Tolerance to high temperature in F$_5$ inbred lines of tomato

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ABSTRACT

High temperatures in the growing tomato have caused a reduction in fruit set and consequently productivity. This work aimed to evaluate F$_5$ lines of tomato to fruit set and high temperature tolerance in two culture environments. Two experiments were carried out, one in cultivation in greenhouse and the other in the field conditions, from February to June 2012. We evaluated 20 lines F$_5$ of tomato, originating from the segregation of hybrid SE 1055 F$_1$, developed for the hot and humid conditions, with resistance to *Fusarium oxysporum* f.sp. lycopersici race 2, the tomato mosaic virus (*ToMV*), the *Verticilium dahliae* and geminivirus (*TYLCV*) and the control cultivar Yoshimatsu and own hybrid SE 1055 F$_1$. The experiment was performed in a randomized blocks design with 22 treatments, four replications and plots with two plants. We evaluated the total number of fruits per plant (NTF/PL), mass of unmarketable fruits per plant (MFNC/PL), fruit set (PEG), mass of marketable fruits per plant (MFC/PL) and yield of marketable fruits (REND). In the greenhouse were recorded higher temperatures and lower luminosity than in field cultivation. Lines 08, 12 and 13 showed higher fruit set in a greenhouse, being more suitable for cultivation at high temperatures. In the field, the lines 06 and 08 showed that marketable fruit production did not differ from 'Yoshimatsu'. Comparing the field experiment average with the average of greenhouse, a higher fruit set and a higher mass of marketable fruits per plant was achieved in field.

Keywords: *Solanum lycopersicum*, breeding, fruit set.

RESUMO

Tolerância a altas temperaturas em linhagens F$_5$ de tomateiro

As temperaturas elevadas nas áreas de cultivo de tomateiro têm causado redução no pegamento de frutos e consequentemente na produtividade. Este trabalho teve como objetivo avaliar linhagens F$_5$ de tomateiro quanto ao pegamento de frutos e tolerância a altas temperaturas em dois ambientes de cultivo. Foram conduzidos dois experimentos, um no cultivo em casa de vegetação e outro no campo, de fevereiro a junho de 2012. Foram avaliadas 20 linhagens F$_5$ de tomateiro, oriundas da segregação do híbrido SE 1055 F$_1$, desenvolvido para condições quentes e úmidas, com resistência a *Fusarium oxysporum* f.sp. lycopersici race 2, a tomato mosaic virus (*ToMV*), a *Verticilium dahliae* e geminivirus (*TYLCV*), além das testemunhas cultivar Yoshimatsu e o próprio híbrido SE 1055 F$_1$. O delineamento experimental adotado foi em blocos ao acaso, com 22 tratamentos, quatro repetições e parcela útil com duas plantas. Foram avaliados o número total de frutos por planta (NTF/PL), pegamento de frutos (PEG), massa de frutos não comerciais por planta (MFNC/PL), massa de frutos comerciais por planta (MFC/PL) e rendimento de frutos comerciais (REND). Em casa de vegetação foram registradas maiores temperaturas e menor luminosidade em relação ao cultivo no campo. As linhagens 08, 12 e 13 apresentaram maior pegamento de frutos em casa de vegetação, mostrando-se mais indicadas para o cultivo em temperaturas elevadas. No campo, as linhagens 06 e 08 se destacaram na produção de frutos comerciais, não diferindo da 'Yoshimatsu'. Observaram-se em relação à média geral dos ambientes, maiores PEG e MFC/PL das linhagens quando estas foram conduzidas no cultivo em campo.

Palavras-chave: *Solanum lycopersicum*, melhoramento genético, pegamento de frutos.

Intergovernmental Panel on Climate Change (IPCC) announced that the global average temperature could rise 2.6°C by 2050 compared to 1990 and 5.8°C by 2100 (IPCC, 2012a). According to the IPCC (2012b) report this global average temperature rise can cause significant changes in the natural ecosystems, such as higher frequency of drought and increases in heavy rainfall. Many researchers have been studying this rise in the temperature and reported its effect as a serious threat to global agricultural production (Sato *et al.*,

2006; Kamel *et al.*, 2010).

