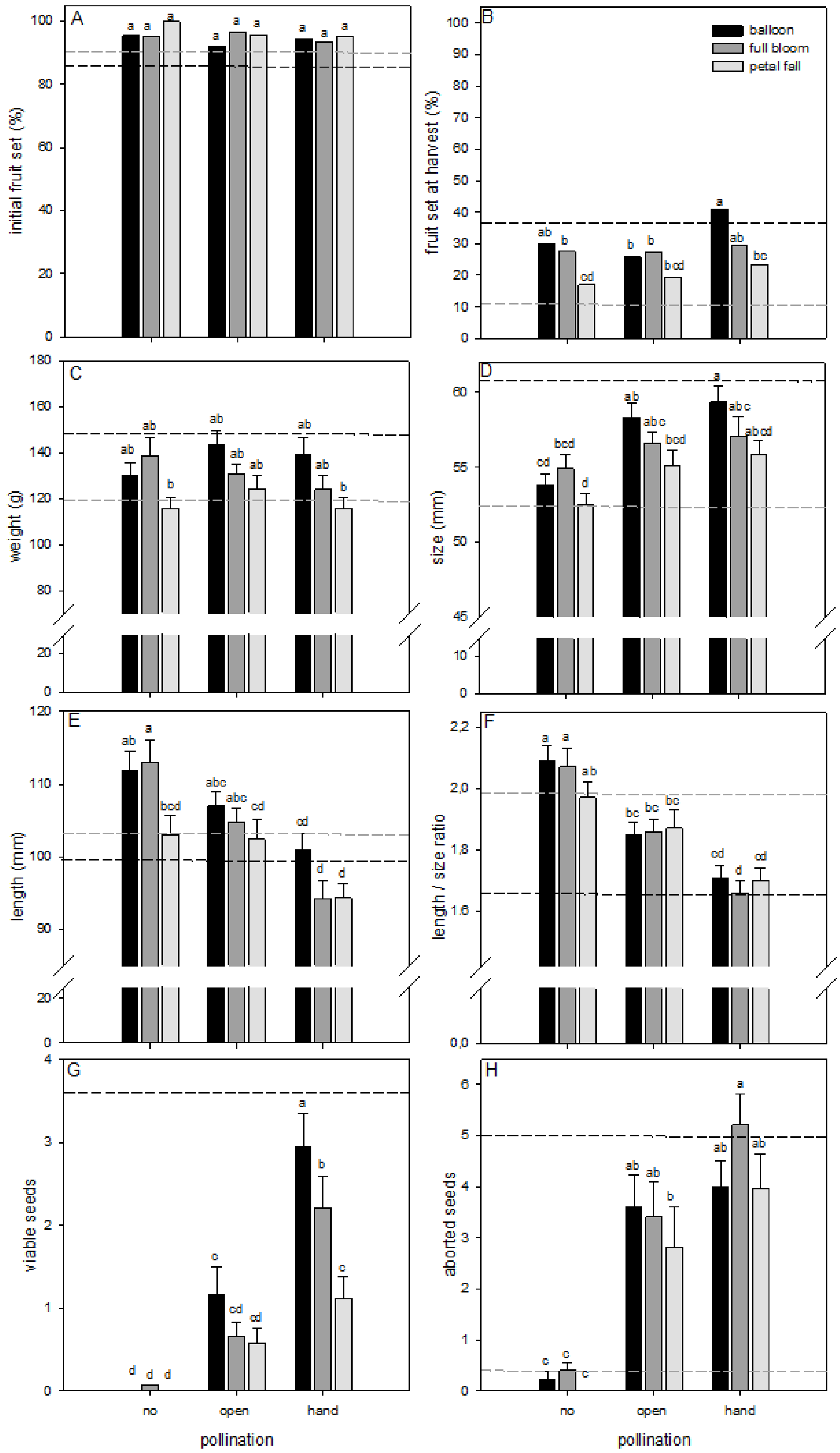

Figure 2. Impact of pollination and gibberellin treatments on fruit parameters. (A) Initial fruit set, (B) fruit set at harvest, (C) fruit weight, (D) fruit size, (E) fruit length, (F) ratio between fruit length and size, number of (G) viable and (H) aborted seeds per fruit. Dashed lines are the values for parthenocarpic control fruits (gray) and control fruits from fertilization (black). Values followed by same letter are not statistically different at 5% level.

