Survey of Thrips (Thysanoptera) Associated with Four Berry Crops in Mexico[1]

José A. Ortiz, Francisco Infante[2], Ricardo A. Toledo-Hernández[3], and Douglas Rodríguez[3]

El Colegio de la Frontera Sur (ECOSUR), Tapachula, Chiapas, México

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Abstract Mexico is one of the major exporters of a variety of berries worldwide. Thrips (Thysanoptera) are highly attracted to berry crops, and several species can become serious pests that limit berry yield. Given the pest status of thrips in berry production and the magnitude and importance of berries for export in Mexico, this study was conducted to survey and identify the thrips fauna associated with commercial berry orchards in Mexico. We sampled berry plants in 41 commercial plantations of blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), raspberry (*Rubus* spp.), and strawberry (*Fragaria* × *ananasa*) in Guanajuato, Jalisco, Michoacán, and Sinaloa during spring and summer 2020. Our study collected 4,394 thrips specimens belonging to 19 species of thrips. Of those, 53.7% were collected from blackberry, 16.1% from blueberry, 15.5% from strawberry, and 14.8% from raspberry. The predominant species in the four berry crops was *Frankliniella occidentalis* (Pergande). Its relative abundance with respect to other species of thrips collected was 52.9% in blueberry, 69% in raspberry, 79.6% in blackberry, and 88.7% in strawberry. The second most abundant species was *Scirtothrips dorsalis* Hood, varying from 2.6% in strawberry to 24.6% in blueberry. Other important phytophagous species recorded were *Frankliniella cephalica* (Crawford) and *Frankliniella gossypiana* Hood. These four species are invasive, polyphagous, and widespread in Mexico; thus, economic damage by one or more of these species can be expected in locales where management measures are not appropriately applied to avoid economic losses. Data gathered in this survey, coupled with information provided by related studies conducted in Mexico, should serve as a basis for further research dealing with monitoring and management of thrips populations.

Key Words sampling, survey, *Frankliniella*, *Scirtothrips*, Mexico

Berries (i.e., blackberry, blueberry, raspberry, and strawberry) are popular fruits due to their pleasing flavor and year-round availability. Because berry consumption is also associated with health benefits (Foito et al. 2018, Huang et al. 2012, Yang and Kortesniemi 2015), the global market for berries has experienced significant growth (FAOSTAT 2023, González-Ramírez et al. 2020).

The worldwide demand for berries provides an enormous opportunity for food-producing countries such as Mexico, where the production of berries is mainly destined for exportation. Although a considerable capital investment is required, the

[1]Received 2 September 2024; accepted for publication 19 September 2024.
[2]Corresponding author (email: finfante@ecosur.mx).
[3]Driscoll's, Departamento de Investigación Aplicada, Zapopan, Jalisco, México.

high international prices have stimulated establishment of berry crops. In the last decade, cultivated land with berries has more than doubled in Mexico, from 24,000 to 55,000 ha (ANEBERRIES 2023). Mexico has become the world's biggest producer of blackberries (298,024 tons), second in raspberry (128,848 tons), third in strawberry (861,337 tons), and the sixth in blueberries (48,999 tons) (FAOSTAT 2023, SIAP 2023). With an estimated US$4,700 million, berries are the second highest valuable agricultural product in Mexico, having a significant impact on the national economy (SENASICA 2023).

Grower preference for profitable cash crop production has altered land use in many regions of Mexico. Traditional crops, such as maize, sorghum, soybean, sugarcane, and wheat, have been gradually replaced in favor of products for the international markets, such as berries (González-Ramírez et al. 2020, Orozco-Ramírez et al. 2017). Establishment of berry crops, however, usually has resulted in new insect–plant associations and the introduction of invasive pests into the new berry-growing areas (Rodriguez-Saona et al. 2019). For example, the spotted-wing drosophila, *Drosophila suzukii* (Matsumura), one of the main pests of berries, was detected in Michoacán state in 2011 (Castro-Sosa et al. 2017). More recently, the invasive pest known as "chilli thrips," *Scirtothrips dorsalis* Hood, was also reported from Michoacán on blueberries (Ortiz et al. 2020).

