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INFLUENCE OF ABIOTIC WEATHER FACTORS ON POPULATION DYNAMICS OF ASIAN CITRUS PSYLLID, *DIAPHORINA CITRI* KUWAYAMA (HEMIPTERA: PSYLLIDAE) IN CENTRAL PUNJAB, PAKISTAN

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ABSTRACT

This study was undertaken the Department of Entomology, University College of Agriculture, University of Sargodha, Sargodha Pakistan during the year 2015. The objective was to determine the population dynamics of Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) in citrus orchards of central Punjab (Pakistan) and also to assess the influence of prevailing abiotic weather factors on its population fluctuations. Random sampling was done from 7-9 years old orchards of Kinnow mandarin (*Citrus reticulata*) and sweet orange; mosambi cultivar (*C. sinensis*) in three citrus growing localities including Faisalabad, Sargodha and Toba Tek Singh districts. Psyllids nymphs and adults were counted with weekly intervals from February to May from 30 cm apical portions of shoots on four sides of each plant. Mean population of both adults and nymphs of Asian citrus psyllids was found higher at Sargodha than other two localities most probably due to prevailing agro-climatic conditions of Sargodha region which are favourable for citrus and, hence, for its insect pests. Average population (± SE) of psyllid nymphs and adults was recorded on Kinnow mandrin as 5.72 ± 0.95 and 5.33 ± 1.17 for Faisalabad, 12.28 ± 0.64 and 6.28 ± 0.63 for Sargodha and 8.06 ± 1.00 and 9.56 ± 0.77 for Toba Tek Singh, respectively. Likewise, average population (+ SE) of psyllid nymphs and adults on sweet orange was recorded as 17.67 ± 1.47 and 8.06 ± 1.21 for Faisalabad, 36.11 ± 2.06 and 16.28 ± 0.63 for sargodha and 13.17 ± 1.89 and 11.17 ± 1.32 for Toba Tek Singh, respectively. Average maximum population of Asian citrus psyllids was recorded in mid-February (34.5 ± 3.3 individuals twig^{-1}) and mid-May (38.5 ± 5.2 individuals twig^{-1}) and minimum in end February (16.3 ± 4.4 individuals twig^{-1}) and end March (17.2.5 ± 3.8 individuals twig^{-1}); on both citrus cultivars at all localities studied. Mean weekly temperature (R^2 value = 51.3) and relative humidity (R^2 value = 51.6) explained significantly psyllid population. Together the three abiotic weather factors explained approximately 69% of the Asian citrus psyllid population.

KEYWORDS: *Citrus sinensis*; *Citrus reticulata; Diaphorina citri*; population dynamics; temperature; relative humidity; regression models; Pakistan.

INTRODUCTION

Citrus fruits belong to family Rutaceae and are grown worldwide especially in tropical and subtropical climates. Citrus originate from the Himalayan region of Southern and North-Eastern India and adjacent China (Gnitter and Hu, 1990). Citrus fruits are rich source of many macro-nutrients such as nutritional fibres and simple carbohydrates and also provide many kinds of micro-nutrients containing vitamin B6, vitamin C, thiamin, pantothenic acid, riboflavin, calcium, potassium, magnesium, phosphorus and copper; which are essentially important for the maintenance of human health and growth (Anon, 2012; Economos and Clay, 1990).

Citrus fruit ranks first in production and area among total fruit trees in the world. In Pakistan, it is grown on an area of about 195,000 hectare with an annual production of 4.7 million tonnes (GoP, 2013-14). Its cultivation in province Punjab is about 95% (Sharif *et al.,* 2009), particularly Sargodha division is the hub of citrus (Iqbal and Hussain, 2009). Sweet orange (*Citrus sinensis*) and Kinnow mandarin (*Citrus reticulata*) are the most important and dominant citrus cultivars of this region. However, there is an enormous production gap between potential and average yield. This yield gap is due to a number of cultural and environmental factors and also due to a wide range of insect pests.

