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Selection of tomato plant families using characters related to water deficit resistance

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ABSTRACT

Environmental stress, such as drought stress, constantly cause production loss. Breeding programs search for genotypes which may overcome climate adversities, producing in ideal as well as in stressful environments. The present work aimed at to evaluate parameters related to water deficit in 20 F_3RC_1 families of tomato plants derived from the crossing with a (WELL) genotype, originated from a drought resistant species, as well as select plants using characters related to water deficit resistance. The delineation was in randomized blocks design with three replications. Two experiments were carried out, the first in Lavras, Minas Gerais state, Brazil, that consisted in evaluating nine F_3RC_1 families derived from two self-fertilizations of the following crosses: {TOM-684 x (WELL x M-82)}. The second experiment was carried out in Ijaci, in the same state, and evaluated the same nine families from the previous experiment and another eleven families obtained from the same crossing. The plants were submitted to water deficit by means of the suspension of irrigation at 35 days after transplanting the seedlings to the field. The families T4, T5, T6, T15, T17 were highlighted regarding fruit production and, among the nine families evaluated in both cultivation environments, the T6 was the most productive, indicating good productive stability. Families T5 and T9 were highlighted for presenting low incidence of blossom-end rot and higher relative water content in leaves. The blossom-end rot incidence and relative water content are good parameter to be indirect selection of plants more resistant to drought.

Keywords: *Solanum lycopersicum*, *S. pennellii*, water deficit indicators, drought resistance.

RESUMO

Seleção de famílias de tomateiro utilizando caracteres relacionados à resistência ao déficit hídrico

Estresses ambientais, como o hídrico, constantemente provocam prejuízos na produção vegetal. Programas de melhoramento buscam genótipos que possam superar as adversidades climáticas, produzindo tanto no ambiente tido com o ideal, quanto nos ambientes estressantes. O presente trabalho teve por objetivo avaliar caracteres relacionados à resistência ao déficit hídrico em 20 famílias F_3RC_1 de tomateiro (*Solanum lycopersicum*) advindas do cruzamento com um genótipo (WELL) proveniente da espécie *S. pennellii*, resistente à seca. O delineamento experimental foi em blocos casualizados com três repetições. Foram realizados dois experimentos, o primeiro em Lavras-MG, que consistiu na avaliação de nove famílias F_3RC_1 advindas de duas autofecundações dos cruzamentos {TOM-684 x (WELL x M-82)}. O segundo experimento foi realizado em Ijaci-MG onde se avaliaram as mesmas nove famílias do experimento anterior e outras onze famílias obtidas do mesmo cruzamento. As plantas foram submetidas ao déficit hídrico por meio da suspensão da irrigação aos 35 dias após o transplantio das mudas para o campo. As famílias T4, T5, T6, T15, T17 destacaram-se quanto à produção de frutos e, dentre as nove famílias avaliadas nos dois locais de cultivo, a T6 foi a mais produtiva, indicando boa estabilidade produtiva. As famílias T5 e T9 destacaram-se por apresentar baixa incidência de podridão apical e maior conteúdo relativo de água na folha. Tanto a podridão apical como o conteúdo relativo de água, são bons parâmetros para a seleção indireta de plantas mais resistentes à seca.

Palavras-chave: *Solanum lycopersicum*, *S. pennellii*, indicadores de déficit hídrico, resistência à seca.

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The increasing water scarcity is leading to an increase of food import in various countries. Around 80 countries, that altogether possess 40% of the world population, already suffer with water scarcity (Hamdy *et al*., 2003). Agriculture is by far the sector responsible for the largest consumption of fresh water on the planet, given that the expense in agriculture may reach 80% of the total available water (Condon *et al.*, 2004). In addition to the elevated consumption, the efficiency in its use is very low, remaining below 45% if not well managed (Hamdy *et al*., 2003). A few strategies must be adopted to maximize the exploration of water resources, such as changes in crop managing and the development of cultivars more effective in the use of water.

Genetic improvement programs that seek the selection of plants with larger efficiency in water use and resistant even to water deficit have obtained little success due to the complexity of the character, which is controlled by many genes with different effects, and is also affected by the intensity of the stress (Bernier *et al.*, 2008). Although resistance to drought is polygenic, some monogenic components may improve plants' efficiency to water use.

