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Influence of Irrigation Schedule on the Biological Parameters of TSSM *T. urticae* Koch. on Okra, Eggplant and Tomato

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A B S T R A C T

Pertinent to various irrigation levels and their impact on mites, the biological parameters were found favourable in daily irrigation schedule followed by once in a week, indicating that daily irrigation is the most suitable moisture regime which supported as many number of *T. urticae* population by maintaining the cell turgor pressure and succulency of leaf which in turn encouraged the uninterrupted feeding process, which is the most suitable condition to favour biology of *T. urticae.* The biology of *T. urticae* was the highest on host plants where as the oviposition period in okra (18.1±0.43 days), in eggplant (17.5±0.60 days), in tomato (17.2±0.75 days), sex ratio and fecundity in okra (122±5.17/♀), eggplant (110±3.12/♀) and tomato (107±3.29/♀), were found to increase on different host plants tested, especially on okra. The higher moisture regime supported maximum load of *T. urticae* favouring growth and development on various host plants compared to infrequent watering schedules. The degree of water stress created was also of substantial importance as mite development was strongly suppressed under heavy drought or water stressed condition.

Introduction

Two-spotted spider mite (TSSM) *Tetranychus urticae* Koch (Acari: Tetranychidae) is the most economically important plant-feeding pest mite in the world (Van Leeuwen *et al.*, 2013). *T. urticae* is a generalist feeder and is among the most polyphagous arthropod herbivores (Agrawal 2000), feeding on more than 1,100 plant species belonging to more than 140 different plant families, including those that are known to produce toxic compounds. *T. urticae* threatens greenhouse production and field, vine, and orchard crops, destroying economically important annual and perennial crops worldwide such as tomatoes, peppers, cucumbers, strawberries, corn, apples, grapes, hops, almonds, peppermint, and citrus (Jeppson *et al.*, 1975). *T. urticae* an assemblage of web spinning mites collectively called spider mites. Spider mites (larvae, nymphs, and adults) produce webs from silk glands located at each palp, hence the root of the 'spider' in the common name. Webbing may be used to protect against factors including wind and rain, natural enemies, and exposure to chemicals; for instance, spray droplets may become trapped in a barrier of webbing and fail to contact the mites (Davis, 1952). Silk webbing is used for a variety of different functions including dispersal, colony establishment, pheromone communication, adhesion to leaf substrate during quiescence (Gerson 1985), and it can play a role in mating (Penman and Cone 1972). *T. urticae* is generally known to be active on the underside of leaves, except under high population density. Crops with symptoms of spider mite infestations include a specking appearance and discoloration. Spider mites damage their host plants while feeding, using specialized piercing-sucking, stylet-like mouthparts to penetrate through the outer epidermal cells and into parenchyma cells (Park and Lee 2002), and thus removing chlorophyll and other cell contents. The loss of chlorophyll results in a visibly patchy discoloration of leaf tissue, as well as a reduced photosynthetic rate and production of nutrients. Economic injury occurs as high populations accumulate and feeding increases, leading to sufficient damage over a period of days. Extreme levels of damage can eventually cause leaf and fruit loss, complete defoliation, and death of the host plant. Soil moisture and irrigation have been shown to influence mite feeding in almonds as well as fruit size and yield in strawberries (Dwyer *et al.,* 1987). Mellors *et al.,* (1984) observed that spider mite populations on soybeans decreased on water stressed plants, although the correlation between population intensity and level of water stress was not statistically significant. English-Loeb (1989), studying mites on chamber-reared garden beans, found a bimodal response of mite populations to plant drought stress, with well-irrigated and moderately stressed plants associated with greatest mite reproductive rates. In contrast, mild or severe drought stress reduced mite fecundity. In one of the experiments, soybean water status found to affect the abundance of adult mites. Further analysis of the effects of water-stressed soybean on mites requires details on the life history, population dynamics and behaviour of mites (Kennedy and Smitley, 1985). In a number of studies covering a wide water stress intensity range it has been shown that: 1. mite fecundity is affected by plant water status, and 2. mites develop faster on water-stressed hosts due to their increased foliar temperature (Oi *et al.,* 1989).

Our research goals were to study different irrigation schedules to determine how this factor influence the reproduction, population buildup and development of two spotted spider mite on various host plants okra, eggplant and tomato.

