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Influence of nitrogen and phosphorus on the biological parameters of TSSM *T. urticae* Koch. On Cassava, French bean and pumpkin

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Abstract
The present investigation was conducted during 2015 at Agricultural College and Research Institute, Madurai to study the influence of host plants and different nutritional status (Nitrogen and Phosphorus) on biological parameters and population buildup of two spotted spider mite *Tetranychus urticae* Koch. The higher dose of nitrogen positively influenced *T. urticae* with shortened egg and larval period in cassava (2.1±0.06 days; 1.1±0.04 days), french bean (2.0±0.06 days; 1.0±0.07 days) and pumpkin (2.1±0.06 days; 1.1±0.03 days). Further, protonymphal period, duetonymphal period, adult longevity, pre-oviposition period and post-oviposition period were also shortened on host plants in higher dose of nitrogen. But the oviposition period in cassava, french bean and pumpkin (17.7±0.45 days; 17.0±0.32 days; 17.5±0.59 days) was found to be higher. Similalrly sex ratio (♂:♀) (1:4.31; 1:3.46; 1:4.07) and fecundity (112/♀; 127/♀; 108/♀) also found maximum in french bean, cassava and pumpkin. The level of nitrogen available in host plants determined the feeding preference of TSSM. When the mites had access to leaf tissues, they preferred to feed on leaf discs and also severity of webbing also was found influenced from plants grown at high nitrogen availability. Among these host plants, cassava, french bean and pumpkin were distinct from other hosts in their reaction. Application of nitrogen had a definite and positive influence on the buildup of population with reference to *T. urticae*. But an increase in the levels of phosphorus in host plants does not favour the growth and development of *T. urticae*.

Keywords: biology of TSSM, *Tetranychus urticae*, impacts of nitrogen and phosphorus

1. Introduction
Mites, the most diverse representatives of the phylum Arthropoda, belong to the subphylum Chelicerata and subclass Acari [1]. Among the arachnids, Acari are the only group, which feeds on plants. Plant feeding mites play an important role as agricultural pests of fruits, vegetables, forage crops, ornamentals and other agricultural crops [2]. Tetranychidae, also known as spider mites, is a large family including about 1,200 species belonging to over 70 genera of worldwide distribution [3]. The two spotted spider mite (TSSM), *Tetranychus urticae* is a member of the family Tetranychidae that contains many harmful species of plant-feeding mites. It was first described by Koch in 1836 and thought to originate from temperate climates [4]. TSSM is one of the most serious pests of many crops including french bean. Due to high reproductive potential and extremely short life cycle, combined with frequent acaricide applications, this mite has developed resistance to almost all conventional pesticides [5, 6]. The mites become serious pest because they have several generations per season. Phytophagous nature, high reproductive potential and short life cycle contributed rapid resistance development to many acaricides even after few applications [7]. Studies on population dynamics of *T. urticae* on french bean revealed that the two spotted red spider mite remained active throughout the crop season in open field condition. 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, sugars, amino acids and semio-chemicals in host plants [8], and plant water content is another important factor [9]. Several studies have indicated the importance of host plant quality on herbivorous insects [10]. Abiotic heterogeneity through crop nutrition can affect the susceptibility of plants to insect pests by altering plant tissue nutrient levels [11]. Excessive use of inorganic fertilizers can cause nutrient imbalances and lower pest resistance [12]. The application of nutrients to the soil aids plants to produce more broad, succulent and fresh leaves which could serve as suitable surfaces for egg-laying by the various pests.

Again, nitrogen has been found to affect the reproduction, longevity and overall fitness of certain pests [13]. Nitrogen has active role in amino acid production and protein synthesis [14]. As a result concentrations of the primary metabolites amino acids (main nutritional resource of insects) in the plant shoots were increased with increasing N availability [15, 16]. Many secondary metabolites produced by plants act as toxins and deterrents for pests and pathogens which are reduced by N.

