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# Effect of Elevated $CO_2$ on the abundance of Soil Arthropods in Rice Ecosystem

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**ABSTRACT: Soil arthropods which are well known as scavenger, play a crucial role in enhancing system production and productivity. An experiment was conducted under Open Top Chambers at National Rice Research Institute, Cuttack to know the effect of elevated $CO_2$ on the abundance and diversity of soil arthropods in rice ecosystem. The experimental unit consists of three concentrations of $CO_2$ *i.e.* one ambient (410 ppm) and two elevated (550 and 700 ppm). Soil samples were collected at monthly interval to assess the effect of elevated $CO_2$ on abundance and diversity of soil arthropods. Observation regarding soil temperature and moisture content was also recorded during the period of study. It was observed that elevated $CO_2$ influenced both soil temperature and moisture in the rice ecosystem. The ecosystem was observed to be inhabited by various group of soil arthropod such as collembolan, acari, coleopteran, dipteran, hymenopteran, millipeds, orthopteran and dermapteran. Among them, collembolan was found to be the major followed by acari and other groups such as Coleoptera, Diptera, Hymenoptera, Millipede, Orthoptera, Dermaptera. A significant effect of elevated $CO_2$ was observed between all the soil arthropods except acari.**

**Keywords:** Rice, Soil arthropod, Collembola, Acari, Elevated $CO_2$, Soil moisture, Soil temperature.

## INTRODUCTION

Soil arthropods play a significant role in organic matter processing and soil structure augmentation processes. They are also involved in soil formation and aeration, increasing the porosity and fertility of the soil by breaking down organic matters. The fertility of soil is an important factor for cultivation of different crops. Because it accommodates multiple functions such as soil formation, litter decomposition, nutrient cycling, assimilation of organic and inorganic elements, mineralization of organic matters of biological origin and also act as reservoir of organic matter (Devi *et al*., 2011); also perform key functions essential to plants such as disease regulation, agrochemical degradation (Sheikh *et al*., 2016). The interactions between soil fauna and flora and their activities help in improving the productivity of soil (Abbas and Parwez 2019). The abundance of soil fauna community is very much influenced under changing scenario of climate directly by altering soil microclimate and indirectly by altering resource availability and the composition of the soil food web (Kardol *et al*., 2011). Hence, a better understanding regarding climate change on abundance of soil arthropods can aid predictions of how soil ecosystems may function under future climatic conditions.

## MATERIAL AND METHODS

The experiment was conducted inside Open Top Chamber (OTC) at ICAR-National Rice Research Institute, Cuttack, Odisha in randomized block design (RBD) with three treatments *i.e.* one ambient $CO_2$ (410 ppm) and two elevated $CO_2$ (550 and 700 ppm) and ten replications during 2018. Ten soil samples ($30\times10\times15$ $cm^3$) from each treatment were randomly collected during February to July from the rice field inside OTC by two sampling methods such as soil sampler and mouth aspirator. The collected soil samples were stored in transparent polythene bags and treatment wise labeled. The soil temperature ($^{\circ}$C) was recorded by the help of soil thermometer and soil moisture (%) was recorded manually by taking the weight of samples before and after extraction. Then the soil arthropods were extracted by Berelese-Tull green funnel extraction method inside the laboratory. The preserved soil arthropods were identified by the stereoscopic binocular microscope and classified order/group wise and then population of each individual were counted.

## RESULTS AND DISCUSSION

The soil arthropod population collected from each treatment were belong to Collembola, Acari, Coleoptera, Diptera, Hymenoptera, Millipede, Orthoptera, Dermaptera orders. The highly dominant group was found to be Collembola followed by Acari under both ambient and elevated $CO_2$ conditions. The high temperature and low moisture content of soil samples were recorded from February to July in the rice field under elevated $CO_2$ as compared to ambient condition.

*A. Soil Climate*

**Soil temperature (°C).** The minimum soil temperatures *i.e.* 26.5, 27.1 and 27.4°C were recorded in the month of February under ambient (410 ppm $CO_2$) and elevated condition (550 and 700 ppm $CO_2$), respectively (Fig. 1). Afterwards, the soil temperature was increased to 29.2, 29.7 and 29.9°C in the month of March followed by 30.4, 31.2 and 31.5°C in the month of April under 410, 550 and 700 ppm $CO_2$, respectively. The soil temperature was recorded maximum in the month of May *i.e.* 32.1, 32.5 and 32.7°C under 410, 550 and 700 ppm $CO_2$ respectively. Again, the soil temperature was dropped to 28.7, 29.4 and 29.7°C in the month of June followed by 28.2, 29.2 and 29.5°C in the month of July under 410, 550 and 700 ppm $CO_2$, respectively.

