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Article

Evaluation and Selection of Ornamental Pepper Elite Lines (*Capsicum annuum* L.) for Ethylene-Insensitivity

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Abstract

Capsicum species are widely used as ornamental. In the post-production stage the exposure to ethylene causes chlorophyll degradation and the leaves and fruits abscission, which resulting in loss of commercial value. This work aimed to evaluate and select pepper elite lines to ethylene insensitivity and their stability in two years of evaluation. Forty genotypes were evaluated at 48, 72 and 96 hours after exposure to ethylene in two years, with three replicates in an entirely randomized design. The evaluated variables were number of leaves, number of fruits and chlorophyll *a* and *b*. The variables were evaluated before the ethylene treatment and the plants were stored in airtight chambers (60L) with 10 μ L L⁻¹ ethylene. New evaluations were made at 48, 72 and 96 hours after the exposition. Leaf and fruit abscission were expressed as loss percentage compared to time zero, before ethylene exposure. The data were subjected to analysis of variance. The means were grouped by Scott-Knott criteria ($p \leq 0.01$). The more stable lines with insensitivity to ethylene (55.50.4.1.2, 56.26.24.1.4, 56.26.33.1.9, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 17.15.4.1.9, 56.26.34.1.2, UFPB284, UFPB58, UFPB393 and UFPB291) must be registered as new cultivars. They can be used to insert ethylene insensitivity into susceptible cultivars.

Keywords: exposure to ethylene; phenotypic stability; registration of cultivars

1. Introduction

The genus *Capsicum* comprises a total of 38 species, of which only six cultivated and marketed worldwide *Capsicum annuum* L., *C. assamicum* J. Purkay. and L. Singh, *C. baccatum* L., *C. chinense* Jacq., *C. frutescens* L. and *C. pubescens* Ruiz e Pav. [1]. *Capsicum* species are widely consumed around the world for various purposes, such as seasoning, condiment, as well as medicinal mainly in Asian countries against many diseases and ailments [2,3].

Recently, the use of pepper for ornamental purposes has also been highlighted. The most of them belong to *C. annuum* and *C. frutescens*. These two species have characteristics that enhance their ornamental value, such as variegated leaves, compact height, leaves, flowers and fruits with different sizes and colors [4,5].

Several factors can affect the post-production shelf life of potted ornamental plants, including exposure to low light intensity during transportation, water stress and exposure to ethylene. The latter being one of the most important factors [6].

Ethylene is a phytohormone produced by various plant organs in response to stress factors, such as drought, or during fruit development and ripening [1]. In ornamental pepper, ethylene induces chlorophyll degradation and the abscission of leaves, flowers and fruit, which leads to a loss of

commercial value [6,7]. Due to the undesirable effects caused by the action of ethylene on a large number of ornamental species, there is a need to manage these effects during the post-production phase [7].

The transportation of ornamental plants logistics in Brazil is primarily overland and that the average transportation time from the main producing regions, the South and Southeast, to supply states in the North and Northeast, can take between 36 and 48 hours. The plants are subject to accumulation and exposure to the ethylene present in the surrounding air compromising the quality and commercial durability of the plants [8].

To improve the post-production life of ornamental pepper plants, it is necessary to inhibit the action of ethylene. This can be done by using chemical agents such as silver thiosulphate (STS) and 1-methylcyclopropene (1-MCP) before exposing the plant to ethylene during transportation, shipping, storage and retail stores or when the plants are subjected to any stress that may induce ethylene production [9]. In addition, it is known that species and/or varieties within the same species of the *Capsicum* genus have different levels of sensitivity to ethylene [6]. In view of these differences, an alternative way of obtaining less sensitivity to the effects of ethylene is through genetic resistance, by selecting insensitive genotypes developed in breeding programs for this purpose.

Therefore, plants with good pot harmony and insensitive to ethylene have been evaluated and selected in recent years in the *Capsicum* Breeding Program for ornamental purposes, developed at the Agricultural Sciences Center (CCA) of the Federal University of Paraíba in partnership with the Federal University of Viçosa (UFV).

In breeding programs for any crop, it is necessary to carry out field trials at the final stage in order to release new cultivars. In Brazil it is a basic requirement for registering the new cultivars in the National Register of Cultivars (RNC). These trials are intended for the final evaluation of elite lines selected in preliminary yield trials, under diverse environmental conditions, in experiments repeated over different years, with the aim of obtaining detailed agronomic information for the launch of new cultivars [10].

In addition, final trials are must observe with the criteria established by the Brazilian Ministry of Agriculture and Livestock (MAPA) and include planning and statistical design that allows for the observation, measurement and analysis of the different characters of the different cultivars, as well as the evaluation of the behavior and quality of the cultivars [11]. Then, the aim of this study was to evaluate lines of pepper plants (*C. annuum* L.) to select ethylene-insensitive individuals with phenotypic stability in two years of evaluation.

2. Materials and Methods

2.1. Plant Material, Cultivation, and Experimental Location

The experiment was carried out between 2020 and 2022, in a greenhouse located in the Laboratory of Biotechnology and Plant Breeding, Agricultural Sciences Center, Federal University of Paraíba (CCA-UFPB), Areia, Paraíba, Brazil.

Forty ornamental pepper genotypes (*Capsicum annuum* L.) were used, comprising 20 elite F₇ elite lines (55.50.36.1.8, 55.50.4.1.9, 56.26.15.1.6, 55.50.4.1.2, 55.50.4.1.1, 56.26.24.1.4, 56.26.33.1.9, 56.26.34.1.4, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 56.8.24.1.2, 56.26.24.1.10, 17.15.4.1.9, 56.26.34.1.2, 56.26.33.1.3, 56.26.24.1.1, 17.15.4.1.5, 55.50.36.1.3, 55.50.44.1.8), obtained by consecutive selfing of an experimental hybrid (UFPB 77.3 × UFPB 134); 14 F₃ lines (UFPB214, UFPB239, UFPB174, UFPB240, UFPB232, UFPB241, UFPB288, UFPB284, UFPB273, UFPB250, UFPB36, UFPB58, UFPB393, UFPB291) previously selected in an early generation test developed by [12], and 6 lines, 4 of which were commercial cultivars ('Pirâmide ornamental'; 'Etna'; 'Stromboli' and 'Calypso'), and the two parents lines UFPB 77.3 and UFPB 134, totaling 40 treatments.

The seeds of the genotypes were sown in 200-cell plastic (polypropylene) trays filled with commercial substrate (Plantmax®). After initial development, the plants with six definitive leaves were transplanted into 900 ml pots, 12 cm high, containing the same substrate, and kept in a

greenhouse. Daily irrigation was carried out and once a week fertigation was applied [13]. Phytosanitary treatment with pesticides was carried out when necessary, throughout the cycle, in order to minimize damage caused by pests and diseases.

2.2. Evaluation of Sensitivity to Ethylene

To determine ethylene sensitivity three plants per genotype were evaluated for the variables number of leaves, number of fruits and chlorophyll *a* and *b* content. The counts and measurements of these variables were carried out before the ethylene treatment, and immediately afterwards, the plants were stored in close chambers with a capacity of 60L [14,15]. The ethylene was applied using a graduated syringe, injecting the gas through silicone septa in the chambers, using a concentration of 10 μ L L⁻¹ (10PPM).

The plants remained inside the hermetic chambers (60 L), in the dark and without irrigation for 48 hours by partially simulating transportation [14]. To assess quality and post-production life, 48 hours after the ethylene treatment the plants were transferred from the inside of the chambers to a room with a temperature of 25° C with 8-10 μ mol s⁻¹ m⁻² of irradiance provided by a white fluorescent lamp, which was irrigated with 100 ml of water/pot when necessary.

New evaluations of the variables were carried out on the plants treated with ethylene over a period of 48 (Day 1), 72 (Day 2) and 96h (Day 3) (the time needed for the plant to start losing its commercial value). The criterion for counting was the number of expanded leaves remaining on the plants and fruit that was still vibrant, with no sign of wilting [7]. Leaf and fruit losses were expressed as a percentage in relation to time zero, before exposure [14].

