

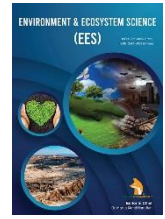


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## RESEARCH ARTICLE

INSECT PEST INCIDENCE IN MUNGBEAN ACROSS VARIED TEMPERATURES AND ELEVATED CO<sub>2</sub> CONCENTRATIONSTamjida Islam Tora<sup>a</sup>, Md. Mamunur Rahman<sup>a</sup>, Mansura Afroz<sup>a</sup>, Md. Ramiz Uddin Miah<sup>a</sup>, Md. Humayun Kabir<sup>b</sup>, Md. Mizanur Rahman<sup>b</sup>, Jahidul Hassan<sup>c</sup>, Md. Abdullah Al Mamun<sup>d</sup><sup>a</sup> Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh<sup>b</sup> Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh<sup>c</sup> Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh<sup>d</sup> Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh\*Corresponding author Email: [mamun@bsmrau.edu.bd](mailto:mamun@bsmrau.edu.bd)

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## ABSTRACT

The effects of climate change, including extreme weather conditions characterized by rising atmospheric CO<sub>2</sub> levels, alterations in precipitation patterns, and elevated temperatures, significantly impact crop production and the prevalence of agricultural pests. This study aimed to unravel the nuanced responses of various insect pests to these dynamic climatic shifts by conducting an experiment within the agronomy field at BSMRAU. The objective was to investigate the incidence of insect pests on mungbean plants under varying temperature and CO<sub>2</sub> level conditions. To achieve this, four open top chambers (OTCs) were deployed, each featuring distinct CO<sub>2</sub> concentrations, OTC-1 (400 ppm), OTC-2 (450 ppm), OTC-3 (500 ppm), and OTC-4 (550 ppm). Additionally, electronic thermo-hygrometers were strategically placed within these chambers to monitor the relevant environmental parameters. The results of this comprehensive study unveiled the presence of five distinct insect species that were observed infesting mungbean crops. These included aphids, ladybird beetles, whiteflies, bean pod borers, and caterpillars. The findings provided valuable insights into the intricate interplay between CO<sub>2</sub> levels, temperature, and the incidence of these insect pests. Notably, it was found that an atmospheric CO<sub>2</sub> concentration of 550 ppm created an optimal environment for aphid infestations, with an ideal temperature range between 32-34°C. In contrast, a concentration CO<sub>2</sub> of 450 ppm was identified as most conducive to the other five insect species. Bean pod borers, in particular, demonstrated a preference for temperatures ranging from 30.1-32.9°C, while the impact of temperature variations on the remaining insect species was deemed statistically insignificant. These findings shed light on the complex relationships between rising CO<sub>2</sub> levels, temperature fluctuations, and insect pest dynamics within the context of mungbean cultivation. The knowledge gained from this research is indispensable for the development of effective strategies to manage and mitigate pest outbreaks in a rapidly changing climate, thereby safeguarding crop yields and ensuring food security. This study advances our comprehension of the intricate ecological interactions within agricultural ecosystems, offering a foundation for more informed decision-making in the face of ongoing climate change challenges.

## KEYWORDS

Mungbean (*Vigna radiata* L.), climate change, open top chamber, temperature and effect.

## 1. INTRODUCTION

Mungbean (*Vigna radiata* L.) is a cherished member of the Leguminosae family, falling under the subfamily Papilionaceae. Its extensive genus comprises over 150 species primarily originating from the continents of Asia and Africa. However, the mungbean, in particular, emerges as a significant edible food legume with profound cultural and economic importance, especially in the regions of South and Southeast Asia. This versatile legume has established a foothold in countries such as India, Malaysia, Bangladesh, Indonesia, Pakistan, Sri Lanka, Vietnam, Thailand, South China, and Cambodia, playing a crucial role in the culinary and nutritional landscape of these nations (Pawar et al., 2023).