Nitrogen in the soil is absorbed by the plant in the form of nitrate and ammonium ions, it is used by plants to synthesize amino acids, proteins and other complex nitrogenous compounds like chlorophyll [17]. Adequate supply of nitrogen is associated with high photosynthetic activity, vigorous vegetative growth and a dark green colour of the leaves. Leaf N concentration can influence interactions between herbivorous arthropods and plants [10]. As such, recommendations that suggest nitrogen fertilization enhances pest resistance are often misguided [18]. A growing body of evidence indicates that high rates of N fertilization can decrease plant resistance by increasing the rate of pest population growth or consumption of plant tissue [19]. This can occur when the luxurious consumption of soil nitrogen enriches the protein and amino acid content on plant tissues or reduces the production of plant defenses against pests that can alter the population dynamics of pests and their natural enemies. Phosphates help in the formation of nucleic acids and high energy phosphate compounds like ATP [20]. N limitation is well documented in insect herbivores, but phosphorus (P) limitation is poorly studied [21], although insect herbivores require not only N but also P to synthesize their proteins. P is required for ATP and nucleic acid synthesis (RNA and DNA), and thus protein production [14]. As a result, its limitation can impose severe consequences for cellular function and ultimately the growth rate of consumers [22]. P limitation has been documented widely in many species of aquatic invertebrates, particularly in *Daphnia* [23]. The objective of this research was to examine the how the addition of different levels of N and P fertilizer to host plants (French bean, Cassava and Pumpkin) would influence their reproduction, population build up and development of TSSM.

2. Materials and Methods

Pot culture experiments were conducted at insectary during 2015 in Acarology Laboratory, Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai to study the impact of different levels of nitrogen and phosphorus (T_1 – Lower dose, T_2 – Medium dose, T_3 – Higher dose compared with an untreated control) applied to various preferred host plants *viz.,* cassava *Manihot esculenta* Crantz, french bean *Phasiolus vulgaris* (L.) and pumpkin *Cucurbita pepo* (L.) of *T. urticae*. Treated plant leaves were collected from each host plants to study the biology and population build up of *T. urticae* Koch in *in-vitro* conditions at ambient conditions in which 27±2ºC temperature, 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.

2.1 Statistical analysis

The data obtained from laboratory experiments were subjected to Analysis of Variance (ANOVA) using software AGRESS. The significance of differences was tested by F-tests, while the significance of difference between the treatment mean values was compared by LSD at 5 per cent probability.

3. Results and Discussion

3.1 Impact of different levels of nitrogen on the biology of TSSM

An investigation was made on the biology of TSSM *T. urticae* on cassava as host plant with different levels of nitrogen T_1 **-** Lower dose (0.5g / plant), T_2 **-** Medium dose (1g / plant), T_3 **-** Higher dose (1.3g / plant) raised in pots, compared with an untreated check. The results revealed that (Table. 1) comparing the various developmental stages on cassava it was observed that the egg period was shorter in T_3 (2.1 days) followed by T_2 (2.5 days) and T_1 (2.8 days) as against untreated check (3.5 days). The larval duration was also comparatively shorter in T_3 (1.1 days) where as it was 1.2 days in T_2 and 1.3 days in T_1, however it was 1.5 days prolonged in untreated check. The protonymphal period was also the least in T_3 (1.0 days) followed by T_2 (1.2 days), T_1 (1.3 days) and untreated check (1.5 days), also the duetonymphal duration exhibited similar trend. As for as adult longevity of ♂ mite is concerned, the duration was the shortest in T_3 (9.7 days) which was on par with T_2 (9.9 days) followed by T_1 (11.5 days) while it was 12.5 days in untreated check. With reference to ♀ mites the adult longevity was the shortest in T_3 (12.4 days) followed by T_2 (13.5 days), T_1 (14.5 days) compared to untreated check (15.5 days). The pre-oviposition period, post-oviposition period, oviposition periods, sex ratio, fecundity and hatching percentage also exhibited similar trend (Table 2).

The biology of TSSM was also studied on french bean with different levels of nitrogen T_1 – Lower dose (3g / plant), T_2 – Medium dose (6g / plant), T_3 – Higher dose (10g / plant) compared with an untreated check. The study corroborated that all the biological parameters *viz.,* egg period, larval period, protonymphal period, duetonymphal period, adult longevity, pre **-** oviposition period and post **-** oviposition period were very shorter with increase in nitrogen levels (Table 1), this also proves the high suitability of the host plant for multiplication of the mites (Table 2).

