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Article

The effect of some fertilizer compounds as a resistance inducer in strawberry plants on life history parameters of *Tetranychus urticae* (Acari: Tetranychidae)

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ABSTRACT

The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch, is a major pest of strawberry crops and pest management strategies are essential to control it. Life table parameters are useful tools for evaluating resistance or susceptibility of host plants to pests. So, the effects of application of some fertilizer compounds on two strawberry cultivars (i.e. Festival and Fortuna), as a resistance inducer (i.e. fulvic acid, humic acid, potassium citrate, and calcium carbonate), have been investigated on biological characters and life table parameters of *T. urticae* under laboratory conditions. Results indicate that the oviposition period, adult longevity period and fecundity of *T. urticae* females were significantly affected when reared on leaf disks of two cultivars treated by above-mentioned fertilizer treatments. The number of deposited eggs per mite female also was remarkably different among the treatments and lower than that of the control. The fertilizer compounds significantly reduced the net reproductive rate (R_0) and intrinsic rate of increase (r) compared to the control. Similarly, the finite rate of increase (λ) and gross reproduction rate (GRR) for the control were significantly higher than that of other treatments. The lower value of the intrinsic rate of increase (r) of *T. urticae* was recorded on Fortuna cultivar of strawberry plants treated by potassium citrate and calcium carbonate than that of other treatments. So, these compounds potassium citrate and calcium carbonate applied on could be relative resistance inducers for Fortuna cultivar of strawberry plants that decrease *T. urticae* populations. This suggests that these inducers with Fortuna cultivar could be employed toward a sustainable management of *T. urticae*.

KEY WORDS: Induced resistance; life table parameters; mites control; strawberry fertilization; TSSM.

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INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.: Rosaceae) is one of the export crops with an economic importance, being the most popular, and its fruits consumed directly or used in the manufacture of many commercial products, such as jams, juices, nectars, and purees (Klopotek *et al.* 2005). Its cultivation has an important economic role in Egypt agricultural sector due to the increase in national income resulting from its export. However, it is severely affected by the infestation of the two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Sato *et al.* 2004), its damages are caused by the motile forms that cause the appearance of chlorotic points on leaves, which develop into yellowish spots until completely reddish leaves. New leaves may be infested, and this depends on the pest

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infestation (Fornazier and Pratisoli 2006).

The high infestations of *T. urticae* in strawberry fields reduce the photosynthetic rate of this plant and are easily noticeable by the formation of webs (Fadini *et al.* 2004; Bernardi *et al.* 2015). This reduces plant growth and strawberry yield, which ultimately affects the quality and quantity of strawberry produced (Klamkowski *et al.* 2006; Sato *et al.* 2007; Rezaie *et al.* 2013; Monteiro *et al.* 2014; Hata *et al.* 2016). Its high population densities are due to *T. urticae* traits such as short life cycle, high fecundity, arrhenotokous parthenogenesis, and its extraordinary ability to adapt to different hosts and environmental conditions (Agut *et al.* 2018). Also, the heat emanating from the plastic mulching (cultivation tunnels) can shorten the *T. urticae* cycle (Fornazier and Pratisoli 2006).

Control of this mite has largely been based on the use of acaricides. Therefore, one of the major problems in the control TSSM is its ability to rapidly develop resistance to many acaricides after only a few applications (De Ponti 1985; Van Pottelberge *et al.* 2008). Additionally, pesticides pose negative effects on the environment and human health (Kavousi and Talebi 2003; Ahmed *et al.* 2021). Nevertheless, in the integrated pest management programs, the use of pesticides can weaken the performance of natural enemies since phytoseiid mites are generally more susceptible to pesticides than other mites (Croft 1990). To minimize the effect of chemical control on natural enemies and provide an ecological balance between pests and their natural enemies, these control strategies can be combined to provide a more reasonable form of pest management (Kogan 1998). As a result, the use of chemical agents with low toxicity for natural enemies and/or the use of pesticide-resistant predatory mites have been exploited in integrated pest management programs (Croft 1990). It is important, in the integrated pest management (IPM) programs, to select efficient pesticides with little negative effects on the natural enemies (Colomer *et al.* 2011).

Therefore, it is necessary to search for other methods to control this mite which can be exploited as an important tool in integrated mite management (IMM) programs. Induced resistance can also play an important role in controlling mites by using chemical elicitors such as Jasmonic acid (JA), Salicylic acid (SA) and ethylene, which confer resistance to mites (Shivaji *et al.* 2010; War *et al.* 2012; Afifi *et al.* 2015). The natural resistance inducer can be used as a dependable method for chemical residues reduction in the environment along with conventional methods (Llorens *et al.* 2017).

The elicitors of induced responses can be sprayed on crop plants to build up the natural defense system against damage caused by herbivores (War *et al.* 2012). Because these compounds stimulate a wide range of defense responses that include antioxidative enzymes, proteinase inhibitors (PIs), volatile organic compounds (VOCs), alkaloid production, trichome formation and secretion of extrafloral nectar (EFN) they play an important role in plant's indirect defense (Dickens 2006; Mao *et al.* 2007; Pauwels *et al.* 2009; Afifi *et al.* 2010, 2015).

Some studies have assessed the effects of some chemical elicitors or fertilizer compounds on pest fertility and life table parameters or on the induction of resistance in plants. The net reproductive rate (R_0) and intrinsic rate of increase (r) of *T. urticae* are significantly reduced on beans fertilized by potassium sulfate 60% (Damghani *et al.* 2021). Also, Dahmardeh *et al.* (2018) stated that the potassium phosphite, amino acid complex, and biologic siderophoric as a fertilizer compound on bean plants significantly affected the life table parameters of *T. urticae*. The foliar spraying of salicylic acid, methyl jasmonate, potassium humates, and potassium silicate on tomato plants are involved in plant defense against the red spider mite, *T. urticae* (Afifi *et al.* 2015; Ahmed 2018). Fertilizing strawberry plants by CaSO_4 and K_2SO_4 compounds led to lower infestation of *T. urticae*, due to the increase in these compounds of the total phenols and amino acid in plants (Afifi *et al.* 2010). The effects of silicon (Si) on biological, reproductive and population aspects of two-spotted spider mite on strawberry plants have been studied (Gatarayihya *et al.* 2010; Sadeghi *et al.* 2016; Ribeiro *et al.* 2021).

Biological and life table parameters, especially intrinsic rate of increase (r), have been used as indicators of pest population performance to assess the level of plant resistance to herbivorous pests

(Adango *et al.* 2006; Ali *et al.* 2013; Golizadeh *et al.* 2016). The intrinsic rate of increase (r) is usually considered as a measure of the plant resistance level against pests (Leszczynski 1987). Therefore, plants that support pest populations and exhibit higher values of r are comparatively less resistant than those supporting the populations with lower values of r (Ahmed 2018; Fahim *et al.* 2020).

IPM is an agricultural approach that aims to keep pests numbers under the economic threshold by implementing a group of crop protection practices, and making the plants resistant is one of these practices. Therefore, the present study aimed to obtain a clear image of some fertilizer compounds used in resistance enhancement of two commercial strawberry cultivars as host plants of *T. urticae* by considering their effects on life table parameters and biological characters of the mite. Knowing the fertilizer compounds most suitable for resistance enhancement in strawberry plant against TSSM could be exploited as an important tool in mite management strategies in both integrated and organic strawberry production.

MATERIAL AND METHODS

Fertilizer compounds

Fulvic acid 10% and humic acid 15% (liquid) as an organic fertilizer compound obtained from Soil Fertility and Plant Nutrition Research Department-Agricultural Research Center, Giza, Egypt. In addition to two compounds of chemical fertilizer, potassium citrate 55% and calcium carbonate 95% (powder) obtained from Green Gold and Piochem companies, respectively. These compounds were selected to evaluate their effect on life table parameters and biological characters of *Tetranychus urticae*.

Strawberry cultivars

Two strawberry cultivars (Festival and Fortuna) commonly grown in Egypt were selected and treated by the foliar application of these fertilizer compounds. Seedlings of two strawberry cultivars were planted on terraces containing six rows of strawberry plants in greenhouses (9 × 40 m) in the farm of the Faculty of Agriculture, Cairo University, Egypt.

The experiment included treatments (fulvic acid, humic acid, potassium citrate, and calcium carbonate) in addition to the control with each strawberry cultivar (Fortuna and Festival). Strawberry plants received all normal agricultural processes without any pesticide application or other fertilization. These two strawberry cultivars were sprayed weekly, starting from the fifth week of seedlings planting, and the spraying was repeated 15 times. The control was sprayed with distilled water only. The concentrations of fulvic acid, humic acid, potassium citrate, and calcium carbonate compounds were 600, 600, 550, and 255 ppm, respectively. These concentrations were chosen based on the concentration recommended in most commercial fertilizer formulations. A compressor sprayer (5 L capacity) was used.

Mite stock culture

The stock culture of *T. urticae* was reared on leaves of copperleaf shrubs (*Acalypha wilkesiana* Müll. Arg.) onto Acarology Lab., Zoology and Agricultural Nematology Department, Faculty of Agriculture, Cairo University. Leaves were placed on water-saturated cotton pads in dishes. A water-saturated, absorbent cotton strip, 1 cm wide, was placed around the edge of the leaves to prevent mites from escaping. The rearing was maintained in an incubator at 28 ± 2 °C, $65 \pm 5\%$ relative humidity (RH) and (L14: D10 h photoperiod) to maintain a continuous source of mite being used in the study. Experimental conditions were selected based on the average temperatures and humidity of strawberry growing locations in Egypt that we obtained from Central Laboratory for Agricultural Climate, Agricultural Research Center, Giza, Egypt. The cotton bed was soaked with water daily. The colony of mites was left for more than two months before starting the experiment. Leaves were replaced every 7 days. A thin paint brush was used to transfer the mites from old leaves to the new ones.

