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Mohd Yaqoob Dar
(A). School of Studies in Zoology, Jiwaji University, Gwalior, Madhya Pradesh, India
(B). Central Sericultural Research and Training Institute, Central Silk Board, Pampore, Jammu and Kashmir, India
(C). Sant Baba Bhag Singh University, Khiala, Padhiana, Jalandhar, India

GK Ramegowda
Central Sericultural Research and Training Institute, Central Silk Board, Pampore, Jammu and Kashmir, India

RJ Rao
School of Studies in Zoology, Jiwaji University, Gwalior, Madhya Pradesh, India

Irfan Illahi
Central Sericultural Research and Training Institute, Central Silk Board, Pampore, Jammu and Kashmir, India

Correspondence
Mohd Yaqoob Dar
(A). School of Studies in Zoology, Jiwaji University, Gwalior, Madhya Pradesh, India
(B). Central Sericultural Research and Training Institute, Central Silk Board, Pampore, Jammu and Kashmir, India
(C). Sant Baba Bhag Singh University, Khiala, Padhiana, Jalandhar, India

Influence of weather on population build-up of *Tetranychus turkestani* Ugarov & Nikolsii (Acari: Tetranychidae) on mulberry

Mohd Yaqoob Dar, GK Ramegowda, RJ Rao and Irfan Illahi

Abstract
The present study was conducted to measure the population dynamics of *Tetranychus turkestani* (Ugarov & Nikolskii) on four commercial mulberry varieties *viz*., Goshoerami, KNG, Tr10 and Ichinose at CSRTI, Pampore in Kashmir valley. Density of mites per 25 cm^2 from five branches per plant on five randomly selected plants per variety excluding the border plants was recorded fortnightly. Population of *T. turkestani* was significantly low during spring (0.49) to reach maximum in the midst of summer (6.55) on all the varieties studied. Ichinose, KNG and Goshoerami varieties registered highest population while, Tr10 variety relatively resisted population buildup. Temperature and relative humidity of same fortnight and previous fortnight showed positive correlation with population of *T. turkestani* and rainfall and relative humidity showed negative correlations. Multiple regression modules comprising five weather parameters of same fortnight (67-87%) and previous fortnight registered (75-88%) higher R^2 values and were significant for KNG and Tr10.

Keywords: Strawberry spider mite, population build up, *Morus* spp., abundance, weather

1. Introduction
Like most of the economic plantations and field crops, Mulberry, *Morus* spp. (Urticales: Moraceae) is also subject to the attack of a vast pest complex belonging to a large number of insect orders and acarids [1]. Though the frequent leaf picking and pruning of the shoot restrict the pest build up, many of them still find enough time and place on mulberry for feeding and breeding. Mites constitute a huge group of economically important invertebrate arthropods with rich diversity and a wide range of habitats. There are more than 40,000 species grouped under about 1,800 genera [2]. The strawberry spider mite, *Tetranychus turkestani* (Ugarov & Nikolskii) is a widespread pest of many agricultural crops including cotton, beans, cucurbits, alfalfa, soybean and sugar beet [3-6]. Feeding and web production affect the quantity and quality of yield [3, 7]. Strawberry mite feed by piercing through the epidermis and puncture parenchyma cells, leaving light-coloured stipples on the leaf surface which interfere with the photosynthesis. At high population levels, massive brownish yellow spots can be seen on upper leaves until leaves wither and defoliate finally [8, 9].
Studies have revealed that *Tetranychus* sp. in Kashmir valley is impairing the quality of mulberry foliage which indirectly affecting the biological and economic parameters of silkworm and quantity and quality of silk [10, 11]. Mite pest records on mulberry in India alone constitute 50% of the global records (16 species) [12, 13]. Recently, *T. turkestani* as a pest of mulberry was recorded for the first time in Pampore, Jammu and Kashmir during 2010. Information on the damage and pest potential to mulberry is lacking in general and Kashmir valley in particular, which forms the temperate region of the country. In this background, current study was made to delineate the abundance of *T. turkestani* on important commercial varieties of mulberry as well as to understand seasonal variation and varietal performance to pave way for development of Integrated Pest Management.

2. Material and methods
Studies were made from May to October during 2011 and 2012 on four commercial varieties of mulberry, Goshoerami (*M. multicaulis*), KNG, Ichinose and Tr10 (*M. alba*) established at 0.9 m spacing either way, in a plot of 25 m^2 maintained as dwarf plantation for silkworm rearing at Central Sericulture Research and Training Institute, Pampore (33°59'50"N, 74°55'05"E, 1,574 m altitude), Jammu and Kashmir (India) [4].

