

Influence of Climate Factors on Population Density and Damage of Peach Twig Borer, *Anarsia lineatella* Zeller (Lep.: Gelechiidae), in Saman Orchards, Iran

Running title: Influence of climate factors on PTB

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ABSTRACT

The effect of climate factors on the population changes and damage of peach twig borer (PTB), *Anarsia lineatella* Zeller., was studied during 2007-2017 in Saman Orchards, Iran. Time series data of climate and pest population were subjected to the Mann-Kendall trend analysis. Seasonal flight of the pest was studied using pheromone traps from May to October. The percentage of infested twigs was calculated during May and September, while the percentage of infested fruits was determined twice a month from July to September. Results showed increasing trends in the mean temperature of annual, winter and autumn seasons (Kendall's statistics were 0.63, 0.49 and 0.42, respectively). Moreover, there were significant increasing trends in annual mean minimum, mean maximum and absolute minimum temperatures (0.53, 0.63 and 0.46, respectively). The number of annual and January frost days (-0.55 and -0.51, respectively) and mean relative humidity of Jun, July, August, September and October showed decreasing trend. PTB population and damage showed significant and increasing trends during the studied years. According to stepwise regression analysis the percentage of relative humidity, mean annual minimum temperature and mean annual temperature were the most statistically significant variables influencing the percentage of infested branches ($r = 0.94$, $r^2 = 0.88$, $F(3,6) = 14.40$, $P = 0.004$) and pest population ($r = 0.98$, $r^2 = 0.96$, $F(4, 5) = 3.18$, $P = 0.001$). The pest population and damage will increase under studied climate change scenarios (A1F, A1T, A1B, A2, B1 and B2) in the future, which is more significant in A1F than others.

Key words: *Anarsia*, Infestation, Seasonal flight, Climate scenarios, Trend analysis

INTRODUCTION

Peach twig borer [PTB], *Anarsia lineatella* Zell. (Lep.: Gelechiidae), is the most important pest in peach (*Prunus persicae* Batsch) orchards as well as other stone fruits such as almond, apricot,

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31 plum and nectarine (Mamy *et al.*, 2014). Larvae of the overwintering generation burrow into
32 developing shoots, while in subsequent generations, as twig tissue hardens, they cause
33 considerable losses in quantity and quality of the fruits (Roshandel, 2019). Studies showed that
34 climate factors (Temperature, precipitation, and humidity) are the most critical factors influencing
35 distribution and seasonal activity of the insects under field conditions (Ullah *et al.*, 2012; Bayu *et*
36 *al.*, 2017). Moreover, the population growth parameters of the insects and mites such as
37 developmental rate, reproduction, survival, and longevity vary with the climate factors (Riahi *et*
38 *al.*, 2013; El-Halawany and Abdel-wahed, 2013). According to Kocmánková *et al.*, (2010),
39 temperature is probably the most important environmental variable affecting population dynamics
40 of the insects.

41 Agricultural crops and their corresponding pests' population and damages are affected directly
42 and indirectly by changing in temperature and other climate factors (Skendzic *et al.*, 2021).
43 Climate factors directly influence the pests' life table parameters, whereas they indirectly affect
44 the relations between pests, host plants, environment, and other insect species (Prakash *et al.*,
45 2014). Liang and Elbakidze (2011) reported significant relationship between outbreak of the pests
46 and changes in the environmental factors. Various studies investigated the impact of climate
47 changes on the distributions, migration, population changes, and damage of insect pests such as
48 the onion thrips, *Thrips tabaci* Lindeman (Bergant *et al.*, 2005), Lepidoptera species (Sparks *et*
49 *al.*, 2007), the plain tiger, *Anosia chrysippus* L. (Sudan *et al.*, 2015), and the leopard moth, *Zeuzera*
50 *pyrina* L. (Fekrat and Farashi, 2022, Saeidi *et al.*, 2022 and 2023).

51 Considering the importance of the climate variables, this study was conducted to investigate the
52 effect of climate factors on the population changes and damage of PTB in Saman Orchards,
53 Chaharmahal va Bakhtiari Province, Iran. The results are helpful for predicting the pest population
54 in the future under different climate change scenarios and applying suitable tactics to reduce the
55 pest-induced crop losses and sustainable management of *A. lineatella* in peach orchards.

56 MATERIALS AND METHODS

57 Meteorological data

58 Meteorological data of the Saman Synoptic Station were obtained from the Iran Meteorological
59 Organization, Chaharmahal va Bakhtiari Province. The geographical coordinates of the studied
60 station were: latitude 32.44 N, longitude 50.87 E and altitude 2057 m. The studied climate
61

62 variables were: mean temperature of different months and seasons, annual mean temperature,
63 annual mean maximum temperature, annual mean minimum temperature, annual absolute
64 maximum temperature, annual absolute minimum temperature, annual relative humidity, annual
65 precipitation and the number of frost days per year.

67 **Seasonal activity of the pest**

68 Seasonal flight of the adults was studied during 2007-2017 using sex pheromone traps. Four
69 peach orchards with 5 km distances were selected. Peach trees were approximately 4-6 years old,
70 and planted at 3×4 m distances between and along the rows. No insecticide was applied on
71 experimental plots during the period of study. The pheromone dispensers, type of trap and
72 installation height were followed Roshandel (2019). The geographical coordinates of the studied
73 orchards and their distance from the Saman Synoptic Station were given in Table 1.

