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# Effect of elevated $CO_2$ and temperature on life-table parameters of maize aphid, *Rhopalosiphum maidis* (Fitch) (Aphididae: Hemiptera) on maize, *Zea mays* (Linn.)

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**Abstract**
The objective of this study was to examine the life table parameters of maize aphid, *Rhopalosiphum maidis* (Aphididae: Hemiptera) at elevated and ambient concentrations of $CO_2$ (550 and 380ppm $\pm$ 25 ppm, respectively) at six temperatures (20, 25, 27, 30, 33 and 35 °C) for understanding the population dynamics of insect pests. The life table parameters of *R. maidis viz*., intrinsic rate of increase ($r_m$), finite rate of increase ($\lambda$), net reproductive rate ($R_o$) and gross reproductive rate (GRR) were increased with increase in temperatures from 20 °C to 27 °C further declining from 30 °C to 35 °C under both ambient and elevated $CO_2$ conditions. Generation time (T) was reduced with an increase of temperature from 20 °C to 35 °C. The upper temperature threshold for $r_m$, $\lambda$, $R_o$, GRR and T required 26.6, 30.1, 24.9, 25.0 and 34.6 ºC under *e*$CO_2$ conditions whereas it was 29.8, 30.5, 25.7, 25.4 and 34.9ºC under *a*$CO_2$ conditions, respectively. The increased $r_m$, $\lambda$, $R_o$, GRR and decreased T showed the non-linear relationship and can be used for the status of future insect populations.

**Keywords:** *Rhopalosiphum maidis*, upper temperature threshold, life table, non-linear relationship and population dynamics

## Introduction
Corn leaf aphid *Rhopalosiphum maidis* (Fitch.) (Aphididae: Hemiptera), a sap-sucking homopteran insect is the largest group of phloem feeding insect. It is a polyphagous species occurring worldwide on sorghum, barley and wheat besides maize [7]. It is now distributed worldwide in the tropics and warmer temperate regions [1]. Aphids cause mechanical harm and malnutrition to plants by the removal of phloem sap.

Agriculture is one of the most vulnerable sectors to the anticipated climate change with an adverse effect on crop yields. The increased levels of atmospheric $CO_2$ concentrations can have a direct effect on the growth rate of crop plants. Temperature has a direct influence on insect activity, rate of development and also plants. The predicted changes in temperature and $CO_2$ concentration affect the population dynamics and the status of insect pests of various crops. Plants with $C_4$ photosynthesis will respond little to rising atmospheric $CO_2$ because a mechanism to increase the concentration of $CO_2$ in leaves causes $CO_2$ saturation of photosynthesis at ambient conditions. Numerous studies have shown that the annual average temperature of the earth will increase 1 °C by 2025 and the probable rise in temperature by the end of the century is expected to reach 3 °C [8]. The parameters associated with life table are crucial for understanding population growth potential and for establishing effective management tactics to pest control in general because they provide information on development, reproduction and mortality of a pest population [5].

So far, there is no published report from India on the effect of *e*$CO_2$ and six different temperatures on *R. maidis*. Hence, in the present study, life table parameters of *R. maidis* were examined at two levels of $CO_2$ and six different temperatures to estimate the temperature thresholds which would be useful in status of the pest populations.

## Materials and methods
### Maintenance of *Rhopalosiphum maidis* culture
The corn leaf aphids, *R. maidis* were collected from the field and maintained at an optimum temperature of 27 ± 1 ºC and 75 ± 5% RH in the insectary of Entomology section, CRIDA,