Seasonal variation of *T. turkestani* was studied following the established standard methodologies [14, 15, 16]. All the four selected commercial mulberry varieties were examined for the presence of mites and their densities from 25 cm^2 of the each ventral side of leaf. Five plants from each variety (one plant from each corner and one from the centre of plot leaving the border rows) with five branches from each plant and 10 fully opened leaves from tip on each branch were observed randomly with the help of 20X hand lens. Observations were made at fortnightly from all the four mulberry varieties to know the host preference by *T. turkestani* and host influence on pest population build-up.

Data on weather parameters (*i.e.*, maximum and minimum temperatures (T_{max} and T_{min}), relative humidity (RH %) and rainfall (RF) (mm) recorded daily at hourly basis were obtained from the automatic weather station (WatchDog® 2700, Spectrum Technologies, Illinois, USA) of the Institute during the study period to understand their role in population build up and seasonal variation of *T. turkestani*.

2.1 Statistical analysis

Resultant data was subjected to one way ANOVA to check seasonal influence on the population build-up of *T. turkestani* on all four varieties. Influence of weather parameters prevailed during the same fortnight (SFN: 0–15 days prior to observation) and preceding fortnight (PFN: 16–30 days prior to observation) of observation on the seasonal variation of *T. turkestani* were analyzed by deploying the Pearson's correlation and multiple regression analysis using Sigma stat 3.5® software.

3. Results

3.1 Varietal preference

The present study revealed that, *T. turkestani* was present on all the four varieties of mulberry under investigation and was dominant on Ichinose variety (3.37 mites/25 cm^2followed by KNG (3.13), Goshoerami (2.97) and was least on Tr10 (1.56) mulberry variety throughout the seasons (May-October) (Table 1) and years (2011 and 2012) (Fig 1 & 2). Observations also revealed that highest population of *T. turkestani* were present on the 2nd, 3rd and 4th leaf of the branch from the top. On an average irrespective of season Ichinose registered highest population with 3.37 mites per 25 cm^2, followed by KNG (3.13), Goshoerami (2.97) and least (1.56) mites on Tr10 variety (Table 1). A varietal reaction exists there, Tr10 being offered relative resistance/tolerance to population build-up of *T. turkestani* compared to Ichinose on which population density was more than two folds of that on Tr10.

3.2 Seasonality of *T. turkestani*

Population of *T. turkestani* was abundant significantly during July to August months (summer season) in both the years of study (Table 1; Fig. 1 & 2) on all the four varieties studied. Irrespective of the varieties and years of study, *T. turkestani* population was more than two folds of the overall mean during June II fortnight to Aug II fortnight (summer season) indicating the peak activity and population density on mulberry in Kashmir valley.

Observation on number of mites per 25 cm^2 irrespective of varieties showed a similar trend during both the years of study and were very low (0.47 ± 0.12 and 0.50 ± 0.14 mites/25 cm2) during first fortnight at the end of spring and reached to significantly higher population (6.11 ± 1.37 and 6.99 ± 1.29 mites/25 cm^2) during 2nd fortnight of July (mid-summer) and then showed a steady decreased to 0.65 ± 0.12 and 0.70 ± 0.10 mites per 25 cm^2 at the end of October (early winter) with the onset of leaf fall during 2011 and 2012 respectively (Fig. 1 and 2).

During 2011, abundance of *T. turkestani* with respect to varieties was very low of 0.13 mites per 25 cm^2 on Tr10, 0.39 on Goshoerami, 0.63 on KNG and 0.73 mites per 25 cm^2 of Ichinose, during 1st fortnight of May, which significantly increased to reach maximum, 3.05, 7.29, 6.41, and 7.69 mites per 25 cm^2 during 2nd fortnight of July, which gradually reduced to reach a minimum of 0.44, 0.60, 0.80 and 0.74 mites per 25 cm^2 on Tr10, Goshoerami, KNG and Ichinose varieties, respectively in 2nd fortnight of October (Fig. 1).

