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Investigating Impact of Carbon Dioxide Concentration on *Halyomorpha halys* Stål, 1855 [Hemiptera (Heteroptera: Pentatomidae)]Egg Hatching: A Response Surface Methodology Approach

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Abstract – Nowadays, due to global warming, both carbon dioxide (CO_2) rise and temperature increase occur. Such climate changes have significant effects on living things. In this research, the reproduction and egg formation of *Halyomorpha halys* Stål, 1855, also known as the hazelnut pest in the Black Sea Region in our country, was monitored. An air-conditioning cabinet and CO_2 application system suitable for global climate change were developed and the hatching status of the eggs of this pest was examined. Response surface methodology (RSM) was used to investigate and optimize the effects of multiple variables in experimental studies. With this method, necessary evaluations were made in planning the experiments, collecting data, and analyzing the results. RSM, mathematical modeling, and optimization techniques enable us to understand the results of experiments better and optimize processes. In this study, the hatching number of *Halyomorpha halys* eggs with CO_2 applications has been evaluated with RSM. The effectiveness of experimental working conditions, carbon dioxide ratio, and carbon dioxide application time have been determined by RSM. Statistical analysis has been performed in RSM to evaluate the compatibility of real data and model values. Especially when *Halyamorpha halys* eggs were monitored, egg hatching was observed on the 4th day (96th hour) and 5th day (120th hour). According to the results, increasing the carbon dioxide concentration (ppm) decreased the number of eggs hatched.

Keywords – Halyomorpha halys, carbon dioxide application, egg hatchability, response surface methodology, optimization

I. INTRODUCTION

Halyomorpha halys, also known as the brown marmorated stink bug, is a species of insect originating from eastern Asia. This insect, which poses a great threat, especially in agricultural areas, moved to North America and Europe in the 1990s and spread rapidly there. *Halyomorpha halys*, which draws attention with its shield-shaped body structure and ability to secrete foul-smelling liquid, feeds by sucking the sap of many plant species. Therefore, it causes significant damage to agricultural products and causes economic losses. Additionally, entering homes in search of shelter during the winter months causes disturbances in human life. This species, for which effective control methods are difficult to find, is being tried to be controlled with strategies such as biological control and integrated pest management. Research on the biology, distribution dynamics, and control methods of *Halyomorpha halys* is of great importance for the sustainability of agricultural production and the preservation of ecological balance [1,2].

Halyomorpha halys sucks plant sap with its sucking mouthparts. This type of nutrition causes deformities in plants and stains on fruits and vegetables. They develop a defense mechanism by secreting a foul-smelling liquid in case of danger and protecting themselves from many predators. The population is kept under control by using insecticides. Using natural predators, especially the samurai wasp (*Trissolcus japonicus*), can be effective in this regard [3].

Halyomorpha halys is a species that poses a serious problem in both agricultural and domestic areas. It causes economic damage by causing serious losses of farm products. It can affect populations of native species and disrupt ecosystem balance. Various chemical and biological methods control its spread and damage. This insect, detected in East Asia, has spread rapidly around the world and caused great economic damage in many regions. It causes serious crop losses by feeding especially on fruit trees, vegetables, and ornamental plants. Additionally, it enters homes during the winter months, causing discomfort and emitting bad odors in buildings [4].

In the studies conducted within the scope of this research, the response of Halyomorpha halys eggs to changes in carbon dioxide (CO_2) levels is evaluated. The effects of CO_2 levels on the hatching ratio and duration of *Halyomorpha halys*'s eggs have been determined. Findings on applying CO_2 to freshly laid eggs at specific CO_2 levels (400 ppm, 600 ppm, and 670 ppm) are discussed [5]. Optimization studies are carried out according to the response surface methodology (RSM) by applying intermittent CO_2 to the egg hatching and duration of *Halyomorpha halys* (Stål 1855) (Hemiptera: Pentatomidae).

II. MATERIAL AND METHOD

Halyomorpha halys, commonly known as the brown marmorated stink bug, is a species of insect originating from East Asia. It is known by its scientific name (*Halyomorpha halys*), common name (brown marmorated stink bug), family (Pentatomidae), and origin (such as China, Japan, and Korea). Adults are approximately 1.7 cm long. The body is usually brown, sometimes gray or black. Their bodies are broad, oval, and flat, and have a shield-like shape at the top. Their antennae are decorated with black and white bands. The female of this type of insect lays 20-30 eggs under the leaves. The eggs are usually white or light green. After hatching, the young are called nymphs and go through five developmental stages. Nymphs become adults in the final stage. Adults can live for about 6-8 months. *Halyomorpha halys* spread from Asia to North America and Europe through trade and transportation. It feeds on various plants such as apples, peaches, corn, and soybeans and can cause great damage to agricultural products. In addition, since they look for warm places during the winter months, they can enter houses and buildings and cause discomfort. It is tried to be controlled with chemical drugs, physical barriers, and biological control methods [5-7]. Figure 1 shows male and female individuals of *Halyomorpha halys* species [8].