For tomato plants and related species, resistance to drought is found in wild species that are capable of growing and reproducing in environments that present minimum water (Torrecillas *et al.*, 1995). This characteristic may, in principal, be introduced into cultivars or strains with good agronomic characteristics (Ashraf, 2010). The cross between these wild species with the cultivated species may be a viable alternative to obtain more effective cultivars in water use. In previous papers, a monogenic component of the wild species resistant to drought, *S. pennellii,* was introgressed in the cultivar Micro-Tom, obtaining the genotype WELL, "Water Economy Locus in *Lycopersicum*" (Zsögön, 2012). However, the genotype containing WELL is not yet at a commercial background, requiring studies to verify its practical use for obtaining tomato plant commercial cultivars with larger water efficiency and resistant to drought.

Among the characteristics related to the selection of plants more efficient in water use and resistant to drought, fruit productivity and a few secondary characteristics related to productivity in water deficit conditions must be taken into consideration (Bernier *et al.*, 2008). The plants' response to water deficit is related to a complex network of morphological and physiological changes, which may occur with the reduction of leaf size and leaf abscission (Torrecillas *et al.*, 1996), reduction of water content in the leaf (Hetherington & Woodward, 2003), stomata closure (Royer, 2001), increase in leaf temperature (Siddique *et al.*, 2001) and increase in the incidence of blossom-end rot (Adams & Ho, 1993).

To obtain success in a breeding program of this nature, characteristics that facilitate the selection must be identified. Among those, blossom-end rot may be a promising characteristic for being one of the first symptoms to manifest when the tomato plant is in water deficit (Taylor *et al.*, 2004). With the identification of reliable characters and that present practicality in its use, it will be possible to make selection of genotypes with better water use and resistance to water deficit in breeding programs. As such, this work aimed at evaluating characters related to the resistance to water deficit in tomato plant families with WELL (Water Economy Locus in *Lycopersicum*) background.

MATERIAL AND METHODS

Two experiments were carried out one in Ijaci, Minas Gerais, Brazil (21°9′24″S, 44°55′34″W), from June to November, and the second in Lavras, Minas Gerais state, Brazil (21°14′45″S, 44°59′59″W), in the same period as the previous experiment. These experiments were conducted in a protected environment where temperature and maximum and minimum humidity was daily monitored with a digital thermohygrometer (model HTC-1).

The following genotypes are involved in this breeding program: cultivar 82, which possess determined growth and was developed in California University, Davis; TOM-684, which is a commercial strain nearly isogenic to TOM-584, which by its turn derives from the crossing {(Santa Clara x Stevens) x Santa Clara}, after selection for tospovirus resistance; and WELL, which derives from the crossing between *S. pennellii* x Micro-Tom with six back-crosses using Micro-Tom as reoccurring father and selecting for lowest plant-wilting velocity.

Both experiments were set in a completely randomized block design with three replicates. Nine F_3RC_1 families were evaluated in Lavras (T1: BPX-441B-031, T2: BPX-441B-039, T3: BPX-441B-041, T4: BPX-441B-040, T5: BPX-441B-055, T6: BPX-441B-059, T7: BPX-441B-084, T8: BPX-441B-092 and T9: BPX-441B-088) originated from two self-fertilizations of the following cross: {TOM-684 x (WELL x M-82)}. The same nine families and another eleven were tested in Ijaci (T11: BPX-441B-022, T12: BPX-441B-013, T13: BPX-441B-020, T14: BPX-441B-025, T15: BPX-441B-044, T16: BPX-441B-075, T17: BPX-441B-077, T18: BPX-441B-083, T19: BPX-441B-007, T20: BPX-441B-008 and T21: BPX-441B-019) obtained from the same crossing. In both experiments the mother strain TOM-684 was used as witness (T10), which corresponds to a commercial background. All these families were obtained from the selection of previous generations (F_1RC_1 and F_2RC_1) for commercial agronomical characteristics, such as plant and fruit size. No selection was made for characteristics related to water deficit resistance.

The seedlings were produced in polystyrene trays with 128 cells, using commercial substrate Plantmax®. The seedlings were transplanted at 25 days after sowing, when the seedlings reached about 15 cm height.

The soil of the experimental area in Lavras is classified as typical distrofferic Red Latosol and presents texture with 33% sand, 18% silt and 49% clay. The soil in Ijaci is classified as dystrophic Red-Yellow Latosol and presents texture with 30% sand, 15% silt and 55% clay.

