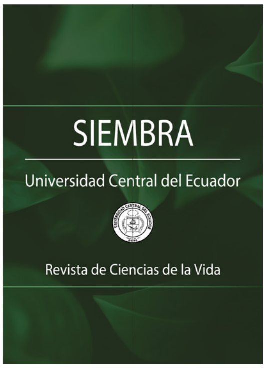
# *Alternative management of arthropods in rice (Oryza sativa L.) in Sébaco, Matagalpa, Nicaragua*




## *Alternativas de manejo de artrópodos en arroz (Oryza sativa L.), en Sébaco, Matagalpa, Nicaragua*

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**Abstract**

Rice (*Oryza sativa* L.) is the world's fourth most important cereal crop, cultivated in 111 countries thanks to its high nutritional value. In Nicaragua, it is the third most economically important crop, generating $190.7 million annually. Producers are constantly seeking management alternatives to reduce losses caused by arthropod pests and increase their yields in response to constant national demand. This study aimed to evaluate arthropod control alternatives in rice cultivation in the municipality of San Isidro, Nicaragua. Between December 2023 and April 2024, six treatments were assessed across four plots. Each experimental plot covered 80 $m^2$, encompassing a total trial area of 1,920 $m^2$. Five applications were made between days 10 and 96, and the number of arthropods found in each treatment was then counted. We estimated the yield for each treatment and conducted an economic analysis. The data were log-transformed to adjust for normality, and analysis of variance and Tukey's test ($p < 0.05$) were then applied. The most effective arthropod pest control was achieved in T5 (chemical treatment), followed by T4 (*Beauveria bassiana* + *Cinnamomum verum*), in which the greatest arthropod population occurred during the crop's developmental and reproductive phases. The highest yield was recorded in the aforementioned treatments, with chemical treatment providing the greatest benefit.

**Keywords**: Entomopathogenic fungi, biopesticides, economic analysis, pests.

**Resumen**

El cultivo de arroz (*Oryza sativa* L.) es el cuarto cereal de importancia en el mundo, cultivándose en 111 países, por su alto valor nutritivo. En Nicaragua es el tercer cultivo de importancia económica, generando 190.7 millones de dólares anuales. La búsqueda de alternativas de manejo para reducir las pérdidas causada por artrópodos plagas es constante por parte de los productores para incrementar sus rendimientos, producto de la constante demanda nacional. Esta investigación se efectuó con el objetivo de evaluar las alternativas de control de artrópodos, en el cultivo de

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arroz, en el municipio de San Isidro, Nicaragua. Para su efecto, durante los meses de diciembre 2023 hasta abril 2024, se evaluaron seis tratamientos en cuatro bloques, cada parcela experimental fue de 80 $m^2$, considerando una superficie total de 1.920 $m^2$ del ensayo. Se realizaron cinco aplicaciones desde los 10 hasta los 96 días, se contabilizó el número de artrópodos encontrados en cada tratamiento, se estimó el rendimiento y realizó el análisis económico. Los datos se transformaron (log 10) para ajustar la normalidad, se empleó análisis de varianza y prueba de Tukey (0,05). El mejor control de artrópodos plagas se obtuvo en los T5 (tratamiento químico), seguido del T4 (*Beauveria bassiana* + *Cinnamomum verum*), donde las mayores poblaciones de artrópodos se presentaron durante la fase de desarrollo y reproductiva del cultivo. El mayor rendimiento se registró en los tratamientos antes mencionados, el tratamiento químico logró mayor beneficio.

**Palabras clave:** Hongos entomopatógenos, bioplaguicidas, análisis económico, plagas.

## 1. Introduction

Rice (*Oryza sativa* L.) is commercially cultivated in 110 countries, 85% of the global production comes from Asia, using 12% of the total cultivated surface. Fifty percent of the caloric demand among the population in different Asian countries depend on this crop, generating 2000 million of indirect and direct jobs (Dorairaj & Govender, 2023; Pérez-Méndez et al., 2020). This crop has a high nutritional value (proteins, carbohydrates, lipids, aminoacids and vitamins). Lipids provide higher nutrition and quality with major health benefits (Verma et al., 2018; Zhu et al., 2024). In Nicaragua, there are various geographical zones suited for rice cultivation, being Valle de Sebaco (Matagalpa) and Malacatoya (Granada) where most of the cultivated surface lays, with 85000 reported hectares (Instituto Nacional de Información de Desarrollo [INIDE], 2012; Laguna Dávila et al., 2024).