Figure 1. *Halyomorpha halys* (Stål, 1855) (1) Male, (2) Female

In this study, CO_2 applications are carried out in a closed system shown in Figure 2. In this system, working conditions and application conditions are constantly checked with a newly developed design. The CO_2 concentration (ppm) in the atmospheric air is determined with the help of a sensor.

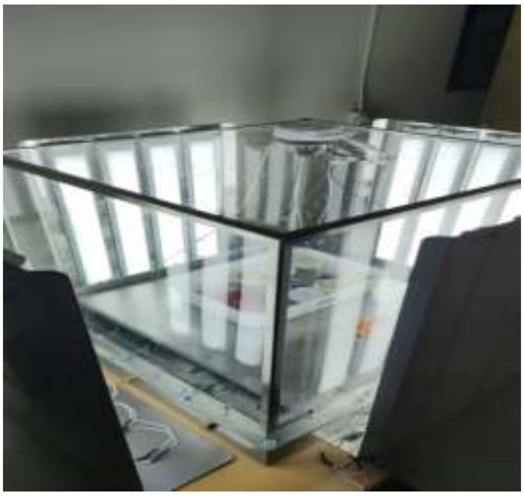

Figure 2. CO_2 application of *Halyomorpha halys*'s eggs

III. RESULTS AND DISCUSSION

Evaluation of CO_2 applications with RSM

RSM is a statistical technique used to investigate and optimize the effects of multiple variables in experimental studies. This method is an important tool for understanding interactions in complex systems by being used in the planning of experiments, data collection, and analysis. The advantages that RSM offers for experimental implementation and optimization are quite diverse. First of all, RSM is designed to minimize the number of variables taken into account in the organization and planning of experiments. This reduces the cost and time of experimental studies and ensures accurate results. Additionally, RSM facilitates understanding and helps optimize the process by creating mathematical models to describe relationships between experiments. RSM is also used to simultaneously evaluate the effects of multiple variables and determine their interactions. This function is extremely useful for isolating and analyzing the effects of factors in complex systems. Therefore, in cases where the effects of many variables are examined together, the detailed analysis and interpretation opportunities provided by RSM are important [9,10]. RSM's mathematical modeling and optimization techniques enable us to understand the results of experiments better and optimize processes. This increases the efficiency of operations, ensures more effective use of resources, and reduces undesirable variations. RSM's combination of statistical methods used to analyze inter-experimental relationships increases the accuracy and reliability of experimental data. In other words, it ensures that the results obtained are more reliable and repeatable. Considering all these advantages, RSM is considered a powerful tool for planning, executing, and optimizing experiments in complex systems. This method has a wide range of applications, from scientific research to industrial processes, and makes a significant contribution to increasing the efficiency of experimental studies [11,12].

In this study, an experimental design was made using RSM in the optimization of carbon dioxide applications. Figure 3 and Figure 4 show the effect of carbon dioxide application on the number of egg hatches according to RSM. As the carbon dioxide concentration increases, the number of hatching of *Halyamorpha halys* eggs decreases. In CO_2 applications, when *Halyamorpha halys* eggs are monitored, egg hatching is observed on the 4th day (96th hour) and the 5th day (120th hour). According to the results obtained, increasing carbon dioxide concentration (ppm) reduces the number of eggs hatched.

