

# A comparison of integrated pest management and conventional practices on insect diversity and economic profitability of cayenne pepper cultivation

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**Abstract.** Hadi MS, Naziha SF, Mulyono RNS, Muhammad FN, Pramana BA, Taufiqurrahman AF, Sunarto BP. 2025. A comparison of integrated pest management and conventional practices on insect diversity and economic profitability of cayenne pepper cultivation. *Biodiversitas* 26: 1519-1525. Cayenne pepper (*Capsicum frutescens*) cultivation generally relies heavily on insecticide applications. Integrated Pest Management (IPM) offers an effective solution to minimize insecticide use while maintaining crop productivity and sustainability. The objective of this study is to compare insect diversity and economic profitability in cayenne pepper cultivation under IPM and conventional practices. The research was conducted in Sukoharjo Village, Bancar Sub-district, Tuban District, East Java, Indonesia, and in the Plant Pest Laboratory, Universitas Brawijaya, Malang, East Java, from October 2023 to May 2024. Insect sampling was carried out using pan traps and pitfall traps to observe flying and ground-dwelling insects, respectively. Data analysis included diversity indices and economic calculations such as total cost, revenue, profit, break-even point, and benefit-cost (B/C) ratio. The results showed that the IPM system supported a greater number of species (20 species) and a higher total abundance of insects (298 individuals) compared to the conventional system (15 species and 240 individuals). IPM favored the presence of predatory insects such as *Paederus* sp., *Omonadus* sp., and *Rynocoris* sp., whereas conventional practices showed a higher abundance of herbivorous insects such as *Myzus persicae* and *Acrididae* sp.. In terms of yield, the IPM system produced 4.74 tons, greater than the 2.55 tons from the conventional system. IPM generated greater revenue and profitability compared to conventional practices. The findings suggest that IPM practices offer dual benefits, enhancing ecological sustainability by increasing predator populations while also improving economic returns for farmers.

**Keywords:** Abundance, herbivore, IPM, pest, predator, species

## INTRODUCTION

Cayenne pepper (*Capsicum frutescens* L.) is a member of the Solanaceae family, valued for its high economic worth and essential role in Indonesian cuisine. Capsaicin not only enhances flavor but also has potential for use in various health and beauty products (Kebu et al. 2024). This plant's ability to survive for extended periods adds to its economic value. With population growth and increasing demand, cayenne pepper production in the province of East Java, Indonesia, increased from 578,883,000 kg in 2021 to 612,408,900 kg in 2022 (BPS 2023). However, there was a significant decline in production in several regencies, including Tuban. In 2021, Tuban produced 56,727,800 kg of cayenne pepper, but this number dropped to 36,678,300 kg in 2022 (BPS 2023). This decline could lead to issues with availability and price stability in the market.

The drop-in cayenne pepper production can be attributed to attacks from plant pests, particularly insect pests that frequently target this crop. Recent studies have identified several major pests affecting cayenne pepper, including *Bemisia tabaci* (whiteflies), *Aphis* (aphids), and *Bactrocera* sp. (fruit flies) (Hasinu et al. 2020; Herlinda et

al. 2021; Temaja et al. 2022). Whiteflies, for example, not only damage plants directly by sucking sap but also act as virus vectors that can infect plants with serious diseases such as begomoviruses (Fiallo-Olivé et al. 2019). Symptoms of whitefly infestation include yellowing leaves and severe damage to infected plant parts (Jeevanandham et al. 2018). Additionally, aphids with their small and soft bodies damage leaves by sucking plant sap, leading to curled and yellowing leaves as well as the formation of honeydew that encourages sooty mold growth, disrupting photosynthesis (Nalam et al. 2019). Meanwhile, *Bactrocera* sp., or fruit flies, attack cayenne pepper plants and cause damage that reduces both quality and yield. Symptoms of fruit fly infestation including the browning of fruits and the presence of black spots, which can contribute to significant yield losses (Syamsudin et al. 2022).

