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Sensitivity of ornamental pepper to ethylene

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ABSTRACT

The genus *Capsicum* has varying levels of sensitivity to ethylene. Variability knowledge allows planning post-production methodologies of potted pepper plants and can be used in breeding programs. The objective of this study was to evaluate the ethylene sensitivity of three ornamental pepper genotypes of the germplasm bank of Universidade Federal de Viçosa. Pepper plants were exposed to 10 $\mu\text{L L}^{-1}$ ethylene during 48 hours. The flowers were highly sensitive to exogenous ethylene in all genotypes except Pimenta colorida which was moderately sensitive. Regarding leaf abscission, Pimenta colorida and Pimentão ornamental are classified as highly sensitive to ethylene application. Already the fruits responded with the early appearance of the typical coloration when ripe, except for Pimenta laranja. When fruits fell, the highest rates were observed for green fruits, followed by ripe green and ripe fruits.

Keywords: *Capsicum annuum*, senescence, commercialization, post-harvest losses.

RESUMO

Sensibilidade da pimenta ornamental ao etileno

As plantas do gênero *Capsicum* têm níveis variáveis de sensibilidade ao etileno. O conhecimento desta variabilidade permite o planejamento de metodologias de pós-produção de pimenteiros em vaso e pode ser usado em programas de melhoramento genético. O objetivo foi avaliar a sensibilidade ao etileno de três genótipos de pimenteiros ornamentais do Banco de Germoplasma da Universidade Federal de Viçosa. Após a exposição das pimenteiros a 10 $\mu\text{L L}^{-1}$ de etileno por 48 horas, observou-se que as flores foram altamente sensíveis ao etileno exógeno em todos os genótipos com exceção da Pimenta colorida que foi moderadamente sensível. Com relação à abscisão de folhas, a Pimenta colorida e o Pimentão ornamental são classificados como altamente sensíveis à aplicação de etileno. Já os frutos responderam com o aparecimento precoce da coloração típica de quando maduros, com exceção da Pimenta laranja. Quando abscindiam, as maiores taxas foram observadas para os frutos verdes, seguidos pelos frutos verde-maduro e maduros.

Palavras-chave: *Capsicum annuum*, senescência, comercialização, perdas pós-colheita.

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Transport is the main factor affecting ornamental quality and longevity of ornamental pepper plants (França *et al.*, 2018). Under the Brazilian transportation conditions, usually in trunk trucks, in the dark, without ventilation and humidity, over 48 hours, there occurs an accumulation and exposure of plants to ethylene present in the surrounding air (exhaust gases or transportation near ripe fruits). Ethylene may prejudice plant quality and commercial durability (Iqbal *et al.*, 2017).

Plant exposure to ethylene can cause leaf, flowers and fruits abscission (Sundaresan *et al.*, 2015; Lima *et al.*, 2017).

et al., 2017). Ethylene accumulates in the air spaces between receptacle and the fruit, where it can coordinate the abscission rate in multiple zones through the combined activity of different degrading enzymes, several of which are regulated by this hormone (Agarwal *et al.*, 2012). However, the ethylene concentration required to cause these effects depend on exposure time, temperature, development stage, and species or variety sensitivity (Xin *et al.*, 2019).

Plants of the genus *Capsicum* have different ethylene sensitivity levels (Lima *et al.*, 2017). This hormone triggers a series of deleterious responses

in potted pepper plants, among them the fruits and leaves abscission in different degrees as a reaction to genotype sensitivity to gas. However, other effects are visible, such as acceleration of chlorophyll degradation, color appearance and flower senescence (Segatto *et al.*, 2013; Qiu *et al.*, 2015).

Segatto *et al.* (2013) verified that the genotypes of ornamental pepper plants BGH 1039, BGH 7073, Calypso and MG 302 present different levels of ethylene sensitivity. Calypso and BGH 1039 were classified as highly sensitive. Calypso is an ornamental pepper of high commercial value due to its great ornamental beauty as a potted

plant, but when exposed to 10 $\mu\text{L L}^{-1}$ ethylene during 24 to 48 hours there occurred 100% leaf abscission. The authors observed variable responses of different genotypes to concentration and time of exposure to this gas, in which *C. annuum* access BGH 1039 and cultivar Calypso are more sensitive to the time than to the concentration of ethylene exposure.

