Original Research Article

Selection of eggplant genotypes tolerant to high temperatures.

ABSTRACT

In the northeast of Brazil, the yield of eggplant has been unpredictable, especially when the flowering coincides with the hottest period of the year. The objective of this study was to evaluate eggplant genotypes for tolerance to high temperatures and to identify correlations between traits that aid the indirect selection of genotypes tolerant to high temperatures. Twenty-two genotypes were arranged in a randomized block design with four replications conducted in a greenhouse and in the open field, both located at the Universidade Federal Rural de Pernambuco, Recife, Pernambuco, Brazil, between December 2016 and May 2017. Positive correlations were obtained for the pairs, number of fruits per plant (NFP) x fruit fixation index (FFI), NFP x production per plant (PP) and PP x FFI and negative for the pair NFP x PP. The associations among the traits pollen viability (PV), FFI, NFP and PP were low and/or negative for all pairs in both environments and indicates that the indirect selection for FFI and PP through PV is not efficient. Higher values for PV, NFP, PP were observed in greenhouse cultivation, while in the field the genotypes had the best performance for fruit weight (FWe) FFI, fruit length (FL), fruit width (FWi) and length/width ratio of fruit (FLWR). In high temperature conditions, the genotypes CNPH 135, CNPH 93, CNPH 79, CNPH 84, CNPH 71, CNPH 71, CNPH 668, Ajimurasaki F1 and Kokushi Onaga F1 with good FFI and CNPH 135 with the highest FFI, PP, PV and PWe. The FFI in 45.4% of the genotypes under high temperatures was low, around 21.3 and 40.5%. In the field, genotypes CNPH 84 and CNPH 668 stood out with the best FFI (> 60%).

Key words: Solanum melongena L., genetic correlations, fruit fixation, pollen viability, productivity.

1. INTRODUCTION

The area cultivated with eggplant (Solanum melongena L.) in Brazil, around 1550 ha/year, is concentrated mainly in the Center-South region [1]. In the northeast, where the annual average temperatures vary from 23 to 27°C [2], eggplant yield has been unpredictable, especially when flowering coincides with the hottest period of the year.

Eggplant is one of the most demanding vegetables at high temperature, with high sensitivity to cold and frost, but during flowering and fruiting it tolerates milder temperatures [3]. The ideal temperature for the growth and development of the eggplant is between 22 and 30°C, while when it drops to 17°C that results in the inhibition of the plant development [4]. Flower abortion is favored by the natural reduction of daylight and by the high temperature of the night (30°C) [5] and productivity is drastically reduced when the temperature exceeds 32°C [6].

That is why it is necessary to adopt strategies for the evaluation and selection of eggplant genotypes tolerant to the effects caused by high temperatures. In this regard, the different genotype responses to the high temperatures are an indispensable factor for the development of more tolerant cultivars, as well as the knowledge about the inheritance of the traits involved in the tolerance to high temperatures is extremely important for breeding programs [7,8].

Similarly, selection based on the highest possible number of traits correlated with high temperatures tolerance constitutes an efficient strategy, since it reduces the probability of genes involved in tolerance to high temperatures being lost during the selective process based only on productivity [8].

With that said, the objective of this study was to select eggplant genotypes tolerant to high temperatures, as well as to estimate the correlations between agronomic traits influenced by high temperatures.

2. MATERIAL AND METHODS

Two experiments were conducted, one in a greenhouse and the other in the open field, both located in the Department of Agronomy, of the Universidade Federal Rural de Pernambuco, Recife, Pernambuco, Brazil, between December, 2016 and May, 2017.

The data of relative air temperature (maximum, average and minimum) in the greenhouse were obtained by a HOBO mini datalogger model and the field data obtained through the Automatic Weather Station from the Department of Rural Technology of the UFRPE (Figure 1).

