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Influence of azoxystrobin dip treatments on postharvest decay of second-crop fig (*Ficus carica*) fruits from Sardinian germoplasm

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Abstract: Fig (*Ficus carica* L.) fruits from the second-crop, cultivars Verde, San Pietro, Perdingiana, and Carcanzi Trota, were harvested on 25 August and 8 September 2005, subjected to 50 or 100 mg/L azoxystrobin (AZO) dip treatments for 30 s and stored for seven days at 18°C (simulated marketing conditions, SMC) or for seven days at 5°C (CS) plus seven days at SMC. After seven days at 5°C, the external decay incidence in control fruit was 3-10%. Treatment with AZO completely suppressed external decay in 'San Pietro', and 'Carcanzi Trota' and resulted in 2 and 8% decay in 'Verde' and 'Perdingiana', respectively. After CS plus 3 days at 18°C, decay in control fruit was measured as 23-41% and 71-85% of August and September harvests, respectively, while in those treated with AZO, average losses were 4-11%. At the end of SMC, all fruit in all treatments decayed, although the rotten area was smaller in AZO treated fruit. Similarly, in fruit stored directly in SMC, AZO significantly reduced decay during the first three days; after seven days all fruit decayed. Internal decay originating from the syconium cavity was higher in fruit harvested in September and was not affected by AZO treatments.

1. Introduction

Decay represents the major cause of postharvest loss of fig (*Ficus carica*), especially in fruit of the second crop when high humidity levels and precipitation cause skin cracking, ostiole splitting, and the growth of pathogens. Postharvest life of figs can vary from a few days to one to two weeks (Ferguson *et al*., 1990; Crisosto and Kader, 2004).

More than in other fruits, the ripening process in figs is very rapid; under favourable environmental conditions, flesh tissue changes from a spongy dry state to a juicy, sweet condition in one-two days. These sudden changes have long been the object of controversy, and whether figs should be considered climacteric or non-climacteric fruit. Indeed, if on one hand the rapid changes of rheological and compositional features are typical of climacteric fruit, on the other hand figs do not share the ability to continue the ripening process once harvested. Normally, unripe harvested figs never rich an optimum eating stage as happens with other climacteric fruits, such as peaches, pears, kaki or apples. Surely, the maturing and ripening processes are so close and rapid to overlap, not allowing a clear sequential separation between these two physiological stages. Nevertheless, the classification of figs as a climacteric species is generally accepted (Marei and Crane, 1971; Ferguson *et al*., 1990).

Susceptibility of figs to decay and physical damage dramatically increases with ripening: as fruit ripens, the defence mechanism of unripe fruit is rapidly lost and various pathogenic microorganisms can develop. Infection sites may involve the outer tissue of the fruit, with pathogens starting to develop on the peel or the underneath tissue through wounds or cracks, or from inside, through infections originating in the syconium cavity, in most cases transported by wasps or other insects (Crisosto *et al.*, 2011).

In parthenocarpic cultivars with closed or partially closed ostiole, which do not need caprification to produce, visits by fig wasps and other insects inside the syconium cannot take place or are markedly reduced. Consequently, infections starting from inner tissues like endosepsis (*Fusarium monilifome)*, souring or fermentation incited by different types of yeast and bacteria carried by different insects, are easier to control than in cultivars with open ostioles (Ferguson *et al.*, 1990; Michailides *et al.*, 1996). In all cases, an efficient control of decay can be achieved by field treatments with insecticides and fungicides.

Azoxystrobin is a strobilurin-like partial-systemic fungicide with broad-spectrum activity against several important pathogens (Gullino *et al.*, 2000). It is considered a

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reduced-risk-fungicide by the United States Environmental Protection Agency and has been registered for field application or postharvest treatments on several crops.

The present study evaluates the efficacy of postharvest treatments with azoxystrobin to control decay on four cultivars of second-crop fig fruits of Sardinian germplasm. Forniti fruits of these cultivars have an open ostiole, so they are very prone to internal decay.

