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Response of squash varieties to *Tetranychus urticae* (Acari: Tetranychidae) and *Bemisia tabaci* (Hemiptera: Aleyrodidae) infestation in relation with its leaf chemical compositions

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Abstract:

Immature fruit of squash (*Cucurbita pepo* L.) is a popular vegetable in Egypt. It can be produced almost as year– round crop. Field studies were carried out to evaluate four squash varieties i.e. Arkan, Dafn, Sama 740 and Andro 174 for their liability to the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) and the whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) infestation during 2015 and 2016 seasons at Beni Suief Governorate, Egypt. Andro 174 variety was the most susceptible during the both seasons, while Sama 740 and Arkam varieties were the most tolerant during the investigated period. Metrological phenome as temperature and humidity played a key role in the *T. urticae* and *B. tabaci* infestations on the tested squash varieties. On the other hand, the sensitivity of squash varieties to the pest injury relies mainly on the phytochemical contents which varied from variety to another, which affect on pest density levels on squash leaves. A positive relationship was found between pest infestations and squash leaf contents *i. e.*, nitrogen, total proteins, total carbohydrates and reducing sugar. In addition, the effect of potassium content, total phenols and tannins was negative effect on the *T. urticae* and *B. tabaci* populations, in where these target pests increased as the leaf content of these components decreased. It is concluded that the obtained results should be taken into account in planning of integrated pest management programs in squash plants.

Introduction

Squash (*Cucurbita pepo* L.) fruits are used for local consumption and for export. They contain some nutritional compounds for human feeding such as moderate quantity of mineral salts, it is eaten cocked as an immature fruit which is rich with fibers and vitamins or consumed for the mature seed which is a good source of fats and protein (Abdein, 2016). It has a highly economic value, and a nutritive food source especially vitamins and is one of the most popular vegetables grown in Egypt (Shehata *et al*., 2009). This crop was infested by two-spotted spider mite, aphids and whitefly (El-Dars *et al*., 2013). The last pests cause a numerous damage in both quantity and quality for crop directly by plant juice loosen or indirectly by plant disease transmitting (Abdel-Salam *et al*., 1982; Geoghiou, 1990; Masaki *et al.*, 1991 and Ibrahim, 2005). Also, more than 200 host plant species were infested by these pests (Abdallah *et al*., 2014). A number of vegetable crops such as tomato, squash, eggplant, cucumber was also subject to *Tetranychus urticae* Koch (Acari: Tetranychidae) infestations during summer plantation causing numerous injuries and yield losses (Kherebe *et al.*, 1984; Heikal and Ali, 2000 and Faris *et al.*, 2004). The whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) caused crop losses by transmitting up to 150 virus species and by inducing plant disorders as likely as squash silver leaf (Polston *et al.*, 2014). Moreover, whitefly secreted honeydew on leaf surface, which lead to the growth of sooty mold fungi, then reduced the efficiency of leaves during photosynthesis processes (Burger *et al.*, 1988; Jimenez *et al*., 1995; Bleicher *et al*., 2000; Byrne *et al.*, 2003 and Lourenção *et al*., 2011).

Recently, the preference and non preference of pests to had gained a significant importance in pest control research programs. However, some issues were carried out with regard to the influence of climatic factors and leaf components on the pest population dynamics, damages and losses on vegetable crops by many authors (Rai *et al*., 1991; Kumar and Sharma, 1993; Kappoor *et al*., 1997; El-Kawass, 2000 and Abou-Zaid, 2003). Leaf chemical contents, varied from variety to another, might be affected on the population level of herbivores (El-Bassiony *et al.*, 2007; Aiad *et al*., 2014 and Azouz *et al*., 2014).

So that, the present work was aimed to evaluate the susceptibility of four squash varieties to *T. urticae* and *B. tabaci* infestations and its correlation with certain leaf phytochemical components. The population dynamics of the mite was also studied throughout the two successive seasons, 2015 and 2016.