Investigation on biology of TSSM on pumpkin with different levels of nitrogen (T_1 **-** Lower dose (18g / plant), T_2 **-** Medium dose (35g / plant) and T_3 **-** Higher dose (46.8g / plant) compared with an untreated check revealed in Table 1. Comparing the various developmental stages on pumpkin it could be observed that the egg period was relatively shorter in T_3 (2.1 days) followed by T_2 (2.5 days) and T_1 (2.9 days) when compared to untreated check (3.4 days). All other biological parameters also exhibited similar trend which is a clear proof when the nitrogen level is increased, the growth and development of *T. urticae* also increased significantly. Whereas the nymphal stages and over all longevity were shortened coupled with higher rate of oviposition favouring the further population buildup of TSSM in a short period (Table 2). However the fecundity was remarkably high and there was a positive correlation between fecundity with increased dose of nitrogen applied to host plant. Hence nitrogen had a positive impact on the biology of TSSM.

This is clear evidence that the higher dose (T_3) of nitrogen significantly influenced the *T. urticae* which reduced the population and life stages *viz.,* egg period, larval period, protonymphal period, duetonymphal period, adult longevity, pre-oviposition period and post-oviposition period on the host plants, on the other hand the oviposition period, sex ratio and fecundity were found to be prolonged. The level of nitrogen available on host plants determined the feeding preference of TSSM. When the mites had access to leaf tissue, they preferred leaf discs from the host plants grown at high nitrogen availability. The severity of webbing also was found influenced due to application of more nitrogen to host plants.

This is clearly substantiated that increased nitrogen level in host plants enhances all the biological parameters leading to an outbreak situation of *T. urticae*. Application of increased nitrogen had a positive correlation with the build up of population with reference to *T. urticae* on all the host plants followed by medium dose of nitrogen. Several reports have also proved this finding that application of nitrogenous fertilizers to apple trees led to higher population build up of *Panonychus ulmi* (Koch), [24]. High contents of carbohydrates and insoluble N compounds in the N- deficient treatment were correlated with higher multiplication rates of the same mite species [25]. Cannon and Connell [26] also reported that higher the level of applied (N, P and K), especially nitrogen, there was a shoot up in the population of spider mite *T. urticae* on soybean plant.

Further Hoffl and *et al.* [27] and Chow *et al.* [28] reported that the impact of nitrogen on biology and reproductive parameters of *T. urticae* and most of obtained results have revealed a positive correlation between nitrogen concentrations and fecundity of two-spotted spider mites. According to Roustaee [29] with excessive use of hydroponic cultivation in greenhouses, presence of a plant nutrition management is inevitable. The foraging results, demonstrated that *T. urticae* had the potential to achieve high longevity and survival rate when nourished with higher levels of nitrogen. The highest gross fecundity rate was observed with the highest nitrogen concentration in nutrient solution and exhibited significant differences with increase in levels of nitrogen. These findings are in conformity with the results of [28] on roses.

Modarres Najafabadi and Vafaei Shoushtari [30] reported an increasing trend for fertility life table parameters of *T. urticae* when nitrogen concentration was increased on beans. In comparing plant species as a host for mites, it was found that nitrogen levels in leaf tissue had a positive correlation with the rate of mite development and fecundity [31].

Wermelinger and Delucchi [32] studied two-spotted spider mite and the effects of different N concentrations on leaves had on the mite sex ratio on apple plants. Results showed a linear response among the three nitrogen levels and all treatments significantly differed from one another. There were also differences in the spider mite species used as well as the host plant.

3.2 Impact of different levels of phosphorus on the biology of TSSM

The biology of TSSM *T. urticae* was studied on cassava with different levels of phosphorus *viz.,* T_1 - Lower dose (0.5g), T_2 - Medium dose (1g) and T_3 - Higher dose (2g) which was compared with an untreated check. The results revealed in Table 3, comparing the various developmental stages on tapioca it could be observed that the egg period was significantly shorter in T_2 (2.8 days) followed by T_3 (3.4 days) and T_1 (3.9 days) when compared to untreated check (4.2 days). The larval duration was also comparatively shorter in T_2 (1.1 days) which was on par with T_3 (1.2 days) followed by T_1 (1.5 days) when compared to untreated check (1.8 days). The protonymphal period and duetonymphal periods also exhibited similar trend. As for as adult longevity was concerned the duration of ♂ mite was the shortest in T_2 (10.1 days) followed by T_3 (11.3 days) which was on par with T_1 (11.4 days) as against untreated check (13.1 days). With reference to ♀ mites the adult longevity was the shortest in T_2 (13.2 days) followed by T_3 (14.1 days) and T_1 (14.7 days), compared to untreated check (15.2 days). The pre-oviposition period was also relatively shorter in T_2 (1.4 days) followed by T_3 (1.7 days) and T1 (1.9 days) which was on par with untreated control. Oviposition period was significantly longer in T_2 (16.5 days) followed by T_3 (15.5 days) which was on par with T_1 when compared to untreated check (15.0 days). So also the post-oviposition period recorded similar trend. The fecundity was the maximum in T_2 (84 eggs/♀) followed by T_1 (82 eggs/♀), untreated check (78 eggs/♀) and T_3 (63 eggs/♀). The hatching percentage, sex ratio also recorded similar trend (Table. 4).

