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Muhammad Abu Bakar
University College of Agriculture, University of Sargodha, Pakistan.

Muhammad Anjum Aqueel
University College of Agriculture, University of Sargodha, Pakistan.

Mubasshir Sohail
University College of Agriculture, University of Sargodha, Pakistan.

Abu Bakar Muhammad Raza
University College of Agriculture, University of Sargodha, Pakistan.

Muhammad Afzal
University College of Agriculture, University of Sargodha, Pakistan.

Muhammad Tayyab
Department of Plant Protection and Quality Control Sargodha, Pakistan

Muhammad Arshad
University College of Agriculture, University of Sargodha, Pakistan.

Correspondence
Mubasshir Sohail
University College of Agriculture, University of Sargodha, Pakistan.
Email: mubasshirsoahilroy@gmail.com

Influence of weather factors on the seasonal abundance of citrus mite *Eutetranychus orientalis* (Klein) on different citrus cultivars

Muhammad Abu Bakar, Muhammad Anjum Aqueel, Mubasshir Sohail, Abu Bakar Muhammad Raza, Muhammad Afzal, Muhammad Tayyab, Muhammad Arshad

Abstract
Citrus mites (Acarina: Arachnida) are distributed worldwide. In addition to citrus, many other plants including fruit crops, vegetables, field and weeds are also hosts of mites. In present research to check the seasonal abundance of mites in four tehsils of district. Data regarding *E. orientalis* adult population was recorded with the interval of seven. Correlation of the citrus mites population with abiotic factors; temperature, humidity and rainfall was also calculated. Over all kinnow variety was found susceptible with maximum population of mite as compare to other citrus varieties. The maximum mite population density was recorded in the tehsil kotmomin as compared to other three tehsils. However relative humidity and rainfall showed significantly negative correlation to the population of *E. orientalis.* The finding of present research suggested that the kinnow is a susceptible variety for mites attack as well as there is impact of abiotic factors on mite population.

Keywords: Citrus mites, Abiotic factors, population density

1. Introduction
Citrus is one of the foremost fruit of Pakistan in stipulations of area, yield and export. Although citrus crop is kept in great esteem, yet present status is defenseless by a number of factors, which impede the fruit yield and quality. Citrus is considered as evergreen trees and shrubs. It belongs to the family *Rutaceae*. All the edible citrus cultivars are species of *Eucitrus.* Mandarin, sweet orange, grapefruit, sweet lime and lemon are best-known examples of citrus fruits. They are widely grown in all suitable subtropical and tropical climates worldwide [1].

Citrus fruit has great nutritional values. It contains appreciable amount of ascorbic acid, fair amount of vitamin A and B, as well as minerals, such as calcium, phosphorus and iron which added to its nutritive properties [2]. Citrus is one of the richest sources of vitamin C. It also contains 3-4% sugar and minerals which are amount essential for proper health and vigor. Citrus fruit contributes to a balanced and healthy life style by preventing liver, lungs and skin cancers; heart diseases; birth defects. Essential oils from orange peel are the most important and widely used flavoring ingredients in many foods, beverages, cosmetics and toothpastes [3].

Citrus production is one of the world's largest agricultural industries. It stands first in area and production among the world's fruits production. The average Citrus production is 108 million tons in the world. China is the largest producer of citrus in the world, followed by Brazil, USA, India and Mexico [4]. Important citrus growing countries are china, India, Japan, Syria, Turkey, Italy, Pakistan, Spain, France, Russia, Egypt, Sudan and Australia. Pakistan is included in the top ten countries in citrus production [5].

The climate of Pakistan is very ideal for growing a number of delicious fruits. Thus a very vast range of sub-tropical, tropical and temperate fruits are grown in the country. Citrus is grown practically all over Pakistan, however due to suitable agro-ecological condition in the Punjab and some parts of KPK are best suited for citrus production.

