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TOMATO IRREGULAR RIPENING IN THE CULIACAN VALLEY, MEXICO

MADUREZ IRREGULAR DE TOMATE EN EL VALLE DE CUALIACÁN, MÉXICO

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SUMMARY

In Mexico, tomato (*Solanum lycopersicum* L.) is the most exported vegetable, and it is also of utmost importance in local markets; however, silverleaf whitefly (*Bemisia argentifolii* Bellows & Perring) attacks reduce production from 30 to 70 %. Although Mexican farmers use different technologies to grow tomato plants, irregular ripening is a generalized concern for adequate yield and product quality. Previous reports on tomato irregular ripening (TIR) associate it to the presence of silverleaf whitefly and low temperatures during harvest. Silverleaf whitefly incidence and temperature effects were measured to establish a relationship to TIR at one of the largest Mexican areas of tomato production. Experiments were carried out on 16 tomato hybrids sowed at the INIFAP Experiment Station in the Culiacan Valley, Mexico. Yield and commercial fruits size were measured, as they are important factors that determine commercialization and destination market (e.g. industrial process, export or domestic market). Silverleaf whitefly incidence and temperature effects on TIR were also analyzed on the basis of yield. TIR symptoms, both temporary (TIRt) and permanent (TIRp) were observed. The term TIRt described fruits that resumed their maturation process during the storage after harvest and reached full ripening after 7 d at 25 ºC. Consistent with previous reports, it was observed that TIRt symptoms were associated to low temperatures (≤ 8 ºC) during early harvest dates. TIRp damaged more fruits and associated to the effect of silverleaf whitefly at high population densities (0.77 to 0.93 adults cm^{-2}), to high temperatures during the harvest season and to susceptible tomato genotypes.

Index words: *Solanum lycopersicum*, *Bemisia argentifolii*, fruit damage, harvest dates, temperature, hybrids.

RESUMEN

En México, el tomate (*Solanum lycopersicumm* L.) es el cultivo hortícola de mayor exportación y una hortaliza de gran importancia en el mercado local, pero el ataque de mosquita blanca (*Bemisia argentifolii* Bellows & Perring) reduce su producción entre 30 y 70 %. Aunque los agricultores mexicanos emplean diferentes tecnologías para cultivar plantas de tomate, la presencia de algunos frutos que muestran madurez irregular es una preocupación generalizada en términos del rendimiento y calidad del producto. Reportes previos en madurez irregular del fruto (MIF) asocian este evento principalmente con la presencia de mosquita blanca (MB) y bajas temperaturas durante la cosecha. La incidencia de MB y efectos de la temperatura se evaluaron para determinar su relación con MIF en una de las mayores áreas de producción de tomate en México. Los experimentos se realizaron con 16 híbridos de tomate plantados en el Campo Experimental Valle de Culiacán, México del INIFAP. Se evaluó el rendimiento y tamaño comercial de los frutos cosechados, con base en su comercio y mercado de destino (e.g. proceso industrial, mercado de exportación o nacional). La incidencia de MB y los efectos de la temperatura sobre la MIF se analizaron en función del rendimiento. Se observaron síntomas de MIF tanto temporales (MIFt) como permanentes (MIFp). El término MIFt se consideró para aquellos frutos que restablecieron su proceso de madurez durante el almacenamiento después de la cosecha y alcanzaron la maduración completa después de 7 d a 25 ºC. En concordancia con reportes previos, se observó que los síntomas de MIFt se asociaron a bajas temperaturas (≤ 8 ºC) presentes durante las fechas de cosecha temprana. MIFp produjo más daños a los frutos y se asoció con el efecto de MB en altas densidades de población (0.77 a 0.93 adultos cm^{-2}), altas temperaturas durante la temporada de cosecha y genotipos de tomate susceptibles.

Palabras clave: *Solanum lycopersicum*, *Bemisia argentifolii*, frutos dañados, fechas de cosecha, temperatura, híbridos.

INTRODUCTION

Mexico is the tenth largest producer of tomatoes (*Solanum lycopersicum* L.) in the world and contributes with 4.04 million tons annually (FAOSTAT, 2016). production of this crop has increased to become the most exported cash crop for the country; it is mainly cultivated in the northern state of Sinaloa (SIAP, 2014). Although most farmers in that state have state-of-the-art tomato-growing technology, adequate pests control is still a crucial factor to guarantee a successful crop.