Materials and Methods

Biology of *T. urticae* Koch on okra, eggplant and tomato

Pot culture experiments were conducted at insectary, Department of Agricultural Entomology, Agricultural College and Research Institute, pot culture studies with different watering frequency (T_1 – Daily irrigation, T_2 – Once in a week, T_3 – Twice in a week compared with an untreated control) applied to various preferred host plants *viz.,* okra *Abelmoschus esculentus* (L.) Moench, eggplant *Solanam melongena* (L.) and tomato *Lycopersicon esculentum* Mill of *T. urticae*. Treated plant leaves were collected from each host plants for study the biology and population buildup of *T. urticae* Koch under laboratory condition in Acarology Laboratory, Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai during 2015 to test the irrigation schedules on the biology of TSSM *T. urticae* Koch. on various host plants (okra, eggplant and tomato) in *in-vitro* conditions at 27±2ºC, 70±5% relative humidity. In this regard, a pair of male and female were selected from the stock culture and transferred to a fresh leaf disc of each host plants. Fresh leaf discs of each host plants were made which were square or circular in shape. The leaf discs were placed on cotton bed in petridish plate facing under surface upward. The cotton bed kept wet by soaking with water twice daily so that the leaf discs remained fresh. Twenty four hours later, the eggs laid were collected from these leaf discs and individually transferred with a fine camel hair brush onto new leaf discs of respective hosts. All the transferred eggs and subsequent stages (larva, nymphs and adult) were carefully monitored daily until reaching adulthood and their survival and moulting to the next stage were recorded. As soon as the adults emerged, the females were differentiated by their round caudal end against male with pointed caudal ends. Based on these observations apart from the hatchability of eggs were calculated immature survivorship and the sex ratio.

Results and Discussion

The biology of TSSM *T. urticae* was studied on okra *Abelmoschus esculentus* (L.) Moench, eggplant *Solanam melongena* (L.) and tomato *Lycopersicon esculentum* Mill with different watering frequency (T_1 – Daily irrigation, T_2 – Once in a week, T_3 – Twice in a week compared with an untreated control) the results revealed that. Comparing the different developmental stages on okra it could be observed that the egg period was least in T_1 (2.4 days) which was on par with T_2 (2.5 days) and T_3 (3.5 days) compared to untreated control (4.2 days). The larval duration was also comparatively shorter in T_1 (1.2 days) followed by T_2 (1.4 days), T_3 (1.5 days) which was on par with untreated control? The protonymphal period was less in T_1 (1.1 days) which was on par with T_2 (1.2 days) followed by T_3 (1.4 days) and compared to untreated control (1.8 days). So also the duetonymphal period was significantly shorter in T_3 (1.3 days) followed by T_1 (1.4 days), T_2 (1.5 days) and compared to untreated control (1.9 days).

As for as adult longevity of ♂ mite is concerned the duration was shorter in T_1 (9.2 days) which was on par with T_2 (9.5 days) followed by T_3 (10.3 days) and compared to untreated control (11.2 days). With reference to ♀ mites the adult longevity was the shortest in T_3 (12.5 days) which was statistically on par with T_1 (12.8 days) followed by T_2 (13.3 days) and compared to over untreated control (15.1 days). The pre-oviposition period was also significantly shorter in T_1 (0.8 days) followed by T_2 (1.1 days) and T_3 (1.4 days) and compared to untreated control (1.7 days).

Oviposition period was relatively longer in T_1 (18.1 days) followed by T_2 (15.4 days) and T_3 (14.4 days) which was on par with untreated control (14.3 days). So also the post-oviposition period was the least in T_1 (1.1 days) which was on par with T_2 (1.2 days) followed by T_3 (1.5 days) and compared to untreated control (1.8 days). The fecundity rate was the highest in T_1 (122 eggs/♀) followed by T_2 (97 eggs/♀) and T_3 (82 eggs/♀) and compared to untreated control (80 eggs/♀). The hatching percentage was also maximum in T_1 (87.70%) followed by T_2 (86.60%), T_3 (85.37%) and over the control (82.50%). The sex ratio (♂:♀) was more in T_1 (1:4.60) followed by T_2 (1:4.38), T_3 (1:2.67) and compared to untreated control (1:2.45). The severity of webbing was intense in T_1 which was on par with T_2, moderate in T_3 and it was mild in untreated control as the population of mite was very fewer in number.