Effect of fertilizer compounds on life table parameters of T. urticae

The influence of selected fertilizer compounds on the biology and life table parameters of *T. urticae* was evaluated on leaves of two strawberry cultivars (Festival and Fortuna), that had received induced resistance treatments. After five applications from spraying strawberry plants with fertilizer compounds in greenhouses, fresh leaves of two strawberry cultivars were taken from one level for all plants with all treatments, washed well with water, then left to dry and cut into discs.

From the laboratory stock cultures, one mated female/replicate was transferred on strawberry leaf section (3 cm of diameter) placed on wet cotton pads in a Petri dish (6 cm in diameter) and left for 24h for oviposition. All dishes were maintained in an incubator at 28 ± 2 °C, $65 \pm 5\%$ R.H and L14: D10 h photoperiod. The cotton bed was soaked with water daily.

After oviposition, female and all eggs except one were removed from every replicate. Forty eggs as replications/treatment and the control. With each strawberry cultivar ($n = 200$ eggs) were used. The eggs present in each treatment were observed daily until the larvae hatched. The period of each developmental stage was observed until all larvae individuals became adults. During the experiment, leaves of discs were replaced every 5 days. Newly emerged adults were separated according to sex and paired into couples, then transferred to new discs for evaluating the pre-ovipositional and ovipositional periods, fecundity, and adult longevity. In discs where males died before females, new males were added from stock colony to the relevant experimental units. However, the data from these males were not used in the analysis. The dead mites and the eggs laid by female individuals in each disc were counted and removed daily until the end of the experiment. The life tables were developed based on the data for all individuals tested (including females, males, and individuals that died during the development of the immature stage) as proposed by Chi (1988).

Statistical analysis (Age-stage, two-sex life table)

Using the TWSEX MSChart application, the raw data of life table parameters were evaluated according to the theory of age-stage, two-sex life table (Chi 2020). According to Chi and Su (2006), the population growth parameters such as (R_0), (r_m), (λ), (T) and (GRR) as well as (s_{xj}), (l_x), (m_x), (f_{xj}) and (v_{xj}) were calculated.

The population parameter means, and standard errors were estimated using the Bootstrap procedure with 100,000 re-sampling, and the life table parameters of TSSM when rearing on leaf-discs from two the strawberry cultivars (Festival and Fortuna) that had received induced resistance by (Fulvic acid, humic acid, potassium citrate and calcium carbonate) and untreated strawberry plants (control) were compared by using a paired bootstrap test (Wei *et al.* 2020).

RESULTS

The impact of the fertilizer compounds on biological parameters of T. urticae

Developmental time, longevity and fecundity

The fertilizer compounds used in resistance enhancement in strawberry plants had affected the developmental duration of *T. urticae* (Tables 1, 2).

The egg incubation time of either female or male was not affected by fertilizer compounds on two strawberry cultivars, except for males on Fortuna cultivar with fulvic acid treatment. The developmental times of larvae, protonymphs and deutonymphs of *T. urticae* in both sexes were remarkably different among the treatments and strawberry cultivars.

The adult longevity and life span of both sexes of *T. urticae* were significantly decreased on both strawberry cultivars which had received induced resistance by these fertilizer compounds when compared with the control.

Adult female longevity of *T. urticae* when reared on leaf-discs from two strawberry cultivars (Festival and Fortuna) was averaged 15.80 and 13.52, 17.32 and 12.59, 15.69 and 11.50, and 13.70

and 11.15 days with fulvic acid, humic acid, potassium citrate and calcium carbonate respectively, compared with when reared on leaf-disks from untreated strawberry cultivars (control) was averaged 19.50 and 15.54 days respectively.

Similarly, life span period of both sexes of *T. urticae* for the control was significantly higher than other treatments. The lowest female longevity of *T. urticae* was observed in the calcium carbonate treatment, followed by potassium citrate treatment with two strawberry cultivars (Festival and Fortuna).

Table 1. Developmental time (Mean \pm SE days) of *Tetranychus urticae* females reared on two strawberry cultivars that were treated with some fertilizer compounds.

Stage	Cultivar	Fulvic acid	Humic acid	Potassium citrate	Calcium carbonate	Control
	Festival	(30)	(31)	(26)	(23)	(28)
Egg		3.70 \pm 0.13b	4.06 \pm 0.14a	4.19 \pm 0.13a	4.26 \pm 0.14a	4.11 \pm 0.15a
Larva		2.13 \pm 0.11a	2.00 \pm 0.13a	2.27 \pm 0.10a	2.26 \pm 0.13a	2.21 \pm 0.12a
Protonymph		1.93 \pm 0.11bc	1.81 \pm 0.08c	2.35 \pm 0.11a	2.17 \pm 0.12ab	2.11 \pm 0.09ab
Deutonymph		2.17 \pm 0.09b	2.26 \pm 0.11ab	2.38 \pm 0.16ab	2.48 \pm 0.10a	2.32 \pm 0.11ab
Pre-adult		9.93 \pm 0.21b	10.13 \pm 0.19b	11.19 \pm 0.29a	11.17 \pm 0.23a	10.75 \pm 0.22a
Adult longevity		15.80 \pm 0.52c	17.32 \pm 0.54b	15.69 \pm 0.51c	13.70 \pm 0.29d	19.50 \pm 0.86a
Life span		25.73 \pm 0.55cd	27.45 \pm 0.61b	26.88 \pm 0.56bc	24.87 \pm 0.30d	30.25 \pm 0.89a
	Fortuna	(27)	(29)	(22)	(20)	(26)
Egg		4.30 \pm 0.13a	4.55 \pm 0.13a	4.59 \pm 0.12a	4.70 \pm 0.15a	4.58 \pm 0.15a
Larva		2.30 \pm 0.10b	2.41 \pm 0.10a	2.64 \pm 0.10a	2.65 \pm 0.13a	2.46 \pm 0.11ab
Protonymph		2.04 \pm 0.11b	2.07 \pm 0.09b	2.41 \pm 0.11a	2.45 \pm 0.11a	2.27 \pm 0.08ab
Deutonymph		2.41 \pm 0.09bc	2.34 \pm 0.11c	2.73 \pm 0.12a	2.80 \pm 0.14a	2.65 \pm 0.09ab
Pre-adult		11.04 \pm 0.21c	11.38 \pm 0.25bc	12.36 \pm 0.21a	12.60 \pm 0.26a	11.96 \pm 0.24ab
Adult longevity		13.52 \pm 0.41b	12.59 \pm 0.32b	11.55 \pm 0.27c	11.15 \pm 0.35c	15.54 \pm 0.33a
Life span		24.56 \pm 0.43b	23.97 \pm 0.40b	23.91 \pm 0.36b	23.75 \pm 0.43b	27.50 \pm 0.39a

Numbers in parentheses represent the number of replicates.

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P \leq 0.05$).

Table 2. Developmental time (Mean \pm SE days) of *Tetranychus urticae* males reared on two strawberry cultivars that were treated with some fertilizer compounds.

Stage	Cultivar	Fulvic acid	Humic acid	Potassium citrate	Calcium carbonate	Control
	Festival	(9)	(7)	(10)	(10)	(12)
Egg		3.56 \pm 0.18bc	3.71 \pm 0.20b	4.00 \pm 0.21ab	4.40 \pm 0.22a	4.00 \pm 0.17ab
Larva		1.78 \pm 0.22b	1.86 \pm 0.15b	2.10 \pm 0.23ab	2.50 \pm 0.17a	2.08 \pm 0.19ab
Protonymph		1.67 \pm 0.17bc	1.57 \pm 0.20c	2.20 \pm 0.25ab	2.40 \pm 0.16a	2.00 \pm 0.17abc
Deutonymph		2.00 \pm 0.17b	2.14 \pm 0.26ab	2.30 \pm 0.26ab	2.60 \pm 0.16a	2.33 \pm 0.19ab
Pre-adult		9.00 \pm 0.38d	9.29 \pm 0.51cd	10.60 \pm 0.56bc	11.90 \pm 0.27a	10.42 \pm 0.19b
Adult longevity		14.89 \pm 0.66ab	13.29 \pm 0.99bc	12.30 \pm 0.69c	11.70 \pm 0.74c	15.76 \pm 0.63a
Life span		23.89 \pm 0.62b	22.57 \pm 0.99b	22.90 \pm 0.85b	23.60 \pm 0.82b	26.17 \pm 0.70a
	Fortuna	(10)	(7)	(8)	(9)	(11)
Egg		3.80 \pm 0.20c	4.14 \pm 0.28bc	4.50 \pm 0.19ab	4.67 \pm 0.17a	4.18 \pm 0.18bc
Larva		1.90 \pm 0.18b	2.29 \pm 0.19ab	2.63 \pm 0.18a	2.56 \pm 0.17a	2.45 \pm 0.16a
Protonymph		1.60 \pm 0.16c	1.86 \pm 0.15bc	2.38 \pm 0.18a	2.44 \pm 0.18a	2.18 \pm 0.12ab
Deutonymph		2.00 \pm 0.21c	2.14 \pm 0.27bc	2.75 \pm 0.25ab	2.78 \pm 0.15a	2.55 \pm 0.16ab
Pre-adult		9.30 \pm 0.42c	10.43 \pm 0.44bc	12.25 \pm 0.36a	12.44 \pm 0.42a	11.36 \pm 0.24b
Adult longevity		12.20 \pm 0.57b	11.14 \pm 0.57bc	10.63 \pm 0.42c	9.33 \pm 0.44d	13.82 \pm 0.61a
Life span		21.50 \pm 0.64b	21.57 \pm 0.57b	22.88 \pm 0.55b	21.78 \pm 0.49b	25.18 \pm 0.72a

Numbers in parentheses represent the number of replicates.

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P \leq 0.05$).

The effects of fertilizer compounds in two strawberry cultivars on adult pre-oviposition period (APOP), total pre-oviposition period (TPOP) and total fecundity (eggs/female) of *T. urticae* females are displayed in Table (Table 3). Adult pre-oviposition period (APOP) is not affected by these fertilizer compounds on Festival cultivar, while is affected by potassium citrate and calcium carbonate treatments on Fortuna cultivar. The influence in total pre-oviposition period (TPOP) was observed in fulvic acid and humic acid treatments in Festival cultivar; this was observed with potassium citrate and calcium carbonate treatments in Fortuna cultivar.