The soil was prepared one month before the seedling transplanting, by means of aeration followed by liming and harrowing. The beds were raised using roto-tillers and measured 20 cm height and 1.0 m length. A soil sample, composed of 10 subsamples, was removed from the 0 to 20 cm layer for chemical analysis and showed the classification: pH (H_2O)= 4.4; H^{++}+Al^{+++}= 5.05 $cmol_c/dm^3$; Ca^{++}= 3.2 $cmol_c/dm^3$; Mg^{++}= 0.8 $cmol_c/dm^3$; P (Mehlich)= 3.1 mg/dm^3; K^+= 0.15 $cmolc/dm^3$; organic matter = 21.00 g/dm^3; CTC= 9.2 $cmol_c/dm^3$; and V%= 45.11%. The amount of limestone mixed in the soil one month before planting was 2.5 t/ha (V= 70%), with Relative Power of Total Neutralizing (RPTN) of 92%, calculated based on chemical analysis of the soil. The basic fertilizing was done three days before the transplanting, using 1000 kg/ha of 8-28-16 NPK, 360 kg/ha of super simple phosphate, 20 kg/ha of borax and 20 kg/ha of zinc sulfate.

The adopted irrigation system was that with self compensating emitters, with a flow rate of 3 L/h, spacing of 30 cm, using two dripping lines per block spaced at 70 cm. The beds were covered by gray polyethylene film (mulching), with 30 μm thickness. In Ijaci the mulching remained on the beds until the end of the experiment. In Lavras the mulching was removed 20 days after the beginning of the stress (DABS), aiming to intensify water deficit. The plants were allocated in the beds, forming two lines of five plants, totalizing ten plants per parcel, spaced at 30 cm, given that each plant was positioned exactly between two dripping points.

In Lavras the tutoring of the plants was done with ribbons set in wires at two meters of height. The plants were tied up to the ribbon every three days, and taken to the height of the wire, thus making the pruning. In Ijaci, the adopted tutoring was that supported by stakes (inverted V), in which were placed bamboo stakes with 1.80 to 2.20 m length, supported in a tilted manner on a stretched wire. The plants were tied to the bamboo at 30 to 40 cm with plastic ribbons. In both locations the side sprouts were eliminated every three days, beginning 15 days after transplanting (DAT) the seedlings and proceeding to the end of the experiment. The sprouts were manually pulled when they presented from one to three cm length.

One tensiometer was installed per replicate, at the depth of 30 cm, which corresponds to the effective rooting depth of tomato plants. After the seedling transplantation, the beds were daily irrigated during 35 days with 5 mm/day water irrigation depth, aiming at the best seedling initial development. From this date on the irrigation was suspended, daily monitoring by the measuring of soil water matric potential. As the objective was the selection of water deficit resistance materials, the irrigation would be turned on when the soil presented water tension equal or superior to 80 kPa, because above that the tomato plants suffer loss due to water deficit (Sá *et al.*, 2005). However, as no symptoms which characterize water deficit were observed during this period, the irrigation was suspended until the witness (TOM-684) presented symptoms that might be related to water deficit, such as wilting, floral cluster abortion, and height and leaf size reduction. As these symptoms were observed only in an advanced stage of cultivation (35 to 40 DABS or 70 to 75 DAT), irrigation was definitely suspended until the end of the culture cycle (60 to 70 DABS).

The following evaluations were done: 1) total fruit production per plant (total mass of each plant's fruit, considering the fruits normal and with low blossom-end rot severity, with results expressed in kg/plant), 2) number of fruits per plant (NFru), (counting the fruits without blossom-end rot of each parcel and dividing by the amount of plants, with results expressed in fruits/plant), 3) average fruit mass (AFM), (relation between fruit production and NFru, with results expressed in g/fruit), 4) height of the plants in undetermined growth at 40 DABS, 5) leaf temperature (^{o}C) at 35 DABS (with infrared thermometer, using the mean of five readings from leaves from the leaf canopy), and 6) blossom-end rot incidence (%) in the upper third of the plant (relation between the number of fruits that present blossom-end rot and the total of harvested fruits). According to preliminary results for fruit production, height and blossom-end rot incidence in the experiment in Lavras, families T4, T5, T6 and T9 were selected along with the witness T10, to execute the following evaluations at 65 DABS: 7) foliar area {relation of mass of a known foliar area (16 foliar discs of 3.18 cm diameter per parcel) in relation to total fresh mass of the leaves}, 8) foliar fresh mass (weighing all green or little senescent leaves manually pulled from four plants per parcel), 9) stem fresh mass (weighing the stem of four plants per parcel). While in Lavras evaluations of families 7 to 9 were done at 64 DABS, in Ijaci the plants were conducted until the end of the cycle, executing only analysis 1, 2, 3 and 6 from this date.

