**Original scientific paper**

# SUSTAINABLE CULTIVATION PRACTICES FOR MITIGATION OF CLIMATE CHANGE ON PEPPER (*Capsicum annuum* L.) CROP

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## ABSTRACT

This study investigates the potential of integrating sustainable agricultural practices to mitigate climate change impacts on the cultivation of pepper (*Capsicum annuum* L.) in the arid regions. Climate-induced challenges such as desertification have further aggravated the issue of pepper cultivation. The experiment was executed in Kochani region in 2021, employing a randomized block design with five different fertilizer treatments including a notable biofertilizer, *Trichoderma harzianum*. The agronomic parameters such as fruit length, diameter, mass, pericarp thickness, and yield have been analysed. The mixed fertilization treatment (MIX) illustrated a significant enhancement in fruit dimensions and yield, whereas the Trichoderma treatment (TRICH) exhibited a notable reduction in non-marketable fruits. The findings validate that the incorporation of Trichoderma with organic and mineral fertilizers not only bolsters plant growth and yield, but also strengthens climate resilience in pepper cultivation. This increases the understanding of biofertilizer utilization in sustainable agriculture, especially in regions struggling with climate adversities. Furthermore, the study underpins the necessity for advanced knowledge in leveraging live organisms like Trichoderma for increasing agricultural productivity and climate resilience in arid regions.

**Key words: Trichoderma, pepper fruit traits, marketable yield**

## INTRODUCTION

Kochani is situated in the eastern region of the country, which during the era of ex-Yugoslavia, was renowned for rice cultivation over an expanse of more than 9000 ha. Because of the loss of markets and more significantly, due to inefficient water utilization for irrigation (primarily flooding), the producers of this region turned to vegetable production. The area dedicated to pepper cultivation for fresh consumption fluctuated between 4000 ha to 8000 ha in the period of 2011 to 2021 (SSO, 2023), as per the statistical office data. Climate change has notably impacted pepper cultivation (Gunawardena & De Silva, 2015), especially within this historically arid region, now exhibiting desert-like characteristics (Mukaetov et al., 2021) accompanied by a swift reduction of organic matter. The manifestations of desertification are already evident in the ongoing soil erosion. As documented by Blinkov et al. (2013) an aggregate of 680 $m^3$ $km^{-2}$ of sediment, typically constituting the fertile topsoil, is being displaced from its origin to either exit the state boundaries or accumulate in natural lakes and reservoirs. This scenario presents the growers in this region with a significantly challenging environment for cultivating a sensitive crop like pepper.

Several greenhouse production systems can be advocated for better environmental control (Nguyen & Lantzke, 2022). However, a substantial portion of the production, even under protected cultivation, remains extensive and soil-based (Popsimonova et al., 2021) Various success stories and methodologies for increasing tolerance to abiotic stresses through grafting techniques have been described by Bayoumi et al. (2022), Niu et al. (2022), and Yang et al. (2022). Employing local varieties, well-adapted to the prevailing climatic and soil conditions, also emerges as a viable strategy to mitigate climate change impacts (Drvoshanova et al., 2021; Sandeva Atanasova et al., 2021), although these pepper varieties may lack the desired marketable uniformity. A multitude of researchers has explored diverse techniques during the cultivation season to alleviate the impacts of climate change. For instance, Saqib and Anjum (2021) suggest alternate planting schedules to avoid critical phases during the cultivation season. Additionally, Maow (2023) emphasizes the significance of irrigation water quality in mitigating salinity stress.

Species of Trichoderma are recognized for their substantial contribution towards abiotic stress tolerance, attributed to their production of various enzymes that boost biocontrol activity. These enzymes play a crucial role in cell wall degradation, hyphal growth, and antagonistic activity against plant pathogens, thereby aiding plants in resisting abiotic stress conditions, and consequently enhancing agronomic and nutritional quality (Manokaran et al., 2014; Liu et al., 2020; Apostol et al., 2022; Guzmán- Guzmán et al., 2023).

With the aim of introducing minimal modifications to the conventional agricultural practices in Kochani, an affected region, we resolved to examine the efficacy of Trichoderma as a biofertilizer in the open-field cultivation of sweet salad pepper.