In addition to pest attacks, the decline in cayenne pepper production can also be attributed to suboptimal cultivation techniques. Inadequate farming practices, such as unbalanced fertilization and pest control methods, can weaken plant resistance to pests (Matowo et al. 2020). Unhealthy plants are more susceptible to infestations by pests such as *B. tabaci* and *Aphis*, which ultimately leads to

reduced yields (Paudel et al. 2020). Therefore, implementing proper cultivation techniques is crucial for maintaining cayenne pepper productivity. Previous research has indicated that the use of mycorrhizal biofertilizers to enhance cayenne pepper growth can improve the plants' resilience against environmental stresses and pest infestations (Hariyono et al. 2021). Moreover, effective pest management strategies, such as Integrated Pest Management (IPM), should be integrated with agricultural practices that promote optimal plant growth. This includes the selection of pest-resistant varieties and the application of efficient fertilization practices to improve the yield and quality of cayenne pepper production (Paudel et al. 2020).

Cayenne pepper can be cultivated using two main methods: conventional methods and IPM. Conventional methods often involve the use of synthetic pesticides to directly reduce pest populations. While effective in the short term, the use of synthetic pesticides can lead to environmental and health issues if not managed carefully. In contrast, IPM focuses on sustainable pest management through environmental-friendly methods. IPM principles include the use of natural enemies such as predatory insects, good soil management, sanitation, and the use of superior pest-resistant plant varieties. Natural enemies can help control pest populations biologically, contributing 50-90% to total pest management (Martin et al. 2013; Seni and Halder 2022). Research on the diversity of predatory insects in various cultivation systems is crucial for identifying the most effective control methods and improving overall yields. By understanding the impacts of pest attacks, climate change, and the application of suitable cultivation systems, farmers can optimize cayenne pepper production and maintain agricultural ecosystem balance. Ongoing research in this field is vital to address the challenges faced by the cayenne pepper industry and ensure sustainable production in the future.

## MATERIALS AND METHODS

### Study area

The research was conducted in Sukoharjo Village, Bancar Sub-district, Tuban District, East Java, Indonesia, and in the Plant Pest Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Brawijaya, Malang. Sukoharjo Village was selected as the field study site due to its extensive cayenne pepper cultivation and various farming practices, making it an ideal location to compare Integrated Pest Management (IPM) and conventional methods. The study was carried out from October 2023 to May 2024, covering a whole cycle to obtain comprehensive data on insect diversity and economic profitability.

### Experimental design

The experimental design for this study involved a comparative analysis of cayenne pepper cultivation under two different treatment systems: IPM and conventional methods. The experiment was conducted using four beds as

replications for each treatment, with a uniform bed size of 20×1 m. Land preparation in both treatments involved hoeing, bed formation, and basic fertilization. Seeds were planted with a spacing of 40 cm and at a hole depth of 5 cm, using seeds aged 30 and 45 days after sowing. Both treatments received synthetic fertilizers containing essential nutrients (N, P, and K). Irrigation was carried out weekly by pumping water through pipes and allowing it to flood the land.

Pest control in the IPM treatment involved the application of bio-insecticides, specifically metarizep and vertiplus, combined with biological control agents such as *Pseudomonas fluorescens*, *Beauveria bassiana*, *Aspergillus niger*, *Trichoderma* sp., and *Bacillus subtilis*. Biological control agents were applied once per two weeks. Meanwhile, pest control in the conventional treatment relied solely on synthetic insecticides without additional biological agents. Weeds removal was performed manually using a sickle in the IPM treatment and using herbicide in conventional treatment. The harvesting process was conducted similarly across treatments by manually picking fruits and collecting them in designated containers. The aim of this experimental setup is to evaluate the effects of different cultivation techniques on insect diversity and economic profitability in cayenne pepper production.

### Insect sampling

The insect sampling was conducted using two types of traps: pan traps and pitfall traps. Pan traps were used to capture flying insects, while pitfall traps were deployed to collect ground-dwelling insects. Five pan traps and five pitfall traps in total were placed in each research field to ensure comprehensive sampling. The traps were filled with a detergent solution to immobilize the insects and were left in the field for 24 hours during each sampling. Sampling was conducted 12 times with interval once a week to monitor insect abundance over time under both cultivation systems.

Following collection, the captured insects were carefully removed from the traps and preserved in 70% ethanol to prevent decomposition and maintain specimen integrity for further analysis. The preserved insects were then taken to the laboratory for identification. Identification was carried out using standard entomological keys and reference materials, specifically referring to Borror and DeLong's Introduction to the Study of Insects (Triplehorn and Johnson 2005). This identification process allowed accurate determination for the guild of insect species present in both the IPM and conventional cultivation systems.