Materials and methods

1. Population fluctuation of *Tetranychus urticae* and *Bemisia tabaci* on four squash varieties:

The population fluctuation of two spotted spider mite, *T. urticae* movable stages and whitefly *B. tabaci* nymphs on the four squash varieties (Arkam, Dafn, Sama 740 and Andro 174 varieties) were recorded per leaf, while other species of mite and insect pests have been neglected due to their occurrence by few numbers. An area of 700 m^2 was divided into 12 plots cultivated at Beni-Ady, Nasr District, Beni Suief Governorate, Egypt, during the summer seasons 2015 and 2016. The squash seeds were planted at 15^{th} March throughout both seasons. Each tested cultivar was represented by three replicates (58 m^2) which were arranged in a randomized complete block design. The experimental area was kept free from any pesticide treatments. To estimate the infestation of *T. urticae* movable stages and nymphs of *B. tabaci* individuals, samples of 30 leaves from each variety were randomly picked at weekly intervals started after three weeks plant age until the end of this experiment. Each sample was kept in a tightly closed paper bag and transferred to the laboratory in the same day to count and recorded the numbers of pest individuals/$inch^2$ using a binocular stereomicroscope. The daily mean of minimum, maximum temperatures and RH %, were obtained from the meteorological records of Central Laboratory for Agriculture Climate, Agriculture Research Center at Dokki, Egypt.

2. Determination of phytochemical leaf components of four tested squash varieties cultivated under open field conditions:

Leaf samples of the squash varieties (Arkam, Dafn, Sama 740 and Andro 174) were collected during the vegetation growth period, then it was cleaned and washed with distilled water and left to dry at room temperature. After that leaves were grinded into fine powder. Determination of nitrogen, reduced sugars and total tannins contents were determined and calculated according method described by Sadasivam and Manickam (1991a, b and c). Furthermore, potassium and total phenols contents were conducted by method of Chapman and Pratt (1961) and Heinonen (1999), respectively. Finally, total of carbohydrates and proteins were estimated and conducted according to method of Crompton *et al.,* (1967) and Bradford (1976), respectively.

3. **Statistical analyses:** Statistical analyses were performed using SAS program computer including F-test and calculated LSD (Least significant difference) to find the differences between seasonal mean numbers of tested pests on four investigated squash varieties (SAS Institute, 2003).

Results and discussion

1) Response of different squash varieties to infestation of *Tetranychus urticae* and *Bemisia tabaci*:

a. The two-spotted spider mite, *Tetranychus urticae*:

Data presented in Table (1) indicated that the tested squash varieties were significantly differed in their *T. urticae* infestations according to the mean numbers of movable mite stages through 2015 and 2016 seasons. Andro 174 variety was a high significant response to *T. urticae* infestation recording of 139.42 and 122.36 movable stages / leaf for two successive seasons, respectively which in turn showed significant differences with the other varieties, Arkam, Dafn and Sama 740. While, Sama 740 variety was the most tolerant variety recorded 62.64 and 56.27 movable stages / leaf for two successive seasons, there were significant differences between the tested varieties with the LSD value were 31.14 and 30.20 during the both two seasons, respectively.

In the present studies the two-spotted spider mite, *T. urticae* was observed the mortality pest infested squash plant and various vegetable crops as well as in okra plant (Allam *et al*., 2014). Our results also were in confirmed with the findings of Puttaswamy and Channabasavanna (1980) who reported that *Tetranychus ludeni* Zacher (Acari: Tetranychidae) started building up during April, and attained its peak during May-June. Similar results were reported by Kumar and Sharma (1993) and Gulati (2004). All of them studied the seasonal occurrence of mites on okra, during summer season.

b. The whitefly, *Bemisia tabaci*:

The obtained results in Table (2) indicated that the tested squash varieties significantly differed in their susceptibility to *B. tabaci* infestation according to the mean population of nymphs through 2015 and 2016. One peak of *B. tabaci* nymphs / variety was observed throughout the two tested seasons on all investigated squash cultivars. Andro 174 variety was the most highly significant response to *B. tabaci* infestation recorded 90.67 and 103.70 nymphs / inch^2 for two successive seasons which in turn, showed significant differences with the other cultivars, Arkam, Dafn, Sama 740. On the other hand, Arkam and Sama 740 varieties were the most tolerant that gave the lowest significant difference in *B. tabaci* being the mean numbers of 32.09 and 30.48 nymphs / inch^2 during both tested seasons, respectively.