The RWC in the leaf was analyzed at four times: 24 hours before induction to water deficit, 15, 30 and 45 DABS. Four leaves from the medium third were removed from each of the eight plants of the parcel and were immediately weighed to determine fresh mass (FM). The same leaves were immersed in distilled water for 24 hours, dried with paper towels and weighed to determine turgid mass (TM). Dry mass (DM) was measured after the leaves were oven dried at 64^{o}C for 48 hours. The values were put into the formula described by Scippa *et al.* (2004):

RWC (%) = {(FM-DM)/(TM-DM)} x 100.

The data regarding Lavras and Ijaci trials were submitted to variance analysis and the means compared by the Scott-Knott test ($p<0.05$). The data referent to the four families selected in Lavras were compared by the Tukey test ($p<0.05$).

RESULTS AND DISCUSSION

Fruit production varied from 1.21 to 3.92 kg/plant in Lavras and from 1.74 to 4.00 kg/plant in Ijaci (Tables 1 and 2). Five families were highlighted according to fruit production (T4, T5, T6, T15, T17) and, among the nine families evaluated in both cultivating environments, T6 was the most productive. The T5 family was also highlighted in regard to fruit production in Lavras, however, in Ijaci, the production was inferior to that of the families T4 and T6. In cereal breeding programs, which obtained larger advances in the selection of drought resistance plants, fruit production direct selection under limited water conditions is the most common strategy used by breeders (Bernier *et al.*, 2008). However, the interaction between the genes that confer water deficit resistance and the genes involved in the productive potential *per se,* which are many, must be taken into consideration (Bernier *et al.*, 2008). As it is impossible to isolate these components, it is not recommended, in the case of the tomato plant, to use fruit productivity separately as a selection parameter, though water deficit does affect it.

The NFru and the AFM, which are the factors that determine the production, are characters that, separately, were not good indicators for the selection of plants more productive under water deficit conditions (Tables 1 and 2). In Lavras, for example, the most productive family (T6) had the same amount of fruits as families T3, T8 and the witness (Table

Table 1. Effect of water deficit on fruit production (FP), number of fruits per plant (NFru), average fruit mass (AFM), plant height, number of leaves per plant (NLea) and foliar temperature (FT) of nine tomato (*Solanum lycopersicum*) plant families obtained in the crossing with WELL genotype {Efeito do déficit hídrico sobre a produção de frutos, número de frutos por planta, massa média de frutos, altura da planta, número de folhas por planta e temperatura foliar de nove famílias de tomateiro (*Solanum lycopersicum*) obtidas no cruzamento com o genótipo WELL}. Lavras, UFLA, 2012.

Families	FP (kg/plant)	NFru (fruits/plant)	AFM (g/fruit)	Height (cm)	NLea	FT (°C)
T1	3.22 b	34.08 c	94.16 a	125.07 d	19.60 c	22.15 b
T2[#]	1.21 c	20.69 d	58.27 b	* -	* -	24.42 a
T3	2.83 b	49.68 b	57.08 b	129.69 c	22.02 a	22.89 a
T4	3.92 a	68.27 a	57.49 b	145.73 a	22.38 a	21.58 b
T5	3.60 a	41.15 c	87.44 a	136.99 b	20.64 b	22.13 b
T6	3.90 a	59.64 b	63.44 b	135.25 b	21.22 b	21.43 b
T7[#]	1.30 c	31.58 c	43.20 c	* -	* -	23.75 a
T8	2.80 b	56.48 b	50.02 c	130.71 c	19.62 c	20.87 b
T9	2.69 b	38.22 c	70.72 b	87.00 e	18.06 d	21.29 b
T10 (witness)	3.27 b	52.65 b	62.12 b	130.51 c	19.77 c	22.23 b

Means followed by the same lowercase letter in the column do not differ among each other statistically by the Scott-Knott test ($p \leq 0.05$). [#]Determined growth families. *Data not measured due to the growth habit of the family {Médias seguidas pela mesma letra minúscula na coluna não diferem estatisticamente entre si pelo teste de Scott-Knott ($p \leq 0,05$). [#]Famílias de crescimento determinado. *Dados não mensurados devido ao hábito de crescimento da família}.