The objective of this study was to evaluate the sensitivity of ornamental pepper genotypes to ethylene action and its effects on the quality of potted plants.

MATERIAL AND METHODS

The research was carried out in a greenhouse of Departamento de Fitotecnia of Universidade Federal de Viçosa and postharvest laboratory. Three genotypes of the UFV germplasm bank (Pimenta ornamental, Pimenta colorida and Pimenta laranja) were evaluated. All genotypes are of the species *Capsicum annuum*.

Seedling production

The seedlings were produced in a protected environment in polystyrene trays filled with commercial Bioplant® substrate. Seedlings with two to three pairs of leaves were transplanted into 900 mL pots (11 cm high, 9.5 cm basal diameter, 13.5 cm larger diameter). At planting, the substrate was fertilized with 2.5 g of the formulation 0-10-10. During the research, fertilizations were made every 20 days with 10.0 g of NPK 10-0-10 formulation. Irrigation, from sowing to transplanting, was performed once a day with enough water to start dripping on the bottom of the tray. From transplanting to seedling setting, the substrate was daily irrigated with 150 mL water/pot. From the initial establishment period until the research end, the substrates were daily irrigated with 150 mL/pot, deposited directly on the substrate, with eventual leaf wetness. Plants were staked when necessary and weed pulled out whenever necessary.

Ethylene application and sensitivity assessment

Plants were taken to a laboratory at the ideal marketing point characterized

by 50% of the plants presenting at least 30% fully ripe fruits, visually determined (fruits with maximum growth size and typical shape of each species, with the specific color demanded by the plant). In the laboratory, plants were stored in hermetically sealed 60 L chambers in the dark, simulating transport. These plants were exposed to applications of 0 (internal control) and 10 $\mu\text{L L}^{-1}$ ethylene during 48 hours (Segatto *et al.*, 2013; Lima *et al.*, 2016; Ribeiro *et al.*, 2018).

After ethylene application, plants were transferred to a room at 20 - 25°C and 7 - 10 $\mu\text{mol s}^{-1} \text{m}^{-2}$ fluorescent light, simulating the interior of malls, supermarkets and homes. This phase was determined by the days between plants removal from the chamber until being commercially inadequate, that is, when they presented 50% leaf and/or fruit abscission and/or 50% leaf senescence.

Accumulated abscission of leaves, fruits and flowers

The accumulated abscission was determined by the total count of leaves, fruits and flowers before and after ethylene application. Closed flower buds, in anthesis and completely open and fertilized were counted. Fruits were separated, considering their ripening stage, in green, ripe green and ripe.

The sensitivity of flowers, leaves and fruits to ethylene was determined by the abscission percentage (AP). When $\text{AP} \leq 10\%$ = insensitive, when $10\% < \text{AP} \leq 50\%$ = moderately sensitive and when $\text{AP} > 50\%$ = highly sensitive.

Data analysis

The experimental design was completely randomized with three repetitions. The experimental unit consisted of one plant per pot. Data analysis was performed through descriptive analysis for each genotype over time.

RESULTS AND DISCUSSION

Pimenta colorida genotype

All flowers (100%) were detached from the plant after application of 10 $\mu\text{L L}^{-1}$ ethylene during 48 hours. The abscission of fruits and leaves was

53.0 and 27.8%, respectively. Of the total detached fruits, 87.1% were in the green and 19.9% in the ripe green stage. Ethylene application did not result in ripe fruits abscission. The red coloration appearance of the fruits in green and ripe green stages was accelerated with ethylene application. Plants exposed to ethylene during 48 hours were unsuitable for commercialization, in contrast to control plants that lasted six days on shelf life (Figure 1).