The oviposition period of *T. urticae* when reared on leaf-disks from Festival and Fortuna cultivars that were treated by fulvic acid, humic acid potassium citrate and calcium carbonate was shorter than in control. It was reduced from 12.82 days in control to 12.40, 13.94, 11.69 and 10.00 days on Festival cultivar, respectively, and from 11.81 days in control to 10.33, 9.55, 7.55 and 6.80 days on Fortuna cultivar, respectively.

Improving resistance in two strawberry cultivars (Festival and Fortuna) by fulvic acid, humic acid potassium citrate and calcium carbonate caused significant reduction in total fecundity of *T. urticae* (Table 3). The total fecundity per female of *T. urticae* was decreased from 74.25 eggs/female (in control) to 63.45, 66.60, 48.46 and 40.87 eggs/female in treatments on Festival cultivar, respectively, and from 55.31 eggs/female in untreated plants to 40.22, 34.28, 27.95 and 21.60 eggs/female in treated plants on Fortuna cultivar, respectively.

The percentage of oviposition days, egg hatchability and sex ratio (females/total individuals) of *T. urticae* reared on strawberry plants that were treated by potassium citrate and calcium carbonate were decreased when compared with untreated strawberry plants (Table 3).

Results indicate that the oviposition period, adult longevity and fecundity of *T. urticae* female were significantly decreased when reared on leaf-disks from two strawberry cultivars that were treated with potassium citrate and calcium carbonate.

Table 3. Mean reproductive period, total fecundity (\pm SE), sex ratio and egg hatchability (%) of *Tetranychus urticae* reared on two strawberry cultivars that were treated with some fertilizer compounds.

Biological aspects	Fulvic acid	Humic acid	Potassium citrate	Calcium carbonate	Control
Festival cultivar					
APOP (days)	1.33 \pm 0.08c	1.42 \pm 0.08bc	1.65 \pm 0.09ab	1.78 \pm 0.08a	1.54 \pm 0.09abc
TPOP (days)	11.27 \pm 0.23b	11.55 \pm 0.24b	12.85 \pm 0.31a	12.96 \pm 0.25a	12.29 \pm 0.28a
Oviposition (days)	12.40 \pm 0.53b	13.94 \pm 0.54a	11.69 \pm 0.59b	10.00 \pm 0.33c	15.82 \pm 0.87a
Total fecundity (eggs/female)	63.45 \pm 3.00b	66.60 \pm 2.98ab	48.46 \pm 3.76c	40.87 \pm 2.22c	74.25 \pm 4.14a
Oviposition days (%)*	78.48%	80.45%	74.51%	73.02%	81.14%
Egg hatchability (%)	97.5%	95%	90%	97.5%	100%
Sex ratio [Nf/N] (%)	75%	77.5%	65%	57.5%	70%
Fortuna cultivar					
APOP (days)	1.59 \pm 0.09b	1.45 \pm 0.09b	1.95 \pm 0.14a	1.95 \pm 0.15a	1.62 \pm 0.09b
TPOP (days)	12.63 \pm 0.22c	12.83 \pm 0.28bc	14.32 \pm 0.27a	14.55 \pm 0.26a	13.58 \pm 0.26b
Oviposition (days)	10.33 \pm 0.35b	9.55 \pm 0.29b	7.55 \pm 0.34c	6.80 \pm 0.36c	11.81 \pm 0.37a
Total fecundity (eggs/female)	40.22 \pm 2.68b	34.28 \pm 1.35c	27.95 \pm 2.32d	21.60 \pm 2.61d	55.31 \pm 2.50a
Oviposition days (%)*	76.44%	75.89%	65.35%	60.99%	75.99%
Egg hatchability (%)	97.5%	92.5%	82.5%	85%	92.5%
Sex ratio [Nf/N] (%)	67.5%	72.5%	55%	50%	65%

APOP Adult pre-oviposition period and TPOP total pre-oviposition period.

* The percentage of oviposition days.

(Nf/N) it is the proportion of female adults in total individuals.

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P \leq 0.05$).

The age-stage specific survival rates (s_{xj})

The age-stage specific survival rates (s_{xj}) of *T. urticae* (Fig. 1) show the probability that a newborn will survive to age x and develop to stage j . Also, these curves illustrate the survivorship, variable developmental rate and stage differentiation. The probability that a newborn egg survived to the adult stage for females was decreased from 0.70 and 0.65 in untreated plants to (0.65 and 0.58) and (0.55 and 0.50) when reared on leaf-disks from Festival and Fortuna cultivars that were treated with potassium citrate and calcium carbonate, respectively, while it was increased to (0.75 and 0.78) and (0.68 and 0.73) in plants that were treated with fulvic acid and humic acid, respectively.

However, this was decreased for males with all treatments on two strawberry cultivars Fortuna and Festival (Fig. 1). According to these results, the lowest survival rate of a newborn egg to female adult stage is related to *T. urticae* reared on strawberry plants that were treated with potassium citrate and calcium carbonate.

Life table parameters

Means and standard errors of the life table parameters r , λ , R_0 , GRR and T values of *T. urticae* (estimated by the bootstrap techniques) on two strawberry cultivars (Festival and Fortuna) untreated and treated with fulvic acid, humic acid, potassium citrate and calcium carbonate are displayed in Table 4. The chemical fertilizer compounds (potassium citrate and calcium carbonate) significantly decreased the intrinsic rate of increase (r), the finite rate of increase (λ), net reproductive rate (R_0) and gross reproduction rate (GRR) of *T. urticae* when reared on leaf-disks from two strawberry cultivars that were treated with them.

Table 4. Life table parameters (Mean \pm SE) of *Tetranychus urticae* reared on two strawberry cultivars that were treated with some fertilizer compounds.

Life table parameters	Fulvic acid	Humic acid	Potassium citrate	Calcium carbonate	Control
Festival cultivar					
Intrinsic rate of increase (r)	0.241 \pm 0.01a	0.230 \pm 0.01a	0.195 \pm 0.01b	0.185 \pm 0.01b	0.221 \pm 0.01a
Finite rate of increase (λ)	1.273 \pm 0.01a	1.258 \pm 0.01a	1.215 \pm 0.01b	1.203 \pm 0.01b	1.247 \pm 0.01a
Net reproductive rate (R_0)	49.95 \pm 5.08a	49.17 \pm 4.78a	31.50 \pm 4.49b	23.51 \pm 3.44b	51.97 \pm 6.10a
Gross reproductive rate (GRR)	56.11 \pm 5.20a	59.32 \pm 4.46a	40.00 \pm 4.59b	29.22 \pm 3.62b	62.38 \pm 6.09a
Mean generation time (T)	16.22 \pm 0.25c	16.96 \pm 0.26bc	17.72 \pm 0.34ab	17.07 \pm 0.25ab	17.89 \pm 0.35a
Fortuna cultivar					
Intrinsic rate of increase (r)	0.196 \pm 0.01a	0.192 \pm 0.01a	0.155 \pm 0.01b	0.135 \pm 0.01b	0.197 \pm 0.01a
Finite rate of increase (λ)	1.217 \pm 0.01a	1.212 \pm 0.01a	1.168 \pm 0.01b	1.145 \pm 0.01b	1.218 \pm 0.01a
Net reproductive rate (R_0)	27.15 \pm 3.47ab	24.85 \pm 2.61b	15.38 \pm 2.52c	10.80 \pm 2.14c	35.95 \pm 4.48a
Gross reproductive rate (GRR)	32.01 \pm 3.52ab	29.50 \pm 2.47b	20.97 \pm 2.83c	15.38 \pm 2.64c	40.75 \pm 4.49a
Mean generation time (T)	16.84 \pm 0.28b	16.73 \pm 0.33b	17.58 \pm 0.29ab	17.61 \pm 0.22a	18.14 \pm 0.32a

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P \leq 0.05$).

The values of these life table parameters of mite are not significantly affected when reared on leaf-disks from strawberry plants that were treated with organic fertilizer compounds (fulvic acid and humic acid) with Festival cultivar.

The lower value of the intrinsic rate of increase (r) of *T. urticae* was observed when reared on leaf-disks from strawberry plants that were treated with potassium citrate and calcium carbonate than other treatments on both cultivars. When reared on leaf-disks from Festival cultivar, the r -value decreased from 0.221 day⁻¹ in control to 0.195 and 0.185 day⁻¹ in treated plants by potassium citrate and calcium carbonate, respectively. Also, r -value decreased from 0.197 day⁻¹ in control to 0.155 and

0.135 day⁻¹ in treated plants, respectively when reared on leaf-disks from Fortuna cultivar.