Citrus orchards in Punjab (Pakistan) are attacked by many species of insect pests and diseases which are very detrimental for the citrus industry (Iqbal *et al.,* 2009). A number of insect species attack the citrus fruits all over the world, but the most important ones are citrus leaf miner (*Phyllocnistis citrella* Stainton), citrus psyllid (*Diaphorina citri* Kuwayama), citrus caterpillar (*Papilio demoleus* Linnaeus), citrus whitefly (*Dialeurodes citri* Ashmead), citrus mealybug (*Pseudococcid and Planococcus* sp.), citrus fruit flies (*Bactrocera zonata* and *B. dorsalis* Saunders), citrus mite (*Paratetranychus* *citri* McGregor) and citrus red scale (*Aonidiella aurantii* Maskell). Among these, Asian citrus psyllids (*D. citri*) are the most damaging pests under agro-climatic conditions of Punjab. Citrus psyllids also act as carriers of the bacteria *Candidatus liberibacter asiaticus* that cause fatal citrus disease, known as citrus greening (CGD) or Huanglongbing (Halbert and Manjunath, 2005; Mahmood *et al.,* 2014).

Asian citrus psyllids (ACPs) are small sucking insect pests (2.7-3.3 mm long) with mottled brown body. Adults are very active and agile and move quickly by little disturbance. Oviposition and development of immature psyllids are restricted to young and tender leaves and growing shoots. ACP has five nymphal instars, which are yellowish-orange in colour (Liu and Tsai, 2000). These insect pests remain active from February to October with peak populations in spring and autumn seasons. However, spring population of ACPs is the most critical and damaging as this is the flowering and blooming period of citrus crop. Both adults and nymphs suck sap from the young foliage and leaves and tender shoots which in turn become yellowish with stunted growth and wither up. In case of severe attack, defoliation and premature fruit dropping occurs and these sucking insect pests can damage upto 50% to citrus crop if not controlled (Hall *et al.,* 2013).

Researchers all over the world are focusing on the ecology and behaviour of psyllids to determine the most susceptible and week stages in psyllid populations which can be exploited to control their infestation and transmission of Huanglongbing disease (Hall *et al.,* 2008 and 2013; Sharma, 2008). Thus, due to the dynamic nature of ACPs, extensive field surveys were undertaken to determine their population dynamics in relation to prevailing abiotic weather factors on sweet orange and Kinnow cultivars in central Punjab (Pakistan).

The basic aim of this study was to assess the different prevailing abiotic weather factors that can be the major determinants of psyllid populations on different citrus cultivars. A better comprehension of the impact of these weather factors on psyllids and of any or all relations among them is central for the development of a reliable pest management approach, primarily for the selection of suitable timing of pesticidal applications and management of Huanglongbing disease.

MATERIALS AND METHODS

This study was carried out in the Department of Entomology, University College of Agriculture, University of Sargodha, Sargodha, Pakistan during the year 2015 at three different citrus growing localities of the province of Punjab. Localities selected for this study included Faisalabad, Sargodha and Toba Tek Singh districts in the central Punjab. Sargodha locality (32°05'N and 72°40'E) included citrus orchards are situated in the surroundings of campus of College of Agriculture, University of Sargodha. Citrus orchards in Faisalabad locality (31°23'N and 72°59'E) are located in the vicinity of PARS (Postgraduate Agriculture Research Station) of the University of Agriculture, Faisalabad (Punjab, Pakistan), while Toba Tek Singh orchards (30°56'N and 72°27'E) are in Chak No. 296/ GB on Toba-Pirmahal Road.

At each locality, six citrus orchards (approx. 7- 9 years old) were selected randomly for each citrus cultivar. In each orchard, ten plants were randomly selected and tagged with red ribbons. Random sampling (pest scouting) was done from selected plants from 30 cm long apex portion of four branches, one on each of four sides of the plant. Nymphal and adult population of psyllids was counted carefully without disturbing the psyllids early in the morning (07:00 to 09:00 am). Population of psyllid nymphs and adults was counted with the help of a magnifying glass with minimum disturbance of the branches. Data were recorded at weekly intervals from February to May. The data regarding abiotic weather factors (i.e. temperature, relative humidity and rainfall) were obtained from the Meteorological Department of each locality for the entire period of pest scouting.

Adult and nymphal population of ACPs was determined at weekly intervals and the data were graphicaly represented to show trend of ACP population alongwith abiotic weather factors. The regression equations and models were worked out for exploring the relationship between weather factors i.e. temperature, rainfall and relative humidity, and ACP population. Analysis of data was done using STATISTICA (V 8.1) software.