The area under citrus production in Pakistan during 2011-2012 was 196 thousand hectares with an average production of 2.14 million tons. All four provinces of Pakistan contribute in citrus production but Punjab produces over 95% of the crop because of its favourable growing conditions greater population and adequate water. Punjab's share is the biggest in Pakistan due to its climate [6]. Sargodha, Sahiwal and Toba Tek Singh are major citrus producing districts

in Punjab. The area under citrus production in Sargodha was 89,399 ha with an average production of 1,025,007 tonnes. It is one of the major sources of income to small and medium size growers and traders [7]. Pakistan contributes 6% share in the total production of citrus in the world. Citrus is also a source of foreign exchange that helps to increase the economic importance of Pakistan [8].

Average yield of citrus is about 12.78 tonnes per hectare in Pakistan while the potential yield of citrus ranges from18-20 tonnes per hectare. Hence a large gap exists between its potential and average yield [9]. This gap in yield is attributed to a number of cultural and environmental factors as well as infectious diseases, caused by different insect and pests. Many insect pests attack on citrus crop and cause low yield. Mites (Acarina: Arachnida) are one of the important pests of citrus [10]. Several factors contribute towards yield decline in citrus fruit, one limiting factor in citrus production is pest and disease problem. Among which the threat from different insects and mites is one of the most important. The losses due to injurious mites are quite substantial, especially during years when climatic conditions favor these pests [11].

Spider mite is one of the most damaging pests in citrus orchards. Its high population causes almost 60% decrease in the leaf chlorophyll and also increase in the transpiration rate. Chlorosis appears in the form of patches on the leaves, and entire leaves may dried and turn brown. For instance, the citrus red mite, *Panonychus citri* (McGregor), reduced production of citrus by 29.25% [12].

The biotic and abiotic factors that influence the ecology of plant-feeding mites on citrus have received considerable attention [13, 14]. Abiotic factors, like temperature, rainfall, humidity, photo-period and wind direction have a great effect on the population density of the pest species [15]. These factors either increase or decrease the developmental time, survival rate and fecundity rate of these species. Each pest species has its own peculiar requirement of survival and hence it is important to determine the respective parameters for each pest. These climatic factors also play a major role on the biology of mites. Population trend of pest is continuously changing with the change in seasonal and environmental factors [16].

An optimum level of moisture has a positive impact on different process of arthropods and other living things. Insect and mite body has range of 50-90% water. Water capacity is greatly different between species of insects, mites and even among different stages of the same species, e.g. caterpillar may have more water in their body, while hard body adults may have low range of water. Moisture has great influence on the development and fecundity growth of the pest species. Moisture requirement varies from species to species [17].

Keeping in view the importance of *E. oriantalis* in citrus, the present study was designed. At present no detailed studies have been conducted on fauna of this economically important pest of citrus. The damages caused by the *E. oriantalis* are major factors of citrus yield reduction in the areas, having its huge population. The factors for abundance of mites may be the development of its insecticidal resistance [18] but the impact of abiotic factors in the citrus culture are also a reason for the increasing population of *E. oriantalis*. To get the suitable control measures, it is important to study its diversity in major citrus growing areas. Our present study is focused on to find out population dynamics or diversity of *E. oriantalis* in District Sargodha. Regardless of its increasing importance, the influence of weather factors on the seasonal incidence of this pest is unknown. Therefore the present study reports the seasonal incidence of citrus mites and effect of weather factors on its incidence.

2. Materials and Methods

Description of the study area

Present study was conducted at 32° 07' N and 72° 67' Latitude and Longitude respectively in Sargodha, Pakistan. The city has a climate of extreme heat in the summers and moderate cold in the winters. The maximum temperature reaches 50 °C (122 °F) in the summer while the minimum temperature recorded is as low as freezing point in the winter. The average annual rainfall is 410 mm. The study was undertaken on citrus cultivars, planting pattern was square. The data collection was carried out during July 2012 to June 2013. The selected orchards were not treated with insecticide, miticides during the survey period.

Assessment of incidence of citrus mites

Spots of citrus were selected from different orchards for proposed research in district Sargodha. Hot spots were marked in designated citrus orchards from four different locations i.e. Sargodha, Bhalwal, Kotmomin and Sahiwal. The hot spots were of three citurs cultivars; Kinnow, Mosambi and Feutrell's Early. The purpose of selection of these verities was to see the impact of different citurs cultivars as host of mites. Eight-ten year old citrus trees (ten plant from each variety) were selected. For data collection, we further replicated the varietal plant three times. Plant from each variety further divided into four quadrants; north, south, east and west. Two sampling method were used for data collection (i) Tap sampling (ii) Shoot examination. Collection was done by tapping the leaves over white paper.