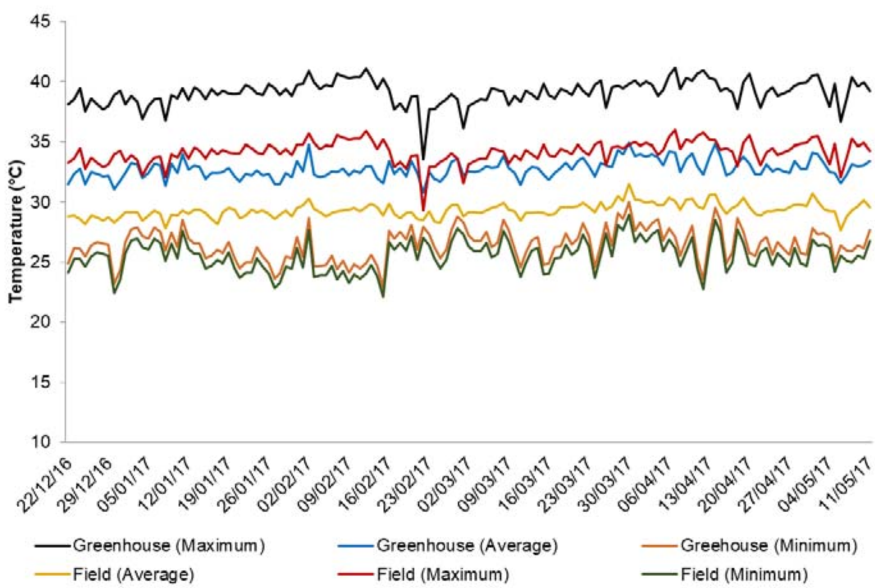

Figure 1. Relative air temperature (maximum, minimum and average) in the greenhouse and in the field, between the months of December 2016 to May 2017.

In both experiments, 22 eggplant genotypes were evaluated in a randomized block design with four replicates and four plants per experimental plot. The sowing was carried out in trays of expanded polystyrene with 128 cells containing sieved coconut powder substrate and kept in a greenhouse in a hydroponic system by subirrigation until reaching the point of transplantation.

In the greenhouse, the temperature ranged from 24 to 41°C, in this environment the seedlings were individually transplanted to vases with 5L capacity containing as inert substrate the coconut powder and spaced at 1.75m between rows and 0,60m between plants. The mineral nutrition and water requirement of the plants were supplied through a nutrient solution distributed automatically by dripping seven to eight times a day.

In the field, the temperature range was between 23 and 36°C, in this environment the seedlings were transplanted to flowerbeds with 0.80 m of spacing between rows and 0.50 m between plants.

Mineral nutrition was carried out according to the technical recommendations for traditional eggplant cultivation and the water requirement supplied through micro-sprinkler irrigation twice a day. In both environments, the temperature range is outside the ideal range for eggplant cultivation (22 to 32°C), confirming that the evaluation occurred under high temperature conditions.

The following parameters were evaluated fruit fixation index, obtained by the equation FFI = number of fruits/number of flower buds x 100, pollen viability (PV) obtained by the equation: PV (%) = number of pollen grains stained with tetrazolium (0.25%)/250 pollen grains evaluated x 100, number of fruit per plant (NFP), production per plant (PP), fruit weight (PWe), fruit length (FL), fruit width (FWi), and fruit length/width ratio (FLWR).

The data were submitted to analysis of joint variance ($p<0.05$). The genotype means were grouped by the Scott-Knott test and the environments compared by Student's T test, both at 5% probability. We also estimated the coefficients of genetic, phenotypic and environmental correlations between the traits for both environments.

The analyzes were performed using the GENES program [9].

3. RESULTS AND DISCUSSION

The average squares for genotypes, environments and genotypes x environments interaction were significant for all traits, indicating the existence of phenotypic differences between genotypes, as well as the inconsistency in their performance when facing temperature variations (Tables 1 and 2).

Table 1. Average squares for the number of fruits per plant (NFP), production per plant (PP), pollen viability (PV), fruit fixation index (FFI) evaluated in 24 eggplant genotypes in a greenhouse and in the field. Recife, Brazil, 2016.