### Data analysis

The data collected from the insect sampling were analyzed using two statistical methods to determine the impact of different cultivation techniques on the populations of predatory and herbivorous insects. Analysis of Variance (ANOVA) with a 5% error rate ( $\alpha$ : 0.05) was conducted to assess whether there were significant differences in insect diversity and populations between the IPM and conventional treatments. Before ANOVA, normality testing of the data was first conducted using the

Shapiro-Wilk test. If the data were found not to have a normal distribution, they were transformed using  $\log(x+1)$ . In addition, Analysis of Similarity (ANOSIM) was also performed to determine the degree of similarity or dissimilarity between the insect populations in the two cultivation systems. Species composition visualization was carried out using a Non-Metric Multidimensional Scaling (NMDS) plot. The data analysis for both systems was conducted using R-Statistics (R Core Team). Then, business calculations in farming involved determining total cost, revenue, profit, break-even point, and benefit-cost (B/C) ratio.

#### Costs

The total cost of production is the sum of both fixed and variable costs. Fixed costs are expenses that remain constant regardless of production levels, such as land rent and equipment depreciation. Variable costs, however, fluctuate with production volume, including expenses for seeds, fertilizers, labor, and irrigation. All spending on fixed and variable costs also total yields and revenues were collected by interviewing farmers.

#### Gross revenue

Revenue analysis was conducted to determine the obtained gross income. The following is the formula for gross revenue calculation.

$$TR = P \times Q$$

Where:

- TR : Total Revenue (Rp)  
P : Production price (Rp/kg)  
Q : Total production (kg)

#### Profit

Profit is calculated by subtracting the total costs (fixed and variable) from the total revenue generated from the sale of cayenne pepper. This calculation helps to determine the financial performance of the cultivation, allowing for the assessment of profitability and decision-making for future production. The following is the formula for profit calculation.

$$\pi = TR - TC$$

Where:

- $\pi$  : Profit (Rp)  
TR : Total Revenue (Rp)  
TC : Total production cost (Rp)

#### Break-Even Point (BEP)

BEP analysis is an evaluation to find the production point that causes profit. BEP can be calculated for production and price. The following are the formulas for BEP calculation.

$$\text{BEP production} = \frac{TC}{P}$$

$$\text{BEP price} = \frac{TC}{Q}$$

Where:

- TC : Total production cost (Rp/period)  
P : Price (Rp)  
Q : Production (Rp/kg)

#### Benefit/Cost Ratio (BCR)

BCR analysis is a measure of the comparison between income and costs. If the BCR value  $>1$ , then the business is feasible to run. The following is the BCR calculation formula.

$$BCR = \frac{TR}{TC}$$

Where:

- TC : Total production cost (Rp/period)  
TR : Total Revenue (Rp/period)

## RESULTS AND DISCUSSION

### Diversity and abundance of pest and predatory insect

Analysis showed differences in the abundance and diversity of insects between conventional and IPM management systems (Table 1). In the order Coleoptera, several predator species such as *Paederus* sp. and *Omonadus* sp. were identified, as well as herbivores such as Chrysomelidae. The order Dermaptera was only represented by *Euborellia* sp., which act as predators, while from the order Diptera, there were *Bactrocera* sp. as herbivores, Dolichopodidae as predators, and *Musca domestica* as detritivores. From the order Hemiptera, herbivores were more abundant, especially *Myzus persicae* in the conventional treatment, while *Rynocoris* sp. acted as predators and were found more in IPM. From the order Orthoptera, both Acrididae species act as herbivores, with small differences in abundance between conventional and IPM treatments. There were also honey bee (*Apis mellifera*) that act as pollinators. Predators and herbivores were more dominant than other guilds. Parasitoids were not found during sampling. Overall, there were 20 species and 298 individuals in total for IPM, greater than 15 species and 240 individuals for the conventional treatment, suggesting that IPM supports larger arthropod populations.