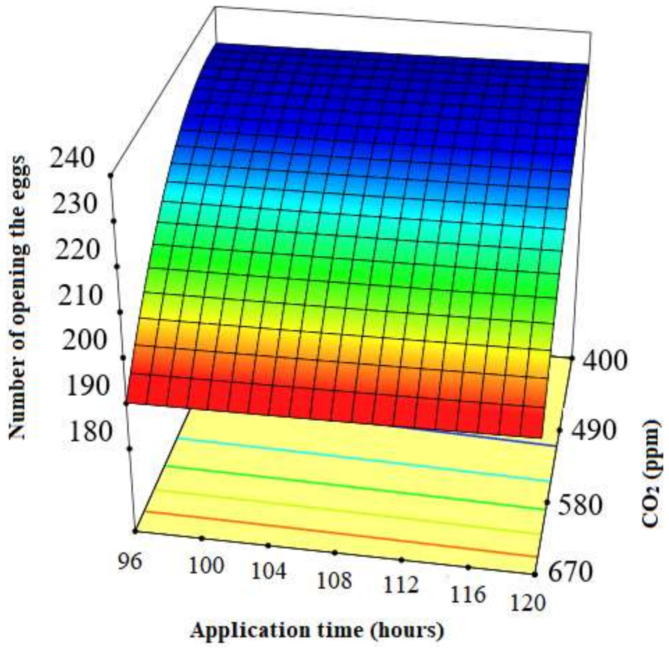

Figure 3. Effect of CO_2 application on egg hatching number according to RSM (3D)

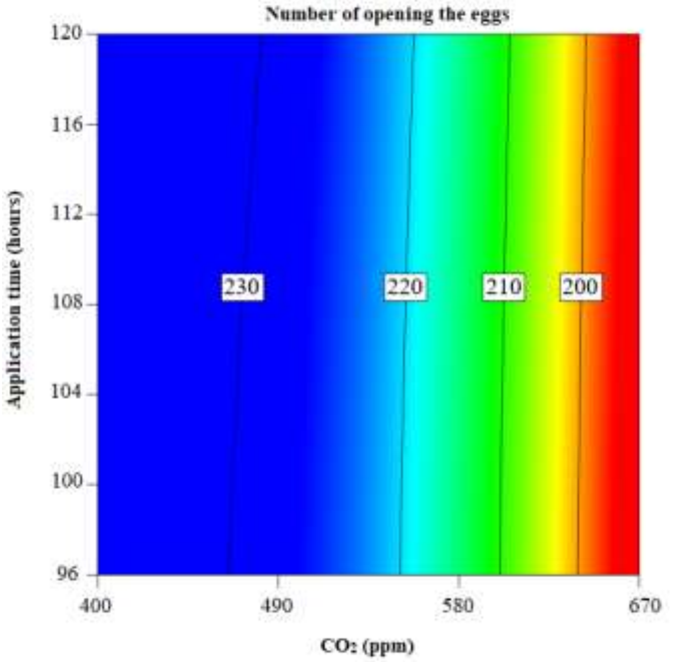

Figure 4. Effect of CO_2 application on egg hatching number according to RSM (2D)

Figure 5 compares the experimental results with the RSM model findings. When the results are evaluated, it is understood that the values in RSM in the CO_2 application are compatible with the actual data. In Figure 6, the change in the number of openings in the egg with CO_2 concentration is clearly expressed. Additionally, Figure 7 shows the frequency distribution of CO2 concentration according to RSM.

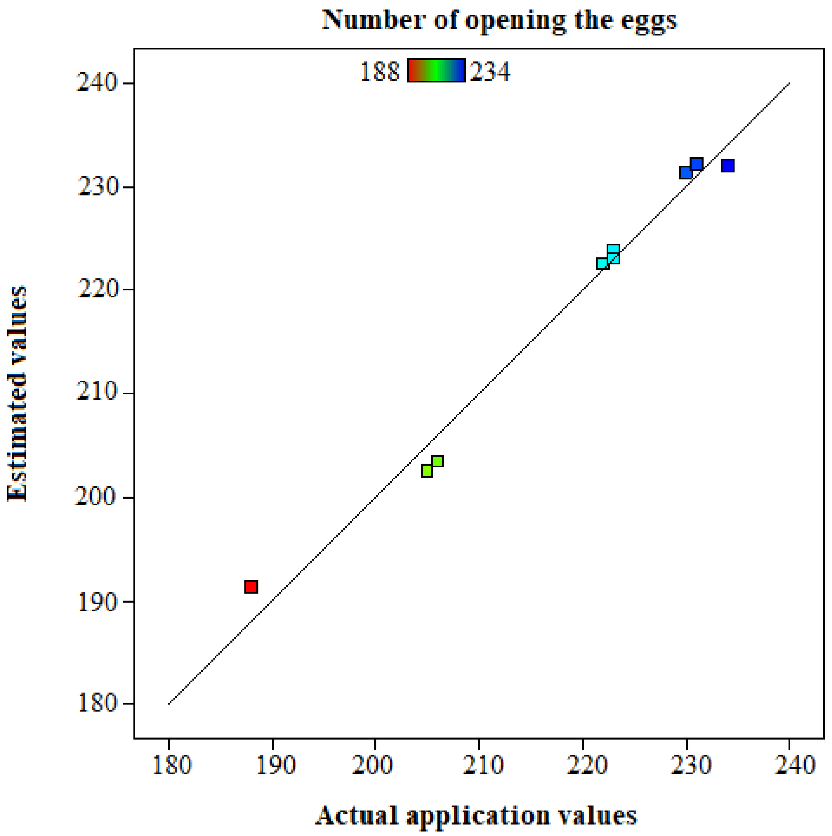

Figure 5. Comparison of CO_2 application results with experimental (actual) and RSM (estimated values)