74 The traps were set up in the peach orchards from April 20 (before the emergence of adult males)
75 to October 30 (the end of the adults' flight) to monitor the pest population. In each orchard, four
76 sex pheromone traps were installed at 50 meters distance to avoid interference between them. All
77 traps were set at a height of 1.5-2 m above ground level and leaves and branches were removed
78 around their entrances. Pheromone traps were checked twice a week until the first capture of adults
79 and then once a week to record the number of captured moths. The pheromone lures and the sticky
80 sheets were replaced every 30 and 15 days, respectively.

81 82 **Twig infestation**

83 Twig damage was determined at the early spring (5th and 20th April and 5th of May) and early fall
84 (1st and 15th of October). For this purpose, in each orchard 10 trees were selected randomly and 10
85 random twigs, from different side of the tree at mid height, were examined and the infestation ratio
86 was calculated.

87 88 **Fruit infestation**

89 Percentage of infested fruits was determined twice a month from the July 5 to September 5
90 (harvesting time). Percentage of infested fruits was determined by examining 10 randomly selected
91 fruits from each tree (totally 10 trees were examined in each orchard) and recording the number of
92 infested and non-infested fruits.

93

94 **Prediction of the pest population changes under different climate change scenarios**

95 The population changes of PTB was estimated under six main scenarios (A1F, A1T, A1B, A2,
96 B1 and B2) defined by the Intergovernmental Panel on Climate Change (IPCC, 2007). These
97 scenarios are based on the emission of greenhouse gases and global warming in the future.
98 According to the IPCC, the temperature will increase at a rate of 0.4, 0.24, 0.28, 0.34, 0.18 and
99 0.24 °C per decade in A1F, A1T, A1B, A2, B1 and B2 scenarios, respectively. According to IPCC
100 (2007), the multi-model mean surface air temperature (SAT) warming and associated uncertainty
101 ranges for 2090 to 2099 relative to 1980 to 1999 are B1: +1.8°C (1.1°C to 2.9°C), B2: +2.4°C
102 (1.4°C to 3.8°C), A1B: +2.8°C (1.7°C to 4.4°C), A1T: 2.4°C (1.4°C to 3.8°C), A2: +3.4°C (2.0°C
103 to 5.4°C) and A1FI: +4.0°C (2.4°C to 6.4°C).

104 105 **Statistical analysis**

106 The Mann-Kendall trend test was run at 95% confidence level on time series data of both
107 climate and pest population for the **studied period**, 2007 to 2017. The null hypothesis H₀ (that
108 assumes there is no trend, in other word the data is independent and randomly ordered), was tested
109 against the alternative hypothesis H₁, which assumes there is a trend. If the **p-value** is less than the
110 significance level α ($\alpha = 0.05$), H₀ is rejected. Accepting H₀ **indicates no trend** while, rejecting
111 H₀ indicates a trend in the time series data (Kendall, 1975; Pohlert, 2016).

112 The software Addinsoft's XLSTAT 2018 was used for performing the statistical Mann-Kendall
113 test. Pearson's correlation coefficient was used to determine the effect of each climate variable on
114 the damage and population changes of PTB. Moreover, stepwise regression was used to find a set
115 of climate variables that significantly influence the population and damage of PTB in peach
116 orchards.

117 118 **RESULTS**

119 **Comparison of climate factors**

120 The average of annual mean temperature from 2007 to 2017 at Saman Synoptic Station was
121 calculated as $13.35 \pm 0.25^\circ\text{C}$, ranging from 11.69 to 14.95°C. Therefore the annual average
122 temperature in the hottest year (2016-17) increased by 2.67 °C compared to the coldest year (2012-
123 13) (Table 2). The same trend was observed in different months **especially**, in winter months.
124 January, February and March showed the highest increase (11, 7.4 and 5.8 °C, respectively) in
125 temperature in the hottest year compare to the coldest one (Table 2). The annual mean maximum

126 temperature from 2007 to 2017 was 20.56 ± 0.28 °C , ranging from 18.23 to 22.25 °C, whereas, the
127 annual mean minimum temperature was calculated 6.24 ± 0.35 °C with the lowest and highest values
128 of 2.95 and 7.62 °C, respectively (Table 2). The annual mean maximum and minimum
129 temperatures in the hottest year increased by 4.02 and 3.67 °C compared to the coldest year,
130 respectively (Table 2). The highest number of frost days was recorded during 2012-2013 growing
131 season (45 days) and the lowest was related to 2016-2017 (6 days). **The lowest** annual absolute
132 minimum temperature **(-21.8 °C)** corresponds to the year 2007-2008 and **the highest** (-6.8) to the
133 growing year 2016-2017 (Table 2). The annual rainfall from 2007 to 2017 ranged from 155.7 to
134 419.3 mm, with a mean of 279.4 ± 21.52 mm. The mean annual relative humidity was recorded as
135 34.73 ± 0.73 % with range 30.95 and 38.73 %, respectively (Table 2).