Thrips are particularly attracted to berry crops. Several dozen species have been reported feeding on flowers, fruits, or leaves of berries without inflicting serious injuries to plants. Some of the more prominent pest species of thrips reported from different parts of the world are *Frankliniella bispinosa* (Morgan), *Frankliniella fusca* (Hinds), *Frankliniella hawaiiensis* (Morgan), *Frankliniella intonsa* (Trybom), *Frankliniella occidentalis* (Pergande), *Frankliniella schultzei* Trybom, *Frankliniella tritici* (Fitch), *Thrips fuscipennis* Haliday, *Thrips imaginis* Bagnall, *Thrips major* Uzel, *Thrips tabaci* Lindeman, *Scirtothrips citri* (Moulton), and *Scirtothrips dorsalis* (Arévalo and Liburd 2007, Haviland et al. 2016, Nielsen et al. 2021, Renkema et al. 2020, Rodriguez-Saona et al. 2010, Steiner and Goodwin 2005). Most of these species can feed and reproduce on all stages of growth of the host plants as well as on all parts of developing flowers and young leaves. Damage by thrips results in necrotic lesions, distortion of fruits, and flower and fruitlet abortion (Rhodes and Liburd 2017, Steiner and Goodwin 2005). Besides the direct damage caused by thrips, they have been implicated as potential vectors of berry viruses (Tan et al. 2022). Although it is well known that berries are infected by multiple viruses (Martin et al. 2013, Martin and Tzanetakis 2015), the only record of an orthotospovirus transmitted by thrips to berry crops is the impatient necrotic spot virus, reported in blackberry (Tzanetakis et al. 2009). There are other cases involving pollen-transmitted viruses (Ilarvirus) in berries, where thrips are acting as vectors by moving pollen from infected to noninfected plants (Dara 2015, Martin et al. 2013, Martin and Tzanetakis 2015).

Considering the importance of thrips in berry production, in this study we surveyed and identified the thysanopteran fauna associated with blackberry, blueberry, raspberry, and strawberry crops in commercial orchards of Mexico. Our objective was to produce an inventory of thrips species present in these crops and identify the dominant species. We believe this information could eventually be useful in other studies to develop crop protection strategies against damaging thrips species.

Materials and Methods

We sampled for thrips on berry crops at 41 commercial plantations of blackberry, blueberry, raspberry, and strawberry located in Guanajuato, Jalisco, Michoacán, and Sinaloa during spring and summer 2020. Because of differences in berry phenology during the study, the number of samples was not equal across the crop species or locations (Table 1). At each locale, the sample area consisted of approximately 0.5 ha. Plants were not sprayed with insecticide at least 1 wk before sampling. Thrips samples were carefully taken from plants for about 30 min, following a zigzag path to cover the whole sampling area. Plants were shaken over a plastic tray (30 $\times$ 50 cm) moistened with alcohol, to detach the thrips from plants. Thrips dropped onto the tray were handled with a camel-hair brush and placed in vials containing 70% ethanol.

In the laboratory, samples in ethanol were processed. Thrips were counted and separated by morphotypes by using a stereo microscope. A subsample based on the different morphotypes was taken from vials for identification purposes. After being punctured in the abdomen with a fine needle to remove the internal body content, thrips were mounted on slides using Hoyer's mounting medium. Slides were dried in an oven at 45°C for 1 wk and eventually identified to species level following the taxonomic keys in Mound and Marullo (1996), Hoddle et al. (2012), and Cavalleri and Mound (2012), among others. Taxonomic determinations of thrips were made by the first and second authors. Representative identified specimens were deposited in the personal collection of F.I. and are available upon request.

Results

Samples from the four berry crops yielded 19 species of thrips representing 11 genera (Table 2). *Frankliniella*, *Neohydatothrips*, and *Scirtothrips* were the predominant genera with six, three, and two species, respectively. Of the 19 species collected, 17 were phytophagous, 1 species (*Hoplandrothrips affinis* Hood) was fungivorous, and 1 species, *Scolothrips sexmaculatus* (Pergrande), was predatory, feeding on other thrips and mites.

Blueberry harbored the greatest number of thrips species, with 11 collected, followed by raspberry, strawberry, and blackberry, with 9, 9, and 7 species, respectively. Only three species of thrips occurred on all four berry crops: *F. occidentalis*, *Neohydatothrips burungae* (Hood), and *Scirtothrips dorsalis* Hood. Two thrips species that are widely reported in Mexico, *Frankliniella cephalica* (Crawford) and *Frankliniella gossypiana* Hood, were not detected in strawberry but were common in the other three berry crops (Table 2).