From each quadrant twenty leaves were examined randomly for mites population using hand lenes (10X). The examined leaves were brought to laboratory using ice box container. These leaves were further examined for confirmation of exact adult mites population under microscope per leave on weekly bases. The data was collected from both upper and lower side of leaves. Collected samples were kept in small glass vile containing 70 percent ethyl alcohol. The data regarding abiotic factors and mites population was correlated. Metrological data was obtained from Metrological department, Sargodha Pakistan.

Statistical analysis

ANOVA was done for estimation of mites population on different citrus cultivars. Mean monthly data of weather factor were calculated for the data from one year (2012-2013). And the means were compared using LSD test. Correlation was established between abiotic factors (maximum and minimum temperature, relative humidity and rainfall) with adult mites population. The data regarding mites population is presented as means (±SE). Statistical analyses were done by using R i386 2.15.3.

3. Results and Discussion

During the present investigation, a field survey was conducted to gather information on the incidence of *E. orientalis* of citrus.

Result showed that kinnow got highest mites population (1.13/leaf) than feutrelly's early (0.76/leaf) and mosambi (0.67/leaf). LSD test expressed that, there is no significant difference between feutrelly's early and mosambi (Fig. 1).

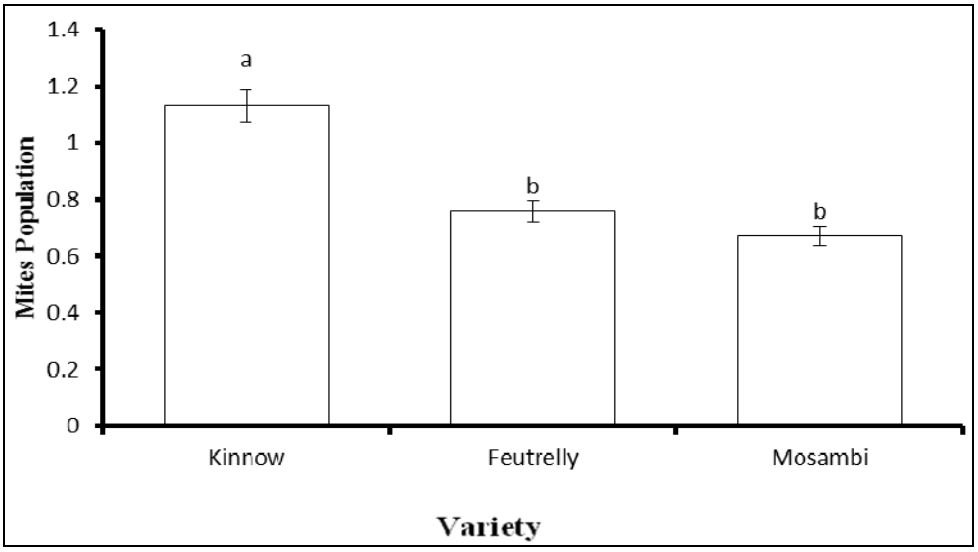

Fig 1: Average population mean over citrus varieties at all locations of district Sargodha.

Mean comparison tested through LSD test showed that, mite population was maximum in Kotmomin (1.016±0.02) and Sahiwal (0.9513±0.021) locality as compared to Bhalwal (0.8441±0.018) and Sargodha (0.6061±0.011) (Fig. 2). Least significant difference test between four tehsils of district Sargodha and mites population was calculated. According to the lettering there is a significant difference of mites population between the kotmomin and Sargodha.