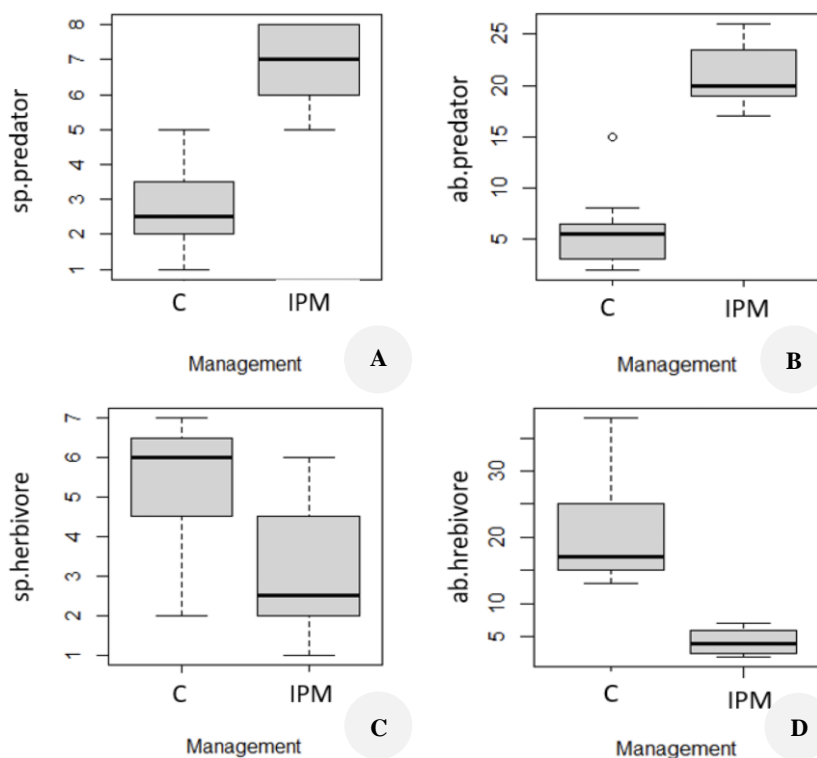
The results showed that the presence of predatory beetles and earwigs tended to be found more in IPM rather than in conventional agriculture. Studies have found that predatory insects, particularly from the order Coleoptera and Hemiptera, are significantly more abundant in IPM systems due to the reduced reliance on insecticides that reduce and harm non-target beneficial organism populations (Castelo-Branco et al. 2016; Rahardjo et al. 2021; Ranjith et al. 2022; Yadav et al. 2022). The use of chemicals in conventional agriculture not only targets pests but also disrupts natural enemies, allowing herbivorous insects, particularly from the order Orthoptera and Hemiptera, to thrive unchecked (Bogusch et al. 2016; Moreno-Rueda et al. 2018). The absence of parasitoids could be due to the abundance of predators in both fields. Based on Gontijo et al. (2015), the presence of predators can reduce parasitization rates by parasitoids.

**Table 1.** Diversity and population of predator and herbivore insect in conventional and IPM management system

Order/Morphospecies	Guild	Conventional	IPM
Coleoptera		50	108
<i>Anotylus</i> sp.	Predator	0	6
<i>Cheilomenes sexmaculata</i>	Predator	6	14
<i>Chlaenius</i> sp. 2	Predator	0	14
<i>Chlaenius</i> sp. 1	Predator	7	11
Chrysomelidae sp.	Herbivore	11	3
<i>Cicindela</i> sp.	Predator	0	8
<i>Omonadus</i> sp.	Predator	9	21
<i>Paederus</i> sp.	Predator	17	31
Dermaptera		8	43
<i>Euborellia</i> sp	Predator	8	43
Diptera		38	79
<i>Bactrocera</i> sp.	Herbivore	13	4
Dolichopodidae sp.	Predator	20	68
<i>Musca domestica</i>	Detritivore	5	7
Hemiptera		110	56
<i>Anthocoris</i> sp.	Predator	0	3
Cicadellidae sp.	Herbivore	30	7
Cydnidae sp.	Herbivore	9	2
<i>Myzus persicae</i>	Herbivore	71	12
<i>Rhynocoris</i> sp.	Predator	0	32
Hymenoptera		6	4
<i>Apis mellifera</i>	Pollinator	6	4
Orthoptera		28	8
Acrididae sp. 1	Herbivore	17	5
Acrididae sp. 2	Herbivore	11	3
Grand Total		240	298