Table 2. Effect of water deficit on fruit production (FP), number of fruits per plant (NFru), average fruit mass (AFM), plant height, incidence of blossom-end rot (BER), and foliar temperature (FT) of 20 tomato (*Solanum lycopersicum*) plant families in the crossing with WELL genotype {Efeito do déficit hídrico sobre a produção de frutos, número de frutos por planta, a massa média de frutos, altura da planta, incidência de podridão apical e temperatura foliar de 20 famílias de tomateiro (*Solanum lycopersicum*) obtidas no cruzamento com o genótipo WELL}. Ijaci, UFLA, 2012.

Families	FP (kg/plant)	NFru (fruits/plant)	AFM (g/fruit)	Height (cm)	BER (%)	FT (°C)
T1	2.27 e	20.77 c	117.74 a	119.07 c	64.14 b	22.91 d
T2[#]	1.74 f	18.63 c	95.37 b	* -	33.47 d	27.13 a
T3	1.97 f	22.50 c	89.52 b	110.92 d	55.45 c	24.20 c
T4	3.37 c	44.77 a	75.36 b	138.42 a	70.04 b	23.49 c
T5	2.84 d	22.50 c	127.32 a	134.41 a	16.52 e	23.85 c
T6	4.00 a	40.73 a	98.76 a	132.81 a	54.60 c	21.68 d
T7[#]	2.55 e	28.30 b	90.22 b	* -	43.84 d	25.38 b
T8	2.42 e	30.80 b	78.59 b	128.75 b	78.52 a	21.77 d
T9	2.77 d	28.27 b	98.37 a	84.57 e	18.52 e	21.85 d
T10 (witness)	3.18 c	34.57 a	92.53 b	128.20 b	81.15 a	22.78 d
T11	2.51 e	39.80 a	64.64 b	126.41 b	64.21 b	22.80 d
T12	2.39 e	21.90 c	109.19 a	119.07 c	51.96 c	22.80 d
T13	1.93 f	25.43 b	75.61 b	111.93 d	91.58 a	21.78 d
T14[#]	1.72 f	18.40 c	93.53 b	* -	92.80 a	23.91 c
T15	3.65 b	41.97 a	87.06 b	135.80 a	38.42 d	22.34 d
T16	2.57 e	25.77 b	99.86 a	111.41 d	87.52 a	22.56 d
T17	3.58 b	40.10 a	89.27 b	136.73 a	37.66 d	22.78 d
T18	2.32 e	28.47 b	82.92 b	107.29 d	84.48 a	22.24 d
T19[#]	2.41 e	23.67 c	105.03 a	* -	42.58 d	24.88 b
T20[#]	2.87 d	26.07 b	111.22 a	* -	39.42 d	26.47 a
T21[#]	1.74 f	21.77 c	82.19 b	* -	57.07 c	26.42 a

Means followed by the same lowercase letter in the column do not differ among each other statistically by the Scott-Knott test ($p \leq 0.05$). [#]Determined growth families. *Data not measured due to the growth habit of the family {médias seguidas pela mesma letra minúscula na coluna não diferem estatisticamente entre si pelo teste de Scott-Knott ($p \leq 0,05$). [#]Famílias de crescimento determinado. *Dados não mensurados devido ao hábito de crescimento da família}.

Table 3. Effect of water deficit over foliar area and blossom-end rot incidence of five tomato (*Solanum lycopersicum*) plant families obtained in the crossing with WELL genotype {efeito do déficit hídrico sobre a área foliar e incidência de podridão apical de cinco famílias de tomateiro (*Solanum lycopersicum*) obtidas no cruzamento com o genótipo WELL}. Lavras, UFLA, 2012.

Families	Foliar area (m^2)	Blossom-end rot incidence (%)
T4	2.01 a	67.47 ab
T5	1.58 b	12.21 c
T6	1.29 c	57.49 b
T9	0.87 d	24.01 c
T10 (witness)	1.56 b	80.44 a

Means followed by the same lowercase letter in the column do not differ statistically among themselves by the Tukey test (p≤0.05) {médias seguidas pela mesma letra minúscula na coluna não diferem estatisticamente entre si pelo teste de Tukey (p≤0,05)}.

