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Agronomic Behavior of Six Saladette Tomato Hybrids Grown under Shade Mesh

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Authors' contributions

This work was carried out in collaboration between both authors. Authors NCM and MPMC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NCM managed the analyzes of the study. Author MPMC managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective was to evaluate six indeterminate saladette tomato hybrids in Southeast, Coahuila, Mexico. Under shade house covered with anti-aphid mesh, to determine their performance, commercial quality and adaptability.
Study Design: The experimental design used in each test was completely randomized model with six treatments and three repetitions each. The treatments were hybrids Lubino were Lubino F_1, Zopilote F_1, Sahariana F_1, Raptor F_1, Quetzal F_1 and RTF-713172 F_1.
Place and Duration of Study: The site was Parras Valley Tomatoes in Parras, Coahuila, México. During april to November 2017.
Methodology: The distance between the lines were 1.80 m, between the plantpots 36 cm and two plants per plantpots, with approximately 30,000 plants per hectare calculated. The genotypes used were Lubino F_1, Zopilote F_1, Sahariana F_1, Raptor F_1, Quetzal F_1 and RTF-713172 F_1. The following

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agronomic characteristics were evaluates: yield, total number of fruits, average fruit weight, number of fruits per bunch, length between clusters, length of internodes, main stem thickness and commercial quality of fruit.
Results: The results indicate that the highest yielding hybrid was Zopilote with 4.3 kg $plant^{-1}$, followed by Saharan, the average weight of the product obtained best in Saharan and Quetzal with 122.33 and 118.33 g respectively, the most compact variety was Zopilote due to the shorter distance between bunches, contrary to what was demonstrated by Lubino.
Conclusion: The best variety for the Southeast of Coahuila is Zopilote F_1, due to its higher yield and for being a compact plant.

Keywords: Yield; commercial quality; climate change; Solanum lycopersicum L.

ABBREVIATIONS

TYLCV : Tomato Yelllow Leaf Curl Virus
TSWV : Tomato Spotted Wilt Virus
TOMV : Tomato Spotted Wilt Virus
FORL : Fusarium oxysporum f. sp. Radices lycopersici
F1 : Fusarium oxysporum f. sp. lycopersici 1
F2 : Fusarium oxysporum f. sp. lycopersici 2
F3 : Fusarium oxysporum f. sp. lycopersici 3
C5 : Corynespora cassiicola
V : Xanthomoas campestris pv. vesicatoriana
Pst : Pseudomona syringae pv. tomato
Pst : Pseudomona syringae pv. tomato
Lt : livelulilla taurica
Sl : Stemphyllium lycopersici

1. INTRODUCTION

Tomato is one of the most important vegetables in Mexico, in 2018 more than 50 thousand hectares were planted, with an average production of 102 t ha^{-1} with production of 3.5 million tons and commercial value of more than 25 500 million of pesos, so it represents 22.5 % of the production among vegetables and contributes 3.5 % of the PIB national agricultural [1]. Numbers by which Mexico provides 25 % of the international market, with the United States and Canada being the main export destinations, with 90 % and 65 % of imports from each country, respectively [1]. But despite its importance, the crop faces problems and challenges to solve in the national territory, one of these problems is the current global climate change and the repercussions it will have in the future, on food production. FAO data indicates that global climate change is one of the greatest challenges facing humanity, since it represents an additional pressure on the environment, pressures ranging from changing weather conditions, to the increase in the level of the seas [2]. What will increase the risk of catastrophic floods, and other effects of global scale, which threaten world food production. These predictions indicate that the effects of climate change will worsen the living conditions of farmers, ranchers, fishermen, etc., causing an increase in hunger and malnutrition. Extreme climatic episodes are increasingly frequent and intense; therefore, the effect will have a negative impact on the availability and access to food, its stability and use [2].

The impacts of climate change are such that humans, plants, livestock and fisheries will be exposed to new pests and diseases, which will imply new risks for food security, food safety and human health. This implies a rapid adaptation to said changes, therefore, a more efficient use of soil-water-environment resources will have to be made. In the agricultural sector, more effective irrigation systems should be developed, superior improved plant varieties, better management of agricultural soils and innovating with cultivation techniques that allow the optimization of resources, in order to minimize the negative effects [3].