2. Materials and Methods

The investigation was carried out on four fig cultivars from Sardinia germoplasm (Chessa and Nieddu, 1994): Verde, San Pietro, Perdingiana, and Carcanzi Trota. Fruits of the second crop were picked on 25 August or 8 September from the collection field of the "*AGRIS Sardegna*" in Sassari. Trees received standard agricultural practices, but no chemical treatment to control pests or diseases had been applied in the previous three years. Fruits were harvested early in the morning and immediately transported to the laboratory, which was located about 10 km from the orchard.

Fruit without defects from each cultivar were selected and divided into three groups. Each group was dipped for 30 s, at room temperature, in: water (control) or water with 50 or 100 mg/L of azoxystrobin (AZO) (Ortiva , Syngenta Crop protection Milan, Italy). After dipping and before storage, all figs were dried at room temperature and each treatment group was divided into two subgroups including eight replications of 25 fruits. The first subgroup was stored for three or seven days at 18°C and 90% relative humidity (RH) (simulated marketing conditions (SMC), while the remaining subgroup was stored for seven days in cold storage (CS) at 5°C and subsequent three or seven days of SMC. Afterwards, CS and SMC fruit were inspected for external and internal decay (endosepsis and souring).

Data were subjected to analysis of variance after transformation of average decay-percentage values in $\sqrt{x}$ or $\arcsin\sqrt{x}$ depending on the range of variation of decay. Separation of the means was accomplished according to Fisher's test of the least significant difference (LSD); actual values are reported.

3. Results

The development of external and internal decay was greatly influenced by picking date and storage conditions. Fruits harvest in August were significantly less prone to decay than those harvested in September, regardless of the cultivars (Figs. 1, 2; Tables 1-4). 'Perdingiana' figs (Table 3) of both harvest dates were the most susceptible with high percentages of external and internal decay, whereas no relevant differences were detected among other cultivars. After seven days of storage at 5°C, the percentage of fruit showing external decay was low in all treatments and harvest dates. When fruits were transferred to SMC,

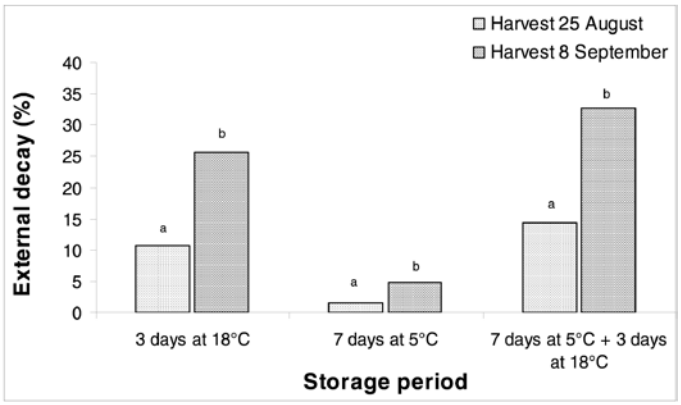

Fig. 1 - Influence of picking date and storage conditions on external decay incidence in second crop production of Verde, San Pietro, Perdingiana and Carcanzi Trota figs. For each storage period histograms with different letters are significantly different, $P \leq 0.05$.

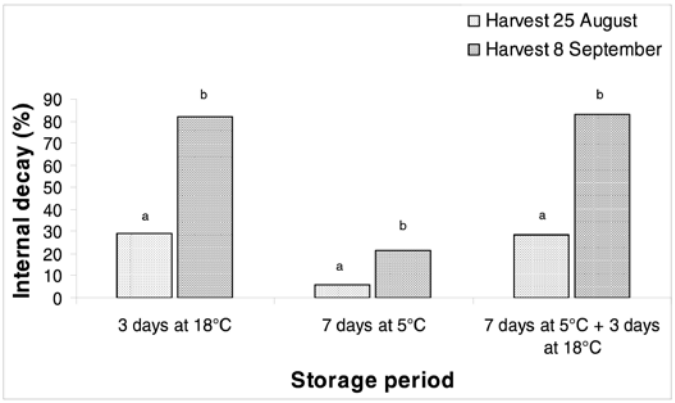

Fig. 2 - Influence of picking date and storage conditions on internal decay incidence in second crop production of Verde, San Pietro, Perdingiana and Carcanzi Trota figs. For each storage period histograms with different letters are significantly different, $P \leq 0.05$.