A slight infestation of *B. tabaci* nymphs / inch^2 was occurred on the first season, 2015 when compared than another investigated season, 2016. These results are in agreement with published literature were supported by Sattar *et al*., 2005 in this study Whitefly nymphs and adults infested numerous cucurbit plants as well as watermelon, Indian squash and melon.

Table (1): Response of different squash varieties to *Tetranychus urticae* infestation under field conditions during 2015 and 2016 seasons.

Varities Inspections date	Mean numbers of *T. urticae* movable stage / inch^2							
	Season 2015				Season 2016			
	Arkam	Dafn	Sama 740	Andro 174	Arkam	Dafn	Sama 740	Andro 174
April, 15th	12.67	12.67	6.67	10.67	7.33	12	5.33	13
22nd	14	18	8.67	27.33	10	21	9.33	25.67
29th	34	38.33	19	49	14	33.33	15.67	45
May, 6th	45	52.33	33.33	71.67	24.33	46.67	26.33	65.67
13th	69.67	74	41.67	111.67	36.67	69	36.67	83.33
20th	92.33	101.67	62.33	145	57.33	93.33	49	108.33
27th	118.67	131.67	85	193.33	76.33	108.67	61.67	148.33
June, 4th	125	138.33	100.67	215	105	123.33	75	175
11th	133.33	160	115	236.67	121.67	150	100	210
18th	148.33	195	131.67	273.33	133.33	185	116.67	233.33
25th	135.33	180	85	200	157	208.33	123.33	238.33
Mean± SE	84.39±15.48 ^{BC}	100.18±19.68 ^{B}	62.64 ±13.21^{C}	139.42 ±17.3^{A}	67.55 ±16.37^{BC}	95.52±20.03 ^{AB}	56.27±12.87 ^{C}	122.36±25.07 ^{A}
LSD	31.14				30.2			

Values singed by the same letter of the same season are not significantly different at alpha = 0.05 % level.

Table (2): Response of different squash varieties to *Bemisia tabaci* infestation under field conditions during 2015 and 2016 seasons.

Inspections date	Mean numbers of *B. tabaci* nymphs / inch^2							
	Season 2015				Season 2016			
	Arkam	Dafn	Sama 740	Andro 174	Arkam	Dafn	Sama 740	Andro 174
April, 15th	4	6	2.67	8.67	8	10.67	4	10
22nd	6.67	10	6	15	11.33	16.33	6	24.67
29th	16.67	24.67	10	24.67	15.33	27.33	8.67	43
May, 6th	25	41.67	34	48.33	24	39.33	16.67	71.67
13th	34	58.33	41.67	70	33.67	51.67	25.67	91.33
20th	46	80.67	53.33	93.33	41.67	65	35	113.33
27th	48.33	103.33	65.67	120.67	55.33	86	48.67	130
June, 4th	65	138.33	76.67	151.67	57.33	117.33	51.67	163.33
11th	58.33	120	66.67	183.33	60	135	62.33	191.67
18th	35	81.67	43.33	166.67	42.33	148.33	50	156.67
25th	14	41.67	35	115	21.67	95	26.67	145
Mean± SE	32.09 ±6.25C	64.21 ±13.37 B	39.55 ±7.64 C	90.67 ±18.7 A	33.7 ±5.72 C	72.00 ±14.45 B	30.48 ± 6.18 C	103.70 ±18.21 A
LSD	19.85				19.84			

Values singed by the same letter of the same season are not significantly different at alpha = 0.05 % level.

2. Interaction between certain weather factors and *Tetranychus urticae* and *Bemisia tabaci* populations during during 2015 and 2016 seasons:

a.The two-spotted spider mite, *Tetranychus urticae* populations:

The simple correlation values (r) in Table (3) illustrated that there was highly significant positive effect of temperature (maximum, minimum and mean temperatures) on the population of *T. urticae* infested the four squash varieties during 2015 and 2016 seasons. On the other hand, average RH % had significantly positive correlation coefficient factor (r) during the first season but insignificant negative relation was observed through 2nd season. Similarly, results were obtained by Gulati (2004); Ismail *et al*. (2007) and Haque *et al*. (2011) in which these issues were reported that temperature was found an important regulatory factor for *T. urticae* building up for numerous vegetable crops with positive correlation.