Hyderabad. The nymphs and adults were reared individually in petridishes (110 X 10 mm) to obtain bulk population for experiments. Light intensity of 30, 000 Lx was provided by 26 W florescent bulb inside the chambers during the 14 hours light period with a relative humidity of 60% (day) and 70% (night). Light illumination is provided through fluorescent lamps horizontally mounted in pairs above each shelf. Air circulation inside the chamber was maintained from a specifically designed air diffuser. The period of light, $CO_2$ concentrations and temperature levels were automatically monitored and controlled using Intellus Ultra Controller. The maize plants (DHM-117) and insects were maintained in open top chambers (OTC) and $CO_2$ growth chambers under respective set conditions at elevated and ambient concentrations of $CO_2$ (550 and 380ppm $\pm$ 25 ppm, respectively) at six temperatures of 20, 25, 27, 30, 33 and 35$\pm$1 ºC. Fully grown foliage (30 days after sowing) obtained from respective treatments was used for feeding trials and leaf quality analysis. The crop was maintained at insecticide free condition throughout the experiment to understand the impact of *e*$CO_2$ and temperature on insect pests.

Experiments on life-tables of *R. maidis* were conducted by adopting cut leaf method at elevated and ambient concentrations of $CO_2$ (550 and 380ppm $\pm$ 25 ppm, respectively) at six temperatures of 20, 25, 27, 30, 33 and 35$\pm$1ºC and a photoperiod of 14L: 10D. The cut corn leaf (6x6 cm) from the top of corn seedlings of 1-2 months old was detached and placed in a petridish with a moist cotton swab on one side of the leaf margin. The cotton swabs were moistened daily to keep the leaf fresh and the leaves were changed on alternate days. In order to construct life-tables, newly hatched 50 first instar nymphs were collected carefully from the stock culture with the help of wet camel hair brush and transferred individually into each petridish containing maize leaves obtained from respective set conditions with 50 replications per each treatment. Each nymph was examined daily and the life-table parameters *viz*., Intrinsic rate of increase ($r_m$), Finite rate of increase ($\lambda$), Net reproductive rate ($R_o$), Gross reproductive rate (GRR) and Mean generation time (T) were calculated and analyzed based on the age-stage, two sex life table model.

**Calculation of life table parameters**

TWOSEX MS Chart software [2] was adopted for calculating various life table parameters using the raw data of insect stages. The theory of age-stage, two-sex life table was implied while analyzing the raw life history data of *R. maidis*. For life table analysis, Bootstrap method, a user-friendly computer program was used to calculate the age-stage specific survival rate (sxj, where x = age and j = stage), the age-stage specific fecundity (fxj: number of eggs produced at each age), the age-specific survival rate (lx) and the age specific fecundity (mx: eggs produced per surviving individual at each age o fecundity).

**Results and Discussion**

**Effect of *e*$CO_2$ and temperature on life table parameters of *R. maidis***

The life table parameters were significantly affected by the interactive effect of *e*$CO_2$ and temperatures. The results pertaining to the life table parameters of *R. maidis viz*., intrinsic rate of increase ($r_m$), finite rate of increase ($\lambda$), net reproductive rate ($R_o$), gross reproductive rate (GRR) and mean generation time (T) were varying at elevated and ambient concentrations of $CO_2$ (550 and 380ppm $\pm$ 25 ppm, respectively) at six temperatures of 20, 25, 27, 30, 33 and 35$\pm$1 ºC (Table 1).