	NFP		PP ($g.plant^{-1}$)		PV (%)		FFI (%)	
Genotypes	Greenhouse	Field	Greenhouse	Field	Greenhouse	Field	Greenhouse	Field
CNPH 135	6.8 Ad	2.6 Bc	1431.4 Aa	621.3 Ba	48.8 Aa	53.0 Aa	24.1 Aa	39.0 Ac
CNPH 60	3.5 Ae	2.3 Ac	443.8 Ad	432.9 Ab	47.7 Aa	48.8 Ab	11.7 Bb	27.8 Ac
CNPH 51	6.4 Ad	4.9 Ac	734.0 Ac	719.0 Aa	49.0 Aa	31.0 Bc	12.5 Bb	28.8 Ac
CIÇA F1	6.8 Ad	3.5 Bc	1140.7 Ab	881.9 Aa	34.2 Ab	13.8 Bd	20.0 Bb	44.4 Ac
CNPH 410	9.9 Ac	2.4 Bc	725.4 Ac	361.7 Bb	47.7 Aa	39.3 Ab	23.2 Aa	30.7 Ac
CNPH 84	18.0 Aa	6.5 Bb	1107.1 Ab	706.5 Ba	54.8 Aa	13.7 Bd	40.5 Ba	83.3 Aa
CNPH 71	7.1 Ad	5.9 Ab	392.8 Ad	470.9 Ab	29.8 Ab	7.3 Bd	21.3 Ba	47.4 Ab
CNPH 668	14.9 Ab	10.7 Ba	752.0 Ac	538.0 Ab	38.0 Ab	26.0 Ac	23.5 Ba	65.8 Ab
K. Onaga F1	7.3 Ad	4.0 Bc	896.3 Ab	727.9 Aa	41.0 Ab	24.0 Bc	33.4 Ba	52.1 Ab
CNPH 146	8.1 Ad	3.2 Bc	742.2 Ac	352.6 Bb	45.5 Aa	27.3 Bc	14.3 Ab	27.9 Ac
CNPH 140	8.6 Ac	6.7 Ab	499.4 Bd	860.2 Aa	32.3 Ab	29.7 Ac	13.7 Bb	57.5 Ab

CNPH 93	8.0 Ad	3.3 Bc	713.2 Ac	583.9 Aa	61.7 Aa	46.3 Ab	24.0 Ba	51.1 Ab
CNPH 47	2.7 Ae	1.7 Ac	448.8 Ad	418.8 Ab	52.3 Aa	36.5 Ab	11.2 Bb	36.9 Ac
CNPH 141	13.0 Ab	3.0 Bc	1062.1 Ab	332.5 Bb	47.2 Aa	32.5 Ac	26.2 Aa	41.8 Ac
CNPH 67	10.9 Ac	4.3 Bc	995.6 Ab	573.5 Ba	49.2 Aa	48.2 Ab	19.4 Bb	37.9 Ac
CNPH 107	7.2 Ad	4.3 Bc	875.0 Ab	459.0 Bb	47.3 Ba	66.8 Aa	17.2 Bb	56.8 Ab
CNPH 53	1.3 Ae	2.3 Ac	248.8 Bb	606.7 Aa	37.8 Ab	45.0 Ab	6.0 Bb	35.0 Ac
CNPH 109	6.3 Ad	3.7 Bc	192.5 Ad	427.5 Ab	47.2 Aa	54.2 Aa	15.1 Ab	23.5 Ac
CNPH 79	8.7 Ac	3.8 Bc	643.8 Ac	597.4 Aa	35.3 Bb	63.7 Aa	29.7 Aa	40.5 Ac
Ajimurasaki F1	19.2 Aa	7.9 Bb	1118.3 Ab	604.0 Ba	54.2 Aa	26.0 Bc	28.9 Ba	55.0 Ab
CNPH 100	5.0 Ae	5.8 Ab	386.0 Ad	677.8 Aa	74.0 Aa	44.8 Bb	20.4 Bb	41.2 Ac
F. Market	2.9 Ae	4.5 Ac	604.8 Ac	550.7 Ab	52.2 Aa	2.0 Bd	11.0 Bb	31.6 Ac
QM (Genotypes)		22388.8 ^{ns}		199.8**		19.8**		40.4**
QM (Environments)		78663.2 ^{ns}		946.1**		9.8**		23.7**
QM (GxE)		3397.6 ^{ns}		15.2**		1.3**		2.1**
Média (greenhouse.)		105.4		14.2		5.9		3.1
Média (Field)		147.7		18.9		5.7		3.9
CV%		23.9		13.3		9.5		15.9