For the chlorophyll *a* and *b* variables, three fully expanded leaves were analyzed, chosen at random from the base, middle and apex of each plant, using the Falker CFL1030 chlorophyllLOG®. Evaluations were carried out at the same intervals as for the other characteristics and were also expressed as a percentage of zero time, before exposure to ethylene.

This same ethylene sensitivity analysis was repeated the following year between January and June 2022, with the same genotypes evaluated, in order to obtain results regarding the behavior of these genotypes in two growing cycles.

2.3. Experimental Design and Statistical Analysis

The design used was entirely randomized, following the with 40 treatments (genotypes) x 3 days (48, 72 and 96 hours after ethylene exposure) x 2 years following a split-split plot arrangement. Forty genotypes were evaluated at three times: 48, 72 and 96 hours after exposure to ethylene and two consecutive cycles (years) with three replicates.

The obtained data were subjected to analysis of variance using the F test and the means were grouped by Scott-Knott criteria ($p \leq 0.01$). All statistical analyses were carried out using the GENES program [16].

3. Results

3.1. ANOVA

In the analysis of variance there was a significant ($p \leq 0.01$) three-way interaction between the factors (genotypes x days x years) only for the leaf abscission. This indicates that the ethylene treatment caused the genotypes evaluated to behave differently in this variable over the evaluation days and in the two years of the experiment (Table 1). Double interactions ($p \leq 0.01$) between genotypes x days (G x D) and genotypes x years (G x Y) were detected for all four characteristics evaluated, showing that there were genotypes that showed different behaviors for the days and years of evaluation. When the factors were isolated, we found that all the characteristics showed significant differences ($p \leq 0.01$) for the years, times (days) and genotypes (Table 1). This shows that exposing

plants to a concentration of 10µl/l of ethylene is enough to generate different responses in ornamental pepper plants (Table 1).

Table 1. Summary of the analysis of variance for four ethylene sensitivity variables in ornamental pepper (*Capsicum annuum* L.).

SV	DF	Mean Squares			
		LA	FA	Cloa	Clob
Years	1	4787.99**	4200.96**	632.97**	676.375**
Days	2	40470.85**	8189.46**	10304.08**	12423.55**
Years x Days	2	155.42 ^{ns}	489.99 ^{ns}	10.11 ^{ns}	0.73 ^{ns}
Error a	12	99.73	39.10	26.39	68.87
Genotypes	39	10203.56**	2831.73**	642.70**	1067.67**
Genotypes x Years	39	1107.36**	255.60**	58.65**	95.08**
Genotypes x Days	78	426.62**	39.31**	78.06**	80.74**
Gen x Days x Years	78	206.76**	17.69 ^{ns}	12.27 ^{ns}	9.63 ^{ns}
Error b	468	67.98	41.17	21.82	58.92
$\bar{X}$		39.07	19.48	18.04	25.45
CVa (%)		25.55	32.08	28.47	32.60
CVb (%)		21.09	32.92	25.89	30.15

^{ns}Not significant, ** significant at 1% probability by the F test. LA–leaf abscission; FA–fruit abscission; Cloa–chlorophyll *a* content; Clob–chlorophyll *b* content. Source: the author.

3.2. Three-Factor Interaction (Genotypes x Days x Years) for Percentage of Leaf Abscission

For the interaction genotypes x days x years (G x D x Y), there was different behavior for leaf abscission in the first year of evaluation for the genotypes treated with ethylene including 56.8.24.1.2, 56.26.24.1.10, UFPB240, UFPB241, UFPB288, 56.26.24.1.1, UFPB250, 55.50.36.1.3 and 55.50.44.1.8 genotypes. The averages recorded on the first day showed significant differences when compared to the other days, demonstrating that despite having a lower rate of leaf abscission on Day 1 (48 hours of treatment), they showed higher rates of leaf loss on the second day (72 hours of treatment), with similar values to those recorded on the third day (96 hours of treatment) (Table 3). This same behavior was observed, in the second year of evaluation for genotypes 56.8.24.1.2, 56.26.24.1.10, 56.26.24.1.1 and UFPB250 (Table 3). In the first year the genotypes UFPB174, UFPB273, 17.15.4.1.5 and G77.3 presented a different behavior with less percentage of leaves abscission in the first two days of evaluation (48h and 72h), and a massive drop on the third day of evaluation (96h). In the second year, the genotypes 55.50.36.1.8, 56.26.33.1.3, UFPB232, UFPB241 and 17.15.4.1.5 behaved in this way (Table 3). Finally, UFPB239 was the only genotype with an increasing and distinct behavior for the three days, and this was observed in the first year of evaluation (Table 3).

For the genotypes treated with ethylene, the averages of leaf abscission were stable in the lines 55.50.4.1.2, 56.26.24.1.4, 56.26.33.1.9, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 17.15.4.1.9, 56.26.34.1.2, UFPB284, UFPB58, UFPB393, and UFPB291 (Table 3) (Figures S1 to S18). All showed similar behavior between the three days after ethylene application and in the two years. In addition to their stability, these were the genotypes that formed groups with the lowest rates of leaf abscission and were therefore the most insensitive to the effect of ethylene on this characteristic, thus presenting potential for selection for ethylene resistance.

The UFPB36, the G134 genitor and the cultivars ‘Pirâmide’ and ‘Calypso’ also showed stability in their behavior in the triple interaction of factors (G x D x Y), but these genotypes were part of groups with the highest rates of leaf abscission, being highly sensitive to the action of ethylene on this characteristic on the days and in the two years of evaluation (Table 3) (Figures S1 to S18).

By evaluating the behavior shown by the lines in the two years (averages for year 1 and 2), 55.50.36.1.8, 55.50.4.1.9, 56.26.15.1.6, 55.50.4.1.1, 56.26.34.1.4, UFPB239, UFPB232 and UFPB288 showed differences in the leaf abscission averages recorded in each year. These showed different behavior with the variation in environment (year) and had higher values in the second year of evaluation. Only the UFPB288 had lower leaf abscission in the second year compared to the first (Table 2). It is important to note that greater leaf abscission in the second year was expected, given that the same plants went through two successive phases of stress caused by the ethylene treatment. Even so, most of the genotypes evaluated did not show statistically different behavior, with similar average values in the two years of evaluation. Of these, the most noteworthy for having shown the lowest leaf abscission in the overall averages for both years, being considered the most insensitive to the action of ethylene on this characteristic, are the lines including 55.50.4.1.2, 56.26.24.1.4, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 17.15.4.1.9, 56.26.34.1.2, 56.26.33.1.3, UFPB58, UFPB393 and UFPB291 (Table 2).

Table 2. Unfolding the genotypes x days x years interaction, year averages and overall averages (years) for the leaf abscission variable in forty genotypes of ornamental pepper (*Capsicum annuum* L.) subjected to ethylene.