Table 1 - Influence of 30-s-dip treatments with azoxystrobin (AZO) at 20°C on external and internal decay incidence in second crop 'Verde' figs after three days at 18°C and 65% RH, or for seven days at 5°C plus three days at 18°C

Treatments	3 days at 18°C		7 days at 5°C		7 days at 5°C plus 3 days at 18°C	
	External decay %	Internal decay %	External decay %	Internal decay %	External decay %	Internal decay %
	Harvested in August					
Control	21 b [z]	23 a	6 b	0 a	31 b	18 a
50 mg/L AZO	5 a	35 a	0 a	0 a	7 a	31 b
100 mg/L AZO	4 a	27 a	0 a	0 a	8 a	24 ab
	Harvested in September					
Control	70 b	88 a	9 b	10 a	82 b	86 a
50 mg/L AZO	9 a	75 a	2 a	18 a	11 a	75 a
100 mg/L AZO	9 a	83 a	1 a	16 a	9 a	81 a

[z] For each storage period and harvesting time values in columns followed by different letters are significantly different at P≤0.05 according to Fisher's test of the least significant difference.

Table 2 - Influence of 30 s-dip treatments with azoxystrobin (AZO) at 20°C on external and internal decay incidence in second crop 'San Pietro' figs after three days at 18°C and 65% RH, or for seven days at 5°C plus three days at 18°C

Treatments	3 days at 18°C		7 days at 5°C		7 days at 5°C plus 3 days at 18°C	
	External decay %	Internal decay %	External decay %	Internal decay %	External decay %	Internal decay %
	Harvested in August					
Control	19 b [z]	32 a	3 a	4 a	23 b	28 a
50 mg/L AZO	3 a	25 a	0 a	7 a	10 ab	34 a
100 mg/L AZO	0 a	27 a	0 a	9 a	2 a	29 a
	Harvested in September					
Control	35 b	73 a	5 a	41 b	71 b	76 a
50 mg/L AZO	8 a	65 a	0 a	37 ab	7 a	71 a
100 mg/L AZO	6 a	72 a	0 a	28 a	9 a	67 a

[z] For each storage period and harvesting time values in columns followed by different letters are significantly different at P≤0.05 according to Fisher's test of the least significant difference.

Table 3 - Influence of 30-s-dip-treatments with azoxystrobin (AZO) at 20°C on external and internal decay incidence in second crop 'Perdingiana' figs after three days at 18°C and 65% RH, or for seven days at 5°C plus three days at 18°C

Treatments	3 days at 18°C		7 days at 5°C		7 days at 5°C plus 3 days at 18°C	
	External decay %	Internal decay %	External decay %	Internal decay %	External decay %	Internal decay %
	Harvested in August					
Control	35 b [z]	33 a	9 b	11 a	41 b	44 b
50 mg/L AZO	4 a	31 a	0 a	12 a	6 a	41 ab
100 mg/L AZO	3 a	35 a	0 a	14 a	4 a	33 a
	Harvested in September					
Control	76 b	91 a	13 b	24 ab	85 b	100 a
50 mg/L AZO	10 a	98 a	8 ab	27 b	19 a	95 a
100 mg/L AZO	13 a	87 a	5 a	19 a	16 a	100 a

[z] For each storage period and harvesting time values in columns followed by different letters are significantly different at P≤0.05 according to Fisher's test of the least significant difference.

