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ENHANCING PLANT GROWTH AND SOIL HEALTH THROUGH ORGANIC FERTILIZERS: THE EFFECTS OF MEALWORM FRASS AND JEEVAMRUTHAM ON *HIBISCUS SABDARIFFA*, *AMARANTHUS HYBRIDUS* AND *CAPSICUM ANNUUM*

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Key words : *Mealworm frass, Jeevamrutham, Plant growth, Sustainable agriculture, Organic fertilizer*

Abstract– This study examines the impact of mealworm frass and Jeevamrutham on the growth of *Hibiscus sabdariffa, Amaranthus hybridus*, and *Capsicum annuum* through a 90-day pot experiment. Four treatments—control, mealworm frass, Jeevamrutham, and a combination of both—were tested, with each treatment maintained in triplicate. Key soil parameters (pH, organic carbon, nitrogen, potassium, and phosphorus) and plant growth indicators (height, fresh weight, basal stem width, and chlorophyll content) were measured at 0, 30, 60, and 90 days. Results indicated that plants treated with the combination of mealworm frass and Jeevamrutham showed the most substantial improvements across all parameters. Soil in the combined treatment exhibited enhanced pH, organic carbon, nitrogen, potassium, and phosphorus levels, contributing to better plant growth outcomes. Statistical analysis confirmed the significant effects of these treatments on both soil and plant metrics. This study supports the potential of mealworm frass and Jeevamrutham as effective organic amendments, suggesting a sustainable approach to improving soil fertility and plant productivity while reducing dependency on synthetic fertilizers.

INTRODUCTION

Agricultural practices have historically relied on synthetic fertilizers, which often lead to environmental degradation, affecting soil health and increasing pollution levels (Tripathi *et al.,* 2020; Hossain *et al.,* 2022). This growing concern has driven research towards sustainable alternatives that can maintain or enhance crop productivity while preserving ecosystem integrity (Ramesh *et al.,* 2005; Virk *et al.,* 2024). Organic fertilizers, such as mealworm frass and Jeevamrutham, are potential eco-friendly solutions. Mealworm frass, a byproduct of insect farming, contains a rich array of nutrients, including organic nitrogen, phosphorus, and potassium, making it a promising biofertilizer (Poveda *et al.,* 2019; Beesigamukama *et al.,* 2022). Jeevamrutham, an Indian-origin organic fertilizer, is known to stimulate soil microbial activity and enhance soil fertility, contributing to improved crop growth (Kumar *et al.,* 2021; Bhattacharjee *et al.,* 2023).

Several studies have highlighted the potential of mealworm frass and similar insect- derived organic materials as biofertilizers. For example, Foughar *et al.* (2024) demonstrated the biostimulant effects of mealworm frass on lettuce, attributing improvements to nutrient release and increased microbial activity in the soil. Similarly, Jeevamrutham has been shown to enhance microbial populations and nutrient availability, fostering better soil structure and plant growth (Udaratta and Uppaluri, 2023; Rai and Jolly, 2024).

While individual benefits of these fertilizers are documented, research on their combined application is limited, especially for crops like *Hibiscus sabdariffa, Amaranthus hybridus,* and *Capsicum annuum*. This gap underscores the need for studies like ours to explore potential synergistic effects when these biofertilizers are used together.

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Despite the promising benefits of these fertilizers, limited studies have explored their combined effect on multiple crops under controlled conditions. This study evaluates the individual and combined effects of mealworm frass and Jeevamrutham on the growth of *Hibiscus sabdariffa*, *Amaranthus hybridus*, and *Capsicum annuum*. The objective is to determine if these treatments can enhance soil nutrient levels and promote sustainable plant growth, thus contributing to the literature on organic fertilizers for sustainable agriculture.

MATERIALS AND METHODS

Experimental Setup: The study was conducted using potted plants under controlled environmental conditions. The experiment used four treatments: (1) control (untreated soil), (2) mealworm frass, (3) jeevamrutham, and (4) combined mealworm frass and jeevamrutham. Each treatment had three replicates for statistical validity. Seeds of *Hibiscus sabdariffa, Amaranthus hybridus*, and *Capsicum annuum* were obtained from certified sources. The soil was a standardized potting mix with initial measurements of pH, organic carbon, nitrogen, potassium, and phosphorus. Plants were monitored over 0, 30, 60, and 90 days to assess the effects of treatments on both soil and plant parameters.

Soil and Plant Analysis: Soil properties were measured using established protocols: pH (pH meter), organic carbon (Walkley-Black method), nitrogen (Kjeldahl method), potassium, and phosphorus (atomic absorption spectroscopy) (Jackson, 1973). Plant growth parameters, including height, fresh weight, basal stem width, and chlorophyll content, were recorded at 0, 30, 60, and 90 days.