Genotypes	Leaf abscission (%)								Overall average (years)
	Year 1				Year 2				
	Day 1	Day 2	Day 3	Average year	Day 1	Day 2	Day 3	Average year	
55.50.36.1.8	14.80 Ag	17.52 Ah	19.65 Ag	17.32 <i>Be</i>	18.81 Be	38.28 Bd	64.41 Ab	40.50 <i>Ad</i>	28.91 d
55.50.4.1.9	19.65 Af	21.04 Ag	25.08 Ag	21.92 <i>Bd</i>	56.55 Ab	75.33 Ab	88.57 Aa	73.48 <i>Ab</i>	47.70 c
‘Pirâmide’	89.87 Aa	93.89 Aa	95.30 Aa	93.02 <i>Aa</i>	86.38 Aa	93.68 Aa	96.39 Aa	92.15 <i>Aa</i>	92.58 a
56.26.15.1.6	8.16 Ag	11.97 Ah	14.26 Ah	11.46 <i>Be</i>	23.43 Ad	36.91 Ad	53.54 Ac	37.96 <i>Ad</i>	24.71 d
55.50.4.1.2	6.66 Ag	9.81 Ah	13.80 Ah	10.09 <i>Ae</i>	9.19 Ae	15.50 Af	23.27 Ae	15.99 <i>Ae</i>	13.04 e
55.50.4.1.1	5.45 Ag	13.00 Ah	17.88 Ag	12,11 <i>Be</i>	22.70 Ad	41.90 Ad	59.39 Ac	41.33 <i>Ad</i>	26.72 d
56.26.24.1.4	5.76 Ag	13.31 Ah	19.36 Ag	12.81 <i>Ae</i>	8.89 Ae	15.98 Af	24.85 Ae	16.57 <i>Ae</i>	14.69 e
56.26.33.1.9	7.44 Ag	12.32 Ah	16.28 Ah	12.01 <i>Ae</i>	13.40 Ae	18.25 Af	24.45 Ae	18.70 <i>Ae</i>	15.36 e
56.26.34.1.4	8.69 Ag	12.12 Ah	16.50 Ah	12.44 <i>Be</i>	35.09 Ac	55.87 Ac	60.77 Ac	50.58 <i>Ac</i>	31.51 d
17.15.48.1.2	6.75 Ag	10.06 Ah	12.16 Ah	9.66 <i>Ae</i>	14.95 Ae	24.41 Ae	27.02 Ae	22.13 <i>Ae</i>	15.89 e
56.26.15.1.5	3.45 Ag	7.12 Ah	10.77 Ah	7.11 <i>Ae</i>	5.04 Ae	11.06 Af	14.87 Ae	10.32 <i>Ae</i>	8.72 e
56.26.33.1.5	5.44 Ag	9.95 Ah	12.42 Ah	9.27 <i>Ae</i>	5.89 Ae	11.57 Af	14.13 Ae	10.53 <i>Ae</i>	9.90 e
56.8.24.1.2	9.09 Bg	60.45 Ad	77.80 Ac	49.11 <i>Ac</i>	37.92 Bc	64.21 Ab	85.23 Aa	62.45 <i>Ac</i>	55.78 c
56.26.24.1.10	18.37 Bf	52.76 Ae	72.19 Ad	47.77 <i>Ac</i>	25.56 Bd	50.48 Ac	70.35 Ab	48.80 <i>Ac</i>	48.29 c
17.15.4.1.9	6.69 Ag	22.30 Ag	28.23 Af	19.07 <i>Ae</i>	5.31 Ae	10.78 Af	16.85 Ae	10.98 <i>Ae</i>	15.03 e
56.26.34.1.2	10.33 Ag	15,16 Ah	21.76 Ag	15.75 <i>Ae</i>	7.43 Ae	11.81 Af	18.98 Ae	12.74 <i>Ae</i>	14.25 e
56.26.33.1.3	8.06 Ag	15.66 Ah	23.71 Ag	15.81 <i>Ae</i>	4.82 Be	9.49 Bf	41.50 Ad	18.60 <i>Ae</i>	17.21 e
‘Stromboli’	10.49 Ag	25.12 Ag	35.28 Af	23.63 <i>Ad</i>	9.08 Ae	25.12 Ae	37.29 Ad	23.83 <i>Ae</i>	23.73 d
UFPB214	17.83 Bf	83.83 Ab	99.25 Aa	66.97 <i>Ab</i>	70.15 Aa	74.91 Ab	95.26 Aa	80.11 <i>Aa</i>	73.54 b
UFPB239	24.29 Cf	61.04 Bd	95.95 Aa	60.43 <i>Bc</i>	80.07 Aa	83.49 Aa	93.19 Aa	85.58 <i>Aa</i>	73.01 b
UFPB174	8.16 Bg	26.86 Bg	68.32 Ad	34.45 <i>Ad</i>	39.46 Ac	49.28 Ac	57.09 Ac	48.61 <i>Ac</i>	41.53 c
UFPB240	35.03 Be	59.05 Ad	76.66 Ac	56.92 <i>Ac</i>	38.09 Ac	45.31 Ac	63.79 Ab	49.06 <i>Ac</i>	52.99 c

UFPB232	9.26 Ag	15.95 Ah	20.38 Ag	15,20 <i>Be</i>	31.69 Bc	50.50 Bc	71.78 Ab	51.33 <i>Ac</i>	33.26 d
UFPB241	19.45 Bf	53.54 Ae	64.96 Ad	45.99 <i>Ac</i>	22.62 Bd	38.44 Bd	68.55 Ab	43.20 <i>Ad</i>	44.59 c
UFPB288	30.61 Be	71.72 Ac	83.70 Ab	62.01 <i>Ac</i>	22.78 Ad	31.85 Ae	47.69 Ad	34.11 <i>Bd</i>	48.06 c
56.26.24.1.1	26.00 Bf	82.56 Ab	92.11 Aa	66.89 <i>Ab</i>	33.77 Bc	68.70 Ab	85.19 Aa	62.55 <i>Ac</i>	64.72 b
17.15.4.1.5	24.23 Bf	36.61 Bf	87.05 Ab	49.30 <i>Ac</i>	17.71 Be	29.78 Be	55.81 Ac	34.43 <i>Ad</i>	41.87 c
UFPB284	24.82 Af	26.46 Ag	28.77 Af	26.69 <i>Ad</i>	18.80 Ae	23.94 Ae	29.30 Ae	24.02 <i>Ae</i>	25.35 d
UFPB273	15.33 Bg	38.59 Bf	68.03 Ad	40.65 <i>Ac</i>	35.22 <i>Ac</i>	53.93 <i>Ac</i>	71.80 Ab	53.65 <i>Ac</i>	47.15 c

Averages followed by the same capital letters on the HORIZONTALLY, lowercase letters on the VERTICALLY and italicized capital letters on the HORIZONTALLY and lowercase letters on the VERTICALLY do not differ statistically, constituting a homogeneous group, according to the Scott-Knott criterion ($p = 0.01$). Source: the author.

Continued **Table 2**

Genotypes	Leaf abscission (%)								Overall average (years)
	Year 1				Year 2				
	Day 1	Day 2	Day 3	Average Year	Day 1	Day 2	Day 3	Average Year	
G77.3	25.75 Bf	45.43 Be	76.16 Ac	49.11 <i>Ac</i>	25.70 Ad	42.23 Ad	59.35 Ac	42.43 <i>Ad</i>	45.77 c
UFPB250	54.27 Bd	77.36 Ab	96.88 Aa	76.17 <i>Ab</i>	48.17 Bb	70.10 Ab	91.52 Aa	69.93 <i>Ab</i>	73.05 b
55.50.36.1.3	30.36 Be	53.53 Ae	69.55 Ad	51.15 <i>Ac</i>	31.83 Ac	44.64 Ac	55.53 Ac	44.00 <i>Ad</i>	47.57 c
55.50.44.1.8	21.35 Bf	46.81 Ae	60.05 Ad	42.74 <i>Ac</i>	31.11 Ac	46.16 Ac	54.89 Ac	44.05 <i>Ad</i>	43.40 c
UFPB36	77.14 Ab	78.82 Ab	82.07 Ac	79.34 <i>Ab</i>	55.24 Ab	68.78 Ab	75.18 Ab	66.40 <i>Ac</i>	72.87 b
G134	70.26 Ac	71.48 Ac	79.35 Ac	73.69 <i>Ab</i>	58.81 Ab	71.45 Ab	77.58 Aa	69.28 <i>Ab</i>	71.49 b
‘Calypso’	91.21 Aa	93.56 Aa	98.89 Aa	94.56 <i>Aa</i>	78.09 Aa	92.44 Aa	97.99 Aa	89.50 <i>Aa</i>	92.03 a
UFPB58	7.83 Ag	13.83 Ah	18.79 Ag	13.48 <i>Ae</i>	8.01 Ae	13.87 Af	18.65 Ae	13.51 <i>Ae</i>	13.50 e
UFPB393	9.11 Ag	12.59 Ah	14.73 Ah	12.14 <i>Ae</i>	6.14 Ae	11.88 Af	20.61 Ae	12.87 <i>Ae</i>	12.51 e
UFPB291	4.56 Ag	12.59 Ah	14.73 Ah	8.09 <i>Ae</i>	4.31 Ae	8.76 Af	13.56 Ae	8.88 <i>Ae</i>	8.48 e
‘Etna’	21.66 Af	33.12 Af	45.60 Ae	33.46 <i>Ad</i>	20.62 Ad	31.16 Ae	41.06 Ad	30.95 <i>Ad</i>	23.20 d

Averages followed by the same capital letters on the HORIZONTALLY, lowercase letters on the VERTICALLY and italicized capital letters on the HORIZONTALLY and lowercase letters on the VER.

