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Determination of the Effects of *Curcuma longa* L. (turmeric) Plant Extract on the Biochemical Properties of *Capsicum annuum* L. (pepper) Plant

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Abstract

The primary objective of this study was to determine how the defense system changes within the context of plant-plant interactions.

To this end, two different concentrations of *Curcuma longa* L. (turmeric) extract (2.5 g/L and 10 g/L) were applied to 8-week-old *Capsicum annuum* L. (pepper) seedlings. After 24-48 and 72 hours, changes in the total protein content and the activity of peroxidase (POX), one of the key defense enzymes in plants, were determined in the seedlings.

Based on our analysis results, the group showing the highest increase in total protein content was the one treated with the 10 g turmeric extract for 24 hours, exhibiting an increase of 47.3% compared to the control group. The highest increase in Peroxidase (POX) activity was observed in the group treated with the 10 g turmeric extract for 72 hours, showing an increase of 67.7%compared to the control.

In light of these findings, it was determined that the turmeric extract supports the biochemical homeostasis of the plants and can stimulate their defense system. This result offers an environmentally friendly approach that could serve as an alternative to synthetic pesticides and elicitors.

This research contributes to the growing literature regarding the importance of phytochemical-based biostimulants in sustainable agricultural practices and establishes a scientific basis for future studies in this field.

Keywords: *Curcuma Longa*; *Capsicum Annuum*; Turmeric Extract; Total Protein; Peroxidase

1. Introduction

In recent years, studies conducted in the fields of plant biotechnology and agricultural biochemistry have revealed the effects of naturally derived plant extracts on the biochemical mechanisms of plants, thereby paving the way for new approaches for alternative applications in agricultural production. Extracts obtained particularly from medicinal and aromatic plants, which contain bioactive compounds such as phenolics, terpenoids, and flavonoids, have been reported to promote plant growth, enhance stress tolerance, and strengthen antioxidant defense networks. Among these plants, *Curcuma longa* L. (turmeric) has become a major focus in both pharmacology and plant physiology due to its high content of biologically active constituents, especially curcumin. The strong antioxidant capacity and physiological regulatory pr

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operties of turmeric extract make it suitable for consideration as an agricultural biostimulant. Therefore, understanding the biochemical responses induced by turmeric extract—particularly in medicinally and economically important species such as pepper plants used in this study, as well as in plants sensitive to environmental stresses—has become an important research topic.

The effects of curcumin on oxidative stress processes have been extensively described in numerous studies. Sharma et al. reported that curcumin suppresses lipid peroxidation in various oxidative stress models and possesses a high level of free radical–scavenging capacity [1]. These findings suggest that curcumin is a potent antioxidant capable of protecting plant cell membranes against oxidative damage. Similarly, Ahmad et al. reported that turmeric extract applied to maize increased the activity of key antioxidant enzymes such as SOD, CAT, and POD, while reducing MDA accumulation [2]. The literature also includes extensive evidence showing that turmeric extract has beneficial effects at low and moderate doses, whereas high concentrations may lead to phytotoxic responses. For instance, González-Peña et al. [3] showed that low doses promoted growth in tomato and lettuce seedlings, while higher doses inhibited root development.

Activation of phenolic metabolism in plants is a critical regulatory step for enhancing antioxidant defense, and several studies have demonstrated that turmeric extract effectively influences this process as well. Kumar et al. [4] found that 2–4% turmeric extract increased total phenolic content and elevated chlorophyll levels in bean plants. Considering that phenolic compounds play important roles in both stress responses and plant developmental processes, turmeric appears to be a potential biostimulant capable of modulating various metabolic pathways. Research by Bano et al. [5] and Yadav et al. [6] further confirmed that appropriately applied turmeric extract accelerates germination, promotes seedling development, increases chlorophyll synthesis, and enhances antioxidant enzyme activities.