In total, 4,394 thrips were collected in these surveys, with 3,795 being adults and 599 larvae. Of those 4,394 specimens, 53.7% were collected from blackberry and 16.1, 15.5, and 14.8% were from blueberry, strawberry, and raspberry, respectively (Table 3; Fig. 1). *Frankliniella occidentalis* was by far the predominant species collected at all 41 plantations and in the four berry crops. More than 50%

Table 1. Location of commercial berry orchards for thrips survey.

Crop	Orchard	Elevation (masl)	Locality	Georeference
Blackberry	1	2,400	Tapalpa, Jalisco	19°56′51.18′′N, 103°42′0.30′′W
	2	1,980	Arandas, Jalisco	20°40′43.03′′N, 102°26′54.14′′W
	3	1,874	Tangancícuaro, Michoacán	19°49′58.96′′N, 102°9′51.62′′W
	4	1,696	Tangancícuaro, Michoacán	19°54′27.80′′N, 102°12′25.74′′W
	5	1,609	Cd. Guzmán, Jalisco	19°40′50.94′′N, 103°31′07.22′′W
	6	1,555	Los Reyes, Michoacán	19°58′52′′N, 102°40′30′′W
	7	1,552	Cd. Guzmán, Jalisco	19°39′53.92′′N, 103°29′36.26′′W
	8	1,535	Cd. Guzmán, Jalisco	19°42′57.80′′N, 103°30′26.89′′W
	9	1,530	Villamar, Michoacán	20°0′52.97′′N, 102°39′14.79′′W
	10	1,360	Zacoalco, Jalisco	20°13′23.97′′N, 103°33′2.25′′W
	11	1,305	Los Reyes, Michoacán	19°35′48.76′′N, 102°29′2.69′′W
	12	1,183	Los Reyes, Michoacán	19°53′55′′N, 102°53′09′′W
	13	18	Guasave, Sinaloa	25°45′03′′N, 108°44′50′′W
	14	17	Los Mochis, Sinaloa	25°44′′36′′N, 108°44′59′′W
Blueberry	1	1,980	Arandas, Jalisco	20°40′43.03′′N, 102°26′54.14′′W
	2	1,874	Tangancícuaro, Michoacán	19°49′58.96′′N, 102°9′51.62′′W
	3	1,774	León, Guanajuato	20°59′05′′N, 101°41′20′′W
	4	1,701	Pénjamo, Guanajuato	20°24′33′′N, 101°40′11′′W

Table 1. Continued.

Crop	Orchard	Elevation (masl)	Locality	Georeference
	5	1,609	Cd. Guzmán, Jalisco	19°40′50.94′′N, 103°31′07.22′′W
	6	1,572	Cd. Guzmán, Jalisco	19°39′29′′N, 103°29′51′′W
	7	1,565	Zamora, Michoacán	19°59′39.33′′N, 102°20′1.97′′W
	8	12	Ahome, Sinaloa	25°47′44′′N, 109°16′17′′W
	9	21	Los Mochis, Sinaloa	25°50′50′′N, 108°53′56′′W
	10	10	Los Mochis, Sinaloa	25°47′22′′N, 109°16′39′′W
Raspberry	1	1,803	Tlazazalca, Michoacán	19°58′37.30′′N, 102°5′16.52′′W
	2	1,707	Tangancícuaro, Michoacán	19°54′56.15′′N, 102°10′45.14′′W
	3	1,705	Tangancícuaro, Michoacán	19°51′23.39′′N, 102°11′49.99′′W
	4	1,580	Zamora, Michoacán	19°58′45.00′′N, 102°17′52.34′′W
	5	1,579	Jacona, Michoacán	19°56′46.12′′N, 102°16′14.86′′W
	6	1,480	Jocotepec, Jalisco	20°19′42.45′′N, 103°29′46.31′′W
	7	18	Los Mochis, Sinaloa	25°45′ 03′′N, 108°44′50′′W
Strawberry	1	2,433	Tapalpa, Jalisco	19°54′41′′N, 103°41′28′′W
	2	2,406	Tapalpa, Jalisco	19°55′40′′N, 103°40′24′′W
	3	2,024	Tupátaro, Michoacán	19°30′49.63′′N, 101°29′84.35′′W
	4	2,022	Tupátaro, Michoacán	19°30′19.69′′N, 101°29′29.54′′W
	5	2,020	Purépero, Michoacán	19°51′34.41′′N, 101°59′35.98′′W

Table 1. Continued.