Statistical Analysis: The data were analyzed using Analysis of Variance (ANOVA) to assess the significance of treatments, time, and their interactions on both soil and plant parameters (DeJarnette and Mamidala, 2023). P-values less than 0.05 were considered statistically significant.

RESULTS AND DISCUSSION

Soil Parameter Changes

We observed notable changes in soil pH, organic carbon, nitrogen, potassium, and phosphorus levels across all treatments. The control group showed a gradual decline in these parameters over time. However, soil treated with mealworm frass, Jeevamrutham, and their combination showed improvements, with the combined treatment yielding the highest pH levels by Day 90, rising from 6.5 to 6.9. The nutrient-rich composition of the organic amendments, supporting soil microbial activity, could be the cause of this change (Houben *et al.,* 2020).

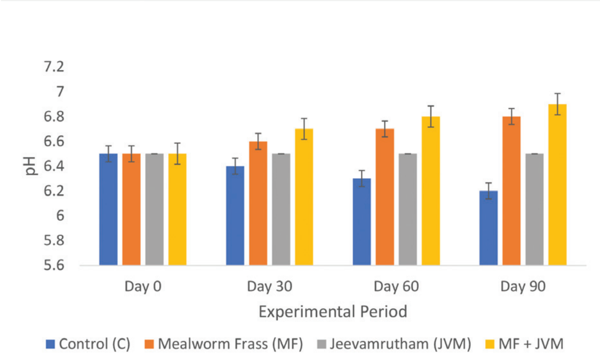

Fig. 1.1. Changes in soil pH of *Hibiscus sabdariffa* pots under various treatments during the experimental period

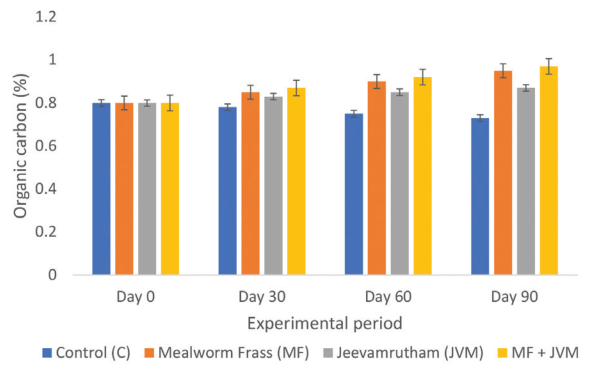

Fig. 1. 2. Changes in soil Organic Carbon (%) of *Hibiscus sabdariffa* pots under various treatments during the experimental period

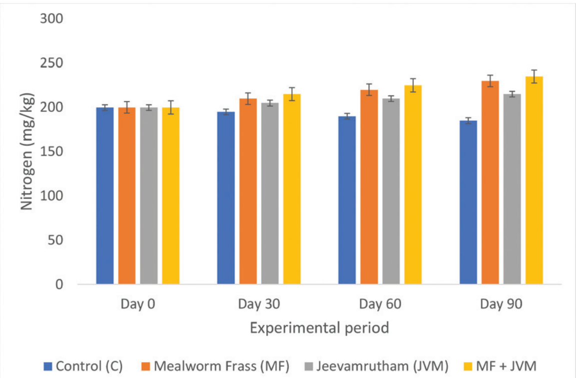

Fig. 1.3. Changes in soil Nitrogen (mg/kg) of *Hibiscus sabdariffa* pots under various treatments during the experimental period

The combined treatment also significantly increased organic carbon from 0.80% to 0.97% by Day 90, highlighting its effectiveness in boosting soil organic matter (Lunagariya *et al.*, 2018). The observed rises in nitrogen, potassium, and phosphorus suggest that mealworm frass and Jeevamrutham offer a balanced nutrient profile when used together. This could make the soil more fertile and less reliant on synthetic fertilizers.

Nitrogen levels showed a clear difference between control and treated groups. While nitrogen in the control decreased from 200 mg/kg to 185 mg/kg, the combination treatment increased nitrogen levels to 235 mg/kg by Day 90. Mealworm frass contributed the most to nitrogen enrichment, indicating its potential to enhance soil fertility over time (Kagata and Ohgushi, 2012 and Van Zanten *et al.*, 2015).

Potassium and phosphorus levels followed a similar trend, with the control group exhibiting a decline. In contrast, mealworm frass and its combination with jeevamrutham significantly improved these nutrient levels (Vibha and Lingaraju, 2020). In the combination treatment, potassium increased from 150 mg/kg to 185 mg/kg, and phosphorus increased from 40 mg/kg to 50 mg/kg, highlighting the role of these organic treatments in replenishing key soil nutrients.