## MATERIALS AND METHODS

The investigation was conducted in 2021 within the region of Kochani, situated at a latitude of 41˚90’ N and longitude of 22˚41’ E, at an elevation of 324 meters above sea level. The plant spacing was configured at 65 cm between rows and 30 cm within the row, establishing a density of 5 plants per square meter. The dimension of each experimental plot was 5.0 square meters, with 20 plants. Ten plants per plot were marked for morphological trait assessment, while the remaining ten were observed for yield component analysis. The utilized pepper cultivar, Sivria, possesses a longstanding tradition of cultivation for fresh consumption. The fruits exhibit a length of approximately 20 cm, a fruit diameter ranging from 4.0 to 5.0 cm, and a pericarp thickness nearing 2.0 mm. Following the kapiya-type pepper, this cultivar remains a favoured choice for both greenhouse and open-field cultivation. The experimental design employed a randomized block arrangement with three replications and five treatments:

Treatment 1: Control – no fertilizer application.

Treatment 2 (TRICH): Fertilization with *Trichoderma harzianum* (trade name Trianum-P, Koppert) initiated at the seed stage, repeated during transplantation at a concentration of 3g $L^{-1}$, and a final application 20 days post-transplantation at 0.9g $L^{-1}$.

Treatment 3 (MIN): Mineral fertilizer application, specifically, a basic NPK fertilizer (8-16-24) at a concentration of 45g $m^{-2}$, followed by KAN 27% at a concentration of 30g $m^{-2}$ post onset of fruit formation.

Treatment 4 (ORG): Organic fertilization utilizing composted chicken manure at a concentration of 45 g $m^{-2}$ with a nutrient ratio of 4-3-3.

Treatment 5 (MIX): Mixed fertilization encompassing Trichoderma, mineral fertilizers and organic manure, each at one-third of the above-mentioned concentrations.

The fertilization schedule was designed based on previously made soil analyses. Soil properties were determined on the base of officially adopted methods in our country, at the Laboratory for soil testing, fertilizers and plants of the Institute of Agriculture, Skopje. Laboratory results and classifications are shown in Table 1.

Table 1. Soil properties on the experimental site

| | **Culture** | **Region** | **Depth (cm)** | **Soil properties** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **pH** | | **$CaCO_3$** | **Organic matter** | **Total nitrogen (N)** | **Available** | |
| | | | | **$H_2O$** | **NKCl** | **%** | **%** | **%** | **$P_2O_5$** | **$K_2O$** |
| | | | | | | | | | **mg/100g. soil** | |
| 1 | **Pepper** | Kochani | 0-30 | 6.37 | 5.11 | 0.00 | 1.40 | 0.0919 | 15.33 | 13.71 |
| | | | | *slightly acid* | *acid* | *non carbonate* | *low* | *low* | *optimum* | *medium* |

The rest of the agricultural practices were performed in standard manner, as close as possible to the already applied agri-technology for pepper in this region. Plant protection was based on IPM (Integrated Pest Management) measures, meaning that regular monitoring and preventive measures were undertaken, resulting in reduced use of plant protection products. The plants were grown without trimming.

The agronomic parameters under observation included: fruit length (mm), fruit diameter (mm), fruit mass (g), pericarp thickness (mm), fruit count per plant, marketable yield per plant (g), non-marketable yield per plant (g), and total yield (t $ha^{-1}$) as derived value.

Data processing was followed by a statistical analysis employing a one-way ANOVA to determine significant variances based on treatment, with LSD multiple range tests utilized for evaluation of significant differences between the treatments ($p < 0.05$ and $p < 0.01$). All analyses were performed using XL STAT Package 2014.5.03 (Addinsoft, 2014)

## RESULTS AND DISSCUSION

Fruit shape index as determined by the length and the fruit diameter is a varietal characteristic. As such, it kept the values that are typical for the Sivria type cultivars. However, the fruit length was significantly higher in the treatment with mixed fertilizers compared to the control treatment ($p > 0.01$) and the Trichoderma treatment ($p > 0.05$). The fruit diameter was observed to be significantly highest also in the mixed treatment, followed, by mineral fertilization and the organic one, as presented in Table 2.