Despite its significance, mungbean encounters substantial challenges in the form of insect pests that relentlessly afflict it throughout its growth stages, from the moment of sowing to the final stages of storage. These

insect pests pose a dual threat to mungbean crops: they not only directly harm the plants but also serve as vectors for various diseases, compounding the challenges faced by agricultural communities. Among the pantheon of economically significant insect pests that wreak havoc on mungbean, several stand out. These include stem flies, thrips, aphids, whiteflies, the pod borer complex, pod bugs, and bruchids (Nair et al., 2019; Swaminathan et al., 2012). Their collective impact is marked by diminished crop yields, damaged quality of harvested produce, and ultimately, adverse effects on food security and economic sustainability.

In Bangladesh, a country heavily reliant on mungbean production, the roster of major insect pests afflicting the crop is extensive. This includes the whitefly, black aphid, leaf hopper, cutworm, stem fly, Bihar hairy caterpillar, tobacco caterpillar (*Spodoptera litura*), gram caterpillar, and the spotted pod borer, along with others (Pawar et al., 2023). These pests represent a formidable challenge for Indian farmers who strive to protect

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their mungbean crops and ensure sustainable yields. In Bangladesh, mungbean cultivation also faces its own array of insect adversaries, with approximately 12 insect species identified as infesting these leguminous plants (Hossain et al., 2009). Among the mungbean menaces encountered in Bangladesh are aphids, jassids, whiteflies, hairy caterpillars, and pod borers, which have been recognized as some of the most common insect pests, inflicting harm on this vital crop.

The intricate relationship between mungbean and these insect pests underscores the need for a comprehensive understanding of the ecological, climatic, and agricultural factors that contribute to their prevalence and impact (Skenszic et al., 2021). Furthermore, climate change, a global phenomenon with far-reaching consequences, has emerged as a paramount influencer in the dynamics of agricultural systems, including the proliferation and behavior of insect pests. The primary drivers of climate change, namely elevated temperatures, increasing levels of atmospheric CO<sub>2</sub>, and alterations in soil moisture content, are anticipated to exert a substantial influence on the complex web of interactions between mungbean crops and their insect adversaries (Fand et al., 2012).

The consequences of climate change on agriculture extend to both direct and indirect effects on crops and the pests that challenge them. Higher temperatures, for example, can directly impact the reproduction, development, survival, and dispersal of insect pests, altering their population dynamics and, consequently, crop losses (Fand et al., 2012). The indirect impacts are equally profound, affecting the broader environment and the interactions of other insect species, such as natural predators, competitors, vectors, and mutualistic organisms (Prakash et al., 2014). The extent of this impact varies based on the specific insect species and their growth patterns (Ghosh et al., 2012).

Temperature emerges as a critical determinant in this intricate web of ecological interactions, significantly influencing insect behavior, mobility, development, and reproduction. Insects display remarkable sensitivity to temperature fluctuations, with a mere 10°C increase potentially doubling their metabolic rates, leading to increased activity and reproductive rates (Kocmankova et al., 2009; Duker et al., 2009). Therefore, as global climate change drives temperature shifts, it is expected to induce changes in how insects interact with host plants, natural enemies, and competitors. These changes may include expanding their geographic ranges, enhancing overwinter survival rates, increasing the number of generations within a year, heightening the risk of invasive insect species, and raising the threat of insect-transmitted plant diseases (Shrestha, 2019).

In addition to temperature, rising atmospheric CO<sub>2</sub> levels are expected to impact the distribution, quantity, and productivity of insects that feed on plants. This phenomenon may alter population densities, growth rates, fecundity, and consumption rates, with significant implications for agricultural ecosystems and crop yields (Fuhrer, 2003; Lehmann et al., 2020). The complex physiological effects induced by elevated temperatures and CO<sub>2</sub> can profoundly influence interactions between agricultural crops and insect pests, thereby reshaping the dynamics of pest outbreaks and crop damage (FAO, 2020). It is essential to recognize that the impact of rising CO<sub>2</sub> levels on insect pests is strongly influenced by the plants that serve as their hosts. While some insects may benefit from increased CO<sub>2</sub>, others may experience negative effects, resulting in a variable response among different insect species (Fuhrer, 2003).