136

137 **Changes in the population of PTB**

138 Seasonal flight of the adults using pheromone traps indicated that PTB completed three
139 generations per year in peach orchards, Saman, Chaharmahal va Bakhtiari **Province, Iran**. Seasonal
140 flight of the adult moths was started **in May** and continued to the end of October with three distinct
141 peaks in the second decade of May, first decade of July and second decade of September. The
142 average number of moths caught (in each trap) in different growing years, has shown in table 3.
143 The lowest (521.39) and highest (1349.10 per trap) numbers of moths caught were observed in
144 2012-13 and 2016-17, respectively.

145 The mean percentage of infested twigs/ tree and infested fruits/ tree during the studied years were
146 calculated 12.95 ± 1.49 and $20.86 \pm 2.47\%$, respectively. The highest infested fruits (33.50%) and
147 infested twigs (20.90%) were observed in 2016-17, whereas the lowest (9.39% and 6.11%,
148 respectively) were observed in 2007-08 (Table 3).

149

150 **Trend analysis**

151 In the studied period, increasing trends were observed in the mean temperature of annual, winter
152 and autumn seasons (Kendall's statistics were, 0.63, 0.49 and 0.42, respectively), while the mean
153 temperature of summer and spring (0.27 and 0.20, respectively) showed no trend. Therefore,
154 among the seasons, **the most considerable warming** occurred in autumn and winter (Table 4). Mean
155 minimum temperature of annual, winter and autumn showed increasing trend (Kendall statistics
156 were 0.53, 0.60, and 0.46, respectively), whereas, there was no trend in mean minimum
157 temperatures of spring and summer seasons. Moreover, there were significant increasing trend in

158 annual (0.63) and autumn (0.42) mean maximum temperatures. Annual and winter absolute
159 minimum temperatures (0.46 and 0.45, respectively) showed significant increasing trend, whereas,
160 absolute maximum temperature of annual, autumn, winter and summer seasons (0.38, 0.44, 0.38
161 and 0.53, respectively) showed increasing trend. Among the studied months, the **highest increase**
162 occurred in January and February temperatures. The Kendall statistics for mean, minimum,
163 maximum, absolute minimum and absolute maximum temperatures of January were calculated as
164 0.56, 0.56, 0.42, 0.46 and 0.38, respectively (Table 4). The number of annual and January frost
165 days showed decreasing **trends** (Kendall statistics were -0.55 and -0.51, respectively) in the studied
166 period. Total precipitation of annual and different months showed no trend, whereas, there were
167 significant and decreasing trends in the mean relative humidity of Jun, July, August, September
168 and October (Kendall statistics were -0.63,-0.74, -0.64, -0.45 and -0.53, respectively)

169 PTB population and damage showed significant and increasing trend during the studied years.
170 The Kendall statistics for the pest population and damage in spring, summer, autumn and annual
171 were 0.68, 0.66, 0.63 and 0.67, respectively (Table 4). Moreover there was significant and
172 increasing trend in the pest population in the May, June, July, August, September and October
173 (Kendall statistics; 0.71, 0.68, 0.67, 0.68, 0.68 and 0.65, respectively).

174

175 **Relation between climate factors and population and damage of PTB**

176 stepwise regression analysis showed that among the different climate variables, the percentage
177 of relative humidity, mean annual minimum temperature and mean annual temperature were the
178 most statistically significant variables influencing the percentage of infested twigs ($r= 0.94$,
179 $r^2=0.88$, $F(3,6)= 14.40$, $P= 0.004$). Moreover, percentage of relative humidity, mean annual
180 minimum temperature, mean annual temperature and July mean temperature ($r= 0.98$, $r^2=0.96$, F
181 $(4, 5) = 3.18$, $P= 0.001$) most closely related to the number of trapped male moths, while the
182 percentage of infected fruits was most closely correlated with percentage of relative humidity ($r=$
183 0.65 , $r^2=0.43$, $F(1,8)= 5.91$, $P= 0.04$) (Table 5).

184 Linear regression models for prediction of the PTB population changes based on the time series
185 data of annual temperatures (mean, minimum, maximum, absolute minimum and absolute
186 maximum temperatures), number of annual frost days, annual precipitation and annual mean
187 relative humidity in Saman Region, Chaharmahal & Bakhtiari Province, were shown in the table
188 (6). Based on the results, the influence of annual mean, minimum and maximum temperatures

189 were statistically significant and positive; whereas the effect of annual frost days and annual
190 relative humidity were statistically significant and negative on PTB population changes (Figures
191 1 and 2).

192
193 **Prediction of pest population changes in the future under climate change scenarios**
194 Based on the climate change scenarios (IPCC 2007), the pest population changes were predicted
195 for the next 20, 40 and 50 years relative to 2017 (years; 2037, 2057 and 2067). Table (7) shows
196 the estimated population of the PTB using the regression model $y = 419.86x - 4903.55$ (population
197 changes to annual mean temperature). As the results show, by assuming the constant influence of
198 other biotic and abiotic factors, the pest population will increase under all tested scenarios, which
199 is greater under A1F compared than others.