^{ns} Not significant at 1% level of probability following F test.
** Significant at 1% level of probability following F test
Means followed by the same letter in the column do not differ by Scott Knott's test at 5% probability.
Means followed by the same letter in column and row do not differ by Student t test at 5% probability

Table 2. Average squares for fruit weight (FWe), fruit length (FL), fruit width (FWi) and fruit length/width ratio (FLWR) evaluated in 24 eggplant genotypes in a greenhouse and in the field. Recife, Brazil, 2016.

	PWe (g.plant^{-1})		**FL (cm)**		**LWi (cm)**		**FLWR**	
Genótipos	Greenhouse	Field	Greenhouse	Field	Greenhouse	Field	Greenhouse	Field
CNPH 135	212.6 Aa	244.5 Aa	12.9 Ab	15.3 Ad	8.1 Ba	9.0 Aa	1.6 Af	1.7 Af
CNPH 60	134.3 Bb	186.2 Ab	12.8 Bb	18.6 Ac	6.5 Bb	7.4 Ab	2.0 Af	2.5 Af
CNPH 51	115.1 Ac	144.5 Ac	15.4 Bb	21.4 Ac	5.0 Ac	4.7 Ad	3.2 Be	4.5 Ad
CIÇA F1	167.5 Bb	257.9 Aa	16.2 Bb	20.7 Ac	6.1 Bb	7.4 Ab	2.7 Af	2.8 Ae
CNPH 410	71.8 Bd	148.7 Ac	13.5 Ab	16.6 Ad	4.7 Bc	5.5 Ac	2.9 Ae	3.0 Ae
CNPH 84	62.4 Bd	108.8 Ac	15.8 Bb	22.3 Ac	3.2 Bd	4.2 Ad	5.0 Ac	5.4 Ad
CNPH 71	52.8 Ad	79.6 Ad	14.3 Bb	19.4 Ac	3.7 Ad	3.7 Ad	3.9 Bd	5.2 Ad
CNPH 668	52.1 Ad	50.3 Ad	7.0 Ad	8.6 Ae	4.7 Ac	4.7 Ad	1.5 Af	1.8 Af
K. Onaga F1	115.1 Bc	171.2 Ab	26.3 Ba	35.1 Aa	4.3 Ac	4.0 Ad	6.1 Bb	8.8 Ab
CNPH 146	86.3 Ac	108.7 Ac	11.0 Bc	14.6 Ad	5.9 Ab	5.6 Ac	1.9 Bf	2.6 Af
CNPH 140	58.5 Bd	126.8 Ac	13.1 Ab	14.1 Ad	3.6 Bd	6.0 Ac	3.7 Ad	2.4 Bf
CNPH 93	82.6 Bc	179.6 Ab	11.9 Bb	21.3 Ac	4.5 Bc	5.7 Ac	2.7 Bf	3.8 Ae
CNPH 47	172.0 Bb	234.4 Aa	13.8 Bb	21.6 Ac	7.5 Aa	7.2 Ab	1.9 Bf	3.1 Ae
CNPH 141	83.0 Ac	117.9 Ac	11.0 Ac	12.4 Ae	5.5 Ab	5.5 Ac	2.0 Af	2.3 Af
CNPH 67	91.9 Ac	125.9 Ac	12.4 Ac	13.7 Ad	5.9 Ab	6.2 Ac	2.1 Af	2.2 Af
CNPH 107	125.2 Ac	104.4 Ac	13.1 Bb	18.0 Ac	5.6 Ab	5.0 Ac	2.3 Bf	3.6 Ae
CNPH 53	194.2 Ba	266.0 Aa	12.2 Bc	15.9 Ad	8.1 Ba	8.9 Aa	1.5 Af	1.8 Af
CNPH 109	28.0 Bd	124.3 Ac	12.4 Ac	14.8 Ad	5.7 Ab	5.9 Ac	2.2 Af	2.5 Af
CNPH 79	75.4 Bd	151.4 Ac	13.4 Ab	16.0 Ad	4.2 Bc	6.2 Ac	3.2 Ae	2.6 Af
Ajimurasaki F1	58.0 Ad	77.0 Ad	23.6 Ba	32.4 Aa	2.5 Ae	2.5 Ae	9.5 Ba	12.9 Aa
CNPH 100	75.6 Ad	118.2 Ac	15.8 Bb	24.7 Ab	3.6 Ad	3.9 Ad	4.4 Bd	6.3 Ac
F. Market	205.4 Aa	123.7 Bc	14.1 Ab	16.7 Ad	7.5 Aa	7.5 Ab	1.9 Af	2.2 Af
QM (Genotypes)		76.3**		298057.4**		939.9**		939.9**
QM (Environments)		661.7**		1210714.9^{ns}		5558.7**		5558.7**
QM (GxE)		27.4**		210725.2**		682.5**		682.5**
Média (greenhouse.)		8.3		734.3		46.7		46.7
Média (Field)		4.4		568.4		35.4		35.4
CV%		29.0		34.6		23.9		23.9