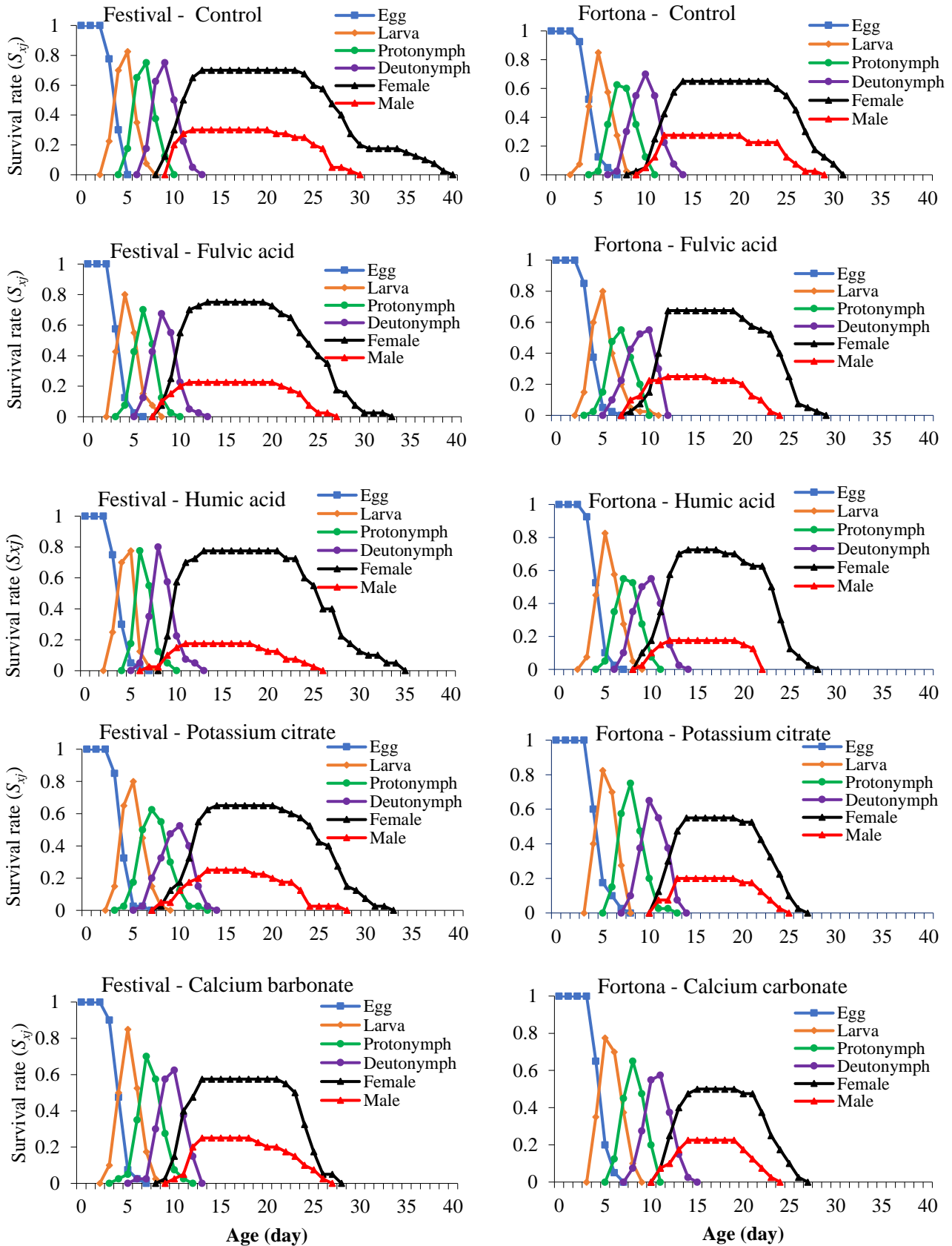


Figure 1. Age-stage survival rate (S_{xj}) of *Tetranychus urticae* reared on two strawberry cultivars that were treated with some fertilizer compounds.

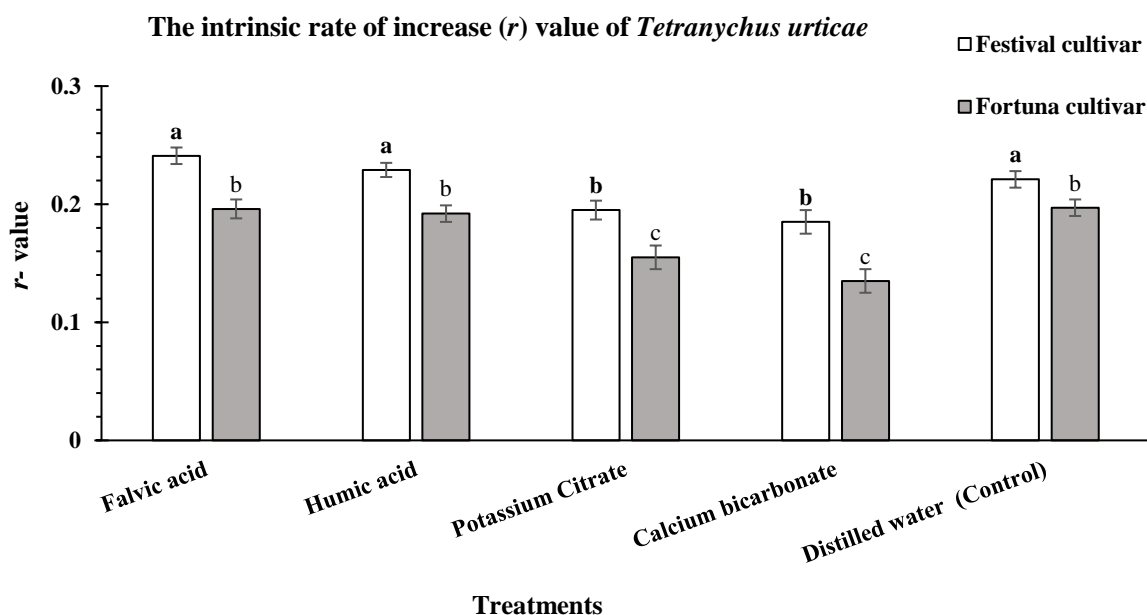


Figure 2. The effect of two strawberry cultivars and some fertilizer compounds on the intrinsic rate of increase (r) of *Tetranychus urticae*.

The net reproductive rate (R_0) of *T. urticae* was decreased when reared on leaf-disks from two strawberry cultivars (Festival and Fortuna) that were treated with potassium citrate and calcium carbonate averaging (31.50 and 23.51 and 15.38 and 10.80) offspring/individual respectively, compared with being reared on leaves of untreated strawberry plants (control) which averaged 51.97 and 35.95 offspring/individual, respectively.

The mean generation time (T) of *T. urticae* was affected only when reared on leaf-disks from the two strawberry cultivars that were treated with organic fertilizer compounds (fulvic acid and humic acid).

Figure 2 shows different changes for intrinsic rate of increase (r) between two strawberry cultivars (Festival and Fortuna). The r of *T. urticae* was significantly higher when reared on leaf-disks from Festival cultivar than Fortuna cultivar. Also, for r of *T. urticae* no significant difference was observed between Festival and Fortuna cultivars treated with calcium carbonate.

Age-specific survival rate (l_x) and fecundity curve

Figure 3 shows different changes in the l_x of individuals developing from offspring of *T. urticae* when reared on leaf-disks from two strawberry cultivars (Festival and Fortuna) that were treated with fulvic acid, humic acid, potassium citrate and calcium carbonate compared with the control. It remains stable to day 20 in control, while it decreased after 5, 5, 4, and 6 days in Festival strawberry cultivar treated with fulvic acid, humic acid, potassium citrate and calcium carbonate, respectively.

However, the l_x of individuals on Fortuna strawberry cultivar was different from Festival cultivar. In the control, it remains stable to day 5 then decreased to 0.93 in day 7 and remains stable to day 20.

The chemical fertilizer compounds (potassium citrate and calcium carbonate) were highly influential on the l_x of female developing from of *T. urticae* when reared on leaf-disks from two strawberry cultivars that were treated with them (Fig. 3).

The highest daily fecundity (peak of m_x) was 4.43 egg/individual/day which occurred on day 19 of the life span of *T. urticae* when reared on leaf-disks from untreated strawberry plants (Festival cultivar), while it decreased to 3.71 and 3.85 eggs/individual/day on day 18 and 16 of the life span of *T. urticae* with potassium citrate and calcium carbonate treatments, respectively. On the contrary,

when rearing *T. urticae* on leaf-disks from strawberry plants had treated by organic fertilizer compounds (fulvic acid and humic acid), the peak of m_x increased to 4.87 and 4.76 eggs/individual/day on day 17, respectively.