RESULTS AND DISCUSSION

The data revealed that maximum population of Asian citrus psyllid adults and nymphs was found in the months of mid-February and mid-May both on sweet orange and Kinnow mandarin orchards in Faisalabad district, while the lowest psyllids population was recorded from end February to end March and mid-April (Fig. 1). Same population dynamics were also observed for Toba Tek Singh and Sargodha districts. (Fig. 2 and 3). These results are in line with the findings of Li *et al.* (1996) who found minimum citrus psyllids population in February and April and highest in March and May. In another study (Ahmed *et al.,* 2004), environmental factors exhibited barely any correlation with the population abundance of ACPs, while present results showed that mean weekly temperature was positively correlated with the population of Asian citrus psyllid adults and

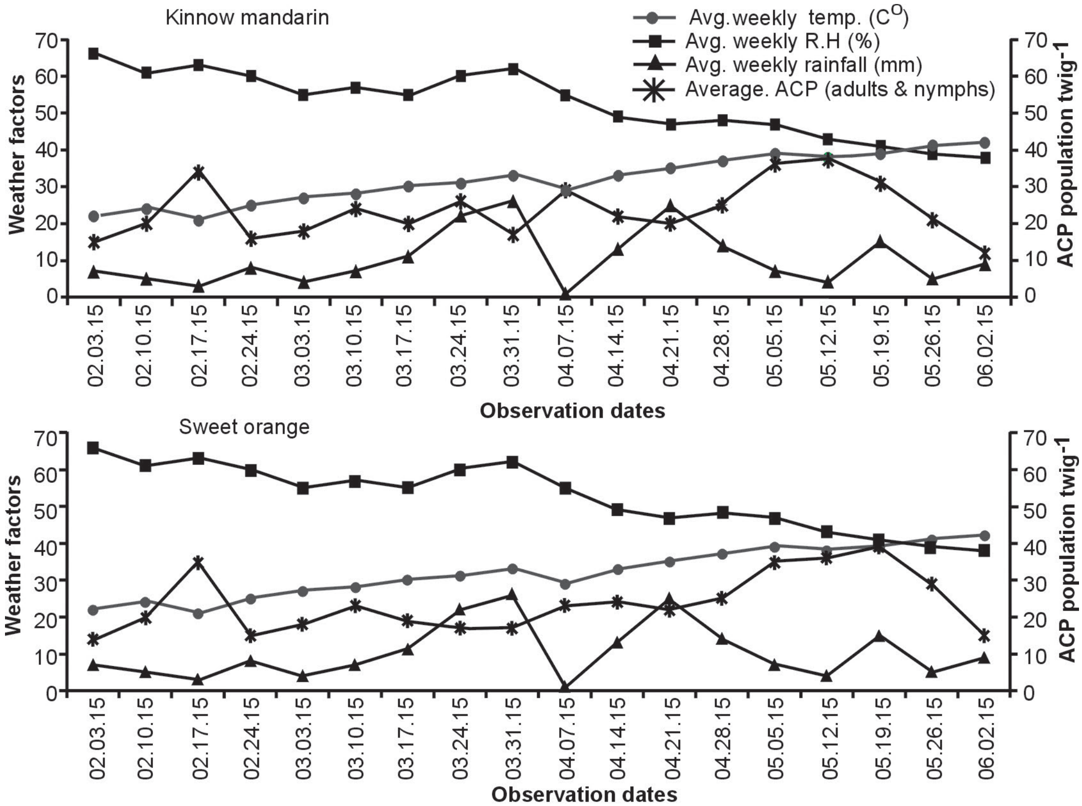

Fig. 1. Effect of abiotic weather factors on the population fluctuations of Asian citrus psyllid *Diaphorina citri* (Hemiptera: Psyllidae) in district Faisalabad.