Pimentão ornamental genotype

The accumulated abscission of leaves, flowers and fruits was 78.7; 44.4 and 5.4%, respectively. Of the total detached fruits, 87.1% were green and 12.9% ripe green. After removal from the chamber, some leaves that persisted attached on the plant were yellowish. It was also evident that fruits in the mature green ripening stage that persisted attached on the plant had color intensification with the ethylene application. No fruit abscission was observed on control plants. This genotype lasted only one day after ethylene application, while control plants lasted five days (Figure 2).

Pimenta laranja genotype

Flowers were more sensitive to ethylene than leaves and fruits, resulting in 100% flower, 8.5% leaf and 4.1% fruit abscission after ethylene application. Flowers from control plants have 100% abscission, while the leaves and fruits did not present representative abscission, lasting five days of shelf life. The abscission observed on the control plants on the seventh day was due to the senescence process and leaf abscission related to low radiation conditions (8-10 $\mu\text{mol s}^{-1} \text{m}^{-2}$ fluorescent light) inside the storage environment. In contrast to the other genotypes evaluated, Pimenta laranja, did not present change or intensification of fruit coloration after ethylene application, regardless of fruit maturity stage (Figure 3).

Ethylene sensibility

Most plants are sensitive to ethylene (Iqbal *et al.*, 2017) after exposure to 0.5 - 1.0 $\mu\text{L L}^{-1}$ (Abeles *et al.*, 1992). Generally, there is no response between 0.001 - 0.01 $\mu\text{L L}^{-1}$; there are noticeable effects between 0.01 - 0.1 $\mu\text{L L}^{-1}$; there