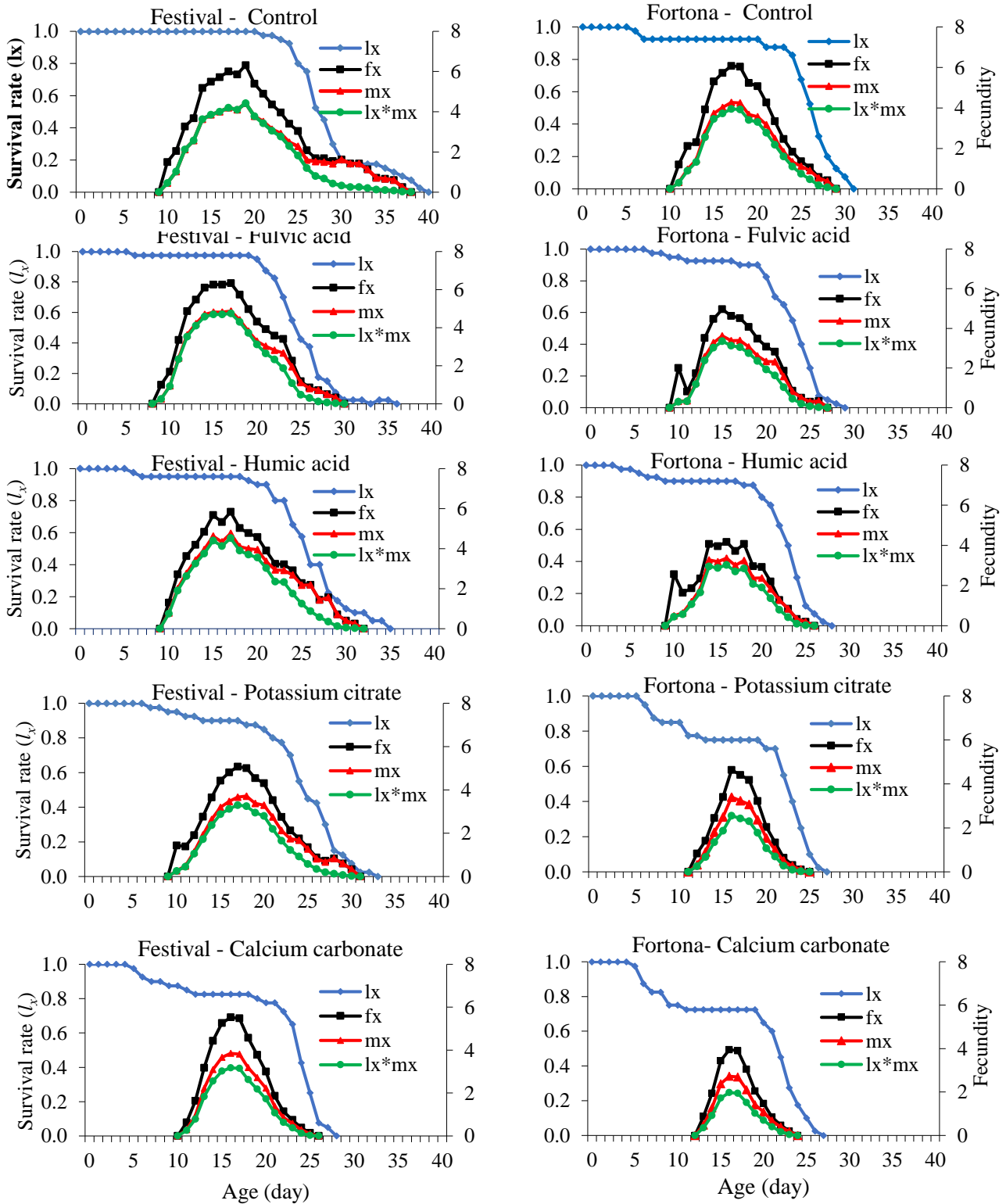


Figure 3. Age-specific survival rate (l_x), age-stage fecundity of female (f_{xy}) and age-specific fecundity (m_x) of *Tetranychus urticae* reared on two strawberry cultivars that were treated with some fertilizer compounds.

However, when rearing TSSM on leaf-disks from untreated plants of Fortuna cultivar, the highest daily fecundity (m_x) was 4.27 eggs/individual/day which was occurred on day 17 of the life span of *T. urticae*, but the peak of m_x decreased to 3.62, 3.36, 3.40 and 2.72 eggs/individual/day on days 15, 16, 16 and 16 of the life span of *T. urticae* when reared on strawberry plants were treated bwithy fulvic acid, humic acid, potassium citrate and calcium carbonate, respectively.

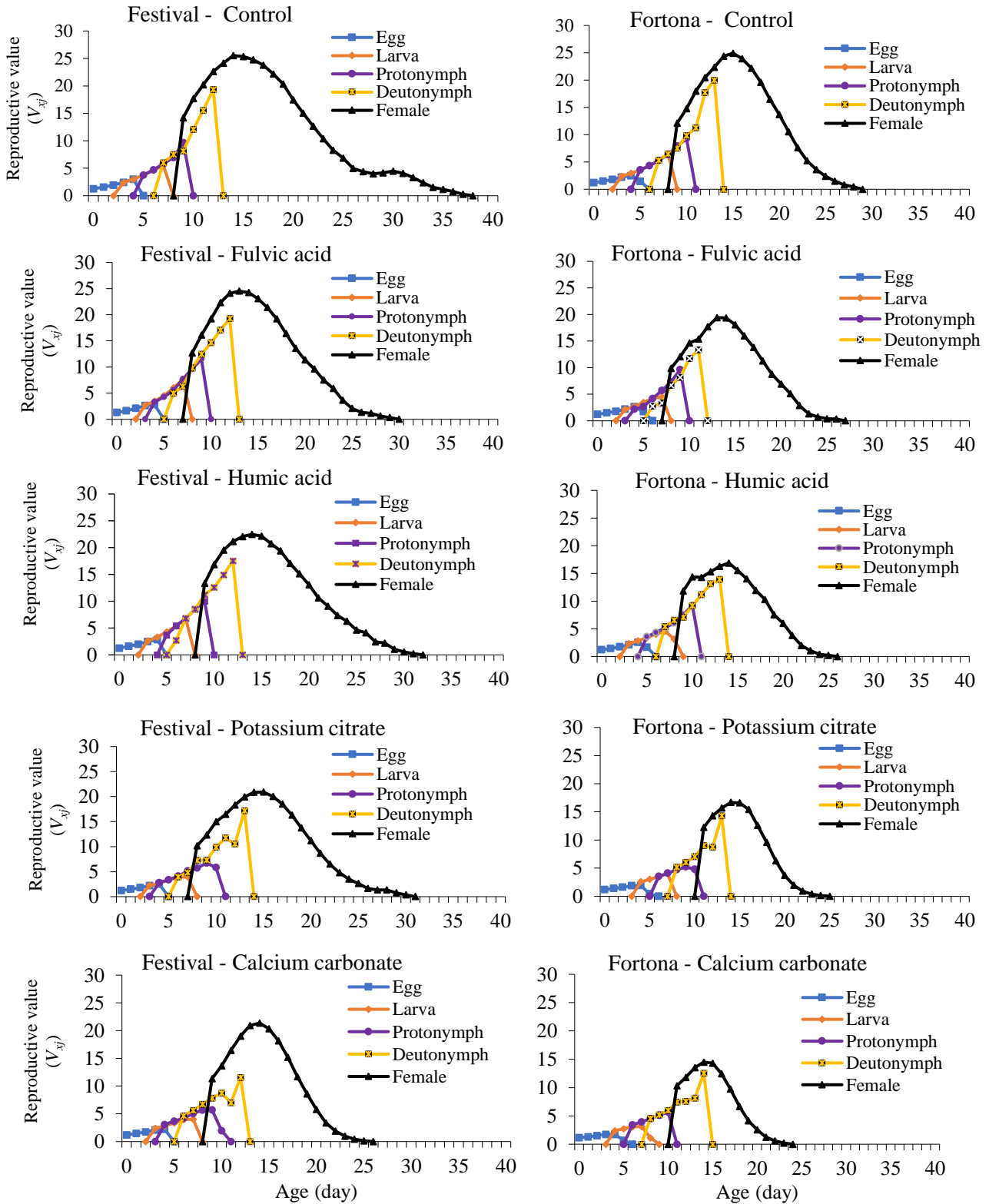


Figure 4. Age-stage reproductive value (V_{xj}) of *Tetranychus urticae* reared on two strawberry cultivars that were treated with some fertilizer compounds.

The mean number of offspring produced by *T. urticae* individuals of the age x and stage j per day is shown with the age-stage-specific fecundity (f_{xj}) in Figure 3. The start of oviposition of the first female on untreated plants of two strawberry cultivars (Festival and Fortuna) occurred at the age 10 and 11 days, while on strawberry plants treated with fulvic acid, humic acid, potassium citrate and calcium carbonate occurred at the age 9, 10, 10, 11, and 10, 10, 12, 13 days, respectively. This difference may be due to the effect of these fertilizer compounds on total pre-oviposition period (TPOP).

The highest daily fecundity (peak of f (i , female) of the two-spotted spider mite on the above-mentioned cultivars was 6.32 and 6.08 eggs occurred at the age of 19 and 17 days on untreated strawberry plants, respectively; while on strawberry plants treated by fulvic acid, humic acid, potassium citrate and calcium carbonate were 6.33, 5.84, 5.08 and 5.52 eggs occurred at the age 17, 17, 17 and 16 days, and 4.96, 4.17, 4.64 and 3.95 eggs that occurred at the age 15, 17, 16 and 16 days, respectively (Fig. 3).

Age-stage reproductive value

The age-stage reproductive value (v_{xj}) is the contribution of individuals of age x and stage j to the future population. The reproductive value for a new egg (v_{01}) of the *T. urticae* on untreated and treated strawberry plants is the finite rate of increase (λ) (Fig. 4, Table 4). The highest reproductive value (peak of v_{xj}) of *T. urticae* was 25.52 and 24.93 at the age of 14 and 15 days on untreated plants of two strawberry cultivars (Festival and Fortuna), respectively.

When rearing *T. urticae* on leaf-disks from strawberry plants treated with fulvic acid, humic acid, potassium citrate and calcium carbonate, the peak of v_{xj} was decreased to 24.50, 22.64, 20.91 and 21.36 at the age of 13, 14, 15 and 14 days with Festival cultivar, respectively. While the v_{xj} values on Fortuna cultivar was decreased to 19.42, 16.89, 16.66 and 14.48 at the age of 13, 14, 14 and 14 days on the above-mentioned fertilizer compounds, respectively.

DISCUSSION

It is difficult to use pesticides to combat this mite on strawberry plants. Therefore, it is necessary to search for other methods to control this mite. Such methods could be exploited as an important tool in mite management strategies, for instance, selecting the least susceptible strawberry cultivars (Fahim *et al.* 2020) or enhancing strawberry resistance by resistance inducers (Afifi *et al.* 2010). As a result, in this study, the effects of fulvic acid, humic acid, potassium citrate and calcium carbonate as resistance inducers were investigated in two strawberry cultivars in regards to the life table parameters of *T. urticae*.

The results indicate that the oviposition period, adult longevity and fecundity of *T. urticae* females were significantly affected when reared on leaf-disks from strawberry plants that had received induced resistance by these compounds.

There are many previous investigations describing the effects of some chemical elicitors or fertilizer compounds on pest fertility and life table parameters or on the induction of resistance in plants. For example, jasmonic acid (JA) and salicylic acid (SA) can activate induced defenses in plants against herbivores (Bruinsma *et al.* 2010; Hamm *et al.* 2010). Several previous studies demonstrated that potassium is a critical component of the synthesis and allocation of primary metabolites in plants, and these physiological characteristics influence metabolic, hormonal and signaling pathways in plants; this can have strong effects on plant susceptibility or resistance to insect (Amtmann *et al.* 2008). Fertilizing strawberry plants by CaSO_4 and K_2SO_4 compounds led to a decrease the infestation of *T. urticae*, due to the increase in these compounds of the total phenols and amino acid in plants (Afifi *et al.* 2010). Numerous studies of the effects of potassium nutrition on pest infestation have been done, with 63% showing that potassium fertilizer application reduces insects and mites in plants (Amtman *et al.* 2008; Damghani *et al.* 2021). The induced resistance in strawberry plants increase

phenols that reducing feeding, developmental times and fecundity of *T. urticae* (Dabrowski and Bielak 1978). Plant hormones regulate signaling pathways to produce secondary metabolites and defensive proteins that have a detrimental effect on various biological parameters of herbivores (Agut *et al.* 2018). The effects of SA and JA in tomato on *T. urticae* and *T. evansi* Baker and Pritchard were confirmed by Alba *et al.* 2015.