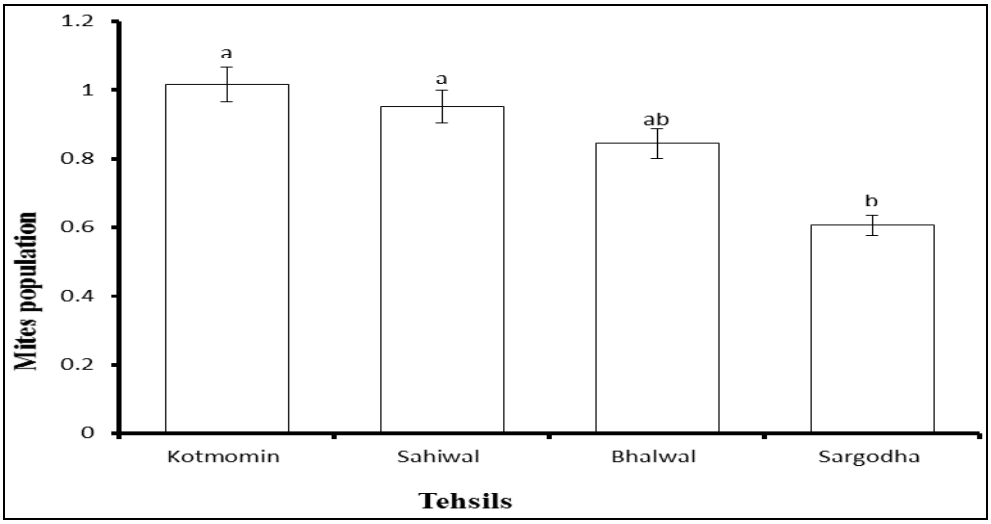

Fig 2: Average population of mites over all citrus varieties.

Multiple regression models were used to check the combined effect of all the weather factors on the population of mite. The results were represented below in Table. 1. There regression equations in all the stepwise regression models were found to be fitted the best.

Regression equation expressed that there will be 0.043, 0.029 and 0.023% increase in mite population for unit change in maximum temperature (X1), the fixed values of other independent factors in case of Kinnow, Feutrelly' early and Mosambi respectively in the case of sahiwal. While there will be 0.083, 0.068 and 0.045% raise of mite population for the unit change in minimum temperature over the constant value of other abiotic factors in case of Kinnow, Feutrelly' early and Mosambi respectively. But unlike above there will be the 0.00276, 0.0020 and 0.0038% decrease in density of the mite population for the unit change in relative humidity for the fixed values of X1, X2 and X4 in three different verities of citrus. At the last a unit change in rainfall will decrease in population up to 0.003, 0.0031 and 0.0011% in case of Kinnow, Feutrelly' early and Mosambi respectively.

At Kotminin regression model expressed that there will be 0.030, 0.036 and 0.04% increase in mite population for unit change in maximum temperature for the fixed values of other independent factors in case of Kinnow, Feutrelly' early and Mosambi respectively. As it is obvious for the calculated equation that there will be 0.030, 0.067 and 0.04% raise of mite population for the unit change in minimum temperature over the constant value of other abiotic factors in case of

Kinnow, Feutrelly' early and Mosambi respectively. It is depicted form the regression equation that there will be 0.018, 0.019 and 0.04% decrease in density of the mite population for the unit change in relative humidity for the fixed values of X1, X2 and X4. At the last a unit change in rainfall will decrease in population up to 0.038, 0.028 and 0.15% for the same values of other abiotic factors on Kinnow, Feutrelly early and Mosambi respectively.

According to the (table 1) regression equation there will be 0.019, 0.006 and 0.002% increase in mite population for unit change in maximum temperature (X1) for the fixed values of other independent factors in case of Kinnow, Feutrelly' early and Mosambi respectively at Bhalwal. Expression of Y (mite population density) will be 0.040, 0.025 and 0.031% raise of mite population for the unit change in minimum temperature over the constant value of other abiotic factors. But unlike above there will be the 0.017, 0.013 and 0.013% decrease in density of the mite population for the unit change in relative humidity for the fixed values of X1, X2 and X4 in case of Kinnow, Feutrelly' early and Mosambi respectively. At the last a unit change in rainfall (X4) will decrease in population up to 0.028, 0.024 and 0.02%.