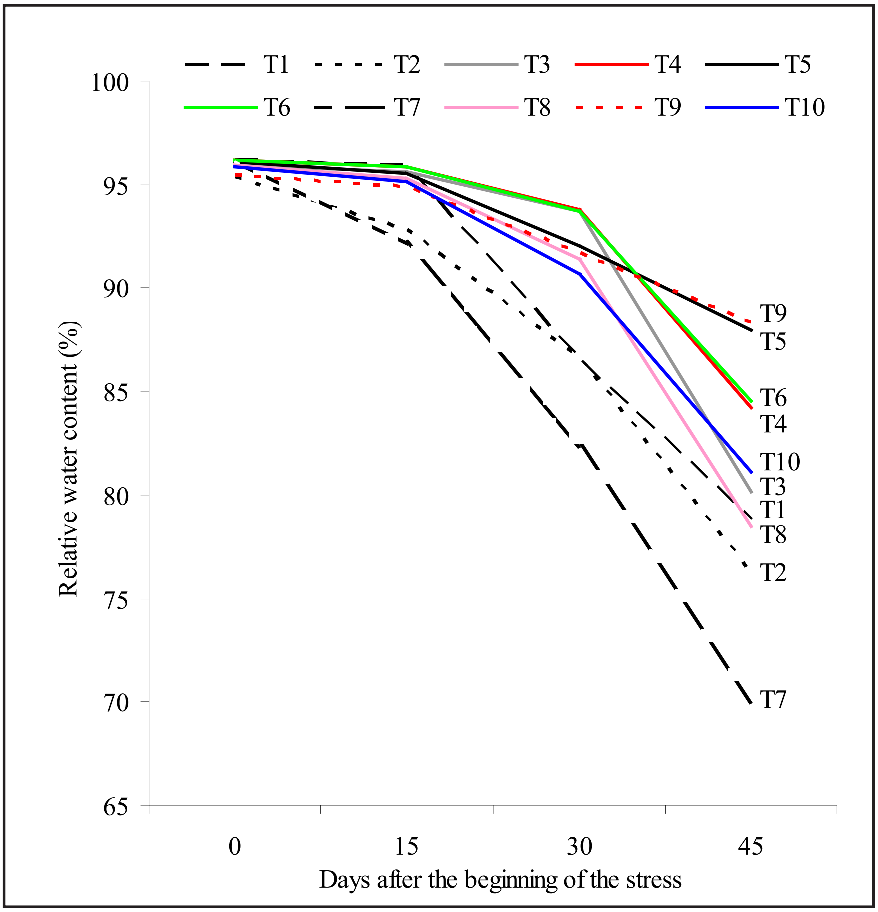

Figure 1. Relative water content in the leaves of ten tomato (*Solanum lycopersicum*) plant families (F_3RC_1) obtained in the crossing with WELL genotype {conteúdo relativo de água em folhas de 10 famílias (F_3RC_1) de tomateiro (*Solanum lycopersicum*) obtidas no cruzamento com o genótipo WELL}. Lavras, UFLA, 2012.

1), which were the less productive undetermined growth families. In Ijaci the same may be observed for AFM, in which the families T1, T5, T9, T12, T16, T19 and T20, which had low productivity, presented equivalent AFM to the smallest treatment (T6) (Table 2). The AFM of all F_3RC_1 families were equal to the commercial witness TOM-684, which demonstrates the genetic progress obtained for this character in previous generations (F_1RC_1 and F_2RC_1).

Regarding plant height, there were family behavior differences in both cultivating locations. In Lavras, families T4, T5 and T6 which were the most productive were also the tallest, all of them superior to the witness, in height as well as in production (Table 1). In Ijaci, families T4 and T5 did not follow this relation (Table 2), fact that may be related to the tutoring system adopted in Ijaci (inverted V), which made the plants vertical growth and, consequently, the height measuring difficult. This characteristic suffers great effect of the adopted handling system, and can't be configured as a safe parameter for the selection of plant resistance to water deficit. However, growth reduction was observed by Colla *et al.* (1999) when the tomato plant was submitted to water blade reduction superior to 20%. Under water deficit conditions cellular expansion is more difficult due to the interruption of xylem water flow to the expanding cells (Nonami, 1998), decreasing cellular turgor. With this occurs reduction of growth and loss of characteristics related to production (Hussain *et al*., 2008).

