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Impact of weather parameters on seasonality of phytophagous mites

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Abstract
Climatic and weather changes not only affect the status of insect pests but also affect their population dynamics, distribution, abundance, intensity and feeding behavior. Both a-biotic (temperature, humidity, light) and biotic (host, vegetative biodiversity, crowding and diets) stresses significantly influence the insects and their population dynamics. Pest populations have a tendency to fluctuate with the environmental factors. A-biotic disturbances particularly upper and lower thermal affects the insect population fluctuation. Various insects respond to a-biotic factors like humidity, thermal affect, light and food etc. in different ways. Pest mites cause economic losses to the crop growers and significantly reduce the photosynthetic rate of plants due to stomatal limitation. The development and population densities of mites are very sensitive to weather conditions. Out of all-weather parameters, temperature is an important abiotic factor which has direct relation with the pest population levels in means of mite growth, survivorship and fecundity of mites. Therefore, knowing the weather requirements for pest fluctuations weather factors should be considered when developing pest management programs for mites.

Keywords: Phytophagous mites, weather effect, seasonality, temperature, humidity

Introduction

Phytophagous mites have earned the attention of astrologist and progressive farmers from all over the world (Gupta, 1985 and 1991, Wilson *et al*., 1998, Walsh *et al*., 1998 and Singh *et al*., 2000) [16, 17, 47, 48, 41]. Phytophagous mites are serious pests in indoor and outdoor agricultural ecosystems and it is well known for causing considerable damage in major crops (Hoy, 2011) [21]. The tetranychid mite, Tetranychus utricle Koch is the major and worldwide mite pest species on agricultural crops (Alatawi *et al*., 2005) [2]. This species is the most common mite widely spread on vegetables, especially soybean, cucurbits, squash and okra (Zaher, 1984) [50]. It is common in greenhouses where it is an important pest of vegetables (beans, capsicum, cucumbers, eggplant, tomato, melon, strawberries, etc.). Many investigators surveyed several species of phytophagous insects and mites that infest vegetables all over the world (Hassan *et al*., 1986 and Rai & Indraject, 2011) [18, 37].

Broad mite, *Polyphagotarsonemus latus* (Banks), is an important pest of tropical and temperate crops such as cotton, citrus, tomato, potato, chili-pepper, beans, papaya and mango (Hill, 1975) [19] and damage concentrated on the young leaves, but sometimes cause damage to specific plant parts like stem, flower, or tips of shoots. Economic losses due to these mites are quite substantial; amidst erratic climatic conditions which favor them (Abou-Setta and Childers, 1989) [1]. Plant feeding mites can cause injury in several ways can cause reduction in crop yield as well as aesthetic injuries, because of webbing produced by the mites. Nymphs and adults of the mites injure the plants leaf or fruit surface by piercing the plant cells with their chelicerae and sucking the sap preferably from upper leaf surface of leaves leading to cholorosis, reduced photosynthetic rates and finally drop down. At the high population on the host, it can suppress flower and leaf development and ultimately affect the yield and quality of fruits produced (Fraulo *et al*., 2008) [13].

Pest population fluctuates with changes in biotic and abiotic factors (George 2019) [4] and these factors influence the ecology of plant-feeding mites. Population density of the mites on host plants is usually highly variable and mostly depends on the environmental conditions (Lenort, 2005) [28]. Abiotic factors like temperature, rainfall, humidity, photo-period and wind direction (Turi *et al*., 2012) [44] have influence on developmental time, survival rate and fecundity rate of these species. Temperature is the main abiotic factor influencing the temporal and spatial distribution of insects and mites in the field (Bonato *et al*., 1990) [7].

Population growth rates largely determine the pest status of spider mites (Janssen and Sabelis, 1992) [22] and temperature strongly affects population growth (Gotoh *et al*., 2010) [15]. Knowledge of different parameters favoring the survival of each pests to be more precise its microclimate is very important to identify the weak link for its management. Therefore, the present investigation was planned with the objective to find out the impact of weather on seasonality of phytophagous mites that can be used to forecast their potential distribution, abundance and development of management practices to phytophagous mite.

In India 12 species of phytophagous mites are considered as major pests and 12 as minor pests on different crops (Gupta, 1991 and Singh *et al.*, 2000) [17, 41]. The major plant feeding mites belong to families of spider mite (Tetranychidae), false spider mite (Tenuipalpidae) and gall mite (Eriophyidae). The important injurious mites of these families are listed in Table 1.