^{ns} Not significant at 1% level of probability following F test.
** Significant at 1% level of probability following F test
Means followed by the same letter in the column do not differ by Scott Knott's test at 5% probability.
Means followed by the same letter in column and row do not differ by Student t test at 5% probability

The phenotypic, genetic and environmental correlation coefficients practically did not differ between the environments, in relation to the direction and magnitude (Table 3). These differences can occur due to factors caused by gene variation and the environment, which affect the traits through different physiological mechanisms [10], that means we cannot only infer about the correlation between the traits in a generalized way, disregarding the environments in that the genotypes were cultivated.

The magnitudes and directions of the phenotypic and genetic correlation coefficients were similar (Table 3). In only 28.6 and 21.4% of the pairs obtained in the greenhouse and in the field, respectively, the estimates were higher than 0.6. However, in 14.3% of the pairs obtained in the greenhouse and 10.7% obtained in the field, the estimates were higher than -0.6, in both cases indicating a strong association between the traits. Phenotypic correlations have genetic and environmental causes, but only genetic ones involve an association of inheritable nature [11].

Genetic correlations higher than 0.6 were obtained in the following pairs: number of fruits per plant x fruit fixation index, number of fruits per plant x production per plant and production per plant x fruit fixation index. These results indicate that the selection based on the fruit fixation index will indirectly result in the increase of the number of fruits and of the production per plant. However, the negative correlation between the number of fruits per plant x fruit weight, shows a physiological limit of the plant, so that the selection for only the increase of the fruit fixation index and number of fruits per plant, would cause the reduction of fruit weight, affecting the quality and standard size of the genotype (Table 3).

In the crucial traits for the selection of genotypes tolerant to high temperatures, it was verified that in the pairs in which the pollen viability is correlated with the fruit fixation index, number of fruits per plant and fruit weight, the magnitudes of the correlations were low and/or negatives for both environments (Table 3) and it shows that selection based exclusively on pollen viability with tetrazolium solution (25%) would not be efficient in the indirect selection of genotypes with higher fruit fixation index and production by plant.