The amount of variability explained variance (E.V. %) could be attributed to the combined effect of the tested weather factors on the *T. urticae* population on the four squash varieties were recorded more than 80% during the two successive seasons, 2015 and 2016. E.V. % was 93.33, 95.66, 90.61 and 92.40 % on Arkam, Dafn, Sama-740 and Andro-174 varieties throughout the 1st season, respectively. Moreover, it was 86.32, 85.81, 88.56 and 84.62 % for the previously mentioned varieties during 2nd season, respectively. These results agree with that obtained by Allam *et al.* (2014), who illustrated that the simultaneous impact of certain environmental variable factors and other factors on the census of the mite pest and its predators revealed that, temperature, relative humidity and plant age were the most vital factors effected on the population densities of this species. Also, Ghallab *et al.* (2001) revealed that the population of tetranychid mites including *T. urticae* correlated with temperatures.

Table (3): Simple correlation between mean numbers of *Tetranychus urticae* movable stage on different squash varieties and certain climatic factors during 2015 and 2016 seasons.

	Varieties	Simple correlation values								Explained variance%
		Max. Temp.		Min. Temp.		Mean Temp.		Mean RH%		
		r	p	r	P	r	P	r	p	
2015	Arkam	0.785	0.004	0.918	0.001	0.874	0.004	0.671	0.024	93.330
	Dafn	0.748	0.008	0.891	0.002	0.843	0.011	0.738	0.010	95.660
	Sama 740	0.721	0.012	0.869	0.005	0.817	0.021	0.719	0.013	90.610
	Andro 174	0.769	0.006	0.901	0.001	0.858	0.007	0.686	0.020	92.400
2016	Arkam	0.831	0.002	0.905	0.001	0.897	0.002	-0.43	0.189	86.320
	Dafn	0.822	0.002	0.903	0.001	0.893	0.002	-0.45	0.171	85.810
	Sama 740	0.833	0.002	0.924	0.001	0.910	0.001	-0.46	0.158	88.560
	Andro 174	0.828	0.002	0.907	0.001	0.899	0.002	-0.51	0.110	84.620

b.The whitefly, *Bemisia tabaci* populations:

Data tabulated in Table (4) revealed that the simple correlation coefficient (r) was highly significant positive relationship between three tested temperature and the population of *B. tabaci* nymphs infested the four squash varieties during both two seasons. On the other hand, a significant positively effective during the 1st season. However, a non significant negative through the 2nd season with average RH%. the combined effective of the investigated weather factors on the *B. tabaci* activity during experimental time. The combined effect of explained variance of the four tested factors on *B. tabaci* population were (56.69, 62.07, 74.50 and 87.32 %) during the 1st season and were 61.10, 80.95, 68.77 and 82.66 % throughout 2nd season on Arkam, Dafn, Sama-740 and Andro-174 varieties, respectively.

Table (4): Simple correlation between mean numbers of *Bemisia tabaci* nymphs on different squash varieties and tested climatic factors during 2015 and 2016 seasons.

Varieties		Simple correlation values								Explained variance%
		Max. Temp.		Min. Temp.		Mean Temp.		Mean RH%		
		r	P	r	p	r	p	r	P	
2015	Arkam	0.647	0.031	0.709	0.015	0.689	0.019	0.218	0.520	56.690
	Dafn	0.684	0.020	0.772	0.005	0.743	0.009	0.348	0.294	62.070
	Sama 740	0.746	0.008	0.837	0.001	0.805	0.003	0.342	0.304	74.500
	Andro 174	0.732	0.010	0.879	0.002	0.826	0.002	0.678	0.022	87.320
2016	Arkam	0.551	0.079	0.570	0.067	0.586	0.058	-0.731	0.011	61.100
	Dafn	0.821	0.002	0.875	0.001	0.881	0.000	-0.649	0.031	80.950
	Sama 740	0.692	0.018	0.741	0.009	0.745	0.009	-0.699	0.017	68.770
	Andro 174	0.812	0.002	0.870	0.001	0.874	0.001	-0.703	0.016	82.660