Intrinsic rate of increase ($r_m$) indicates the rate of progeny production per female per day. The $r_m$ of *R. maidis* significantly varied among the two levels of $CO_2$ and six different temperatures. The $r_m$ of *R. maidis* was 0.2749, 0.4235, 0.4693, 0.4630, 0.3433 and 0.099 day$^{-1}$ under *e*$CO_2$ conditions whereas it was 0.2083, 0.297, 0.3644, 0.3485, 0.2425 and 0.057 day$^{-1}$ under *a*$CO_2$ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. Finite rate of increase ($\lambda$) indicates the number of individuals added to the population per head per unit time or number of births per female per day. The $\lambda$ of *R. maidis* was 1.316, 1.527, 1.599, 1.589, 1.409 and 1.104 day$^{-1}$ under *e*$CO_2$ conditions whereas it was 1.231, 1.347, 1.439, 1.417, 1.274 and 1.059 day$^{-1}$ under *a*$CO_2$ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. Net reproductive rate ($R_o$) indicates number of times that the population would multiply by the end of each generation. The $R_o$ of *R. maidis* under *e*$CO_2$ was 44.38, 65.28, 75.42, 36.74, 7.42 and 1.68 nymphs per female whereas it was 36.68, 54.00, 60.36, 22.78, 4.60 and 1.38 nymphs per female under *a*$CO_2$ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. The GRR of *R. maidis* under *e*$CO_2$ was 45.62, 66.89, 76.68, 39.35, 9.66 and 3.32 nymphs per female whereas it was 37.85, 56.77, 63.68, 25.46, 6.54 and 2.76 nymphs per female under *a*$CO_2$ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. The mean generation time (T) indicates the time required to complete a generation. The T of *R. maidis* under *e*$CO_2$ was 13.79, 9.87, 9.21, 7.78, 5.84 and 5.22 days whereas the T was 17.29, 13.39, 11.25, 8.97, 6.29 and 5.57 days under *a*$CO_2$ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. The increased $r_m$, $\lambda$, $R_o$, GRR with increase in temperatures from 20 °C to 27 °C but declined with further increase in temperature and the T was decreased with increase in temperatures from 20 °C to 35 °C.

The present life table parameters of *R. maidis* were in conformity with the findings of [8], who reported that the $r_m$, $\lambda$ and $R_o$ of groundnut aphid, *Aphis craccivora* was increased with increase in temperature from 20 °C-27°C and later started declining from 30 °C-35 °C. The $R_o$ was higher at 27 °C temperature by recording 84.23 nymphs per female at *e*$CO_2$. The reduction of T was evident from 13.41 days at 20 °C to minimum of 5.91 days at 35 °C and followed the non-linear trend at *e*$CO_2$. The results are in agreement with the findings of [10], who reported that the *R. maidis* fed on barley leaves had the highest $r_m$, $R_o$ and reduced T under the *e*$CO_2$ and temperatures and concluded that the interactive effect of both *e*$CO_2$ and temperatures on aphid biology may exacerbate aphid damage on barley leaves. Similar results were observed by [3], who reported that the soybean aphid, *Aphis glycines* had the highest finite rate of increase and intrinsic rate of increase at 27 °C (2.128 and 0.533 day$^{-1}$) than at 22 °C (1.897 and 0.445 day$^{-1}$) due to greater proportion of the offspring produced when compared to 22 °C.

**Effect of *e*$CO_2$ and temperature on non-linear relationship and upper temperature thresholds of *R. maidis* on maize**

The non-linear models developed at *e*$CO_2$ and *a*$CO_2$ conditions across the temperatures for life table parameters *viz.*, $r_m$, $\lambda$, $R_o$, GRR and T were depicted in Figure 1a and 1b.

The non-linear trend was observed at *e*$CO_2$ which are as follows ($r_m = -0.005x^2 + 0.266x - 3.086$, $R^2$=0.915), ($\lambda = -0.006x^2 + 0.366x - 3.311$, $R^2$=0.931), ($R_o = -0.722x^2 + 36.08x$

- 385.5, $R^2$=0.888), (GRR = -0.782$x^2$ – 36.48x – 389.8) and (T= 0.032$x^2$ - 2.219x + 43.31, $R^2$=0.993) and similar non-linear trend was observed ($r_m$ = -0.004$x^2$ + 0.239x - 2.892, $R^2$=0.934), (λ = -0.005$x^2$ + 0.301x - 2.665, $R^2$=0.940) ($R_o$ = -0.675$x^2$ + 34.79x - 399.0, $R^2$=0.809), (GRR = -0.653$x^2$ + 33.27x – 370.8) and (T = 0.045$x^2$ - 3.147x + 67.83, $R^2$=0.998) at $aCO_2$ and temperatures, respectively (Table 1). The best fit quadratic form of equation with higher $R^2$ (0.915 and 0.934) at $eCO_2$ and $aCO_2$ was noticed between $r_m$ and temperature. Other parameters *viz.*, $R_o$ (0.888 and 0.809), λ (0.931 and 0.940), GRR (0.895 and 0.825) and T (0.993 and 0.998) followed the similar trend under both $eCO_2$ and $aCO_2$ conditions across the temperatures. The upper temperature threshold for $r_m$, λ, $R_o$, GRR and T required 26.6, 30.1, 24.9, 25.0 and 34.6ºC under $eCO_2$ conditions whereas it was 29.8, 30.5, 25.7, 25.4 and 34.9 ºC under $aCO_2$ conditions, respectively.