Table 1. Statistical results (mixed linear model) of the impact of pollination and gibberellin treatments on fruit parameters.

Factor	Weight	Length	Size	Length/size	Viable seeds	Aborted seeds
Gibberellin	F=4.11	F=5.75	F=9.21	F=21.15	F=68.39	F=14.8
	p=0.0434	p=0.0170	p=0.0026	p<0.0001	p<0.0001	p=0.0001
Moment	F=7.08	F=5.34	F=6.02	F=0.30	F=8.22	F=2.58
	p=0.001	p=0.0052	p=0.0027	p=0.7401	p=0.0003	p=0.0769
Pollination	F=1.74	F=16.96	F=27.33	F=66.34	F=85.99	F=42.73
	p=0.1765	p<0.0001	p<0.0001	p<0.0001	p<0.0001	p<0.0001
Gibberellin × pollination	F=6.01	F=3.05	F=5.99	F=0.02	F=4.43	F=1.52
	p=0.0027	p=0.0485	p=0.0028	p=0.9763	p=0.0125	p=0.2197
Moment × pollination	F=1.04	F=1.18	F=0.82	F=1.01	F=3.06	F=0.46
	p=0.3844	p=0.3210	p=0.5100	p=0.4036	p=0.0168	p=0.7682

We observed a strong positive correlation between fruit weight and size (Figure 3). Both parameters were also positively correlated with fruit length but to a lesser extent (Figure 3). The longest and most elongated fruits were observed in unpollinated flowers treated with gibberellin at balloon or full bloom stages and the less elongated fruits were observed when gibberellin was applied at full bloom or petal fall stages on hand-pollinated flowers (Figure 2C, D). This confirms previous results showing that parthenocarpic fruits were more elongated than those from fertilization and that gibberellin treatment tended to increase the proportion of misshaped fruits (Quinet and Jacquemart, 2015; Smessaert et al., 2020; Vercammen and Gomand, 2008; Warnier, 2000).