200
201 **DISCUSSION**
202 Insects and mites life table parameters, distribution and seasonal activity significantly influence
203 by climate factors under field conditions (Petzoldt and Seaman, 2006; Ullah *et al.*, 2012; Bayu *et*
204 *al.*, 2017; Saeidi and Nemati, 2017 and 2020). Our results indicated that PTB population and
205 damage significantly affected by climate variables in Saman Orchards, Chaharmahal va Bakhtiari
206 Province, Iran. The pest population was significantly increased by increasing temperatures, while
207 decreased by increasing the percentage of relative humidity and number of frost days. The effect
208 of changes in temperature and humidity was reported on development and outbreak of many
209 agricultural pests such as spider mites (Mandal *et al.*, 2006; Ahmed *et al.*, 2012; Kumar *et al.*,
210 2015), bark beetles (Bentz *et al.*, 2010; Yihdego *et al.*, 2019), whiteflies (Pathania *et al.*, 2020),
211 *Thrips tabaci* (Bergant *et al.*, 2005), *Anosia chrysippus* (Sudan *et al.*, 2015) and Leopard moth,
212 *Zeuzera pyrina* L. (Saeidi *et al.*, 2023). Beside the direct impact, climate factors may indirectly
213 influence the pest population through changes in the physiology, existence of the host plants
214 (Prakash *et al.*, 2014) and decreasing of the secondary metabolites (Yihdego *et al.*, 2019).
215 Minimizing the environmental stress such as prolonged drought reported as one of the cultural
216 method to control of PTB in peach orchards (Roshandel *et al.*, 2022; Erhaft *et al.*, 2021) and wood
217 borers in the forest (Rauault *et al.*, 2006).

218 Trend analysis using Mann-Kendall method (Nicolson and Palao, 1993; Xu *et al.*, 2003; Pohlert,
219 2016) indicated significant trends in the studied climate factors during 2007-2017. Mean
220 temperatures of annual, different seasons and months showed significant and increasing trend,

221 whereas number of annual frost days and percentage of relative humidity indicated decreasing
222 trend. The phenomenon of climate change and increasing average temperature, or global warming,
223 is a serious threat to the future of human life. According to Pachauri and Reisinger (2007),
224 increase in greenhouse gases and climate changes is primarily due to human activities such as
225 development of industrial activities and transportation systems and it is expected the earth could
226 experience global warming of 1.4 to 5.8 °C over the next century. Our results indicated an
227 increasing trend in the temperature during the studied period (2007-2017) in Saman (Chaharmahal
228 va Bakhtiari Province) Meteorological Synoptic Station. According to Skendzick *et al.* (2021), one
229 of the most important consequences of climate change is the increase in temperature, which
230 ultimately affects other climatic phenomena and leads to changes in the agricultural pest
231 population. Global climate warming could trigger an expansion of insect geographic range,
232 increased overwintering survival, increased number of generations, increased risk of invasive
233 insect species and insect-transmitted plant diseases, as well as changes in their interaction with
234 host plants and natural enemies (Skendzick *et al.*, 2021).

235 Our results indicated significant and increasing trend in the mean minimum temperatures of
236 annual, winter and autumn seasons (especially January and February months) which may
237 significantly influence on the twig damage and number of emerging PTB adults in the first
238 generation. According to Hill (1987), winter is the most critical season for many insect pests, as
239 low temperatures significantly increase mortality and reduce their populations in the following
240 season. Pachauri and Reisinger (2007) indicated that global warming is most pronounced in
241 winter at high latitudes, therefore, insects that undergo a winter diapause are likely to experience
242 the most significant changes in their thermal environment (Bale and Hayward, 2013). Considering
243 that PTB overwinters in the form of the first to second instar larvae inside the twigs and shoots
244 (Roshandel *et al.*, 2022 ; Erhaft *et al.*, 2021), therefore low temperatures may kill the young larvae
245 in the soft, thin and none-woody branches and reduce the number of emerged PTB adults in the
246 spring generation. According to Erhaft *et al.*, (2021) the spring moth emergence (1st flight) started
247 from third decade of April and peaked on second decade of May. In another study Kujawski (2011)
248 reported the warmer winter reduces the mortality of the pests over-wintering stages, and as a result,
249 their population increase sharply in the next season. Based on the evidence obtained from fossils,
250 the insect species diversity and feeding intensity have a direct relationship with temperature
251 (Kujawski, 2011). Biological activities and the number of pest generations significantly affected

252 by rising temperature, therefore warmer March and April allow overwintering PTB larvae to start
253 their feeding in early spring and cause more damage. Erhaft *et al.*, (2021) reported that the
254 overwintered larvae started their feeding when the mean daily temperature increased to 10° C in
255 April. Moreover, increasing temperature (up to optimum) during spring and summer seasons
256 favors faster development and emerging of PTB adults. Previous studies showed the pest could
257 complete 2-4 generations depending on climate conditions. Studies have shown that PTB complete
258 three generations per year in Sanliurfa Province, Turkey (Mamay *et al.*, 2014), in Romania
259 (Iacob,1970) and Saman, Chaharmahal va Bakhtiari Province, Iran (Erhaft *et al.*, 2021), while two
260 generations in the Czech Republic (Kocourek *et al.*, 1996) and four generations in northern Utah,
261 USA (Alston and Murray, 2007).