One of the most critical pests in tomato that affects yield and product quality is silverleaf whitefly (SLW) (*Bemisia argentifolii* Bellows & Perring). This pest can cause yield losses from 30 to 100 % (Czosnek, 2007). McCollum *et al.* (2004) pointed out that SLW is responsible for a severe physiological disorder in fruits: tomato irregular ripening

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(TIR). The resulting detrimental quality is associated to the amount of toxins deposited by nymphs feeding on the fruit. Additionally, Davino *et al.* (2017) reported that blotchy symptoms in tomato fruits are also related to the Pepino mosaic virus, which is transmitted by *Trialeurodes vaporariorum*. Similar symptoms, in the absence of SLW, were observed in other studies when tomato fruits were exposed to low temperatures (Masarirambi *et al.*, 2009).

The most common symptom observed in fruits with TIR is a non-uniform color of the inner and outer layers of the pericarp. Another symptom is related to fruit consistency: fruit softening is inhibited in infected treatments (Hanif-Khan *et al.*, 1999). Schuster (2002) provides further descriptions of TIR symptoms such as non-uniform or inhibited red color in longitudinal sections, which results in an increased amount of white tissue. Although green tomato fruits appear normal at harvest, TIR symptoms appear later when fruits are stored for ripening. In some cases, TIR symptoms can disappear and damaged fruits might recover their red color and reach complete ripening.

Some researchers have evaluated different storage conditions to reduce or eliminate TIR symptoms. Powell and Stoffella (1995), determined that ethylene does not improve the development of uniform red color in tomatoes affected by TIR. They also observed that 34 to 56 % of SLW infected tomatoes developed external symptoms while 71 % presented internal symptoms. External symptoms disappeared during final stages of ripening when stored at room temperature (20 to 22 ºC); however, internal symptoms remained. Furthermore, Guillén *et al.* (2007) reported that fruit ripening at low temperature (10 ºC) inhibits ethylene accumulation and lowers lycopene content, and this can be prevented when stored at 20 ºC.

Hanif-Khan *et al.* (1996) studied SLW effects in cherry tomato infested with SLW and concluded that this pest induces TIR symptoms and produces a series of longitudinal red stripes with yellow, green, or red blotches. They also observed a dry and white colored tissue inside infected fruits, mainly in the endocarp across locules. This symptom was noticed to a lesser extent on the radial pericarp. Similar to the findings of Powell and Stoffella (1995), some damaged fruits were able to recover their red color during storage; however, internal white tissues and dry consistency remained. It has been reported that most tomato genotypes are susceptible to TIR, although damage level is variable (Powell and Stoffella, 1995).

Considering the importance of TIR on the profitability of tomato production and the increasing incidence of SLW in Sinaloa, the objectives of this research were to identify and quantify damage extent in fruits showing TIR symptoms and to determine the influence of both temperature and SLW incidence on the irregular ripening of different tomato hybrids.

MATERIALS AND METHODS

Experimental site and genetic material

Experiments were carried out in open field cultivation under irrigated conditions at the INIFAP Experiment Station in the Valley of Culiacan, Sinaloa State, México (24º 35' 23" N; 107º 25' 20" W and 17 masl) from August 2011 to March 2012. Plants were sowed in vertisol soil, at pH 7.3 to 7.7, and 0.9 % of organic matter content. Sixteen tomato genotypes of indeterminate growth were evaluated at two planting dates (Table 1). Eight of these genotypes were round-type tomatoes (830600987, Panzer, 830402457, Baron, 830505606, Arthurus, Pilavy y Stealth), and the other eight were saladette-type tomatoes (Cuauhtemoc, Moctezuma, Espartaco, Indio, Abuelo, Ramses, Soberano and Anibal).

Experimental design and crop management

A randomized complete blocks design with factorial arrangement and three replications was employed. The experimental units consisted of three 6-m long rows, separated by 1.5 m. For crop management, local techniques and guidelines regarding weeding, staking, pruning, pesticides use, fertirrigation and fruit thinning were followed accordingly to Villarreal *et al.* (2002). Air temperature was measured daily after flowering by using a data logger (Watchdog A-Series, Spectrum® Technologies, Inc., Aurora, IL, USA).