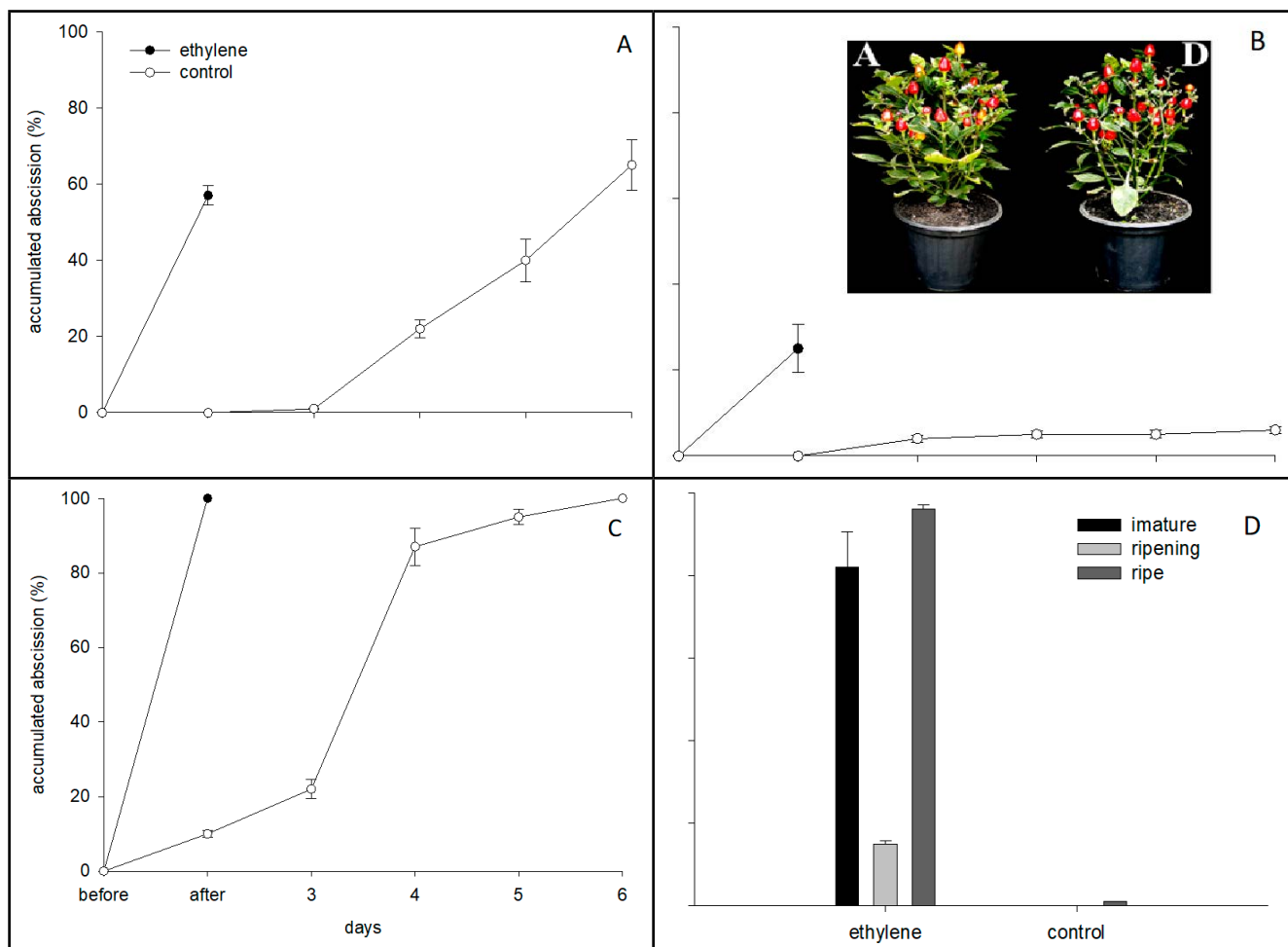


Figure 1. Accumulated abscission (%) of leaves (A), fruits (B) and flowers (C) of *Pimenta colorida* (*Capsicum annuum*) before and after application of $10 \mu\text{L L}^{-1}$ ethylene and during the post production phase. (D) Abscission (%) of ripe, unripe and ripe green fruits after application of $10 \mu\text{L L}^{-1}$ ethylene during 48 hours. Vertical bars mean the standard deviation of the mean ($n = 3$). Viçosa, UFV, 2015.

is 50% of the maximum response between $0.1 - 1.0 \mu\text{L L}^{-1}$ and saturation between 1.0 and $10 \mu\text{L L}^{-1}$ ethylene. That's why varieties or organs classified as sensitive or insensitive to ethylene were thus considered, after exposure to saturating concentration conditions of exogenous ethylene. Plants considered unresponsive to $10 \mu\text{L L}^{-1}$ ethylene may be considered insensitive.

Different responses of diverse organs of the same plant (flowers, leaves or fruits) and among *Capsicum* species suggest different sensitivity levels in each particular organ and, therefore, different response intensities. This may possibly be related to the ethylene receptors amount in the different organs. In addition, the ethylene effect may be independent or dependent on its interaction with other hormones. Multiple receptors of a phytohormone

may be involved in nonredundant responses, in different tissues, at different development stages or in different environmental stimuli (Iqbal *et al.*, 2017).

The expression profiles of ethylene biosynthesis and signaling pathways is different in two coffee cultivars, one late and one early (Sagio, 2012). Expression analysis of *CaACO1-like* and *CaACO4-like* genes and *CaETR4-like* ethylene receptor indicated that higher ethylene production levels in early coffee fruits would be related to the induction of *CaETR4-like* degradation, increasing ethylene sensitivity and consequently early maturation process. In late cultivars, the ethylene production may not be sufficient to deactivate *CaETR4-like* levels and thus changes in ripening occur at a slower rate.

On the present pepper genotypes,

these indications can be observed; for example, due to the fact that the *Pimenta laranja* leaves did not respond to the exogenous ethylene application, but on the genotypes *Pimenta colorida* and *Pimentão ornamental* occurred high leaf abscission. In the specific case of the events observed and associated with the exogenous ethylene application on leaves, possibly in the varieties responsive to exogenous ethylene, there was an interaction between this and other hormones, such as auxin (Abeles *et al.*, 1992). Ethylene triggering abscission, while auxin would be involved in sensitizing cells to ethylene. The leaf remains attached to the plant due to an auxin gradient flowing from the limb towards the stem. The decrease of this gradient associated with the high ethylene concentration probably stimulated the genes activation that