The T4 family was the only one which presented, at the end of the culture cycle, larger foliar area in relation to the witness, demonstrating great capacity for vegetative development even in severe stress conditions (Table 3). However, this did not reflect in productive performance, for the same did not overcome in productivity families T5 and T6 in both cultivation environments. On the other hand, the most productive family (T6) presented smallest foliar area among the most productive families and the witness. Tahi *et al.* (2008) also observed foliar area reduction in plants submitted to water deficit. The reduction of foliar mass and/or foliar area is related to the decrease in turgor pressure, provoked by the reduction of the soils' water potential, which reduces cellular expansion (Shao *et al*., 2008). The reduction of foliar area implies in the decrease of radiation interception, decrease of photosynthesis and, consequently, decreases in dry mass accumulation (Anjum *et al*., 2011). The difference between the families is also related to different F_3RC_1 strain backgrounds.

Families T5 and T9 presented levels inferior to 20% of blossom-end rot. Families T2, T7, T15, T17, T19 and T20 presented intermediate levels of blossom-end rot incidence, varying from 20 to 50%. A third group, composed of 12 families, presented blossom-end rot incidence superior to 50% (Tables 2). This segregation of 2:6:12 is typical of monogenic inheritance (1/8:2/8:5/8) in generation F_3, which is expected in families of WELL genotype genealogy, which has a locus of monogenic inheritance responsible for increasing water use efficiency (Zsögön, 2012).

To obtain success in a breeding program of this nature, characteristics that facilitate selection must be identified. Among these, blossom-end rot may be a promising characteristic for being one of the first problems to manifest when the tomato plant is under water deficit conditions. It is a characteristic of easy measurement and it is mostly related to water deficit (Taylor *et al.*, 2004). The intensification of this problem occurs when the tomato plants are submitted to average soil water tension superior to 81.0 kPa (Sá *et al.*, 2005). In this experiment, 80 kPa tension was observed at 20 DABS. From this date, increase of blossom-end rot incidence was expected and, plants which presented lower incidence might be indirectly considered more resistant to water deficit. Therefore, among various characteristics evaluated, blossom-end rot may be the one most intimately related to plant resistance to water deficit, and may integrate strategy of selection of tomato plants resistance to this form of stress. However, other characteristics must be taken into consideration, for blossom-end rot may be influenced by various other factors, such as saline stress (Franco *et al.*, 1999), high temperatures (Ho *et al.*, 1993), physical soil characteristics, cationic balance of the soil solution, relative humidity of the air (Kreij, 1996), among others.

Foliar temperature only discriminated plants of determined and undetermined cycle, due to the fact that they differ in response to water deficit. This fact was observed in Lavras as well as in Ijaci, with temperatures varying from 23.75 to 24.20°C (mean = 25.3°C) for plants of determined cycle and from 20.80 to 24.20°C (mean = 22.4°C) for plants of undetermined cycle, considering both cultivating environments (Tables 1 and 2). The increase of temperature probably occurred due to the decrease in plant transpiration, this being the main cooling mechanism for plants (Siddique *et al.*, 2001). Furthermore, high foliar temperatures have a narrow relation with carbon fixation in the various steps of photosynthesis (Medlyn *et al.*, 2002).

Relative water content is apparently related to lower blossom-end rot incidence, for families T9 and T5, which presented lower blossom-end rot incidence, were also the ones which presented larger RWC at 45 DABS, with approximately 88% water (Figure 1). The witness presented 81.09% RWC, higher only than the least productive families (T1, T2, T3, T7 and T8).

The maintenance of foliar turgor in response to water deficit is due to the chemical signaling in the root system, proportioned by abscisic acid or by the apoplastic pH, which induces stomata closing (Hartung *et al.*, 2002; Wilkinson & Davies, 2008). For cotton, Parida *et al.* (2008) attributed the increase of RWC to proline accumulation, conferring water deficit resistance to the plant. For Blum (2005), plants in moderate or severe water deficit conditions can maintain cellular turgor by means of osmotic adjustments, which is decrease in osmotic pressure caused by the accumulation of solutes in the cells, which maintains the hydro potential gradient and, at the same time, the turgidity necessary for cellular growth. The maintenance of high RWC is a way of measuring the plant's water state (Anjum *et al*., 2011), considered by Luo (2010) one of the most important physiological characteristics related to dehydration tolerance mechanisms.

All physiological mechanisms discussed above influenced the plants' response to water deficit, allowing families T5 and T9 to be highlighted in water stress conditions. The blossom-end rot incidence and relative water content are good parameters to indirect select plants which are more resistant to drought.

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