Sampling and data collection

Once the harvest season started, tomato samples were taken at 10 harvest dates for ten weeks. The first harvest date was set once most fruits reached physiological maturity. SLW monitoring was performed using 12 yellow sticky traps (30 × 15 cm) per plot, placed 15 cm below the plant canopy; monitoring initiated after anthesis and lasted until the tenth harvest date (Gusmão *et al.*, 2005). Traps were removed once a week and the number of SLW adults per cm^2 was determined by considering total counts per unit area.

Fruit yield (t ha^{-1}) was determined for all harvest dates across two planting dates. This trait was divided into three categories according to NMX-FF-031-1997 (SAGARPA, 1997): fruit for export market (weight > 220 g and diameter > 7 cm), for domestic market (weight > 160 g and diameter > 5.7 cm), and for the processing industry (weight < 140 g and diameter < 5.7 cm). At each harvest date, tomatoes

Table 1. Planting dates and fertirrigation treatments used for growing 16 tomato genotypes for TIR evaluation. Cualiacan, Sinaloa, Mexico, 2011-2012.

Planting date	Days to harvest	Irrigation depth (mm)	Units (kg ha^{-1})				
			N	P	K	Ca	Mg
1. August 10th	203	429	95	25	130	209	66
2. September 04th	182	380	85	20	95	200	50

N: nitrogen; P: phosphorous; K: potassium; Ca: calcium; Mg: magnesium.

were separated into two categories: healthy fruits and fruits with visible TIR symptoms (i.e. fruits with white or yellow longitudinal marks). Selected tomatoes were stored at 25 ± 1 ºC for 7 d to monitor changes in color and physiological damage. As observed during storage, TIR symptoms were classified either as temporary (TIRt) or permanent (TIRp). Fruits with TIRt reached complete ripening after the aforementioned storage period. In fruits with TIRp, symptoms remained through the time of storage.

Statistical analysis

Analysis of variance, means comparison (least significant difference, LSD P ≤ 0.05), as well as principal component analysis (PC) were performed using SAS (SAS Institute, 2010) to determine differential effects of the evaluated factors on TIR.

RESULTS AND DISCUSSION

Temperatures and SLW population

Daily maximum and minimum temperatures recorded after tomato flowering are shown in Figure 1. Before the first harvest date (December 26th) took place, temperature ranged from 12 to 27 ºC which, to some extent, facilitated the initial increase of SLW population. On the other hand, low temperatures (below 8 ºC) on January 7th-10th, 12th, and 30th; and February 1st, 2nd, and 4th affected SLW growth and maintained population constant; however, after February 18th, an SLW population growth took place; which was mainly associated to a temperature increase within the range of 10 to 32 ºC. This finding agrees with the observations of Nava-Camberos *et al.* (2001) as they pointed out that temperatures between 11 and 35 ºC lead to a significant presence of SLW, since this temperature range shortens the number of days needed for an SLW egg to become an adult. This was probably one of the reasons that the highest SLW population densities (> 0.9 adults cm^{-2}) were recorded after March 3rd when warmer temperatures were present (Figure 1).