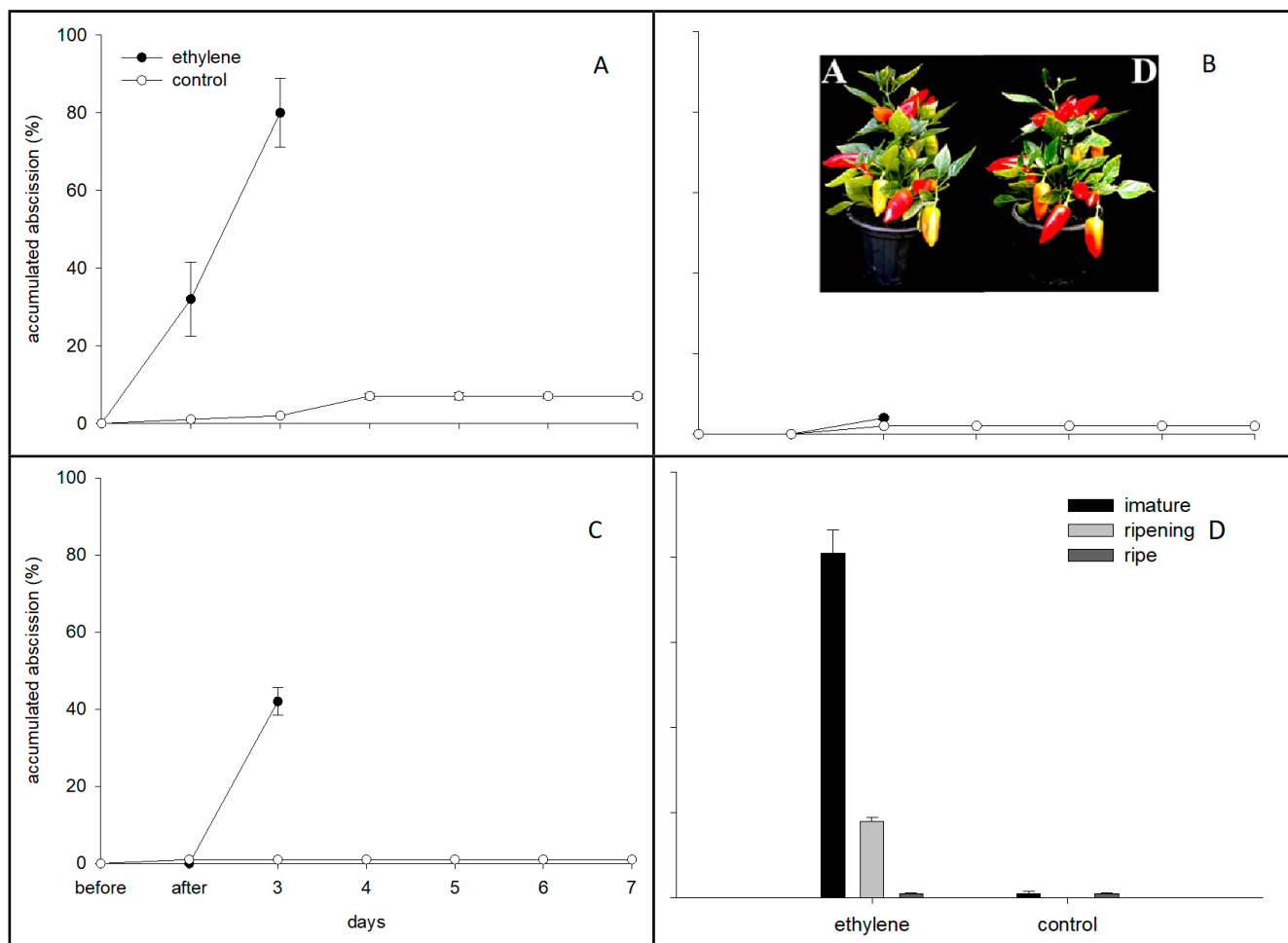


Figure 2. Accumulated abscission (%) of leaves (A), fruits (B) and flowers (C) of Pimentão ornamental (*Capsicum annuum*) before and after application of $10 \mu\text{L L}^{-1}$ ethylene and during the post production phase. (D) Abscission (%) of ripe, unripe and ripe green fruits after application of $10 \mu\text{L L}^{-1}$ ethylene during 48 hours. Vertical bars mean the standard deviation of the mean ($n=3$). Viçosa, UFV, 2015.