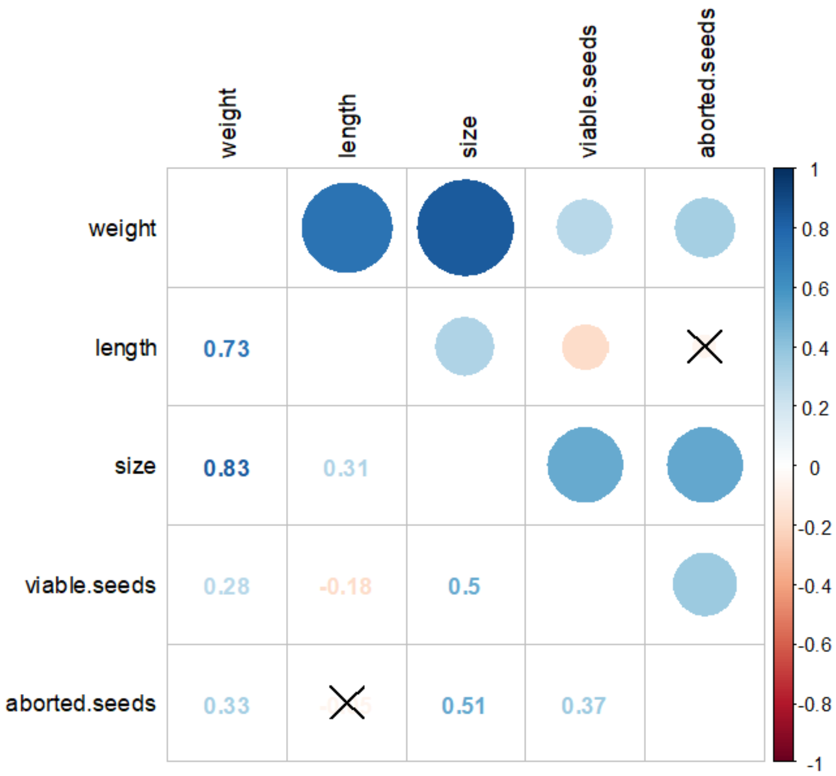

Figure 3. Correlations among fruit parameters. Values are the Pearson correlation coefficients. X: non-significant correlation at 5% level.

The gibberellin treatment also negatively affected seed development (Figure 2E, F). The number of viable seeds decreased in fruits from fertilization treated with gibberellin; the later the application, the greater the effect (Figure 2E). The number of seeds per fruit was positively correlated with fruit weight and size (Figure 3) as previously reported (Quinet and Jacquemart, 2017). The decrease of fruit weight and size observed in fruits from fertilization treated with gibberellin could thus be explained by the lower development of viable seeds. Indeed, seeds communicate through hormones to the surrounding tissues to promote fruit growth (McAtee et al., 2013).

Altogether, our results showed that whether gibberellin treatment could improve fruit yield and size of parthenocarpic fruits, it negatively affected development of fruits from fertilization. Moreover, the application of gibberellins before full bloom gave better results on fruit parameters than after full bloom. Such differences could be explained by hormonal modifications along flower and fruit development. We previously reported that hormonal profile differed in cross-pollinated and unpollinated 'Conférence' flowers and that gibberellin treatment modified the hormonal profile (Quinet et al., 2019b). We may not exclude that the modification of hormone metabolism induced by gibberellin application stimulated fruit development in unpollinated flowers but negatively affected fruit development of cross-pollinated flowers, and that the effect depended on the timing of application. Vercammen and Gomand (2008) also reported that gibberellin treatment at full bloom did not always improve fruit yield and Quinet and Jacquemart (2015) showed that the gibberellin effect depended on the year. According to Vercammen and Gomand (2008) and Vercammen et al. (2015), gibberellin treatment is not necessary in years without frost damage and when the number of flower buds is sufficient. According to them, in case of frost damage, half of a recommended dose of GA4/7 could be enough and a treatment with Regalis in addition to gibberellin could be recommended if the number of flower buds is low (Vercammen and Gomand, 2008; Vercammen et al., 2015). Lordan et al. (2019) observed that gibberellin treatment after petal fall decreased individual fruit weight and size and that the higher the dose, the lower the value. They also recommended discarding repeated applications since they cause excessive fruit set, which can greatly reduce fruit weight (Lordan et al., 2019). However, it is not specified in their studies whether the experiments were performed in 'Conférence' monoculture or in orchards with pollinizer trees. According to Smessaert et al. (2020), the combination of gibberellin application and bumblebee supplementation in 'Conférence' orchards resulted in significantly higher amounts of normally shaped pears compared to gibberellin application alone.

CONCLUSIONS

In this study, we investigated whether gibberellin application improve fruit set and fruit parameters of parthenocarpic and fruits from fertilization. We observed that gibberellin application increased the final fruit set as well as the size and weight of parthenocarpic fruits, as long as treatment was applied at the balloon or full bloom stages. However, gibberellin application had rather a negative impact on fruits from fertilization and decreased fruit set, seed set, fruit weight, and fruit size when applied at full bloom or after. Thus, our results suggested that gibberellin application before or at full bloom could be interesting in 'Conférence' monoculture where mainly parthenocarpic fruits are produced. However, in 'Conférence' orchards where pollinizer trees and beehives are settled to increase cross-pollination, gibberellin application would be rather unfavorable, especially if applied after full bloom.

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