In the latest years, all over the world, an increase in planting of various crops has been noticed, including tomato, in high temperature regions or environments, either in the field or greenhouse. The stress caused by high temperatures in these environments causes a reduction in the number of pollen grains in susceptible tomato genotypes, reducing fruit set (Firon *et al.*, 2006).

The temperature considered optimal for the production of tomato ranges from

21 to 28°C during the day and from 15 to 20°C during the night. Considering that the night temperature is also considered a limiting factor to good fruit set in tomato (Filgueira, 2008).

Traits such as pollen grains viability, osmotic pressure, production of fruits per plant and fruit set are suggested by some authors (Abdul-Baki & Stommel, 1995; Hanson *et al.*, 2002; Saeed *et al.*, 2007) for evaluation and selection of heat tolerant genotypes. For this, the use of experiments in field and greenhouse still stands as the most appropriate

methodology to evaluate the tolerance to heat.

Considering that the increase of growing tomato in high temperature environments, the elucidation of these mechanisms of protection and the identification of the genes related to the tolerance have been presented as the best strategy for selection of heat tolerant genotypes (Bita *et al.*, 2011).

Similarly, tomato accessions collected in sites presenting natural high temperatures conditions can constitute important sources of genetic variability for heat tolerance (Giordano *et al.*, 2005).

The choice of commercial hybrids to form the base population which will be worked is justified for being already tested in various environments, resistance genes to important diseases of tomato and for showing great proportion of favorable *loci* previously set (Bison *et al.*, 2003; Carvalho *et al.*, 2004; Amorim & Souza, 2005; Ferreira *et al.*, 2009).

Given the above, this work aims to identify and select F$_5$ inbred lines of tomato concerning the fruit set and tolerance to high temperatures in two growing environments: greenhouse and field.

MATERIAL AND METHODS

Two experiments were carried out, one in a greenhouse and the other in the field, conducted at Universidade Federal Rural de Pernambuco, Recife, Pernambuco state, Brazil, from February to June 2012. In figures 1, 2 and 3 are shown the climate characterization of the temperature, humidity and solar radiation, during the experiments, for both growing environments.

Randomized block design with four replications was used. Each plot was consisted of two plants, spaced at 0.6 m in the row and 1.0 m between rows. In both experiments, 20 lines F$_5$ of tomato, originating from the segregation of hybrid SE 1055 F$_1$ and control treatment: cultivar Yoshimatsu, resistant to bacterial wilt and tolerant to high temperatures, and the hybrid SE 1055 F$_1$ itself.

The lines were obtained from F$_2$

plants, originating from hybrid SE 1055 F$_1$, developed for hot and humid conditions by East-West Seed Company. SSD method for the advancement of the segregating generations was used, being recorded 180 lines in the F$_5$ generation. Hybrid 'SE 1055 F$_1$' shows resistance to *Fusarium oxysporum* f. sp. *lycopersici* race 2, to tomato mosaic virus (ToMV), *Verticilium dahliae* and geminivirus (*TYLCV*). In order to represent 180 lines F$_5$, 20 of these lines were sampled, randomly, to represent the random model for the genotypes.

For the experiment in the greenhouse, the sowing was performed in polystyrene trays of 128 cells containing Plantmax® substrate. When the seedlings have developed four definitive leaves, they were transplanted to plastic pots with a capacity of 8.5 L, containing washed powdered coconut peels.

Forty days after sowing, another sowing was done, the same way of the first one, for the production of seedlings for the experiment in the field, where they were transplanted to bags of cultivation, called slabs, made of polyethylene, 15 cm in diameter and 2.0 m in length. The bags, filled with washed coconut powder, were distributed in six seedbeds covered with mulching, double face, black and white. Each seedbed received 18 bags of cultivation, divided into two rows of nine bags, each block consisting of three rows of slabs. In each bag, two holes were opened, spaced at 0.6 m one from the other, forming a plot, consisted of two plants.