262 As the results showed climate variables especially rising temperatures, decreasing the number of
263 frost days and reducing percentages of relative humidity strongly affect population and damage of
264 PTB in the peach orchards. Rising temperature not only affects the behavior, population dynamics,
265 distribution, growth and development, survival and reproduction of insects (Petzoldt and Seaman,
266 2006; Skendzic *et al.*, 2021), but also may increase the survival of overwintering stages of insects
267 at higher elevations, and lead to expansion of their geographic range (Pareek *et al.*, 2017).
268 Therefore, our findings are useful for predicting PTB population and damage in the future under
269 different climate change scenarios to reduce pest-induced crop losses using suitable integrated pest
270 management tactics. Applying of efficacious control methods such as pheromone traps (for
271 monitoring, mass trapping, or mating disruption), cultural techniques (removing infested twigs and
272 minimizing drought stress) and insecticides application (at the proper time and dosage) are
273 basically depend on our knowledge about changes in seasonal activity, population dynamic, and
274 distribution of PTB.

275

276 ACKNOWLEDGEMENTS

277 Financial support provided by the Agricultural and Natural Resources Research, Education &
278 Extension Organization, Iran is gratefully acknowledged.

279

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406 **Table 1.** Geographical coordinates of the studied orchards and their distance from Saman
 407 Synoptic Station, Chaharmahal Bakhtiari Province.

Orchard location	Geographical coordinates (latitude and longitude)	Altitude (m)	Distance from the station (km)
Shoorab	32.49 N, 50.95 E	1970	9
Cham khorram	32.47 N, 50.95 E	1641	5.5
Cham jangal	32.52 N, 50.85 E	1703	12
Cham chang	32.52 N, 50.09 E	2280	8.5

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 411 **Table 2.** Mean of different climate variables in Saman Synoptic Station, Chahrmahal & Bakhtiri
 412 Province, from 2007-2017

Climate variables	Mean	SE	Range
No. of frost days	67	3.7	19 - 89
Annual absolute minimum temperature	-12.69	1.63	(-21.8) – (-6.8)
Annual absolute maximum temperature	36.68	0.24	35.6 – 38.5
Annual mean maximum temperature	20.56	0.28	18.23 – 22.25
Annual mean minimum temperature	6.24	0.35	2.95 – 7.62
Annual mean temperature	13.35	0.27	11.69 – 14.95
Annual precipitation	279.4	21.52	155.7 – 419.3
Annual relative humidity	34.73	0.73	30.95– 38.73
January mean temperature	1.05	1.09	(-5.8) – 5.7
February mean temperature	2.42	0.67	(-0.8) – 7.1
March mean temperature	7.08	0.50	3.34 – 9.13
April mean temperature	10.63	0.41	8.44 – 13.35
May mean temperature	15.96	0.36	13.77 – 17.60
Jun mean temperature	21.45	0.36	19.20 – 22.94
July mean temperature	24.98	0.28	22.4 – 26.1
August mean temperature	24.09	0.52	19.5 – 26.3
September mean temperature	21.42	0.31	18.75 – 22.92
October mean temperature	16.95	0.27	15.16 – 18.26
July mean temperature	10.39	0.48	7.80 – 13.19
July mean temperature	4.28	0.39	1.75 – 6.82
Autumn mean temperature	10.35	0.27	8.6 – 11.8
Winter mean temperature	3.44	0.6	(-0.6) – 6.7
Spring mean temperature	16.02	0.28	14.2 – 17.6
Summer mean temperature	23.59	0.35	20.2 – 24.9

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Table 3. Mean number of moths caught (in each trap), the percentage of infected twigs/tree and percentage of infected fruits/tree during the studied years 2007-2017, in Saman Orchards, Iran.

Growing year	Moth population	Infected twigs%	Infected fruits%
2007-08	407.11	6.11	9.39
2008-09	454.08	6.82	10.47
2009-10	548.03	8.23	12.64
2010-11	782.90	11.75	18.05
2011-12	860.30	14.15	27.00
2012-13	521.40	9.85	16.15
2013-14	782.90	15.45	24.05
2014-15	938.50	17.25	27.45
2015-16	1173.10	18.95	29.95
2016-17	1349.10	20.90	33.50
Mean	781.74	12.95	20.86
SD	295.96	4.93	8.19
SE	89.41	1.49	2.47

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Table 4. Mann-Kendall trend analysis on time series data of climate variables in different months and peach twig borer population for the time period 2007 to 2017