The investigation on the biology of TSSM *T. urticae* on french bean with different levels of phosphorus *viz.,* T_1 – Lower dose (5g), T_2 – Medium dose (10g) and T_3 – Higher dose (20g), compared with an untreated check. Comparing the various developmental stages on french bean it could be observed that the egg period was the shortest in T_2 (2.1 days) followed by T_3 (2.5 days) and T_1 (2.9 days) as against untreated check (3.4 days). The larval duration was also comparatively shorter in T_2 (1.1 days) followed by T_3 (1.3 days) and T_1 (1.6 days) which was on par with untreated check (1.7 days) (Table. 3). The protonymphal period, duetonymphal period, adult longevity, pre-oviposition period, post-oviposition period were shorter in medium dose (T_2), but there was no corresponding increase in case of T_3 when the dose of phosphorus was increased (Table. 4).

The investigation on the biology of TSSM *T. urticae* was studied on pumpkin with different levels of phosphorus *ie.,* T1 – lower dose (18g), T_2 – medium dose (35g) and T_3 – higher dose (121.8g) with an untreated check. The results (Table. 3) revealed that phosphorus nutrition to the host plant had no significant effect. Impact of all the biological parameters of TSSM at the three levels of phosphorus even the increased dose of phosphorus, didn't have any marked effect on the longevity or fecundity of the mite on this particular host, which is a clear indication that phosphorus nutrition to host plant will not alter the biology of TSSM (Table. 4).

The findings of our current study shows that the medium dose of phosphorous has a marked effect on biology of *T. urticae* on host plants. Among these host plants, cassava, french bean and pumpkin were significantly different from other host plants. An increase in the level of phosphorus in host plants does not favour the growth and development of *T. urticae* population on various host plants.

The effects of phosphorus on TSSM are more or less uniform, only a few studies have been made with reference to this element. Suski [33] found high P supply enhanced the survival of *P. ulmi.* Higher values of carbohydrates and insoluble N compounds in apple plants, induced by a P deficient treatment, were positively correlated with higher population growth of *T. urticae* [25].

The P content in leaves of various cucurbit varieties, on the other hand, could not be related to the population size of *T. neocaledonicus* Andre [34]. Phosphorus fertigation of sorghum and corn showed only a slight influence on *O. pratensis* [35]. Three phosphorus levels *viz.,* (0.32, 0.64, and 1.28 mM (equivalent to 4.48, 8.96 and 17.92 ppm, respectively) were used and the results showed that there was no difference of the number of mites per host plant or the amount of plant injury between the two different P fertigation rates.

According to Chen [36] Phosphorus had no effect on the mite population levels until 8th week. Week 8 results showed that plants applied with 0.32 mM/ 4.48 ppm phosphorus were of lower quality (not saleable) than host plants applied with 0.64 mM/ 8.96 ppm and 1.28 mM/ 17.92 ppm. Further interpretation suggests that higher rates of phosphorus allow for better compensation for mite feeding injury. Phosphorus on ivy geranium can therefore have a positive effect with tetranychid mites within certain concentration. There are several 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 host plant moisture regimes, whose interaction influence the biology, growth and development duration, population dynamics and out breaks to cause heavy yield loss. Among these, the key factor is host plant moisture regimes in influencing the growth / metabolism and rate of development of TSSM on various host plant significantly.