3.3. Two-Factor Interaction (Genotypes x Days) for the Averages of Fruit Abscission (%), Chlorophyll *a* and *b* Content (%)

For the interaction genotypes x days (G x D) in the variable fruit abscission in plants subjected to ethylene, there was a different behavior in the averages on the first day compared to the other evaluation days in the four test cultivars: ‘Pirâmide’, ‘Stromboli’, ‘Calypso’ and ‘Etna’; in the two genitors: G77.3 and G134; and in the lines 56.26.33.1.3, UFPB214, UFPB239 and UFPB36 (Table 3). Strain 55.50.36.1.3 had similar behavior on the first two days, with greater abscission only on the third day. All the other genotypes showed a stable increase in their averages over the three days evaluation with the lowest averages in UFPB284 (Day 1 = 7.53%; Day 2 = 9.63%; Day 3 = 11.45%) and the highest in 56.26.24.1.10 (Day 1 = 35.05%; Day 2 = 46.80%; Day 3 = 56.63%) (Table 3).

For chlorophyll *a*, most of the genotypes evaluated showed a distinct increase in the rates of this variable during the evaluation days (G x D). For these, there were three kinds of behavior. In the first, genotypes in which their averages on the first day were significantly different from those recorded on the other days were 55.50.4.1.2, 56.26.33.1.9, 56.26.34.1.4, 56.26.15.1.5, 56.8.24.1.2, 17.15.4.1.9, UFPB239, UFPB174, UFPB 240, UFPB241, 56.26.24.1.1, G77.3, UFPB36, G134 ‘Calypso’ and ‘Etna’ (Table 3). Secondly, the genotypes 55.50.4.1.9, 17.15.48.1.2, 56.26.24.1.10, 56.26.34.1.2, 56.26.33.1.3, ‘Stromboli’ and UFPB393 were similar in their averages on the first and second day, with a significant difference in the values recorded only on the third day (Table 3). And lastly, the materials whose behavior was different for the three days: 55.50.36.1.8, ‘Pyramid’, 56.26.15.1.6, 55.50.4.1.1, 56.26.24.1.4, 56.26.33.1.5 and UFPB214 (Table 3).

For the variable chlorophyll *b* content, a total of 17 genotypes showed different behavior in their averages recorded between days (Table 3). Of these, the genotypes whose averages on the first day differed from those obtained on the other days were: 55.50.36.1.8, ‘Pirâmide’, 56.26.15.1.6, 55.50.4.1.1, 56.26.24.1.4, 56.26.33.1.9, 56.26.34.1.4, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 56.26.24.1.10, 56.26.33.1.3, UFPB214, UFPB241, G77.3 and UFPB58 (Table 3). Only the ‘Stromboli’ cultivar showed similar averages on the first two days, with a difference only on the third. All the other genotypes had stable averages, with no significant differences over the days, indicating that most of the materials did not have a greater effect on the rate of chlorophyll *b* degradation observed at the different times after exposure to ethylene (Table 3).

Table 3. Unfolding the genotypes x days interaction, for the variables fruit abscission, chlorophyll *a* and *b* content (%) in forty genotypes of ornamental pepper (*Capsicum annuum* L.) submitted to ethylene in two years of evaluation.

Genotypes	Fruit abscission (%)			Chlorophyll <i>a</i> content (%)			Chlorophyll <i>b</i> content (%)		
	Day 1 (48h)	Day 2 (72h)	Day 3 (96h)	Day 1 (48h)	Day 2 (72h)	Day 3 (96h)	Day 1 (48h)	Day 2 (72h)	Day 3 (96h)
55.50.36.1.8	8.57 Ae	11.90 Ag	15.64 Ah	9.00 Cc	26.29 Bc	35.61 Ab	12.13 Bd	27.64 Ac	37.32 Ac
55.50.4.1.9	14.43 Ad	17.92 Ae	23.55 Af	16.67 Bb	18.50 Bd	27.70 Ac	26.69 Ab	29.41 Ac	35.50 Ac
‘Pirâmide’	40.71 Ba	53.23 Aa	58.75 Ab	8.94 Cc	31.54 Bb	40.28 Ab	6.44 Be	28.73 Ac	39.30 Ab
56.26.15.1.6	8.50 Ae	13.69 Af	18.58 Ag	16.02 Cb	37.05 Ba	49.57 Aa	21.06 Bc	44.21 Aa	45.04 Ab
55.50.4.1.2	7.21 Ae	13.02 Af	16.69 Ag	9.82 Bc	20.41 Ad	27.14 Ac	23.84 Ab	30.16 Ac	33.21 Ad
55.50.4.1.1	6.77 Ae	10.06 Ag	14.79 Ah	9.86 Cc	27.64 Bc	34.87 Ab	12.01 Bd	32.17 Ac	36.37 Ac
56.26.24.1.4	6.93 Ae	11.45 Ag	15.50 Ah	16.56 Cb	27.52 Bc	36.55 Ab	16.71 Bd	24.32 Ad	31.72 Ad
56.26.33.1.9	6.44 Ae	9.90 Ag	13.36 Ah	12.21 Bc	20.77 Ad	23.40 Ad	25.36 Bb	33.77 Ac	39.60 Ab
56.26.34.1.4	6.76 Ae	11.80 Ag	15.19 Ah	10.30 Bc	19.85 Ad	24.50 Ad	15.38 Bd	25.23 Ad	30.77 Ad
17.15.48.1.2	5.83 Ae	9.34 Ag	11.96 Ah	11.00 Bc	14.24 Bf	21.15 Ae	21.48 Bc	30.51 Ac	35.50 Ac
56.26.15.1.5	11.24 Ad	15.85 Af	18.64 Ag	15.63 Bb	24.40 Ac	30.80 Ac	21.01 Bc	42.98 Aa	49.16 Aa
56.26.33.1.5	7.53 Ae	10.46 Ag	13.33 Ah	9.51 Cc	19.64 Bd	27.02 Ac	13.41 Bd	28.23 Ac	34.38 Ac
56.8.24.1.2	4.54 Be	9.97 Bg	21.13 Af	23.10 Ba	32.70 Ab	38.71 Ab	20.35 Ac	27.92 Ac	32.98 Ad
56.26.24.1.10	35.05 Bb	46.80 Ab	56.63 Ab	10.07 Bc	16.40 Be	23.91 Ad	9.74 Be	21.15 Ad	23.96 Ae
17.15.4.1.9	9.19 Ae	16.48 Af	20.18 Ag	7.62 Bd	15.40 Ae	22.35 Ae	13.23 Ad	18.77 Ae	24.89 Ae
56.26.34.1.2	11.65 Ad	17.93 Ae	21.86 Af	8.38 Bd	12.92 Bf	17.79 Af	18.21 Ad	22.26 Ad	25.64 Ae
56.26.33.1.3	16.43 Bd	26.33 Ad	33.37 Ae	16.23 Bb	20.44 Bd	29.18 Ac	25.30 Bb	36.69 Ab	44.41 Ab
‘Stromboli’	16.76 Bd	26.94 Ad	36.84 Ad	4.51 Bd	9.74 Bg	15.15 Af	14.52 Bd	23.70 Bd	40.54 Ab
UFPB214	13.80 Bd	21.82 Ae	28.64 Ae	16.38 Cb	27.50 Bc	36.20 Ab	20.64 Bc	32.32 Ac	40.52 Ab
UFPB239	12.81 Bd	24.61 Ad	30.27 Ae	9.74 Bc	21.57 Ad	27.06 Ac	12.54 Ad	19.54 Ae	24.43 Ae
UFPB174	12.31 Ad	19.23 Ae	24.56 Af	11.15 Bc	17.60 Ae	20.80 Ae	12.18 Ad	18.29 Ae	21.41 Af
UFPB240	7.38 Ae	13.51 Af	17.47 Ag	7.39 Bd	13.39 Af	16.33 Af	15.08 Ad	21.75 Ad	26.08 Ae
UFPB232	6.71 Ae	11.43 Ag	15.08 Ah	8.56 Ad	10.82 Ag	15.68 Af	12.61 Ad	18.29 Ae	23.75 Ae

