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Screening of the strawberry-resistant cultivars against the two spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae) infestation under field conditions in Ismailia Governorate

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Abstract

A field experiment was conducted during one growing season (2018-2019) in Ismailia Governorate to investigate the susceptibility of eleven strawberry cultivars to *Tetranychus urticae* Koch (Acari: Tetranychidae) infestation and its predators. According to our findings, the highest density of *T. urticae* motile stages peaked in January, February and March in Florida and gaviota cultivars (cv), then declined to its lowest level in April and May for all cultivars. During the study period, two predators were identified: *Phytoseiulus persimilis* Athias-*Henriot* (Acari: Phytoseiidae) and *Scolothrips longicornis Priesner* (Thysanoptera: Thripidae). The cv. Florida and gaviota were more susceptible to *T. urticae* infestation, whereas sweet charlie is the most tolerant. Our results showed a negative correlation between the abundance of *T. urticae* motile stages and the temperature in all cultivars except cv. nabila. Except for crystal and amiga cultivars, *T. urticae* showed a negative correlation between adult stage abundance and relative humidity. However, both predators demonstrated a negative correlation with temperature and relative humidity in cv. tudla and gaviota, respectively, were positively correlated with relative humidity in cv. fortona, Florida, crystal, and sweet charlie. Therefore, the variability in strawberry cultivars is essential for identifying the most tolerant cultivar plant for *T. urticae* infestation that is compatible with Integrated Pest Management programs.

Introduction

Due to its high nutritional content, strawberry (Rosaceae) is one of the consumers' favorite fruits. The total world strawberry production was 8.89 million tons. Approximately 0.40 million hectares were planted yearly, averaging 22.41 tons/ha. Egypt's strawberry production is about 0.46 million tons, which is about 0.012 million hectares (FAOSTAT, 2019). Numerous pests may greatly hinder strawberry cultivation, such as the two spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae), a dangerous chelicerate pest that invaded many vegetable crops, including strawberries (Nyoike and Liburd, 2013). Chemical management is often the simplest method for crop protection, but *T. urticae*'s short life cycle renders it ineffective (Van Leeuwen *et al*., 2010). Several studies have been done to identify alternative control methods to chemical ones (Razmjou *et al*., 2006 and Abou Zeid, 2018).

The host plant resistance is a safe process for controlling pests, as it is not expensive and naturally safe (Sedaratian *et al*., 2009). Therefore, it is important to choose cultivars (cv.) that are less favored by the pest and at least would lead to delayed outbreaks. Utilizing resistant plants is considered one of the most proper non-chemical methods for the management of *T. urticae*, in addition to determining the most preferred cultivar for *T. urticae* feeding to be used for mass rearing of predatory mites (Perdikis *et al*., 2008 and Izzet *et al*., 2017). Identifying the pest's population dynamics may be facilitated by the investigation of predator-prey relations, which can also aid in developing IPM programs (Tehri *et al*., 2014).

Our objective was to screen the resistant strawberry cultivars and the most susceptible ones and study their effects on the population fluctuation of *T. urticae* as well as its predators. In addition, we aimed to investigate how climatic variables influence the occurrence pattern of this pest.

Materials and methods

A field experiment was carried out at Ismailia Agricultural Research Station's experimental farm. The growing season extends from September 2018 to May 2019, using eleven strawberry cultivars: Florida, 029, fortona, festival, amiga, crystal, camarosa, gaviota, tudla, nabila, and sweet charlie. Frozen seedlings were sown in 4 replications for each cultivar and 50 plants per replica. Except for maintaining the whole region pesticide-free, standard farming procedures were followed.

Five plants were selected at random for every cultivar replication. *T. urticae* population density was determined every two weeks by randomly selecting three random leaves representing the plant's top, middle, as well as the bottom canopy. Consequently, 30 leaves/replication were studied simultaneously for each cultivar. The harvested leaves were placed in labeled polythene bags and sent to the Acarology laboratory for examination utilizing a stereo binocular microscope (Olympus SZ-PT, Japan). According to Kumar *et al.* (2015), the mites' total number was counted in the 2.5 cm^2 area on the underside of the leaf, while the predators were recorded in the whole leaf area, as described by Poe (1980). Relative humidity as well as field temperature records were obtained from the Central Laboratory for Agricultural Climate, Agricultural Research Center, Giza, Egypt.