Mineral nutrition and water requirements of plants, for both experiments, were supplied by nutrient solution, with concentrations of N, P, K, Ca, Mg, S, Cl of 187.5, 57.5, 354, 190, 50, 99 and 70.5 mg L^{-1}, respectively and micronutrients Fe, Mn, Zn, Cu, B and Mo, 3.375, 0.875, 0.175, 0.07, 0.417 and 0.075 mg L^{-1}, respectively. The irrigation system used was dripping, with a 2 L h^{-1} emitter, three times a day. The irrigation time varied according to the crop water requirement, at different growth stages. These two methods of planting, in pots and slabs, are called hydroponics with substrate.

The plants were tutored, vertically, with plastic ribbon, stuck in wires

stretched horizontally. As the plants developed, the sprouting of lateral branches was done until the first cluster.

Preventive insecticide applications were made for pest control: The whitefly (*Bemisia argentifolii*), white mite (*Polyphagotarsonemus latus*), greenbug (*Myzus persicae*), thrips (*Frankliniella schultzei*) and the tomato fruit small driller (*Neoleucinodes elegantalis*).

The evaluated traits were total number of fruits per plant (NTF/PL); fruit set (PEG), relationship between number of commercial fruits and total number of flowers in the first three floral clusters; mass of unmarketable fruits per plant (MFNC/PL); mass of commercial fruits per plant (MFC/PL) and yield of marketable fruits (REND), relationship between mass of marketable fruits and total mass of fruits. Eight harvests were performed, from April to June 2012, in the experiment conducted in the greenhouse. In the field experiment, six harvests were performed, from May to June 2012.

Six descriptors for tomato indicated by Ministry of Agriculture, Livestock and Food Supply were used for morphologic traits. Thus, ten fruits of each genotype were taken, obtained in the two first harvests, and the following descriptors were observed (a) fruit shape (flattened, rounded, elliptical, rectangular, cylindrical, cordate and piriformis); (b) number of locules per fruit (fruits cut transversely to observation); (c) fruit color [using a scale ranging from 1 to 4 (1= green; 2= yellowish red; 3= orange red; 4= red and 5= intense red), visually determinated]; (d) green shoulder (presence or absence of the characteristics in the fruits); (e) pedicel abscission (visual assessment, considering the presence or absence in clusters) and (f) growth habit (considering the number of leaves until the first inflorescence, whether or not the branch ended in an inflorescence and the plant height).

The statistical analysis of the traits was performed by the program Genes, v.3.0 (Cruz, 2006). From the experimental data, the individual analysis of variance was conducted in each environment studied in order to verify if the average squares were

and if the two environments could be included in the joint analysis without restrictions. When the assumptions were met, the joint analysis was performed using the following model: $Y_{ijk} = m + G_i + B/A_{jk} + A_j + GA_{ij} + E_{ijk}$, where Y_{ijk}= observation of the plot; m= overall mean; G_i= effect of the ith treatment; B/A_{jk}= effect of A$_{jk}$-th block; A_j= effect of the jth environment and E_{ijk}= experimental error. Then, the Scott Knott test (p<0.5) was used, to compare the averages, and from the test, the performance of F$_5$ inbred lines in two environments and in each environment was analyzed.

RESULTS AND DISCUSSION

In Table 1 is shown the morphological characterization made from the tomato descriptors for type of growth, presence of green shoulder in the fruits, abscission of the pedicel, color of the fruit, fruit shape and number of locules, suitable for characterization and registration of cultivars by the Ministry of Agriculture, Livestock and Supply-MAPA (BRASIL, 2005).

For green shoulder, most lines and control treatments did not show this characteristic, with exception of lines 13 and 19 (Table 1). For fresh tomatoes, the appearance of the fruit is a determining factor in market value to the consumer, based, mainly, on color, shape and absence of undesirable morphological traits. The presence of green shoulder in the fruits is one of these undesirable traits which alters the color of ripe fruits, leaving them orange red or yellowish, depreciating the fruit.