The selected fertilizer compounds in this study significantly reduced the total developmental times, oviposition periods and fecundity of *T. urticae* on the two tested cultivars. The results indicate that *T. urticae* could survive and complete its life cycle in all treatments, but the development and fecundity of this mite is significantly reduced when reared on plants treated by these fertilizer compounds, especially with potassium citrate and calcium carbonate. These outcomes are consistent with Damghani *et al.* (2021) who demonstrated that the longest preadult development time of TSSM was related to individuals reared on the fertilized bean with potassium sulfate 60%, while the shortest period was related to those on 30% ammonium nitrate and 60% urea. This is in addition to total fecundity of *T. urticae* reared on fertilized beans with different concentrations of ammonium nitrate (especially 60% ammonium nitrate) were significantly higher than the other fertilizer compounds.

Likewise, Esmaily *et al.* (2019) stated that the induced resistance by jasmonic and abscisic acids on tomato plants significantly prolonged development and reduced the survival of immature stages of greenhouse whitefly (*Trialeurodes vaporariorum* Westwood) and reduced the longevity and fecundity of adults. Also, Dahmardeh *et al.* (2018) noted that the total developmental time, longevity and fecundity of *T. urticae* was reduced when reared on leaf-disks from bean plants that had received induced resistance by fertilizer compound (biolog siderophoric) than in untreated bean plants. The developmental times, reproductive aspects of *T. urticae* were affected by the induced resistance on two tomato hybrids (Supper-gekal and Salymia 65010) by potassium humates, potassium silicates, salicylic acid and methyl jasmonate. Potassium humates was the highest influence on fecundity of *T. urticae* females, followed by potassium silicates and salicylic acid which have medium effects and methyl jasmonate with the lowest effect (Ahmed 2018). Also, Choh *et al.* (2004) showed that the number of eggs laid by *T. urticae* was significantly reduced in tomato plants treated with 0.1 mM of JA. In addition, the fecundity and survival rate of *T. urticae* females were significantly reduced in tomato plants treated by methyl JA compared with the control (Worrall *et al.* 2012).

The mites reared on plants treated with the potassium citrate and calcium carbonate, had lowest developmental time and fecundity when compared with other treatments and the control. In addition, the values of r , λ , R_0 and GRR of *T. urticae* were significantly reduced in treated plants with them on the two strawberry cultivars. The fertilizer compounds, potassium citrate and calcium carbonate are the most influential for *T. urticae*, due to the reduction in the intrinsic natural increase (r), net reproductive rate (R_0), and fecundity. The lower value of the intrinsic rate of increase (r) of *T. urticae* was observed when reared on leaf-disks from strawberry plants that were treated with potassium citrate and calcium carbonate than other treatments, especially in Fortuna cultivar. It was 0.195 and 0.155 and 0.185 and 0.135 day⁻¹ compared with the control (0.221 and 0.197 day⁻¹) on Festival and Fortuna cultivars, respectively. These results are in agreement with Damghani *et al.* (2021) who demonstrated that the values of intrinsic rate of increase (r), net reproductive rate (R_0) and the gross reproductive rate (GRR) of *T. urticae* reared on bean fertilized with potassium sulfate 60% were significantly lower than the other fertilizer treatments. Likewise, Dahmardeh *et al.* (2018) who stated that the lowest values of the life table parameters (r , λ , R_0 and GRR) were observed in the biolog siderophoric treatment, compared with other treatments and the control. Mohamadi *et al.* (2017) observed that when plant growth promoting rhizobacteris (PGPR) (*Pseudomonas fluorescens* Flügge) was used as a treatment in tomato plants against *Tuta absoluta* (Meyrick), values of R_0 , r , and λ were overall lower, which is in agreement with the results of this study. Likewise, Ahmed (2018) found the potassium humates and potassium silicates have more impact on r , λ , R_0 and GRR of *T. urticae* on two tomato hybrids (Supper-gekal and Salymia 65010) compared with other treatments.

The highest fecundity of *T. urticae* females was recorded on Festival cultivar (74.25 eggs/female) compared with Fortuna cultivar (55.31 eggs/female). The higher fecundity on Festival cultivar may be due to leaf structure and the quality and/or quantity of its nutrients; this makes it more suitable for this mite than the Fortuna cultivar. Also, in this study, the r value of *T. urticae* was significantly higher when reared on leaf-disks from Festival cultivar than Fortuna cultivar (Fig. 2). Likewise, Fahim *et al.* (2020) found a significant difference in biology and life table parameters of *T. urticae* when reared on Wanter star, Markez, Fortuna and 029 strawberry cultivars. The lower rate of fertility was recorded on Wanter star and Fortuna as compared to other cultivars; therefore, Wanter star and Fortuna are introduced as a resistant cultivars against *T. urticae* infestation.

The results in the current study showed that the lower values of r and R_0 of *T. urticae* are evidence to the resistance of the host plants to the mite pest, and vice-versa. Also, the lower values of r and R_0 of *T. urticae* indicate a clear image of the best fertilizer compounds as a resistance inducer, which suggests that these inducers could be employed toward a sustainable management of *T. urticae*. The lowest value of r in potassium citrate and calcium carbonate treatments on Fortuna cultivar was related to the lower fecundity of *T. urticae* females on this cultivar. The R_0 and r values are significant indicators of the population dynamics of mite pests (Sabelis 1985; Krips *et al.* 1998). However, comparisons of R_0 and r commonly give great insight beyond the parameters of life history (Zhang *et al.* 2007). The intrinsic rate of increase (r) was greatly affected by the different treatments. The r is an accurate index for assessing pest performance on different states of host plants, and it reflects many factors, such as fecundity, generation times, and survival of the pest (Southwood and Henderson 2000).

In the current study, the age-specific survival and fecundity curves demonstrated that treated strawberry plants with the fertilizer compounds especially, potassium citrate and calcium carbonate caused reductions in survival and fecundity of offspring of *T. urticae* compared with the control. This indicates that plants treated with potassium citrate and calcium carbonate affected the survivorship of subsequent generations of *T. urticae*. The treated plants with potassium citrate and calcium carbonate had reduced the reproduction and survivorship of offspring of *T. urticae* than the control. Because of the variable developmental rates occurring among *T. urticae* individuals, the survival curve of *T. urticae* reared on treated plants with potassium citrate and calcium carbonate showed significant stage overlap. The *T. urticae* when reared on leaf-disks from Festival and Fortuna cultivars that were treated with potassium citrate and calcium carbonate had reduced age-specific survival rate (l_x) values (Fig. 3); also, the age-specific maternity ($l_x m_x$) values were reduced by these resistance inducers. Similarly, age-specific reproductive value was decreased in mites reared on treated plants (Fig. 4).

Finally, from the Figures 3 and 4 it can be noted that the effect of chemical fertilizer compounds (potassium citrate and calcium carbonate) on survival rate (l_x), fecundity of female (f_{xj}), fecundity rate (m_x) and reproductive value (v_{xj}) of *T. urticae* is higher than organic fertilizer compounds (fulvic acid and humic acid). Also, differential effects of strawberry cultivars on life table parameters and reproductive aspects were observed; Fortuna cultivar was more effective than Festival cultivar on biological parameters of *T. urticae* when being reared on leaf-disks from it.

CONCLUSIONS

The Fortuna strawberry cultivar was the least favorable for development and reproduction of TSSM especially, when fertilized by potassium citrate or calcium carbonate than other Festival cultivar. Slower development and population growth on strawberry plants fertilized by potassium citrate or calcium carbonate could help to reduce the application of acaricides. The use of resistant and partially resistant cultivars with fertilizer compounds such as potassium citrate and calcium carbonate to enhance the efficiency of control measures against *T. urticae* is one of the most important elements of an effective IPM strategy.

