Influence of pesticide use on flower formation and fertility of some fruit species

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Summary: This review evaluated previous studies on the effect of pesticide use on flower formation and fertility of some fruit species. The study was divided into two parts. First part of the overview will evaluate the most commonly used fungicides on pollen toxicity and their germination ability under fungicide exposure on different fruit species. Effect of fungicides on fruit set was also critically reviewed. Second part of the study summarised those few studies which determined the effect of some insecticides and acaricides on flower formation and fertility.

Key words: fungicides, insecticides, acaricides, flower, fertility, fruit

Introduction

When searching literature on pesticide use affecting fruit tree flowers, it can be seen that most papers paid attention to fungicides affecting flower parts' development and fertility, and a relatively small number of papers dealt with the relationships between insecticides, acaricides or other chemical compounds and flowers.

Therefore, in this sub-chapter, firstly, the effect of several fungicides then insecticides along with other chemical compounds on flowers will be discussed in details.

Effect of fungicides on flower formation and fertility

Detrimental effects of fungicide sprays on pollen germination, fruit set, and/or yield were reported on apple (*Legge & Williams*, 1975; *Church & Williams*, 1977, 1978; *Brown & Hendrix*, 1978; *Ries*, 1978; *Church* et al., 1983ab; *Church & Williams*, 1983; *Fell* et al.,1983; *Marcucci & Filiti*, 1984; *Butt* et al., 1985; *Mayer & Lunden*, 1986; *Watters & Sturgeon*, 1990; *Cooley*, 1991; *Cooley & Greene*, 1994; *Kubik* et al., 2000; *Yi* et al., 2003c), pear (*Marcucci & Filiti*, 1984; *Butt* et al., 1985; *Mayer & Lunden*, 1986), sweet cherry (*Eaton*, 1961), pecan (*Wetzstein*, 1990; *He & Wetzstein*, 1994), peach (*Olien* et al., 1995) and almond (*Yi* et al., 2003abc).

As fungicides are applied frequently against apple scab and powdery mildew during the bloom period, several studies examined the effect of different fungicide compounds on pollination, pollen viability, pollen tube growth and fertility. *Legge & Williams* (1975) were the first to write down the adverse effect of fungicidal sprays on the pollination of apple flowers. Two years later, *Church &*

Williams (1977, 1978) showed that captan, benomyl and thiophanate-methyl inhibited pollen germination of apple *in vitro*. They were able to show that an *in vitro* test was effective in assessing the relative toxicity of fungicides and they found good correlations between *in vitro* and *in vivo* results on fungicide toxicity. In the same study, authors found that fungicide applications made within 24 hours of pollination were very detrimental to pollination and fruit set. Moreover, *Church & Williams* (1977) sprayed hand-pollinated stigmas with different fungicides either before or after pollination. The results indicated that if pollination occurred two hours before spraying, pollen growth was inhibited, but if pollination occurred two hours after spraying, pollen tubes developed relatively well (*Table 1*). In addition, *Brown & Hendrix* (1978) indicated that the detrimental effect of fungicides on apple pollen germination resulted in lower fruit set.

Church & Williams (1983) and *Church* et al., (1983a) clearly demonstrated that captan can dramatically decrease pollen viability of apple. They showed the detrimental effect both under laboratory and field conditions. Among the tested

Table 1 Percent of hand-pollinated stigmas showing adequate pollen tube development sprayed with different fungicides either before or after pollination (adopted from *Church & Williams,* 1977)

| Treatments	Time of pollination relative to spraying			
	1 day before	2 hours before	2 hours after	1 day after
Control	84	79	79	92
Benomyl	76	67	84	96
Captan	88	25	70	84
Dinocap	84	20	85	64
Thiophanate-methyl	84	80	89	84

products, captan was the only fungicide that greatly reduced pollen germination in both laboratory and orchard tests (*Table 2*). Moreover, Church et al. (1983b) also showed that spray volume can also influence the toxicity effect of fungicides to pollen growth. They showed that dilute applications of captan were more toxic to pollens than the 5-time-concentrated one. In the following years, similar results were obtained by *Fell* et al. (1983), *Marcucci & Filiti* (1984), *Butt* et al. (1985) and *Mayer & Lunden* (1986) about fungicide effect on pollen germination and viability.