UFPB241	4.67 Ae	9.42 Ag	14.87 Ah	12.81 Bc	19.11 Ad	24.64 Ad	27.22 Bb	36.06 Ab	43.44 Ab
UFPB288	6.29 Ae	13.13 Af	15.91 Ah	13.66 Ab	16.45 Ae	19.59 Ae	12.45 Ad	17.30 Ae	22.26 Ae
56.26.24.1.1	7.62 Ae	12.78 Ag	16.77 Ag	9.19 Bc	15.49 Ae	17.37 Af	10.29 Ae	16.23 Ae	19.46 Af
17.15.4.1.5	6.43 Ae	10.20 Ag	14.08 Ah	11.51 Ac	13.58 Af	15.59 Af	40.92 Aa	47.15 Aa	51.16 Aa
UFPB284	7.53 Ae	9.63 Ag	11.45 Ah	6.90 Ad	11.45 Ag	12.60 Ag	12.29 Ad	16.37 Ae	20.34 Af
UFPB273	6.98 Ae	10.70 Ag	14.03 Ah	12.88 Ac	18.35 Ad	20.45 Ae	15.01 Ad	18.90 Ae	23.74 Ae

Averages followed by the same uppercase letters in HORIZONTALLY and lowercase letters in VERTICALLY do not differ statistically, constituting a homogeneous group, according to the Scott-Knott criterion ($p = 0.01$). Source: the author.

Continued **Table 3**

Genotypes	Fruit abscission (%)			Chlorophyll <i>a</i> content (%)			Chlorophyll <i>b</i> content (%)		
	Day 1 (48h)	Day 2 (72h)	Day 3 (96h)	Day 1 (48h)	Day 2 (72h)	Day 3 (96h)	Day 1 (48h)	Day 2 (72h)	Day 3 (96h)
G77.3	30.47 Bc	38.45 Ac	44.96 Ac	16.38 Bb	23.19 Ac	28.40 Ac	13.62 Bd	23.77 Ad	31.98 Ad
UFPB250	17.00 Ad	22.91 Ad	28.61 Ae	12.24 Bc	18.17 Ad	20.63 Ae	11.56 Ad	16.24 Ae	18.97 Af
55.50.36.1.3	13.87 Bd	17.16 Bf	27.95 Ae	11.56 Bc	19.56 Ad	25.94 Ad	27.52 Ab	31.34 Ac	34.60 Ac
55.50.44.1.8	12.64 Ad	16.37 Af	21.54 Af	7.72 Ad	9.65 Ag	14.46 Af	26.10 Ab	32.52 Ac	37.44 Ac
UFPB36	27.35 Bc	35.73 Ac	42.31 Ac	10.29 Bc	17.72 Ae	21.25 Ae	22.96 Ac	29.87 Ac	36.71 Ac
G134	39.53 Ba	55.26 Aa	58.56 Ab	11.66 Ac	16.11 Ae	17.70 Af	35.16 Aa	38.62 Ab	40.21 Ab
‘Calypso’	42.18 Ba	58.29 Aa	63.97 Aa	7.43 Bd	13.95 Af	16.99 Af	19.34 Ac	27.16 Ac	31.56 Ad
UFPB58	7.45 Ae	12.43 Ag	16.62 Ag	10.79 Bc	18.99 Ad	24.16 Ad	13.15 Bd	27.33 Ac	31.72 Ad
UFPB393	9.95 Ae	15.86 Af	23.14 Af	12.50 Bc	15.17 Be	23.34 Ad	8.97 Ae	14.33 Ae	18.56 Af
UFPB291	6.54 Ae	10.38 Ag	14.99 Ah	4.90 Ad	8.12 Ag	11.55 Ag	9.01 Ae	14.81 Ae	19.51 Af
‘Etna’	13.11 Bd	25.17 Ad	31.62 Ae	4.78 Ad	9.56 Ag	11.11 Ag	14.93 Ad	18.23 Ae	22.64 Ae

Averages followed by the same uppercase letters in HORIZONTALLY and lowercase letters in VERTICALLY do not differ statistically, constituting a homogeneous group, according to the Scott-Knott criterion ($p = 0.01$). Source: the author.

3.4. Two-Factor Interaction (Genotypes x Years) for Fruit Abscission (%), Chlorophyll a and b Content (%)

For the variable fruit abscission, the behavior was different in the two years (G x Y) for the genotypes: ‘Pirâmide’, 55.50.4.1.1, 56.26.24.1.10, 17.15.4.1.9, 56.26.34.1.2, 56.26.33.1.3, UFPB174, ‘Calypso’, UFPB58 and UFPB291. From these, only strain 56.26.24.1.10 showed lower fruit loss in the second year compared to the first, and for the others the behavior was reversed. This may have been due to the same reason mentioned for the leaf abscission averages, since the same plants went through two successive phases of stress caused by ethylene treatment, which made them more fragile in the second year, with consequent greater abscission (Table 4). On the other hand, the lines with similar averages and the lowest fruit abscission values in both years (overall averages) were: 55.50.36.1.8, 56.26.15.1.6, 55.50.4.1.2, 56.26.24.1.4, 56.26.33.1.9, 56.26.34.1.4, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 56.8.24.1.2, 17.15.4.1.9, UFPB240, UFPB232, UFPB241, UFPB288, 56.26.24.1.1, 17.15.4.1.5, UFPB284, UFPB273 and UFPB393 (Table 4).

When evaluating the chlorophyll a averages, only 56.26.15.1.6 showed different behavior in the average values for the two years, with the rate of chlorophyll a degradation being 39.37% in the first year, with a reduction to 29.05% in the second year (Table 4). The other genotypes behaved similarly between the years, with 56.26.34.1.2 (13.03%), UFPB240 (12.37%), UFPB232 (11.69%), 56.26.24.1.1 (14.02%), 17.15.4.1.5 (13.56%), UFPB284 (10.32%) 55.50.44.1.8 (10.61%) UFPB291 (8.19%) and ‘Etna’ were the materials with the lowest overall averages. While the highest were recorded by 56.26.15.1.6 (34.21%) and 56.8.24.1.2 (31.51%) (Table 4).

For chlorophyll b levels, the behavior was different between the years in strain 55.50.4.1.9 and cultivar ‘Etna’ (Table 4). In all the other genotypes, the behavior was similar in both years. In the performance of the overall averages, 14 genotypes formed a homogeneous group with the lowest degradation rates, with the lowest drop being recorded in UFPB393 (13.95%). Meanwhile, 6 genotypes were in the group with the highest rates, with the highest degradation percentage for the line 17.15.4.1.5 (46.41%) (Table 4). In general, the other genotypes showed intermediate average values for the degradation of chlorophyll b content, ranging from 22.04 to 36.91% (Table 4).