Table 1: Important Mite Pests of Indian Fruit Plants

Sr. No	Family/Mite Species and Common Name	Major Host Plants
	Tetranychidae	
1	*Bryobia praetiosa* Koch (Brown clover mite)	Pear
2	*Eutetranychus africanus* (Tucker)	Pear, Peach
3	*Eutetranychus anneckei* Meyer (Lowveld citrus mite)	Pear, Peach, Citrus, Orange, Jackfruit, Mulberry
4	*Eutetranychus orientalis* (Klein) (Oriental citrus mite)	Pear, Peach,
5	*Eotetranychus hirsti* Pritchard and Baker (Fig spider mite)	Fig
6	*Oligonychus coffeae* (Nietner) (Red tea mite)	Pear, Peach
7	*Oligonychus mangiferus* (Rahman and Sapra) (Mango red spider mite)	Mango
8	*Panonychus citri* (Mcgregor) (Citrus red mite)	Apple, Pear, citrus
9	*Panonychus ulmi* (Koch) (European red mite)	Pear, Apple
10	*Tetranychus urticae* Koch (Two spotted spider mite)	Pear, Peach, Apple
	Tenuipaldidae	
11	*Brevipalpus phoenicis* (Geijskes) (Scarlet mite/ Reddish black flat mite/Leprosis mite)	Guava
12	*Brevipalpus californicus* (Banks) (Citrus flat mite)	Citrus
13	*Larvacarus transitans* (Ewing) (Ber gall mite)	Ber (*Zyziphus mauritian*
14	*Dolichotetranychus floridanus* (Banks) (Pineapple flat mite)	Pineapple
15	*Raoiella indica* Hirst (Coconut red mite)	Coconut
16	*Tenuipalpus ludhianaenis* (Sadana and Chhabra)	Pear
17	*Tenuipalpus pruni* Maninder and Ghai	Pear, Peach
18	*Tenuipalpus pyrusae* Maninder and Ghai	Pear, Peach, Guava
	Eriophyidae	
19	*Aceria mangiferae* Sayed (Mango bud mite)	Mango
20	*Aceria litchii* (Kiefer) (*Litchi erineum* mite)	Litchi
21	*Aceria guerrerronis* (Keifer) (Coconut eriophyid mite)	Coconut
22	*Eriophyes cernuus* Massee (Jujube (Ber) gall mite)	Jujube (ber)
23	*Epitrimerus pyri* (Nalepa) (Pear bud mite)	Pear
24	*Phytoptus pyri* (Pagenstecher) (Pear leaf blister mite)	Pear
25	*Aculus cornutus* (Banks) (Peach silver mite)	Pear, Peach, Almonds

Effect of temperature on mite's population

Intensity of change in climatic ecosystem noted by meteorological science has showed a direct and indirect effect on the prey and host relationship, their immune responses and rate of development, their fecundity and various physiological functions (Yumamura, 2006) [49]. Abiotic factor affect the incidence/seasonality of different mite species on different plants. Temperature is the main abiotic factor influencing the temporal and spatial distribution of insects and mites in the field (Perring *et al.* 1984; Bonato *et al.* 1990) [7, 36]. Population count of *Polyphagotarsonemus latus* was also more in the nurseries due to the high/low temperature with high humidity (>70-90%) combinations (George *et al*. 2019) [4]. The mite population increased with rising temperature especially during summer months and then drastically reduced during monsoon season due to fall in temperature and high rainfall. A second peak with rise in minimum temperature -relative humidity favored multiplication of mites till December. Ghoshal *et al.* (2011) [14] studied the seasonality of false spider mites on guava and observed average population size in November and January with its peak population in May when the mean temperature, relative humidity and rainfall were 31-20 °C, 72-62% and 1.05 mm respectively. George *et al*. in 2019 [4] observed the abundance of mites in two peaks: April-May and October to December extended upto February in certain years. The climatic factors such as temperature, relative humidity, rainfall, sunshine hours etc. are very important for the productivity of tea as well as outbreak of pests in tea (Alder and Roessler, 1964) [3]. Pest population have a tendency to fluctuate with the environmental factors. The degree of influencing factors determined the magnitude of increase or decrease in number of mite population. The climatic factors exercise a dominating effect on the fecundity, incubation period, reproductive capacity, longevity and development of mite pests. The effect of temperature meteorological parameters on population buildup of red spider mite, *Tetranycus* telarius in okra in North Bhiar showed the negative relation of mite population with minimum temperature and a positive relation with maximum temperature and relative humidity (Mandal *et al.*, 2006) [30]. Mandal *et al.* (2006) [30] reported that the activity of the red spider mite showed non-significant negative correlation with maximum temperature and positive correlation with minimum temperature. Morning and afternoon relative humidity showed a significant positive association with the activity of mites.