Plant growth parameters

Plant growth measurements showed that plants in the combined treatment exhibited the highest growth rates across all species. For instance, *Hibiscus sabdariffa* in the combination treatment had a fresh weight of 15 g and a height of 45 cm by Day 90, compared to 12.5 g and 40 cm in the control group. Similarly, *Capsicum annuum*, under combined treatment, attained a height of 50 cm and a fresh weight of 18 g.

The wider basal stems and higher chlorophyll levels in plants that were treated with organic chemicals suggest that they are better at

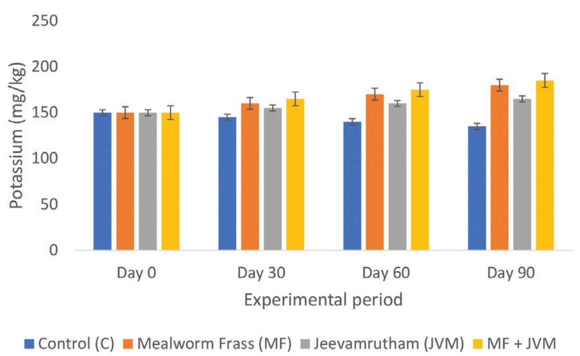

Fig. 1.4. Changes in soil Potassium (mg/kg) of *Hibiscus sabdariffa* pots under various treatments during the experimental period

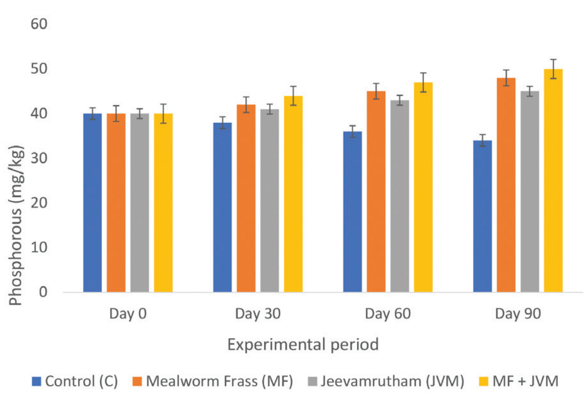

Fig. 1.5. Changes in soil Phosphorous (mg/kg) of *Hibiscus sabdariffa* pots under various treatments during the experimental period

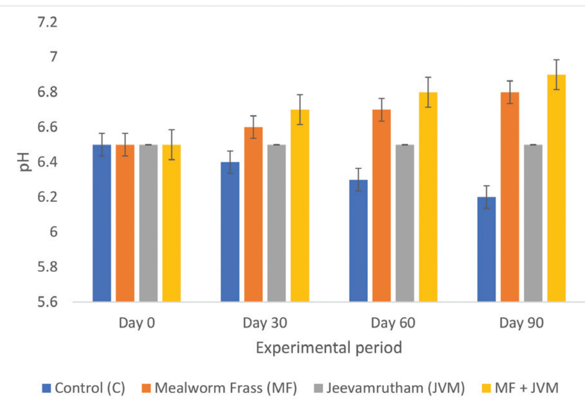

Fig. 1.6. Changes in soil pH of *Amaranthus hybridus* pots under various treatments during the experimental period

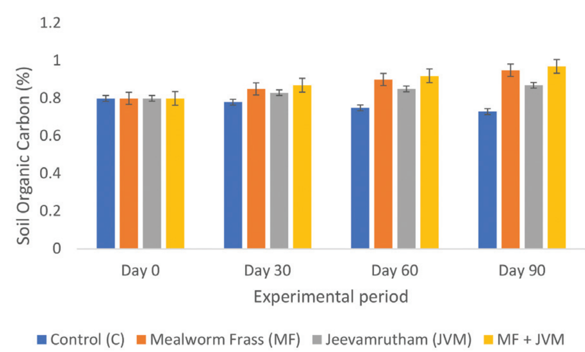

Fig. 1.7. Changes in soil Organic Carbon (%) of *Amaranthus hybridus* pots under various treatments during the experimental period

photosynthesis and keeping their structure (Saini *et al.*, 2022). These findings align with previous research on biofertilizers, which demonstrates the potential of organic inputs to strengthen plant vigor and promote sustainable agriculture (Nath *et al.*, 2023).