Table 4. Unfolding the genotypes x years interaction, for the variables fruit abscission, chlorophyll *a* and *b* content (%) in forty genotypes of ornamental pepper (*Capsicum annuum* L.) submitted to ethylene in two years of evaluation.

Genotypes	Fruit abscission (%)			Chlorophyll <i>a</i> content (%)			Chlorophyll <i>b</i> content (%)		
	Year 1	Year 2	Average (years)	Year 1	Year 2	Average (years)	Year 1	Year 2	Average (years)
55.50.36.1.8	7.79 Ae	16.28 Ae	12.04 d	23.22 Ab	24.05 Aa	23.63 b	27.54 Ab	23.86 Ac	25.70 c
55.50.4.1.9	15.38 Ad	21.89 Ad	18.63 c	20.45 Ab	21.47 Aa	20.96 b	36.53 Aa	24.53 Bc	30.53 b
‘Pirâmide’	42.49 Bb	59.30 Aa	50.90 a	31.34 Aa	22.50 Aa	26.92 b	26.82 Ab	22.83 Ac	24.82 c
56.26.15.1.6	9.46 Ae	17.72 Ae	13.59 d	39.37 Aa	29.05 Ba	34.21 a	40.00 Aa	33.54 Ab	36.77 a
55.50.4.1.2	9.30 Ae	15.32 Ae	12.31 d	19.36 Ac	18.89 Aa	19.12 c	27.96 Ab	30.18 Ab	29.07 b
55.50.4.1.1	5.15 Be	15.93 Ae	10.54 d	24.10 Ab	24.16 Aa	24.13 b	27.07 Ab	26.64 Ac	26.85 c
56.26.24.1.4	9.58 Ae	13.02 Ae	11.30 d	27.07 Ab	26.68 Aa	26.88 b	23.55 Ac	24.95 Ac	24.25 c
56.26.33.1.9	8.70 Ae	11.10 Ae	9.90 d	16.75 Ac	20.84 Aa	18.80 c	32.53 Aa	33.29 Ab	32.91 b
56.26.34.1.4	10.22 Ae	12.27 Ae	11.25 d	14.95 Ac	21.49 Aa	18.22 c	24.62 Ac	22.97 Ac	23.80 c
17.15.48.1.2	5.25 Ae	12.83 Ae	9.04 d	13.99 Ac	16.93 Ab	15.46 c	30.21 Ab	28.12 Ac	29.17 b
56.26.15.1.5	13.10 Ae	17.38 Ae	15.24 d	23.02 Ab	24.21 Aa	23.61 b	38.39 Aa	37.04 Ab	37.72 a
56.26.33.1.5	9.67 Ae	11.21 Ae	10.44 d	17.65 Ac	19.80 Aa	18.72 c	23.00 Ac	27.68 Ac	25.34 c
56.8.24.1.2	10.11 Ae	13.65 Ae	11.88 d	32.11 Aa	30.91 Aa	31.51 a	26.90 Ab	27.26 Ac	27.08 c
56.26.24.1.10	57.92 Aa	34.40 Bc	46.16 a	12.66 Ac	20.93 Aa	16.79 c	15.44 Ad	21.12 Ac	18.28 d
17.15.4.1.9	10.27 Be	20.30 Ad	15.28 d	12.61 Ac	17.64 Ab	15.12 c	17.76 Ad	20.16 Ac	18.96 d
56.26.34.1.2	7.32 Be	26.97 Ad	17.15 c	12.03 Ac	14.03 Ab	13.03 d	22.96 Ac	21.11 Ac	22.04 c
56.26.33.1.3	17.09 Bd	33.66 Ac	25.38 c	21.89 Ab	22.01 Aa	21.95 b	34.40 Aa	36.53 Ab	35.47 a
‘Stromboli’	25.88 Ad	27.81 Ad	26.85 c	9.11 Ac	10.49 Ab	9.80 d	25.44 Ab	27.07 Ac	26.25 c
UFPB214	17.46 Ad	25.38 Ad	21.42 c	27.12 Ab	26.27 Aa	26.70 b	33.33 Aa	28.99 Ac	31.16 b
UFPB239	22.17 Ad	22.96 Ad	22.57 c	18.28 Ac	20.63 Aa	19.45 c	16.48 Ad	21.19 Ac	18.83 d
UFPB174	13.88 Be	23.52 Ad	18.70 c	15.88 Ac	17.15 Ab	16.52 c	16.57 Ad	18.01 Ac	17.29 d
UFPB240	9.47 Ae	16.11 Ae	12.79 d	11.42 Ac	13.32 Ab	12.37 d	18.14 Ad	23.79 Ac	20.97 d
UFPB232	9.39 Ae	12.76 Ae	11.07 d	10.77 Ac	12.61 Ab	11.69 d	15.71 Ad	19.81 Ac	17.76 d

UFPB241	9.61 Ae	9.70 Ae	9.65 d	20.40 Ab	17.30 Ab	18.85 c	36.59 Aa	34.56 Ab	35.58 a
UFPB288	11.05 Ae	12.50 Ae	11.78 d	14.84 Ac	18.29 Ab	16.57 c	17.13 Ad	17.54 Ac	17.33 d
56.26.24.1.1	12.68 Ae	12.10 Ae	12.39 d	13.51 Ac	14.52 Ab	14.02 d	12.60 Ad	18.06 Ac	15.33 d
17.15.4.1.5	8.38 Ae	12.09 Ae	10.24 d	12.08 Ac	15.03 Ab	13.56 d	44.20 Aa	48.63 Aa	46.41 a
UFPB284	11.44 Ae	7.64 Ae	9.54 d	7.17 Ac	13.47 Ab	10.32 d	12.89 Ad	19.77 Ac	16.33 d
UFPB273	8.90 Ae	12.25 Ae	10.57 d	14.83 Ac	19.62 Aa	17.23 c	19.22 Ac	19.52 Ac	19.37 d

Averages followed by the same uppercase letters in HORIZONTALLY and lowercase letters in VERTICALLY do not differ statistically, constituting a homogeneous group, according to the Scott-Knott criterion ($p = 0.01$). Source: the author.

Continued **Table 4**

Genotypes	Fruit abscission (%)			Chlorophyll <i>a</i> content (%)			Chlorophyll <i>b</i> content (%)		
	Year 1	Year 2	Average (years)	Year 1	Year 2	Average (years)	Year 1	Year 2	Average (years)
G77.3	40.22 Ab	35.70 Ac	37.96 b	21.93 Ab	23.39 Aa	22.66 b	21.99 Ac	24.25 Ac	23.12 c
UFPB250	21.66 Ad	24.02 Ad	22.84 c	13.32 Ac	20.70 Aa	17.01 c	15.55 Ad	15.63 Ac	15.59 d
55.50.36.1.3	19.52 Ad	19.80 Ad	19.66 c	17.70 Ac	20.34 Aa	19.02 c	28.15 Ab	34.16 Ab	31.16 b
55.50.44.1.8	17.11 Ad	16.59 Ae	16.85 c	7.52 Ac	13.70 Ab	10.61 d	30.90 Ab	32.96 Ab	31.93 b
UFPB36	32.52 Ac	37.74 Ac	35.13 b	15.02 Ac	17.83 Ab	16.42 c	26.98 Ab	32.71 Ab	29.85 b
G134	52.33 Aa	49.90 Ab	51.12 a	14.22 Ac	16.10 Ab	15.16 c	34.55 Aa	41.45 Aa	38.00 a
‘Calypso’	43.75 Bb	65.87 Aa	54.81 a	11.25 Ac	14.33 Ab	12.79 d	23.45 Ac	28.58 Ac	26.02 c
UFPB58	7.37 Be	16.96 Ae	12.17 d	15.08 Ac	20.89 Aa	17.98 c	21.19 Ac	26.94 Ac	24.07 c
UFPB393	11.77 Ae	20.87 Ad	16.32 d	15.59 Ac	18.42 Ab	17.01 c	10.02 Ad	17.88 Ac	13.95 d
UFPB291	5.18 Be	16.09 Ae	10.64 d	6.41 Ac	9.97 Ab	8.19 d	9.92 Ad	18.97 Ac	14.44 d
‘Etna’	22.20 Ad	24.40 Ad	23.30 c	7.96 Ac	9.01 Ab	8.49 d	12.48 Bd	24.72 Ac	18.60 d

Averages followed by the same uppercase letters in HORIZONTALLY and lowercase letters in VERTICALLY do not differ statistically, constituting a homogeneous group, according to the Scott-Knott criterion ($p = 0.01$). Source: the author.