In eggplant the different developmental stages of *T. urticae* was observed that the egg period was the least in T_1 (2.5 days) followed by T_2 (2.9 days) which was on par with T_3 and compared to untreated control (3.2 days). The larval duration was relatively shorter in T_1 (1.2 days) which was on par with T_2 followed by T_3 (1.5 days) and compared to untreated control (1.9 days). Protonymphal period and duetonymphal period were shorter in T_1 and on par with T_2 followed by T3. With reference to adult longevity the ♂ had a duration of (10.2 days) in T_1 on par with T_2 (10.5 days) and T_3 (11.7 days) and compared to untreated control (12.5 days). With reference to ♀ adult longevity was the shortest T_1 (13.1 days) which was on par with T_2 (13.5 days), T_3 (14.0 days) and compared to untreated control (15.1 days). Pre-oviposition period and post-oviposition period were shorter in T_1 followed by T_2 and T_3. Oviposition period was relatively longer in T_1 (17.5 days) which was on par with T_2 (17 days) followed by) T_3 (16.5 days) and compared to untreated control (14.5 days). The fecundity rate was the highest in T_1 (110 eggs/♀) followed by T_2 (95 eggs/♀) and T_3 (89 eggs/♀) which was on par with untreated control (66 eggs/♀). Hatching percentage was also maximum in T_1 (90.00%) followed by T_2 (87.37%), T_3 (85.39%) and compared to untreated control (78.79%). Sex ratio (♂:♀) was more in T_1 (1:4.43) followed by T_2 (1:3.61), T_3 (1:3.33) and compared to un treated control (1:3.13). The severity of webbing was intense in T_1 and on par with T_2 followed by moderate in T_3 and untreated control.

Observing the various developmental stages on tomato it could be perceived that the egg period was significantly shorter in T_3 (2.3 days) on par with T_1 (2.3 days) followed by T_2 (2.7 days) and compared to untreated control (3.3 days). The larval duration was comparatively shorter in T_1 (1.2days) followed by T_2 (1.3 days), T_3 (1.5 days) and compared to untreated control (1.8 days). The protonymphal period was least in T_1 (1.2 days) followed by T_2 (1.3days), T_3 (1.6 days) and compared to untreated control (1.7 days). The duetonymphal period, adult longevity, pre-oviposition period and post-oviposition period also showed similar trend.

The oviposition period was relatively longer and fecundity rate was maximum in T_1 (107 eggs/♀) followed by T_2 (96 eggs/♀) and T_3 (84 eggs/♀) and compared to untreated control (72 eggs/♀). The hatching percentage was also maximum in T_1 (89.72%) followed by T_2 (85.42%), T_3 (83.33%) and compared to untreated control (81.94%). Sex ratio (♂:♀) was more in T_1 (1:3.00) followed by T_2 (1:2.90), T_3 (1:2.89) and compared to untreated control (1:2.69). Webbing intensity was moderate in T_1 and T_2 followed by very light webbing in T_3 and untreated control. Thus all the biological parameters were favourable in T_1 indicating that daily irrigation is the most suitable moisture regime which supported as many numbers of *T. urticae* population by maintaining the cell turgor pressure and succulence of leaf which in turn encouraged the uninterrupted feeding activity, which is most suitable for other biological parameters (Table 1).

The results revealed that among the three different watering schedules *viz.,* (Daily irrigation, once in a week and twice in a week compared with an untreated control) significantly influenced all the developmental stages of *T. urticae* on host plants *viz.,* okra, eggplant, and tomato tested. In the present study it is clear that all the biological parameters of TSSM *viz.,* egg period, larval period, protonymphal period, duetonymphal period, adult longevity, pre-oviposition period and post-oviposition period were the shortest in daily irrigation schedule followed by once in a week and twice in a week. The oviposition period, fecundity, hatching percentage, sex ratio and webbing intensity was found to be more in daily irrigation followed by once in a week. Thus all the biological parameters were favourable in daily irrigation followed by once in a week indicating that daily irrigation is the most suitable moisture regime which supported as many number of *T. urticae* population probably by maintaining the cell turgor pressure and succulency of leaf which inturn encouraged the uninterrupted feeding process, which is most suitable for other biological parameters (Table 2).