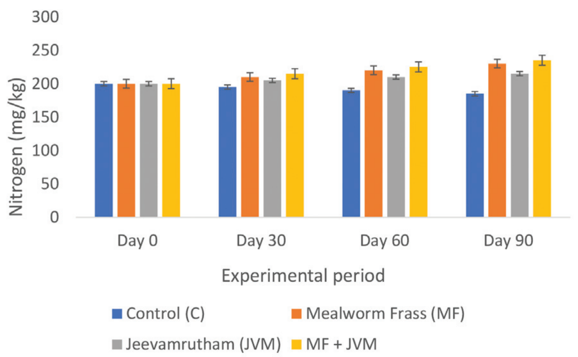

Fig. 1.8. Changes in soil Nitrogen (mg/kg) of *Amaranthus hybridus* pots under various treatments during the experimental period

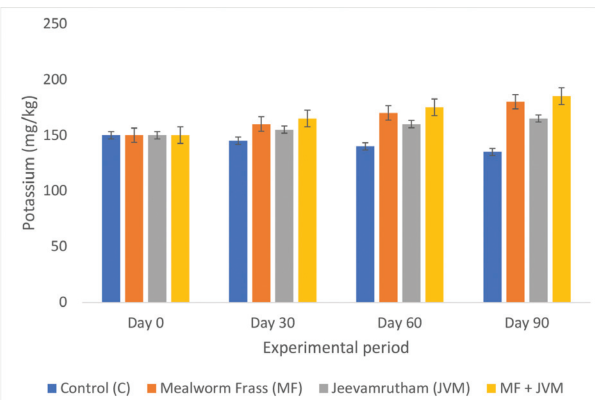

Fig. 1.9. Changes in soil Potassium (mg/kg) of *Amaranthus hybridus* pots under various treatments during the experimental period

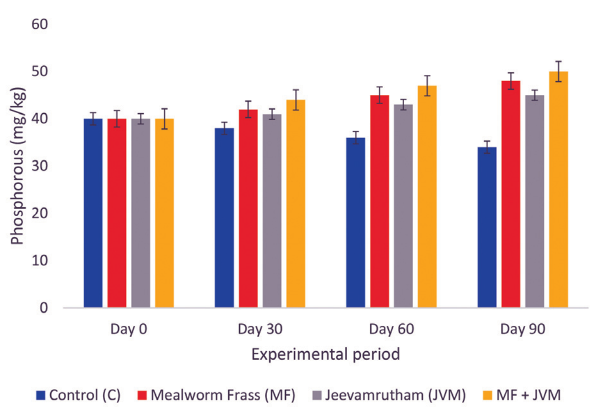

Fig. 1.10. Changes in soil Phosphorous (mg/kg) of *Amaranthus hybridus* pots under various treatments during the experimental period

Statistical Significance

ANOVA results confirmed the statistical significance of the treatments on soil and plant parameters, with

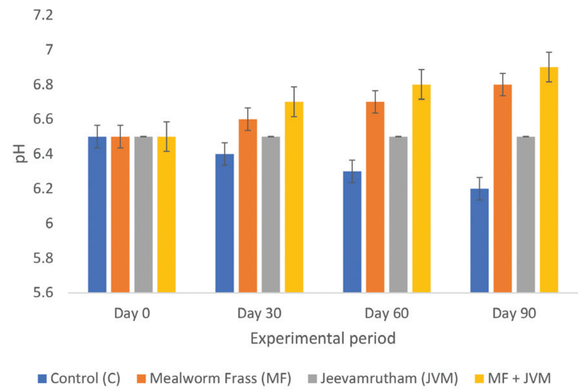

Fig.1.11. Changes in soil pH of *Capsicum annuum* pots under different treatments during the experimental period

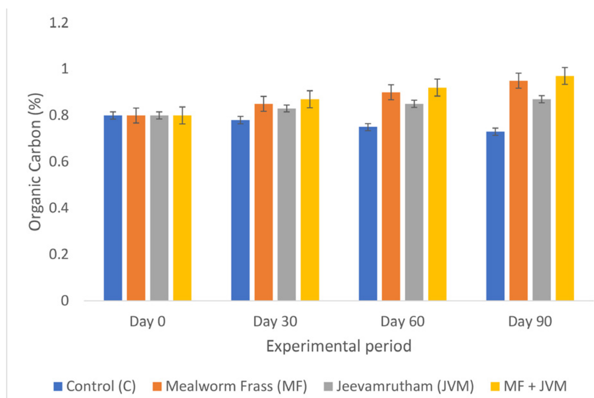

Fig.1.12. Changes in soil Organic Carbon (%) of *Capsicum annuum* pots under different treatments during the experimental period