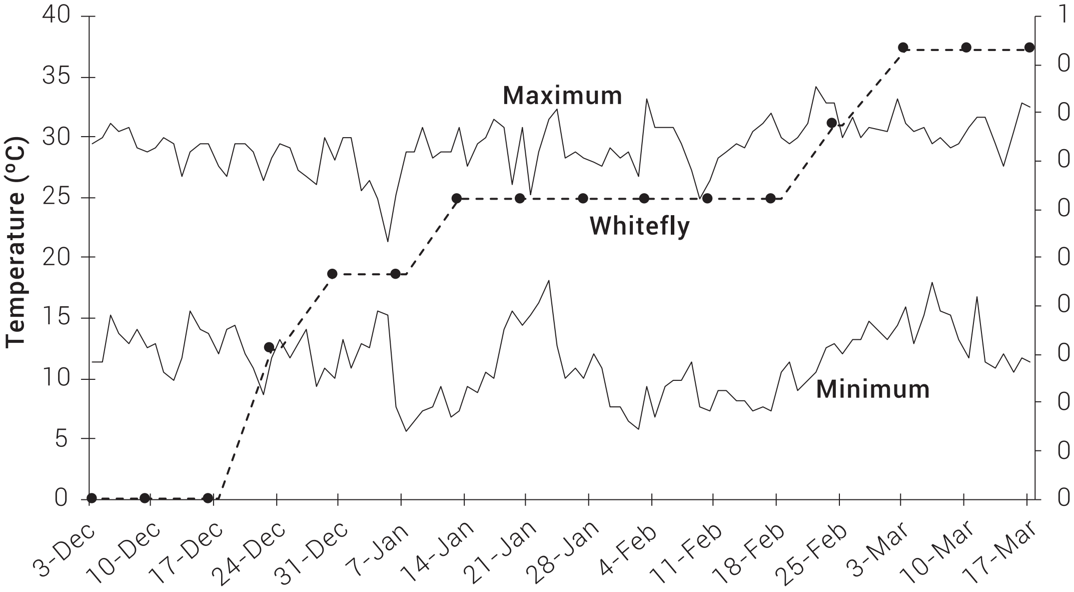

Figure 1. Maximum and minimum temperatures recorded during harvest season and SLW population densities (black circles) in tomato experimental plots. Cualiacan, Sinaloa, Mexico, 2011-2012.

There were five SLW population peaks between December 2011 and March 2012; the first one with a population of 0.3 adults cm^{-2} and no TIR signs was recorded on December 17th with temperatures ranging from 12 to 27 ºC; the second one, with a population of 0.5 adults cm^{-2} was recorded on December 30th with temperatures between 10 and 28 ºC. After December 30th, SLW population remained constant for about two weeks which was probably due to the low temperature (6 ºC) recorded on January 7th. The third peak, with an SLW population of 0.6 adults cm^{-2} was recorded on January 14th with a temperature interval from 9 to 27 ºC. SLW population density in the third peak remained stable for about one month (January 14th to February 18th); however, during this time, TIR symptoms were visible. The fourth peak was recorded on February 25th. Temperatures at this date ranged from 13 to 34 ºC with an SLW population density of 0.8 adults cm^{-2}. The final SLW population peak was recorded on March 5th with temperatures from 13 to 30 ºC and SLW population density of 0.9 adults cm^{-2}. Again, it is worth noting that SLW population growths took place when temperatures varied in the range from 11 to 35 ºC as reported by Nava-Camberos *et al.* (2001) for adequate SLW development.

Analysis of Variance

Significant differences in TIRp were detected (Table 2) either due to main effects or different factors interactions. In relation to fruit yield (classified either for export and domestic market, or for the processing industry), the different sources of variation of the model (planting dates, harvest dates, tomato hybrids, and their interactions) were highly significant, and harvest dates had the largest influence on yield (Table 3).

On the other hand, the most significant effect ($P \leq 0.01$) on TIRt was observed at the two-way interaction tomato hybrids × harvest dates, but the three-way interaction planting dates × hybrids × harvest dates was also important ($P \leq 0.05$). This finding suggests a connection between the environment (harvest and planting date) and some susceptible hybrids that leads to TIRt expression.

Planting dates

There was a significant effect of planting dates on both TIRt and TIRp. Although tomato yield was higher in the second planting date, yield losses due to TIRp also increased by 113 % in relation to the first planting date (Table 4). TIRp effects were associated to SLW population densities that increased in the second planting date, mainly due to the presence of higher temperatures (Figure 1). Although tomato genotypes showed a shorter season in the second planting date, the warmer environment could have boosted SLW effects on TIRp. Interestingly, the warmer temperatures did not affect yield negatively.

It was observed that fruit damage caused by TIRp was more severe than damage caused by TIRt. When comparing planting dates, more cases of TIRt symptoms were recorded in the first date, with 87 % more damage than that observed in the second planting date. Increased TIRt incidence was probably linked to low temperatures, especially during the third harvest date (January 9th) when minimum temperatures were between 5.7 and 7.7 ºC during the three days prior and four days after harvest; however, fruits with TIRt started ripening again when stored at 25 ºC ± 1 ºC for 7 d. These findings agree with data reported by Guillén *et al.* (2007) who concluded that low-temperature treatments in ripening tomato fruits inhibit lycopene accumulation and ethylene production, and that this might be prevented by using higher storage temperatures (20 ºC).

Table 2. Mean squares and statistical significance for tomato fruit yield, and yield losses due to temporary and permanent TIR evaluated on 16 tomato hybrids. Culiacan, Sinaloa, Mexico, 2011-2012.