Climate variable	Kendall's tau/Trend	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Winter	Spring	Summer	Autumn	Annual
Mean temperature	Kendall's tau	0.56**	0.31	-	0.20	0.309	0.13	0.05	0.16	0.34	0.34	0.31	0.34	0.42*	0.27	0.20	0.49**	0.63**
	Trend	IT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	IT	NT	NT	IT	IT
Minimum temperature	Kendall's tau	0.56*	0.42*	0.13	0.24	0.24	0.16	0.20	0.05	0.34	0.42	0.38	0.23	0.46*	0.20	0.055	0.60**	0.53**
	Trend	IT	IT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	IT	NT	NT	IT	IT
Maximum temperature	Kendall's tau	0.42*	0.34	-0.12	0.16	0.309	0.09	0.20	0.055	0.45*	0.24	0.20	0.27	0.31	0.24	0.24	0.42*	0.63**
	Trend	IT	NT	NT	NT	NT	NT	NT	NT	IT	NT	NT	NT	NT	NT	NT	IT	IT
No. frost days	Kendall's tau	-	-0.31	-0.02	---	---	---	---	---	---	---	---	-	-0.55**	---	---	-0.019	-0.55**
	Trend	DT	NT	NT	---	---	---	---	---	---	---	---	NT	DT	---	---	NT	DT
Absolut minimum temperature	Kendall's tau	0.46*	0.42*	-0.34	-	-0.12	-0.15	0.018	0.09-	0.17	0.22	-0.13	0.12	0.45*	-0.16	0.17	0.12	0.46*
	Trend	IT	IT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	IT	NT	NT	NT	IT
Absolut maximum temperature	Kendall's tau	0.38*	0.16	-0.22	0.37	0.17	-0.07	0.09	0.53**	0.05-	0.44*	0.43*	0.33	0.38*	-0.07	0.53**	0.44*	0.38*
	Trend	IT	NT	NT	NT	NT	NT	NT	IT	NT	NT	NT	NT	IT	NT	IT	IT	IT
Total precipitation	Kendall's tau	0.27	-0.09	-	0.01	0.24	-0.26	0.18	-0.28	-0.18	0.08	-0.20	-	-0.05	-0.01	0.07	-0.20	-0.63**
	Trend	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	DT
Relative humidity%	Kendall's tau	-0.27	-0.42*	0.31	0.09	-0.20	-	-	-0.64**	-0.45*	-	-0.31	-	0.23	-0.38	-0.71**	-0.27	-0.49*
	Trend	NT	DT	NT	NT	NT	DT	DT	DT	DT	DT	NT	NT	NT	NT	DT	NT	DT
PTB population	Kendall's tau	---	---	---	---	0.71**	0.68**	0.67**	0.68**	0.68**	0.65**	---	---	---	0.68**	0.66**	0.63**	0.67**
	Trend	---	--	--	---	IT	IT	IT	IT	IT	IT	--	---	---	IT	IT	IT	IT

* and ** statistically significant at 5 and 1% probability level
 IT, DT and NT, Increasing trend, Decreasing trend and No trend, respectively

Table 5. Stepwise regression analysis for determine the most statistically significant climate variables influencing the percentage of infested twigs, percentage of infected fruits and PTB population in Saman Orchards, Iran.

PTB population and damage	Variables Entered	Model	R ²	Mean square	F	Significant level
Percentage of infested twigs	of percentage of relative humidity, mean annual minimum temperature and mean annual temperature	$y = 186.38 - 1.94 x_1 + 9.21 x_2 - 12.26 x_3$	0.88	71.18	14.40	0.004
Percentage of infected fruits	of percentage of relative humidity	$y = 78.79 - 1.69 x_1$	0.43	285.05	5.91	0.04
PTB population	percentage of relative humidity, mean annual minimum temperature, mean annual temperature and July mean temperature	$y = 13280.75 - 116.36 x_1 + 681.13 x_2 - 811.12 x_3 - 77.99 x_4$	0.97	266162.22	20.62	0.001

y= pest population and x= climate variable

x₁, x₂, x₃ and x₄ are percentage of relative humidity, mean annual minimum temperature, mean annual temperature and July mean temperature, respectively.

1 **Table 6.** Linear regression models for prediction of peach twig borer population in relation to
 2 climate variables, in Saman Orchards, Iran (y= Pest population and x= Climate variable).

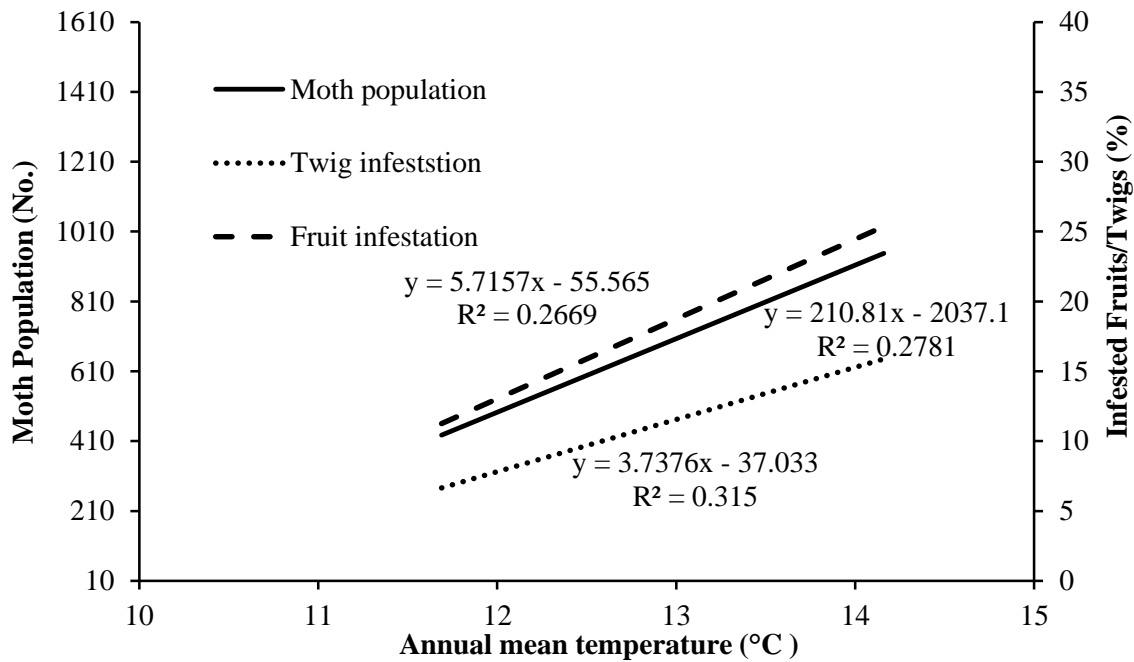
Climate variable	Model	R ²	Mean square	F	Significant level
Mean temperature	y= 419.86 x - 4903.55 **	0.77	344079.4	16.42	0.01
Minimum temperature	y= 463.37 x -2262.86 *	0.52	235213.06	5.50	0.05
Maximum temperature	y= 354.79 x - 6505.38 **	0.85	382826.03	28.98	0.003
No. frost days	y= -16.1 x +1195.82*	0.56	252908.12	6.45	0.05
Absolut minimum temperature	y= 11.69 x + 482.81	0.004	1813.11	0.02	0.89
Absolut maximum temperature	y= 46.47 x +1376.67*	0.45	205061.58	4.20	0.09
Total precipitation	y= -2.30 x + 1559.19	0.28	125775.68	1.94	0.22
Relative humidity%	y= -57.90 x + 2863.23*	0.56	251038.84	6.34	0.05