The problems that derive from global climate change today, suppose the need to create, develop and implement new cultivation techniques and technologies that allow reducing the negative impact on agricultural activities and at the same time satisfy the needs of farmers and consumers [4], [5]. In order to face these problems, trying the new hybrids developed by the seed companies or institutions, from a local and regional point of view, has become an activity increasingly practiced by farmers, whose purpose is to find the ideal variety for the area of production and for the environment under which it develops [6,7]. Because hybrids respond differently in production systems, geographic areas, and environments, since they show varied productivity [8,9]. Previous studies on tomato indicate that testing hybrids or varieties in the different production regions allows determining their adaptability, yield, tolerance to pests and diseases in a given region [10], and that the highest yielding varieties are those of greater attraction by farmers, so going ahead with the tests is relevant, since it allows making recommendations and suggestions to the producer [11], in addition to the tests it can also determine if it is possible to use an F_2 for commercial production [12]. Similar studies have been carried out on pepper crops [13,14], cucumber [15] and melon [16]. Due to the foregoing challenges posed by global climate change, it was proposed to investigate the performance of six indeterminate saladette tomato hybrids under shady house conditions covered with anti-aphid mesh in Southeast Coahuila.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

The experiment was conducted in Spring-Summer 2017 at the Parras Valley Tomatoes in Parras de la Fuente, Coahuila, Mexico, located at 25° 26"13´ N and 101, 11" 0´,W, with an average annual temperature of 14-18° C and an average annual precipitation of 490 mm. The work was carried out with the support of the company's phenology department.

2.2 Genetic Materials

The genetic material tested was Lubino F_1 Nirit Seeds, which is precocious, with fruits of sizes L and XL, resistance to TYLCV, TSWV, ToMV, V, F1, F2, F3 and C5. Zopilote F_1 BHN Seeds of strong and healthy plant, with abundant roots, vigorous stem, short internodes, leaves of medium size, with fruits L and XL, of wall and thick cuticle, with excellent firmness and resistance to F2, ToMV, TSWV. Sahariana F_1 Syngenta Seeds with strong, vigorous and balanced plant for long cycles, high productivity, with XL sizes, excellent for areas of high luminosity and low relative humidity, as well as high resistance to V, ToMV, TSWV, F3, Forl, Lt, Sl, and intermediate resistance to Meloydogine. Raptor F_1 BHN Seeds with good vigor, uniformity and health, medium-sized leaves, good vegetative / reproductive balance, fruits of sizes L and XL, as well as resistance to V, F2, ToMV, TSWV, TYLCV, Pst. Quetzal F_1 BHN Seeds with a strong plant, thick stems and short internodes, with wide adaptability to hot climates, fruits of sizes L and XL, resistance to V, F2, ToMV, TSWV, TYLCV. RTF-713172 F_1.

2.3 Establishment under Shade House and Crop Management

The hybrid seedlings were assembled at the Protoplaneta seedbed located in San Luis Potosí, Mexico, and sent to the Parras Valley Tomatoes. The transplant was performed the last week of July 2017, in pots of white polyethylene bags with a capacity of 20 liters, which were filled with 100 % perlite as an inert substrate, pH 7, particle size 0.2-0.5 mm, which is cheap and used commercially by the agricultural company. Once the substrate was moistened, the transplant was performed. Two plants per pot were placed at a depth of approximately 8 to 10 cm, so that the root ball was completely covered. The experiment was conducted under a completely randomized experimental arrangement with six treatments (F_1 hybrids) and three repetitions each, with 6 useful plants with complete competition in each experimental unit, with a distance between rows of 1.8 m and between plantpots of 36 cm and two plants per plantpots, giving. As a result, a planting density of approximately 30 000 plants per hectare, the shade house cover where the experiment was carried out is made of glass-colored anti-aphid mesh with 20 % shade (40 x 25 mesh).

The nutrition of the crop was based on that used by the company, which is based on the nutrient solution proposed by Steiner (1966), modified according to the phenological stage of the crop and the chemical composition of the irrigation water used. The nutritive solution was supplied in percentage according to the growth stage of the crop, which consisted of applying 50 % four days after transplanting, 75 % 20 days after transplanting, and once flowering and mooring were started, it was supplied 100 %, the drainage used was that recommended by the company's grower and is 10 %. For pest control, weekly applications of organic products based on chili, garlic and onion extract were made, in addition to neem extract and roma® soap, when the incidence was higher, synthetic chemical products such as Spirotetramat at 15.3 % were used, Spiromesifen at 23.1 %, Imidacloprid 17 % + cylfutrin 12 % at the rate of 1 $ml.L^{-1}$.