Crop	Orchard	Elevation (masl)	Locality	Georeference
	6	1,980	Arandas, Jalisco	20°40′43.03′′N, 102°26′54.14′′W
	7	1,874	Tangancícuaro, Michoacán	19°49′58.96′′N, 102°9′51.62′′W
	8	1,695	Tangancícuaro, Michoacán	19°51′58.52′′N, 102°12′41.85′′W
	9	1,658	Santiago, Michoacán	19°55′50.26′′N, 102°24′37.69′′W
	10	1,566	Zamora, Michoacán	19°59′52.80′′N, 102°19′55.64′′W

Table 2. Diversity of thysanopterans in commercial berry crops of Mexico. Species were identified from subsamples taken, considering the different morphotypes in the original sample.*

Thrips Species	Blackberry	Blueberry	Raspberry	Strawberry
Terebrantia				
Anaphothrips sudanensis	0	1^{J}	0	0
Arorathrips mexicanus	0	0	1^{M}	0
Chaetisothrips striatus	1^{J}	0	0	0
Frankliniella borinquen	0	$4^{M, S}$	3^{M}	4^{M}
Frankliniella brunnea	0	1^{M}	0	1^{M}
Frankliniella cephalica	$19^{M, S}$	21^{S}	22^{S}	0
Frankliniella gossypiana	$15^{J, M, S}$	$19^{M, S}$	4^{S}	0
Frankliniella occidentalis	$234^{J, M}$	$127^{J, M, S, G}$	$120^{J, M, S}$	$134^{J, M}$
Frankliniella williamsi	0	0	$3^{M, S}$	0
Neohydatothrips burungae	$5^{M, J}$	$3^{J, M}$	$6^{J, M}$	1^{J}
Neohydatothrips samayankur	0	0	0	1^{M}
Neohydatothrips tibialis	0	0	0	2^{M}
Scirtothrips citri	0	1^{M}	0	0
Scirtothrips dorsalis	$19^{J, M, S}$	$59^{J, M, S, G}$	$13^{J, M, S}$	$4^{J, M}$
Scolothrips sexmaculatus	0	0	2^{M}	0
Tenothrips frici	0	1^{M}	0	0
Thrips tabaci	0	3^{M}	0	2^{M}
Tubulifera				
Haplothrips gowdeyi	0	0	0	2^{M}
Hoplandrothrips affinis	1^{M}	0	0	0

* Superscript capital letters represent locales: G, Guanajuato; J, Jalisco; M, Michoacán; and S, Sinaloa.

of thrips adults collected from the four berry crops were *F. occidentalis*. The second most predominant species was *S. dorsalis*, especially in blueberry, blackberry, and strawberry. *Frankliniella cephalica* and *F. gossypiana* were frequently collected and should also be considered a potential risk for the berry production in Mexico.

Discussion

Our survey successfully assessed the thrips species inhabiting commercially grown blackberry, blueberry, raspberry, and strawberry in Mexico. The sampling

Table 3. Numbers of thrips adults and immatures collected in sampling of commercial berry crops in Mexico.