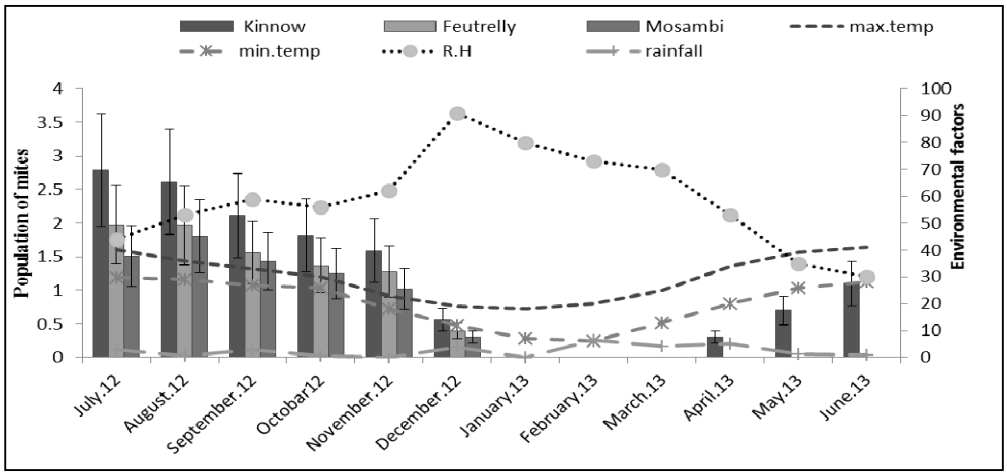

Fig 3.3: Month wise graph of mite population of Bhalwal

Graph showed the mite population activity and magnitude of the abiotic factors, starting from the july 2012 to may 2013 at bhalwal. The peak activity was recorded from July to November but in December there was a decrease in mite population activity. While quick decline was observed in remaining months. Overall kinnow got maximum population as compared to other varieties. After the pause in population activity kinnow plant got mite individual first in the month of April.

During research it was observed that all varieties of citrus possess the infestation of mites. The finding of present investigation showed that all the citrus cultivars were found susceptible for mites attack. The result are in accordance to the observation of Allen and McCoy, [19] for different citrus varieties. In some studies the abundance of mites was observed at it peaks during March-April. Smith-Meyer, [20] which is in contrast to the finding of present studies, where the maximum mites population was observed during July. There may be reason of rainfall during that season.

Present investigation showed a peak infestation was recorded during July to September. Afterward the declined in population density was observed in the month of November. Dhooria and Butani, [21] also reported that the maximum population of *E. orientalis* on *Citrus* during May-June as well as in September. While Lal, [22] recorded the maximum population *E. orientalis* during January-April. Patil, [23] observed maximum population of phytophagous mites during low temperature i.e February and November in the area of Dharward India.

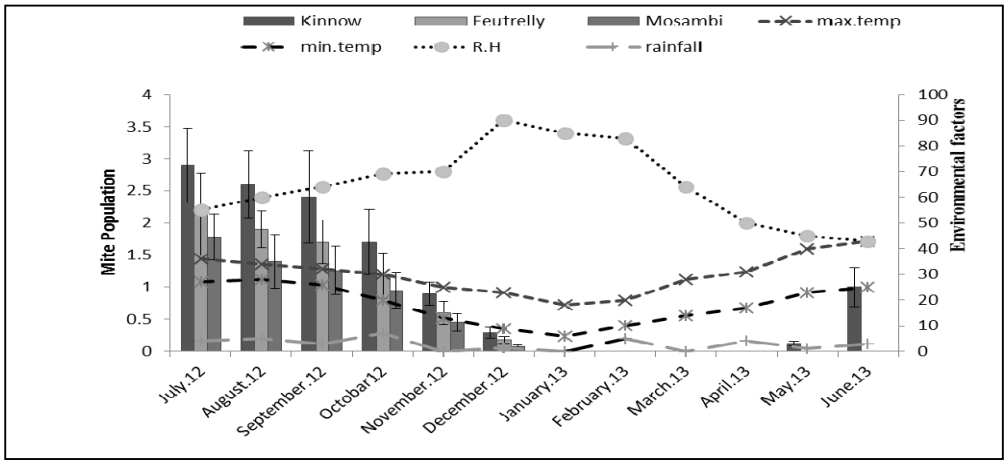

Fig 3.4: Month wise graph of mite population of Sahiwal

Table 1: Effect of abiotic factors on mite population in different Tehsils of District Sargodha, Pakistan.