Although the number of studies directly examining the effects of turmeric extract on *Capsicum annuum* L. (pepper) is limited, the existing research provides noteworthy findings. Rana et al. [7] applied 1%, 3%, and 5% turmeric extract to pepper seedlings and reported that the 3% dose notably decreased MDA levels while significantly increasing SOD and CAT activities. The same application also promoted the accumulation of phenolic compounds, increased total chlorophyll content, and improved growth parameters. Similarly, the study conducted by Alkan and Yıldırım in Türkiye [8] reported that the 3% extract concentration yielded the most effective physiological and biochemical outcomes. These studies offer a strong foundation for research investigating the biochemical effects of turmeric extract on pepper plants.

The effects of turmeric extract on plant physiology are not limited to antioxidant defense systems. Several studies have shown that the extract can influence microbial activity (Sarma et al. [9]), provide protective effects against soil-borne pathogens (Gautam et al. [10]), and play a regulatory role in ion homeostasis in plants (Zhou et al. [11]). Singh and Srivastava reported that turmeric essential oil may exert regulatory functions through various physiological mechanisms by influencing stomatal conductance and water-use efficiency [12]. These findings suggest that turmeric-derived products exhibit multifunctional regulatory effects in plants, not only in extract form but also in variants such as essential oils.

Overall, it is understood that *C. longa* L. (turmeric) extract can positively influence several biochemical processes in plants, including reducing oxidative stress, strengthening antioxidant defense mechanisms, supporting chlorophyll synthesis, and activating phenolic metabolism. The available findings indicate that plants grown under stressful conditions respond favorably to turmeric extract, and that appropriate dose optimization can significantly promote plant development. The limited number of studies conducted on pepper plants also suggests that turmeric extract induces notable biochemical changes in pepper seedlings. Therefore, the present study is expected to contribute valuable insights to both the scientific literature and practical agricultural applications.

2. Materials and methods

The *C. annuum* L. seedlings used in the study were obtained from certified seeds. The seeds were sown into 28-cell trays containing a perlite–peat mixture at a 1:2 ratio. The seedlings were grown in a controlled plant growth chamber at 25±2 °C with a light intensity of 24,000 lux. Irrigation was carried out with distilled water every other day. All experiments were conducted with three replications.

For turmeric applications, commercially obtained pure turmeric powder was used. First, a stock solution was prepared using distilled water. The two concentrations used in the research, 2.5 g/L and 10 g/L, were prepared by diluting the stock solution.

The prepared solutions were applied to the leaves of pepper seedlings at equal volumes using a hand sprayer, with three trays assigned to each concentration. The control group received only distilled water. Following a single application, the seedlings were harvested at 24, 48, and 72 hours and processed for analysis.

For each group, 1 g of material was weighed from freshly harvested, young, and healthy leaves. The leaves were ground for 1 minute in cold porcelain mortars placed in an ice bath using 0.05 M Sodium Acetate buffer to obtain leaf homogenates. The homogenates were filtered through cheesecloth into Eppendorf tubes, centrifuged at 13,000 rpm for 15 minutes at +4 °C, and stored at −20 °C until analysis.

All solutions used in the analyses were freshly prepared throughout the study. The Bradford method was employed for total protein analysis [13]. Total protein content was measured spectrophotometrically at 595 nm using plastic cuvettes. Absorbance values were calculated based on a standard protein curve prepared with 2 mg/mL BSA.

Peroxidase (POX) activity measurements were performed according to the method of Kanner and Kinsella [14]. All measurements were conducted in the spectrophotometer with three technical replicates.

3. Results

When the biochemical changes induced by turmeric extract in pepper seedlings were evaluated, it was concluded that the extract increased the total protein content at appropriate doses and exposure times. In particular, the 10 g/L dose resulted in a pronounced increase at the 24th hour, indicating that the extract can trigger a strong metabolic response in a short period of time.
Findings related to peroxidase (POX) activity revealed that the extract markedly activated the plant's antioxidant defense system. Turmeric applied at low concentrations increased POX activity steadily in a time-dependent manner.