Crop	Orchard	Locality	Adults	Immatures
Blackberry	1	Arandas, Jalisco	78	1
	2	Cd. Guzmán, Jalisco	245	54
	3	Cd. Guzmán, Jalisco	189	28
	4	Cd. Guzmán, Jalisco	90	14
	5	Guasave, Sinaloa	73	17
	6	Los Mochis, Sinaloa	28	5
	7	Los Reyes, Michoacán	272	8
	8	Los Reyes, Michoacán	223	22
	9	Los Reyes, Michoacán	88	23
	10	Tangancícuaro, Michoacán	278	58
	11	Tangancícuaro, Michoacán	97	3
	12	Tapalpa, Jalisco	63	2
	13	Villamar, Michoacán	257	28
	14	Zacoalco, Jalisco	115	2
Blueberry	1	Ahome, Sinaloa	24	6
	2	Arandas, Jalisco	60	18
	3	Cd. Guzmán, Jalisco	80	72
	4	Cd. Guzmán, Jalisco	40	1
	5	León, Guanajuato	29	9
	6	Los Mochis, Sinaloa	98	15
	7	Los Mochis, Sinaloa	23	10
	8	Pénjamo, Guanajuato	27	14
	9	Tangancícuaro, Michoacán	101	12
	10	Zamora, Michoacán	63	6
Raspberry	1	Jacona, Michoacán	200	49
	2	Jocotepec, Jalisco	38	0
	3	Los Mochis, Sinaloa	25	11
	4	Tangancícuaro, Michoacán	67	0
	5	Tangancícuaro, Michoacán	111	6
	6	Tlazazalca, Michoacán	7	0
	7	Zamora, Michoacán	103	36

Table 3. Continued.

Crop	Orchard	Locality	Adults	Immatures
Strawberry	1	Arandas, Jalisco	10	0
	2	Purépero, Michoacán	57	1
	3	Santiago, Michoacán	34	23
	4	Tangancícuaro, Michoacán	119	25
	5	Tangancícuaro, Michoacán	29	2
	6	Tapalpa, Jalisco	105	9
	7	Tapalpa, Jalisco	21	1
	8	Tupátaro, Michoacán	76	6
	9	Tupátaro, Michoacán	47	0
	10	Zamora, Michoacán	105	12

was conducted at 41 localities within the primary area cultivated with berries so that the study was representative and provided important information on the thrips species composition associated with berry crops.

Of the 19 thrips species identified in the samples from these berry crops, 17 are phytophagous. The predominant species in the four berry crops was consistently *F. occidentalis*. Its relative abundance with respect other species of thrips was 52.9% in blueberry, 69% in raspberry, 79.6% in blackberry, and 88.7% in strawberry. The second most abundant species was *S. dorsalis*, varying from 2.6% in strawberry to 24.6% in blueberry. The third and fourth most common species found were *F. cephalica* and *F. gossypiana*, two species of thrips that are very common in tropical regions of Central America (Mound and Marullo 1996). These two species were more frequently collected in samples from Sinaloa (Table 2). Other prominent species captured included *F. borinquen*, *N. burungae*, and *T. tabaci*. Apparently, only *F. occidentalis* and *S. dorsalis* appear to be persistent pests of economic importance in berries, whereas the other species are considered as occasional pest species. Although most thrips species are herbivorous, there currently is a low risk of economic damage to berry crops by these other species due to their low population numbers.

Frankliniella occidentalis and *S. dorsalis* are two of the most common thrips damaging berry crops. Both species are invasive, highly polyphagous, and widespread globally (Atakan 2011, Kumar et al. 2013, Pinent et al. 2011, Reitz et al. 2020, Renkema et al. 2020). They can establish in new habitats relatively easily and are highly adaptable to different hosts. Other than berries, approximately 240 and 225 plant species are reported as hosts for *F. occidentalis* (Sampson 2018, Tommasini and Maini 1995) and *S. dorsalis* (Kumar et al. 2013), respectively. Usually, adults and larvae of *F. occidentalis* feed on leaves, flowers, and developing fruits (Reitz 2009), whereas *S. dorsalis* feeds primarily on fresh leaves and