This crop is highly important for the agricultural sector because it constitutes an essential part in the diet of Nicaraguan people. Rice is cultivated in three systems: mechanized dryland farming, traditional dryland farming, and flood irrigation (during the dry season). In this context, national production is driven by small and medium farmers, while the flood irrigation system is concentrated mostly in high-scale farmers, increasing 2.5% in 2023 (Laguna Dávila et al., 2024; Téllez Gaitán & Rivera Alonzo, 2015). According to the data from Instituto Nacional Tecnológico (INATEC, 2018), the per capita rice consumption in Nicaragua has shown a significant increase from 29.54 kg to 51.82 kg from 2015 to 2018.

This crop is affected though by different arthropod pests, where most of them can cause direct or indirect damage (virus transmission), weakening grain's quality and quantity. For this reason, management strategies should be developed to minimize the negative impact to the environment and human health, without posing a risk on crop yield (Laguna Dávila et al., 2024; Ruíz Sáenz, 2020). One of these environmentally friendly alternatives is the use of entomopathogenic microorganisms, which can infect the host to bio-regulate the population (Ramos et al., 2020).

The present study aimed to evaluate the different alternatives to control arthropod pests in rice crop in Valle de Sebaco of the department of Matagalpa, Nicaragua, thus reinforcing the knowledge on arthropod behavior and the integrated management practices adapted to the agroecological local conditions.

## 2. Materials and Methods

### *2.1. Study location*

The research was carried out in the farm Yerba Buena of the municipality of San Isidro, department Matagalpa, which is located at 05° 85' 897'' North latitude, and 14° 16' 310' West latitude, at 471 m a.s.l. The climatic conditions during the months of December 2023 to April 2024, belonging to the dry season, were average temperature of 21-30 °C, precipitation of 800 to 2,000 mm and relative humidity of 70-84%. The rainy season belongs to the months of May to October (Benavidez Meza, 2023). The meteorological information was obtained in the meteorological station Davis Vantage Pro2™ plus, 001D0A00BD6D, property of Formuladora Nicaragüense Hanon Talavera [FORMUNICA] (Figure 1).

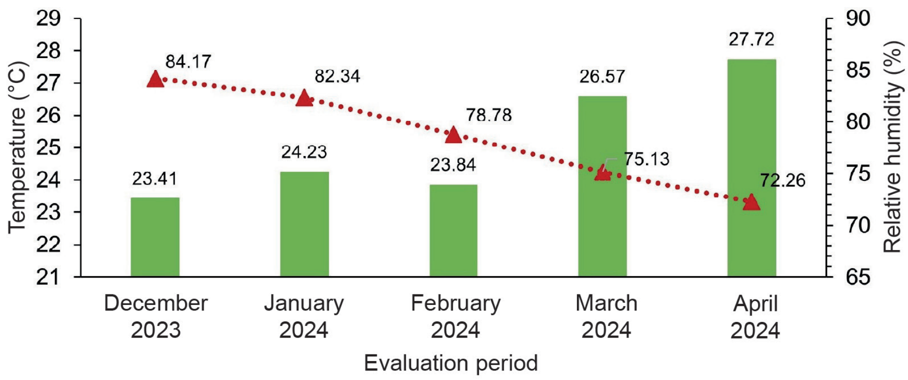


**Figure 1.** Changes in relative humidity and precipitation in the municipality of San Isidro, Matagalpa during the study period (December 2023 - April 2024) (Davis Vantage Pro2™ plus, 001D0A00BD6D).