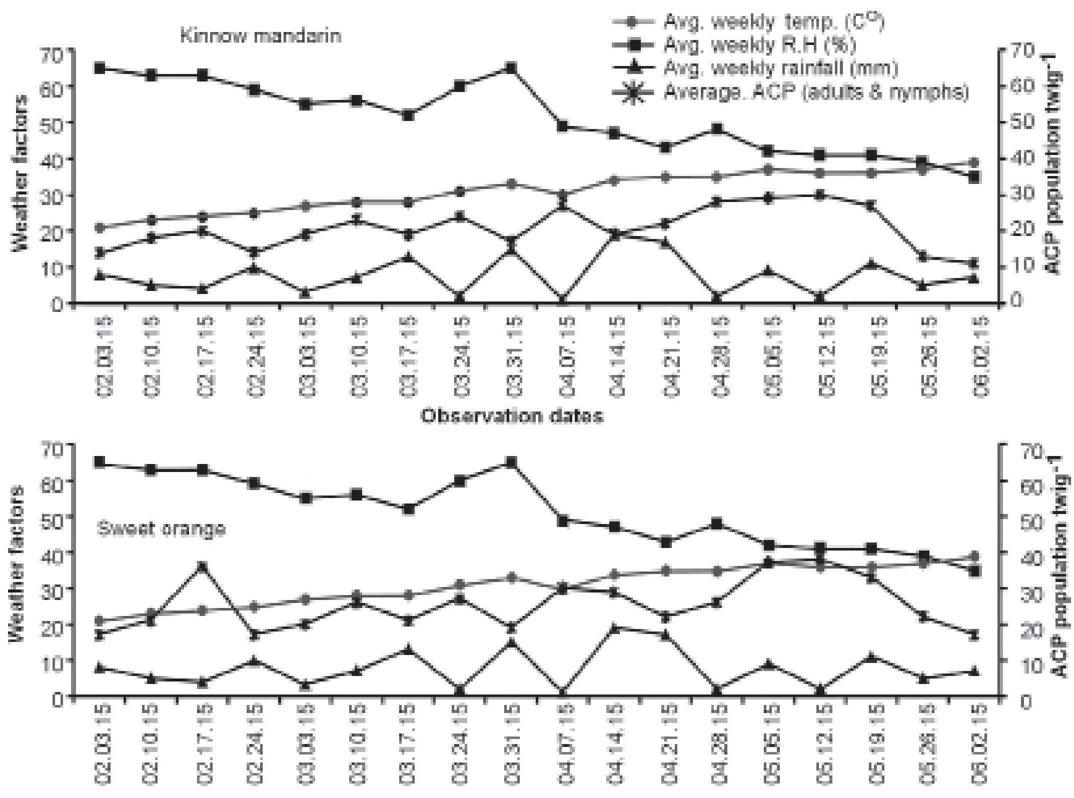

Fig. 2. Effect of abiotic weather factors on the population fluctuations of Asian citrus psyllid *Diaphorina citri* (Hemiptera: Psyllidae) in district Sargodha.