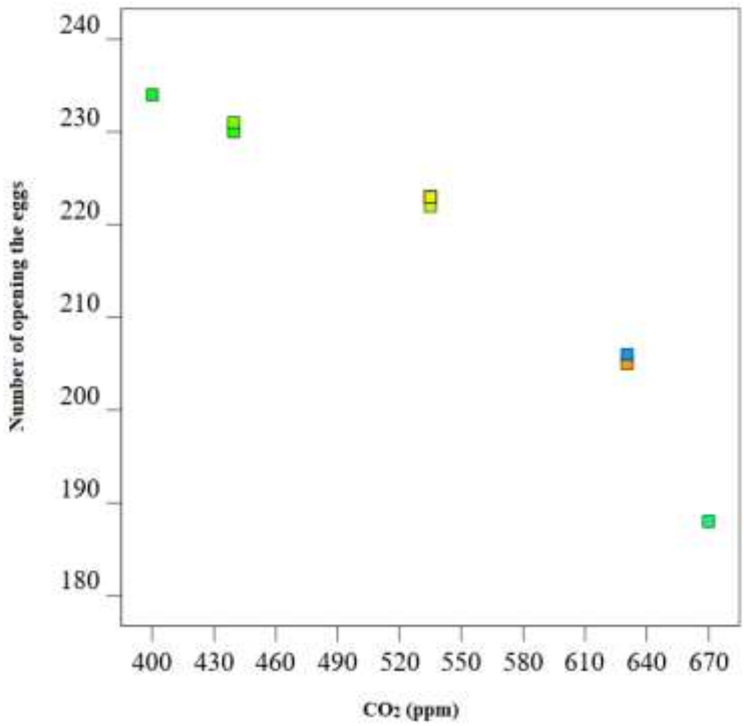

Figure 6. Number of eggs hatched by CO_2 concentration (ppm) according to RSM

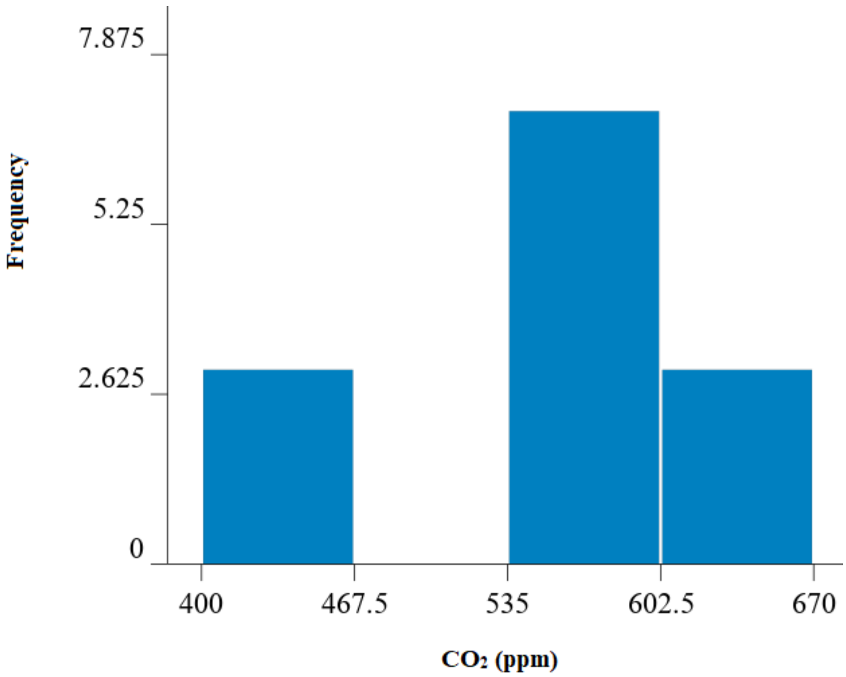

Figure 7. Frequency distribution of CO_2 concentration according to RSM

Conclusions

In this research, a new air conditioning cabin is developed by taking into account the change in CO2 ratio. Considering the increase in CO_2 concentration in the atmosphere in the future, the egg-laying and egg-hatching times of some harmful insects have been evaluated. The present study examined the reproduction and egg development of *Halyomorpha halys* Stål, 1855, commonly referred to as the hazelnut pest, in the Black Sea region of our nation. The hatching state of the eggs was investigated, and an air conditioning cabinet and CO_2 application system appropriate for the changing worldwide environment were designed.