Table 2 Toxicity of fungicides to pollen in vivo and in vitro (adopted from *Church* et al., 1983a)

Treatments	In vivo		In vitro	
	Concentration (kg/450 l)	Germinated pollen/stigma	LD50 (amount needed to kill 50% pollen)	Pollen germination (% of control)
Control	–	1.9	–	–
Benomyl	0.9 kg	1.5	18.1	95
Captan	3.2 kg	0.5	0.7	6
Dodine	0.18 kg	0.3	15.7	100
Mancozeb + Ziram	3.2 + 3.2 kg	1.5	16.3	100
Sulphur	6.7 kg	0.1	16.5	75

The studies of *Watters & Sturgeon* (1990) compared the effects of sterol-inhibiting fungicides, dodine and captan on pollen germinations. They also showed that captan was the most toxic to pollen. Dodine was the second most toxic fungicide to pollens. The sterol-inhibiting fungicides did not have a significant effect on pollen germination (*Figure 1*).

Cooley (1991) concluded that application of captan during bloom may create problems with pollen germination. These results partly explain why some orchards had problems with fruit set, when captan and dodine had been used. *Cooley* (1991) also suggested that the safest route to take may be to avoid applying any fungicide during good pollination weather. If a fungicide must be used, then one of the less toxic fungicides should be applied. *Cooley & Greene* (1994) made direct experiments to know whether captan, copper hydroxide, mineral oil and sterol-inhibiting fungicide sprays affected only pollen germination or also had an influence on fruit set. The results showed that captan and
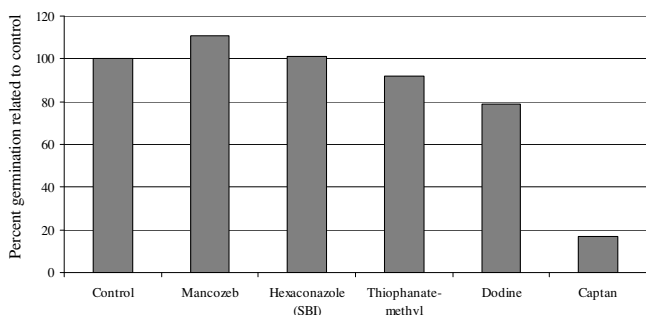
Figure 1 Germination of apple pollens in fungicide laboratory tests (adopted from *Watters & Sturgeon,* 1990)

fenarimol with or without copper hydroxide applications, did not influence fruit set significantly on cv. 'McIntosh' in New England (*Table 3*). Moreover, they indicated that timings of captan application did not result in significant reduction of fruit set.

Table 3 Fruit set following treatments of captan, fenarimol, copper hydroxide and their combination on cv. 'McIntosh' in New England (adopted from *Cooley & Greene,* 1994)

Treatments	Fruit set (number / cm^2)
Control	3.8 a
Captan	5.7 a
Fenarimol	6.7 a
Copper hydroxide	5.7 a
Copper hydroxide + Captan	5.8 a
Copper hydroxide + Fenarimol	5.1 a

Kubik et al. (2000) made further experiments on residues of captan (contact) and difenoconazole (systemic) fungicides in bee products from an apple orchard. They placed ten bee colonies in the middle of a ten-hectare-apple orchard at about 10% in bloom. The orchard was sprayed with a mixture of a captan and difenoconazole fungicides. The residues of fungicides in honey had very low contamination – 0.0006 mg/kg of difenoconazole and 0.009 mg/kg of captan. Contamination of pollen was much higher (about 0.043 and 2.99 mg/kg of difenoconazole and captan, respectively). The most contaminated was bee bread, with 0.27 and 6.39 mg/kg of difenoconazole and captan, respectively. *Kubik* et al. (2000) also demonstrated that difenoconazole penetrates about 1.66 and 1.16 times more efficiently into honey and bee bread, respectively, than captan. But in pollen pellets from apple, the penetration coefficient was lower than 1. This observation corroborates the suggestion that in fresh pollen some fungicides may be fixed by sugars, aminoacids, or even proteins. *Yi* et al. (2003c) evaluated captan, myclobutanil and streptomycin sprays on pollen germination and pollen tube growth. They found that captan significantly reduced pollen germination, by 20% compared with water controls when pollination was conducted 18 hours after treatment. The number of tubes that reached the basal part of the style within 20 h was not affected. In contrast, myclobutanil and streptomycin had no significant effect on pollen tube growth.

Fungicide toxicity results on pollens of pear (*Marcucci & Filiti*, 1984; *Butt* et al., 1985; *Mayer & Lunden*, 1986) and sweet cherry (*Eaton*, 1961) were similar to those found in apple.

On the pecan cv. 'Desirable', *Wetzstein* (1990) and *He & Wetzstein* (1994) studied the effect of six fungicides (dodine, propiconazole, thiophanate-methyl, fentin hydroxide, benomyl and sulphur) on pollen germination Pollen was collected and germinated on pesticide-free media. Fentin hydroxide applied three times a week caused the least inhibition, and reduced germination only in thrice weekly sprays. Dodine, propiconazole and sulphur reduced pollen

germination the most severely. Fungicides applied during early season growth may contribute to abnormal microspore development, pollen degeneration and retarded development of catkins and leaves.