Table 2. Fruit traits in different fertilization treatments

| Treatments | Fruit traits: Fruit length (mm) | | Fruit diameter (mm) | | Fruit shape index |
|---|---|---|---|---|---|
| Control | 173.0 | | 28.8 | | 6.0 |
| TRICH | 187.3 | * | 30.4 | | 6.2 |
| MIN | 197.3 | | 33.6 | ** | 5.9 |
| ORG | 189.8 | | 32.8 | ** | 5.8 |
| MIX | 218.1 | ** | 33.9 | ** | 6.4 |
| LSD 0.01** | 33.4 | | 4.5 | | NA |
| LSD 0.05* | 27.5 | | 3.7 | | NA |

*Trichoderma* species have primarily been studied and used as biocontrol agents and there is limited information available specifically on their use as biofertilizers, and even less on pepper crop (Guzmán-Guzmán et al., 2023). Therefore, we had to compare our results with familiar crops, such as tomato. For example in an experiment with *Trichoderma, Pseudomonas,* and *Rhizobium* on two tomato varieties (Punjab Ratta and Punjab Gourav) the treatments had a significant influence on various characters, including fruit length and fruit diameter (Mahajan et al., 2023) which is not in accordance with our results if we observe the effect of Trichoderma separately.

Table 3. Yield parameters in different fertilization treatments

| | Yield parameters | | |
|---|---|---|---|
| Treatments | Fruit mass (g) | Number of fruits per plant | Pericarp thickness (mm) |
| Control | 39.62 | 12.8 | 2.57 |
| TRICH | 43.36 | 13.2 | 3.32 * |
| MIN | 47.18 | 13.9 ** | 3.09 * |
| ORG | 49.37 | 13.0 * | 2.93 |
| MIX | 54.48 ** | 14.3 ** | 3.88 ** |
| LSD 0.01** | 14.07 | 1.3 | 0.99 |
| LSD 0.05* | 11.57 | 1.1 | 0.81 |

Largest individual fruit mass was observed in the MIX treatment, that was significantly higher compared to the control treatment ($p > 0.01$), whereas the rest of the treatments had heavier fruits than the control, but there was no significant difference. For the number of fruits per plant, and the pericarp thickness the similar pattern was observed, the MIX treatment again having significantly highest value, followed by the treatment with mineral fertilizer ($p > 0.01$) and the treatment with organic fertilizers ($p > 0.05$). Surprisingly, in respect of pericarp thickness, beside the fruits from the MIX treatment that had the thickest fruit wall ($p > 0.01$), the Trichoderma treated plants were also significantly thicker compared to the control and to the organic manure treatment ($p > 0.05$), followed by the fruits from the mineral fertilizer treatment, as presented in Table 3.

In a similar experimental set-up, Tangga et al. (2022) investigated the effect of empty fruit bunch (EFB) compost, 100% Trichoderma biofertilizer, and their 50% mixture on the growth and yield performance of chili plants. Regarding the mean plant weight, there was a significant difference ($p<0.05$) between the treatments, the mixture having the highest values for the number of fruit and fruit weight of chilli plants.

The total yield (Figure 1) per plant was the highest in the MIX treatment ($p > 0.05$), whereas the marketable yield in the MIN treatment was significantly higher than the control treatment, but similar to the rest of treatments with exception to the MIX treatment (Table 4). Exceptionally low number of non-marketable fruits (misshaped, sun scald or blossom end rot) was observed in the Trichoderma treatment. The contribution of this beneficial trait can be recognized also in the MIX treatment that had also relatively low percentage of non-marketable fruits.

Table 4. Yield components per plant under different fertilization treatments

| | Yield components per plant | | |
|---|---|---|---|
| Treatments | Marketable yield (g) | Non-marketable yield (g) | Total yield (g) |
| Control | 407.7 | 71.1 | 507.8 |
| TRICH | 540.4 | 29.2 ** | 575.5 |
| MIN | 594.9 * | 66.2 | 662.8 |
| ORG | 540.2 | 72.8 | 645.3 |
| MIX | 722.2 ** | 75.7 | 784.8 ** |
| LSD 0.01** | 229.4 | 38.9 | 209.7 |
| LSD 0.05* | 188.7 | 32.0 | 172.5 |

Kubheka & Ziena (2022) have explained the effect of Trichoderma on the nutrient uptake as follows: "In acidic soils, phosphorus gets bound up, becoming inaccessible to the crops—a situation far from ideal. Trichoderma species solubilize phosphates via the secretion of enzymes known as phytase. The action of phytase is triggered by the presence of insoluble tricalcium phosphate. On the other hand, *Trichoderma koningiopsis* tackles phosphate solubilization by producing alkaline phosphatase enzyme. Thus, the presence of Trichoderma in the rhizosphere augments both the availability and absorption of nutrients, as it facilitates the conversion of essential nutrients from an inaccessible to an accessible form for the plant."

