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# Ecological studies of California red scale, *Aonidiella aurantii* (Hemiptera: Diaspididae) infested *Citrus sinensis* in Giza Governorate

**Omaima, A. Balboul and Samah, M. Y. Helmy**

*Scale Insects and Mealybugs Research Department, Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt.*

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**Abstract:**

The California red scale, *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) is considered a key pest of citrus that has spread during the last decades up to cover a vast extension of agricultural landscapes. It was detected in *Citrus sinensis* var. balady of a private orchard located at El-Saff, area, Giza Governorate. During two years 2014 and 2015, *A. aurantii* population dynamics and seasonal trends were studied on this *Citrus* variety. The results indicated that, population of *A. aurantii* recorded three activity peaks of abundance and three overlaping generations/year. In the first year of study three peaks of infestation were recorded in mid-May, mid-August and October first, while in the second year, these peaks were observed during May first, August first and October first. The first generation of first year started from February first till the mid- May. The second generation was extended from mid-May till the mid-August, third generation was indicated on mid -August till the mid- December. *A. aurantii* showed the same trend with the second year and had three generations. The duration of the first one was extended from mid-January to May first and the second generation lasted from May first to August first, while the third generation from August first till mid-December. The calculated infestation rates of *A. aurantii* were high in summer, spring and autumn months, whereas, relatively low rate of infestation were recorded with winter months in both years. There was positive significant relationship between metrological factors and the total population of *A. aurantii* and a simultaneous occurrence of the total population of *A. aurantii*, while relative humidity relations was negative in first season and positive in the second season but insignificant in both.

## Introduction

Citrus come second only to grapes in planting production of fruit trees worldwide (Spiegel-Roy and Goldschmidt, 1996) and the most important fruit crops in Egypt. Its plantations reached nearly 395.731 feddans producing 3.730.685 tons in Egypt, according to the 2011 statistics of the

Egyptian Ministry of Agriculture, The California red scale *Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae) is one of most important pests infested citrus trees in different parts of the world (Karaca, 1998; Claps *et al*., 2001 and Abd-Rabou, 2009). This pest instars its mouthparts deep into plant tissue and sucks sap from parenchyma cells. Prolonged infestation may cause leaf drop and defilation and dieback of twigs and eventually large branches. Maturing fruit can become completely encrusted with scales; developing scales form prominent pits on young fruit which are still evident when the fruit matures. Such fruit tend to dry out and fall off. Even the trunk can become heavily infested (Bedford, 1998). Considerable differences in the population densities of this pest were recorded in different parts of the world Selim,1993 and Morsi,1999 in Egypt; Yarpuzlu *et al*. (2008) in Turkey and Kaiju (2013) in Youxi county of Fujian province, Chinese.

The present study was conducted throughout two successive seasons from early January, 2014 till December, 2015. The scope of the study included the seasonal changes in the population densities of the California red scale, *A. aurantii* on *C. sinensis* var. balady in private orchard located at El-Saff area, Giza Governorate, duration and number of generations under the field conditions as well as the effect of daily means of temperature and relative humidity on its activity to select an effective program for its control.

## Materials and methods

### 1. Location and sampling;

The present work was carried out on *C. sinensis* of private orchard (called Shaarany orchard) located at El-Saff area, Giza Governorate for two year extending from early January, 2014 until December,2015. The selected orchard received the normal agricultural practices without application any control measures before and during the period of study. Ten trees were selected at the grove infested with *A. aurantii* Selected trees were approximately similar in size, shape, height and vegetation. Samples were picked up at two-week intervals throughout the study. Samples size was 20 leaves representing cardinal directions (east-west-north-south) and tree core. The samples were packed in polyethylene bags with minute holes then transferred directly to the laboratory for examination, using stereoscopic microscope binocular.

### 2.Meteorological data:

To reveal the relation between climatic condition and fluctuation of *A. aurantii* population, means of daily temperature, relative humidity and wind at Giza Governorate were obtained from the Meteorological Station of the Agricultural Research Center, Egypt and the half monthly mean was calculated.

### 3.Statistical analysis:

All parameters concerning *A. aurantii* population density on balady orange trees were reduced to three-specific means and these means were used in statistical analysis. All data were evaluated statistically using ANOVA and means compared using Duncan's Multiple Range Test at $P<0.05$). The relationship between the population density of *A. aurantii* and both temperature (Maximum and minimum temperature) and relative humidity (R.H.) were tested using simple correlation and multiple regression analysis. All statistical analyses were done using the software package Costat (Costat, 2005).