As for the environmental correlations, these were negative and very low in 25 and 21.4% of the pairs obtained in the greenhouse and in the field, respectively. However, in the pairs number of fruits per plant x production per plant, number of fruits per plant x fruit fixation index (greenhouse), fruit length x fruit length/width ratio and production per plant x fruit fixation index (greenhouse) the environmental correlations were higher than 0.6 (Table 3).

Among the traits of greatest interest for selection of genotypes tolerant to high temperatures, the environmental correlations were very low, with values close to zero, showing the lack of environmental correlation in the association of these traits (Table 3). Environmental correlations occur between two traits when they are influenced by the same variations of the environment. When negatives, they indicate that the environment favors one trait to the detriment of the other and, when positive, they indicate that both traits were benefited or harmed by the same environmental causes [11].

Table 3. Phenotypic, genetic and environmental correlation coefficients between traits evaluated in eggplant genotypes in a greenhouse and in the field. Recife, Brazil, 2016.

	Correlation coefficients					
	Phenotypic		**Genetic**		**Environmental**	
Traits	**Greenhouse**	**Field**	**Greenhouse**	**Field**	**Greenhouse**	**Field**
NFP x PP	0.6**	0.3	0.6	0.3	0.7	0.8
NFP x FWe	-0.6**	-0.7**	-0.6	-0.8	-0.1	0.0
NFP x PV	0.0	-0.4	0.0	-0.4	0.1	0.0
NFP x FFI	0.7**	0.7**	0.8	0.8	0.7	0.0
NFP x FL	0.2	0.0	0.2	0.0	0.1	0.1
NFP x FWi	-0.7**	-0.6**	-0.7	-0.7	0.0	0.1
NFP x FLWR	0.5	0.4	0.6	0.4	0.2	0.1

PP x FWe	0.2	0.2	0.1	0.2	0.5	0.5
PP x PV	0.1	-0.2	0.1	-0.4	0.1	0.2
PP x FFI	0.6**	0.4	0.6	0.6	0.6	-0.1
PP x FL	0.2	0.4	0.2	0.4	0.3	0.4
PP x FWi	-0.1	0.0	-0.1	-0.1	0.2	0.3
PP x FLWR	0.2	0.2	0.2	0.3	0.1	0.2
FWe x PV	0.0	0.2	0.0	0.2	0.1	0.1
FWe x FFI	-0.4	-0.3	-0.5	-0.4	0.0	-0.1
FWe x FL	0.0	0.1	0.0	0.1	0.4	0.3
FWe x FWi	0.8**	0.8**	0.8	0.8	0.6	0.7
FWe x FLWR	-0.4	-0.3	-0.4	-0.3	0.0	0.0
PV x FFI	0.1	-0.3	0.1	-0.3	0.0	0.1
PV x LF	0.1	-0.2	0.1	-0.2	0.1	0.0
PV x FWi	-0.1	0.3	-0.1	0.3	0.2	0.0
PV x FLWR	0.2	-0.3	0.2	-0.3	-0.1	0.0
FFI x FL	0.4	0.2	0.5	0.3	-0.1	-0.2
FFI x FWi	-0.6**	-0.5*	-0.7	-0.6	0.0	0.1
FFI x FLWR	0.6**	0.3	0.6	0.4	0.0	-0.2
FL x FL	-0.4	-0.5*	-0.4	-0.5	0.3	0.1
FL x FLWR	0.8**	0.9**	0.8	0.9	0.8	0.9
FL x FLWR	-0.7**	-0.7**	-0.8	-0.8	-0.2	-0.3

* and ** significant at the 5% and 1% levels, respectively, of the probability by the F test and "ns" not significant by the T test.

Number of fruits per plant (NFP), production per plant (PP), pollen viability (PV), fruit fixation index (FFI), fruit weight (FWe), fruit length (FL), fruit width (FWi) and fruit length/width ratio (FLWR).

