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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 CO₂ (550 and 380ppm ± 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 (rm), finite rate of increase (λ), net reproductive rate (R₀) 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 CO₂ conditions. Generation time (T) was reduced with an increase of temperature from 20 °C to 35 °C. The upper temperature threshold for rm, λ, R₀, GRR and T required 26.6, 30.1, 24.9, 25.0 and 34.6 °C under eCO₂ conditions whereas it was 29.8, 30.5, 25.7, 25.4 and 34.9°C under aCO₂ conditions, respectively. The increased rm, λ, R₀, 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 CO₂ 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 CO₂ concentration affect the population dynamics and the status of insect pests of various crops. Plants with C₄ photosynthesis will respond little to rising atmospheric CO₂ because a mechanism to increase the concentration of CO₂ in leaves causes CO₂ 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 eCO₂ and six different temperatures on *R. maidis*. Hence, in the present study, life table parameters of *R. maidis* were examined at two levels of CO₂ 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 °C 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, CO₂ 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 CO₂ growth chambers under respective set conditions at elevated and ambient concentrations of CO₂ (550 and 380ppm ± 25 ppm, respectively) at six temperatures of 20, 25, 27, 30, 33 and 35±1 °C. 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 eCO₂ 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 CO₂ (550 and 380ppm ± 25 ppm, respectively) at six temperatures of 20, 25, 27, 30, 33 and 35±1°C 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 (rᵅ), Finite rate of increase (λ), Net reproductive rate (Rₒ), 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**

TWOOSEX 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 eCO₂ and temperature on life table parameters of *R. maidis***

The life table parameters were significantly affected by the interactive effect of eCO₂ and temperatures. The results pertaining to the life table parameters of *R. maidis* viz., intrinsic rate of increase (rᵅ), finite rate of increase (λ), net reproductive rate (Rₒ), gross reproductive rate (GRR) and mean generation time (T) were varying at elevated and ambient concentrations of CO₂ (550 and 380ppm ± 25 ppm, respectively) at six temperatures of 20, 25, 27, 30, 33 and 35±1 °C (Table 1).

Intrinsic rate of increase (rᵅ) indicates the rate of progeny production per female per day. The rᵅ of *R. maidis* significantly varied among the two levels of CO₂ and six different temperatures. The rᵅ of *R. maidis* was 0.2749, 0.4235, 0.4693, 0.4630, 0.3433 and 0.099 day⁻¹ under eCO₂ conditions whereas it was 0.2083, 0.297, 0.3644, 0.3485, 0.2425 and 0.057 day⁻¹ under eCO₂ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. Finite rate of increase (λ) indicates the number of individuals added to the population per head per unit time or number of births per female per day. The λ of *R. maidis* was 1.316, 1.527, 1.599, 1.589, 1.409 and 1.104 day⁻¹ under eCO₂ conditions whereas it was 1.231, 1.347, 1.439, 1.417, 1.274 and 1.059 day⁻¹ under eCO₂ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. Net reproductive rate (Rₒ) indicates number of times that the population would multiply by the end of each generation. The Rₒ of *R. maidis* under eCO₂ 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 eCO₂ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. The GRR of *R. maidis* under eCO₂ 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 eCO₂ 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 eCO₂ was 13.79, 9.87, 9.21, 7.78, 5.84 and 2.52 days whereas the T was 17.29, 13.39, 11.25, 8.97, 6.29 and 5.57 days under eCO₂ conditions at 20, 25, 27, 30, 33 and 35 °C, respectively. The increased rᵅ, λ, Rₒ, 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 rᵅ, λ and Rₒ 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 Rₒ was higher at 27 °C temperature by recording 84.23 nymphs per female at eCO₂. 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 eCO₂. The results are in agreement with the findings of [10], who reported that the *R. maidis* fed on barley leaves had the highest rᵅ, Rₒ and reduced T under eCO₂ and temperatures and concluded that the interactive effect of both eCO₂ 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 eCO₂ and temperature on non-linear relationship and upper temperature thresholds of *R. maidis* on maize**

The non-linear models developed at eCO₂ and eCO₂ conditions across the temperatures for life table parameters viz., rᵅ, λ, Rₒ, GRR and T were depicted in Figure 1a and 1b. The non-linear trend was observed at eCO₂ which are as follows (rᵅ = -0.005x² + 0.266x - 3.086, R²=0.915), (λ = -0.006x² + 0.366x - 3.311, R²=0.931), (Rₒ = -0.722x² + 36.08x
- 385.5, $R^2=0.888$), (GRR = -0.782x$^2$ – 36.48x – 389.8) and similar non-linear trend was observed ($r_m$ = -0.004x$^2$ + 0.239x - 2.892, $R^2=0.934$), ($\lambda$ = -0.005x$^2$ + 0.301x - 2.665, $R^2=0.940$) ($R_o$ = -0.675x$^2$ + 34.79x - 399.0, $R^2=0.809$), (GRR = -0.653x$^2$ + 33.27x – 370.8) and (T = 0.045x$^2$ - 3.147x + 67.83, $R^2=0.998$) at $e\text{CO}_2$ and temperatures, respectively (Table 1).

The best fit quadratic form of equation with higher $R^2$ (0.915 and 0.934) at $e\text{CO}_2$ and $a\text{CO}_2$ was noticed between $r_m$ and temperature. Other parameters viz., $R_o$ (0.888 and 0.809), $\lambda$ (0.931 and 0.940), GRR (0.895 and 0.825) and T (0.993 and 0.998) followed the similar trend under both $e\text{CO}_2$ and $a\text{CO}_2$ conditions across the temperatures. 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°C under $e\text{CO}_2$ conditions whereas it was 29.8, 30.5, 25.7, 25.4 and 34.9°C under $a\text{CO}_2$ conditions, respectively.

Similar non-linear trend was noticed by [4] at $e\text{CO}_2$ compared to that of $a\text{CO}_2$ 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 ($\lambda$) and net reproductive rate ($R_o$) of R. maidis on maize
In conclusions, this study indicated the life table parameters of *R. maidis* were significantly influenced by the interactive effect of CO₂ 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 field conditions.

**References**

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