In order to grow fresh tomato, indeterminate type cultivars, as well as, semi-determinated and determinated type can be used. In Table 1, lines of the three types of growth were verified, but a predominance of semi-determinated type was observed.

For number of locules, shape and color of the fruits, most lines fit the commercial standard with red fruits, rounded or elliptical, bi or trilocular (Table 1).

The average values of the maximum temperature during the whole period of the experiment in the greenhouse and in the field were 37.46 and 32.55°C, respectively (Figures 1 and 2). The ideal temperature for the vegetative development is around 18-28°C (Saeed *et al.*, 2007), however, some tomato genotypes can tolerate high temperatures with a higher amplitude.

The average values of the minimum temperature, in the greenhouse and in the field, were 22.53 and 23.5°C during the whole period of the experiment. These values are far above the ideal for the crop, which is 15 to 18°C (Rudick *et al.*, 1977). The radiation was not considered a limiting factor for the development of the plants in the field. However, in the greenhouse the average of daily solar radiation during the whole

Table 1. Characterization of F$_5$ lines for the main morphological descriptor according to the Ministry of Agriculture, Livestock and Supply (MAPA) [caracterização dos genótipos para as principais características morfológicas segundo o descritor do Ministério da Agricultura Pecuária e Abastecimento (MAPA)]. Recife, UFRPE, 2012.

Genotype	Growth habit	Green shoulder	Pedicel abcission	Fruit color	Fruit shape	Locules (n^o)
01	semi-determinated	-	-	red	round	3
02	semi-determinated	-	-	red	cordiform	2
03	semi-determinated	-	-	red	round	2
04	determinated	-	-	red	elliptical	2
05	determinated	-	-	red	elliptical	2
06	semi-determinated	-	-	red	elliptical	2
07	semi-determinated	-	-	red	round	2
08	semi-determinated	-	-	red	round	2
09	determinated	-	no	red	elliptical	2
10	semi-determinated	-	-	red	round	2
11	semi-determinated	-	-	red	elliptical	2
12	semi-determinated	-	-	red	elliptical	2
13	semi-determinated	yes	-	orange red	round	2
14	semi-determinated	-	-	red	round	2
15	indeterminated	-	-	red	round	2
16	determinated	-	-	red	elliptical	2
17	semi-determinated	-	-	red	round	2
18	determinated	-	-	red	elliptical	2
19	indeterminated	yes	-	orange red	round	2
20	indeterminated	-	no	red	elliptical	2
SE 1055 F$_1$	semi-determinated	-	-	red	round	2
Yoshimatsu	indeterminated	-	-	red	flattened	>3

Table 2. Estimates of the average of total number of fruits per plant (NTF/PL), fruit set (PEG), mass of unmarketable fruits per plant (MNFC/PL), mass of marketable fruits per plant (MFC/PL) and yield of fruits (REND), evaluated in two environments [estimativas das médias para número total de frutos por planta (NTF/PL), pegamento de frutos (PEG), massa de frutos não comerciais por planta (MNFC/PL), massa de frutos comerciais por planta (MFC/PL) e rendimento de frutos (REND), avaliados em dois ambientes]. Recife, UFRPE, 2012.