Despite the critical importance of understanding these intricate ecological interactions and their implications for crop protection and food security, global research on the impact of climate change on insect pests and crop diseases remains insufficiently explored. This knowledge gap underscores the significance of the present study, which was undertaken with the primary objective of investigating the incidence of different insect pests on mungbean plants across a spectrum of temperature and CO<sub>2</sub> level scenarios. By delving into the nuances of this complex relationship, the study aims to shed light on the potential effects of climate change on mungbean cultivation, offering insights that could inform strategies for more resilient and sustainable crop production in a changing world.

## 2. MATERIALS AND METHODS

### 2.1 Experimental site

The experiment was conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during kharif-II season (last week of September to first week of December). The site was located between 24°09' North latitude and 90°26' East longitude with an elevation of 8.4 m from sea level.

### 2.2 Crop culture chamber

The experiment was conducted inside the open top chamber (OTC). Iron frames were used to build four OTCs, each measuring 9 m<sup>2</sup>. To deflect air and prevent the reduction of desired CO<sub>2</sub>, the OTC had a frustum at the top of the chamber. A cylindrical, double-walled plenum was constructed around the base of the chamber to ensure equal CO<sub>2</sub> circulation. The interior of the plenum had various-sized or numerous gas outlets. The smaller one was nearest to the gas inlet pipe. Using a manifold, gas regulators, pressure gauge, underground pipeline, and a blower to circulate ambient air, CO<sub>2</sub> gas was delivered to the chambers from CO<sub>2</sub> gas cylinders (acquired from Bangladesh Oxygen Limited). A portable Pn system (model: LICOR 6400, Lincoln, Nebraska) was used to determine the CO<sub>2</sub> concentration inside the OTC regularly. Ventilation fans were used to maintain equilibrium air temperature inside the OTC. These fans supply a mixture of air and CO<sub>2</sub> from gas cylinder and cool air into the chamber from outside. Daily air temperatures were recorded from the inside and outside of the OTC. Every OTC featured a door that allowed access to the room for data collection where the crop was being managed.

### 2.3 Treatments and data collection

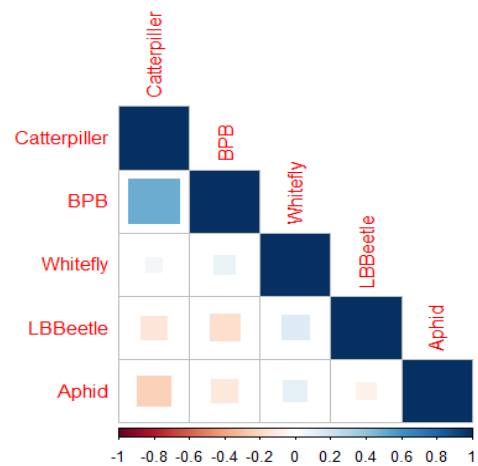
BU mung-6 was grown inside OTCs. Before sowing seeds, the soil was prepared using spade. The seeds were sown on 24 August, 2022. For conducting the experiment, insect data was collected from 4 different treatments in OTCs where different CO<sub>2</sub> concentration was created anthropogenically. The four concentration according to OTC were; OTC 1 with ambient/400 ppm CO<sub>2</sub>, OTC 2 with 450 ppm CO<sub>2</sub>, OTC 3 with 500 ppm CO<sub>2</sub> and OTC 4 with 550 ppm CO<sub>2</sub>. For temperature measurement, electronic thermo-hygrometer was placed inside the treatment OTCs. Data collection was started when the plant was near the reproductive stage. Data was taken from 22 September 2022 to 23 October 2022 with 3 days interval. 3 replications were taken randomly from each treatment and data were collected from top 6 leaves.