## Results and discussion

### 1.General trend of population fluctuation of *Aonidiella aurantii* on *Citrus sinensis* trees:

Results represented in Table (1) and illustrated in Figure (1) showed the half monthly means of nymphs and adults (females) and total population density of *A. aurantii* infesting *C. sinensis* var. balady in Giza Governorate during 2014 year. Density of *A. aurantii* nymphs on citrus trees was low during January, February and

March then began to increase gradually to form a small significant peak on May first (888 nymphs/20 leaves/tree), then two large approximately equal peaks on August first (1854 nymphs/20 leaves/tree) and the beginning of October (1960 nymphs/20 leaves/tree). Also, three peaks of adult females were observed on mid-May (621 adult females /20 leaves/tree), mid-August (1387 adult females/20 leaves) and mid-October (1550 adult females /20 leaves/tree).

Overall combined numbers of individuals (Nymphs and adult females) on balady citrus leaves indicated that activity of *A. aurantii* extended from February to November with a small activity peak on May first (1239 individuals/ 20 leaves/tree), peak of intermediate population density during mid-August (2725 individuals /20 leaves/tree) and the large peak on mid-October (3075 individuals /20 leaves/tree).

Results of the second year of investigation (2015) as represented in Table (1) and Figure (2) showed that general population trends, number of peaks of nymphs and adult females of *A. aurantii* were similar to those in the previous year, (2014). Density of *A. aurantii* nymphs on citrus leaves have significant peak on May first (634 nymphs/20 leaves/tree) and two large peaks on mid-July (1094 nymphs/20 leaves/tree) and mid-September (1570 nymphs/20 leaves/tree). The three peaks of adult females were observed on May first (475 adult females/20 leaves/tree), August first (919 adult females/20 leaves/tree), and mid-October (1189 adult females /20 leaves/tree).

**Table (1): Half monthly mean counts of** *Aonidiella aurantii* **of different stages, on** ***Citrus sinensis*** **trees during two years 2014 and 2015.**