Similar non-linear trend was noticed by [4] at $eCO_2$ compared to that of $aCO_2$ conditions. Similar observations of Increased $R_o$ and reduction of T were reported in case of *Myzus persicae* [6] and *R. maidis* on barley leaves [10]. The present results indicated that the association between $CO_2$, temperature and life table parameters was non-linear and were best fit. Many empirical models by incorporating $r_m$ as a key parameter were used for prediction of population dynamics of insect pests. Temperature-driven phenology models developed using laboratory information can be used for projection of status of future insect population [9].

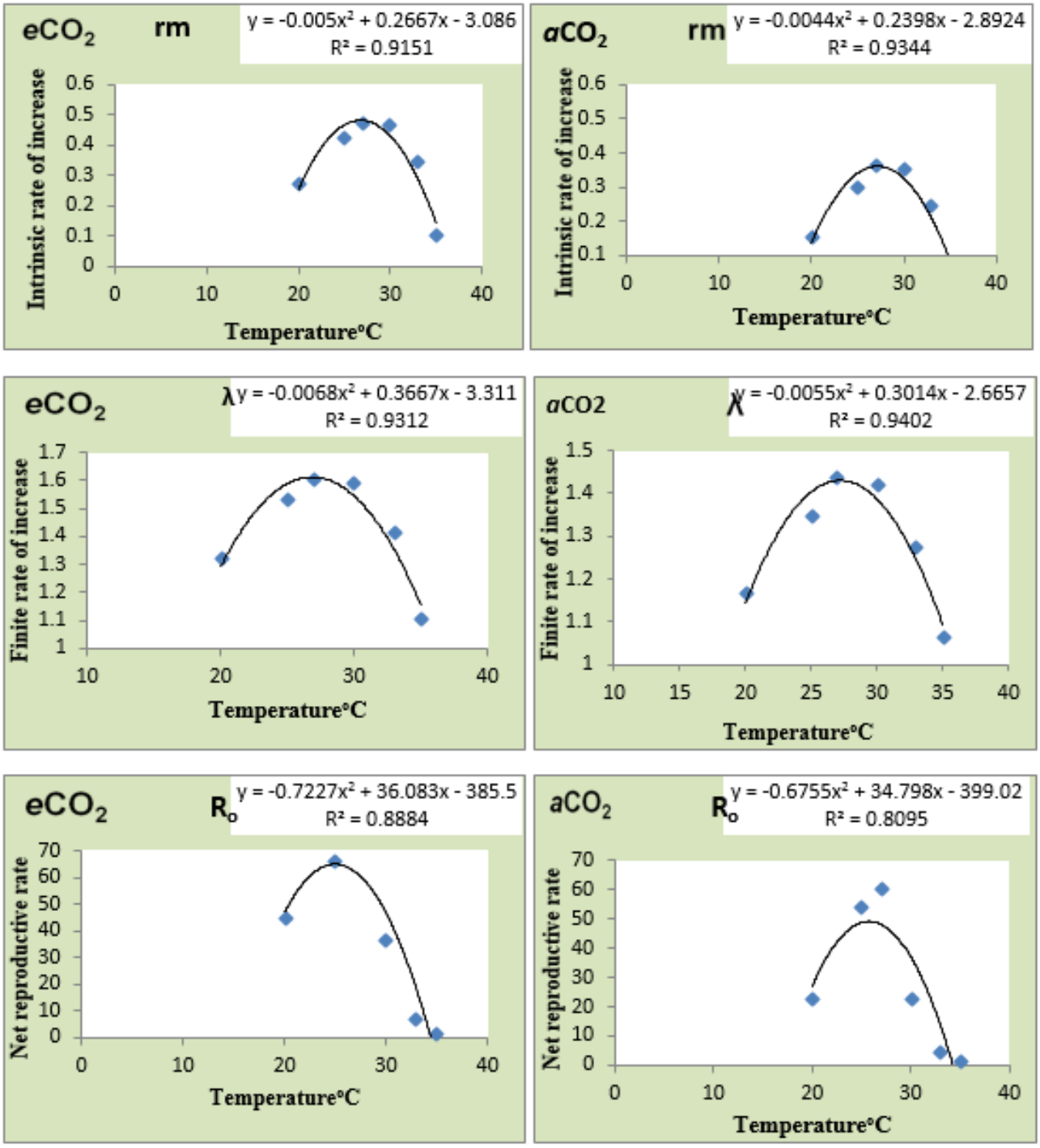


**Fig 1a:** Effect of elevated $CO_2$ and temperatures on intrinsic rates of increase ($r_m$), intrinsic rates of increase (λ) and net reproductive rate ($R_o$) of *R. maidis* on maize