Statistical Analysis

The percentage of infested leaves on the collected samples was calculated. The density of the individuals per leaf was calculated and represented as the Mean (±SE). The means were evaluated utilizing analysis of variance (ANOVA), and comparisons of means were conducted using Duncan's test with a P = 0.05. To evaluate the relationship between T°C, RH., and the number of *T. urticae* life stages and predators, a Pearson correlation coefficient (r) was calculated**.**

Results and discussion

The mean abundance (±SE) of *T. urticae* motile stages is shown in Table (1). The results showed that the highest density of the adult stage was recorded in cv. Florida in November, December, and January (2.75 ± 0.46, 3.10 ± 0.65, and 15.33 ± 1.58, respectively). During the months of

February and March, cv. gaviota recorded the highest density (15.00 ± 1.53 and 6.07 ± 0.70, respectively). In April, the highest density was recorded in cv. crystal (3.30 ± 0.32) while in May, it was recorded in cv. tudla (2.77 ± 0.31). The lowest density of the adult stage in all months was recorded in cv. sweat chairl, amiga, and camarosa. There were highly significant differences between strawberry cultivars with respect to mite abundance (F = 34.64, P = 0.000). The cv. gaviota had the highest percentage of infested leaves (70 to 98.33%), followed by cv. Florida (20 to 98.33%) and then cv. festival (38.33% to 96.67%) (Figure 1).

The mean abundance (±SE) of the *T. urticae* nymphal stage is depicted in Table (2). Results showed that the highest density of the nymphal stage was recorded in the cv. Festival in November and December (3.38 ± 0.70 and 5.99 ± 1.11, respectively). In January, cv. Florida showed the highest density (22.28 ± 3.42) while cv. gaviota (20.93 ± 3.26) in February, then density decreased in all cultivars from March to May. There were highly significant differences between strawberry cultivars with respect to mite abundance (F = 24.86, P = 0.000). The highest percentage of infested leaves was recorded in cv. gaviota ranged between (63.33 to 96.67%), followed by cv. festival (33.33 to 86.67%) (Figure 2).

Our survey revealed the presence of two predators, *Phytoseiulus persimilis* Athias-*Henriot* (Acari: Phytoseiidae) and *Scolothrips longicornis Priesner* (Thysanoptera: Thripidae). Data depicted in Table (3) indicate that *P. persimilis* started to appear in February only in cv. Gaviota and Florida (2.82 ± 0.31 and 2.40 ± 0.28, respectively), while in March, the highest density was recorded in cv. Gaviota (2.03 ± 0.18). In April, *P. persimilis* was the highest in cv. Crystal (2.70 ± 0.35). There were highly significant differences between strawberry cultivars with respect to mite abundance (F = 56.50, P = 0.000). The highest percentage of infested leaves was recorded in cv. Gaviota (35 to 93.33%), followed by cv. Florida (56.67 to 100%) (Figure 3).

Regarding *S. longicornis*, the highest density was recorded in cv. crystal in March and April (0.33 ± 0.06 and 0.52 ± 0.09, respectively) (Table 4). There were highly significant differences between strawberry cultivars with respect to mite abundance (F = 18.62, P = 0.000). The highest percentage of infested leaves was recorded in cv. crystal (41.67%), followed by cv. gaviota ranged between (1.67 to 21.67%), and then cv. Florida (6.67 to 21.67%) (Figure 4).

Except for cv. nabila, our results indicated a negative correlation between the T°C and total *T. urticae* motile stages. Regarding the predators, they were negatively correlated with the T°C in all cultivars except in cv. tudla (Table 5). In all cultivars except for cv. crystal and amiga, there was a negative correlation between RH. and the adult stage, whereas the nymph stage exhibited a positive correlation with RH. in cv. 029, crystal, and amiga. Additionally, a negative correlation was observed between RH. and both predators in cv. gaviota and tudla, whereas a positive correlation was observed in cv. fortona, Florida, crystal, and sweet charlie were recorded (Table 6).

Table (1): Mean abundance (±SE) of *Tetranychus urticae* adult stage on strawberry cultivars during the growing season extending from November (2018) to May (2019).