In experimental investigations, the effects of several factors were examined and optimized using response surface methodology (RSM). By using this approach, the essential assessments were completed for designing the experiments, gathering information, and interpreting the findings. The hatching number of *Halyomorpha halys* eggs with CO_2 applications has been assessed using RSM. This method has established the efficacy of the CO_2 ratio, CO_2 application time, and experimental working conditions. In RSM, statistical analysis has been done to assess how well real data and model values match. Hatching of the eggs was noted on the fourth day (96th hour) and the fifth day (120th hour), particularly when *Halyamorpha halys* eggs were examined. The results showed that the number of eggs that hatched dropped as the CO_2 concentration (ppm) increased.

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REFERENCES

[1] Dinçer, B., Akpınar, H., *Purification of Acetylcholinesterase from Halyomorpha halys (Stål)(Heteroptera: Pentatomidae) and Management of Control of the Pest through Inhibition of the Enzyme*. International Journal of Tropical Insect Science, 2023: 43(5), 1421-1429.

[2] Leskey, T., Hamilton, G., Hooks, C., Krawczyk, G., Harper, J., Bergh, C., ... Brunner, J., *Biology, Ecology, and Management of Brown Marmorated Stink Bug in Orchard Crops, Small Fruit, Grapes, Vegetables and Ornamentals*. International Journal of Tropical Insect Science, 2013: 43, 1421-1429.

[3] Scala, M., Fouani, J. M., Zapponi, L., Mazzoni, V., Wells, K. E., Biondi, A., ... Anfora, G., *Attraction of egg parasitoids Trissolcus mitsukurii and Trissolcus japonicus to the chemical cues of Halyomorpha halys and Nezara viridula*. Insects, 2022: 13(5), 439.

[4] Bosco, L., Moraglio, S. T., Tavella, L., *Halyomorpha halys, a serious threat for hazelnut in newly invaded areas*. Journal of Pest Science, 2018: 91, 661-670.

[5] Özgen, İ., Aydoğmuş, E., Topdemir, A., Kalender, M., Güral, Y., Buran, A. *Determination of Effect of Three Different Atmospheric Carbon Dioxide Applications on Egg-Hatching Ratio and Hatching Times of Halyomorpha halys (Stål 1855)(Hemiptera: Pentatomidae)*. Journal of the Heteroptera of Turkey, 2024: 6(1): 39-47.

[6] Yang, S. Y., Zhan, H. X., Zhang, F., Babendreier, D., Zhong, Y. Z., Lou, Q. Z., ... Zhang, J. P., *Development and fecundity of Trissolcus japonicus on fertilized and unfertilized eggs of the brown marmorated stink bug, Halyomorpha halys*. Journal of pest science, 2018: 91, 1335-1343.

[7] Taylor, C. M., Coffey, P. L., DeLay, B. D., Dively, G. P., *The importance of gut symbionts in the development of the brown marmorated stink bug, Halyomorpha halys (Stål)*. Plos One, 2014: 9(3), e90312.

[8] Medal, J., Smith, T., Santa Cruz, A., *Biology of the brown marmorated stink bug Halyomorpha halys (Heteroptera: Pentatomidae) in the laboratory*. Florida Entomologist, 2013: 96(3), 1209-1212.

[9] Aydoğmuş, E., *Biohybrid nanocomposite production and characterization by RSM investigation of thermal decomposition kinetics with ANN*. Biomass Conversion and Biorefinery, 2022: 12(10), 4799-4816.

[10] Aydoğmuş, E., Arslanoğlu, H., Dağ, M., *Production of waste polyethylene terephthalate reinforced biocomposite with RSM design and evaluation of thermophysical properties by ANN*. Journal of Building Engineering, 2021: 44, 103337.

[11] Şahal, H., Aydoğmuş, E., *Production and characterization of palm oil based epoxy biocomposite by RSM design.* Hittite Journal of Science and Engineering, 2021: 8(4), 287-297.

[12] Dağ, M., Aydoğmuş, E., Yalçin, Z. G., Arslanoğlu, H., *Diatomite reinforced modified safflower oil-based epoxy biocomposite production: Optimization with RSM and assessment of outcomes by ANN*. Materials Today Communications, 2023: 35, 106327.