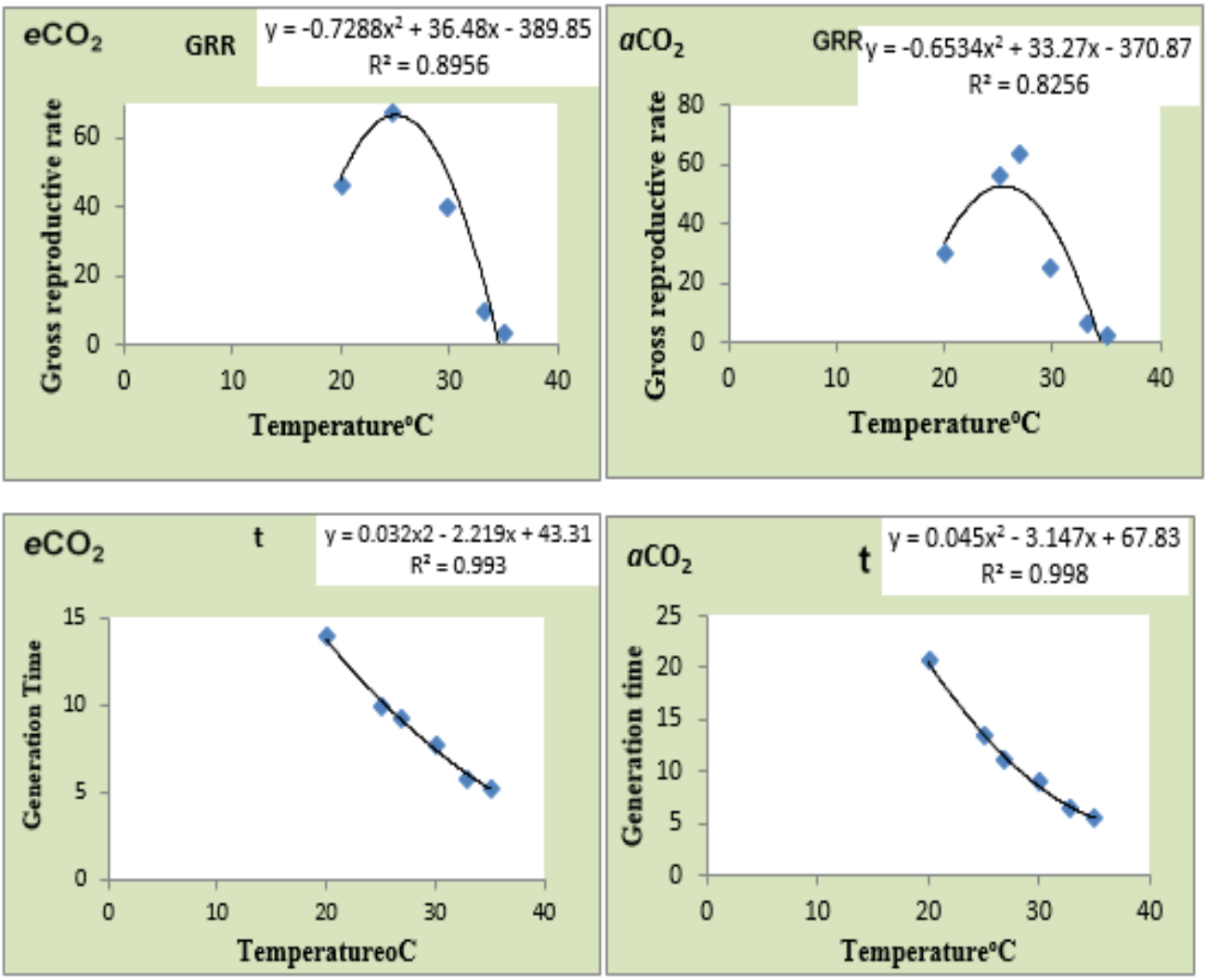


**Fig 1b:** Effect of elevated $CO_2$ and temperatures on gross reproductive rate (GRR) and mean generation time (T) of *R. maidis* on maize

**Table 1:** Effect of elevated $CO_2$ and temperature on life table parameters of *R. maidis* on maize

| Temp. (°C) | Intrinsic rate of increase ($r_m$, day$^{-1}$) | | Finite rate of increase ($\lambda$, day$^{-1}$) | | Net reproduction rate ($R_o$, offsprings per female) | | Gross reproductive rate (GRR, offsprings per female) | | Mean generation time (T, days) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *a*$CO_2$ (380 ppm) | *e*$CO_2$ (550 ppm) | *a*$CO_2$ (380 ppm) | *e*$CO_2$ (550 ppm) | *a*$CO_2$ (380 ppm) | *e*$CO_2$ (550 ppm) | *a*$CO_2$ (380 ppm) | *e*$CO_2$ (550 ppm) | *a*$CO_2$ (380 ppm) | *e*$CO_2$ (550 ppm) |
| **20** | 0.2083±0.0013 (0.000002) | 0.2749±0.0023 (0.000005) | 1.2316±0.0015 (0.000002) | 1.3165±0.0031 (0.000009) | 36.68±0.071 (0.00513) | 44.38±0.0692 ( 0.00478) | 37.85±0.13 ( 0.02) | 45.62± 0.34 (0.12) | 17.29±0.103 (0.011) | 13.79±0.115 (0.013) |