Overall, it was determined that different concentrations of turmeric extract exerted positive effects on both total protein content and POX activity. Consequently, it can be stated that turmeric extract has the potential to stimulate and enhance metabolic activities in pepper seedlings.

3.1. Changes in Total Protein Content

The effects of different concentrations of turmeric extract on the total protein content of pepper seedlings were determined as follows:

In the control group, the total protein content was measured as 0.344 mg/mL. After the application of 10 g/L turmeric extract, the total protein content increased by 47.3% compared to the control at the 24th hour. Following the application of 2.5 g/L turmeric extract, total protein content increased by 20.9%, 27.6%, and 25.0% at 24, 48, and 72 hours, respectively, compared to the control (Figure 1).

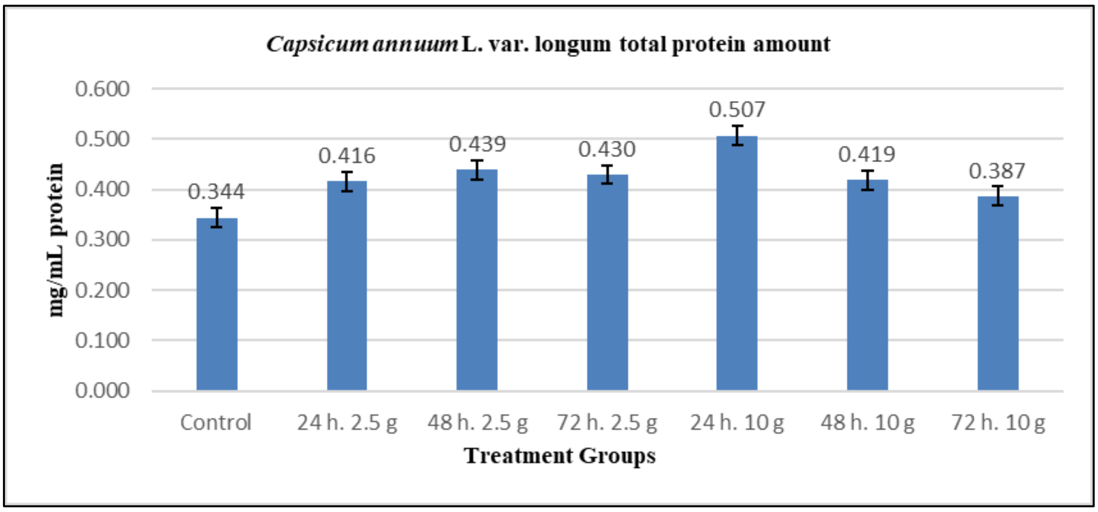

Figure 1 Effect of *Curcuma longa* L. extract on the total protein content of *Capsicum annuum* L.

Although the application of turmeric extract at a concentration of 10 g/L caused an increase compared to the control, it was observed that the increases in total protein content gradually declined at 48 and 72 hours. This indicates that although the high dose provides strong metabolic activation in the early period, this activation diminishes over time and approaches the levels of the control group in subsequent hours. Overall, it was determined that the extract exhibited its maximum effect particularly at the 24-hour – 10 g/L application, while its effectiveness at other doses and exposure times was more limited and time-dependent.

3.2. Changes in Peroxidase (POX) Activity

POX activity increased in all turmeric extract treatment groups compared to the control. At the low concentration, POX activity increased by 12.0%, 41.4%, and 50.1% at 24, 48, and 72 hours, respectively. This consistent increase indicates that the low dose induces a progressively strengthened defense response over time.

In the high concentration (10 g/L) application, although POX activity was approximately 7.8% lower than the control at the 24th hour, it reached the highest level among all groups at the 48th hour with an increase of 48.1%, and at the 72nd hour with an increase of 67.7%. These findings indicate that the high concentration creates a short-term suppressive effect in the early stage but triggers a strong defense response in the following hours (Figure 2).