2.4 Determination of Evaluated Variables

The total yield in kilograms per plant ($kg. plant^{-1}$) was estimated by harvesting the fruits of each plant that were harvested for ten weeks (75 to 150 days after transplanting), which were weighed on a Sartorius model TS 1352Q37 digital precision scale, to then calculate the yield per hectare (t ha^{-1}). The total number of fruits (TNF) harvested in each plant was counted, considering the total sum of the harvests. The average fruit weight (AFW) was calculated by dividing the total fruit weight by the total number of fruits per plant, the number of fruits per bunch (NFB), accounting for the amount of fruits harvested in each bunch. The length between clusters (LBC) and length of internodes (LI) were estimated using a tape measure graduated in cm, while the main stem thickness (MST) was estimated with a digital vernier of the Autotec® brand graduated in mm at 5 cm from the base of the stem.

2.5 Determination of Commercial Quality

To determine the commercial quality of the fruits, they were weighed individually on a Sartorius model TS 1352Q37 digital precision weighing machine, and it was carried out in four intermediate harvests, the first one 85 days after transplanting (DAT), the second at 106, the third at 127 and the last at 148 DAT. From the data obtained, the percentage was calculated according to its commercial classification, and it was carried out dividing the kilograms of each commercial quality by the total kilograms harvested and multiplied by one hundred, which was used to extrapolate and calculate the commercial yield in tons per hectare. In each treatment (kg plant^{-1} * total number of plants per hectare), which was estimated by multiplying the classification percentage (in unit) by the calculated total tons harvested and expressed as follows.

$$\%\,classification = \frac{kg.\ of\ each\ classification}{total\ kg.} * 100$$

$$Tons\ of\ classification\ calculated = \%\,classificaction\ (unit) * total\ tons\ calculated$$

2.6 Statistic Analysis

Statistical analysis was performed with the SAS Version 9.1 program. The experimental design and statistical analysis was with the completely randomized model with six treatments and three repetitions each, with comparison of Tukey means (*Tukey≤ .05*).

3. RESULTS AND DISCUSSION

3.1 Yield and Components Yield

The analysis of variance showed significant statistical differences between hybrids for all the variables evaluated (ANOVA ≤ .05). The Tukey ≤ .05 mean comparison test (Fig. 1) indicates that the hybrid Zopilote F_1 had the highest performance with 4.3 kg plant^{-1} or 129.14 t ha^{-1}, followed by Sahariana and RTF-713172 with 3.67 and 3.33 kg plant^{-1} and 110.18 and 100.01 t ha^{-1} respectively, said numbers indicate that Zopilote outperformed Lubino in 108 %, Quetzal in 88.3 % and Raptor in 71.7 %. The average fruit weight was higher in the Saharan and Quetzal hybrid with 122.33 and 118.33 g, respectively, followed by Zopilote and Lubino in average weight. Regarding the number of fruits per bunch, a similar behavior was observed in five of the hybrids, with the exception of Quetzal, which was the one with the lowest number of fruits per bunch. The different response that the hybrids showed, was probably due to the genetic load of each one, which was expressed in a phenotype with particular characteristics of each cultivar, characteristics that make it adaptable, not very adaptable or not adaptable to a production system, determined geographical area and crop management. Furthermore, it is influenced by the response of hybrids over time, mainly due to environmental changes from one year to another [17], since each variety shows variations in performance, due to its individual adaptability to specific environmental conditions [18,11], an example of this is that in the Amazon pepper is better if grown in the open field than in a greenhouse [19]. In addition to the specific adaptation of the genotypes to the different exposed environments [8]. However, it is also important to consider adaptability and tolerance to viruses, pests and diseases [16], as well \as the sensory quality of the fruits produced, since it changes between hybrids, and this quality determines the target market and its final price in the market [20].

3.2 Agronomic Performance Indicators

Some agronomic performance indicators, such as the length between clusters, were similar in five hybrids (Table 1), with the exception of Zopilote, which was the variety with the shortest distance between clusters, which was 30 % less than the rest, which is to highlight and take into account, since producers generally seek tomato plants with short internodes and compact size for concentrated productions, which allow better management of the plant and crops in general. While the length of internodes, Lubino stood out with 6.74 cm with the longest length between clusters. The largest stem thickness was obtained by Lubino with 9.13 mm, followed by