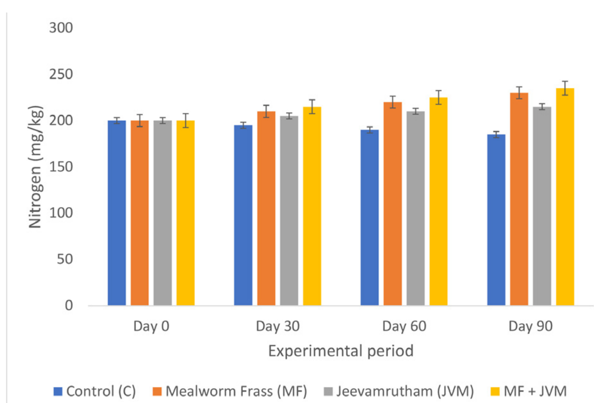

Fig. 1. 13. Changes in soil Nitrogen (mg/kg) of *Capsicum annuum* pots under different treatments during the experimental period

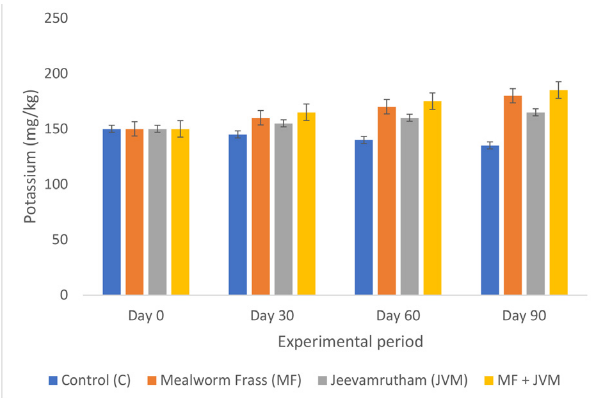

Fig.1.14. Changes in soil Potassium (mg/kg) of *Capsicum annuum* pots under different treatments during the experimental period

p-values less than 0.001 for all comparisons. The results were affected by both the type of treatment and how long it was given. This shows that mealworm frass and Jeevamrutham play a part in improving the relationship between plants and soil.

CONCLUSION

This study shows that using mealworm frass and Jeevamrutham together greatly improves the fertility of the soil and the growth of *Hibiscus sabdariffa*, *Amaranthus hybridus*, and *Capsicum annuum*. The treatments improved soil pH, organic carbon, nitrogen, potassium, and phosphorus levels, contributing to higher plant heights, fresh weights, basal stem widths, and chlorophyll content. The findings suggest that these organic fertilizers can support sustainable agriculture by reducing reliance on chemical fertilizers.

We recommend further research to explore long-term impacts, optimize application rates, and evaluate effects across various soil types and crop species. This study offers valuable insights into eco-friendly fertilization strategies that contribute to sustainable farming practices.

Over time, the use of mealworm frass and Jeevamrutham, both alone and in combination, had a positive impact on soil characteristics (Ramesh *et al.,* 2005). The addition of mealworm frass, both alone and in conjunction with Jeevamrutham, resulted in a considerable increase in soil pH as well as elevated levels of organic carbon, nitrogen, potassium, and phosphorus. These findings indicate that mealworm frass can serve as a highly effective organic amendment for improving soil fertility (Nogalska, 2022).

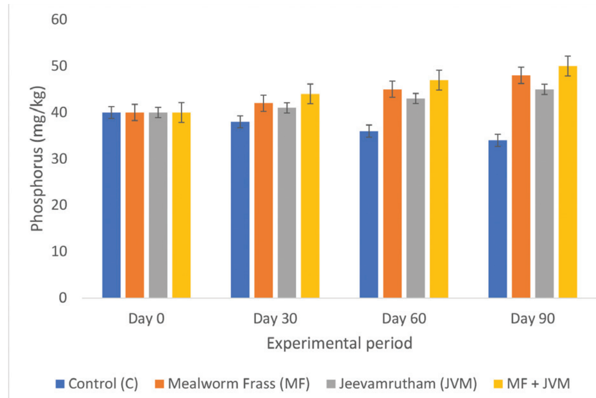

Fig.1.15. Changes in soil Phosphorus (mg/kg) of *Capsicum annuum* pots under different treatments during the experimental period

Plant growth parameters

Control plants showed the slowest growth, with *Hibiscus sabdariffa* reaching only 12.5 g in fresh weight and 40.0 cm in height by Day 90. In contrast, plants treated with the combination of mealworm frass and jeevamrutham showed the most significant increases, with *H. sabdariffa* achieving a fresh weight of 15.0 g and a height of 45.0 cm. In the same way, *Capsicum annuum* grown in a combination treatment