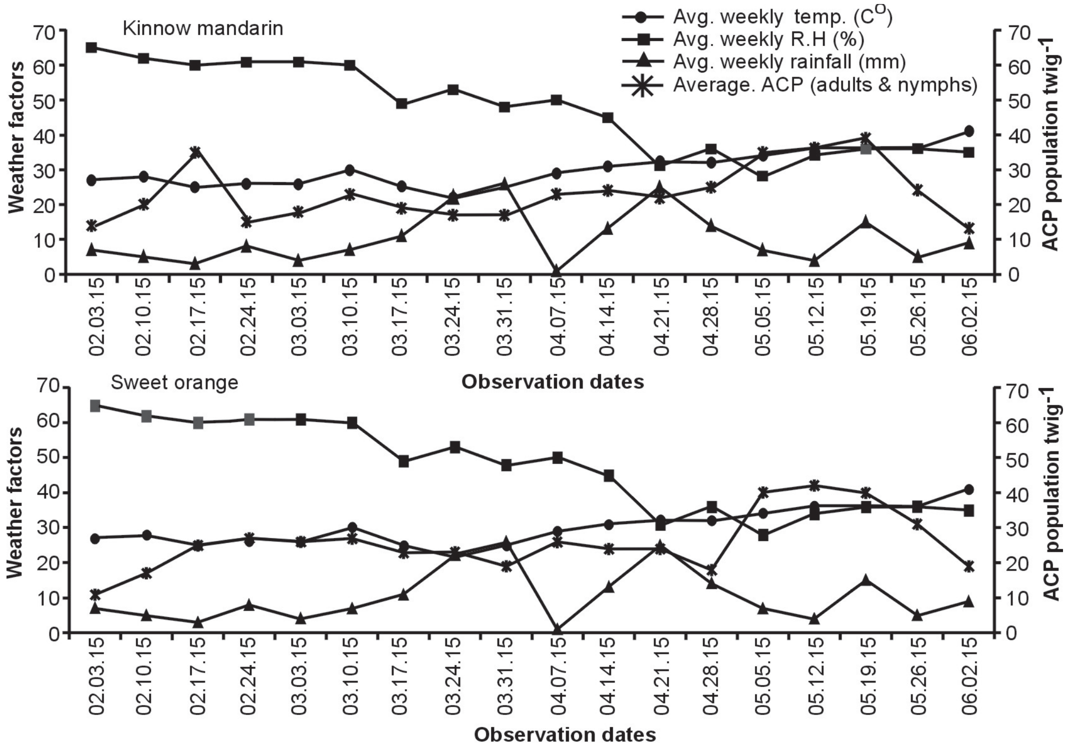

Fig. 3. Effect of abiotic weather factors on the population fluctuations of Asian citrus psyllid *Diaphorina citri* (Hemiptera: Psyllidae) in district Toba Tek Singh.

nymphs. It indicated that as temperature increased in the start of spring season, population of both adult and nymph psyllids also augmented. The increased incidence of rainfall during studied period might have triggered the growth of early sprouts of citrus plants resulting into a subsequent outbreak of ACPs, because the young sprouts and foliage of orchard tress are attractive and preferred sites for feeding and oviposition by citrus psyllids (Galo *et al.,* 2002). Grafton-Cardwell *et al.* (2013) described that under the tropical climate conditions, numerous generations of citrus psyllids can be observed throughout the whole year and their population development rates are affected by the prevailing weather and physiological conditions of the plants. As the optimal temperature for the development of ACPs ranges between 25 and 28°C (Liu and Tsai, 2000), excessively low temperatures in winter (below 3.0°C) and high temperatures in summer (above 32-34°C) would have impeded the development of ACPs as found in all three localities in this study (Fig. 1, 2 and 3).

Regression models indicate that temperature and relative humidity alone proved as the principal determinants of psyllids population fluctuations. Mean weekly temperature explained maximally with about 41, 52 and 64% adjusted R^2 values for district Faisalabad (Table 1), Sargodha (Table 2) and Toba Tek Singh (Table 3), respectively. Mean weekly relative humidity explained significantly but negatively the psyllids population with about 55, 59 and 41% adjusted R^2 values for district Faisalabad, Sargodha and Toba Tek Singh, respectively. Rainfall data were found negatively correlated with pest population as it disturbs the psyllid nymphs and adults directly by physical action and indirectly by enhancing other population suppressing factors such as diseases outbreaks (Avery *et al.,* 2011). Together the three abiotic weather factors explained approximately 69% of the Asian citrus psyllid population. These results clearly illustrate the dependence of Asian citrus psyllid populations on environmental factors, more particularly on weather factors.

Table. 1. Regression model for ACP population and abiotic weather factors on Kinnow mandarin and sweet orange in Faisalabad.

Parameters	Regression equation	R^2 value (%)	Adjusted R^2 value (%)
Avg. weekly temp. (c°)	ACP = -3.40+0.927 Temp.	44.6	41.1
Avg. weekly RH(%)	ACP = 67.7 -0.790 R.H	57.5	54.9
Avg. weekly rainfall (mm)	ACP = 30.0 -0.369 R.F.	9.1	3.5
Avg. weekly temp. (c°) + Avg. weekly RH(%)	ACP = 79.8-0.179 Temp.-0.912R.H.	57.8	52.2
Weekly temp. (c) + Avg. weekly RH (%) + Avg. weekly rainfall (mm)	ACP = 17.3+0.827 Temp. -0.222 R.H-0.560 R.F.	69.8	63.3

Table 2. Regression model for ACP population and abiotic weather factors on Kinnow mandarin and sweet orange in Sargodha.

Parameters	Regression equation	R^2 Value (%)	Adjusted R^2 value (%)
Avg. weekly temp. (C°)	ACP = -3.75+0.943 Temp	54.7	51.9
Avg. weekly RH(%)	ACP =54.3-0.561 R.H.	61.8	59.3
Avg. weekly rainfall (mm)	ACP = 28.8 – 0.420 R.F.	10.7	5.1
Avg. weekly temp (C°) + Avg. weekly RH (%) +	ACP = 36.0+0.330 Temp. -0.404 R.H.	63.5	58.7
Weekly temp. (C°) + Avg. weekly RH (%) + Avg. weekly rainfall (mm)	ACP = 29.8+0.533 Temp. -0.324 R.H. 0.537 R.F.	80.3	76.1

Table. 3. Regression model for ACP population and abiotic weather factors on Kinnow mandarin and sweet orange in Toba Tek Singh.