encoded hydrolytic enzymes, mainly cellulases and polygalacturonases that acted by weakening the bonds between the structural polymers, depolymerizing them and weakening the cell walls in the abscission zone. Polygalacturonase is also related to cell separation in both leaf and flower abscission (Merelo *et al.*, 2017).

All evaluated genotypes presented fruit abscission percentages lower than 10%, classifying them as insensitive to exogenous ethylene, taking the abscission parameter as a criterion. In contrast, on all varieties, except for Pimenta laranja, fruit color acceleration was observed, although pepper is classified as non-climateric.

Brackmann *et al.* (2005) observed that, eight days after the application of ethylene at 100 and $1000 \mu\text{L L}^{-1}$ concentrations, 'Vidi' peppers had a

higher red color index of the epidermis and there was a higher quantity of red fruits. It was also observed that fruits harvested at the ripe green ripening point reached higher red color indexes of the epidermis.

Krajayklang *et al.* (2000) considered the ethylene application inefficient for the red color development in cv. PS72285, being that the ripening point at harvest influenced much more the development of red pepper color than the ethylene application ($100 \mu\text{L L}^{-1}$). These same authors concluded that peppers harvested with epidermis starting red pigmentation, developed satisfactory red coloration, but the time needed to reach it was much longer than fruits harvested with 50% of the green-red surface.

Regarding flowers, all studied varieties presented high abscission

(100%). This observation corroborates with researchers like Tingley & Prince (1990) who claim that flowers are generally more sensitive to ethylene than foliage and their effects on them, including flower buds that are much more visible and measurable even for a short time of exposure to ethylene (up to 24 hours).

Shelf life

An ornamental pepper vase should have a good formation and stems with good vase coverage and sets without these characteristics are returned to the supplier (França *et al.*, 2018; Veiling Holambra, 2019). Under the real conditions in which ornamental plants are transported in Brazil, usually in trunk trucks in the dark, without ventilation and irrigation, for more than 48 hours (Junqueira & Peetz, 2005), the genotypes Pimenta colorida