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REFERENCES

- Adango, E., Onzol, A., Hannal, R., Atachi, P. & James, B. (2006) Comparative demography of the spider mite, *Tetranychus ludeni* on two host plants in West Africa. *Journal of Insect Science*, 6(49): 1536–1545. DOI: [10.1673/031.006.4901](https://doi.org/10.1673/031.006.4901)
- Afifi, A.M., Ali, F.S., Shalaby, E.A., El-Saiedy, E.M.A. & Ahmed, M.M. (2015) Enhancement of resistance in tomato plants using different compounds against the two-spotted spider mites *Tetranychus urticae* Koch. *Research Journal of Environmental Sciences*, 9(3): 119–136. DOI: [10.3923/rjes.2015.119.136](https://doi.org/10.3923/rjes.2015.119.136)
- Afifi, A.M., El-Laithy, A.Y.M., Shehata, S.A. & El-Saiedy, M.A. (2010) Resistance of strawberry plants against the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae). In: Sabelis, M.W. & Bruin, J. (Eds.), *Trends in Acarology*. Proceedings of the 12th International Congress, Amsterdam, The Netherlands, pp. 505–507.
- Agut, B., Pastor, V., Jaques, J.A. & Flors, V. (2018) Can plant defence mechanisms provide new approaches for the sustainable control of the two-spotted spider mite *Tetranychus urticae*? *International Journal of Molecular Sciences*, 19(2): 614. DOI: [10.3390/ijms19020614](https://doi.org/10.3390/ijms19020614)
- Ahmed, M.M. (2018) The impact of resistance enhancement in tomato plants on *Tetranychus urticae* life history traits. *Acarines*, 12(1): 81–86. DOI: [10.21608/ajesa.2008.164303](https://doi.org/10.21608/ajesa.2008.164303)
- Ahmed, M.M., Abdel-Rahman, H.R. & Abdelwines, M.A. (2021) Application of demographic analysis for assessing effects of pesticides on the predatory mite, *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Persian Journal of Acarology*, 10(3): 281–298. DOI: [10.22073/pja.v10i3.66756](https://doi.org/10.22073/pja.v10i3.66756).
- Alba, J.M., Schimmel, B.C.J., Glas, J.J., Ataide, L.M.S., Pappas, M.L., Villarroel, C.A., Schuurink, R.C., Sabelis, M.W. & Kant, M.R. (2015) Spider mites suppress tomato defenses downstream of jasmonate and salicylate independently of hormonal crosstalk. *New Phytologist*, 205: 828–840. DOI: [10.1111/nph.13075](https://doi.org/10.1111/nph.13075)
- Ali, F.S., Afifi, A.M., El-Saiedy, E.M.A. & Ahmed, M.M. (2013) Biology, life tables parameters of *Tetranychus urticae* Koch and two Phytoseiidae predatory mites on two watermelon cultivars. *Acarines*, 7(1): 25–30. DOI: [10.21608/AJESA.2013.4921](https://doi.org/10.21608/AJESA.2013.4921)
- Amtmann, A., Troufflard, S. & Armengaud, P. (2008) The effect of potassium nutrition on pest and disease resistance in plants. *Physiologia Plantarum*, 133: 682–691. DOI: [10.1111/j.1399-3054.2008.01075.x](https://doi.org/10.1111/j.1399-3054.2008.01075.x).
- Bernardi, D., Botton, M., Nava, D.E. & Zawadneak, M.A.C. (2015) Guia para identificação e monitoramento de pragas e seus inimigos naturais em morangueiro. *Embrapa, Brasília*, 46 pp.
- Bruinsma, M., van Loon, J.J. & Dicke, M. (2010) Increasing insight into induced plant defense mechanisms using elicitors and inhibitors. *Plant Signaling and Behavior*, 5(3): 271–274. DOI: [10.4161/psb.5.3.10623](https://doi.org/10.4161/psb.5.3.10623)
- Chi, H. (1988) Life table analysis incorporating both sexes and variable development rates among individuals. *Environmental Entomology*, 17: 26–34. DOI: [10.1093/ee/17.1.26](https://doi.org/10.1093/ee/17.1.26)
- Chi, H. (2020) Computer program for the age-stage, two-sex life table analysis. National Chung

- Hsing University, Taichung. Available from: <http://140.120.197.173/Ecology/prod02.htm> (Accessed on 28.05.2020).
- Chi, H. & Su, H.Y. (2006) Age-stage, two-sex life tables of *Aphidius gifuensis* (Ashmead) (Hymenoptera: Braconidae) and its host *Myzus persicae* (Sulzer) (Homoptera: Aphididae) with mathematical proof of the relationship between female fecundity and the net reproductive rate. *Environmental Entomology*, 35: 10–21. DOI: [10.1603/0046-225X-35.1.10](https://doi.org/10.1603/0046-225X-35.1.10)
- Choh, Y., Ozawa, R. & Takabayashi, J. (2004) Effects of exogenous jasmonic acid and benzo (1,2,3) thiadiazole-7-carbothioic acid S-methyl ester (BTH), a functional analogue of salicylic acid, on the egg production of a herbivorous mite *Tetranychus urticae* (Acari: Tetranychidae). *Applied Entomology and Zoology*, 39(2): 311–314. DOI: [10.1303/aez.2004.311](https://doi.org/10.1303/aez.2004.311)
- Colomer, I., Aguado, P., Medina, P., Heredia, R.M., Fereres, A., Belda J.E. & Viñuela, E. (2011) Field trial measuring the compatibility of methoxyfenozide and flonicamid with *Orius laevigatus* Fieber (Hemiptera: Anthocoridae) and *Amblyseius swirskii* (Athias-Henriot) (Acari: Phytoseiidae) in commercial pepper greenhouse. *Pest Management Science*, 67: 1237–1244. DOI: [10.1002/ps.2173](https://doi.org/10.1002/ps.2173)
- Croft, B.A. (1990) *Arthropod biological control agents and pesticides*. John Wiley and Sons, New York, 723 pp.
- Dabrowski, Z.T. & Bielak, B. (1978) Effect of some plant chemical compounds on the behaviour and reproduction of spider mites (Acarina: Tetranychidae). *Entomologia Experimentalis et Applicata*, 24: 117–126. DOI: [10.1111/j.1570-7458.1978.tb02788.x](https://doi.org/10.1111/j.1570-7458.1978.tb02788.x)
- Dahmardeh, A., Latifi, M. & Saberi Riseh, R. (2018) Effect of induced resistance in bean plants on *Tetranychus urticae* life table parameters. *Systematic and Applied Acarology* 23(8): 1627–1640. DOI: [10.11158/saa.23.8.12](https://doi.org/10.11158/saa.23.8.12)
- Damghani, M., Asadi, M. & Khanamani, M. (2021) Effect of different fertilizer regimes on life table parameters of *Tetranychus urticae* (Acari: Tetranychidae) on resistant bean cultivar. *Journal of Agricultural Science and Technology*, 23(4): 853–863.
- De Ponti, O. (1985) Host plant resistance and its manipulation through plant breeding. In: Helle, W. & Sabelis, M.W. (Eds.), *Spider mites: Their biology, natural enemies and control*. Vol. 1A, Elsevier Science Publishers B.V., Amsterdam, pp. 395–403.
- Dickens, J.C. (2006) Plant volatiles moderate response to aggregation to pheromone in Colorado potato beetle. *Journal of Applied Entomology*, 130: 26–31. DOI: [10.1111/j.1439-0418.2005.01014.x](https://doi.org/10.1111/j.1439-0418.2005.01014.x)
- Esmaily, S., Samih, M.A. & Izadi, H. (2019) Induced resistance by jasmonic and abscisic acids and *Nesidiocoris tenuis* feeding on *Solanum lycopersicum* against *Trialetrodes vaporariorum*. *International Journal of Pest Management*, 67(1): 46–57. DOI: [10.1080/09670874.2019.1669843](https://doi.org/10.1080/09670874.2019.1669843)
- Fadini, M.A.M., Pallinz, A. & Venzon, M. (2004) Controle de ácaros em sistema de produção integrada de morango. *Ciência Rural*, 34: 1271–1277. DOI: [10.1590/S0103-84782004000400053](https://doi.org/10.1590/S0103-84782004000400053)
- Fahim, S.F., Momen, F.M. & El-Saiedy, E.-S.M. (2020) Life table parameters of *Tetranychus urticae* (Trombidiformes: Tetranychidae) on four strawberry cultivars. *Persian Journal of Acarology*, 9(1): 43–56. DOI: [10.22073/pja.v9i1.54771](https://doi.org/10.22073/pja.v9i1.54771)
- Fornazier, M.J. & Pratisoli, D. (2006) Pragas do morangueiro. In: Balbino, J.M.S. (Ed.), *Tecnologias para produção, colheita e pós-colheita de morangueiro*. 2nd ed., Incaper, Vitória, pp. 59–68.
- Gatarayiha, M.C., Laing, M.D. & Miller, R.M. (2010) Combining applications of potassium silicate and *Beauveria bassiana* to four crops to control two spotted spider mite, *Tetranychus urticae*

- Koch. *International Journal of Pest Management*, 56: 291–297. DOI: [10.1080/09670874.2010.495794](https://doi.org/10.1080/09670874.2010.495794)
- Golizadeh, A., Jafari-Behi, V., Razmjou, J., Naseri, B. & Hassanpour, M. (2016) Population growth parameters of rose aphid, *Macrosiphum rosae* (Hemiptera: Aphididae) on different rose cultivars. *Neotropical Entomology*, 46(1): 100–106. DOI: [10.1007/s13744-016-0428-4](https://doi.org/10.1007/s13744-016-0428-4)
- Hamm, J., Stout, M. & Riggio, R. (2010) Herbivore-and elicitor-induced resistance in rice to the rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) in the laboratory and field. *Journal of Chemical Ecology*, 36: 192–199. DOI: [10.1007/s10886-010-9751-0](https://doi.org/10.1007/s10886-010-9751-0).
- Hata, F.T., Ventura, M.U., Carvalho, M.G., Miguel, A.L., Souza, M.S., Paula, M.T. & Zawadneak, M.A. (2016) Intercropping garlic plants reduces *Tetranychus urticae* in strawberry crop. *Experimental and Applied Acarology*, 69(3): 311–321. DOI: [10.1007/s10493-016-0044-3](https://doi.org/10.1007/s10493-016-0044-3).
- Kavousi, A. & Talebi, K. (2003) Side-effects of three pesticides on the predatory mite, *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, 31(1–2): 51–58. DOI: [10.1023/b:appa.0000005127.42123.98](https://doi.org/10.1023/b:appa.0000005127.42123.98).
- Klamkowski, K., Sekrecka, M., Fonyodi, H. & Treder, W. (2006) Changes in the rate of gas exchange, water consumption and growth in strawberry plants infested with the two-spotted spider mite. *Journal of Fruit and Ornamental Plant Research*, 14: 155–162.
- Klopotek, Y., Otto, K. & Bohm, V. (2005) Processing strawberry to different products alters contents of vitamin c, total phenolics, total anthocyanins, and antioxidant capacity. *Journal of Agricultural and Food Chemistry*, 53: 5640–5646. DOI: [10.1021/jf047947v](https://doi.org/10.1021/jf047947v)
- Kogan, M. (1998) Integrated pest management: Historical perspectives and contemporary developments. *Annual Review of Entomology*, 43: 243–270. DOI: [10.1146/annurev.ento.43.1.243](https://doi.org/10.1146/annurev.ento.43.1.243)
- Krips, O.E., Witul, A., Willems, P.E.L. & Dicke, M. (1998) Intrinsic rate of population increase of the spider mite *Tetranychus urticae* on the ornamental crop gerbera: intraspecific variation in host plant and herbivore. *Entomologia Experimentalis et Applicata*, 89(2): 159–168. DOI: [10.1046/j.1570-7458.1998.00395.x](https://doi.org/10.1046/j.1570-7458.1998.00395.x)
- Leszczynski, B. (1987) Winter wheat resistance to the grain aphid *Sitobion avenae* (Fabr.) (Homoptera, Aphididae). *International Journal of Tropical Insect Science*, 8: 251–254. DOI: [10.1017/S174275840000730X](https://doi.org/10.1017/S174275840000730X).
- Llorens, E., García-Agustín, P. & Lapeña, L. (2017) Advances in induced resistance by natural compounds: towards new options for woody crop protection. *Scientia Agricola*, 74(1): 90–100. DOI: [10.1590/1678-992x-2016-0012](https://doi.org/10.1590/1678-992x-2016-0012)
- Mao, Y.B., Cai, W.J., Wang, J.W., Hong, G.J., Tao, X.Y., Wang, L.J., Huang, Y.P. & Chen, X.Y. (2007) Silencing a cotton bollworm P450 monooxygenase gene by plant-mediated RNAi impairs larval tolerance of gossypol. *Nature Biotechnology*, 25(11): 1307–1313. DOI: [10.1038/nbt1352](https://doi.org/10.1038/nbt1352).
- Mohamadi, P., Razmjou, J., Naseri, B. & Hassanpour, M. (2017) Population growth parameters of *Tuta absoluta* (Lepidoptera: Gelechiidae) on tomato plant using organic substrate and biofertilizers. *Journal of Insect Science*, 17(2): 36. DOI: [10.1093/jisesa/iex011](https://doi.org/10.1093/jisesa/iex011)
- Monteiro, L.B., Kuhn, T.M., Mogor, A.F. & da Silva, E.D. (2014) Biology of the two-spotted spider mite on strawberry plants. *Neotropical Entomology*, 43(2): 183–188. DOI: [10.1007/s13744-013-0184-7](https://doi.org/10.1007/s13744-013-0184-7).
- Pauwels, L., Inzé, D. & Goossens, A. (2009) Jasmonate-inducible gene: What does it mean? *Trends Plant Science*, 14: 87–91. DOI: [10.1016/j.tplants.2008.11.005](https://doi.org/10.1016/j.tplants.2008.11.005).
- Rezaie, M., Saboori, A., Baniameri, V. & Allahyari, H. (2013) Susceptibility of *Tetranychus uticae* Koch (Acari: Tetranychidae) on seven strawberry cultivars. *International Research Journal of Applied and Basic Science*, 4: 2455–2463.