Based on ANOVA analysis, predators tended to be more abundant in IPM, both in terms of diversity ( $F_{1,22}$ : 45.84;  $P < 0.001$ ; Figure 1.A) and abundance ( $F_{1,22}$ : 81.11;  $P < 0.001$ ; Figure 1.B). In contrast, herbivores were more dominant in conventional methods, shown from the higher diversity ( $F_{1,22}$ : 13.39;  $P < 0.001$ ; Figure 1.C) and significant abundance ( $F_{1,22}$ : 92.94;  $P < 0.001$ ; Figure 1.D). These results suggest that IPM favors more diverse and abundant predators, whereas conventional methods favor more herbivore populations.

The results indicated that IPM supports more predatory insects than conventional agriculture. Lu et al. (2015) stated that a component of IPM in agriculture system management provides better breeding habitats for predators such as Coccinellidae. This led to the stability of the agroecosystem, since pest populations are suppressed naturally by the presence of many predators. According to Duque-Gamboa and Toro-Perea (2023), prey in the form of pests or other herbivores becomes alternative prey for predators in land for cultivation; this is a key aspect of IPM strategies that promote biodiversity and ecosystem stability through natural pest maintenance. Other than predators, populations of pests or other herbivore insects in IPM are also suppressed by the usage of bio-agents. Korine et al. (2022) stated that combining enhancement methods for natural enemies with a friendly pesticide or bio-agents are crucial management strategies in IPM to avoid harming beneficial insects.



**Figure 1.** A, B. Differences of species richness and abundance of predators IPM and conventional management; C, D. Differences of species richness and abundance of herbivores in IPM and conventional management

Species composition tests using ANOSIM showed that the composition of predators between conventional management and IPM was significantly different (R: 0.566; P: 0.001; Figure 2.A), signaling a clear difference in predator communities between the two systems. Meanwhile, the difference in the composition of herbivores was less clear but still statistically significant (R: 0.116; P: 0.028; Figure 2.B), indicating that herbivores were homogeneous between conventional management and IPM.

The finding of this research was that predators tended to be found more on land for cultivation with IPM systems rather than with conventional agriculture. According to Rahmawasih et al. (2022), minimal use of pesticides in IPM systems allows for the sustained presence of natural predators, which can significantly suppress pest populations. In contrast to IPM, conventional agriculture makes use of only bio-insecticides without bio-agents or management of predators to control pest populations, which leads to the reduction of not just pests but also natural enemies and predators. Tillman et al. (2015) stated that the application of insecticides has been linked to the reduction of predator species and their effectiveness in controlling pest populations. The presence of natural enemies is strongly supported by other vegetation within the field (Fadhilah et al. 2023; Wibowo et al. 2023). The use of herbicides in the field can eliminate wild weeds, some of which serve as supplementary resources for natural enemies. The presence of flowering weeds within reasonable limits is one way to conserve biological control agents (Hatt and Doring 2024). Greater weed diversity leads to a decreased pest population (Madden et al. 2021). In addition, IPM had a better ecological balance of herbivores and predators compared to conventional agriculture. Since the ecological balance of the food chain is itself influenced heavily by management strategies in agriculture, IPM systems provide better conservation of predators. Zalucki et al. (2015) found that IPM better