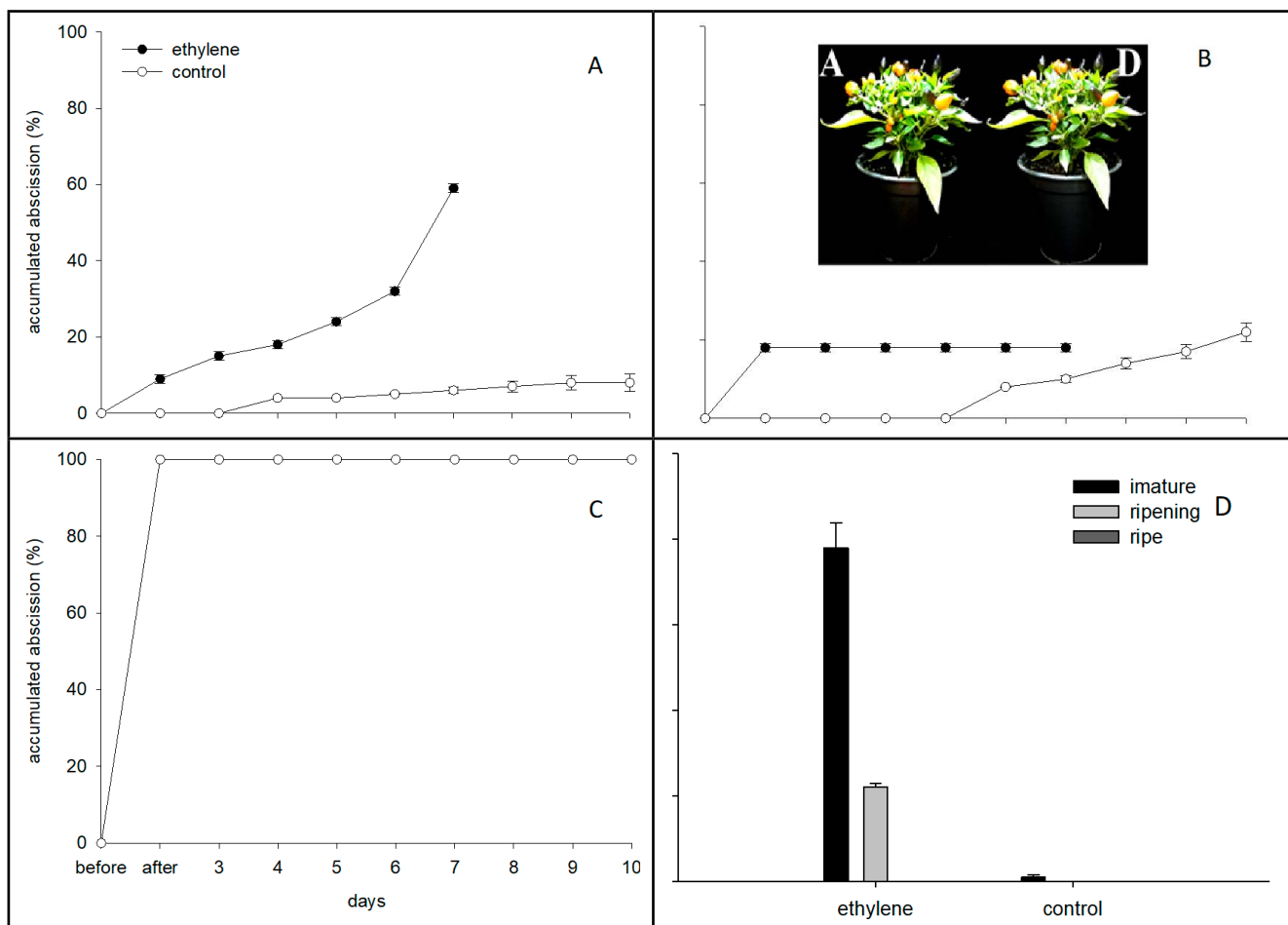


Figure 3. Accumulated abscission (%) of leaves (A), fruits (B) and flowers (C) of *Pimenta laranja* (*Capsicum annuum*) before and after application of $10 \mu\text{L L}^{-1}$ ethylene and during the post production phase. (D) Abscission (%) of ripe, unripe and ripe green fruits after application of $10 \mu\text{L L}^{-1}$ ethylene during 48 hours. Vertical bars mean the standard deviation of the mean ($n=3$). Viçosa, UFV, 2015.

and Pimentão ornamental would be immediately discarded because their ornamental characteristics were compromised by the abscission of their leaves. *Pimenta laranja* would be discarded due to the yellowing of more than 50% leaves and not by leaf abscission. The low radiation ($8-10 \mu\text{mol s}^{-1} \text{m}^{-2}$ fluorescent light) in the room in which the plants were subjected after treatment may explain this fact. According to Cavatte *et al.* (2013), this response is dependent on the variety. In his research, plants of the BGH 1039 variety when transported in the presence of light had a lower leaf abscission rate than in the dark. For the purple variety, the dark is the condition that favors the maintenance of the plant's ornamental quality

Under indoor conditions such as malls, supermarkets and the consumer's residence, plants are generally exposed

to 12 h light at intensities ranging from $8-10 \mu\text{mol s}^{-1} \text{m}^{-2}$ (Nell & Hoyer, 1995). This conditions affect their quality and durability due to the increased ethylene production and/or sensitivity of plants in this condition and/or the low photosynthetically active radiation condition.

There is a difference in sensitivity between *Capsicum* genotypes to exogenous ethylene. Flowers are more sensitive to the hormone than leaves and fruits. The fruits sensitivity is dependent on the ripening stage, with green fruits being more sensitive to ethylene than ripe and ripe green fruits.

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