Genotypes	MFC/PL (kg)		NTF/PL		PEG (%)		MFNC/PL (kg)		REND (%)	
	Green house	Field	Green house	Field	Green house	Field	Green house	Field	Green house	Field
01	1.50 Bb	2.60 Ac	121.63 Aa	57.50 Ba	39.25 Bc	72.25 Aa	0.73 Ab	0.31 Ba	66.25 Bc	88.75 Aa
02	1.34 Bb	2.84 Ac	60.50 Ac	51.87 Aa	30.25 Bc	73.25 Aa	0.36 Aa	0.20 Aa	69.25 Bc	91.50 Aa
03	1.33 Ab	1.81 Ad	122.50 Aa	55.90 Ba	42.75 Bc	74.50 Aa	0.79 Ab	0.33 Ba	62.25 Bc	83.50 Aa
04	1.81 Bb	3.60 Ab	98.66 Ab	72.52 Aa	48.75 Bb	83.75 Aa	0.71 Ab	0.24 Ba	71.50 Bc	93.25 Aa
05	1.01 Bb	2.47 Ac	66.12 Ac	53.98 Aa	38.50 Bc	65.25 Aa	0.69 Ab	0.25 Ba	59.00 Bc	86.50 Aa
06	2.61 Ba	4.35 Aa	118.62 Aa	62.90 Ba	57.75 Ab	67.75 Aa	1.18 Ac	0.15 Ba	68.00 Bc	96.25 Aa
07	2.30 Aa	2.78 Ac	73.98 Ab	44.87 Ba	52.25 Bb	82.50 Aa	0.43 Aa	0.19 Aa	83.50 Aa	92.75 Aa
08	3.38 Aa	4.30 Aa	77.80 Ab	67.37 Aa	76.62 Aa	72.25 Aa	0.33 Aa	0.19 Aa	90.00 Aa	95.50 Aa
09	2.36 Aa	3.21 Ab	88.25 Ab	60.37 Ba	41.75 Bc	74.50 Aa	1.06 Ac	0.18 Ba	67.00 Bc	93.50 Aa
10	1.85 Ab	2.09 Ad	102.87 Aa	51.75 Ba	58.75 Bb	73.50 Aa	0.94 Ac	0.28 Ba	64.75 Bc	86.50 Aa
11	2.41 Aa	3.34 Ab	111.88 Aa	60.50 Ba	36.25 Bc	75.00 Aa	0.70 Ab	0.15 Ba	74.50 Bb	95.00 Aa
12	3.00 Aa	2.23 Ad	128.37 Aa	48.91 Ba	80.25 Aa	77.00 Aa	0.58 Ab	0.25 Ba	82.75 Aa	89.25 Aa
13	3.06 Aa	1.46 Bd	57.75 Ac	52.41 Aa	80.75 Aa	63.00 Aa	0.36 Ba	0.64 Ab	88.75 Aa	67.50 Bb
14	1.79 Ab	2.43 Ac	125.50 Aa	60.02 Ba	47.50 Bb	69.00 Aa	1.06 Ac	0.28 Ba	62.00 Bc	88.25 Aa
15	2.38 Aa	2.45 Ac	73.81 Ab	44.00 Ba	52.00 Bb	69.50 Aa	0.39 Aa	0.09 Ba	85.50 Ba	95.50 Aa
16	2.36 Aa	3.21 Ab	88.25 Ab	60.37 Ba	53.75 Bb	75.00 Aa	1.06 Ac	0.18 Ba	41.50 Be	84.00 Aa
17	1.35 Bb	3.15 Ab	121.62 Aa	64.08 Ba	49.00 Bb	72.25 Aa	1.25 Ad	0.25 Ba	48.00 Be	91.75 Aa
18	1.65 Bb	3.56 Ab	93.71 Ab	53.48 Ba	43.00 Bc	88.50 Aa	0.60 Ab	0.11 Ba	70.75 Bc	96.25 Aa
19	1.15 Bb	2.88 Ac	52.87 Ac	63.50 Aa	27.00 Bc	75.25 Aa	0.36 Aa	0.28 Aa	74.50 Bb	89.50 Aa
20	0.93 Bb	2.93 Ac	52.87 Ac	58.23 Aa	46.75 Bb	82.75 Aa	0.45 Aa	0.33 Aa	67.50 Bc	89.00 Aa
SE 1055 F_1	1.76 Bb	2.91 Ac	145.25 Aa	68.98 Ba	53.25 Bb	80.00 Aa	1.35 Ad	0.23 Ba	53.25 Bb	80.00 Aa
Yoshimatsu	2.12 Ba	4.40 Aa	104.37 Aa	83.15 Aa	41.00 Bc	64.50 Aa	0.85 Ab	0.89 Ac	70.50 Bc	82.25 Aa
Average	1.92 B	2.88 A	96.15 A	57.89 B	50.05 B	74.14 A	0.75 B	0.27 A	69.20 B	89.3 A
CV (%)	28.73		22.66		15.73		25.38		8.65	