4. Discussion

4.1. Three-Factor Interaction (Genotypes $\times$ Days $\times$ Years) for Percentage of Leaf Abscission (%)

The significant difference that ethylene caused in the behavior of leaf abscission of the genotypes over the days of evaluation is a result similar to that obtained by [5], evaluating the effects of exposure to this hormone in the post-production of F₆ populations of ornamental pepper, demonstrating that exposure time is one of the factors that can significantly affect the response of plants to the action of the hormone.

It should be noted that the lines 55.50.4.1.2, 56.26.24.1.4, 56.26.33.1.9, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 17.15.4.1.9, 56.26.34.1.2, UFPB284, UFPB58, UFPB393 and UFPB291 showed similar behavior between the three days after ethylene application and in both years. In addition to this stability, these were the genotypes that formed groups with the lowest rates of leaf abscission and were therefore the most insensitive to the effect of ethylene on this trait, thus presenting potential for selection and future indication for ethylene resistance. According to [17], the selection of plants with lower leaf abscission, capable of maintaining their aesthetic value even in the face of the action of ethylene, is an important factor in maintaining a longer post-production life for ornamental plants.

The UFPB36, the genitor G134 and the cultivars 'Pirâmide' and 'Calypso' behaved similarly between days, as well as showing a high rate of leaf abscission. [6,18]. Lima et al. [18] reported 100% leaf loss in the 'Calypso' cultivar compared to the control plants, after the ethylene treatment, similar to this work. This corroborates by the fact that even though this is an excellent ornamental cultivar, it has the disadvantage of being highly sensitive to the deleterious action of ethylene. [17], studying pepper recently treated with different levels of the growth regulator Placobutrazol (PBZ), 96 hours after the application of ethylene in the same quantities as in this study, found leaf abscission values of 49.42 to 80.50% for the cultivar 'Pirâmide', depending on the different concentrations of PBZ applied. This shows that for this cultivar, even the treatment with the highest levels of PBZ was unable to prevent the deleterious effects of ethylene on leaf abscission. According to the classification and quality standards of the [19], after transportation a commercial ornamental pepper plant must have a good formation and stems with good pot coverage (blossoming) and batches without these characteristics are discarded or returned to the supplier. Therefore, based on the performance observed in this work, the aforementioned strain, the genitor and the cultivars 'Calypso' and 'Pirâmide' would be rejected because their ornamental characteristics were compromised by the greater abscission of their leaves after being treated with ethylene.

4.2. Two-Factor Interaction (Genotypes $\times$ Days) for the Averages of Fruit Abscission (%), Chlorophyll *a* and *b* Content (%)

Generally evaluating the averages of the 40 genotypes recorded over the course of the days, there were variations between them in their sensitivity to fruit abscission caused by ethylene, with some genotypes being less sensitive, others with intermediate sensitivity and some with greater sensitivity. This corroborates the results of [20], who, when assessing ornamental pepper genotypes for their sensitivity to ethylene for fruit abscission, also reported that the hormone affected the loss of fruit by the plants to varying degrees. With values of 27.8% in the 'colored pepper' genotype, 5.4% in 'ornamental bell pepper' and 4.1% in 'orange bell pepper'.

For the chlorophyll *a* averages, the increase in the degradation rate over the days of evaluation is a result similar to that obtained by [21], when evaluating the sensitivity to ethylene of an access called 'BGH 1039' (*C. annuum* L.), where a greater degradation and consequent reduction in chlorophyll *a* and total chlorophyll content was observed in plants treated with 10 μ L L⁻¹ of ethylene for 48 hours, whose chlorophyll *a* values were 6.38 mg dm⁻² before treatment and 4.76 mg dm⁻² after. And total chlorophyll was 8.67 and 7.06 mg dm⁻² before and after treatment, respectively. In addition, the aforementioned study stated that the plants from this access tended to show symptoms of yellowing of the leaves, making it a negative visual aspect for marketing.

[5], evaluating eight F₆ lines of ornamental peppers and two test cultivars, found significant differences in chlorophyll *b* content between the genotypes only 96 hours after exposure to ethylene. [21], studying the action of ethylene on the 'BGH 1039' access, reported that there was no significant reduction in the chlorophyll *b* content during 48 hours of evaluation, with values of 2.28 mg dm⁻² (before) and 1.95 mg dm⁻² (after), showing that the losses in the rate of this characteristic have a smaller effect on the time of exposure to ethylene.

4.3. Two-Factor Interaction (Genotypes x Days) for the Averages of Fruit Abscission (%), Chlorophyll a and b Content (%)

The lines 55.50.36.1.8, 56.26.15.1.6, 55.50.4.1.2, 56.26.24.1.4, 56.26.33.1.9, 56.26.34.1.4, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 56.8.24.1.2, 17.15.4.1.9, UFPB240, UFPB232, UFPB241, UFPB288, 56.26.24.1.1, 17.15.4.1.5, UFPB284, UFPB273 and UFPB393 showed similar averages in both years and were part of the group with the lowest averages observed, thus having lower sensitivity to ethylene for fruit abscission. According to [22], in ornamental pepper, potted plants, the fruits are the main decorative elements and are the ones that most attract consumers' attention when they buy them. Therefore, it is necessary that, in addition to being of an adequate size for ornamentation, they should have colorful fruits that contrast with the foliage and that after stages of stress, such as exposure to ethylene, these fruits remain on the plant, thus contributing to maintaining their commercial value [17].

On the other hand, for the genotypes that showed different behavior in the variables evaluated for the factors genotypes x years, the presence of the genotype x environment interaction (G x E) was evident. This interaction is defined as the differential behavior of genotypes in different environments [22,23]. Thus, when a given genotype is evaluated in a series of environments, in addition to the environmental and genetic effects, an additional effect is detected, provided by their interaction [24]. Given that in this study the same materials were evaluated repeatedly in two growing cycles, it was expected that genotypes with different behaviors would emerge when faced with the stress caused by ethylene treatment. In this context, it is important that repeated trials were carried out in different environments (years), providing greater support for the selection and recommendation of cultivars with phenotypic stability and adaptability, helping in the choice of the best materials to continue the ornamental pepper breeding program, with a view to the future launch of cultivars with ornamental value and less sensitivity to the action of ethylene.

5. Conclusions

Among the genotypes, there are materials with less sensitivity to leaf and fruit abscission, which can be used to obtain genetic resistance to ethylene through crossbreeding to introduce resistance genes into susceptible cultivars.

Based on the stability of the behavior presented in the two years of study, as well as the excellent performances obtained in all the characteristics for evaluating sensitivity to ethylene, the selection of the lines 55.50.4.1.2, 56.26.24.1.4, 56.26.33.1.9, 17.15.48.1.2, 56.26.15.1.5, 56.26.33.1.5, 17.15.4.1.9, 56.26.34.1.2, UFPB284, UFPB58, UFPB393 and UFPB291 for continuation of the breeding program, with the potential to be registered and launched as ethylene-insensitive ornamental pepper cultivars in the future.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org.