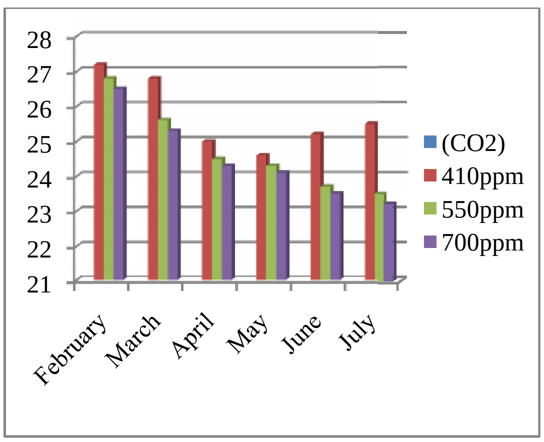


**Fig. 1.** Soil temperature (°C).

**Soil moisture (%).** The soil moisture contents were fluctuated according to soil temperatures under ambient condition whereas constantly decreased under elevated condition. The maximum soil moisture per cent was recorded *i.e.* 27.2, 26.8 and 26.5% in the month of February during 2018 under 410, 550 and 700 ppm $CO_2$, respectively. Then the soil moisture per cent was decreased to 26.8, 25.6 and 25.3% in the month of March followed by 25.0, 24.5 and 24.3% in the month of April and 24.6, 24.3 and 24.1% in the month of May under 410, 550 and 700 ppm $CO_2$, respectively (Fig. 2). Again, the soil moisture per cent was slightly increased in the month of June *i.e.* 25.2% followed by 25.5% in the month of July under ambient condition whereas the constantly decreased soil moisture percent were recorded 23.7 and 23.5% in June followed by 23.5% and 23.2% in July under 550 and 700ppm $CO_2$, respectively.

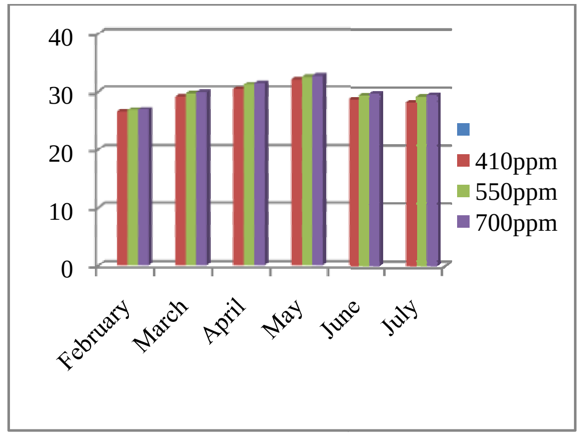


**Fig. 2.** Soil moisture (%).

*B. Population dynamics*

In the rice ecosystem, the population of Collembola significantly differed from each other under ambient and elevated condition of carbon dioxide. During the month of February, the population density of Collembola found to be higher under ambient condition (5.40) as compared to elevated conditions *i.e.*, 550 ppm (4.40) and 700 ppm (3.70) $CO_2$ (5.40) (Table 1). Adjacently, in the month of March, the density was increased to 6.30 under 410 ppm $CO_2$, but decreased to 3.80 and 3.20 under 550 and 700 ppm $CO_2$, respectively. After that, during the cropping period *i.e.* in the month of April and May (hottest season) the density was decreased to 4.50 and 4.10, respectively but again increased to 5.00 in the month of June under 410 ppm $CO_2$ whereas the decreasing population were recorded to be 3.40, 3.10 and 2.60 respectively under 550 ppm $CO_2$ followed by 2.80, 2.60 and 2.20 respectively under 700 ppm $CO_2$. Then in the month of July, the density 5.70 was increased under410 ppm $CO_2$ but decreased to 2.20 and 1.90 under 550 and 700 ppm $CO_2$, respectively. The total population was 5.17, 3.25 and 2.73 under 410, 550 and 700 ppm $CO_2$, respectively.

**Acari.** The acari population in the rice field was influenced by soil temperature and moisture and also increased but not significantly under elevated $CO_2$ condition. In the month of February, the higher population density was observed under elevated condition *i.e.* 1.70 and 1.80 at 550 and 700 ppm $CO_2$ respectively than ambient condition *i.e.* 1.50 at 410 ppm $CO_2$ (Table 2). Then in the month of March, April, May, June and July the population densities 1.20, 1.60, 1.80, 1.90 and 1.40 respectively fluctuated under 410 ppm $CO_2$ whereas the increasing population were recorded to be 1.80, 1.80, 2.00, 2.20 and 2.30 respectively under 550 ppm $CO_2$ followed by 2.10, 2.30, 2.40, 2.40 and 2.50 respectively under 700 ppm $CO_2$. The average population densities were recorded as 1.47, 1.97 and 2.25 under 410, 550 and 700 ppm $CO_2$, respectively.