The time for development stages decreased as the temperature level increased, which may be due to difference in host plant. With a slight difference that beyond 27 °C to 31 °C the time for development of all stages took longer time and compared to temperature range in between 17 to 27 ^{0}C (Riahi *et al.*, 2013) [38]. Variation in temperature significantly affected the developmental stages of both the male and female of the mite species (*Tetranychus urticae* Koch and European Red Mite (ERM), *Panonychus ulmi* Koch (Tetranychidae: Acarina) in apple. The total developmental duration of *T. urticae* Koch female was 12.4 days at 24-26 ºC and 10.0 days at 29-31 ºC while for male it was 10.8 days at 24-26 ºC and 8.3 days at 29-31 °C. The developmental duration of ERM female was 12.18 at 24-26 °C and 9.8 days at 29-31 ºC while for male it was 11.61 days at 24-26 °C and 9.35 days at 29-31 °C (Maula and Khan, 2015) [8].

The development of *Tetranychus urticae* Koch and *Eotetranychus lewisi* (McGregor) mites on strawberry was faster at 20 (6.67 to 7.33 days) and 25 °C (3.33 to 3.67 days) as compared to 15 °C (11.66 to 13.33 days). The total time taken for the development of both the mite was found to be decreased with increase in temperature and maximum fecundity was observed at 25 °C (Kaur and Zalom, 2017) [33]. Several authors have reported maximum population of *Eutetranychus orientalis* (Klein), on citrus during May-June as well as in September (Patil, 2003) [35]. Mite population has also been recorded mainly during winter months, i.e., second fortnight of December to second fortnight of February with average of 5–6 mites/shoot/vine (Kulkarni *et al*., 2008). While Ebrahim (2000) [9] recorded the maximum population of *E. orientalis* during January-April; maximum population of phytophagous mites during low temperature i.e February and November in the area of Dharward, India (Patil, 2003; Bourdeaux, 1963) [35]. Two population peaks of *P. olievora* was observed on leaves and fruits in February and March/May on Valencia orange. A sudden increase in mite density during April-May may be attributed to rise in maximum temperature combined with lower relative humidity while low minimum temperature with high relative humidity during October to January during 2011-16. Epidemic outbreak of citrus rust mite in certain citrus groves from three different districts in Maharashtra severely affected the marketable yield.

Rainfall

Rainfall is one of the major climatic factors that affect the growth, development and yield of crop as well as outbreak of mite. Too much water can be devastating for some pests. Raindrops can physically dislodge them from their host plant and behaviour patterns can be disrupted. Prolonged or heavy rain with big rain drop washes off mites from host. Mites move to underside of the leaf. It leads to high mortality of mites. It also escorts to less breeding of mites. Eggs of red spider mite is least affected. The droplet size of rain has reduced in a small i.e. drizzling. So, light rain with intermittent sunlight increases the populations of red spider mites (Khan et al., 2008) [25]. Bhagat and Singh (1999) [5] concluded that rainfall was the major factor which contributed to the low population of two spotted spider mite on brinjal. According to Prasad and Singh (2003) [27], low rainfall and humidity as well as high temperature enhanced the activity of mite in okra. Temperatures above 30°C negatively affect European red mite egg laying and development. Two spotted spider mites tolerate higher temperatures before suffering detrimental effects.

Chinniah *et al.* (2007 and 2009) [10, 11] found positive correlation between maximum temperature and mite population in okra, whereas the relative humidity and rainfall had significant negative correlation with mite population. They also reported that minimum temperature, wind velocity and sunshine hours had no significant effect on the population dynamics of two spotted spider mite. Kanika and Monika (2013) [24] noticed positive significant relation between temperature and mite's population in brinjal, while non-significant positive relationship was obtained between total amount of rainfall and population of mites. Monica *et al.* (2014) [32] reported that maximum temperature maintained highly positive correlation and relative humidity recorded at 0700 hrs showed significant negative correlation effect on mite population in brinjal. The infestation increased with rainfall, but the rate was not same in all the rainy months (May-October). In June rainfall was the maximum but infestation percentage was the maximum having less rainfall in March-May than June. Heavy rainfall might have washed out the mite population from the leaves. At the onset of first rain during February or early March, tea begins to flush and pest continues its life process on tea (Sana, 1989) [40]. Positive correlations between temperature and mite population and negative correlation between rainfall and relative humidity and mite population has been reported (Singla and Sadana, 1998) [42]. Twelve number of rainy days with 114 mm rainfall during March to May and prolonged dry spells during monsoon season from June to August, 2015 might have caused the increased incidence levels of rust mite on spring season fruits of *Citrus reticulata* and Swirski *et al* (1989) [43] also revealed that commonly, high temperature and low relative humidity would accelerate the growth of mite population.