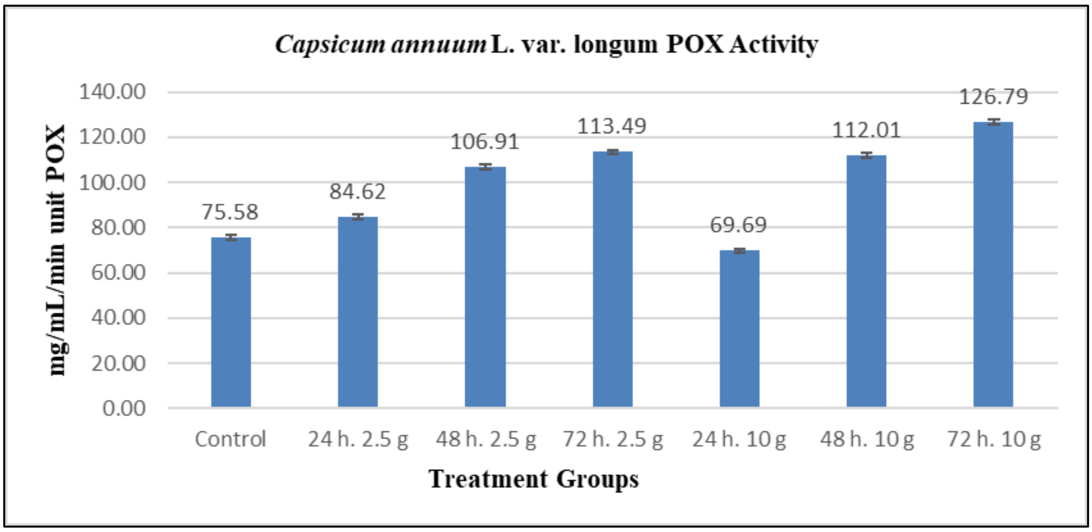

Figure 2 Changes in POX activity induced by *Curcuma longa* L. extract in *Capsicum annuum* L.

Overall, it was determined that the treatments significantly increased total protein content and POX activity in a dose- and time-dependent manner, with the high concentration inducing the most pronounced defense response at the later time points. These results indicate the potential of the extract to be used as a natural plant activator.

4. Discussion

In conclusion, when compared with previous scientific studies, it was found that different concentrations of turmeric extract triggered defense reactions in pepper seedlings in a time-dependent manner. This finding aligns with the results reported by Sharma et al. [1], who demonstrated that curcumin reduces lipid peroxidation by neutralizing free radicals. Additionally, the observed increases in total protein content, phenolic compound accumulation, and photosynthetic pigment levels indicate an enhancement of metabolic activity. Similar findings reported by Ahmad et al. [2] and Kumar et al. [4] support the hypothesis that turmeric extract can function as a regulatory agent of biochemical processes under stress conditions.

The results obtained in this study revealed that turmeric extract, when applied at suitable concentrations, exerts positive effects on plant physiology. However, the fact that some studies report phytotoxic effects at high doses (González-Peña et al., 2022) [3] highlights the critical importance of dose optimization for such applications. Previous studies conducted on pepper plants (Rana et al. [7]; Alkan & Yıldırım [8]) similarly support the trend observed in this study, indicating that turmeric extract exerts a stimulatory role on the phenolic metabolism of pepper plants. Overall, it is understood that *Curcuma longa* L. extract possesses both metabolic regulatory and biostimulant properties. These findings demonstrate that turmeric extract may be considered a natural activator or supportive agent in agricultural biotechnology and provide a scientific basis for more comprehensive future studies in this field.

Compliance with ethical standards

Acknowledgments

This research includes datas obtained from a Master's Thesis prepared by Özlem SAYIN at the Çanakkale Onsekiz Mart University School of Graduate Studies.

Disclosure of conflict of interest

There is no conflict of interest in this study.

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