Average values followed by lowercase letters within column and capital letters within row do not differ by Scott-Knott test at 5% probability. CV (%) obtained from the joint variance analysis [médias seguidas pelas letras, minúsculas na coluna e maiúsculas na linha, não diferem entre si pelo teste de Scott-Knott em nível de 5% de probabilidade. CV (%) obtido na análise conjunta].

period of the experiment was 7.1 MJ m⁻² day⁻¹, lower the trophic limit 8.4 MJ m⁻² day⁻¹, suitable for the crop (FAO, 1990). This way, high temperature and low radiation are directly related to the development of the plants and to the lower fruit set in the greenhouse (Andriolo, 2000).

The joint analysis showed that no significant differences among genotypes were noticed, between environments and genotype x environment interaction by F test ($p \leq 0.01$), for all traits evaluated, except for MFNC/PL and MFC/PL, which did not show any significance between the environments (Table 2).

For NTF/PL, MFNC/PL and MFC/PL the coefficient of variation was above 20%, considered acceptable for these traits, as observed in other studies (Carvalho *et al.*, 2003; Cargnelutti Filho *et al.*, 2004). For PEG and REND, the coefficient of variation was 15.73 and 8.65%, respectively, which shows good experimental precision for evaluations.

The general average of the total number of fruits per plant (NTF/PL) was higher in the greenhouse, with 96.15 fruits, in relation to the field, which obtained 57.89 fruits (Table 2). Evaluating the performance of two hybrids of tomato Sunny and EF-50, grown in protected and non protected environments, Fontes *et al.* (1997) observed that the number of fruits produced was significantly influenced by genotypes and the growing environment. The hybrid Sunny produced 31.2 and 15.0 fruits per plant, in protected and non protected environment, respectively, while the hybrid EF-50 produced only 26.8 and 12.5 fruits per plant.

In tomato growth in greenhouse, according to Table 2, the lines 01, 03, 06, 10, 11, 12, 14 and 17 showed the highest values for NTF/PL, and they did not differ among themselves and in relation to control 'Yoshimatsu' and 'SE 1055 F_1', by Scott Knott test at 5% probability. These results are much higher than the ones found by Eklund *et al.* (2005) that, evaluating the performance of five hybrids and
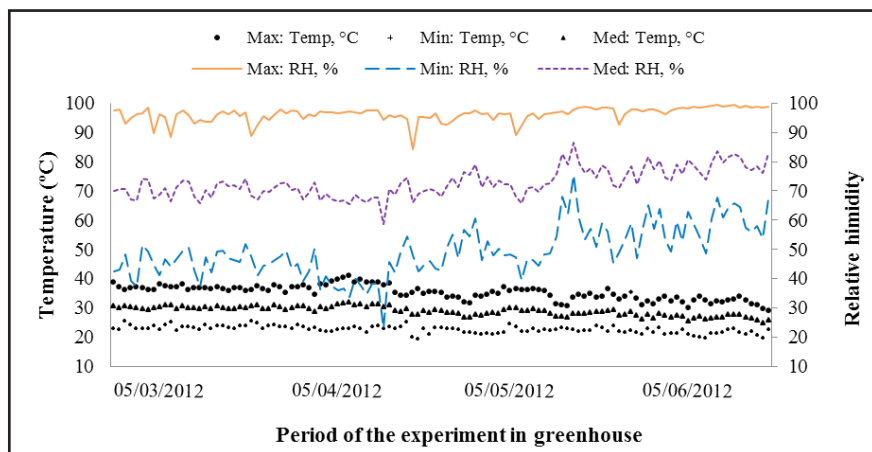
Figure 1. Temperature and relative humidity maximum, minimum and average in greenhouse, from March to June (temperatura e umidade relativa máxima, mínima e média da casa de vegetação, nos meses de março a junho). Recife, UFRPE, 2012.
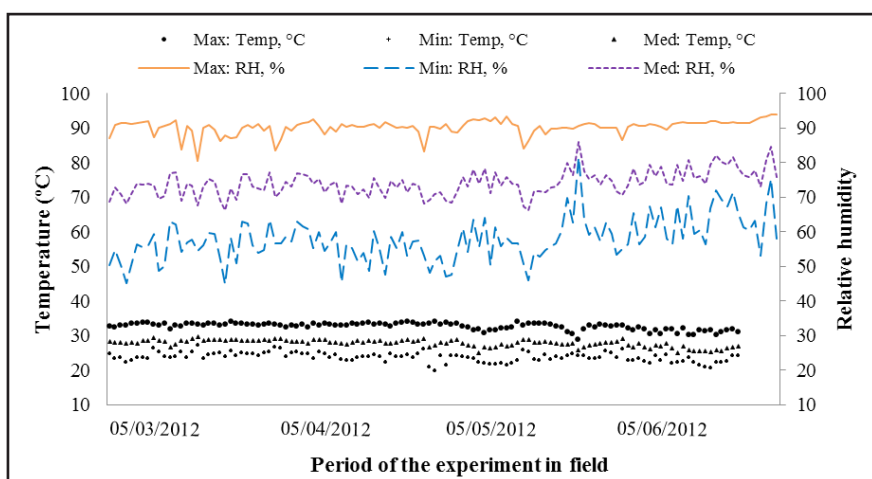
Figure 2. Temperature and relative humidity maximum, minimum and average on the field from March to June (temperatura e umidade relativa máxima, mínima e média do campo, nos meses de março a junho). Recife, UFRPE, 2012.