### *2.2. Methodology design*

The study was experimental, with longitudinal cut, and used a randomized Complete Block Design [RCBD] with four blocks, six treatments (five based on entomopathogenic fungi (*Beauveria bassiana*, *Metarhizium anisopliae*), and their combination with botanical extracts from cinnamon (*Cinnamomum verum*) and garlic (*Allium sativum*). These were compared with chemical management (Control or famer management) (Table 1). Twenty-four experimental parcels were set, each one having 80 m$^2$, and the blocks' area 480 m$^2$, for a total area of 1,920 m$^2$. Five applications were done from the 10$^{th}$ to the 96$^{th}$ days of rice germination, with a frequency of 15 days (Table 1). The sampling was done weekly, selecting three dots per useful parcel. An entomopathogenic net was used to capture the macro arthropods at each point. Ten double steps were done, starting with the first sampling at the 11$^{th}$ day until the 104$^{th}$ day, and a behavioral description of the arthropods was given during the different phenological stages of rice cultivar and evaluated treatments.

To identify the present arthropods in rice cultivar, the collected specimens were conserved in 70% alcohol in each treatment and phenological stage of the crop. The methodology proposed by Montgomery et al. (2021), Obregon-Corredor et al. (2021) and Sanchez-Alvarado et al. (2023) was used. The specimens were preserved in 70% alcohol and were stored in Eppendorf tubes for their identification at the entomology lab at the Agrarian National University. Dichotomous taxonomic keys were used for their identification (Jiménez-Martínez, 2020).

**Table 1.** Description of the treatments evaluated for arthropod management in rice cultivation.

| Treatments | Description of the active ingredient [a.i] | Doses | Moment of application |
|---|---|---|---|
| T1 | *Beauveria bassiana* + *Allium sativum* | 1,000 ml | All crop cycle |
| T2 | *Beauveria bassiana* + *Metarhizium anisopliae* + *Allium sativum* | 1,000 ml | All crop cycle |
| T3 | *Metarhizium anisopliae* + *Purpureocillium lilacinum* + *Azadirachta indica* - *Cinnamomum verum* | 1,000 ml | All crop cycle |
| T4 | *Beauveria bassiana* + *Cinnamomum verum* | 1,000 ml | All crop cycle |
| T5 | Acetamiprid + Emamectin Benzoate | 100 g | Developmental stage (Applied from 11 to 23 days) |
| | Imidacloprid + Buprofezin | 200 ml + 400 ml | Developmental stage (Applied from 23 to 35 days) |
| | Imidacloprid + Pyriproxyfen | 100 g + 333 ml | Developmental stage (Applied from 23 to 51 days) |
| | Thiocyclam hydrogenoxalate + Buprofezin | 200 ml + 400 ml | Reproductive stage (Applied from 55 to 67 days) |
| | Carbosulfan + Pyriproxyfen | 500 ml + 333 ml | Reproductive stage (Appied from 77 to 91 days) |
| T6 | *Beauveria bassiana* + *Metarhizium anisopliae* | 1,000 g | All crop cycle |

### *2.3. Evaluated variables*

The information obtained from each sampling was quantified and organized by order, family, genre and species. The arthropods were also divided into pests and beneficials, and their total abundance per treatment at different crop developmental stages were calculated by observing the physiological changes in rice plants (Laguna Dávila et al., 2024). The harvest of each experimental unit was performed at the end of the cycle, and the yield was recorded at 13% humidity in kg $ha^{-1}$. The rentability of the treatments was considered through an economic analysis, through partial budgets, considering the selling price in a rice field. The costs for each treatment, including the application costs, were obtained to get the summatory of the total variable costs. Likewise, a dominance analysis and a marginal rate of return were applied following the methodology of the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT, 1988).

### *2.4. Analysis of the information*

The data was organized in a matrix according to each variable. Then, the data was processed using R software (R Core Team, 2023; version 4.2.3), where data transformation at logarithmic scale ($log_{10}$) was executed to adjust normality. The analysis of variance [ANOVA] was then performed, and the homogeneity of variance was assessed (Levene test). Finally, multiple comparisons of means test, or Tukey test (0.05), was done to verify the groups with differences.

## 3. Results and Discussion

### *3.1. Arthropod behavior*

The analysis of variance performed across the different treatments showed significant differences ($p < 0.0001$). The arthropods captured with higher frequency in the treatments were: *Tagosodes orizicolus* and *Sitobion avenae*, the populations of other arthropods were low. These results could be associated with the effectiveness of the chemical products. A different scenario was found when evaluating the different phenological stages of the crop that showed the arthropods' populations varied depending on the development of the rice plant (Table 2).