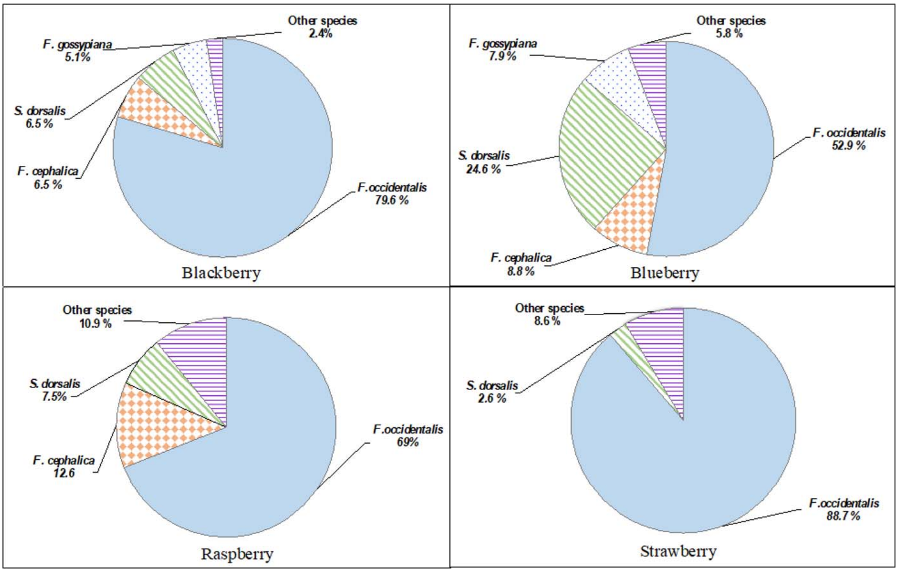

Fig. 1. Species composition of thrips associated with four berry crops in Mexico.

young fruits (Renkema et al. 2020). Given the pest status and risk of these two thrips species and their distribution throughout the main berry-growing areas of Mexico, we recommend that implementing a thorough monitoring program for thrips populations should be instituted to prevent damage and crop losses from these pests.

Our results concur with those of other published thrips surveys reported from Mexico. Six of the species found in our survey have already been reported from berry crops in Mexico. For example, *F. occidentalis* was reported from numerous localities infesting blackberry, blueberry, and raspberry (Cubillos-Salamanca et al. 2019, Martínez-Ortega et al. 2023, Ortiz et al. 2020, Sánchez-Roncancio et al. 2001). The corn trips, *Frankliniella williamsi* Hood, was recorded from blackberry and raspberry (Mejía-Mandujano et al. 2023, Sánchez-Roncancio et al. 2001), *F. gossypiana* has been reported in blueberry (Mejía-Mandujano et al. 2023), *F. cephalica* from blueberry (Ortiz et al. 2020), *S. dorsalis* from blackberry and blueberry (Martínez-Ortega et al. 2023, Ortiz et al. 2020), and *T. frici* from blackberry (Cubillos-Salamanca et al. 2019). The remaining 13 species that we collected and identified represent new records for berry crops in Mexico.

Cubillos-Salamanca et al. (2019) also confirmed that *F. occidentalis* was the most common species in samples collected from blackberry in Jalisco and Michoacan. Zamora-Landa et al. (2020) collected and identified only three species of thrips from blackberry and blueberry crops in Michoacan: *Thrips palmi* Karny, *Frankliniella bruneri* Watson, and *Frankliniella fortissima* Watson. Among those, the dominant species was *T. palmi*, constituting 76.7% of those thrips collected. Ortiz et al. (2020) found *S. dorsalis* as the most abundant species on blueberry leaves collected in Michoacan, with *F. occidentalis* being the second most predominant. Bayardo-Cambero et al. (2023) reported that, in Nayarit, they found eight phytophagous species associated with blueberry, with *S. dorsalis* by far the most predominant species. Mejía-Mandujano et al. (2023) noted that *S. dorsalis* was the most economically important thrips species in organic blueberries growing in Jalisco. Finally, in a study carried out in Michoacan on blackberry and blueberry, Martínez-Ortega et al. (2023) reported that 96% of species collected belonged to *Frankliniella* and *Scirtothrips*. The most abundant species in blackberry var. Laurita and Elvira was *F. occidentalis*, whereas *S. dorsalis* was dominant in blackberry var. Dasha and blueberry var. Arana. Although all these studies were performed in diverse places and by using different methodologies for the collection of thrips, their conclusions align with the results that we obtained in our study.

In summary, our study provides baseline data on the diversity of thysanopterans occupying berry crops in Mexico. The survey confirms the presence of 19 thrips species in 41 berry-growing locales, with *F. occidentalis* and *S. dorsalis* being the predominant species, followed by *F. cephalica* and *F. gossypiana*. With the knowledge that these four species are invasive, polyphagous, and widespread, severe economic damages in berry crops are expected in orchards where control measures are not applied in a timely manner. We hope that the data gathered in this survey, complemented by results provided by other related studies carried out in Mexico, will be used as a basis for further research dealing with monitoring of thrips and development of insect pest management plans.

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