| **25** | 0.297±0.00176 (0.000003) | 0.4235±0.00335 (0.000011) | 1.347±0.0023 (0.000006) | 1.5273±0.0052 (0.000026) | 54.0±0.0900 (0.0081) | 65.28±0.0689 (0.00475) | 56.77±0.37 (0.13) | 66.89±0.31 (0.1) | 13.39±0.079 ( 0.006) | 9.87±0.078 (0.006) |
| **27** | 0.3644±0.0026 (0.000007) | 0.4693±0.00449 (0.00002) | 1.4397±0.0037 (0.000014) | 1.599±0.00718 (0.000052) | 60.36±0.068 (0.00464) | 75.42±0.0819 (0.00671) | 63.68±0.39 ( 0.15) | 76.68±0.28 (0.08) | 11.25±0.081 (0.007) | 9.21± 0.088 (0.008) |
| **30** | 0.3485±0.0032 (0.000011) | 0.4630±0.00497 (0.000025) | 1.4171±0.0046 (0.000021) | 1.589±0.00790 (0.000062) | 22.78±0.078 (0.00609) | 36.74±0.0879 (0.00772) | 25.46±0.36 (0.13) | 39.35±0.36 (0.13) | 8.97±0.081 (0.007) | 7.78±0.084 (0.007) |
| **33** | 0.2425±0.0047 (0.000022) | 0.3433±0.00354 (0.000013) | 1.2745±0.0059 (0.000036) | 1.4097±0.0049 (0.000025) | 4.6±0.11311 (0.01279) | 7.42±0.11058 (0.01223) | 6.54±0.36 (0.13) | 9.66±0.28 (0.08) | 6.29±0.074 (0.005) | 5.84±0.055 (0.003) |
| **35** | 0.0578±0.0089 (0.00008) | 0.0994±0.00916 (0.000084) | 1.0595±0.0095 (0.00009) | 1.1046±0.0101 (0.000102) | 1.38±0.0691 (0.00478) | 1.68±0.08053 (0.00649) | 2.76±0.15 (0.02) | 3.32±0.47 (0.22) | 5.57±0.079 (0.006) | 5.22±0.051 (0.003) |