Cultivars	Nov. (2018)	Dec. (2018)	Jan. (2019)	Feb. (2019)	Mar. (2019)	Apr. (2019)	May (2019)
Festival	1.97±0.32	3.00±0.53	2.72±0.28	4.27±0.87	3.52±0.41	0.65±0.13	0.65±0.13
Fortona	1.17±0.20	1.15±0.11	4.25±0.60	6.00±1.08	4.10±0.68	0.53±0.19	0.52±0.13
Gaviota	2.08±0.33	2.70±0.53	5.12±0.70	15.00±1.53	6.07±0.70	2.27±0.40	1.58±0.25
Florida	2.75±0.46	3.10±0.65	15.33±1.58	10.85±1.01	4.97±0.58	0.45±0.16	0.22±0.05
029	2.25±0.41	2.18±0.44	2.57±0.40	3.10±0.42	5.47±0.72	1.82±0.27	1.03±0.13
Nabila	0.98±0.13	0.58±0.13	1.35±0.17	0.91±0.19	1.25±0.21	1.00±0.14	2.30±0.27
Tudla	1.33±0.17	1.33±0.16	2.55±0.56	4.90±0.85	3.32±0.64	0.67±0.13	2.77±0.36
Crystal	0.00±0.00	0.00±0.00	1.12±0.29	1.07±0.38	5.05±0.86	3.30±0.32	0.60±0.10
Sweet Charlie	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Amiga	0.00±0.00	2.85±0.49	2.78±0.50	0.13±0.06	1.82±0.32	1.52±0.20	0.00±0.00
Camarosa	0.00±0.00	0.00±0.00	1.53±0.22	1.60±0.78	2.50±0.33	2.58±0.32	0.00±0.00

Table (2): Mean abundance (±SE) of *Tetranychus urticae* nymphal stage on strawberry cultivars during the growing season extending from November (2018) to May (2019).

Cultivars	Nov. (2018)	Dec. (2018)	Jan. (2019)	Feb. (2019)	Mar. (2019)	Apr. (2019)	May (2019)
Festival	3.38±0.70	5.99±1.11	3.75±0.80	4.62±0.69	5.40±0.94	0.73±0.22	0.97±0.15
Fortona	1.43±0.29	1.75±0.47	4.48±1.64	4.33±0.97	2.97±0.46	0.38±0.11	0.42±0.10
Gaviota	2.93±0.39	4.47±0.93	6.35±1.54	20.93±3.26	5.73±0.75	6.30±1.05	5.40±0.90
Florida	1.72±0.48	1.97±0.56	22.28±3.42	15.67±2.03	6.90±1.07	0.33±0.06	0.00±0.00
029	5.65±0.95	6.40±0.88	1.60±0.32	2.32±0.50	3.23±0.53	1.65±0.33	0.77±0.10
Nabila	1.12±0.26	0.27±0.09	0.75±0.16	1.07±0.21	0.95±0.20	0.32±0.09	0.85±0.15
Tudla	1.63±0.38	0.73±0.14	1.90±0.63	2.62±0.40	0.80±0.23	0.70±0.15	1.17±0.27
Crystal	0.00±0.00	0.00±0.00	4.17±1.01	2.28±0.75	3.92±0.58	4.29±0.45	0.00±0.00
Sweet Charlie	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Amiga	0.00±0.00	3.35±0.54	3.27±0.54	0.07±0.03	2.37±0.32	1.55±0.23	0.00±0.00
Camarosa	0.00±0.00	0.00±0.00	0.80±0.12	1.96±0.36	1.95±0.33	3.65±0.93	0.00±0.00

Table (3): Mean abundance (±SE) of *Phytoseiulus persimilis* on strawberry cultivars during the growing season extending from November (2018) to May (2019).

Cultivars	Nov. (2018)	Dec. (2018)	Jan. (2019)	Feb. (2019)	Mar. (2019)	Apr. (2019)	May (2019)
Festival	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Fortona	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00
Gaviota	0.00±0.00	0.00±0.00	0.00±0.00	2.82±0.31	2.03±0.18	0.68±0.09	0.92±0.21
Florida	0.00±0.00	0.00±0.00	0.00±0.00	2.40±0.28	1.02±0.15	0.00±0.00	0.00±0.00
029	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Nabila	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Tudla	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.57±0.12	0.65±1.18
Crystal	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.35±0.19	2.70±0.35	0.00±0.00
Sweet Charlie	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Amiga	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Camarosa	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table (4): Mean abundance (±SE) of *Scolothrips longicornis* on strawberry cultivars during the growing season extending from November (2018) to May (2019).

Cultivars	Nov. (2018)	Dec. (2018)	Jan. (2019)	Feb. (2019)	Mar. (2019)	Apr. (2019)	May (2019)
Festival	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Fortona	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Gaviota	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.07	0.18±0.06	0.02±0.02	0.08±0.03
Florida	0.00±0.00	0.00±0.00	0.00±0.00	0.07±0.03	0.22±0.05	0.00±0.00	0.00±0.00
029	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Nabila	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Tudla	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.12±0.04
Crystal	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.33±0.06	0.52±0.09	0.00±0.00
Sweet Charlie	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Amiga	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Camarosa	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table (5): The correlation coefficient between the temperature and the different stages of *Tetranychus urticae* and its predators on strawberry cultivars.