| Date of inspection | Mean number of individuals/20 leaves | | | | | | Temp. | | | | R.H. % | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | | | 2015 | | | 2014 | | 2015 | | | |
| | Nymph | Adult | Total | Nymph | Adult | Total | Max. | Min. | Max. | Min. | 2014 | 2015 |
| 01-Jan | 107 | 160 | 267 | 125 | 158 | 283 | 18.6 | 10.2 | 20.06 | 11.5 | 68 | 56.44 |
| 15-Jan | 84 | 104 | 188 | 91 | 124 | 215 | 21 | 11.06 | 15.07 | 8.6 | 50.06 | 51.47 |
| 01-Feb | 60 | 57 | 117 | 88 | 30 | 118 | 19.73 | 10.53 | 20.19 | 11.25 | 60.2 | 49.31 |
| 15-Feb | 148 | 42 | 190 | 96 | 43 | 139 | 21.38 | 11.69 | 19.73 | 10.6 | 62.15 | 42.33 |
| 01-Mar | 197 | 83 | 280 | 126 | 101 | 227 | 23.2 | 13.87 | 18.62 | 9.77 | 44.87 | 57.77 |
| 15-Mar | 240 | 126 | 366 | 181 | 136 | 317 | 24.56 | 13.63 | 23 | 13.2 | 53.31 | 58.73 |
| 01-Apr | 330 | 178 | 508 | 297 | 191 | 488 | 26.6 | 14.73 | 24.44 | 13.25 | 46.13 | 48.44 |
| 15-Apr | 481 | 300 | 781 | 514 | 247 | 761 | 30.33 | 17.8 | 24.33 | 14 | 45.87 | 48.27 |
| 01-May | 888 | 351 | 1239 | 634 | 475 | 1109 | 30.33 | 19.87 | 28 | 15.27 | 40.53 | 41.53 |
| 15-May | 578 | 621 | 1199 | 448 | 410 | 858 | 32.19 | 20.13 | 29.2 | 17.33 | 44.5 | 50.27 |
| 01-Jun | 498 | 410 | 908 | 369 | 319 | 688 | 32.19 | 20.13 | 33.63 | 20.19 | 44.5 | 41.56 |
| 15-Jun | 466 | 325 | 791 | 502 | 398 | 900 | 32.67 | 21.47 | 31.27 | 20.4 | 45 | 51.47 |
| 01-Jul | 537 | 297 | 834 | 777 | 509 | 1286 | 35.13 | 22.53 | 33.07 | 22.4 | 44.87 | 47.87 |
| 15-Jul | 1090 | 368 | 1458 | 1094 | 757 | 1851 | 34.8 | 23.13 | 32.67 | 22.4 | 53.2 | 55.4 |
| 01-Aug | 1854 | 512 | 2366 | 906 | 919 | 1825 | 33.63 | 23.44 | 35.94 | 23.81 | 54 | 49 |
| 15-Aug | 1338 | 1387 | 2725 | 697 | 520 | 1217 | 34.67 | 24.27 | 37.27 | 26.73 | 53.13 | 47.8 |
| 01-Sep | 1150 | 909 | 2059 | 803 | 593 | 1396 | 35.44 | 24.56 | 35 | 25.31 | 56.13 | 56.19 |
| 15-Sep | 1519 | 835 | 2354 | 1138 | 684 | 1822 | 33.73 | 23.87 | 35.13 | 24.4 | 51.87 | 57.87 |
| 01-Oct | 1960 | 780 | 2740 | 1570 | 895 | 2465 | 33.13 | 22.93 | 35.47 | 24.87 | 49.73 | 44.53 |
| 15-Oct | 1525 | 1550 | 3075 | 727 | 1189 | 1916 | 29.73 | 19.07 | 31.6 | 21.93 | 55.4 | 58.2 |
| 01-Nov | 1053 | 1104 | 2157 | 488 | 816 | 1304 | 28.19 | 19.06 | 29.63 | 20.25 | 51.13 | 58.38 |
| 15-Nov | 992 | 810 | 1802 | 318 | 378 | 696 | 26.2 | 16.53 | 25.53 | 16.67 | 53.6 | 68.47 |
| 01-Dec | 515 | 527 | 1042 | 274 | 300 | 574 | 22.13 | 14.2 | 24.6 | 15.33 | 64.6 | 59.73 |
| 15-Dec | 273 | 408 | 681 | 139 | 199 | 338 | 23.47 | 13.73 | 19.93 | 11.33 | 57.53 | 63.8 |
| Total | 17883 | 12244 | 30127 | 12402 | 10391 | 22793 | | | | | | |
| Average | 745.1 | 510.2 | 1255 | 516.8 | 433 | 949.7 | 28.46 | 18.02 | 27.64 | 17.53 | 52.1 | 52.7 |