Population abundance *T. turkestani* during 2012 was 0.14 mites per 25 cm^2on Tr10, 0.39 on Goshoerami, 0.68 on KNG and 0.77 mites per 25 cm^2 on Ichinose during 1st fortnight of May which significantly increased to attain the maximum-3.15, 7.89, 8.33 and 8.60 mites per 25 cm^2during 2nd fortnight of July and then showed a gradually decrease to a minimum level of 0.43, 0.67, 0.85 and 0.83 mites per 25 cm^2 during 2nd fortnight of October on Tr10, Goshoerami, KNG and Ichinose, respectively (Fig. 2).

Pooled observations irrespective of years showed a seasonal fluctuation in the population build-up of *T. turkestani* in the commencement of study and very low of 0.39, 0.66, 0.14 and 0.75 mites per 25 cm^2on Goshoerami, KNG, Tr10 and Ichinose during 1st fortnight of May, which showed considerable increase to reach maximum of 7.59, 7.37, 3.10 and 8.15 mites per 25 cm^2 during 2nd fortnight of July, which gradually reduced to reach a minimum of 0.64, 0.83, 0.43 and 0.78 mites per 25 cm^2 on above said varieties, respectively in 2nd fortnight of October (Table 1).

3.3 Impact of weather on population of *T. turkestani*

Current study observed the influence on population build-up of *T. turkestani* by all-weather parameters, *viz.,* temperature, humidity, rainfall and number of rainy days, among all the impact of temperature was highly significant. Correlation analysis revealed that the incidence of *T. turkestani* on four popular mulberry varieties was swayed by the ability of the host and varying of weather factors. Correlation analysis that among the entire five weather parameters, temperature minimum, temperature maximum and relative humidity of same fortnight (SFN) and previous fortnight (PFN) showed a positive correlation while rainfall and relative humidity showed negative correlations apart from SFN rainfall which showed positive correlation with population of *T. turkestani* (Table 2). Population of *T. turkestani* on all the four varieties registered highly significant and positive correlation with SFN and PFN minimum and maximum temperatures except Ichinose variety where minimum temperature had a significant correlation. Positive influence of relative humidity in all the four varieties of mulberry was not significant enough except for Tr10 where, SNF showed significant correlation. With SFN and PFN weather among all these five weather parameters rainfall and rainy days showed negative correlation with the population of *T. turkestani* on all four mulberry varieties except with SFN weather wherein rainfall showed positive correlation which was not significant enough to stand the relation (Table 2).

The multiple regression modules with five weather parameters of same fortnight and previous fortnight showed reliable R^2 values in all four varieties except Goshoerami which showed fairer and reliable R^2 value with same fortnight weather (Table 3).

Table 1: Seasonal abundance of *Tetranychus turkestani* on four mulberry varieties at Pampore, Kashmir, India during, 2011–12 (Pooled mite incidence)

Variety / Fortnights 2011 & 2012	Goshoerami	KNG	Tr10	Ichinose	Mean
	Number of mites/leaf (Mean ± SE)*				
May I	0.39±0.01^{a}	0.66±0.03^{a}	0.14±0.01^{a}	0.75±0.02^{a}	0.49
May II	0.99±0.02^{a}	1.32±0.05^{a}	0.56±0.05^{a}	1.21±0.06^{a}	1.02
June I	2.31±0.21^{b}	2.12±0.03^{b}	1.20±0.01^{b}	2.45±0.15^{b}	2.02
June II	2.89±0.09^{b}	3.32±0.11^{bc}	1.72±0.08^{b}	3.34±0.36^{c}	2.82
July I	6.63±0.26^{cd}	6.54±0.56^{d}	2.98±0.11^{bc}	7.53±0.28^{d}	5.92
July II	7.59±0.30^{cde}	7.37±0.96^{de}	3.10±0.05^{cd}	8.15±0.46^{de}	6.55
Aug I	5.67±0.43^{c}	4.91±0.07^{c}	2.96±0.16^{bc}	5.94±0.14^{cd}	4.87
Aug II	3.27±0.45^{bc}	4.17±0.22^{c}	2.04±0.06^{b}	4.31±0.16^{c}	3.45
Sep I	2.21±0.30^{b}	2.90±0.05^{b}	1.75±0.07^{b}	2.48±0.04^{b}	2.34
Sep II	1.98±0.23^{ab}	2.33±0.03^{b}	1.29±0.05^{b}	2.21±0.04^{b}	1.95
Oct I	1.15±0.05^{ab}	1.13±0.18^{a}	0.57±0.09^{a}	1.30±0.04^{a}	1.04
Oct II	0.64±0.04^{a}	0.83±0.03^{a}	0.43±0.01^{a}	0.78±0.04^{a}	0.67
Mean	2.97±0.69	3.13±0.64	1.56±0.30	3.37±0.75	2.76

*Means in a column superscript with different letters are significantly different (ANOVA, followed by Tukey-Kramer multiple comparison test at $p<0.05$).