**Table 2.** Analysis of Variance for arthropod abundance found in the treatments and phenological stages in rice cultivation.

| Arthropods | Treatments | DDG | AIC |
|---|---|---|---|
| **Pests** | | | |
| *Tagosodes orizicolus* M. | 0.0001** | 0.0001** | 26.53 |
| *Hydrellia* spp K. | $0.3190^{NS}$ | 0.0001** | 14.01 |
| *Spodoptera* spp S. | $0.8790^{NS}$ | 0.0002** | 5.41 |
| *Hortensia* spp. W. | $0.5700^{NS}$ | 0.0200* | 56.52 |
| *Conocephalus* spp | $0.6180^{NS}$ | 0.0005** | 26.07 |
| *Sitobion avenae* | 0.0001** | 0.0001** | 61.05 |
| **Benefitials** | | | |
| *Tetragnatha* spp W. | $0.4300^{NS}$ | 0.0007** | 26.27 |
| *Sympetrum danae* S. | $0.0992^{NS}$ | 0.0003** | 68.71 |
| *Atrichopogom* spp K. | $0.2601^{NS}$ | 0.0004** | 22.33 |
| *Cycloneda sanguinea* L. | $0.8715^{NS}$ | 0.0029** | 11.32 |
| *Zelus pedestris* F. | $0.9217^{NS}$ | 0.0005** | 17.74 |

** Highly Significant (0.01), * Significant (0.05), NS = Not Significant, AIC = Akaike Index, DDG = Days after germination.

The results found by Albertini (2022) and Benites Ronquillo (2019) support that the dynamics of the arthropod populations show a behavior associated with the developmental bases of the crop. The least abundance of *Tagosodes orizicolus* and *Sitobion avenae*se was registered in the treatments T5, T1, T4 and T6. There was greater impact on the plant during the final period of the vegetative stage and the start of the reproductive one. This behavior responds to the feeding habits of both arthropods (Table 3). Moreira et al. (2021) mentions that *Tagosodes orizicolus* constitutes the main pest in rice crop, and their control has been mainly managed with chemical products (pesticides). However, biological control regulates the population of the insect and other pests through infection and feeding on the insect. This is observed due to its wide distribution and diversity of the hosts (Brunner-Mendoza et al., 2019; Castillo-Carrillo et al., 2021; McGuire & Northfield, 2020; Pérez Iglesias & Rodríguez Delgado, 2019¸ Vivas-Carmona et al., 2017).

**Table 3.** Total abundance of pest arthropods in rice crops, in the different treatments and phenological stages of the crop.

| Treatments | | Arthropods | | | |
|---|---|---|---|---|---|
| | | *T. orizicolus* | | *S. avenae* | |
| | T1 | 45.54 | ab | 1.20 | ab |
| | T2 | 52.27 | a | 1.70 | a |
| | T3 | 53.00 | a | 1.13 | a |
| | T4 | 47.63 | ab | 0.54 | ab |
| | T5 | 24.90 | b | 0.13 | b |
| | T6 | 40.27 | ab | 0.86 | ab |
| **DDG** | | | | | |
| 11 | Development stage | 6.33 | d | 0.00 | b |
| 23 | | 18.50 | d | 0.00 | b |
| 35 | | 18.16 | d | 0.00 | b |
| 46 | Vegetative stage | 14.17 | d | 0.00 | b |
| 51 | | 11.67 | d | 0.00 | b |
| 55 | | 86.67 | ab | 0.00 | b |
| 67 | | 107.83 | a | 0.58 | b |
| 77 | Reproductive stage | 60.33 | bc | 0.00 | b |
| 86 | | 56.67 | bc | 4.00 | a |
| 91 | | 39.83 | cd | 5.66 | a |
| 104 | | 63.16 | bc | 0.00 | b |

* Different letters in the same column after the value indicate statistically significant differences ($p < 0.05$) according to the Tukey test.