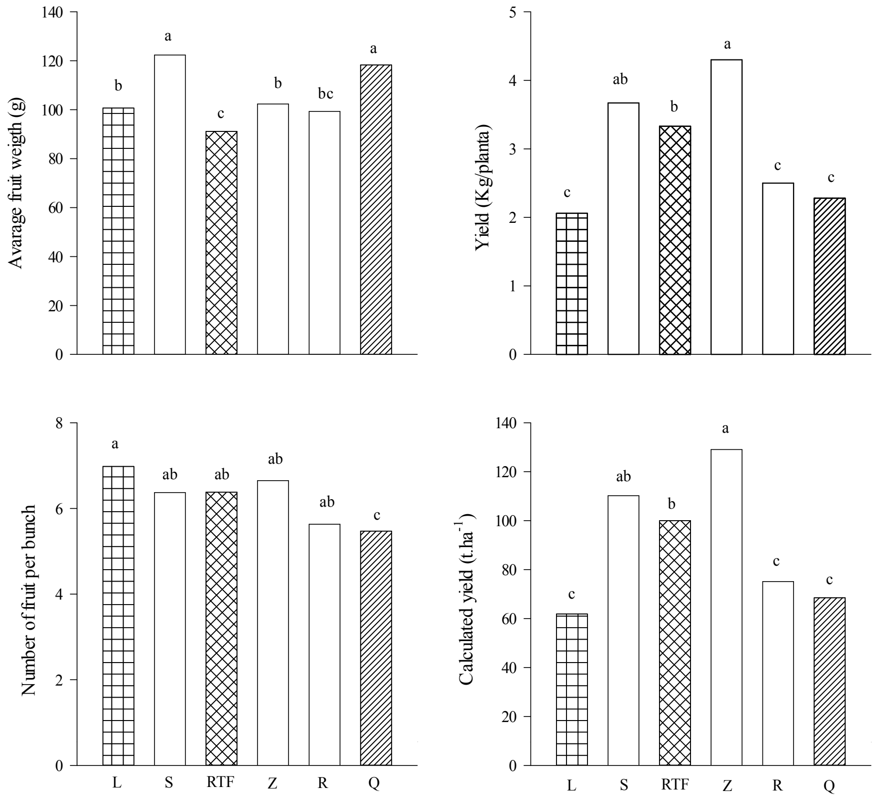

Fig. 1. Yield averages and components evaluated in six saladette tomato hybrids evaluated in Parras de la Fuente, Coahuila, México,L= Lubino F_1, S= Sahariana F_1, RTF= RTF-713172 F_1, Z= Zopilote F_1, R= Raptor F_1 y Q= quetzal F_1

Raptor and Quetzal with 9.04 and 8.68 mm, respectively. These phenotypic changes are the result of the genotypes' response to the environment in which they develop [8,10]. In addition to the fact that crop management also defines and determines their productivity in the long term [14]. Hybrids would probably have had a different behavior if they had been tested under greenhouse or open field conditions.

3.3 Commercial Quality of the Fruit

Another parameter that determines the selection of a variety as good and ideal for cultivation in a certain area and under a certain condition, is the commercial quality of the fruit (Table 2). When commercial quality was expressed as a percentage (%), the variety Zopilote stood out in fruits of size XXL with 3.17 %, followed by Sahariana with 2.62 %, in sizes XL Raptor stands out with 15 %, followed by Zopilote and Saharan with 10.3 and 9 %, respectively, while the highest percentage of L sizes was found in RTF-713172 and Quetzal with 37.38 and 36.92 %, respectively, regarding size M Lubino stood out with 57 %, followed by Zopilote and Sahariana with 54 %, hybrids The ones that had the highest percentage of small fruits were Quetzal and RTF-713172, which is little or undesirable for the producer.

When the percentage of commercial classification of each variety was expressed and extrapolated to tons per hectare (Fig. 2) shown above. It was found that the highest production of XXL and XL sizes were presented by vulture with 4.1 and 13.32 t ha^{-1} respectively, followed by Sahariana and Raptor, while the highest percentage of L sizes had RTF-713172 with 37.39 t ha^{-1}, followed by Zopilote and Quetzal with 27.6 and 25.2 t ha^{-1}, respectively, regarding fruits of size M, Zopilote also stood out with 70.31 t ha^{-1}, followed by Sahariana with 60.3 t ha^{-1}. The hybrids that produced the smallest fruits were RTF-713172 and Sahariana. According to the results found, it is inferred that

Table 1. Averages of agronomic performance indicators in six saladette tomato hybrids evaluated in Parras de la Fuente, Coahuila, México