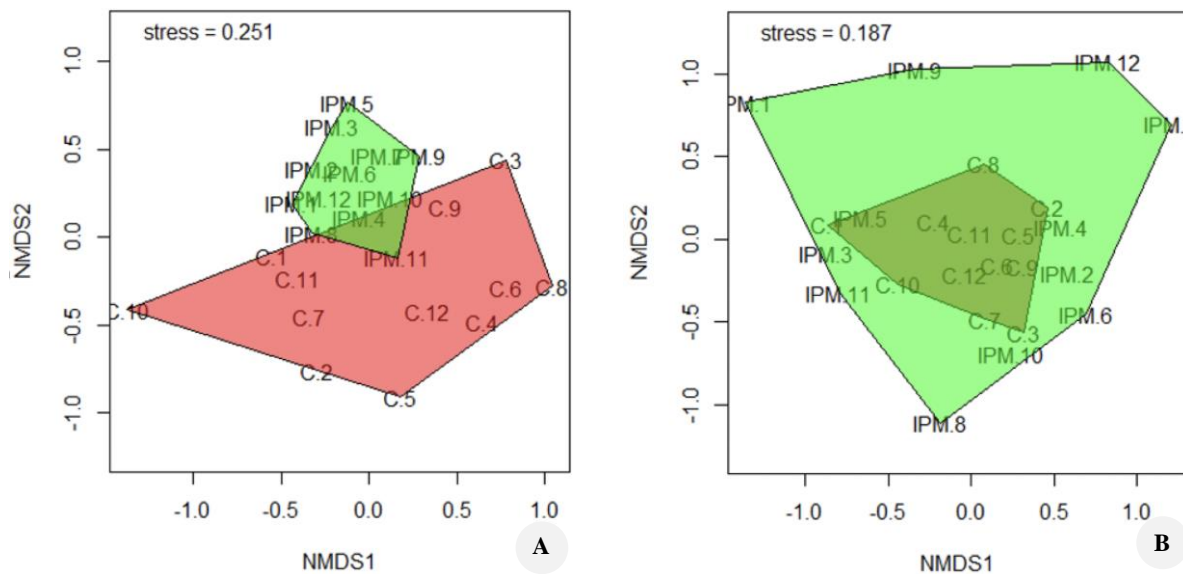
conserves natural enemies such as predators, while conventional agriculture relies on chemical controls that tend to favor pest populations by reducing the populations of their natural enemies.

**Farming business analysis**

The difference in fixed and variable costs arises due to differences in management from planting to harvest between conventional management and IPM. IPM practices do not use synthetic pesticides and rely on biological agents. The production and application of biological agents require additional costs. This was the reason for the difference in variable costs between the two approaches. Variable costs for IPM were higher than for conventional management. The total yield of cayenne pepper in the IPM system reached 4.74 tons, while the conventional system produced only 2.55 tons. With the market price of cayenne pepper at that time set at 50,000 IDR per kilogram, the revenue generated from the IPM system was significantly higher compared to the conventional system (Table 2).

**Table 2.** Farming analysis on IPM and conventional treatments in Sukoharjo Village, Bancar Sub-district, Tuban District, East Java, Indonesia in 1 ha area

Components	IPM	Conventional
Fixed costs	IDR 4,327,000	IDR 4,327,000
Variable Costs	IDR 136,471,181	IDR 114,696,153
Total production cost	IDR 140,798,181	IDR 119,023,153
Gross revenue	IDR 237,175,000	IDR 127,750,000
Net income	IDR 96,376,818	IDR 8,726,846
Break-Even Point (BEP)		
Production BEP	3,857 kg	3,260 kg
BEP price	IDR 28,444/kg	IDR 34,006/kg
Benefit Cost Ratio (B/C Ratio)	1.68	1.07



**Figure 2.** A. Differences of species composition of predators in IPM and conventional management; B. Differences of species composition of herbivores in IPM and conventional management

The cropping system in the IPM method was more profitable than the conventional method, as the IPM cultivation system uses a combination of appropriate and specific cultivation techniques, employs biological agents, and limits dependence on synthetic chemical pesticides. The essence of IPM lies in its ability to integrate multiple biological, cultural, physical, and chemical control strategies into a cohesive system that maintains pest populations at levels that do not cause damage to provide maximum economic output (Pretty and Bharucha 2015; Dara 2019; Tiwari 2024). The IPM cultivation system needs to be carried out in a sustainable manner to provide more effective and efficient benefits to the economic aspects. The B/C ratio value has a correlation with agricultural activities carried out in the long term or in the next planting season. Studies have shown that the adoption of protected cultivation facilities can lead to significant improvements in farm profitability, especially after the initial investment period (Liao et al. 2020).

The results of this study indicate that IPM supports a higher presence of predatory insects, which play a crucial role in controlling pest populations, whereas conventional methods tend to have a higher abundance of herbivorous insects that can potentially damage crops. From an economic perspective, the IPM system is proven to be more profitable than conventional practices, as evidenced by the higher yield and revenue. The combination of ecological benefits through enhanced natural pest control, as well as economic advantages through increased profitability, demonstrates that IPM is a sustainable approach that benefits both the environment and farmers. These findings highlight the potential of IPM as a viable strategy for improving agricultural productivity while maintaining ecological balance.

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