3 * and ** significant at 5 and 1% level, respectively

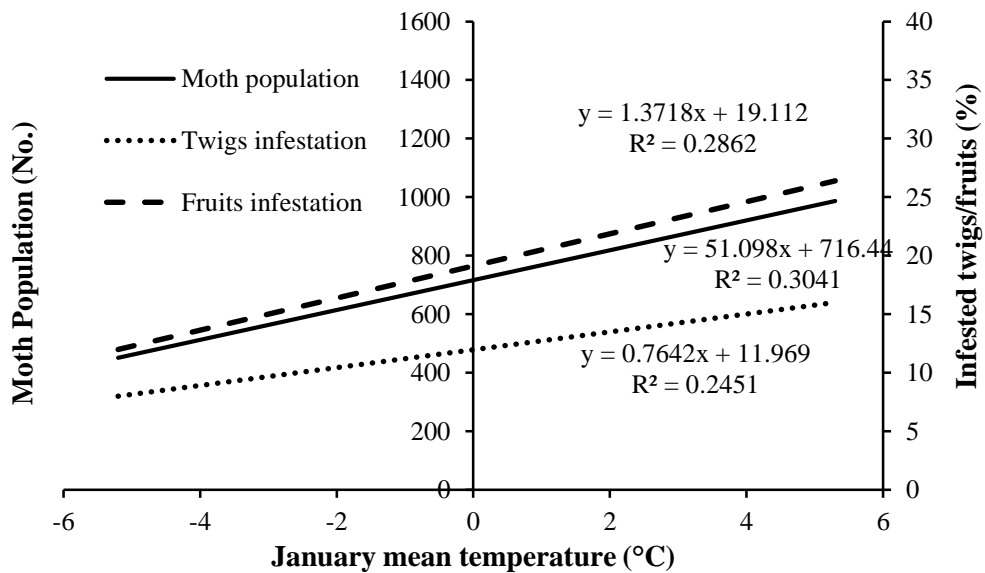
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 5 **Table 7.** Prediction of peach twig borer population changes (no. moth/trap/year) in the future
 6 under different climate change scenarios for the next 20, 40 and 50 years relative to 2017.

Scenario	Increasing temperature/ decade	Increasing temperature for the PTB population increase for the next					
		20 years	40 years	50 years	20 years	40 years	50 years
A1F	0.4	15.51	16.31	16.71	1608.479	1944.367	2112.311
A1T	0.24	15.19	15.67	15.91	1474.123	1675.656	1776.423
A1B	0.28	15.27	15.83	16.11	1507.712	1742.834	1860.395
A2	0.34	15.39	16.07	16.41	1558.095	1843.6	1986.353
B1	0.18	15.07	15.43	15.61	1423.74	1574.89	1650.465
B2	0.24	15.19	15.67	15.91	1474.123	1675.656	1776.423

7 y= 419.86x-4903.55, mean annual temperature in 2017= 14.71



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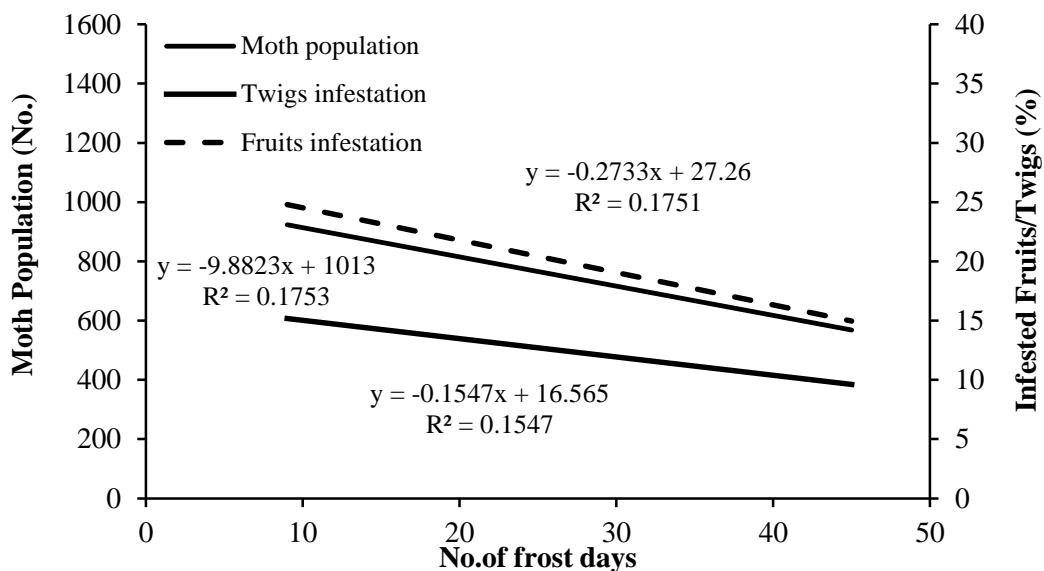