Table 2: Correlations of weather parameters with population dynamics of *Tetranychus turkestani* on mulberry during 2011–12 at Pampore, Kashmir, India (Pooled weather and mite incidence)

Weather parameters Mulberry variety		T_{min}	T_{max}	RF	RD	RH
Goshoerami	Same Fortnight	0.75**	0.71**	0.48	-0.08	0.42
	Previous Fortnight	0.66*	0.74**	-0.11	-0.35	0.07
KNG	Same Fortnight	0.81**	0.76**	0.45	-0.10	0.48
	Previous Fortnight	0.71**	0.77**	-0.04	-0.37	0.13
Tr10	Same Fortnight	0.85**	0.78**	0.57	-0.03	0.58*
	Previous Fortnight	0.80**	0.88**	-0.01	-0.36	0.20
Ichinose	Same Fortnight	0.77**	0.74**	0.46	-0.13	0.43
	Previous Fortnight	0.66*	0.74**	-0.074	-0.35	0.08

*, ** Significant at p = 0.05 and p = 0.01, respectively, T_{min}: Minimum temperature, T_{max}: Maximum temperature, RF: Rainfall, RD: No. of rainy days, RH: Relative humidity.

Table 3. Multiple regression modules/equations for population dynamics of *T. turkestani* on mulberry with weather parameters during 2011-12 at Pampore, Kashmir, India (Pooled weather and mite incidence)

Mulberry Variety	*T. turkestani*	Module	R	R^2%	Adjusted R^2	F-value	P-value
Goshoerami	SFN	15.130-(0.716RD)+(0.0558RF)-(0.173RH)+(0.462T_{min})-(0.164T_{max})	0.82	67	0.39	2.41	0.16
	PFN	59.182-(0.504RD)-(0.0310RF)-(0.650RH)+(1.304T_{min})-(0.989T_{max})	0.87	75	0.55	3.68	0.07
KNG	SFN	3.595-(0.542RD)+(0.0174RF)-(0.0290RH)+(0.393T_{min})+(0.0482T_{max})	0.86	74	0.53	3.44	0.08
	PFN	63.329-(0.630RD)+(0.0116RF)-(0.672RH)+(1.349T_{min})-(1.00T_{max})	0.90	82	0.67	5.43	0.03*
Tr10	SFN	3.784-(0.259RD)+(0.0175RF)-(0.0245RH)+(0.231T_{min})-(0.0995T_{max})	0.91	82	0.68	5.63	0.03*
	PFN	16.956-(0.145RD)-(0.0051RF)-(0.223RH+(0.422T_{min})-(0.194T_{max})	0.94	88	0.79	9.20	0.009**
Ichinose	SFN	16.139-(0.828RD)-(0.0505RF)-(0.174RH)+(0.531T_{min})-(0.191T_{max})	0.85	72	0.48	3.04	0.10
	PFN	70.781-(0.639RD)-(0.0175RF)-(0.773RH)+(1.490T_{min})-(1.179T_{max})	0.88	77	0.58	4.01	0.06

*, ** Significant at p=0.05 and p=0.01, respectively, RD: No. of rainy days, Rf: Rainfall, RH: Relative humidity, T_{min}: Minimum temperature, T_{max}: Maximum temperature, SFN: same fortnight, PFN: previous fortnight.

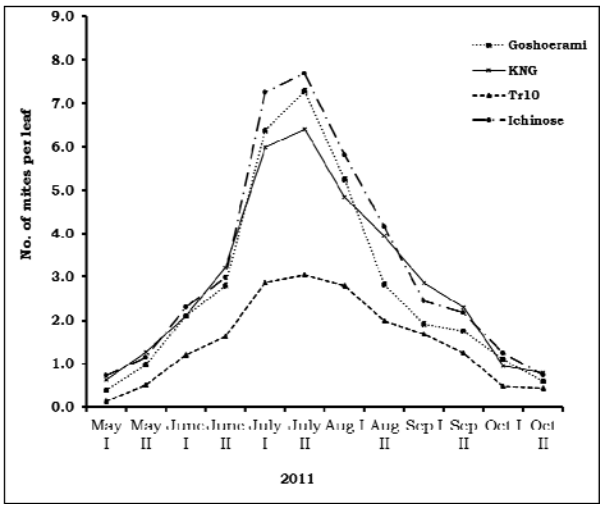

Fig 1: Seasonal abundance of *Tetranychus turkestani* on four mulberry varieties at Pampore, Kashmir, India during 2011.