Table 1: Influence of nitrogen levels on the biology of TSSM *T. urticae* Koch. on cassava, french bean and pumpkin

Host plants	Watering frequency	Duration in days (Mean* ±S.D.)					
		Egg	Larva	Protonymph	Duetonymph	Adult longevity	
						♂	♀
Cassava	T_1-Lower dose (0.5g)	2.8±0.02^{c}	1.3±0.03^{c}	1.3±0.06^{c}	1.6±0.05^{c}	11.5±0.38^{b}	14.5±0.72^{c}
	T_2-Medium dose (1g)	2.5±0.10^{b}	1.2±0.01^{b}	1.2±0.03^{b}	1.4±0.02^{b}	9.9±0.37^{a}	13.5±0.74^{b}
	T_3-Higher dose (1.3g)	2.1±0.06^{a}	1.1±0.04^{a}	1.0±0.04^{a}	1.3±0.03^{a}	9.7±0.33^{a}	12.4±0.43^{a}
	Untreated check	3.5±0.07^{d}	1.5±0.05^{d}	1.5±0.02^{d}	1.8±0.05^{d}	12.5±0.35^{c}	15.5±0.14^{d}
	SEd	0.0407	0.0159	0.0359	0.0385	0.0690	0.2789
	CD(P=0.05)	0.0887	0.0347	0.0782	0.0839	0.1503	0.6076
French bean	T_1-Lower dose (3g)	2.9±0.17^{c}	1.5±0.03^{c}	1.5±0.10^{c}	1.6±0.06^{c}	11.7±0.29^{c}	13.9±0.50^{c}
	T_2-Medium dose (6g)	2.4±0.01^{b}	1.2±0.03^{b}	1.3±0.08^{b}	1.3±0.05^{b}	10.3±0.45^{b}	13.1±0.58^{b}
	T_3-Higher dose (10g)	2.0±0.08^{a}	1.0±0.07^{a}	1.0±0.01^{a}	1.1±0.02^{a}	9.5±0.44^{a}	12.3±0.34^{a}
	Untreated check	3.3±0.16^{d}	1.7±0.05^{d}	1.8±0.04^{d}	1.8±0.03^{d}	12.1±0.49^{c}	14.2±0.84^{c}
	SEd	0.0511	0.0376	0.0228	0.0296	0.14524	0.2738
	CD(P=0.05)	0.1113	0.0820	0.0497	0.0646	0.3320	0.5965
Pumpkin	T_1-Lower dose (18g)	2.9±0.12^{c}	1.5±0.05^{c}	1.6±0.03^{c}	1.7.±0.06^{c}	12.1±0.08^{c}	15.2±0.71^{c}
	T_2-Medium dose (35g)	2.5±0.10^{b}	1.3±0.05^{b}	1.3±0.05^{b}	1.5±0.05^{b}	11.3±0.06^{b}	14.3±0.01^{b}
	T_3-Higher dose (46.8g)	2.1±0.11^{a}	1.0±0.03^{a}	1.1±0.05^{a}	1.3±0.01^{a}	10.2±0.42^{a}	13.6±0.14^{a}
	Untreated check	3.4±0.13^{d}	1.7±0.11^{d}	1.9±0.02^{d}	2.0±0.02^{d}	12.9±0.28^{d}	16.1±0.80^{d}
	SEd	0.5160	0.0217	0.0347	0.0284	0.1893	0.2577
	CD(P=0.05)	1.1242	0.0472	0.0757	0.01619	0.4124	0.5614

*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: Influence of nitrogen levels on adult stages of TSSM *T. urticae* Koch. on cassava, french bean and pumpkin