According to Ebrahim (2000) [9], optimum temperature for development is between 30 to 32 ºC and it developed well at high humidity and particularly after rain. While in the case of relationship between the rainfall and mite density, there was significant negative correlation present except for cultivars like *Citrus jambhiri* and *Citrus limonia*. Although it is obvious that as rainfall increases, the mite's population will be decreased but they have weak dependence upon each other. Prolonged or heavy rain with big rain drop washes off mites from host. Kumar *et al*. (2003) [27] observed that the mite population showed a non-significant positive correlation with relative humidity and weekly rainfall in French marigold.

Humidity

Humidity is an important climatic factor that influences the growth and development of plant as well as it interferes with the population build-up of mite. Hot and dry weather with low humidity lead to high infestation of red spider mites. It encourages less feeding, slower egg laying and shorter life span. Like temperature, relative humidity was also found to be positively related with the infestation of red spider mites in tea. Infestation increases with the increase of relative humidity and vice-versa (Ahmed *et al*., 2012) [29]. Humid weather (75% to 90% RH) is needed for *Polyphagotarsonemus latus* development and that hot, humid weather during exposure to broad mite feeding seems to intensify the symptoms of damage (Jones and Brown, 1983). Among the abiotic factors relative humidity and rainfall were observed to be the most prominent contributors for the population fluctuation (Hobza and Jepson, 1974) [20]. The temperature and relative humidity has a major effect on the population of European red mite. There was an increase in both the population of both the motile and eggs of spider mite with the increase in temperature from 13-21 °C and the relative humidity ranges from 55-85% or above (Bhagata *et al.*, 2014) [6].

The population of Sucking pests infesting sole soybean had a positive correlation with minimum temperature while, negative correlation with rainfall, maximum temperature and afternoon relative humidity (Bhamare *et al*., 2018) [45].

Other factors

Sunshine hour is a major weather parameter. Red spider mite is a positively phototropic pest. Light duration (sun light intensity and penetration) in daytime influences the buildup of mite population. Light has the positive response in the upper surface of the leaves. It influences egg laying, Oviposition rhythm, with the maximum Oviposition at dawn and dusk when there is a rapid change in light intensity. Changes in light regime i.e. light to dark leads to peak Oviposition. Egg hatching is the maximum at red light. Light penetration within the canopy regulates the distribution of mites. Sunshine hours were found to be positively related with the infestation of red spider mite in tea; the higher sunshine hours, the higher was the percentage of infestation.

The influence of weather factors such as temperature, relative humidity, sunshine hours, rainfall and water requirement of crop are very important and played vital effect on red spider mite infestation. A prolong drought during early part of the season hinders normal growth of the bushes and the severity of mite attack gradually increases with their quick multiplication. Drought is related to temperature, humidity, light duration, wind effect, shade status, soil type and drainage condition etc. which have the positive effect on red spider mite incidence (Ahmed *et al.,* 2012) [29]. Climatic factors such as temperature, relative humidity and sunshine hours showed positive relationship with the infestation of red spider mite. All the parameters except rainfall were found highly correlated (r = 0.91, 0.92 & 0.91 respectively) with the field infestation of mite. On the other hand, heavy rainfall & cloud coverage and water requirement of crop were found to be negatively correlated (r = -0.89 & r = -0.49) with the infestation of mite (Ahmed *et al*., 2012) [29]. On summer okra crop seasonal incidence as influenced by weather parameters on mite's population reached its peak during last week of April with 8.40 mites in 6.25cm2 leaf area/ 3 leaves. The correlation between mite population was positively significant against maximum temperature (r= 0.841**), minimum temperature (r= 0.805**), evaporation (r= 0.803**), wind velocity (r= 0.728**) and bright sunshine hours (r= 0.649*), while with morning R.H (r= - 0.717**) and evening R.H (r= - 0.643*) it was negatively significant (c *et al*., 2010) [15].

Conclusion

Although the weather factors are beyond control in nature, some of these situations interfere with the spray fluids and also might have influenced resistance or tolerance of the pest due to exposer to inadequate toxicity from the applied chemical. Thus knowing the behaviour of this particular pest under variable weather factors, this study may be helpful in rescheduling the miticides use and modifications of some available control options to reduce the infestation of phytophagous mites. Agriculturists/astrologists should keep in mind that climate change is likely to be a gradual process that will give them some opportunity to adapt. Astrologists who closely monitor the occurrence of mites in their fields and keep records of the severity, frequency, and cost of managing pests over time will be in a better position to make decisions about whether it remains economical to continue to grow a particular crop or use a certain pest management technique.

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