	Sahiwal						Kotmomin						Bhalwal					
	Kinnow		Feutrelly's early		Mosambi		Kinnow		Feutrelly's early		Mosambi		Kinnow		Feutrelly's early		Mosambi	
	t-value	Pr (>|t|)	t-value	Pr (>|t|)	t-value	Pr (>|t|)	t-value	Pr (>|t|)	t-value	Pr (>|t|)	t-value	Pr (>|t|)	t-value	Pr (>|t|)	t-value	Pr (>|t|)	t-value	Pr (>|t|)
Intercept	-1.21	0.237	-2.05	0.053	-0.88	0.388	2.193	0.04*	4.109	0.0005***	-0.01	0.987	2.828	0.01*	3.979	0.0008***	2.191	0.04*
X1	2.175	0.042*	2.265	0.0348*	2.001	0.0592	1.408	0.0175 *	-2.09	0.0497*	1.392	0.0180*	1.336	0.197	0.652	0.522	0.171	0.866
X2	5.729	1.32e-05***	7.133	6.55e-07***	5.269	3.55e-05***	2.177	0.04231*	5.967	9.63e-06*	2.199	0.0404*	3.394	0.00304**	2.975	0.00782**	2.456	0.0238*
X3	-0.39	0.6991	0.446	0.6587	-0.92	0.3662	-3.78	0.0012***	-4.40	0.0003***	-0.07	0.4.626	-3.38	0.0031***	-4.24	0.0004***	-2.34	0.0301*
X4	0.150	0.8825	-0.10	0.91823	0.942	0.3576	-0.52	0.52430	-0.54	0.59414	-1.80	0.087	-2.25	0.03596*	-2.03	0.05580	-1.79	0.088
Multiple R^2=0.908			Multiple R^2=0.925		Multiple R^2=0.901		Multiple R^2=0.924		Multiple R^2=0.929		Multiple R^2-=0.849		Multiple R^2=0.935		Multiple R^2=0.926		Multiple R^2=0.842	
Adjusted R^2=0.889			Adjusted R^2=0.910		Adjusted R^2=0.881		Adjusted R^2=0.908		Adjusted R^2=0.913		Adjusted R^2=0.817		Adjusted R^2=0.921		Adjusted R^2=0.910		Adjusted R^2=0.808	
P= 4.28e-10			P= 5.5e-11		P= 8.8e-10		P= 2.2e-10		P= 1.231e-10		P= 1.403e-07		P= 2.258e-10		P= 1.827e-10		P= 2.241e-07	
$Y= -1.0316 + 0.043 X_1 + 0.083 X_2 - 0.0028 X_3 + 0.0030 X_4$			$Y= -1.154 + 0.0297 X_1 + 0.0689 X_2 - 0.0021 X_3 + 0.0024 X_4$		$Y= -0.443 + 0.0234 X_1 + 0.0454 X_2 - 0.0038 X_3 + 0.0113 X_4$		$Y= 1.481 + 0.309 X_1 + 0.0309 X_2 - 0.0182 X_3 + - 0.0381 X_4$		$Y= 2.363 - 0.0369 X_1 + 0.0678 X_2 - 0.0186 X_3 + -0.0284 X_4$		$Y= -0.015 + 0.0406 X_1 + 0.0408 X_2 - 0.0052 X_3 + -0.153 X_4$		$Y= 1.631 + 0.0193 X_1 + 0.0402 X_2 - 0.0175 X_3 + -0.0287 X_4$		$Y= 1.675 - 0.007 X_1 + 0.025 X_2 - 0.0016 X_3 + -0.0189 X_4$		$Y=1.353 + 0.0026 X_1 + 0.0311 X_2 - 0.013 X_3 + 0.024 X_4$	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

X1=Maximum temperature, X2= Minimum temperature, X3= Relative humidity, X4= Rainfal

Mite population density was recorded month wise at tehsil sahiwal. Graph also showed the values of abiotic factors with respect to the months. Kinnow plant showed maximum attraction towards mite individual. While on mosambi plant lowest population was recorded. At all citrus varieties peak activity was recorded from July to November. But absence of mite started from December. A significant positive correlation between mites population and temperature (max. and min.) was observed during the entire period of research. In particular area of Sargodha (Punjab) highest population of mites was recorded in warm humid condition (July-August). At the temperature of 36 ℃ in July the maximum population was recorded 3.1 mites per leaf. While according to Ebrahim [24] optimum temperature for development is between 30 to 32 ℃ and it development well at high humidity and particularly after rain. Optimum temperature for its developments is 28-31 °C and low relative humidity [25].