Host plants	Watering frequency	Duration in days (Mean* ±S.D.)			Fecundity (No.of eggs /♀), (Mean*±S.D.)	Hatching %	Sex ratio (♂:♀)
		Pre-oviposition	Oviposition	Post-oviposition			
Cassava	T_1-Lower dose (0.5g)	1.5±0.04^{c}	14.2±0.08^{c}	1.7±0.07^{b}	91±0.07^{c}	82.11	1:3.55
	T_2-Medium dose (1g)	1.2±0.08^{b}	16.5±0.44^{b}	1.3±0.03^{a}	106±0.03^{b}	85.09	1:3.87
	T_3-Higher dose (1.3g)	1.2±0.05^{a}	17.7±0.45^{a}	1.2±0.08^{a}	112±0.08^{a}	85.21	1:4.31
	Untreated check	1.8±0.02^{d}	13.3±0.42^{d}	1.8±0.09^{b}	84±0.09^{d}	80.49	1:2.94
	SEd	0.0247	0.2792	0.0490	2.2218	-	-
	CD(P=0.05)	0.0539	0.6084	0.1068	4.841	-	-
French bean	T_1-Lower dose (3g)	1.6±0.03^{c}	15.3±0.53^{c}	1.2±0.06^{c}	108±0.06^{c}	76.33	1:2.94
	T_2-Medium dose (6g)	1.2±0.06^{b}	16.1±0.48^{b}	1.0±0.04^{b}	122±0.04^{b}	88.09	1:3.31
	T_3-Higher dose (10g)	0.9±0.04^{a}	17.0±0.32^{a}	0.8±0.08^{a}	127±0.08^{a}	92.43	1:3.46
	Untreated check	1.7±0.12^{c}	14.2±0.31^{d}	1.3±0.11^{d}	96±0.11^{d}	68.89	1:2.67
	SEd	0.0330	0.2632	0.0510	1.0389	-	-
	CD(P=0.05)	0.0528	0.6289	0.0482	0.0181	-	-
Pumpkin	T_1-Lower dose (18g)	1.5±0.04^{c}	16.1±0.48^{c}	1.2±0.03^{c}	86±0.03^{c}	82.14	1:3.22
	T_2-Medium dose (35g)	1.2±0.07^{b}	16.8±0.22^{b}	1.0±0.07^{b}	97±0.07^{b}	89.12	1:3.65
	T_3-Higher dose (46.8g)	1.0±0.05^{a}	17.5±0.59^{a}	0.8±0.01^{a}	108±0.01^{a}	90.72	1:4.07
	Untreated check	1.7±0.02^{d}	15.2±0.25^{d}	1.5±0.04^{d}	79±0.04^{d}	78.46	1:2.91
	SEd	0.0353	0.3162	0.0126	1.3282	-	-
	CD(P=0.05)	0.0770	0.6889	0.0275	2.8938	-	-

*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 3: Influence of phosphorus levels on the biology of TSSM *T. urticae* Koch. on cassava, french bean and pumpkin

Host plants	Doses	Duration in days (Mean* ±S.D.)					
		Egg	Larva	Protonymph	Duetonymph	Adult longevity	
						♂	♀
Cassava	T_1-Lower dose (0.5g)	3.9±0.11^{c}	1.5±0.07^{c}	1.7±0.07^{c}	1.9±0.02^{c}	11.4±0.26^{b}	14.7±0.34^{c}
	T_2-Medium dose (1g)	2.8±0.12^{a}	1.1±0.02^{a}	1.1±0.06^{a}	1.4±0.03^{a}	10.1±0.23^{a}	13.2±0.57^{a}
	T_3-Higher dose (2g)	3.4±0.17^{b}	1.2±0.03^{a}	1.3±0.08^{b}	1.6±0.04^{b}	11.3±0.39^{b}	14.1±0.79^{b}
	Untreated check	4.2±0.05^{d}	1.8±0.02^{d}	1.8±0.04^{c}	2.0±0.03^{d}	13.1±0.54^{c}	15.2±0.84^{d}
	SEd	0.0667	0.0256	0.0309	0.0303	0.1611	0.2857
	CD(P=0.05)	0.1454	0.0558	0.0674	0.0661	0.3510	0.6225
French bean	T_1-Lower dose (5g)	2.9±0.14^{c}	1.6±0.04^{c}	1.6±0.06^{b}	1.5±0.08^{b}	11.8±0.31^{c}	14.8±0.43^{c}
	T_2-Medium dose (10g)	2.1±0.08^{a}	1.1±0.07^{a}	1.1±0.05^{a}	1.2±0.03^{a}	9.9±0.31^{a}	12.9±0.14^{a}
	T_3-Higher dose (20g)	2.5±0.11^{b}	1.3±0.06^{b}	1.2±0.05^{a}	1.4±0.04^{b}	10.8±0.42^{b}	13.7±0.51^{b}
	Untreated check	3.4±0.14^{d}	1.7±0.05^{c}	1.9±0.02^{c}	1.7±0.02^{c}	12.4±0.58^{c}	15.0±0.69^{c}
	SEd	0.0789	0.0232	0.0320	0.0292	0.1883	0.1054
	CD(P=0.05)	0.1718	0.0505	0.0697	0.0635	0.4103	0.2297
Pumpkin	T_1-Lower dose (18g)	3.0±0.08^{c}	1.5±0.06^{c}	1.4±0.09^{b}	1.7±0.04^{c}	12.2±0.17^{c}	15.3±0.67^{c}
	T_2-Medium dose (35g)	2.2±0.17^{a}	1.1±0.04^{a}	1.2±0.07^{a}	1.3±0.09^{a}	10.5±0.16^{a}	13.6±0.56^{a}
	T_3-Higher dose (121.8g)	2.6±0.07^{b}	1.3±0.02^{b}	1.4±0.02^{b}	1.5±0.07^{b}	11.3±0.17^{b}	14.5±0.42^{b}
	Untreated check	3.4±0.04^{d}	1.7±0.07^{d}	1.9±0.04^{d}	1.7±0.06^{c}	13.0±0.59^{d}	16.4±0.66^{d}
	SEd	0.0507	0.0239	0.0317	0.0260	0.1233	0.2682
	CD(P=0.05)	0.1105	0.0522	0.0690	0.0567	0.2687	0.5843