Table.1 Influence of irrigation schedule on the biological parameters of TSSM *T. urticae* Koch. on okra, eggplant and tomato

Host plants	Watering frequency	Duration in days (Mean* ±S.D.)					
		Egg	Larva	Protonymph	Duetonymph	Adult longevity	
						♂	♀
Okra	**T_1-Daily irrigation**	2.4±0.09[a]	1.2±0.02[a]	1.1±0.02[a]	1.3±0.02[a]	9.2±0.11[a]	12.5±0.51[a]
	T_2-Once in a week	2.5±0.03[a]	1.4±0.05[b]	1.2±0.01[b]	1.4±0.05[b]	9.5±0.25[b]	12.8±0.73[a]
	T_3-Twice in a week	3.5±0.10[b]	1.5±0.05[c]	1.4±0.03[c]	1.5±0.05[c]	10.3±0.32[c]	13.3±0.78[b]
	Untreated control	4.2±0.03[c]	1.5±0.02[c]	1.8±0.03[d]	1.9±0.05[d]	11.2±0.25[d]	15.1±0.59[c]
	SEd	0.0359	0.0133	0.022	0.0149	0.0187	0.1949
	CD(P=0.05)	0.0782	0.0289	0.0479	0.0324	0.0407	0.4246
Eggplant	**T_1-Daily irrigation**	2.5±0.09[a]	1.2±0.02[a]	1.1±0.04[a]	1.2±0.04[a]	10.2±0.18[a]	13.1±0.38[a]
	T_2-Once in a week	2.9±0.03[b]	1.2±0.04[a]	1.2±0.01[b]	1.3±0.06[b]	10.5±0.46[a]	13.5±0.68[a]
	T_3-Twice in a week	2.9±0.13[b]	1.5±0.05[b]	1.5±0.05[c]	1.6±0.01[c]	11.7±0.50[b]	14.0±0.17[b]
	Untreated control	3.2±0.08[c]	1.9±0.03[c]	1.6±0.03[d]	1.8±0.05[d]	12.5±0.53[c]	15.1±0.36[c]
	SEd	0.0439	0.0133	0.0198	0.0125	0.1546	0.1925
	CD(P=0.05)	0.0955	0.0375	0.0432	0.0272	0.335	0.4195
Tomato	**T_1-Daily irrigation**	2.3±0.05[a]	1.2±0.06[a]	1.2±0.04[a]	1.4±0.04[a]	9.8±0.47[a]	12.3±0.57[a]
	T_2-Once in a week	2.3±0.10[a]	1.3±0.04[b]	1.3±0.01[b]	1.5±0.03[b]	10.5±0.45[b]	12.5±0.68[a]
	T_3-Twice in a week	2.7±0.12[b]	1.5±0.02[b]	1.6±0.06[c]	1.7±0.03[c]	11.4±0.25[c]	13.2±0.69[b]
	Untreated control	3.3±0.09[c]	1.8±0.06[c]	1.7±0.02[d]	1.9±0.01[d]	11.5±0.54[c]	15.3±0.64[c]
	SEd	0.0423	0.015	0.0155	0.0155	0.1151	0.1574
	CD(P=0.05)	0.0157	0.0326	0.0337	0.0337	0.2507	0.3429

*Each value is the mean of four replications.
In a column, mean±S.D. followed by common superscript(s) are at par by LSD (P= 0.05), Abbreviations: ♂- Male; ♀- Female.

Table.2 Pre-oviposition, oviposition, post-oviposition periods, fecundity (No.of eggs /♀), hatching %, sex ratio and webbing intensity of TSSM, *T. urticae* on okra, eggplant and tomato