The genotypes produced on average 8.3 fruit.plant-1 in the greenhouse and on average 4.4 fruits.plant-1 in the field, with range of variation between environments of 3.9 fruits.plant-1 (Table 1). There was a greater variation for the number of fruits per plant in genotypes grown in the greenhouse, with the genotypes Ajimurasaki F1 and CNPH 84 standing out and obtaining means of 19.2 and 18.0 fruit.plant-1 respectively. The genotypes CNPH 668 (15.0 fruit.plant-1) and CNPH 141 (13.0 fruits.plant-1) formed the second largest group of means, while in 41% of the genotypes, among them, Ciça F1 and Kokushi Onaga F1 , had means ranging from 6.3 to 8.1 fruits.plant-1. The performance was considered unsatisfactory in 22.8% of the genotypes, as it presented means between 2.9 and 5.0 fruit.plant-1, among them the Florida Market with 2.9 fruit.plant-1, whose mean was lower than that reported by other authors [12,13].

Going against the results obtained in the greenhouse, the variation in the field for fruit production per plant was lower (Table 1). In this environment, the genotype CNPH 668 stood out alone with 10.7 fruit.plant-1. The genotypes CNPH 84, CNPH 71, CNPH 140 and CNPH 100 did not differ from the genotype Ajimurasaki F1 (7.9 fruit.plant-1). However, the agronomic production per plant of 72.8% of the cultivated genotypes in the field was unsatisfactory, including Ciça F1 (3.5 fruit.plant-1), Kokushi Onaga F1 (4.0 fruits.plant-1) and Florida Market (5.0 fruit.plant-1). These results are below those obtained by another author for the same genotypes and culture conditions [14]. The unsatisfactory performance for the number of fruits per plant in the field may be due to the influence of other factors and not only the temperature (Table 1).

The mean values for the trait production per plant were higher in the greenhouse (734.3 g.plant-1), with a variation range of 165.9 g.plant-1 in relation to the production obtained in the field (68.4 g.plant-1). In the greenhouse, genotype CNPH 135 (1431.4 g.plant-1) stood out as the most productive, while 18.2% of the genotypes did not differ from the commercial cultivars Ciça F1, Kokushi Onaga F1 and Ajimurasaki F1 and formed a group with means between 875.0 and 1140.7 g.plant-1. The other groups were formed by approximately 32% of the genotypes each and presented mean values between 604.8 and 752.0 g.plant-1, among them the Florida Market. The less productive genotypes showed averages between 192.5 and 448.7 g.plant-1 (Table 1).

In the field, the variation for production per plant was lower, however, the most productive genotypes corresponded to 54.5% and had means varying between 573.5 and 881.9 g.plant-1, with the genotype Ciça F1 (881.9 g.plant-1) standing out as the most productive. In the other 45.5%, the averages were between 332.5 and 550.7 g.plant-1, among which, the Florida Market genotype (550.7 g.plant-1). Such results are lower than those obtained by other authors [6,12,13,14].

The percentage of viable pollen in genotypes grown in the greenhouse (46.7%) was higher than those obtained by genotypes grown in the field (35.5%), a difference of 11.2% (Table 1). These values are close to those reported by other authors for the same tetrazolium concentration [15], as well as other authors not obtaining satisfactory results with different concentrations of tetrazolium. However, there is no report in the literature of a universal technique for evaluating eggplant pollen [16].

About 68.2% of the genotypes grown in the greenhouse showed averages between 47.2% (CNPH 141 and CNPH 109) and 61.7% (CNPH 93), among them, Ajimurasaki F1 (54.2%). Meanwhile, 31.9% showed means between 29.9% (CNPH 71) and 41% (Kokushi Onaga F1), including Ciça F1 with 34.2% of viable pollen. In the field, only 18.2% of the genotypes presented means between 53% (CNPH 135) and 66.9% (CNPH 107), followed by 31.9% with values between 36.5% (CNPH 47) and 48.9% (CNPH 60). While 31.8% of the genotypes, including Kokushi Onaga F1 and Ajimurasaki F1, showed averages between 24% (Kokushi Onaga F1) and 32.5% (CNPH 141). The lowest percentages were obtained in 22.7% of the genotypes, among them the genotypes Ciça F1 and Florida Market with averages of 13.8% and 2%, respectively. In both environments, the obtained pollen viability values were lower than those reported by other authors [6, 15,16].