Hybrids	LBC (cm)	LI (cm)	MST (mm)
Lubino F_1	33.12 a[&]	6.74 a	9.13 a
Sahariana F_1	31.66 a	5.23 b	7.63 bc
RFT-713172 F_1	31.74 a	5.42 b	7.46 c
Zopilote F_1	25.67 b	5.05 b	8.24 abc
Raptor F_1	30.76 ab	5.60 b	9.04 ab
Quetzal F_1	32.12 a	5.72 b	8.68 abc
Significant	**	**	**
CV (%)	5.97	6.099	6.07

***= Highly significant (P =.05), &= equal letters in the same column are statistically equal Tukey ≤ .05, CV = coefficient of variation, LBR= length between clusters, LI= length of internodes, MST= main stem thickness*

Table 2. Commercial quality expressed as a percentage of six saladette-type tomato hybrids evaluated in Parras de la Fuente, Coahuila, México

			(%)		
Hybrids	Jumbo (XXL)	Extra large (XL)	Large (L)	(Medium) M	Small (S)
Lubino F_1	0.00	0.33	20.39	56.91	22.37
Sahariana F_1	2.64	9.01	15.82	54.73	17.80
RFT-713172 F_1	0.55	8.84	37.38	28.55	24.68
Zopilote F_1	3.17	10.32	21.43	54.44	10.63
Raptor F_1	1.58	15.04	20.84	44.85	17.68
Quetzal F_1	1.64	5.37	36.92	30.84	25.23

XXL= Jumbo (>150g), XL= Extra large (120-150g), L= Large (100-120g), M= Medium (80-100g), S= Small (60-80g)

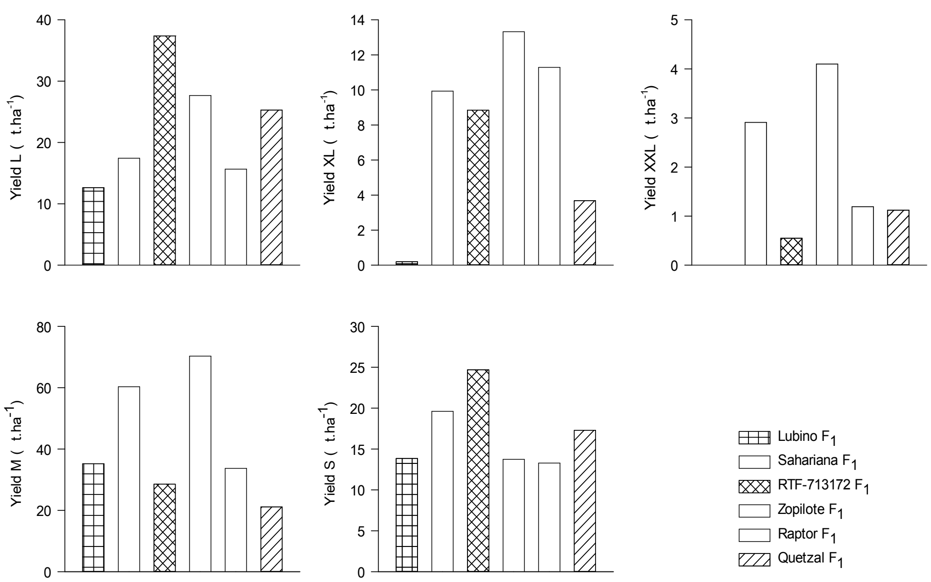

Fig. 2. Commercial quality in tons per hectare of six saladette-type tomato hybrids evaluated in Parras de la Fuente, Coahuila, México

the variety best adapted to the region and the cultivation system tested, as per global yield and its commercial classification, were Zopilote and RTF-713172 for generating a greater amount of extra large sized fruits, and large sized fruit, which are make the difference and are marketed at a better price in the national market and in the export market, however, Zopilote was also superior in medium-sized fruits and these are marketed at prices that are also acceptable. In relation to the aforementioned, [21] points out that the profitability of a greenhouse cultivation depends largely on obtaining high yields and the quality of its individual fruits per unit area, in addition to the harvest time.

4. CONCLUSION

For the Southeast region of Coahuila, of the hybrids evaluated, Zopilote F_1 was the one that best adapted under the shade covered with anti-aphid mesh and using 100 % perlite as substrate, since it was a compact plant produced the highest total yield and commercial quality of fruits. As a consequence of current changes in the environment, it is recommended to carry out adaptability studies of the new varieties or hybrids that are offered in the market, since they allow determining, if a variety is adaptable to be cultivated in a certain region, based on the yield and the commercial quality of its fruits. However, it is also important to consider their adaptability or tolerance to viruses, pests and diseases.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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