two cultivars in protected environment, observed that the best hybrid produced 35.75 fruits per plant.

Overall, the plants with high NTF/PL may not be the most productive, because many fruits in the same plant become small, reducing fruit quality and production. As observed, for lines 08 and 13, which showed values for NTF/PL much lower than the reported lines before and obtained the higher values for MFC/PL in the greenhouse. Except line 12, which showed high NTF/PL, not differing from lines 08 and 13 for MFC/PL.

In the field, lines and control treatments did not show significant differences among themselves for NTF/PL. Also in field conditions, Pena *et al.*

(2012), studying the cultivar Yoshimatsu and four advanced generation progenies of tomato, observed lower NTF/PL than the values shown in this work.

The fruit set (PEG) refers to the percentage of flowers produced in each cluster which were pollinated, developed and formed fruit. In the field, PEG was higher than in the greenhouse (Table 2), notably, because of the best temperature conditions.

Considering the growth in the greenhouse, the lines 08, 12, 13 showed the higher values for PEG, 76.62, 80.25 and 80.75%, respectively, not differing among themselves and differing from the others by Scott Knott test at 5% probability, indicating the greater tolerance to high temperatures. These

data are according to the values found by Kamel *et al.* (2010), who evaluated F_2 plants, resulting from the crossing between contrasting parents, observed up to 68.5% PEG, in high temperature conditions. However, Hanson *et al.* (2002) observed average of 30% of PEG, when evaluating PEG also for F_2 plants, resulting from the crossing between tolerant and susceptible parent.

Analyzing the number of flowers per cluster and the number of fruit set, Silva *et al.* (2000) verified that the average percentage of fruit set ranged from 2.5%, in the cultivar Santa Clara, which is not tolerant to high temperatures, to 40% in line CL5915, which is tolerant to high temperatures. This highlights the importance of the use of tolerant genotypes for the cultivation in high temperature.

For the mass of unmarketable fruits per plant (MFNC/PL), the direct effect of unfavorable environmental conditions on fruit set was verified. With the reduction in the number of viable pollen, the authors noticed lower fertilization and reduced number of seeds and deformed fruits, considered unmarketable.

The general average for MFNC/PL in the greenhouse was significantly higher than in the field (Table 2). This fact shows the negative influence of higher temperatures on fruit set.

As Table 2 shows, line 17 and hybrid SE 1055 F_1 showed higher values for MFNC/PL, not differing among themselves by Scott Knott test at 5% probability. As for the lines 02, 07, 08, 13, 15, 19 and 20, lower values for MFNC/PL were found and they also did not differ among themselves. These lines showed to be less affected by high temperatures.