Host plants	Watering frequency	Duration in days (Mean* ±S.D.)			Fecundity (No.of eggs /♀), (Mean*±S.D.)	Hatching %	Sex ratio (♂:♀)	Webbing intentsity
		Pre-oviposition	Oviposition	Post-oviposition				
Okra	T_1-Daily irrigation	0.8±0.08[a]	18.1±0.43[a]	1.1±0.05[a]	122±5.17[a]	87.70	1:4.60	S
	T_2-Once in a week	1.1±0.03[b]	15.4±0.26[b]	1.2±0.01[b]	97±2.27[b]	86.60	1:4.38	S
	T_3-Twice in a week	1.4±0.03[c]	14.4±0.34[c]	1.5±0.06[c]	82±2.95[c]	85.37	1:2.67	MS
	Untreated control	1.7±0.05[d]	14.3±0.36[c]	1.8±0.04[d]	80±2.24[c]	82.50	1:2.45	L
	SEd	0.0174	0.0982	0.0271	1.5096	-	-	-
	CD(P=0.05)	0.0379	0.214	0.0591	3.2892	-	-	-
Eggplant	T_1-Daily irrigation	1.0±0.06[a]	17.5±0.60[a]	1.1±0.02[a]	110±3.12[a]	90.00	1:4.43	S
	T_2-Once in a week	1.2±0.06[b]	15.5±0.66[ab]	1.4±0.03[b]	95±1.69[b]	87.37	1:3.61	S
	T_3-Twice in a week	1.6±0.07[c]	15.2±0.28[a]	1.7±0.07[c]	89±2.18[c]	85.39	1:3.33	MS
	Untreated control	1.8±0.02[d]	14.5±0.80[c]	1.7±0.05[c]	66±2.35[c]	78.79	1:3.13	MS
	SEd	0.0242	0.2887	0.0221	0.0083	-	-	-
	CD(P=0.05)	0.0528	0.6289	0.0482	0.0181	-	-	-
Tomato	T_1-Daily irrigation	1.1±0.15[a]	17.2±0.75[a]	1.2±0.03[a]	107±3.29[a]	89.72	1:3.00	MS
	T_2-Once in a week	1.4±0.12[b]	16.5±0.35[b]	1.5±0.01[b]	96±3.24[b]	85.42	1:2.90	MS
	T_3-Twice in a week	1.7±0.09[c]	15.5±0.33[c]	1.5±0.04[b]	84±4.98[c]	83.33	1:2.89	L
	Untreated control	1.8±0.19[d]	13.9±0.63[d]	1.9±0.08[c]	72±3.25[d]	81.94	1:2.69	L
	SEd	0.0223	0.2136	0.0167	0.8646	-	-	-
	CD(P=0.05)	0.0487	0.4654	0.0363	1.8838	-	-	-

*Each value is the mean of four replications.
In a column, mean±S.D. followed by common superscript(s) are at par by LSD (P= 0.05),
Abbreviations: ♂- Male; ♀- Female; L- Low webbing; MS-Moderate webbing; S-Severe webbing.

The time taken for various developmental stages found decreased in different watering frequency on various host plants. According to Oi *et al.*, 1989; Louda and Collingey, 1992; Huberty and Denno (2004) water deficit causes physiological changes in plants, including a reduced synthesis of secondary metabolites or protective compounds, which a negative effect on feeding efficiency of mites, increased content of soluble nitrogen (amino acids, amides) and free sugars, which improves the overall nutritional potential of plant tissues, and the development of mites which contributes to a shorter duration of their individual stages, i.e. eggs, larvae, protonymph, deutonymph and adults.

Mattson and Haack, (1987) who also have published the degree of imposed water stress was substantial importance as mite development was strongly suppressed under heavy drought condition. In contrast, Wilson (1994) who found that the leaf damage per mite was slighter on well-watered plants than on water-stressed plants and importantly, the area of severely damaged leaf was far smaller on well-watered plants. The low ratio of intense damage to overall leaf damage on the well-watered plants contrasts with that observed on water-stressed plants, where mites tend to feed preferentially in protected sites on the leaf surface, spreading only as the damaged area becomes unsuitable.

Hollingsworth and Berry (1982), DeAngelis *et al.*, (1983), Mellors *et al.*, (1984), Youngman and Barnes (1986). Oloumi-Sadeghi *et al.*, (1988) found that water stress reduced the density of mites and especially it influenced the density of females and eggs. And also contrast water deficit that may influence leaf suitability for mites include: more, and qualitatively different, epicuticular waxes that are known to influence herbivory (Eigenbrode and Espelie, 1995); secondly changes in concentration of nutrients and of secondary metabolites in plant tissues, often invoked to explain differences in herbivore responses to host plant moisture status. Sadras *et al.*, (1998), according to whom visual symptoms of damage were more pronounced on well-watered plants, where females preferred to feed and lay eggs and water-stressed plants could not affect the density of spider mites. In comparison with unstressed host plants, the abundance of spider mites on water-stressed hosts may increase, decrease or remain unchanged (English-Loeb, 1989). Mite behavior and life parameters are affected by environmental factors, such as temperature, moisture, habitat morphological and chemical components of host plants, especially by the nutrients, such as nitrogen, phosphorus, sugars, amino acids and semio-chemicals in host plants and apart from this the host plant moisture regimes factor play key role in influencing the growth / metabolism and rate of development of TSSM on various host plant significantly.

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