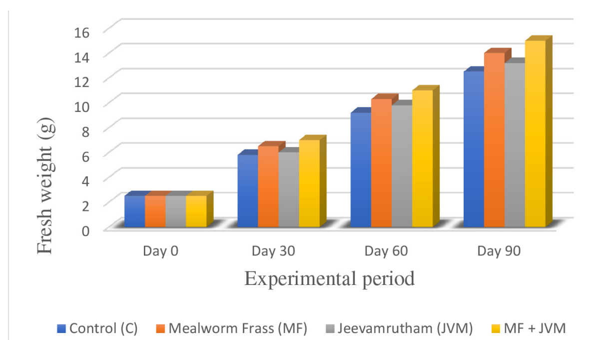

Fig. 2.1. Changes in plant fresh weight (g) were observed in *Hibiscus sabdariffa* pots under various treatments during the experimental period

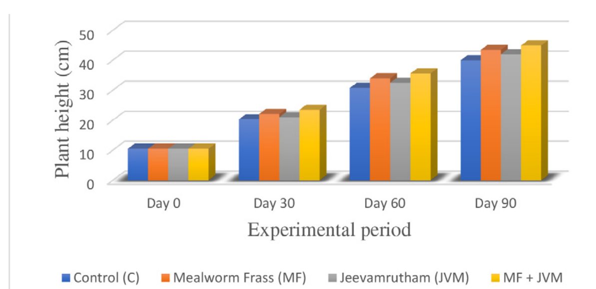

Fig. 2.2. Changes in plant height (cm) were observed in *Hibiscus sabdariffa* pots under various treatments during the experimental period

gained 18.0 g of fresh weight and 50.0 cm in height, showing that these organic inputs help plants grow together (Fig-2.1 to 2.12) Yonika Saini *et al.*, 2022).

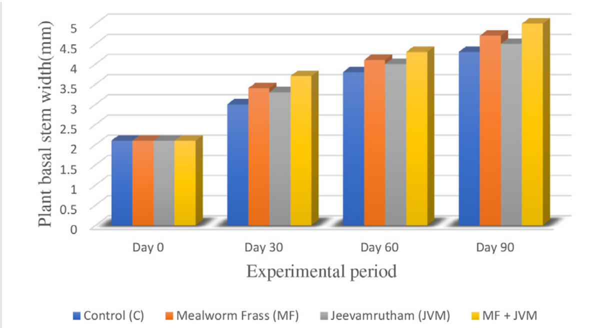

Fig. 2.3. Changes in plant basal stem width(mm) were observed in *Hibiscus sabdariffa* pots under various treatments during the experimental period

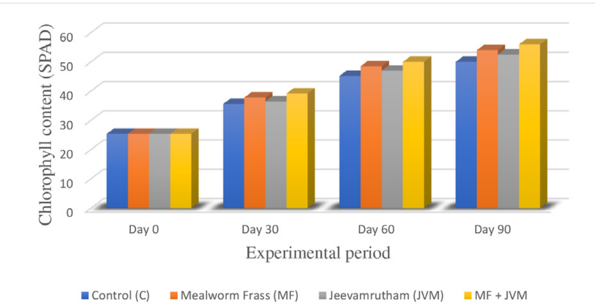

Fig. 2.4. Changes in Chlorophyll content (SPAD) were observed in *Hibiscus sabdariffa* pots under various treatments during the experimental period

Basal stem width and chlorophyll content also followed the same pattern, with the control group showing the least improvement. When *Amaranthus hybridus* was treated with mealworm frass and jeevamrutham together, the stem width increased the most, from 1.5 mm to 3.8 mm, and the chlorophyll content increased the most, from 20.3 SPAD to 50.0 SPAD. This shows that the plants were stronger overall and were better at photosynthesis under these conditions (Suprava Nath *et al.*, 2023).

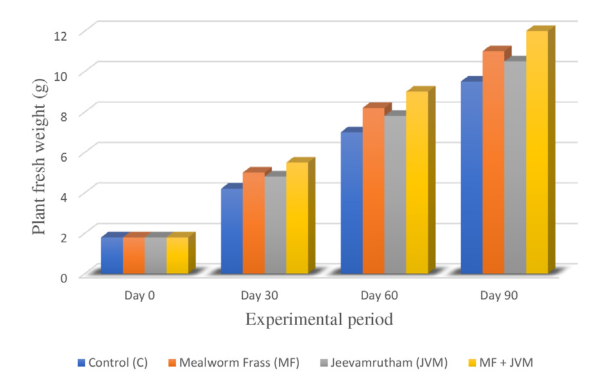

Fig. 2.5. Changes in plant fresh weight (g) were observed in *Amaranthus hybridus* pots under various treatments during the experimental period

Additionally, measurements were taken for a few plant growth parameters, such as fresh weight, plant height, basal stem width, and chlorophyll content. *Hibiscus sabdariffa*, in control, demonstrated the smallest increase in all parameters. Mealworm frass resulted in notable enhancements in fresh weight, plant height, basal stem width, and chlorophyll content. Some progress was made, according to Jeevamrutham (Przemieniecki *et al.*, 2021).