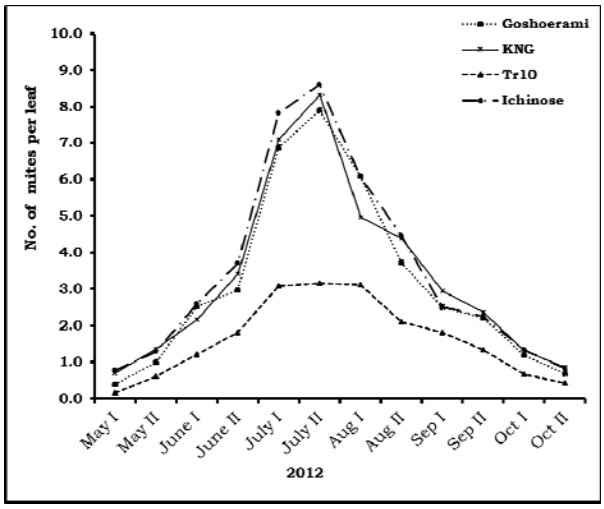

Fig 2: Seasonal abundance of *Tetranychus turkestani* on four mulberry varieties at Pampore, Kashmir, India during 2012.

4. Discussion

The spider mites, also called web spinning mites, are the most common and ubiquitous mite pests among all the pests in the gardens and farms. Mites cause damage by sucking cell contents (sap) from the plant leaves. At first, the damage shows up as a stippling of light dots on the leaves; sometimes the leaves take on a bronze colour. As feeding continues, the leaves turn yellow and drop off. Often leaves, twigs and fruit are covered with large amounts of webbing. Present investigations revealed that *T. turkestani* was present on all four varieties of mulberry investigated and was predominant on Ichinose variety followed by KNG, Goshoerami and least population was recorded on Tr10 mulberry variety throughout the year. Record of this mite on mulberry in India is first of its kind even though it has been reported from other plants. Report of widespread distribution of *Tetranychus* sp. throughout the Kashmir valley [17] renders a greater support for record of this mite pest on mulberry. *Tetranychus turkestani* has been reported as a pest of cowpea (*Vigna unguiculata* Walp) in Kashmir valley causing the failure of this important pulse crop [18]. A variety of *Tetranychus* spp. has been reported as pests of mulberry throughout the world. *Tetranychus kanzawai* has been reported as a major pest of mulberry in Japan causing considerable damage [19]; *T. ludeni* causing significant damage to mulberry in Tamil Nadu [20]. Biradar, [21] reported *T. urticae* on mulberry from Karnataka, which causes severe damage to leaf crop. Two spotted spider mite (*T. urticae*) has been reported from Kashmir valley causing significant damage to fruits and leaves in apple orchards [22]. Studies also revealed that highest population of *T. turkestani* was present on the 2nd, 3rd and 4th leaf of the branch from the top (which is very critical for the young age worm (chawki) rearing as 3rd and 4th are being used for them) which borrows support from the studies of Chouhan *et al*., [23], who has reported *Polyphagotarsonemus latus* as pest on mulberry from Coonoor (Tamil Nadu), Dehradun (Uttarakhand), Delhi and Jammu and Kashmir and witnessed higher population of this mite on tender leaves preferably on 3rd and 4th leaves below the bud. The ill effects of mite infested leaf feeding on silkworms and rearing performance have been documented [10, 11] which needs to be investigated to greater depths. Present investigation revealed a greater variation in feeding preference of *T. turkestani* on different mulberry varieties registering highest population (3.22 and 3.52 mites per 25 cm^2, respectively) during 2011 and 2012 years and least population (1.50 and 1.62 mites/25 cm^2) on Tr10 variety. Information generated on the mulberry varietal preference of *T. turkestani* is first of its kind.