In general, this work ultimate that both temperature and relative humidity were familiar factors affecting the development rate of *T. urticae* and *B. tabaci*, followed by other factors such as initial population and growth condition of plants. Many authors studied the different relationship between Tetranychidae, Phytoseiidae, Tenuipalpidae, Tarsonemidae, Stigmaeidae and the tested sucking and leaf miner pests with various meteorological factors was extensively reported by, El-Saidy *et al*. (2012) on *Phaseolus* and eggplant and Allam *et al*. (2014) on okra plant. Also, different pests [*Liriomyza trifolii* (Burgess) (Diptera : Agromyzidae), *B. tabaci*, *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) and *Thrips tabaci* (Lindeman) (Thysanoptera: Thripidae)] were correlated with some weather factors (Shalaby, 2004)

Finally, thermelogical factors such as minimum, maximum and mean temperatures and average relative humidity were important factors which effect on the development rate of both *T. urticae* and *B. tabaci* on squash.

3. **Effect of phytochemical components of squash leaf of the tested varieties on the infestation of of *Tetranychus urticae* and *Bemisia tabaci*:**

One of the most important factors which may explain the susceptibility or the tolerance of squash varieties to the infestation of *T. urticae* and *B. tabaci* was the phytochemical components in their leaves. So data tabulated in Table (5) showed the mean infestation rates of *T. urticae* and *B. tabaci* movable stage and nymphs / inch^2 , respectively, on four different squash varieties namly; Arkam, Dafn, Sama-740 and Andro-174 and the corresponding amount of their leaf contents, Nitrogen, total proteins, total carbohydrates, reducing sugar, tannins and total phenols at the plant growth stages during 2016 season and their relation with *T. urticae* and *B. tabaci* infestation.

Regarding Andro-174 variety, it was observed that the higher contents of all tested leaf contents than other tested varieties except on reduce sugar (3.77) and potassium contents as well as the nitrogen of 695.33, total proteins of 4.17, total carbohydrates of 23.57, total phenols of 2.15 and tannins of 775.67 and also, it had the highest general mean of the population density of *T. urticae* (122.36 mite /inch^2) and *B. tabaci* (103.70 nymphs/inch^2), while, the potassium content and reducing sugar were recorded the highest amount in Dafn leaves cultivar (175.00 and 9.83), respectively and the lowest content were recorded in Sama 740 leaves (110.67 and 4.98) for these two chemical components, respectively (Table, 5).

Table (5): Measurement amount of phytochemical components in leaves of four squash varieties during season 2016.

Cultivars	Mean numbers/ inch^2		phytochemical components						
	T. urticae	*B. tabaci*	Nitrogen content	Potassium content	Total protein	Total carbohydrates	Reducing sugars	Total phenols	Tannins
Arkam	67.55 bc	33.70 c	612.00 b	152.67 a	3.18 b	15.53 b	7.45 b	1.72 bc	696.33 a
Dafn	95.52 ab	72.00 b	284.67 c	157.00 a	1.95 c	16.99 b	9.83 a	1.60 c	608.00 b
Sama 740	56.27 c	30.48 c	254.00 c	110.67 c	1.67 c	18.28 b	4.98 c	1.95 ab	747.67 a
Andro 174	122.36 a	103.70 a	695.33 a	133.00 b	4.17 a	23.57 a	3.77 c	2.15 a	775.67 a
LSD	30.2	19.84	57.18	15.73	6.48	2.84	1.72	0.28	86.1

Concerning the relation between the population levels of *T. urticae* and *B. tabaci* and the previously mentioned components, data was arranged in Table (6) showed that the calculated correlation coefficient values were significantly positive in case of nitrogen content for all the tested varieties expect with Dafn variety, the relation was insignificant during 2016 season. In case of potassium content, it was positive on the infestation of mite pest for Dafn and Andro 174 varieties and was a negative effect on the other two tested varieties, Arkam and Sama 740. In addition, for the repellent compounds, total phenol and tannins, there had a negative effect on the *T. urticae* occurrence on the four investigated varieties except for total phenol with Sama 740 cultivar was a positive correlation coefficient.