Sources of variation	DF	Temporary IR	Permanent IR	Yield
Planting dates (D)	1	0.00003 NS	0.00237 NS	229.94**
Tomato hybrids (H)	15	0.00030 NS	0.00912 **	120.62**
Harvest dates (C)	9	0.00029 NS	0.03989 **	866.82**
Blocks	2	0.00031 NS	0.00484 NS	27.08**
D × H	15	0.00034 NS	0.00512 **	35.13**
D × C	9	0.00036 NS	0.00765 **	516.10**
H × C	135	0.00033 **	0.00648 **	15.90**
D × H × C	135	0.00032 *	0.00418 **	8.88**
Error	638	0.00024	0.00206	1.41**
CV (%)		1.56	4.50	12.43

DF: degrees of freedom; *: Significance at $P \leq 0.05$; **: Significance at $P \leq 0.01$; NS: non-significant; CV: coefficient of variation.

Table 3. Mean squares for tomato yield classified for different destinations.

Sources of variation	DF	Destination		
		Export market	Domestic market	Processing industry
Planting dates (D)	1	122.13 **	2.76 **.	6.30 **.
Tomato hybrids (H)	15	65.20 **	14.73 **	2.59 **.
Harvest dates (C)	9	455.07 **	84.28 **	10.07 **.
Blocks	2	4.48 **	4.83 **	0.73 **.
D × H	15	25.80 **	8.18 **	0.63 **.
D × C	9	307.64 **	25.35 **	0.77 **.
H × C	135	10.91 **	3.25 **	0.29 **.
D × H × C	135	7.17 **	2.90 **	0.20 **.
Error	638	1.21	0.26	0.02
CV (%)		17.17	19.78	24.71

DF: degrees of freedom; *: Significance at $P \leq 0.05$; **: Significance at $P \leq 0.01$; CV: coefficient of variation.

Table 4. Yield differences caused by TIRt and TIRp at two different planting dates of 16 tomato hybrids. Cualiacan, Sinaloa, Mexico, 2011-2012.

Planting Dates	Yield loss(kg ha^{-1})		Total yield (t ha^{-1})	Yield for different destinations (t ha^{-1})		
	TIRt	TIRp		Export	Domestic	Processing industry
1. August 10th	2.45	11.25	9.08	6.07	2.52	0.51
2. September 04th	1.31	24.04	10.06	6.78	2.63	0.67
LSD ($P \leq 0.05$)	0.002	0.005	0.151	0.14	0.06	0.01

LSD: least significant difference ($P \leq 0.05$).

In relation to TIRp, Toscano *et al.* (2004) stated that this is a physiological disorder caused by toxins introduced by SLW nymphs when feeding on leaves. Cuellar and Morales (2006) refer to this problem as the "rainbow" and they associate this behavior to the *B. biotype* of *B. tabaci*. Ortega (2008) also relates it to *B. argentifolii*; however, similar symptoms have also been recorded without the presence of SLW at low temperatures (Masarirambi *et al.*, 2009). These findings suggest that it is thus possible to identify two types of ripening irregularities, which is supported by this research.

From a physiological perspective, both TIRt and TIRp are associated to ethylene and lycopene synthesis, necessary components for an adequate tomato ripening. It is well known that the amount of these components in tomato is closely related to temperature during crop development (Cheng *et al.*, 2012). It is also notorious that SLW plays an important role on TIR, especially at temperatures between 11 and 35 °C (Nava-Camberos *et al.*, 2001); however, McKenzie and Albano (2009) pointed out that damage mechanisms associated with TIR and the life cycle of the insect causing this problem are still unclear.

Harvest dates

Symptoms related to TIRt were observed on fruits from harvest dates 3 and 4 within the first planting date. As mentioned before, this result was likely favored by the presence of low temperatures. TIRp symptoms were observed after February 24th in fruits from harvest dates 7, 9 and 10, which occurred when high SLW population densities (0.77, 0.93 and 0.93 adults cm^{-2}, respectively) were present. As a result, yield losses due to TIRp increased in later harvest dates (Table 5).