- Ribeiro, E.B., Castellani, M., Andrade, D.J., Prado, R., Souza, L.A., Freire, D.S. & Savi, P.J. (2021) Biological aspects of the two-spotted spider mite on strawberry plants under silicon application. *Horticultura Brasileira*, 39: 5–10. DOI: [.1590/S0102-0536-20210101](https://doi.org/10.1590/S0102-0536-20210101)
- Sabelis, M.W. (1985) Reproductive strategies. In: Helle, W. & Sabelis, M.W. (Eds.), *Spider mites: Their biology, natural enemies and control*. Vol. 1A, Elsevier Science Publishers B.V., Amsterdam, pp. 265–278.
- Sadeghi, E., Shoushtari, R.V. & Madani, H. (2016) The Influence of *Tetranychus urticae* Koch (Acari: Tetranychidae) life table and reproductive parameters by applying si on bean at laboratory condition. *Advances in Entomology*, 4: 260–267. DOI: [10.4236/ae.2016.45027](https://doi.org/10.4236/ae.2016.45027)
- Sato, M.E., Da Silva, M.Z., Filho, M.F., Matioli, A.L. & Raga, A. (2007) Management of *Tetranychus urticae* (Acari: Tetranychidae) in strawberry fields with *Neoseiulus californicus* (Acari: Phytoseiidae) and acaricides. *Experimental and Applied Acarology*, 42: 107–120. DOI: [10.1007/s10493-007-9081-2](https://doi.org/10.1007/s10493-007-9081-2)
- Sato, M.E., Miyata, T., Da Silva, M., Raga, A. & De Souza Filho, M.F. (2004) Selections for Fenpyroximate resistance and susceptibility, and inheritance, cross-resistance and stability of Fenpyroximate resistance in *Tetranychus urticae* Koch (Acari: Tetranychidae). *Applied Entomology and Zoology*, 39: 293–302. DOI: [10.1303/aez.2004.293](https://doi.org/10.1303/aez.2004.293)
- Shivaji, R., Camas, A., Ankala, A., Engelberth, J. & Tumlinson, J.H. (2010) Plants on constant alert: Elevated levels of jasmonic acid and jasmonate-induced transcripts in caterpillar-resistant maize. *Journal of Chemical Ecology*, 36: 179–191. DOI: [10.1007/s10886-010-9752-z](https://doi.org/10.1007/s10886-010-9752-z)
- Southwood, R. & Henderson, P.A. (2000) *Ecological methods*. Blackwell Science, Oxford, USA, 575 pp.
- Van Pottelberge, S., Van Leeuwen, T., Nauen, R. & Tirry, L. (2008) Resistance mechanisms to mitochondrial electron transport inhibitors in a field-collected strain of *Tetranychus urticae* Koch (Acari: Tetranychidae). *Bulletin of Entomological Research*, 1: 1–9. DOI: [10.1017/S0007485308006081](https://doi.org/10.1017/S0007485308006081)
- War, A.R., Paulraj, M.G., Ahmad, T., Buhroo, A.A., Hussain, B., Ignacimuthu, S. & Sharma, H.C. (2012) Mechanisms of plant defense against insect herbivores. *Plant Signaling and Behavior*, 7(10): 1306–1320. DOI: [10.4161/psb.21663](https://doi.org/10.4161/psb.21663)
- Wei, M.F., Chi, H., Guo, Y.F., Li, X.W., Zhao, L.L. & Ma, R.Y. (2020) Demography of *Cacopsylla chinensis* (Hemiptera: Psyllidae) reared on four cultivars of *Pyrus bretschneideri* and *P. communis* (Rosales: Rosaceae) pears with estimations of confidence intervals of specific life table statistics. *Journal of Economic Entomology*, 113(5): 2343–2353. DOI: [10.1093/jee/toaa149](https://doi.org/10.1093/jee/toaa149)
- Worrall, D., Holroyd, G.F., Moore, J.P., Glowacz, M., Croft, P., Taylor, J., Paul, N.D. & Roberts, M.R. (2012) Treating seeds with activators of plant defence generates long lasting priming of resistance to pests and pathogens. *New Phytologist*, 193: 770–778. DOI: [10.1111/j.1469-8137.2011.03987.x](https://doi.org/10.1111/j.1469-8137.2011.03987.x)
- Zhang, Z.J., Wu, Q.J., Li, X.F., Zhang, Y.J., Xu, B.Y. & Zhu, G.R. (2007) Life history of western flower thrips, *Frankliniella occidentalis* (Thysanoptera, Thripidae), on five different vegetable leaves. *Journal of Applied Entomology*, 131(5): 347–354. DOI: [10.1111/j.1439-0418.2007.01186.x](https://doi.org/10.1111/j.1439-0418.2007.01186.x)

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تأثیر برخی از ترکیبات کودی به عنوان القاکننده مقاومت در گیاه توت فرنگی بر آماره‌های جدول زندگی (*Tetranychus urticae* (Acari: Tetranychidae)

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چکیده

کنه تارتن دو لکه‌ای (TSSM)، *Tetranychus urticae* Koch، آفت اصلی محصولات توت فرنگی است و راهبردهای مدیریت آفات برای کنترل TSSM ضروری است. آماره‌های جدول زندگی ابزار مفیدی برای ارزیابی مقاومت یا حساسیت گیاهان میزبان به آفات هستند. بنابراین، اثرهای کاربرد برخی ترکیبات کودی بر دو رقم توت فرنگی (فستیوال و فورتونا) به عنوان القاکننده مقاومت (اسید فولویک، اسید هیومیک، سیترات پتاسیم و کربنات کلسیم) بر ویژگی‌های زیستی و آماره‌های جدول زندگی کنه تارتن دو لکه‌ای در شرایط آزمایشگاهی بررسی شده است. نتایج نشان می‌دهد که دوره تخم‌گذاری، طول عمر بالغ‌ها و باروری *T. urticae* ماده در هنگام پرورش روی دیسک برگی دو رقم تیمار شده با تیمارهای کودی فوق به‌طور معنی‌داری تحت تأثیر قرار گرفت. تعداد تخم‌های گذاشته شده به ازای هر کنه ماده نیز در بین تیمارها تفاوت زیادی داشت و نسبت به شاهد کمتر بود. ترکیبات کودی به مقدار زیادی میزان خالص تولید مثل (R_0) و میزان ذاتی افزایش (r) را نسبت به شاهد کاهش دادند. به طور مشابه، میزان متناهی افزایش (λ) و میزان ناخالص تولیدمثل (GRR) برای شاهد بسیار بیشتر از سایر تیمارها بود. مقدار کمتر میزان ذاتی افزایش *T. urticae* (r) روی رقم فورتونا توت فرنگی تیمار شده با سیترات پتاسیم و کربنات کلسیم نسبت به سایر تیمارها ثبت شد. بنابراین، این ترکیبات سیترات پتاسیم و کربنات کلسیم اعمال شده بر روی رقم فورتونا توت فرنگی می‌تواند القاکننده مقاومت نسبی باشد که باعث کاهش جمعیت *T. urticae* می‌شود و نشان می‌دهد این القاکننده‌ها با رقم فورتونا می‌توانند برای مدیریت پایدار کنه تارتن دو لکه‌ای استفاده شوند.

واژگان کلیدی: مقاومت القایی؛ آماره‌های جدول زندگی؛ مهار کنه‌ها؛ کود دهی توت فرنگی؛ کنه تارتن دو لکه‌ای.

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