Similar by Mead *et al*. (2010) recorded the same results when tested different maize varieties against *T. urticae*. Moreover, Ahmed (1994) reported that host plants resistance to mite infestation may be attributed to low protein and amino acid contents in leaves, which provided less nutritive diet for the spider mite *T. urticae.* Hoffland *et al*. (2000) stated that the protein concentration in tomato leaves was positively correlated with nitrogen content. Moreover, Zaher *et al.* (1980) recorded insignificantly positive correlation between *T. urticae* infestation on soybean and leaf nitrogen content. Contarawise, Magouz *et al*. (2006) and El-Sanady *et al*. (2008) reported a negative correlation between the population density of movable mite stages and nitrogen contents on soybean plant. The obtained data agreement with Badegana and Payne (2000) stated that there was a positively significant correlation between the intrinsic rate increase (r_m), the finite rate of increase (λ) and nitrogen content in the host plant leaves. Similar results were obtained by Taha *et al.* (2014) when tested different cotton cultivars, they found that the cotton genotype, Giza 90 was the most susceptible to *T. urticae* infestation during 2010 and 2011 seasons. On contrary, Wilson (1993) reported that *T. urticae* populations were unaffected by cotton varieties in Australia.

However, the calculated correlation coefficient (r) values showed the relationship between whitefly (nymphs) abundance and these leaf phytochemical components which resulted that nitrogen, total carbohydrates, and reducing sugar affected positively on the population of *B. tabaci* nymphs, in which, the population increased by increasing the content of these tested components in the count of *B. tabaci* nymphs on the four tested leaves. Moreover, total protein was positively affected on this pest in Dafn and Sama 740 while in Arkam and Andro 174 was negatively affected on this pest. Potassium content, total phenols and tannins had negative effect on the *B. tabaci* nymphs on populations, in where, nymphs of the target pest increased when decreased of the content of these components in the plant leaves.

Table (6): Correlation coefficient (r) and its probability (p) between phytochemical contents of squash varieties and abundance of *Tetranychus urticae* and *Bemisia tabaci* during **season 2016.**

Pests	Varieties	Nitrogen content		Potassium content		Total protein		Total carbohydrates		Reducing sugars		Total phenols		Tannins	
		r	p	R	p	r	p	r	p	r	P	r	p	r	p
T. urticae	Arkam	0.63	0.56	-0.54	0.64	0.77	0.44	0.25	0.84	0.99	0.04	-0.76	0.45	-1.00	0.03
	Dafn	0.96	0.18	0.78	0.43	0.48	0.68	-0.38	0.75	0.03	0.98	-0.27	0.82	-0.10	0.94
	Sama 740	0.97	0.16	-0.60	0.59	0.87	0.33	0.87	0.33	0.99	0.10	0.87	0.33	-0.68	0.53
	Andro 174	0.82	0.39	0.96	0.18	-0.88	0.32	0.31	0.80	0.79	0.42	-0.96	0.17	-0.92	0.25
B. tabaci	Arkam	0.97	0.16	-0.94	0.23	-0.61	0.59	0.78	0.43	0.76	0.45	-0.22	0.86	-0.78	0.43
	Dafn	0.31	0.80	-0.08	0.95	1.00	0.06	0.55	0.63	0.84	0.36	-0.95	0.20	-0.01	0.99
	Sama 740	-0.46	0.70	-0.95	0.20	0.59	0.60	0.66	0.54	0.28	0.82	-0.08	0.95	-0.68	0.53
	Andro 174	1.00	0.02	-0.64	0.56	-1.00	0.05	0.78	0.43	0.33	0.79	-0.65	0.55	-0.56	0.62

We can conclude that the most susceptible variety to the infestation with *T. urticae* and *B. tabaci* was Andro 174 variety during the experimental time. Also, from previously data can be concluded that the different squash varieties tolerant to mite and insect infestation could play an important role contributing to integrated pest management strategies in integrated crop management programs. So, we recommended that squash variety, Sama 740 variety was used in planting because it highly tolerance to these pests.

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