sharp increases in decay development were recorded in all fruit samples especially those of the second harvest date. In particular, after three days at 18°C external decay percentage in control samples ranged between 71 (San Pietro) and 85% (Perdingiana), whereas after seven days at 18°C all fruit decayed, regardless of the treatments (data not shown). AZO treatments significantly reduced external decay in all cultivars. However, the protective activity of AZO lasted few days in fruit held at 18°C. After seven days at 18°C all AZO-treated fruit showed external decay, although the extent of the diseased area was considerably lower than in untreated fruit (data not shown). No statistical differences were detected between the two concentrations of AZO (Tables 1-4). Various pathogens developed on the same fruit. In fruit harvested in August, alternaria rot (*Alternaria alternata*) and to a lesser extent, cladosporium rot (*Cladosporium herbarum*) accounted for more than 90% of decay, whereas in fruit harvested in September the number of pathogens increased. However, alternaria rot was always the main cause of decay, followed by cladosporium rot, grey mold (*Botrytis cinerea*), and Penicillium mold (*Penicillium spp*.). Moreover, moulds of these pathogens, which first initiated the infections, in a nested fashion, were often overwhelmed by Rhizopus rot (*Rhizopus stolonifer*). Internal decay severely developed in all cultivars, especially in 'Perdingiana'. Fruit affected by internal decay were significantly more in samples harvested in September. Storage at 5°C reduced the development of internal decay; when fruits were moved to SMC it dramatically increased (Tables 1-4). The influence of AZO against internal decay was negligible.

4. Discussion and Conclusions

Results of this experiment confirmed the high postharvest perishability of the studied fig cultivars, especially 'Perdingiana'. The susceptibility to microbiological deterioration was highly affected by the harvesting period. Fruits harvested in August experienced significantly less decay than those harvested in September. This is because the higher environmental humidity in September is more favourable to field infection than in August, when weath-

Table 4 - Influence of 30-s-dip treatments with azoxystrobin (AZO) at 20°C on external and internal decay incidence in second crop 'Carcanzi Trota' figs after three days at 18°C and 65% RH, or for seven days at 5 °C plus three days at 18°C

Treatments	3 days at 18°C		7 days at 5°C		7 days at 5°C plus 3 days at 18°C	
	External decay %	Internal decay %	External decay %	Internal decay %	External decay %	Internal decay %
	Harvested in August					
Control	26 b[1]	24 a	0 a	3 a	29 b	18 a
50 mg/L AZO	6 a	29 a	0 a	8 a	8 a	21 a
100 mg/L AZO	4 a	27 a	0 a	5 a	3 a	24 a
	Harvested in September					
Control	58 b	85 ab	10 b	16 a	77 b	82 a
50 mg/L AZO	10 a	77 a	0 a	14 a	6 a	81 a
100 mg/L AZO	4 a	91 b	0 a	9 a	2 a	79 a

[z] For each storage period and harvesting time values in columns followed by different letters are significantly different at P≤0.05 according to Fisher's test of the least significant difference.

er conditions are usually dry. AZO was highly effective against all the main pathogens causing external diseases, confirming its broad spectrum of activity (Gullino *et al*., 2000). However, its effectiveness lasted only three days in fruit held in SMC. After seven days at 18°C all fruit treated with AZO exhibited visible infections, although the extension of the lesions were notably less than in control fruit.

AZO was ineffective against internal decay. All studied cultivars had open ostiole. Figs with open ostiole may be more susceptible to endosepsis caused by *Fusarium moniliforme* and souring, incited by different kinds of yeasts and bacteria (Crisosto *et al*., 2011). Infections of both diseases are caused by entrance into the syconia of fig wasps and vinegar flies (*Drosophyla spp.),* dried-fruit beetles (*Carpopilus spp*.), and thrips (*Thrips spp*. and *Frankliniella spp*.) (Michailides *et al*., 1996; Crisosto *et al*., 2011). In figs with close or narrow ostiole, in which only wasps and bees can enter, internal decay is generally lower.

Proper postharvest technologies, such as precooling, film-wrapping, and conditioning in modified atmosphere environment are shown to extend the keeping quality of fig fruit (Turk, 1989; Piga *et al.*, 1995, 1998; D'Aquino *et al.*, 1998, 2003). However, under shelf-life conditions, the market life of figs decreases dramatically, especially in second crop fruit.

The present results reveal that postharvest application of AZO, even at very low rates which could leave on fruit reside levels lower than field treatments with higher rates, resulted only in a slight delay of decay development, as most of the infections generally occur in the orchard and remain latent until fruit ripen. Thus, postharvest AZO treatments associated with low temperatures can give better results if pest management includes a preventive disinfestation program aimed at reducing the insect populations which act as carrier of pathogens' conidia.

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