The mean value for fruit fixation index in the field was higher, with a range of variation of 23.1% between environments (Table 1). In 45.5% of genotypes cultivated in the greenhouse the trait in question was superior to 21.3%, among them genotypes Kokushi Onaga F1 and Ajimurasaki F1. While, the other genotypes concentrated averages between 6.0% (CNPH 53) and 24.0% (CNPH 93). The highest number of flowers emitted in the greenhouse and consequently the highest abortion favored the reduction of the fruit fixation index in this environment. These results are below those obtained by other authors [6].

Considering the cultivation in the field, genotype CNPH 84 presented the highest fruit fixation index (83.3%). Averages of 47.4% (CNPH 71) and 65.8% (CNPH 668) were observed in 31.8% of the genotypes, among them Kokushi Onaga F1 and Ajimurasaki F1. However, 63.7% of the genotypes had a fruit fixation index between 23.5% (CNPH 109) and 44.4% (Ciça F1), including the Florida Market genotype. Expected results, since under these conditions flower production was lower in relation to the greenhouse, but with a lower abortion rate (Table 1).

In the field, the average for the fruit weight was higher (147.7 g.fruto-1) than in the greenhouse (105.4 g.fruto-1), but with a range of variation of only 42.3 g.fruto-1 (Table 2). In the greenhouse, the best results were obtained in genotypes CNPH 135 (212.6 g.fruit-1), CNPH 53 (194.2 g.fruit-1) and Florida Market (205.4 g.fruit-1). However, in the field, genotypes CNPH 53 (266.0 g.fruit-1), Ciça F1 (257.9 g.fruit-1), CNPH 135 (244.5 g.fruit-1) and CNPH 47 (234.4 g.fruit-1) had the best performances (Table 2).

In relation to fruit length and fruit width traits, the highest averages were obtained in the field with 18.8 and 5.8cm, respectively, showing a fruit length/width ratio of 3.8 (Table 2). Although, in the greenhouse, the averages for length and width of the fruit were 14.2 and 5.3cm and of 3.1 for the fruit length/width ratio.

The fruit length/width ratio is indicative of the shape of the fruit, i.e., the higher the value, the longer the fruit. For this trait, 59.1% of the genotypes grown in the greenhouse and 50.0% of the genotypes grown in the field did not present a significant difference of the genotypes Ciça F1 and Florida Market. However, Ajimurasaki F1 and Kokushi Onaga F1 had the highest values in both environments, with a more elongated shape and they formed isolated groups, differing between the others them and (Table 2).

4. CONCLUSION

Positive correlations were obtained for the pairs, number of fruits per plant (NFP) x fruit fixation index (FFI), NFP x production per plant (PP) and PP x FFI and negative for the pair NFP x PP. The associations among the traits pollen viability (PV), FFI, NFP and PP were low and/or negative for all pairs in both environments and indicates that the indirect selection for FFI and PP through PV is not efficient. Higher values for PV, NFP, PP were observed in greenhouse cultivation, while in the field the genotypes had the best performance for fruit weight (FWe) FFI, fruit length (FL), fruit width (FWi) and length/width ratio of fruit (FLWR). In high temperature conditions, the genotypes CNPH 135, CNPH 93, CNPH 79, CNPH 84, CNPH 71, CNPH 71, CNPH 668, Ajimurasaki F1 and Kokushi Onaga F1 with good FFI and CNPH 135 with the highest FFI, PP, PV and PWe. The FFI in 45.4% of the genotypes under high temperatures was low, around 21.3 and 40.5%. In the field, genotypes CNPH 84 and CNPH 668 stood out with the best FFI (> 60%).

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