### 2.4 Data analysis

Principal component analysis was done to determine the contribution of different parameters to evaluate the effect of insect incidence on different temperature and CO<sub>2</sub> level on mungbean. For detecting correlation and the variance of the individual components PCA were analyzed using Statistical Package Software "R".

## 3. RESULTS

Using correlation matrix, the relationship between the variables was examined. Blue to white colors denote positive correlation, whereas red to white colors denote negative correlation. The deeper the blue color the stronger the positive correlation and the deeper the red color the stronger the negative correlation (Figure 1).

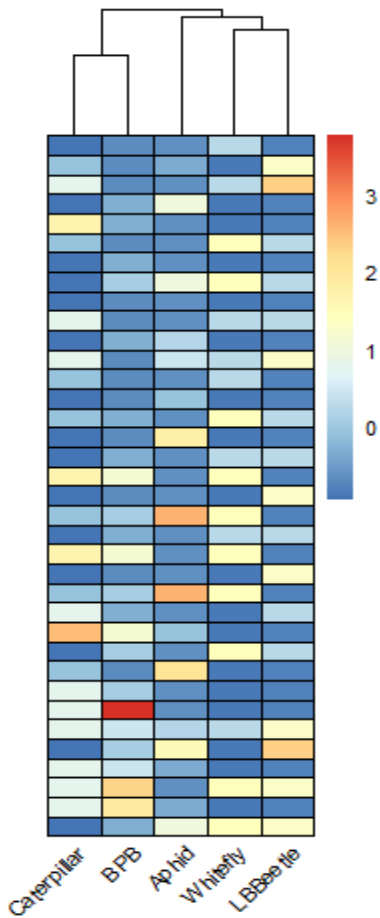


(BPB = Bean pod borer, LBBeetle = Lady bird beetle)

**Figure 1:** Correlation matrix among the different variables. Correlation plots represent the order wise relationship corresponding to color gradient between different variables.

In this figure aphid had weak positive correlation with whitefly, whereas negative correlation with caterpillar, bean pod borer and lady bird beetle. Similarly lady bird beetle had negative correlation with aphid, bean pod borer and caterpillar. Bean pod borer had negative correlation with lady bird beetle and aphid.

Heatmap dendrogram was used to represent the result of a hierarchical clustering calculation of the variables. Depending on the distance measure chosen, the result of a clustering is shown as the distance or similarities between the clustered rows or columns (Figure 2).

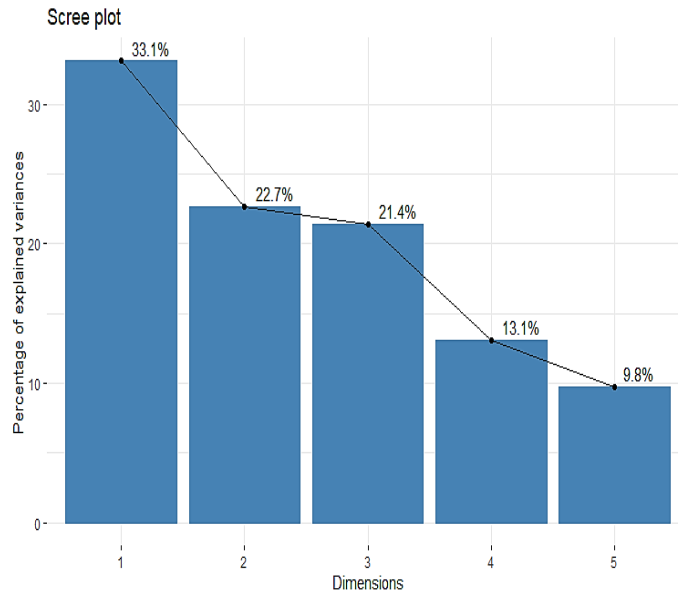


(BPB = Bean pod borer; LBBeetle = Lady bird beetle)