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References

1. Kumar, A.; Kumar, S.; Anju, T.; Ramchiary, N. Genetic, Epigenetic, and Hormonal Regulation of Fruit Development and Ripening in *Capsicum* L. Species. *Annu. Plant Rev. Online, American Cancer Society*. 2021, 4, 295-356. <https://doi.org/10.1002/9781119312994.apr0782>.
2. Kumar, A.; Saikiran, G.; Anju, T.; Anusree, V. K.; Jasna, K.; Sharma, Y. P.; Chandu, K. D.; Singh, K.; Rawoof, A.; Ramchiary, N.; Singh, P.; Thomas, T. D. Biosynthesis, genetic regulation and therapeutic potential of capsaicinoids. *Plant-derived Bioactives*, 2020, 323-350. https://doi.org/10.1007/978-981-15-2361-8_15.
3. Chhakekar, S.S.; Brahma, V.; Rawoof, A.; Kumar, N.; Gaur, R.; Jaiswal, V.; Kumar, A.; Yadava, S.K.; Kumar, R.; Sharma, V.; Babu, S.S.; Ramchiary, N. Transcriptome profiling, simple sequence repeat markers development and genetic diversity analysis of potential industrial crops *Capsicum chinense* and *C. frutescens* of Northeast India. *Ind. Crops Prod.* 2020, 154, 112687. <https://doi.org/10.1016/j.indcrop.2020.112687>.
4. Rêgo, E.R.; Rêgo, M.M. Genetics and breeding of chili pepper *Capsicum* spp. Production and breeding of chilli peppers. 2016, 57-80. <https://doi.org/10.1007/978-3-319-06532-84>
5. Rêgo, E.R.; Freitas, N.S.S.; Pessoa, A.M.S.; Silva, P.D.; Finger, F.L.; Rêgo, M.M. Selection of ornamental peppers elite lines for ethylene-insensitive. *Revista Ceres*. 2022, 69, 294-298. <https://doi.org/10.1590/0034-737X202269030006>.
6. Segatto, F.B.; Finger, F.L.; Barbosa, J.G.; Rêgo, E.R.; Pinto, C.M.F. Effects of ethylene on the post-production of potted ornamental peppers (*Capsicum annuum* L.). *Acta Hort.* 2013, 1000, 217-222. <https://doi.org/10.17660/ActaHortic.2013.1000.28>.
7. Serek, M.; Woltering, E.J.; Sisler, E.C.; Frello, S.; Sriskandarajah, S. Controlling ethylene responses in flowers at the receptor level. *Biotechnol. Adv.* 2016, 24, 368-381. <https://doi.org/10.1016/j.biotechadv.2006.01.007>.
8. Oliveira, M.M.T. Response to ethylene and action of 1-MCP and STS on the longevity of ornamental pepper trees. Viçosa. Dissertation (Master's Degree in Plant Physiology). Federal University of Viçosa. 2015.
9. Finger, F.L.; Silva, T.P.; Segatto, F.B.; Barbosa, J.G. Inhibition of ethylene response by 1-methylcyclopropene in potted ornamental pepper. *Ciênc. Rural*. 2015, 45, 964-969. <https://doi.org/10.1590/0103-8478cr20131386>.
10. Silva, R. S. Adaptability and phenotypic stability of herbaceous cotton lines for the conditions of the northeastern semi-arid region. Campina Grande-PB. 78f. Dissertation (Master's in Agricultural Sciences) State University of Paraíba. 2019.
11. MAPA, Ministry of Agriculture, Livestock and Fisheries. Cultivation and Use Value-VCU. 2023. <https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-agricolas/sementes-e-mudas/registro-nacional-de-cultivares-2013-rnc-1/valor-de-cultivo-e-uso-2013-vcu>. (accessed 13 June 2023).
12. Crispim, J.F. Early generation test in ornamental pepper trees. Dissertation (Master's Degree in Agronomy). Federal University of Paraíba. Areia-PB. 54f. 2022.
13. Mesquita, J.C.P.; Rêgo, E.R.; Silva, A.R.; Silva Neto, J.J.E.; Cavalcante, L. C.; Rêgo, M.M. Multivariate analysis of the genetic divergence among populations of ornamental pepper (*Capsicum annuum* L.). *Afr. J. Agric. Res.* 2016, 11, 42, 4189-4194. <https://doi.org/10.5897/AJAR2016.11671>.

14. Nascimento, M. F.; Rêgo, E. R.; Nascimento, N. F. F.; Santos, R. M. C.; Bruckner, C. H.; Finger, F. L.; Rêgo, M. M. Correlation between morphoagronomic traits and resistance to ethylene action in ornamental peppers. *Hortic. Bras.* 2015, 33, 151-154. <https://doi.org/10.1590/S0102-053620150000200003>.
15. SANTOS, R.M.C.; RÊGO, E.R.; NASCIMENTO, M.F.; NASCIMENTO, N.F.F.; RÊGO, M.M.; BORÉM, A.; FINGER, F.L.; COSTA, D.S. Ethylene Resistance in a F₂ Population of Ornamental Chili Pepper (*Capsicum annuum*). *Acta Horticulturae*, p. 433-438, 2013.
16. Cruz, C. D. Genes Software-extended and integrated with the R, Matlab and Selegen. *Acta Scientiarum. Agronomy*. 2016. 38, 547-552. <https://doi.org/10.4025/actasciagron.v38i4.32629>.
17. Nascimento, M.F.; Araújo, F.F.; Santos, R.M.C.; Silva Neto, J.J.; Bruckner, C.H.; Finger, F.L. Effects of paclobutrazol on ethylene sensitivity of potted pepper cultivars. *Res. Soc. Dev.* 2022, 11, 2, e1911225269-e1911225269. <https://doi.org/10.33448/rsd-v11i2.25269>.
18. Lima, P.C.C.; Ribeiro, W.S.; Oliveira, M.M.T.; Costa, L.C.; Finger, F.L. Ethylene, 1-methylcyclopropene and silver thiosulfate on the post-production of ornamental pepper. *Ciência Rural*, 201. 47,01-08.
19. VEILING HOLAMBRA COOPERATIVE. Ornamental pepper classification criteria. 2016. <http://veiling.com.br/uploads/padroaoqualidade/criterios/pimenta-ornamental-po.pdf>. (accessed 8 june 2023).
20. Ribeiro, W.S.; Carneiro, C.S.; França, C.F.M.; Pinto, C.M.F.; Lima, P.C.C.; Finger, F.L.; Costa, F.B. Sensitivity of ornamental pepper to ethylene. *Hortic. Bras.* 2019, 37, 458-463. <https://doi.org/10.1590/S0102-053620190415>.
21. Araújo, F.F.; Freire, A.I.; Guimarães, M.E.S.; Lima, P.C.C.; Finger, F.L.; Cruz, R.R.P.; Pereira, A.M.; Souza, F.B.M.; Araújo, N.O.; Melo, C.C.V. Use of ethylene action inhibitor on pepper. In: Melo, J. O. F. (Org.). *Ciências Agrárias: o avanço da ciência no Brasil*. Editora científica. 2021, 1, 2, 387-397.
22. Neitzke, R.S.; Fischer, S.Z.; Vasconcelos, C.S.; Barbieri, R.L.; Treptow, R.O. Ornamental peppers: acceptance and preferences by consumers. *Hortic. Bras.* 2016, 34, 102-109. <https://doi.org/10.1590/S0102-053620160000100015>.
23. Silva, P.U.; Meneghetti, C.B.; Bolzan, F.T.; Streck, E.A.; Magalhães Júnior, A.M.; Fagundes Júnior, P.R.R. Productive and agronomic potential of irrigated rice lines in Embrapa's Crop Value and Use (VCU) trials in RS-Safra 2018/19. In: *BRAZILIAN CONGRESS ON IRRIGATED RICE*, 11. Balneário Camboriú, SC. Innovation and development in rice farming: electronic proceedings. Itajaí: Epagri/Sosbai. 2019.
24. Cruz, C.D.; Regazzi, A.J.; Carneiro, P.C.S. Biometric models applied to genetic improvement. 5.ed. Viçosa: UFV. 514p. 2014.

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