On peach, *Olien* et al. (1995) demonstrated that ammonium thiosulphate and fungicides, when applied as tank mixes, could cause burn of blossoms and shoots, but not when applied separately. Nine fungicides, alone and in combination with ammonium thiosulphate were evaluated under commercial orchard conditions. They showed that fruit number per tree was affected only by ammonium thiosulphate and the numbers of blossom blight cankers per tree only by fungicide.

Recently several studies of fungicide toxicity were made on almond pollen (*Yi* et al., 2003abc). Almond is a self-incompatible nut crop that has a fruit set of only approx. 30% of the total number of flowers. Therefore, influence of fungicide sprays on pollens and pollination is of concern, and identification of chemicals having the least detrimental effects would be desirable. *Yi* et al. (2003a) evaluated the effect of *in vitro* fungicide sprays (azoxystrobin, myclobutanil, iprodione and cyprodinil) on stigma morphology in almond. They found that azoxystrobin increased exudate accumulation at 4 and 24 hours after spraying, and localized damage and collapse of stigmatic cells were observed after 24 h. Likewise, myclobutanil caused significant damage to and collapse of papillae. Iprodione had no effect on exudate accumulation but caused marked and severe collapse of stigmatic papillae which was pronounced at 24 hours. Cyprodinil promoted a similar increase in exudate secretion and caused the most severe collapse of stigmatic cells of all the fungicides evaluated. In another almond study, effects of *in vitro* fungicide sprays were evaluated on pollen germination and growth (*Yi* et al., 2003b). Captan and azoxystrobin were the most toxic to pollens, the germination percentages were less than 1 % of the untreated control (*Table 4*). Germination was not

significantly affected by propiconazole and benomyl. Intermediate inhibitory effects on pollen germination were observed with ziram, cyprodinil, maneb, thiophanate-methyl, iprodione, and myclobutanil. In contrast to germination, tube growth was less affected by fungicides (*Table 4*). Again, azoxystrobin and captan reduced tube elongation by approximately to 90%.

The above *in vitro* studies were also repeated under field conditions in an almond orchard (*Yi* et al., 2003c). In the almond orchard, fungicide sprays of azoxystrobin, myclobutanil, iprodione and cyprodinil did not affect pollen germination or tube growth significantly. Authors concluded that there are several other factors (e.g. cold stress, dry weather during flowering, nutritional deficiency, insect damage) which also influence pollen germination and they can mask fungicide spray results of pollination.

Effect of insecticides and acaricides on flower formation and fertility

Detrimental effects of insecticides, acaricides or other chemical compounds on pollen germination, fruit set, and/or yield were reported on apple (*Mayer & Lunden*, 1986; *Bound & Jones*, 2004; *Nichols* et al., 2004). *Mayer & Lunden* (1986) noted that acaricides used during bloom influenced pollen viability of apple and pear. *Nichols* et al. (2004) determined the effect of ammonium thiosulphate and mineral oil applied with carbaryl on blossom properties of the apple cv. 'Northern Spy'. The results showed that fruit abscission and average fruit weight were enhanced by mineral oil applied with carbaryl. *Bound & Jones* (2004) tested ammonium thiosulphate as a blossom thinner on 'Delicious' apple, 'Winter Cole' pear and 'Hunter' apricot. 4%, ammonium thiosulphate was phytotoxic to the crops, resulting in severe burning of foliage and flowers. 1.5%, ammonium thiosulphate reduced the crop load to an acceptable level without excessive damage. The 0.3% concentration was ineffective on cvs. 'Delicious' and 'Winter Cole'. Russet incidence was increased on 'Delicious' by the highest concentration applied at 20% bloom. When ammonium thiosulphate was applied at 2.0% to 'Hunter' apricot at 20, 40, 60, 80 or 100% bloom, fruit set was reduced regardless of the time of application.

Acknowledgements

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Table 4 Germination and tube growth of almond pollen in a laboratory study of ten fungicides (adopted from *Yi* et al., 2003b)

Treatments[a]	Pollen germination related to control (%)	Pollen tube length 2.5 hours after inoculation
Control	100 a	504 a
Propiconazole	103.9 a	422 a
Benomyl	96.3 a	453 a
Myclobutanil	76.4 b	459 a
Iprodione	62.9 c	442 a
Thiophanate-methyl	59.4 cd	403 a
Maneb	50.7 d	165 b
Cyprodinil	30.2 e	163 b
Ziram	18.8 e	107 c
Azoxystrobin	0.6 f	50 d
Captan	0.2 f	53 d

a Recommended field rate

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