**Figure 2:** Heatmap dendrogram visualizing the result of a hierarchical clustering of the analyzed parameters

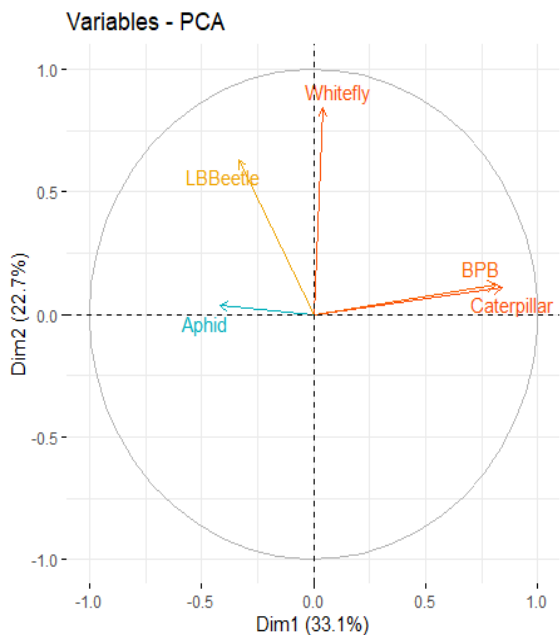
In the heatmap, caterpillar was closely associated with bean pod borer as they offered short distance and formed a clade; while aphid, whitefly and lady bird beetle were in different clade. Among them whitefly and lady bird beetle were closely related than aphid as the distance of aphid with whitefly and lady bird beetle was higher than distance between whitefly and lady bird beetle.

Principal component analysis (PCA) was done with the variables of data collection of different insect incidence in different temperatures and CO<sub>2</sub> levels and it was found that the first two components could explain more than 55% of the variation presented in the (Figure 3). So in the PCA biplot analysis, two dimensions were considered with referring to variance 1 and 2.



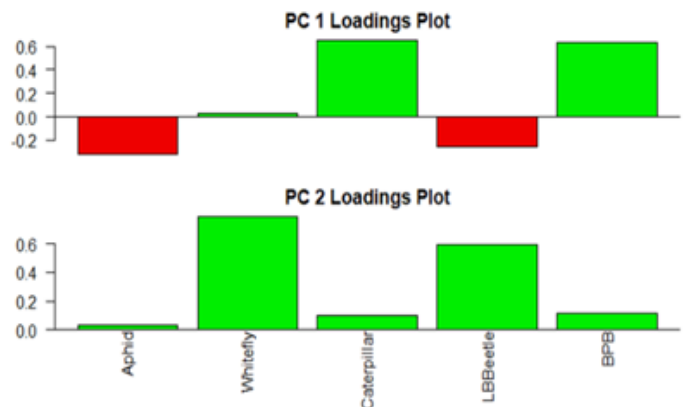
**Figure 3:** Principal component analysis (PCA) among the insect incidence on different temperatures and CO<sub>2</sub> levels

The contribution of different variables in PCA is presented in (Figure 4A, 4B). Here dimension 1 contributed 33.1% and dimension 2 contributed 22.7%. In dimension 1 bean pod borer, caterpillar and whitefly showed positive correlation, while aphid and lady bird beetle showed negative correlation in dimension 1. In dimension 2 all the variables showed positive correlation.