*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 4: Influence of phosphorus levels on adult stages of TSSM *T. urticae* Koch. on cassava, french bean and pumpkin

Host plants	Doses	Duration in days (Mean* ±S.D.)			Fecundity (No.of eggs /♀), (Mean*±S.D.)	Hatching %	Sex ratio (♂:♀)
		Pre-oviposition	Oviposition	Post-oviposition			
Cassava	T_1-Lower dose (0.5g)	1.9±0.05^{c}	15.5±0.73^{b}	1.8±0.03^{c}	82±4.98^{a}	86.67	1:3.15
	T_2-Medium dose (1g)	1.4±0.07^{a}	16.5±0.39^{a}	1.6±0.07^{a}	84±2.40^{a}	89.39	1:3.88
	T_3-Higher dose (2g)	1.7±0.03^{b}	15.5±0.57^{b}	1.7±0.10^{b}	63±2.12^{c}	89.29	1:3.45
	Untreated check	1.9±0.02^{c}	15.0±0.85^{c}	2.0±0.03^{d}	78±3.41^{b}	82.67	1:2.23
	SEd	0.0205	0.2616	0.0325	1.2996	-	-
	CD(P=0.05)	0.0446	0.5701	0.0707	2.8316	-	-
French bean	T_1-Lower dose (5g)	1.7±0.05^{c}	13.2±0.46^{c}	1.5±0.03^{b}	88±3.50^{b}	77.04	1:2.81
	T_2-Medium dose (10g)	1.1±0.08^{a}	15.8±0.50^{a}	0.9±0.04^{a}	91±2.07^{a}	84.31	1:3.62
	T_3-Higher dose (20g)	1.3±0.04^{b}	14.5±0.52^{b}	1.1±0.08^{a}	71±2.60^{c}	79.00	1:3.58
	Untreated check	1.8±0.03^{c}	11.9±0.85^{d}	1.6±0.15^{b}	87±3.10^{b}	70.03	1:2.64
	SEd	0.0267	0.2937	0.0342	1.0587	-	-
	T_1-Lower dose (5g)	0.0582	0.6400	0.0745	2.3067	-	-
Pumpkin	T_1-Lower dose (18g)	1.5±0.09^{c}	14.3±0.63^{c}	1.3±0.06^{c}	78±3.53^{b}	88.97	1:3.26
	T_2-Medium dose (35g)	1.1±0.02^{a}	16.1±0.71^{a}	0.9±0.05^{a}	81±1.96^{a}	91.16	1:3.82
	T_3-Higher dose (121.8g)	1.3±0.04^{b}	15.6±0.58^{b}	1.1±0.01^{b}	58±3.60^{d}	89.23	1:3.53
	Untreated check	1.8±0.02^{d}	14.1±0.77^{c}	1.5±0.09^{d}	74±3.45^{c}	82.83	1:2.74
	SEd	0.0146	0.1979	0.0238	1.6116	-	-
	CD(P=0.05)	0.0319	0.4313	0.0518	3.5115	-	-

*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.

4. Conclusion

From the present investigation it is evident that there are several factors, such as temperature, moisture, habitat, morphological and chemical components of host plants, especially by the nutrients, such as nitrogen, phosphorus, whose interaction influence the biology, growth and development duration, population dynamics and out breaks to cause heavy yield loss. Among these, the key factor is host plant moisture regimes in influencing the growth / metabolism and rate of development of TSSM on various host plant significantly.

5. References

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