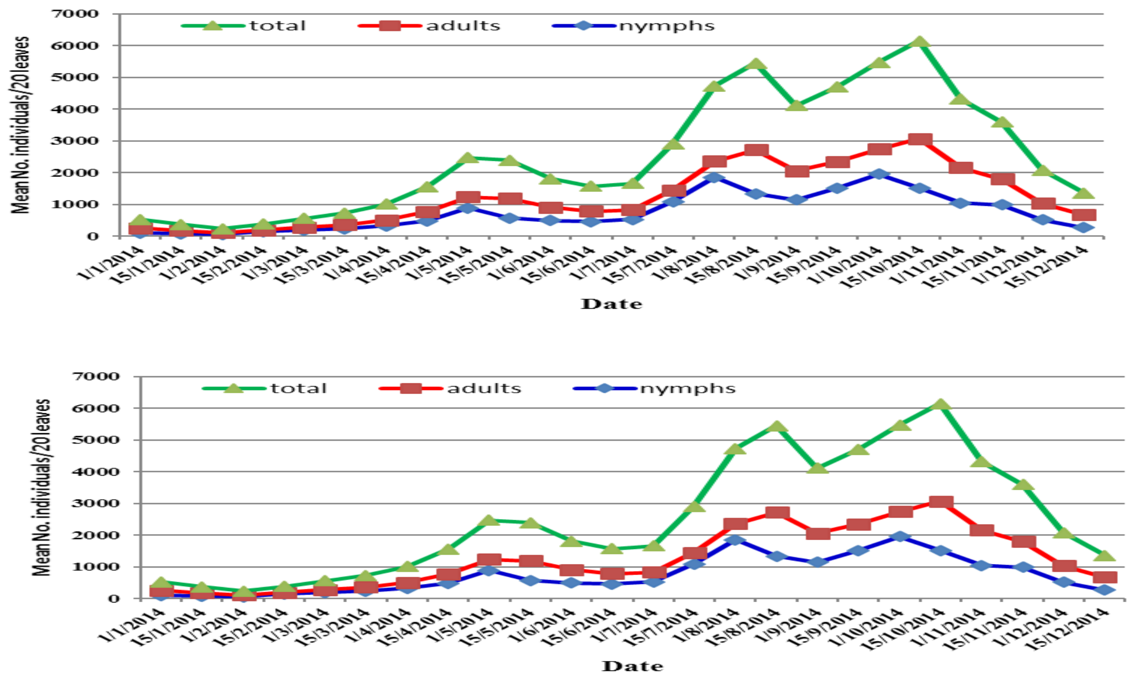


**Figure (1): Half monthly mean counts of *Aonidiella aurantii* of different stages on *Citrus sinensis* trees during the first year (2014).**

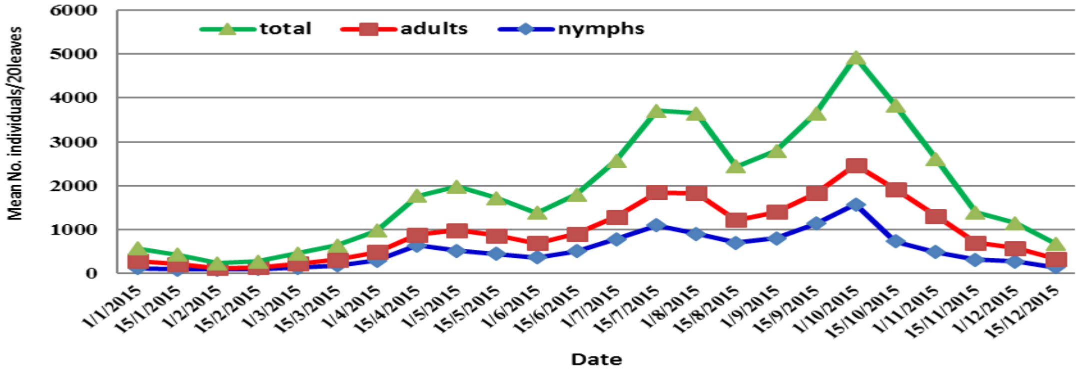


**Figure (2): Half monthly mean counts of *Aonidiella aurantii* of different stages on *Citrus sinensis* trees during the second year (2015).**

The total numbers of individuals (nymphs and adult females) on citrus leaves indicated that activity of *A. aurantii* extended from February to December with three activity peaks on May first (1109 individuals/20 leaves/tree), mid-July (1851 individuals/20leaves/ tree) and October first (2465 individuals /20 leaves/tree). Generally, the obtained results in the first and second year of study showed that, the insect population reached maximum during August in the two years, while it highest population level recorded in October. The pest population reached its minimum level in winter during mid-January and February first in the two seasons.

These results are consistent with that obtained by Selim (2014) stated that population of *A. aurantii* had three annual peaks on Balady orange during the two successive seasons at Giza governorate and four peaks on Succari orange. The obtained results of Farghaly *et al* .(2016) showed that, during the first season of investigation, *A. Aurantii* had three peaks of nymphs representing overlapping generations per season, which occurred in the first and second years (2011/2012 and 2012/2013). The 1$^{st}$ peak appeared in March, the 2$^{nd}$

peak was observed in June while, the 3rd peak was in Oct. The first peak of crawlers is observed around the end of May, the second at the end of August and the third around November depending on the climatic conditions (Ripollés, 1990; Rodrigo and García-Marí, 1992). From September 2009 to August 2010, *A. aurantii* was able to produce 3 important peaks, one in the autumn, the second one in the winter season, third one in the spring and the fourth one in the summer period (Belguendouz-Benkhelfa *et al*., 2013).