Cultivars	*Tetranychus urticae* stages				Predators			
	Nymph		Adult		*Phytoseiulus persimilis*		*Scolothrips longicornis*	
	Pearson Correlation	Sig.	Pearson Correlation	Sig.	Pearson Correlation	Sig.	Pearson Correlation	Sig.
Festival	-0.56	0.194	-0.66	0.107	-	-	-	-
Fortona	-0.72	0.067	-0.64	0.121	-0.09	0.845	-	-
Gaviota	-0.34	0.453	-0.50	0.249	-0.13	0.787	-0.11	0.807
Florida	-0.66	0.104	-0.69	0.087	-0.36	0.433	-0.24	0.597
029	-0.18	0.697	-0.52	0.231	-	-	-	-
Nabila	0.12	0.800	0.73	0.062	-	-	-	-
Tudla	-0.28	0.539	-0.14	0.771	0.68	0.091	0.909**	0.004
Crystal	-0.63	0.127	-0.26	0.570	-0.16	0.733	-0.17	0.715
Sweet Charlie	-	-	-	-	-0.15	0.751	-0.15	0.751
Amiga	-0.56	0.195	-0.57	0.182	-	-	-	-
Camarosa	-0.42	0.344	-0.57	0.185	-	-	-	-

(**) Significant at P = 0.01 (-) Not recorded

Table (6): The correlation coefficient between the relative humidity and the different stages of *Tetranychus urticae* and its predators on strawberry cultivars.

Cultivars	*Tetranychus urticae* stages				Predators			
	Nymph		Adult		*Phytoseiulus persimilis*		*Scolothrips longicornis*	
	Pearson Correlation	Sig.	Pearson Correlation	Sig.	Pearson Correlation	Sig.	Pearson Correlation	Sig.
Festival	-0.17	0.715	-0.33	0.463	-	-	-	-
Fortona	-0.68	0.092	-0.59	0.165	0.46	0.299	-	-
Gaviota	-0.10	0.829	-0.28	0.547	-0.03	0.945	-0.10	0.839
Florida	-0.74	0.057	-0.74	0.060	0.11	0.809	0.08	0.861
029	0.27	0.562	-0.30	0.513	-	-	-	-
Nabila	-0.69	0.085	-0.34	0.453	-	-	-	-
Tudla	-0.61	0.150	-0.49	0.262	-0.36	0.424	-0.84*	0.017
Crystal	-0.22	0.636	0.05	0.914	0.47	0.291	0.45	0.309
Sweet Charlie	-	-	-	-	0.05	0.911	0.05	0.911
Amiga	0.11	0.996	0.04	0.930	-	-	-	-
Camarosa	0.30	0.508	-0.03	0.955	-	-	-	-