A maximum rainfall was recorded during January to May while peak population of mites recorded in the month of July. During the month of December the maximum rainfall was also recorded. So the relationship between rainfall and mites density was non-significant and negative correlation. Relative humidity showed negative significant correlation between the mite population densities in all varieties of citrus at Sargodha district. Maximum relative Humidity was recorded in the month of November –December while minimum relative humidity was observed in the month July to September. But maximum mites population was recorded in July to August and there was a decline in population in November to onward. Swirski *et al.*, [26] also revealed that commonly, high temperature and low relative humidity would accelerate the growth of mite population. At the same time high humidity increase their population of natural enemy, especially fungi that can suppress mite population.

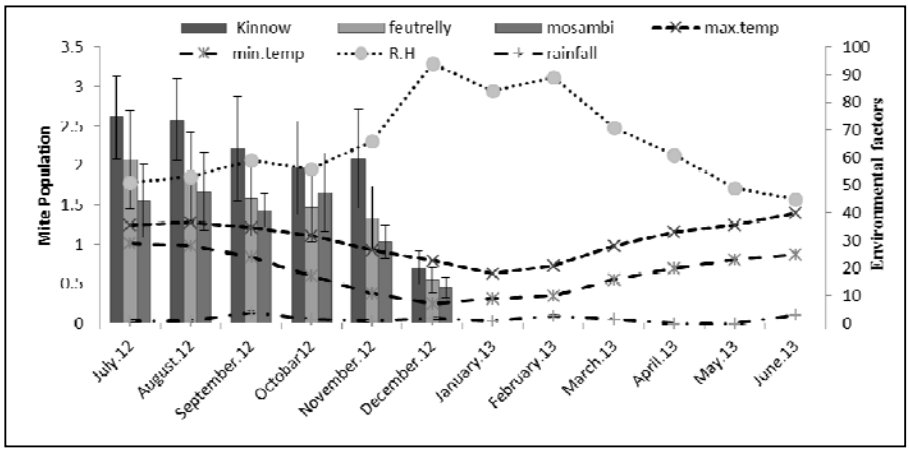

Fig 3.5: Month wise graph of mite population of Kotmomin

Graph showed the mite population activity and magnitude of the abiotic factors, starting from the July 2012 to May 2013 at Kotmomin. The peak activity was recorded from July to November but in December there was a decrease in mite population activity. While quick decline was observed in remaining months. Overall kinnow got maximum population as compared to other varieties. Low population was recorded on mosambi. Ghoshal *et al.*, [27] studied effect of false spider mites on guava. They observed the average population size in November and January. They also observed its peak population in May when the mean temperature, relative humidity and rain fall were 31-20 °C, 72-62% and 1.05 mm respectively. According to present research mites population was high from 3rd week of July to the end of November. Afterwards population declined steadily from 1st week of January to the month of May. As rainfall data shown, rainfall was maximum in the same during as January to May as compared to the previous month. The peak population was observed in the month of July. While the peak rainfall was recorded in the month of December. While in the case of relationship between the rainfall and mites density, there is non-significant negative correlation present. It is obvious that as rainfall increases, the mites population will be decreased but they have weak dependence upon each other.

Kumar *et al.*, [28] observed that the mite population showed a non-significant positive correlation with relative humidity and weekly rainfall in French marigold.

The findings of present research will lead to manage the citrus orchards according to the seasonal abundance of the *E. orientalis*. As the observation of current research showed a lower population on Mosambi tress, it can be use to develop some genetic characters of Mosambi leaves in Kinnow and other susceptible verities against this mites. For the farmer present research has produced a seasonal ranking of phytophagous mites according to the area of citrus production and climatic condition. So a farmer can adopt appropriate practices to manage these mites. At the same time monitoring of this pest has also been done to suppress its population by using different tactics of IPM.

In future the present research will lead to a base line for the application of Bio-control agents against these mites in relation to agro-ecosystem.

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