Amaranthus hybridus, in line with *Hibiscus sabdariffa*, had the lowest growth, whereas the combined therapy demonstrated the biggest enhancements in all growth parameters. The control, *Capsicum annuum*, had the smallest increase, but mealworm frass and the combo treatment demonstrated the most notable enhancements (Houben *et al.*, 2021 and Houben *et al.*, 2020).

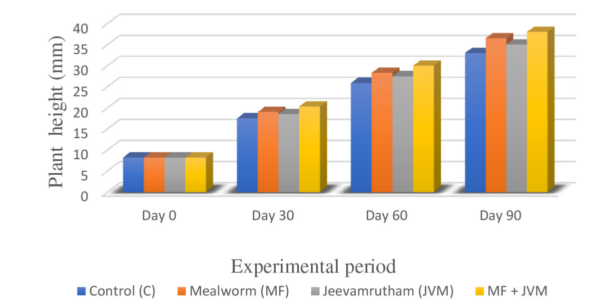

Fig. 2.6. Changes in plant height (mm) were observed in *Amaranthus hybridus* pots under various treatments during the experimental period

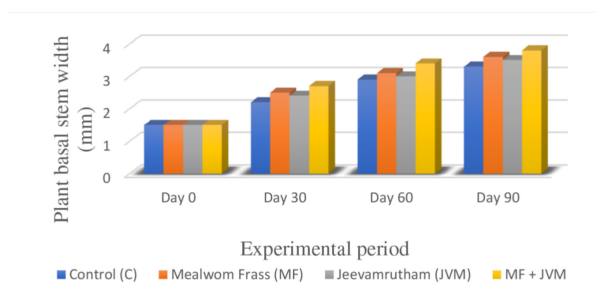

Fig. 2.7. Changes in plant basal stem width (mm) were observed in *Amaranthus hybridus* pots under various treatments during the experimental period

The enhanced growth of the plants reflected the improved soil parameters due to the treatments. The combination of mealworm frass and Jeevamrutham yielded the best results, significantly increasing plant fresh weight, height, basal stem width, and chlorophyll content across all three plant species (Quilliam *et al.*, 2020 and Van de Zande *et al.*, 2024). This indicates that these treatments not only improve soil health but also promote better plant growth and development (Frost C.J., Hunter M.D., 2004 and Nogalska *et al.*, 2022).

Statistical analysis

The statistical analysis of data was conducted using the ANOVA method to determine the significance of the treatment, time, and their interaction on soil and plant growth parameters. The ANOVA results (Table 3) show that treatment, time, and interaction between treatment and time were highly significant ($p < 0.001$) for all soil and plant growth parameters across the three species. This suggests that both the type of treatment and its duration played crucial roles in influencing soil and plant characteristics.

For all three test plant species: Significant disparities were detected in pH values as a result of the treatment, time, and their interaction ($p < 0.001$). Significant variations were observed in the levels of organic carbon for different treatments, time periods, and their combined effect ($p< 0.001$). The study revealed significant effects of treatment , time, and their interaction on nitrogen levels ($p < 0.001$). The study found significant variations in potassium levels as a result of the medication, time, and their combined effect ($p < 0.001$). Phosphorus: The study revealed significant effects for therapy, time, and the interaction between them ($p < 0.001$).

The ANOVA results validate the statistical significance of the observed alterations in soil and plant growth parameters. The small p-values

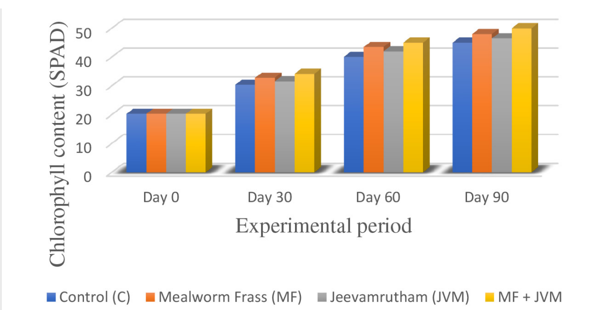

Fig. 2.8. Changes in Chlorophyll content (SPAD) were observed in *Amaranthus hybridus* pots under various treatments during the experimental period