A

(Dim1 = Dimension 1; Dim2 = Dimension 2; BPB = Bean pod borer; LBBeetle = Lady bird beetle)



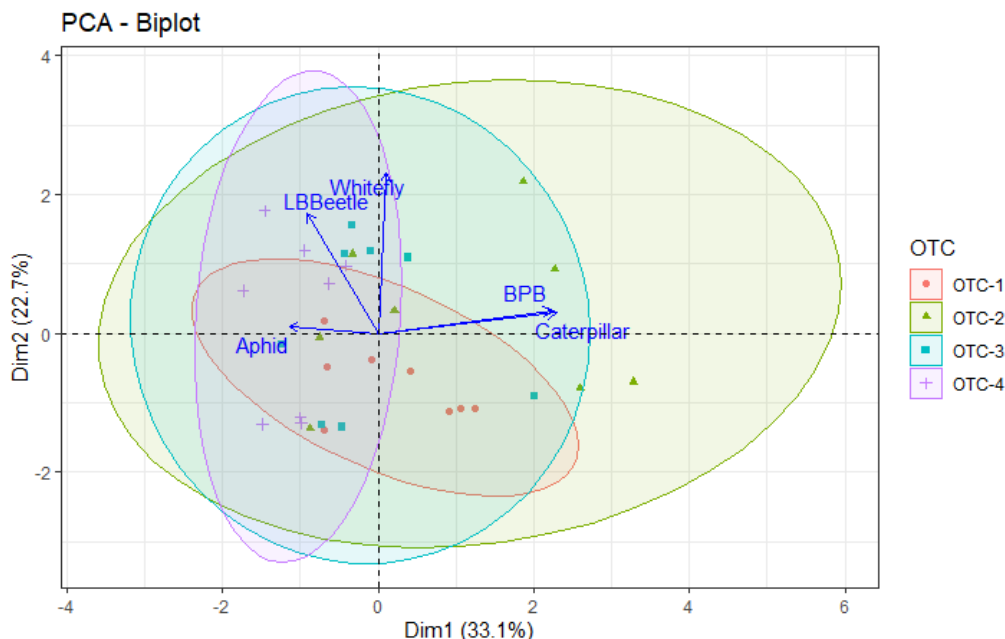
B

**Figure 4:** Principal component analysis representing different variables for different temperature and CO<sub>2</sub> levels.

The data had been collected for 5 insect species- aphid, whitefly, caterpillar, lady bird beetle and bean pod borer to evaluate the effect of different CO<sub>2</sub> levels and temperatures on incidence of insect pests on mungbean. Aphid and lady bird beetle exposed negative correlation (contributing 41.67% and 33.31% respectively) in dimension 1 but positive correlation (contributing 3.46% and 63.01% respectively) in

dimension 2. In dimension 2 all the five insect species showed positive correlation. Among them strongest positive correlation was with whitefly 84.16% followed by lady bird beetle.

The contribution of different variables in PCA with its corresponding treatments (CO<sub>2</sub> concentration) is presented in (Figure 5).



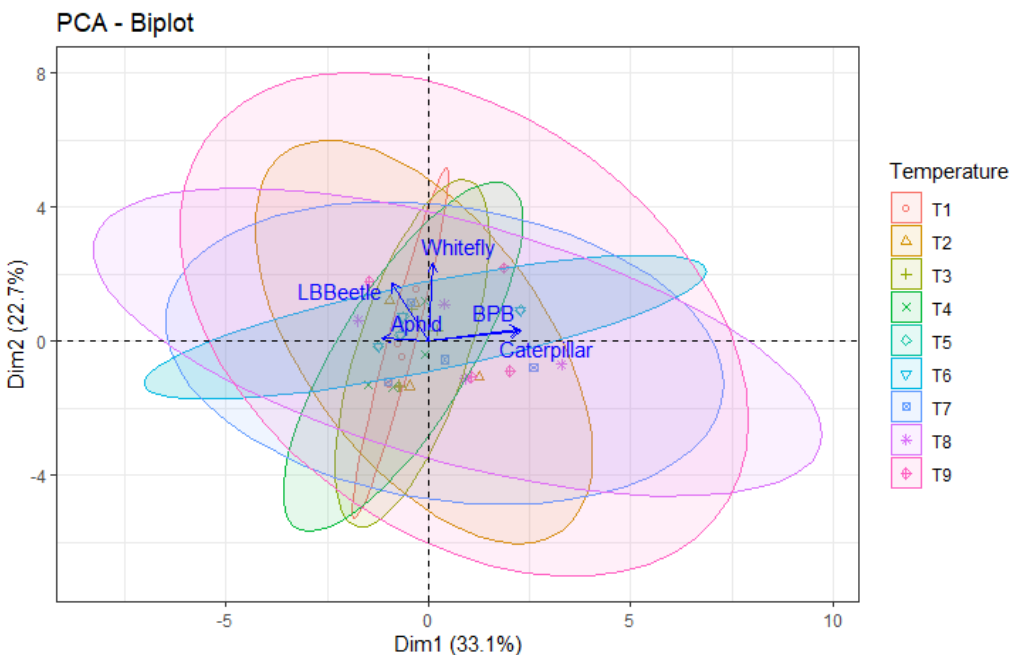
(Dim1 = Dimension 1; Dim2 = Dimension 2; OTC-1 = 400 ppm CO<sub>2</sub>; OTC-2 = 450 ppm CO<sub>2</sub>; OTC-3 = 500 ppm CO<sub>2</sub>; OTC-4 = 550 ppm CO<sub>2</sub>; BPB = Bean pod borer; LBBeetle = Lady bird beetle)