(*) Significant at P = 0.05 (-) Not recorded

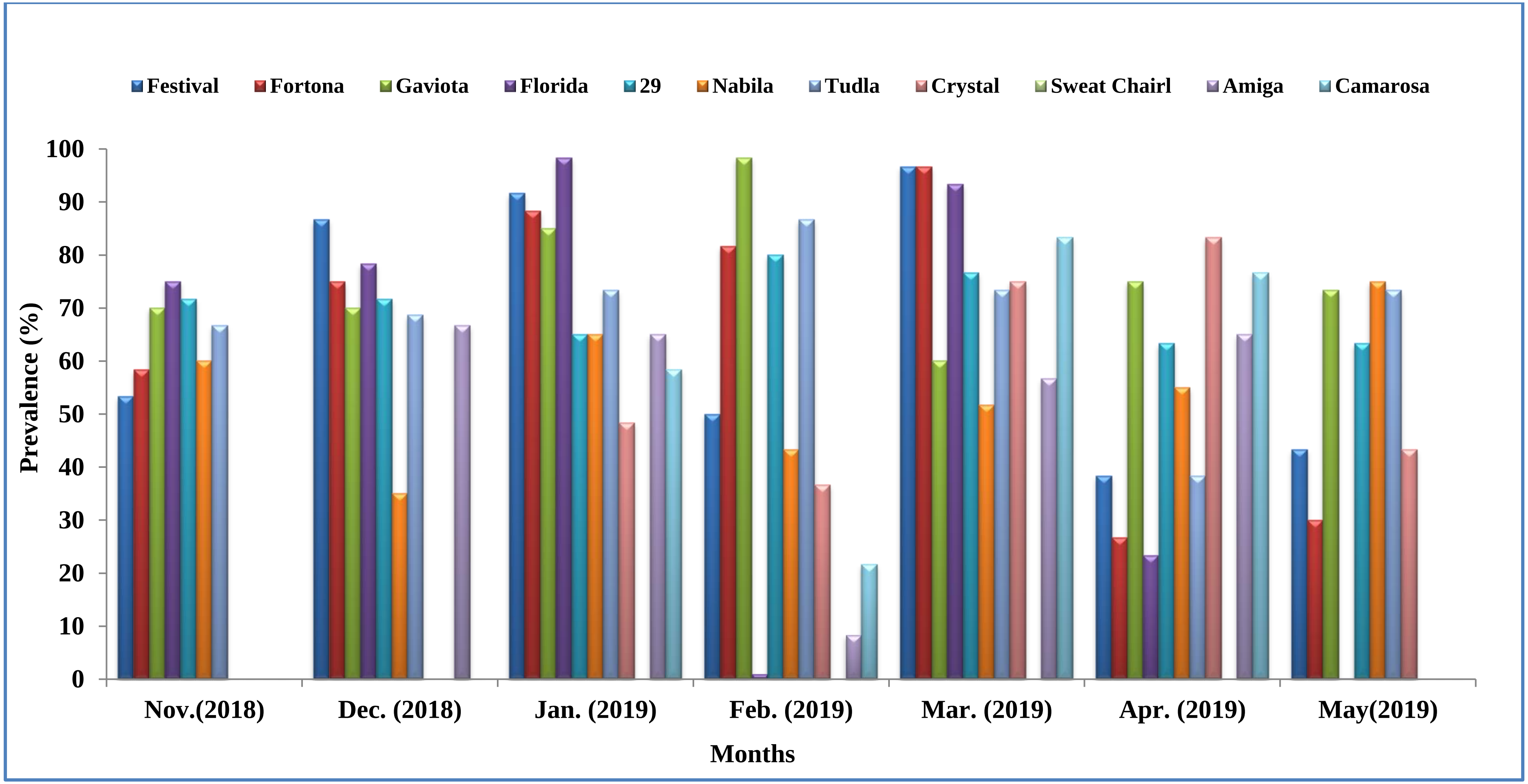

Figure (1): Monthly prevalence of *Tetranychus urticae* adult stage on strawberry cultivars during the growing season extending from November (2018) to May (2019).

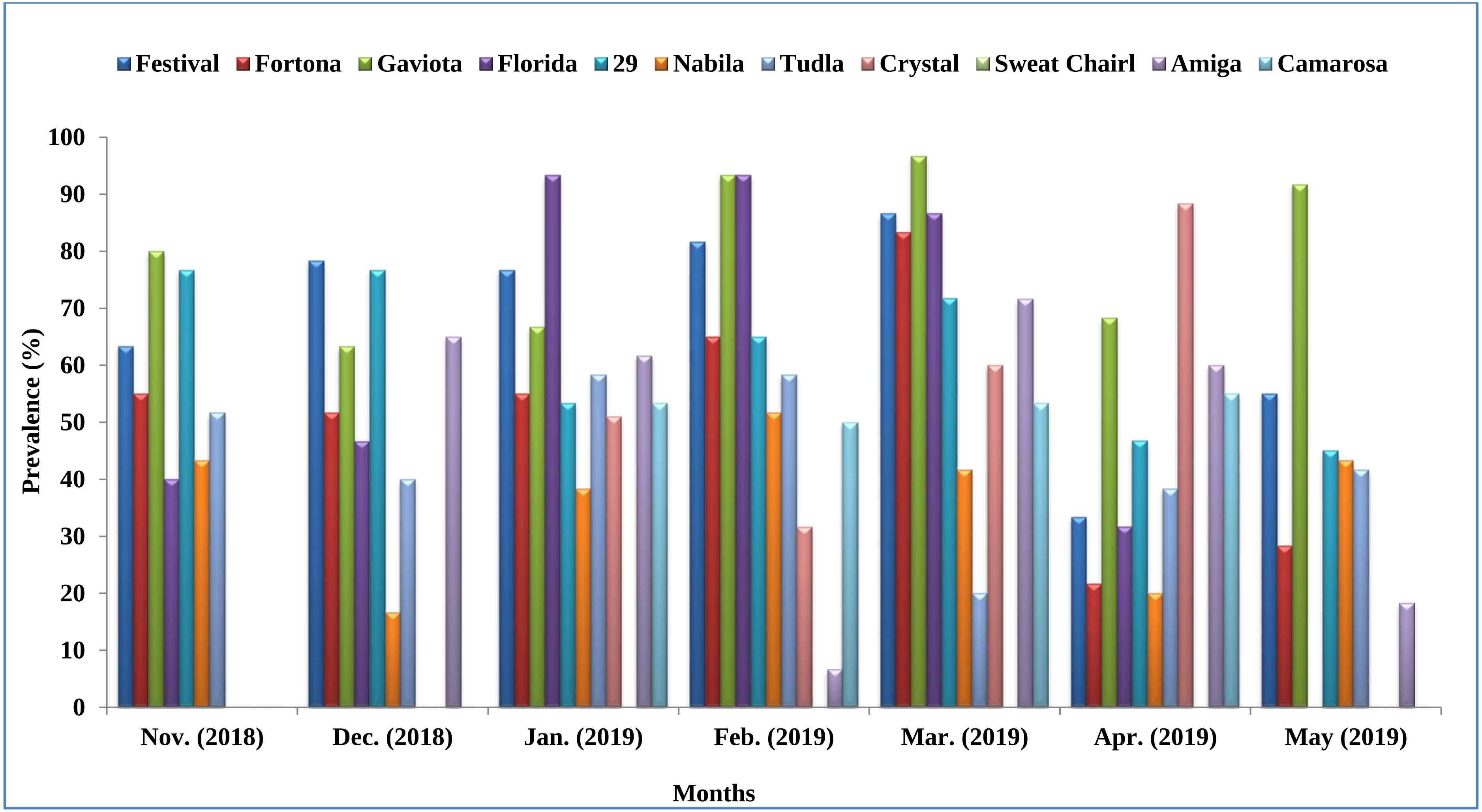
Festival
Fortona
Gaviota
Florida
29
Nabila
Tudla
Crystal
Sweat Chairl
Amiga
Camarosa
Prevalence (%)
100
90
80
70
60
50
40
30
20
10
0
Nov. (2018)
Dec. (2018)
Jan. (2019)
Feb. (2019)
Mar. (2019)
Apr. (2019)
May (2019)
Months