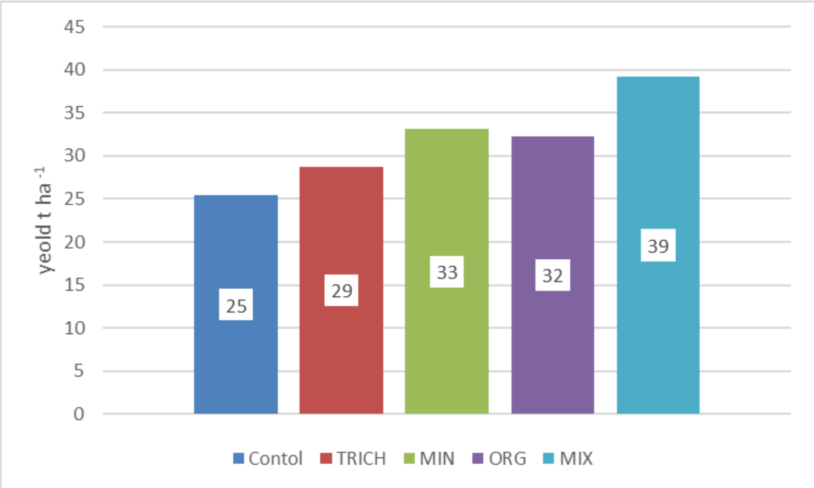


Figure 1. Total yield (t ha $^{-1}$) under different fertilization treatments

In our experiment, the soil was well supplied with phosphorus (Table 1) which was probably made well available along with the other nutrient supplied by the mineral and organic fertilizers to enable the best results in the MIX treatment.

## CONCLUSIONS

It can be concluded that Trichoderma combined fertilizer application strategy stimulates plant growth, improves yield, and enhances nutrient absorption in pepper plants. In that way the treated plants, in combination with organic and mineral fertilizers are more resilient to abiotic stresses. Adjustment of Trichoderma can be useful for increasing climate resilience in pepper production. It should also be noted that its effective use and application requires advanced knowledge, because it is live organism and its storage and manipulation can affect the quality.

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## REFERENCES

Apostol, F. D., Dinu, M., Dumitru, M. G., Maracineanu, L. C., Josceanu, A. M., & Giugea, N. (2022). Influence of Fertilization With Trichoderma Atroviride and Fulvic Acids Upon the Nutritive Constituents in Long Pepper Fruits. *UPB Scientific Bulletin, Series B: Chemistry and Materials Science*, *84*(4), 83–98.

Bayoumi, Y., Shalaby, T., Abdalla, Z., Shedeed, S., Abdelbaset, N., El-Ramady, H., & Prokisch, J. (2022). Grafting of Vegetable Crops in the Era of Nanotechnology: A photographic Mini Review. *Environment, Biodiversity and Soil Security*, *6*(2022), 133–

148. https://doi.org/10.21608/jenvbs.2022.147280.1181

Blinkov, I., Kostadinov, S., & Marinov, I. T. (2013). Comparison of erosion and erosion control works in Macedonia, Serbia and Bulgaria. *International Soil and Water Conservation Research*, *1*(3), 15–28. https://doi.org/10.1016/S2095-6339(15)30027-7

Drvoshanova, B., Ivanovska, S., Jankulovska, M., Popsimonova, G., & Ibushoska, A. (2021). Evaluation of fruit traits in pepper (type kapiya) collection from North Macedonia. *Acta Horticulturae*, *1320*, 25–32. https://doi.org/10.17660/actahortic.2021.1320.3

Gunawardena, M. D. M., & De Silva, C. S. (2015). Identifying the Impact of Temperature and Water Stress on Growth and Yield Parameters of Chilli (*Capsicum annuum* L.). *OUSL Journal*, *7*(0), 25. https://doi.org/10.4038/ouslj.v7i0.7306