**Table 1: Monthly mean population density of Collembola during 2018.**

| Treatments ($CO_2$) | February | March | April | May | June | July | Mean |
|---|---|---|---|---|---|---|---|
| 410ppm | 5.40 | 6.30 | 4.50 | 4.10 | 5.00 | 5.70 | 5.17 |
| 550ppm | 4.40 | 3.80 | 3.40 | 3.10 | 2.60 | 2.20 | 3.25 |
| 700ppm | 3.70 | 3.20 | 2.80 | 2.60 | 2.20 | 1.90 | 2.73 |
| SE(m)± | 1.99 | 1.56 | 1.70 | 1.99 | 1.22 | 1.22 | 0.65 |
| $CD_{(P<0.05)}$ | 2.14 | 2.04 | 1.77 | 1.83 | 1.60 | 1.59 | 0.85 |

**Table 2: Monthlymean population density of Acari during 2018.**

| Treatments ($CO_2$) | February | March | April | May | June | July | Mean |
|---|---|---|---|---|---|---|---|
| 410ppm | 1.50 | 1.20 | 1.60 | 1.80 | 1.90 | 1.40 | 1.47 |
| 550ppm | 1.70 | 1.80 | 1.80 | 2.00 | 2.20 | 2.30 | 1.97 |
| 700ppm | 1.80 | 2.10 | 2.30 | 2.40 | 2.40 | 2.50 | 2.25 |
| SE(m)± | 0.92 | 1.08 | 0.99 | 0.68 | 0.73 | 0.97 | 0.52 |
| $CD_{(P<0.05)}$ | NS | NS | NS | NS | NS | NS | NS |

**Table 3: Monthly mean population density of other groups during 2018.**

| Treatments ($CO_2$) | February | March | April | May | June | July | Mean |
|---|---|---|---|---|---|---|---|
| 410ppm | 8.40 | 9.30 | 7.50 | 7.10 | 8.70 | 8.00 | 8.17 |
| 550ppm | 7.40 | 6.20 | 5.30 | 4.90 | 3.80 | 3.50 | 5.18 |
| 700ppm | 6.50 | 4.80 | 3.70 | 3.50 | 2.60 | 2.30 | 3.90 |
| SE(m)± | 2.24 | 1.54 | 1.72 | 1.52 | 1.35 | 1.34 | 0.76 |
| $CD_{(P<0.05)}$ | 2.82 | 2.01 | 2.24 | 1.99 | 1.77 | 1.75 | 0.99 |

Mean of ten replications, $P<0.05$ is significant

**Other groups.** The other groups of soil arthropods found in the rice field also influenced by soil climatic conditions such as temperature and moisture under ambient and elevated $CO_2$ conditions and significantly differed from each other. The population density of other groups was found to be 8.40 in the month of February and was higher under ambient condition (410 ppm $CO_2$) than elevated condition *i.e.* 7.40 and 6.50 at 550 and 700 ppm $CO_2$ respectively (Table 3). In the month of March, the population was increased to 9.30 under 410 ppm $CO_2$ but decreased to 6.20 and 4.80 under 550 and 700 ppm $CO_2$, respectively. Then in the month of April and May, the population were decreased to 7.50 and 7.10, respectively but again increased to 8.70 in the month of June under 410 ppm $CO_2$ whereas the decreasing population were recorded to be 5.30, 4.90 and 3.80 respectively under 550 ppm $CO_2$ followed by 3.70, 3.50 and 2.60 respectively under 700 ppm $CO_2$. In the month of July, the population was increased (8.00) under 410 ppm $CO_2$, but decreased to 3.50 and 2.30 under 550 and 700 ppm $CO_2$, respectively. The total population densities were 8.17, 5.18 and 3.90 under 410, 550 and 700 ppm $CO_2$, respectively.

**Relative abundance of soil arthropod**

The percent relative abundance of Collembola, Acari and other groups were 34.9, 9.9 and 55.2% respectively under 410ppm $CO_2$ (Fig. 3) followed by 31.3, 18.9 and 49.8% respectively under 550ppm $CO_2$ and 30.7, 25.3 and 43.9% respectively under 700ppm $CO_2$.