There were significant increases in yield ($P \leq 0.05$) during the first four harvest dates. Harvest dates 5 and 6, on the other hand, had considerable yield reduction (-1.3 and -2.4 t ha^{-1}, respectively) in relation to harvest date 4. Harvest date 7 (February 24th) though, had a yield similar to that observed in harvest date 4; however, due to an SLW population density of 0.773 adults cm^{-2}, harvest date 7 showed fruits with TIRp symptoms, especially on those for export markets. In general, TIRp mainly affected yield for export markets; for example, on March 12th (harvest date 9) the highest SLW population density (0.93 adults cm^{-2}) caused

Table 5. Tomato yield characteristics due to TIRt and TIRp across 10 different harvest dates. Culiacan, Sinaloa, Mexico, 2011-2012.

Harvest dates	Yield loss(kg ha^{-1})		Total yield (t ha^{-1})	Yield for different destinations (t ha^{-1})		
	TIRt	TIRp		Export	Domestic	Processing industry
1	0.00	0.00	3.54	2.24	1.10	0.19
2	0.00	0.00	5.35	3.91	1.27	0.18
3	12.29	0.00	8.29	6.10	1.90	0.29
4	6.56	0.00	12.48	9.22	2.82	0.52
5	0.00	0.00	11.09	7.87	2.72	0.52
6	0.00	0.00	10.01	7.12	2.31	0.55
7	0.00	7.64	11.42	7.84	2.87	0.76
8	0.00	0.00	12.42	8.43	3.21	0.81
9	0.00	53.82	11.27	6.59	3.69	1.02
10	0.00	115.004	9.85	4.93	3.88	1.09
LSD	0.004	0.012	0.33	0.31	0.14	0.04

LSD: least significant difference ($P \leq 0.05$).

considerable TIRp increase and significant yield reduction ($P \leq 0.05$). In consequence, tomato yield for the domestic market and the processing industry increased from harvest dates 7 to 10 ($P \leq 0.05$).

Tomato genotypes

Only genotypes 830402457 and Moctezuma showed fruits with TIRt symptoms (Table 6). In consequence, their use could result in lower yields and reduced income for farmers if necessary actions are not taken to protect plants from low temperatures (≤ 8 ºC). It is important to mention that SLW population densities ranged from 0.46 to 0.62 adults cm^{-2} when fruits with TIRt symptoms were harvested.

On the other hand, genotypes Soberano, Cuauhtemoc, Ramses and Anibal had better performance. They had the highest yields without TIRt and TIRp symptoms. Soberano was the best genotype across all harvest dates in terms of yield ($P \leq 0.05$), especially that for export and domestic markets ($P \leq 0.05$). Cuauhtemoc was the second best genotype in terms of both total yield and yield for the export market ($P \leq 0.05$). Although genotype Ramses had high yield, and it did not show TIRt or TIRp symptoms, Soberano and Cuauhtemoc were considered as the first choices in terms of overall quality according to our results.

In relation to TIRp susceptible genotypes, Panzer showed the largest yield loss due to TIRp (120 kg ha^{-1}). It also produced the least amount of fruits for the processing industry. If more harvest dates had been evaluated beyond harvest date 10, fruits with TIRp symptoms could have increased dramatically, assuming increased SLW population densities and warmer temperatures were present.

Principal component analysis

The first three principal components (PC) accounted for 93 % of the total variation in the experiment (Table 7). PC1 was mainly influenced by total yield, yield for export and TIRp; while PC2 was mainly influenced by TIRt. Figure 2 shows dispersion of tomato genotypes based on a biplot constructed with the first two principal components. It can be noticed that hybrids with the largest PC1 (mainly influenced by the best total yield, yield for export markets and low TIRp) were Cuauhtemoc, Soberano, Abuelo, Anibal, and Ramses. Although Abuelo showed some TIRp damage, its yield across harvest dates was not significantly affected. On the other hand, genotypes with low yield were Panzer, Pilavy, and 830505606, and Panzer was the most susceptible to TIRp.

CONCLUSIONS

The damage caused by TIRt was associated to temperatures below 8 ºC. TIRt susceptible genotypes such as 830402457 and Moctezuma showed normal ripening when stored at 25 ºC for 7 d. Damage caused by TIRp was severe and related to the incidence of SLW at relatively high population densities (0.77 to 0.93 adults cm^{-2}) which were observed at the end of the harvest season when warmer temperatures were present. Most of the genotypes were susceptible to TIRp, but they exhibited differential yield losses across harvest dates.

Table 6. Tomato yield characteristics due to TIRt and TIRp for 16 tomato genotypes. Culiacan, Sinaloa, Mexico, 2011-2012.