**Figure 5:** Biplot generated through principal component analysis corresponding with different CO<sub>2</sub> levels

In this figure, OTC-2 crosses both dimension 1 and dimension 2. In OTC-2 bean pod borer and caterpillar had high positive correlation (49.90%) as they almost overlapped each other. Lady bird beetle incidence was statistically similar in all 4 OTCs which indicate different CO<sub>2</sub> didn't have any significant effect in lady bird population. Bean pod borer incidence was significantly different in OTC-2. CO<sub>2</sub> effect was similar with bean pod borer in case of caterpillar as incidence was significantly different in OTC-2

among the four OTCs. Aphid incidence was significant in OTC-4 followed by OTC-3. Whitefly incidence was higher in OTC-2. So the CO<sub>2</sub> levels suitable for aphid was OTC-4 = 550 ppm and for other 4 insect species was OTC-2 = 450 ppm.

The contribution of different variables in PCA with its corresponding treatments (Temperatures) in presented in (Figure 6).



[Dim1 = Dimension 1; Dim2 = Dimension 2; BPB = Bean pod borer; LBBeetle = Lady bird beetle; T1 = (26.1-27.5)°C; T2 = (25.5-28.1)°C; T3 = (30.8-32.8)°C; T4 = (28.6-29.9)°C; T5 = (32-34)°C; T6 = (27.9- 29.3)°C; T7 = (32-35)°C; T8 = (30.1-32.9)°C; T9 = (30.2-31.2)°C]

**Figure 6:** Biplot generated through principal component analysis corresponding with different temperatures.

In this figure, T9 temperature covers all the insect species, it means all the experimental insect species can do well in temperature range 30.2-31.2°C.

The suitable temperature range for aphid was T5 = 32-34°C followed by T6 = 27.9- 29.3°C and T4 = 28.6-29.9°C. Temperature treatment was

statistically significant in T8 and T9 for bean pod borer, so the suitable range was T8 = (30.1-32.9) °C and T9 = (30.2-31.2)°C. Whitefly incidence was highest in T6 temperature but the temperature effect was statistically insignificant for whitefly. Similarly here was no significant difference between different temperature treatments on rest of the insect species.

#### 4. DISCUSSIONS

Our study result was closely related with who found that aphids had the highest intrinsic rate of natural increase at 1050 ppm CO<sub>2</sub> and future increases in CO<sub>2</sub> will increase aphid population outbreaks (Amiri-Jami et al., 2012). Their research provides support to the hypothesis with agreement to other studies that, unlike chewing insects, aphids may not be negatively affected by increasing CO<sub>2</sub> concentration (Awmack and Harrington, 2000; Stacey and Fellowes, 2002). In fact, they may even benefit from it. In case of bean pod borer the result was partially aligned with who found plant damage was higher at low CO<sub>2</sub> concentration (350 ppm) than other two treatments (550 ppm and 750 ppm) as the plant defensive enzymes were lower at low concentration CO<sub>2</sub> (Sharma et al., 2016).