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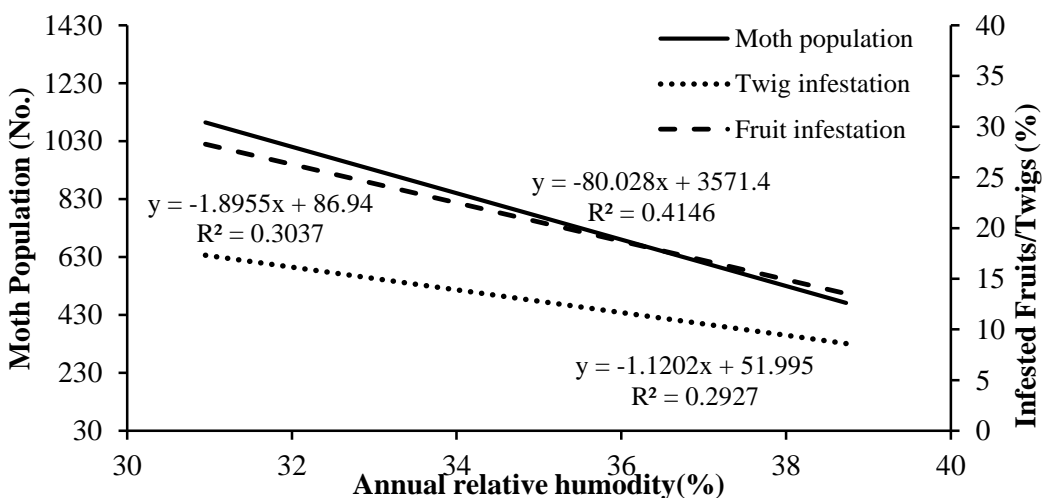
16 **Figure 1.** Relation between annual and January mean temperatures and PTB population and
 17 damage in Saman Orchards, Iran.

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Figure 2. Relation of number of frost days and annual relative humidity with PTB population and damage in Saman Orchards, Iran.

تأثیر عوامل اقلیمی بر تراکم جمعیت و خسارت کرم سرشاخه‌خوار هلو، *Anarsia lineatella* Zeller Lep.،
(Gelechiidae)، در باغ‌های سامان، ایران

زریر سعیدی

چکیده

تأثیر عوامل اقلیمی بر تغییرات جمعیت و خسارت کرم سرشاخه‌خوار هلو، *Anarsia lineatella* Zeller، طی سال‌های
1386 تا 1396 در باغ‌های شهرستان سامان (ایران) مورد بررسی قرار گرفت. داده‌های سری زمانی اقلیمی و جمعیت آفت
تحت تجزیه و تحلیل روند Mann-Kendall قرار گرفتند. پرواز فصلی آفت با استفاده از تله‌های فرمونی از اردیبهشت تا

33 مهر بررسی شد. درصد سرشاخه‌های آلوده در اردیبهشت و شهریور محاسبه شد، در حالی که درصد میوه‌های آلوده به صورت
34 دو بار در ماه از تیر تا شهریور تعیین شد. نتایج نشان دهنده روند افزایشی در میانگین دمای سالانه، زمستان و پاییز بود (آمار
35 کندال به ترتیب 0/63، 0/49 و 0/42 بود). همچنین روند افزایشی معنی داری در دماهای میانگین حداقل، میانگین حداکثر و
36 حداقل مطلق سالانه (به ترتیب 0/53، 0/63 و 0/46) مشاهده شد. تعداد روزهای یخبندان سالانه و دی‌ماه (به ترتیب 0/55-
37 و 0/51-) و میانگین رطوبت نسبی خرداد، تیر، مرداد، شهریور و مهر روند کاهشی را نشان دادند. جمعیت و
38 خسارت سرشاخه‌خوار هلو در طول سال‌های مورد مطالعه روند افزایشی و معنی داری را نشان داد. بر اساس تحلیل رگرسیون
39 گام به گام، درصد رطوبت نسبی، میانگین دمای حداقل سالانه و میانگین دمای سالانه از نظر آماری معنی‌دارترین متغیرهای
40 تأثیرگذار بر درصد شاخه‌های آلوده ($r=0/94$ ، $r^2=0/88$ ، $F(3,6)= 14/40$ ، $P= 0/004$) و جمعیت آفت ($P= 0/001$)،
41 $r=0/98$ ، $r^2=0/96$ ، $F(3,6)= 3/18$) بودند. جمعیت و خسارت آفت تحت سناریوهای تغییر اقلیم مورد مطالعه (A1F،
42 A1T، A1B، A2، B1 و B2) در آینده افزایش خواهد یافت، که این افزایش در سناریوی A1F نسبت به سایرین بیشتر
43 است.
44