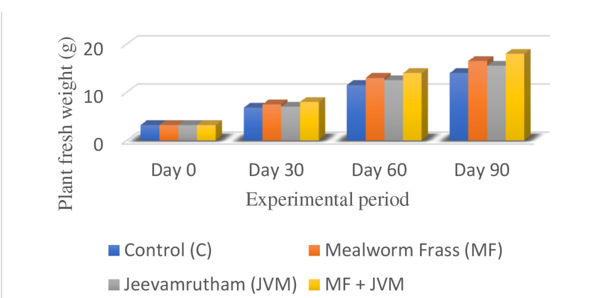

Fig. 2.9. Changes in plant fresh weight (g) were observed in *Capsicum annuum* pots under various treatments during the experimental period

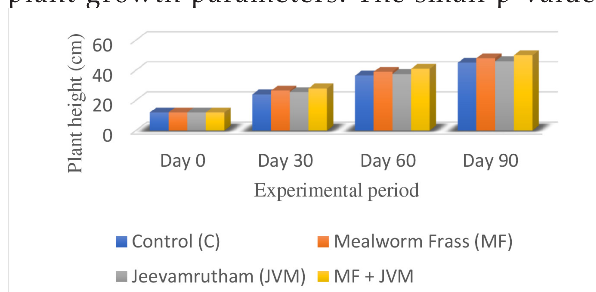

Fig. 2.10. Changes in plant height (cm) were observed in *Capsicum annuum* pots under various treatments during the experimental period

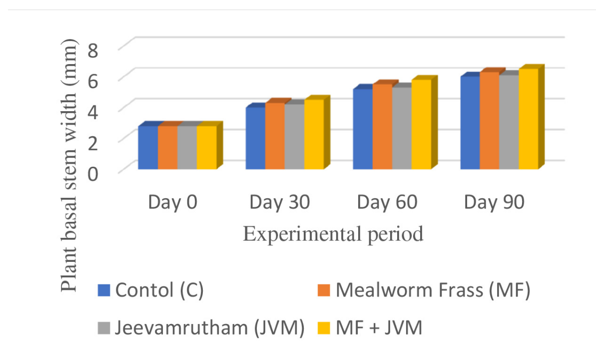

Fig. 2.11. Changes in plant basal stem width (mm) were observed in *Capsicum annuum* pots under various treatments during the experimental period

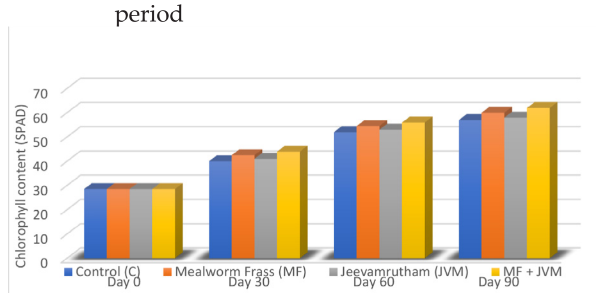

Fig. 2.12. Changes in plant Chlorophyll content (SPAD) were observed in *Capsicum annuum*

(<0.001) for all parameters provide compelling evidence against the null hypothesis, demonstrating that the treatments and their interactions with time have a significant impact on both soil quality and plant development. Consequences

These findings provide evidence for the efficacy of organic amendments such as mealworm frass and Jeevamrutham in promoting sustainable agriculture (Poveda *et al.*, 2019 and Fuertes- Mendizábal *et al.*, 2023). Their application has the potential to enhance soil fertility, promote plant development, and potentially decrease reliance on chemical fertilisers (Poveda, 2021 and Antoniadis *et al.*, 2023).

Additional research could explore into the enduring consequences of these interventions and their influence on agricultural productivity and quality.

CONCLUSION

The study shows that mealworm frass, jeevamrutham, and the two of them together are good for the health of the soil and the growth of three types of plants: *Hibiscus sabdariffa, Amaranthus hybridus,* and *Capsicum annuum*. The combined application of these organic treatments consistently enhanced soil parameters such as phosphorus, nitrogen, potassium, organic carbon, and pH, while significantly improving plant growth indicators such as fresh weight, height, basal stem width, and chlorophyll content. Following these results suggests that using mealworm frass and jeevamrutham together or separately is a long-term, eco-friendly way to improve soil fertility and plant productivity, cut down on chemical fertilisers, and encourage the use of organic amendments that promote sustainable farming.

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Author contributions

Y.Avasn Maruthi (YMR) led the investigation, provided mentorship, and was responsible for writing, reviewing, and editing. D. Divya, M. Mounica, and P. Pushpala worked on the practical component.

Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

Conflict of Interest - None

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