Population of said mite was significantly copious in the month of July and August while during rest of the year recorded lower population densities. July month recorded the peak activity of *T. turkestani* on all the four mulberry varieties throughout the month. From August onwards it started declining and reached the minimum level by the end of October coinciding with onset of leaf fall. This variation in population build may be due to the prevailing weather factors as a temperature of around 25 °C with relative humidity of 70 to 75 percent is considered favourable for mite population build-up. The results lend support from finding of Dar *et al.* [14] who observed nearly same seasonal variation in population build-up of *P. ulmi* on mulberry in Kashmir valley. Karmakar *et al.* [24] reported a peak population of *P. ulmi* during the second fortnight of March (19.74 mites/leaf) in mulberry gardens of West Bengal under subtropical climatic conditions. The incidence of *T. kanzawai*, *Panonychus citri* and *Eotetranychus suginomensis* on mulberry was harsh in the summer- autumn rearing season in Japan [25]. Damage due to red mite, *T. bimaculatus* on mulberry was also more during dry season in Japan [26]. Population of *Tetranychus truncates* increases tremendously at the end of wet season in Thailand and overwinters in the egg stage [27]. Thus highest population during both the years in summer season (July-August) on all the four varieties investigated may be due to dry season as reported by other workers.

In the present study it was observed that weather conditions *viz.,* temperature, relative humidity, rainfall and number of rainy days of same fortnight and previous fortnight, influenced the population build-up of *T. turkestani* significantly. Maximum and minimum temperatures of SNF and PFN showed highly significant correlations with population build-up of *T. turkestani* on all the four varieties of mulberry while as rainfall and rainy days registered a negative but non-significant correlation. Similar results were observed by Dar *et al*., [28, 14] where the population of *Tetranychus* sp. and *P. ulmi* on mulberry varieties were extremely inclined by weather parameters and experienced that population build-up of both these species showed decline in number of mites per leaf as the temperature and relative humidity decreased. This variation in population of *T. turkestani* probably may be due

temperature and relative humidity as they are the key factors in determining population of mite on different plants lend support to the current findings. A negative correlation of rainfall with population build-up may be due to that during rainfall some of mites may be washed out with the rain from the mulberry foliage. Multiple regression modules revealed that same and previous fortnight weather parameters contributed to 67-88 of total variation in the population of mites with highly significant contribution (88%) on Tr10 variety and with reliable or fairly reliable R^2 values on other three varieties. Results borrow support from previous findings [14] were weather parameters showed reliable R^2 values with population of *P. ulmi* on mulberry. The current results showed close conformity with the findings of Ramegowda *et al*. [29] where regression module comprising of five weather parameters showed higher probability and reliable R^2 values for both incidence and severity of lesser mulberry Pyralid and mulberry looper. Studies on mulberry gardens of Tamil Nadu revealed that the population of *T. equitorius* was maximum from March to June and showed a reduction during August and then remained at lower level up to January-February. Such a sudden fall in mite population from August on wards was attributed to the heavy rainfall during that period [30]. Population of mites remain in peak during hot seasons in Karnataka on mulberry [31]. Similar results were observed at Conoor in Tamil Nadu, India were population of *P. latus* was first noticed in January, increased till April and reduced in May due to various cultural operations. The said mite again climbs up slowly to reach higher density during October and November which again declined for the period of December with reduction in temperature [32]. Current study are strongly supported by the findings of Pillai *et al*. [30] and Chauhan *et al*. [32], where in highest and lowest mite populations was obtained during hottest and coldest periods of study, respectively. Prasad and Singh [33] reported that, the mite population started building up on pumpkin crop from the second fortnight of March and continued to reach maximum during the first fortnight of July lend support to the present study. Reports on the seasonal activity of *T. cinnabarinus* and *T. neocaledonicus* on brinjal at Udaipur Rajasthan by Sharma and Pandey, [34] lend support to the present findings on mulberry mite activity in Kashmir valley. Both these mites had almost similar population fluctuation between October and January with a low population level which increased rapidly to reach peak during May on all varieties. Mashue *et al*. [35] reported that high temperature and drought conditions favoured the occurrence of mite.

5. Conclusion

Studies clearly concluded that, *T. turkestani* is a serious pest of mulberry and can cause significant loss to mulberry foliage in summer and posing risk to summer and autumn silkworm rearing. The literature on pest epidemic of mites in different mulberry fields gives us the intimation of the influence of farthest weather conditions. Knowledge on the behaviour of *T. turkestani* under variable weather situation may be helpful in rescheduling the miticides use and modifications of some available control options to reduce the infestation of this mite in mulberry gardens particularly during silkworm rearing season in temperate conditions so as to get good quantity and quality of silk.

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