Considering that rice crop is affected by different important arthropods, it was determined that in the case of *Hydrellia* spp. and *Spodoptera* spp., major effects were caused at the start of the developmental stage of the plant (Table 4). This research agrees with the study by Muñoz Conforme et al. (2017), who reported the effects of *Spodoptera* spp. in plants from the family Poaceae from the first growing stages until the reproductive stages. The effects caused by these organisms are directly related to the management strategies used by the farmer, being chemical management the strategy used with higher frequency. Likewise, *Hortensia* spp. presented a higher abundance in the developmental stage of the plant as it contains higher quantities of sap than the rice plant. On the other hand, the populations of *Conocephalus* spp. were abundant in the reproductive stage since there was abundant food available (Table 4). The use of chemical and biological alternatives is employed by the farmers within integrated pest management, the combination of insecticides with entomopathogenic fungi significantly reduce the negative effects of pests (Castro López y Martínez Osorio, 2019; Rampoldi, 2017). Habitat conservation in the fields provides refugee for the beneficial organisms, which reduces production costs by regulating pests' population (Herrera et al., 2018).

**Table 4.** Arthropod abundance, in the different phenological stages of rice cultivation.

| DDG | | *Hydrellia* spp. | | *Spodoptera* spp. | | *Hortensia* spp. | | *Conocephalus* spp. | |
|---|---|---|---|---|---|---|---|---|---|
| 11 | Developmental stage | 2.50 | *b* | 32.33 | a | 0.17 | bc | 0.00 | e |
| 23 | | 18.50 | *a* | 10.00 | b | 1.33 | a | 1.83 | bc |
| 35 | | 121.83 | *a* | 8.83 | b | 0.00 | c | 0.33 | cde |
| 46 | Vegetative stage | 3.50 | b | 2.17 | cd | 0.33 | bc | 0.66 | cde |
| 51 | | 4.33 | b | 2.00 | cd | 0.00 | c | 0.50 | cde |
| 55 | | 0.50 | b | 3.33 | c | 0.83 | ab | 0.17 | de |
| 67 | | 0.33 | b | 3.33 | c | 0.00 | c | 0.67 | cde |
| 77 | Reproductive stage | 0.00 | b | 2.00 | cd | 0.00 | c | 1.50 | bcd |
| 86 | | 1.83 | *b* | 0.83 | de | 0.00 | c | 8.17 | a |
| 91 | | 0.16 | *b* | 1.00 | de | 0.17 | bc | 6.67 | a |
| 104 | | 0.00 | b | 0.00 | e | 0.00 | c | 3.33 | b |

* Different letters in the same column after the value indicate statistically significant differences ($p < 0.05$) according to the Tukey test.

### *3.2. Economic analysis of the treatments*

The effects of pests on foliar tissue have a direct impact on yield. There were no significant differences in yield between evaluated treatments (Figure 2). The estimation of economic parameters allows to evaluate technologic feasibility used on crop management, and to take better decisions (Ávalos-Cerdas & Villalobos-Monge, 2018). The partial budget analysis showed that the highest costs and benefits corresponded to treatments T4 and T5 (Table 5). When comparing alternatives in terms of economic efficiency, the dominance analysis (Table 6), showed that treatments T1, T3, T4, T5, T6 are considered as non-dominated, and subjected to marginal return analysis. However, T2 was dominated by the rest of the study treatments.