**2.Number and duration of annual field generations:**

The number of generations of *A. aurantii* under the field conditions was taken from the annual number of peaks of nymphs. The number of annual generations of *A. aurantii* during the two years on citrus trees is graphically illustrated in Figures (3 and 4). *A. aurantii* had three overlapping generations (Figure, 3); the first generation took about three months and half, started from 1st of February till the mid of May 2014 (the maximum number of nymphs occurred on the mid of May). Duration of the second generation was nearly three months (extended from mid of May till the mid of August), its peak was indicated on 1st of August. Third generation was indicated on mid of August till the mid of December. Its peak was recorded on 1st October. This means that both first and second generations continued over 90 days each compared with the third generation which continued for 120 days.

As for the results of the second year 2015 (Figure, 4); *A. aurantii* showed the same trend and had three generations. The duration of the first one was about three months and half (extended from mid of January to 1st of May) its peak attained on the 1st of May. The second generation lasted for about three months from 1st of May to 1st of August, with the peak on the mid July. The third generation took about four months and half (from 1st of August till mid December) its peak was evident in 1st October.

Selim (2014) concluded that California red scale insect had three generations per year during February-May, April-August and August-December. While in the second year, these generations were during March-June, May-October and October-March. These results were agreed with Habib *et al*. (1972); Selim (1993) and Morsi (1999) in Egypt, who found that this insect had 3-4 generations per year on citrus, Yarpuzlu *et al*. (2008) in Turkey, Kaiju (2013) in Youxi county of Fujian province, Chinese, mentioned that three generations of red scale may develop annually on citrus. Rizk *et al*. (1978) stated that *A. aurantii* have five annual generations in Middle Egypt. Moustafa (1992) reported that the california red scale have 3-4 generations which varied according to host and zone of trees.

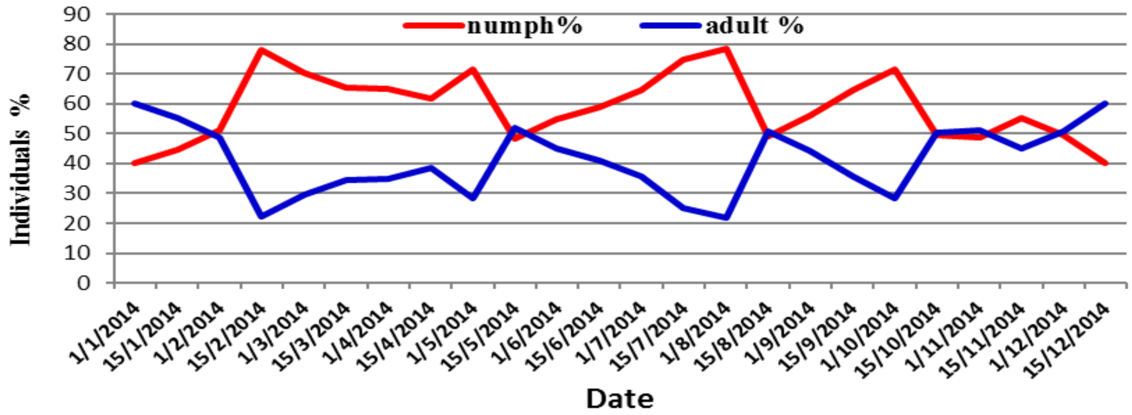


**Figure (3): Annual generations and their durations of** *Aonidiella aurantii* **on *Citrus sinensis* trees, at Giza Governorate during the first year (2014).**

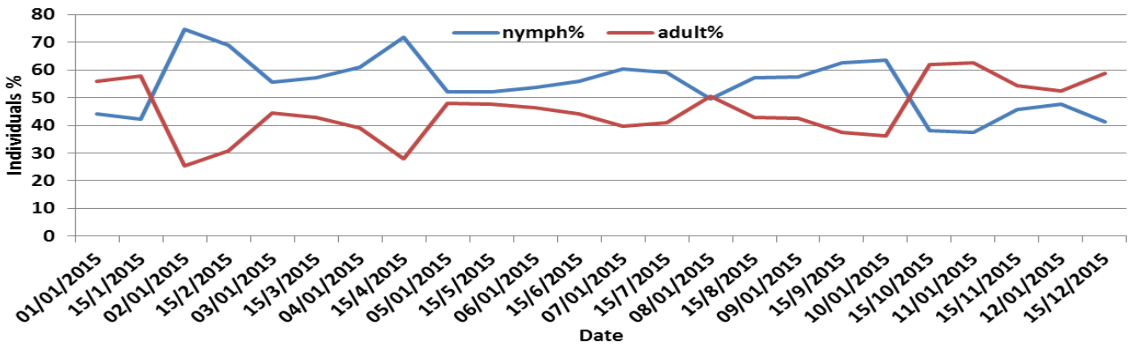


**Figure (4): Annual generations and their durations of *Aonidiella aurantii* on *Citrus sinensis* trees, at Giza, Governorate during the second year (2015).**