Guzmán-Guzmán, P., Kumar, A., de los Santos-Villalobos, S., Parra-Cota, F. I., Orozco-Mosqueda, M. del C., Fadiji, A. E., Hyder, S., Babalola, O. O., & Santoyo, G. (2023). Trichoderma Species: Our Best Fungal Allies in the Biocontrol of Plant Diseases—A Review. *Plants*, *12*(3), 1–35. https://doi.org/10.3390/plants12030432

Liu, Q., Meng, X., Li, T., Raza, W., Liu, D., & Shen, Q. (2020). The growth promotion of peppers (*Capsicum annuum* L.) by *Trichoderma guizhouense* NJAU4742-based biological organic fertilizer: Possible role of increasing nutrient availabilities. *Microorganisms*, *8*(9), 1–23. https://doi.org/10.3390/microorganisms8091296

Mahajan, G., Rattan, P., & Sharma, A. (2023). Effect of microbial inoculants on growth , yield and quality attributes of tomato *(Solanum lycopersicum)*. *The Pharma Innovation Journal, Volume 11, September. 1503-1511, https://www.thepharmajournal.comvarieties*

Manokaran, R., Sharma, P., Sharma, M., Raja, M., & Shanmugam, V. (2014). Status of Trichoderma research in India: A review Want more pepers like this? Status of Trichoderma research in India: A review. *Downloaded from Academia.Edu  Indian Phytopath*, *67*(1), 1–19.

Maow, B. A. (2023). Effects of Irrigation Water Salinity Levels on Pepper Plant (*Capsicum annuum* ) Yield and Quality Properties and Soil Characteristics. *Research square* 1–19.

Mukaetov, D., Andonov, S., Chukaliev, O., Dimov, Z., Martinovska Stojcheska, A., Tanaskovik, V., Nikolov, N., Mincev, I., Poposka, H., & Dimitrov, L. (2021). *Report on climate change in agricultural sector, vulnerability and adaptation. Prepared for Ministry of Environment and Physical Planning of the Republic of North Macedonia (MOEPP).*

Nguyen, G. N., & Lantzke, N. (2022). Mitigating the Adverse Effects of Semi-Arid Climate on Capsicum Cultivation by Using the Retractable Roof Production System. *Plants*, *11*(20). https://doi.org/10.3390/plants11202794

Niu, M., Wei, L., Peng, Y., Huang, Y., & Bie, Z. (2022). Mechanisms of increasing salt resistance of vegetables by grafting. *Vegetable Research*, *2*(1), 1–9. https://doi.org/10.48130/VR-2022-0008

Petros Kubheka, B., & Weldegabir Ziena, L. (2022). Trichoderma : A Biofertilizer and a Bio-Fungicide for Sustainable Crop Production. In *Trichoderma - Technology and Uses*. IntechOpen. https://doi.org/10.5772/intechopen.102405

Popsimonova, G., Benko, B., Karic, L., & Gruda, N. (2021). Production systems in southeastern European greenhouses. *Acta Horticulturae*, *1326*, 137–143. https://doi.org/10.17660/ActaHortic.2021.1326.18

Sandeva Atanasova, N., Jankulovska, M., & Ivanovska, S. (2021). Genetic diversity of Macedonian embroidered pepper (Capsicum spp.) based on fruit morphological traits. *Acta Horticulturae*, *1320*, 33–40. https://doi.org/10.17660/ActaHortic.2021.1320.4

Saqib, M., & Anjum, M. A. (2021). Mitigation of climate change effect in sweet pepper (*Capsicum annuum* L.) through adjustment of planting time. *Pakistan Journal of*

*Agricultural Sciences*, *58*(3), 919–927. https://doi.org/10.21162/PAKJAS/21.9735

State Statistical Office of North Macedonia, (last approached on April, 2023), available at https://www.stat.gov.mk/Default_en.aspx

Tangga, C. K., Mohidin, H., & Abdullah, S. (2022). The Effect of Empty Fruit Bunch (EFB) Compost and Trichoderma Biofertilizer on Growth and Yield Performance of Chili ( Capsicum annuum L. Var. Kulai). *IOP Conference Series: Earth and Environmental Science*, *1114*(1). https://doi.org/10.1088/1755-1315/1114/1/012070

Yang, L., Xia, L., Zeng, Y., Han, Q., & Zhang, S. (2022). Grafting enhances plants drought resistance: Current understanding, mechanisms, and future perspectives. *Frontiers in Plant Science*, *13*(October), 1–17. https://doi.org/10.3389/fpls.2022.1015317

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