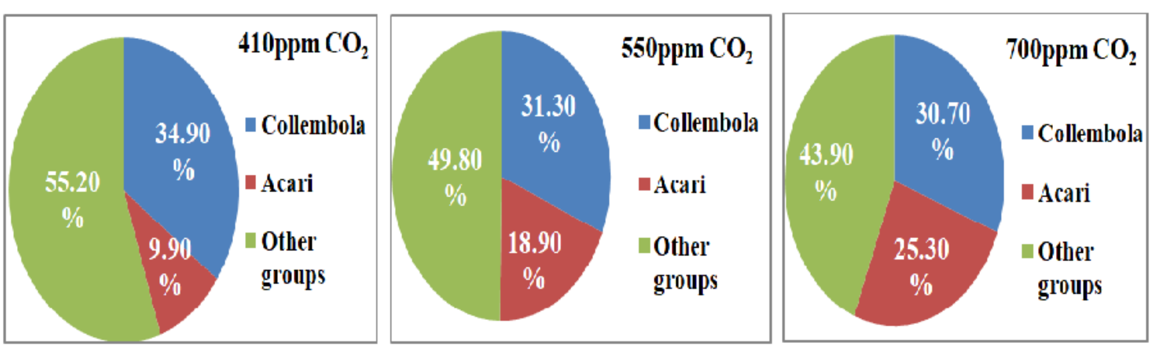


**Fig. 3.** Relative abundance (%) of soil arthropod during 2018.

### Effects of soil moisture and temperature on soil arthropod under elevated $CO_2$

In the present study, we observed that soil temperature had negative and non-significant interaction with collembolan and other group of population whereas had a positive and non-significant interaction with acari population under all the concentration of $CO_2$. Significant role of soil moisture was observed on the abundance of soil arthropod under elevated conditions of $CO_2$. The population of collembola and other groups were observed to be increase with increase in soil moisture whereas that of acari was observed to be decreased with decrease in soil moisture content.

In the present study, the low moisture content in soil during March to May under elevated $CO_2$ may be due to high water use efficiency of the crops because of dry season (Uddin *et al*., 2018). In contrast, the soil moisture increased under elevated $CO_2$ (Nelson *et al*., 2004; Leipprand and Gerten 2006; Carrillo *et al*., 2010). The collembola was found to be the major constitute of soil arthropod in the rice field followed by Acari and other groups such as coleoptera, Diptera, Hymenoptera, Millipede, Orthoptera, Dermaptera Since, no published work on effect of elevated $CO_2$ on soil arthropod population was found, hence the data observed were not compared with other published scientific reports. However, similar observations were reported by (Fonseca and Sarkar 1998; Roy and Roy 2006; Ramezani *et al*., 2018; Sitlhou and Singh 2019). Florian *et al*. (2019) observed low and high population density of collembolan and acari respectively under low moisture (drought) condition. Roy and Roy (2006) and Sarkar *et al*. (2014) and Sarkar *et al*. (2016) found lowest faunal population of collembolan and mites during the summer month and highest during post monsoon period. The highest Acari population was found in the month of June and July under ambient and elevated $CO_2$, respectively (Mohapatra *et al.*, 2021).

**Table 4: Correlation Co-efficient between soil arthropods and abiotic factors (Soil Temperature and Moisture).**

| Correlation Co-efficient | | Soil Temperature | Soil Moisture |
|---|---|---|---|
| 410 ppm | Collembola | $-0.645^{NS}$ | $0.968^{**}$ |
| | Acari | $0.362^{NS}$ | $-0.872^{*}$ |
| | Others | $-0.600^{NS}$ | $0.985^{**}$ |
| 550 ppm | Collembola | $-0.334^{NS}$ | $0.968^{**}$ |
| | Acari | $0.134^{NS}$ | $-0.872^{*}$ |
| | Others | $-0.378^{NS}$ | $0.985^{**}$ |
| 700 ppm | Collembola | $-0.376^{NS}$ | $0.984^{**}$ |
| | Acari | $0.635^{NS}$ | $-0.985^{**}$ |
| | Others | $-0.499^{NS}$ | $0.999^{**}$ |

**NS**: Non-significant
**: Significant at 5 % Probability

## CONCLUSION

The above results concluded that elevated $CO_2$ also affected soil arthropod population other than acari in the rice field by influencing the soil edaphic factors such as temperature and moisture. Higher temperature and lower moisture content of soil resulted in lower density and abundance of soil arthropod population under elevated $CO_2$.

## FUTURE SCOPE

Elevated $CO_2$ study has impact on soil arthropod population which helps in deciding the criteria of improvement of productivity of both soil as well as crop.

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