Parameters	Regression Equation	R^2 value (%)	Adjusted R^2 value (%)
Average weekly temperature (c°)	ACP = - 18.3 + 1.50 Temp	66.4	64.3
Average weekly RH (%)	ACP = 50.6 - 0.504 R.H.	44.8	41.4
Average weekly rainfall (mm)	ACP = 30.3-0.337 RF	7.3	1.5
Average weekly temp. (c°) + Average weekly RH	ACP =-7.7+1.31 Temp. -0.104 R.H.	67.3	62.9
Weekly temp. (c°)+Avg. weekly RH (%)+Avg. weekly rainfall (mm)	ACP = 22.1+0.809 Temp. -0.327 R.H -0.403 R.F.	73.6	67.9

Average population (±SE) of psyllid nymphs and adults on Kinnow mandarin was recorded as 5.72±0.95 and 5.33±1.17 for Faisalabad, 12.28±0.64 and 6.28±0.63 for Sargodha and 8.06±1.00 and 9.56±0.77 for Toba Tek Singh, respectively. Likewise, average population (±SE) of psyllid nyumphs and adults on sweet orange was recorded as 17.68±1.47 and 8.06±1.21 for Faisalabad, 36.11± 2.06 and 16.28+0.63 for Sargodha and 13.17±1.89 and 11.17±1.32 for Toba Tek Singh, respectively (Fig. 4). Similarly mean population of both adults and nymphs of Asian citrus psyllids remained higher on sweet orange (*Citrus sinensis)* than on Kinnow mandarin (*C. reticulata*) in all three localities (Fig. 4). Mean population of both adults and nymphs of Asian citrus psyllids was found higher in Sargodha than other two localities (Fig. 4). The reason for this trend might be due to prevailing agro-climatic conditions of Sargodha region which are more favuorable for citrus production and, hence, for its insect pests (Ahmed *et al.,* 2004).

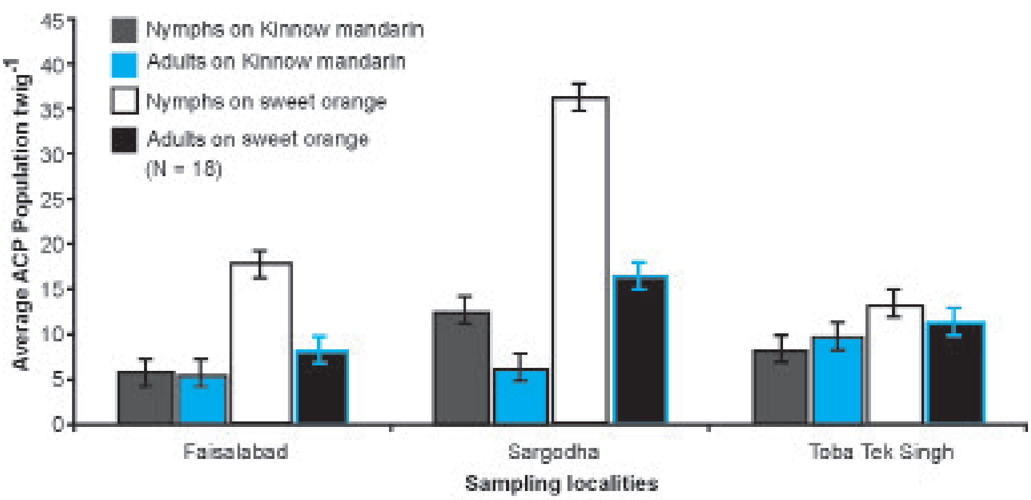

Fig. 4. Mean population of Asian citrus Psyllids (±SE) on Kinnow mandarin (*C. reticulata*) and sweet orange (*C. sinensis*) in three localities.

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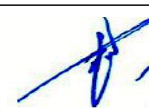
CONTRIBUTION OF AUTHORS

S. No.	Name of Author	Contribution of Author	Signatures
1.	Muhammad Fiaz	Performed experiments, analyzed data and prepared manuscript	
2.	Muhammad Afzal	Provided technical assistance in experimentation and proof read the manuscript	
3.	Muhammad Zeeshan Majeed	Conceived and designed the experimental protocols and performed statistical analysis