In the field, only line 13 and cultivar Yoshimatsu showed higher MFNC/PL, differing statistically from the others. In relation to line 13, this line showed higher MFNC/PL in the field due to the presence of many small fruits. However, the cultivar Yoshimatsu showed many split and malformed fruits.

For mass of marketable fruits per plant (MFC/PL), the average growth in the field was higher than the average
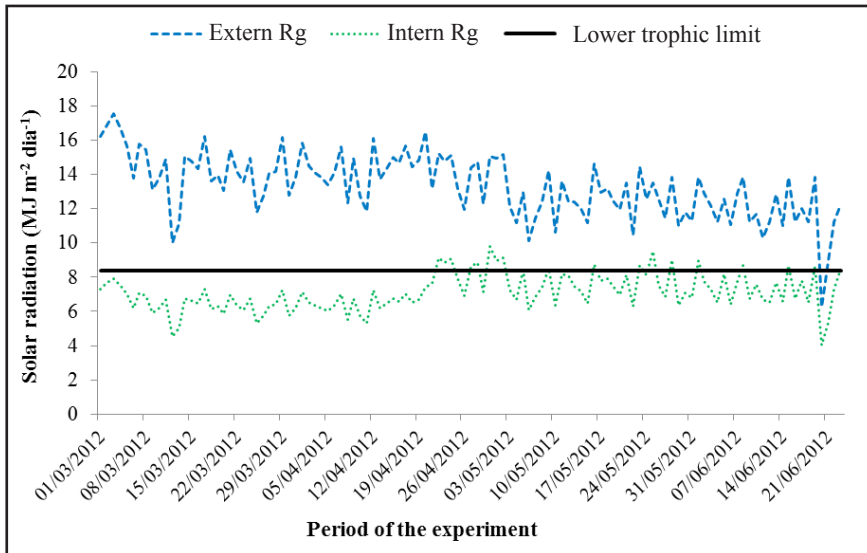
Figure 3. Radiation inside the greenhouse and in field, from March to June (radiação dentro da casa de vegetação e em campo, nos meses de março a junho). Recife, UFRPE, 2012.

grown in the greenhouse, being 2.88 and 1.92 kg, respectively, highlighting the strong influence of high temperatures on this trait.

Lines 08, 12 and 13 showed the highest values for MFC/PL in the greenhouse, being these values above 3.0 kg of fruits per plant. These lines showed to be more productive (Table 2), although they did not differ from lines 06, 07, 09, 11, 15, and 16 and 'Yoshimatsu', which showed values ranging from 2.3 to 2.6 kg of fruits per plant. In the field, the most productive lines were 06 and 08 and cultivar Yoshimatsu.

Studies on commercial hybrids have shown productivity in the greenhouse with averages above 110 t ha^{-1} (Gualberto *et al.*, 2002; Caliman *et al.*, 2005; Gualberto *et al.*, 2007). In other studies, like this one, some commercial hybrids were evaluated in high temperature environments and these hybrids showed to be less productive, with averages ranging from 26.17 to 65.16 t ha^{-1} (Eklund *et al.*, 2005; Pereira *et al.*, 2012).

High temperatures and low radiation observed in the greenhouse influenced MFC/PL of lines 04, 09, 11, 16, 17 and 18, which although showed more than 3.0 kg/plant in the field, in the greenhouse showed much lower production.

The general average for REND obtained in the greenhouse was significantly lower than the average obtained in the field experiment. Nevertheless, lines 07, 08, 12, 13 and 15 obtained yield over 80%, standing out from the others for this trait (Table 2). In the field, the lines and two control treatments did not differ among themselves, except for line 13.

Based on the results, the authors concluded that lines 08, 12 and 13 showed higher fruit set in the greenhouse, being more suitable for cultivation at high temperatures. In the field, lines 06 and 08 stood out in the production of marketable fruits, and they did not differ from cultivar Yoshimatsu.

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