Figure (2): Monthly prevalence of *Tetranychus urticae* nymphal stage on strawberry cultivars during the growing season extending from November (2018) to May (2019).

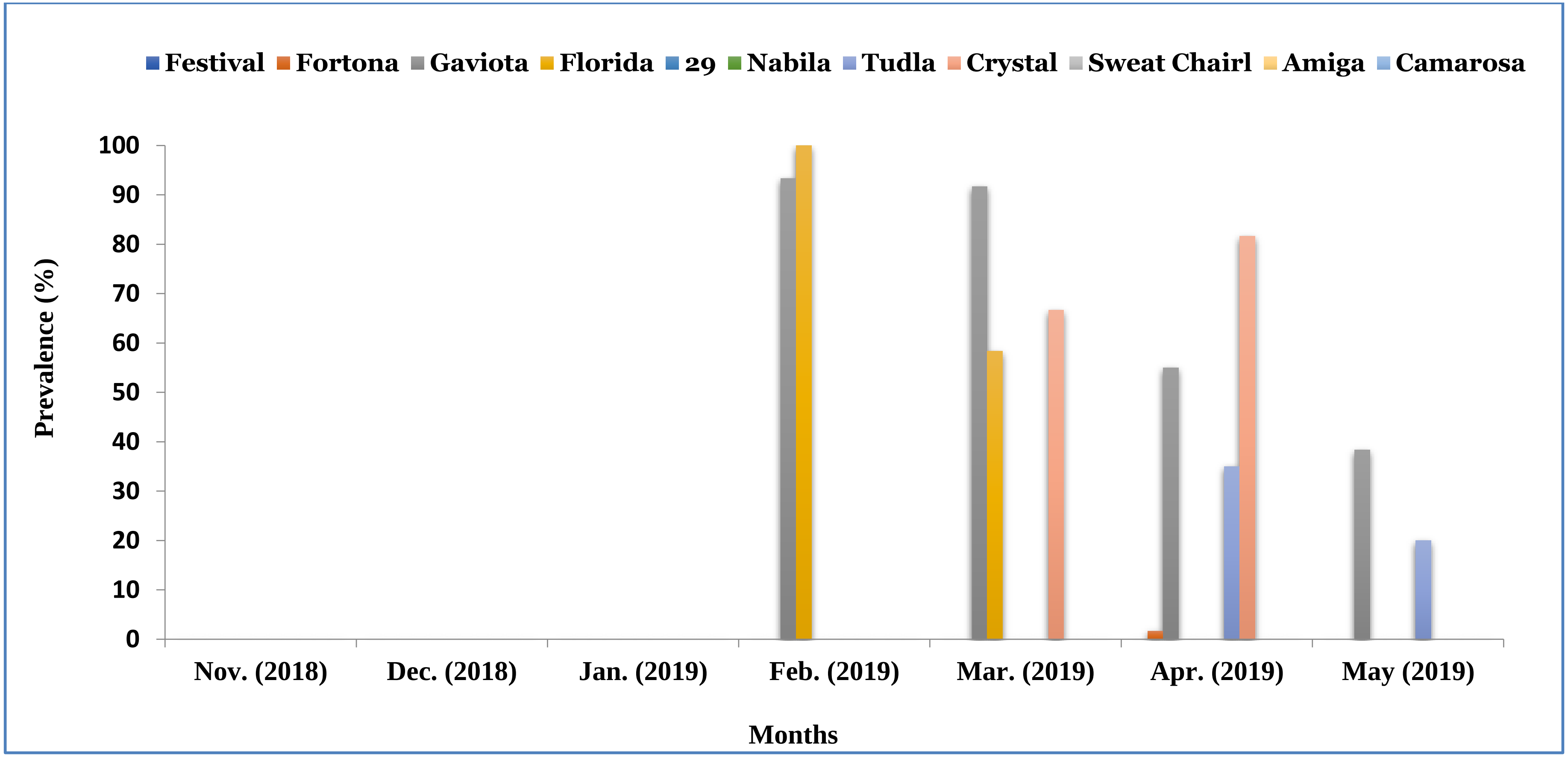

Figure (3): Monthly prevalence of *Phytoseiulus persimilis* on strawberry