### 3.Effect of prevailing hygrothermic conditions on the population densities of *Aonidiella aurantii*:

The measured relationships between the population densities of *A. aurantii* and the main weather factors (Maximum and minimum temperatures and relative humidity) were studied during two studied years, (2014-2015) in Giza governorate as in Table (2).

#### 3.1. Effect of daily maximum temperature:

Results in the Table (2) showed that, there are positive significant correlation between the total insect population activity and maximum temperature (r=0.658 and 0.845) in both years, (2014-2015). The partial regression coefficient value (P.reg= 23.56 and 18.74) showed highly positive significant in the two years.

#### 3.2. Effect of the night minimum temperature:

The effect of minimum temperature on the total population during two years of study (Table, 2) indicated highly positive significant correlation during the two years (r=0.842and 0.872) respectively. The single effect of this factor on the total population activity appeared from (P.reg = 13.51and 10.93) which was positive significant effect.

#### 3.3. Effect of daily mean relative humidity:

Daily mean relative humidity (Table, 2) had negative relation, insignificant on the total population (r = -0.047) in 1st year but positive relation insignificant (r = 0.083). The single effect of this factor on the total population activity appeared from the partial regression coefficient value (P.reg = 52.54 and 53.53) which was positive insignificant effect in both years.

#### 3.4. The combined effect of daily mean temperature and humidity: -

The combined effect of climatic factors on California red scale, *A. aurantii* during the two years of study (Table, 2) was significant (F=14.193 and 9.110) and the explained variance (E.V) presented (68% and 57.7%) during the two years of study. In general, the population densities of *A. aurantii* depend on the temperature and relative humidity. According to (Abdelrahman, 1974), low temperatures are the most determinant factor for the abundance and distribution of the scale *A. aurantii* and the duration of the life-cycle of *A. aurantii* increases under the influence of low temperatures. El-Shouny (1987) stated that winter low temperature plays a great role in population reduction during winter and produces the greatest mortality in this respect. Population increases are observed under conditions of low humidity when temperatures are below 30oC and high humidity when temperatures are higher (McLaren, 1971). According to Bodenheimer (1951), optimum conditions for the development of the scale are temperatures between 23 and 27.5$^{o}$C and 70 – 80% de R.H.

**Table (2): Effect of both temperature and relative humidity on Aonidiella aurantii total population on citrus leaves at Giza Governorate, Egypt during the two studied years (2014-2015).**

| Statistical Parameters | First year (2014) | | | Second year (2015) | | |
|---|---|---|---|---|---|---|
| | Temperature | | R.H.% | Temperature | | R.H.% |
| | Tmax. | Tmin. | | Tmax. | Tmin. | |
| **Simple correlation** | | | | | | |
| Corr.Coef. (r) | 0.658 ±0.16 | 0.842±0.12 | -0.047±2.13 | 0.845±0.11 | 0.872 ±0.10 | 0.083±0.21 |
| Probability(p) | < 0.0005 | < 0.0001 | 0.8287 | 0.0001 | 0.0001 | 0.7005 |
| Correlation significant | Yes | Yes | No | Yes | Yes | No |
| **Partial Regression** | | | | | | |
| Partial Regres. Coef (b) | 23.56± 3.06 | 13.51± 2.34 | 52.54 ± 5.17 | 18.74±2.68 | 10.93 ± 2.12 | 53.53± 5.38 |
| Regression Coefficient $r^2$ | 0.433 | 0.563 | 0.002 | 0.714 | 0.761 | 0.007 |
| F-value | 16.8 | 28.363 | 0.048 | 55.02 | 69.935 | 0.152 |
| Probability (p) | < 0.0005 | < 0.0001 | 0.8287 | 0.0001 | 0.0001 | 0.7005 |
| Regression significant | Yes | Yes | No | Yes | Yes | No |
| **Combined factors** | | | | | | |
| *E.V* (Explained variance) | 68 | | | 57.7 | | |

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