Genotypes	Yield loss (kg ha^{-1})		Total yield ($t\ ha^{-1}$)	Yield for different destinations ($t\ ha^{-1}$)		
	TIRt	TIRp		Export	Domestic	Processing industry
Panzer	0.00	120.19	8.04	5.49	2.48	0.19
830402457	19.66	17.48	8.47	5.77	2.23	0.52
Espartaco	0.00	15.73	10.64	7.78	2.51	0.34
Indio	0.00	19.23	10.09	6.16	3.17	0.75
Baron	0.00	21.85	9.82	6.42	2.86	0.61
830505606	0.00	6.55	7.15	4.44	1.67	1.00
Moctezuma	10.50	20.99	10.38	7.60	2.30	0.48
Pilavy	0.00	2.18	7.75	5.42	1.78	0.61
Cuauhtemoc	0.00	0.00	11.19	7.24	3.19	0.80
Arcturus	0.00	17.48	8.85	6.15	2.43	0.34
830600987	0.00	17.48	8.73	6.14	1.96	0.58
Abuelo	0.00	12.23	11.44	7.59	3.13	0.72
Anibal	0.00	0.00	10.75	7.18	2.77	0.84
Ramses	0.00	0.00	10.92	7.23	3.00	0.69
Soberano	0.00	0.00	10.99	7.36	3.10	0.57
Stealth	0.00	10.92	7.92	4.85	2.65	0.43
LSD	0.005	0.01	0.42	0.39	0.18	0.05

LSD: Least Significant Difference ($P \leq 0.05$).

Table 7. Eigenvectors, eigenvalues and variance explained by the first three principal components (PC) of 16 tomato genotypes evaluated at two planting dates and 16 harvest dates.

Original variables	Eigenvectors		
	PC1	PC2	PC3
Temporary IR	-0.08	0.90	0.30
Permanent IR	-0.35	-0.28	0.87
Yield	0.58	0.02	0.16
Export market	0.53	0.16	0.20
Domestic market	0.48	-0.26	0.28
Eigenvalue	2.85	1.07	0.70
Proportion of variance explained	0.57	0.22	0.14

IR: irregular ripening.

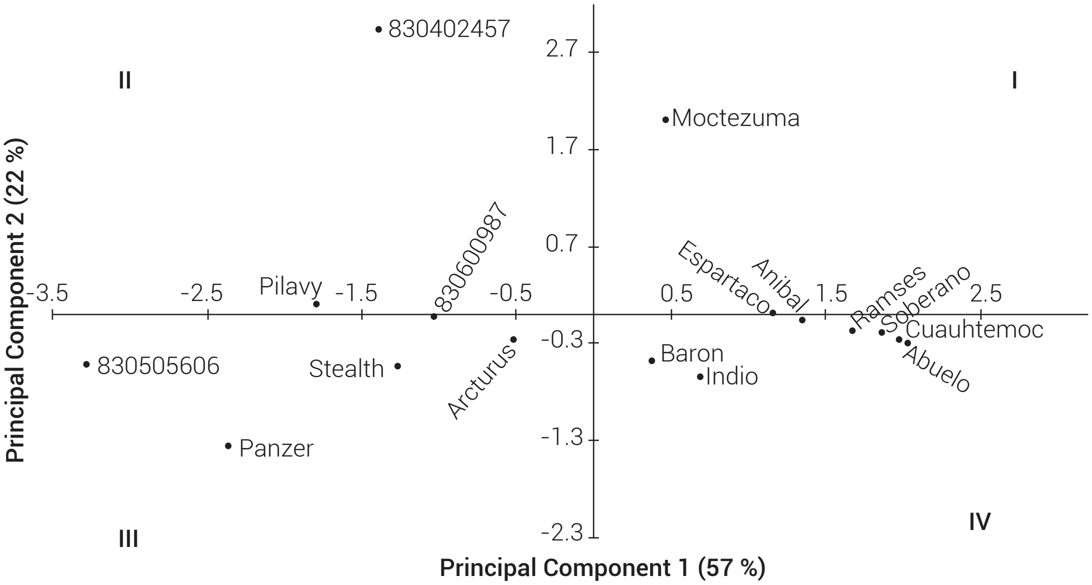

Figure 2. Dispersion plot of different tomato genotypes based on the first two principal components.

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