cultivars during the growing season extending from November (2018) to May (2019).

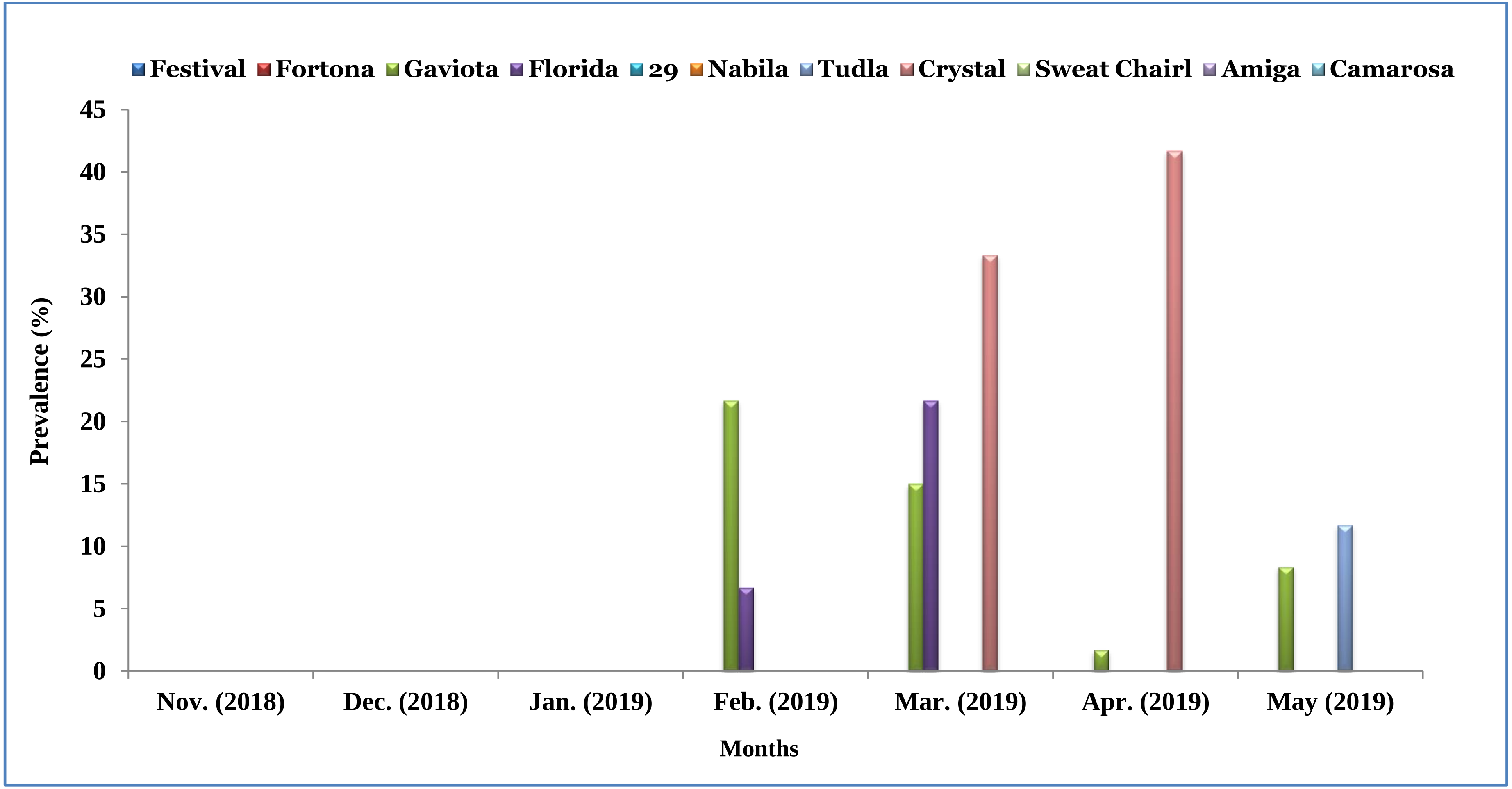

Figure (4): Monthly prevalence of *Scolothrips longicornis* on strawberry cultivars during the growing season extending from November (2018) to May (2019).