## Conclusion

In conclusions, this study indicated the life table parameters of *R. maidis* were significantly influenced by the interactive effect of $CO_2$ and temperatures. Life tables compilation provided a comprehensive understanding of the development, survivorship and fecundity of a population cohort. Life table analysis reveals the fitness of a population under variable biotic and abiotic conditions. The ideal condition for the growth of *R. maidis* was 27 °C temperature. This study provides the biological response of *R. maidis* to a wide range of temperatures to predict its population dynamics under filed conditions.

## References

1. Blackman RL, Eastop VF. Aphids on the world's crops: An Identification and Information Guide. 2nd ed: John

Wiley & Sons, New York. 2000; 466.
2. Chi H. TWO-SEX MS Chart; computer programe for age-stage two-sex life table analysis. National Cheung Hsing University, Taichung, Taiwan. 2005; (http://140.120.197.173/ecology/prod/02.htm).
3. Hirano K, Honda K, Miyai S. Effects of temperature on development, longevity and reproduction of the soybean aphid, *Aphis glycines* (Homoptera: Aphididae). Applied Entomology and Zoology. 1996: 31(1):178-180.
4. Kuo MH, Chiu MC, Perng JJ. Temperature effects on life history traits of the corn leaf aphid, *Rhopalosiphum maidis* (Homoptera: Aphididae) on corn in Taiwan. Applied Entomology and Zoology. 2006; 41(1):171-177.
5. Maia A, Luiz AJB, Campanhola C. Statistical inference on associated fertility life table parameters using Jackknife technique: computational aspects. Journal of Economic Entomology. 2000; 93:511-518.
6. Oehme V, Hogy P, Franzaring J, Zebitz CPW, Fangmeier A. Response of spring crops and associated aphids to elevated atmospheric $CO_2$ concentrations. Journal of applied botany and food quality. 2011; 84:151-157.
7. Smith CM, Boyko EV. The molecular bases of plant resistance and defence responses to aphid feeding: current status. Environmental and Experimental Botany.2007; 122:1-16.
8. Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB. Contribution of working group I to the fourth assessment of the intergovernmental panel on climate
9. change. Cambridge University Press, Cambridge, UK, 2007.
10. Srinivasa Rao M, Shaila O, Vennila S, Rama Rao CA. Impact of *e*$CO_2$ and temperature on *Aphis craccivora* koch. on groundnut and future pest status during climate change scenarios. Journal of Plant Physiology and Pathology. 2017; 5:4.
11. Vincent P, Jones Carrie HM, Tome Lois CC. Life tables for the Koa Seed worm (Lepidoptera: Tortricidae) based on degree-day demography. Population Ecology. 1997; 26:1291-1298.
12. Xie H, Zhao L, Wang W, Wang Z, Ni X, Cai W, *et al*. Changes in life history parameters of *Rhopalosiphum maidis* (Homoptera: Aphididae) under four different elevated temperature and $CO_2$ combinaions. Journal of Economic Entomology. 2014; 107(4):1411-1418.