Moreover the pod borer has prolonged larval stage at high CO<sub>2</sub> concentration as a result of their increased food consumption, the body weight of larvae and pupae was decreased, which in turn decreased the percentage of moth emergence, lowering fecundity of the pest ultimately (Sreenivas et al., 2022). Our research contradicts with who found that survival rate was higher at 850 ppm CO<sub>2</sub> than 450 ppm CO<sub>2</sub> concentration, while we found that lady bird incidence was higher at 450 ppm CO<sub>2</sub> (Van Doan et al., 2021). The possible reason for this difference could be due to the interaction between different insect species found in the OTC and different temperature conditions or just due to genetic drift in the higher CO<sub>2</sub> concentration OTCs. Plants grown at higher CO<sub>2</sub> (700 ppm) levels than those at 440 ppm had an indirect adverse impact on whiteflies and this range could be varied for different host plant species (Penalver-Cruz et al., 2020).

Environmental elements such as temperature, precipitation, and humidity generally control whitefly populations largely. Whitefly population growth is positively correlated with high temperatures and high humidity levels (Pathania et al., 2020). But in this study there was no significant effect of temperatures on whitefly populations, it could be due to interaction between different insect species in the same field under control conditions. According to Schwarz and Frank, adult Asian lady bird beetle consumed more aphid biomass at higher temperature compared to other two temperature treatment of their study and increased temperatures may affect prey development as well as increase consumption rate predator (Schwarz and Frank, 2019). Moreover high temperature is detrimental to aphid population.

According to Kuo et al. in case of corn aphid, adult longevity was significantly declined at 30°C and 35°C (Kuo et al., 2006). The fecundity of cotton aphid decreased at 32°C and 35°C (Liu et al., 2021). But our study conflicts with the findings, might be varied with different host species and interaction with others insect species. In case of bean pod borer, with rising temperatures from 14.4°C to 29.3°C, the developmental times for eggs, larvae, and pupae were decreased and all stages of development had a delay at higher temperatures and the highest thermal threshold was determined to be between 29.3 and 31.9°C (Adati et al., 2004). They also found that at 34.3°C temperature survival rate of immature forms were below 10%. Thus our result of the study aligned with their research whereas Ganapathy found 20°C to 28°C was the preferred temperature range for growth and development (Ganapathy, 2010).

#### 5. CONCLUSION

In conclusion, mungbean is a vital food crop in several Asian nations, and the presence of various insect pests poses a significant challenge to its cultivation and food security. In this context, the influence of climate change, including rising temperatures and elevated CO<sub>2</sub> levels, on insect pest dynamics and crop losses is a matter of substantial concern. As climate change directly impacts the behavior and development of insect pests, its effects ripple through agricultural ecosystems, impacting crop yields and food security. This study elucidated some of the prevalent insect species found on mungbean plant such as aphid and their natural enemy lady bird beetle, whitefly, bean pod borer and caterpillar. Most of them have a higher incidence on around 450 ppm CO<sub>2</sub> level, but aphid incidence was higher at 550 ppm where the temperature range for aphid was 32-34°C.

The suitable temperature range for bean pod borer was (30.1-32.9)°C and the effect of treatment of temperature range was non-significant for whitefly, lady bird beetle and caterpillar. The study's exploration of these

complex relationships provides valuable insights into the challenges faced by mungbean cultivation in the face of a changing climate. It is imperative that such research continues to expand and deepen our understanding of the ecological intricacies at play, enabling the development of effective strategies to mitigate pest outbreaks and ensure sustainable crop production. Ultimately, these efforts are critical for safeguarding food security in regions where mungbean is a staple crop and for promoting agricultural resilience in the face of climate change.

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