Differential susceptibility of cultivars to *T. urticae* attack was indicated by differences in infestation levels between cultivars observed in the current investigation. *T. urticae* density on strawberry cultivars peaked in January, February, and March in cv. Florida and gaviota then declined after that becoming the minimum during April and May in all cultivars. These results are in accordance with Fahim and El Saiedy (2021) who detected two peaks for *T. urticae* infestation in February or March, depending on the cultivar. In contrast, Castilho *et al.* (2015) found that the density of *T. urticae* in strawberries increased, reaching a peak in September and then decreasing with a slight increase in predatory mite density. Similarly, Garcia and Gonzalez-Zamora (1999) indicated that the infestation of *T. urticae* on strawberry cultivars diminished in winter, elevated again in March or April, and peaked at the spring season's end.

Our findings showed that cv. Florida, fortona, festival, and gaviota were the most susceptible to *T. urticae* infestation, whereas sweet charlie is the most tolerant. Our results are similar to those obtained by Afifi *et al.* (2010) who found that cv. camarosa is more susceptible to *T. urticae* infestation compared to sweet charlie. Similarly, Rezaie *et al*. (2013) revealed that cv. gaviota was the least preferred to *T. urticae* than cv. sequoia and Marak. In addition, Mohamed and El Ghobashy (2013) found that Sweet Charlie and chandler are the least preferable varieties to *T. urticae* infestation. In contrast, Ottaviano *et al.* (2013) showed that cv. festival was classified as moderately resistant, while cv. camarosa, festival, and sweet charlie were intermediate. The cultivars Florida, festival, and camarosa adversely affected *T. urticae* biology, suggesting the potential for antibiosis resistance, so these cultivars were less favorable to *T. urticae* development (Karlec *et al.*, 2017).

In addition, Fahim and El Saiedy (2021) observed that the cv. 029 were more susceptible to *T. urticae* infestation, followed by markez, fortona, and wanter star cultivars. Contrary to our findings, they suggested that the other plants in a strawberry field should replace cv. 029 in order to better control *T. urticae*. Consequently, differences in the strawberry cultivars' suitability for the development as well as, the reproduction of *T. urticae* explain the differences in *T. urticae* populations on the various cultivars evaluated (Fahim *et al.*, 2020).

Regarding the associated predators, both predators appeared from February to May in only four cv. gaviota, Florida, crystal and tudla. This finding is in conformity with Garcia-Mari and Gonzalez-Zamora (1999) showed that the main predator of *T. urticae* in a strawberry was *P. persimilis*. Oatman *et al*. (1981) noticed that *S. longicornis* is an important predator among 11 predators reported for *T. urticae* that causes severe damage to strawberries.

The primary abiotic factor controlling mite population dynamics in the field is the temperature (Bonato *et al.*, 1990). It has a major impact on population increase; consequently, it is possible to predict the prospective distribution as well as the abundance of mite pests by determining the temperature requirements of their various phases (Maula and Khan, 2016). Our results indicated a negative correlation between the abundance of *T. urticae* motile stages and the T°C in all cultivars (Majeed *et al.,* 2016 and Fahim and El-Saiedy, 2021). However, contrary findings from previous literature support the positive relationship between the population of spider mites and temperature (Meena *et* *al.*, 2014; Castilho *et al.* 2015; Chauhan and Shukla 2016). In addition, Salmane (2015) illustrated that the elevated temperature in the early season might contribute to increasing *T. urticae* abundance, in addition to having a more adverse effect on strawberry plants in terms of foliage damage induced by mites.

This study demonstrated that strawberry cultivars differ in their susceptibility to *T. urticae* infestation during the growing season investigated. It was determined that variability between strawberry cultivars is necessary for determining the most suitable and preferred cultivar plant for *T. urticae*, which can be used for the successful rearing of spider mites (cv. Florida, fortona, festival, and gaviota) and for identifying the most tolerant cultivars (Sweet charlie) that can be incorporated into IPM programs.

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