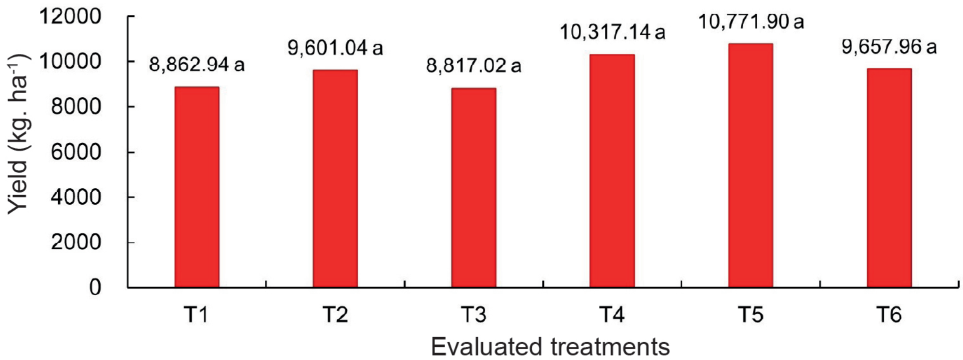


**Figure 2.** Yield (kg. ha), obtained in rice cultivation for the different treatments evaluated (Tukey=0.05).

**Table 5.** Partial budget in dollars (US$*) for the treatments evaluated in rice cultivation.

| Treatments | Adjusted yield kg ha$^{-1}$ | Gross profit US$ ha$^{-1}$ | Variable costs US$ ha$^{-1}$ | Net profit US$ ha$^{-1}$ |
|---|---|---|---|---|
| T1 | 8,862.94 | 4,899.06 | 2,201.968 | 2,697.092 |
| T2 | 9,601.03 | 5,307.05 | 1,959.543 | 3,347.507 |
| T3 | 8,817.01 | 4,873.68 | 2,080.756 | 2,792.924 |
| T4 | 10,317.13 | 5,702.88 | 2,282.776 | 3,420.104 |
| T5 | 10,771.89 | 5,954.25 | 2,229.898 | 3,724.352 |
| T6 | 9,657.96 | 5,338.52 | 2,166.160 | 3,172.360 |

* One US dollar is equivalent to 36.62 córdobas.

**Table 6.** Dominance analysis for the treatments evaluated in rice cultivation.

| Treatments | Variable costs US$ ha$^{-1}$ | Net profit US$ ha$^{-1}$ | Observations* | |
|---|---|---|---|---|
| T2 | 1,959.543 | 3,347.507 | T2 | D |
| T3 | 2,080.756 | 2,792.924 | T2 a T3 | ND |
| T6 | 2,166.160 | 3,172.360 | T3 a T6 | ND |
| T1 | 2,201.968 | 2,697.092 | T6 a T1 | ND |
| T5 | 2,229.898 | 3,724.352 | T1 a T5 | ND |
| T4 | 2,282.776 | 3,420.104 | T5 a T4 | ND |

* ND: Not Dominated, D: Dominated.

The marginal rate of return determined that T4 (575.34%), followed by T3 (444.31%), showed the highest rates of return. This means that for each invested dollar, US$ 5.75 is expected for T4 and US$ 4.44 for T3 (Table 7). In this study, the altered biological or combined treatments with botanic products kept arthropod pest population within the allowed threshold. Siu Palma et al. (2023) demonstrated that the management strategies, where botanic and biological products are used, reduced effects caused by pests and production costs.

**Table 7.** Marginal rate of return analysis for the treatments evaluated in rice cultivation.

| Treatments | Variable costs US$ ha$^{-1}$ | Net profit US$ ha$^{-1}$ | IMBN* | IMCV** | Marginal rate of return % |
|---|---|---|---|---|---|
| T5 | 2,229.898 | 3,724.352 | | | |
| T4 | 2,282.776 | 3,420.104 | 304.24 | 52.88 | 575.34 |
| T6 | 2,166.160 | 3,172.360 | 175.15 | 206.61 | 84.77 |
| T3 | 2,080.756 | 2,792.924 | 379.44 | 85.40 | 444.31 |
| T1 | 2,201.968 | 2,697.092 | 95.83 | 121.21 | 79.06 |

* IMBN = Difference in the net benefit of the treatments; **IMCV = Difference in the variable costs of the treatments.

Considering the economic importance of rice crop in Nicaragua and worldwide, this study could provide an alternative for arthropod pest management in traditional productive systems.

## 4. Conclusions

The treatments T6, T5, T4 and T1 managed to control pest arthropods in rice crop by reducing their population along the different developmental stages of the plant. The main pests recorded were *Tagosodes orizicolus*, *Hydrellia* sp, and *Spodoptera* sp, being the developmental and reproductive stages where the highest population number was encountered. In the economic analysis, T5 obtained the highest yield, net profit and marginal rate of return. All the treatments, except for T2, are profitable, and could be used as management strategies for pests in rice crops.

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## Contributor roles

- José Manuel Laguna Dávila: conceptualization, investigation, methodology, resources, data curation, formal analysis, writing – original draft.
- Juan Carlos Morán Centeno: conceptualization, data curation, formal analysis, writing – original draft.

## Ethical implications

Ethics approval not applicable.

## Conflict of interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

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