# Comparison of weed control methods in rice in the rainy and dry seasons

Comparación de métodos de control de malezas en arroz en época lluviosa y de sequía

Comparação de métodos de controle de plantas daninhas em arroz nas épocas chuvosa e seca

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## Abstract

Integrated weed management strategies are crucial to reduce crop production costs. The objective was to compare weed control techniques according to their efficiency and profitability in rice cultivation during the rainy and dry seasons. It was carried out under the quasi-experimental modality with the Student's t-test under a descriptive research type. Structured questionnaires were administered to 70 rice farmers in the area. Weeds were identified in areas every 10 m² within the rice crop, 10 and 15 days after sowing. The efficiency (E) of weed management in rice crops was calculated by applying the formula $\% efficiency = 1 \frac{MP}{Mt} * 100$. The results showed that manual weeding has a monthly frequency, being used both in the rainy season (40 %) and in the dry season (44 %). The frequency of herbicide application was adjusted to the crop stage in the rainy season (39 %) and in the dry season (46 %). The efficiency (E) using the mechanical method was below one month during the rainy and dry seasons, registering 43%. Manual weeding showed an E of 49 % in the rainy season and 42 % in the dry season for up to 30 days. The combination of herbicides: Metsulfuron-methyl + Quinclorac; pyrazosulfuron-ethyl + Quinclorac, exhibited an E greater than 80 %, for more than 30 days in both seasons. The highest profitability was in the rainy season, thus presenting mechanized control USD 0.09 in rainfall and USD 0.04 in drought, chemical control USD 0.09 in rainfall and USD 0.07 in drought, and manual weeding USD 0.10 in rainfall and USD 0.06 in drought, for every dollar spent during the cultivation of rice.

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## Resumen

Las estrategias de manejo integrado de malezas resultan cruciales para disminuir costos de producción en cultivos. El objetivo fue comparar técnicas de control de malezas según su eficiencia y rentabilidad en el cultivo de arroz en época lluviosa y seca. Se efectuó bajo la modalidad cuasiexperimental con la prueba de T-student bajo una investigación de tipo descriptiva. Se realizaron cuestionarios estructurados a 70 cultivadores de arroz de la zona. Las malezas fueron identificadas en áreas cada 10 m² dentro del cultivo de arroz, a los 10 y 15 días posteriores a la siembra. La eficiencia (E) del manejo de las malezas en las siembras de arroz, se calculó aplicando la fórmula $\% \, eficiencia = 1 \frac{\text{MP}}{\text{Mt}} * 100$. Los resultados evidenciaron que el deshierbe manual tiene una frecuencia mensual, siendo utilizada tanto en la época de lluvia (40 %) como en sequía (44 %). La frecuencia de aplicación de herbicidas se ajustó a la etapa del cultivo en estación de lluvia (39 %) y sequía (46 %). La eficiencia (E) mediante el método mecánico se situó por debajo de un mes durante la época lluviosa y seca, registrando un 43 %. El deshierbe manual mostró una E de 49 % en época lluviosa y 42 % en época seca hasta 30 días. La combinación de herbicidas: Metsulfuron metil + Quinclorac; Pyrazosulfuron ethyl + Quinclorac, exhibió una E mayor al 80 %, por más de 30 días en ambas épocas. La mayor rentabilidad fue en la época de lluvia, presentando así, el control mecanizado USD $ 0,09 en lluvia y USD $ 0,04 en sequía, el control químico USD $ 0,09 en lluvia y USD $ 0,07 en sequía y el deshierbe manual USD $ 0,10 en lluvia y USD $ 0,06 en sequía, por cada dólar gastado durante el cultivo del rubro arroz.


**Palabras clave**: control de maleza, efectividad del control, manejo integrado de malezas, rentabilidad, valoración económica.


## Resumo

Estratégias integradas de manejo de ervas daninhas são cruciais para reduzir os custos de produção agrícola. O objetivo era comparar as técnicas de controlo de infestantes de acordo com a sua eficiência e relação custo-eficácia no cultivo de arroz em estações chuvosas e secas. Foi realizado na modalidade quase-experimental com teste T-student sob pesquisa do tipo descritiva. Questionários estruturados foram aplicados a 70 produtores de arroz da região. As plantas daninhas foram identificadas em áreas a cada 10 m² dentro da cultura do arroz, 10 e 15 dias após a semeadura. A eficiência (E) do manejo de plantas daninhas na cultura do arroz foi calculada aplicando-se a fórmula $\% \, eficiencia = 1 \frac{\text{MP}}{\text{Mt}} * 100$. Os resultados mostraram que a capina manual tem frequência mensal, sendo utilizada tanto no período chuvoso (40 %) quanto no período seco (44 %). A frequência de aplicação dos herbicidas foi ajustada à fase da cultura no período chuvoso (39 %) e seca (46 %). A eficiência (E) pelo método mecânico ficou abaixo de um mês no período chuvoso e seco, registrando 43 %. A capina manual apresentou E de 49 % no período chuvoso e 42 % no período seco por até 30 dias. A combinação de herbicidas: Metsulfuron metil + Quinclorac; Pirazosulfuron etil + Quinclorac, apresentaram E superior a 80 %, por mais de 30 dias em ambos os períodos. A maior rentabilidade foi no período chuvoso, apresentando assim controle mecanizado USD $ 0,09 na chuva e USD $ 0,04 na seca, controle químico USD $ 0,09 na chuva e USD $ 0,07 na seca e capina manual USD $ 0,10 na chuva e USD $ 0,06 na seca, para cada dólar gasto durante o cultivo do arroz.


**Palavras-chave:** controle de plantas daninhas, efetividade de controle, manejo integrado de plantas daninhas, rentabilidade, valorização econômica.

## Introduction

Rice (*Oryza sativa* L.), widely cultivated in areas with a hot humid climate, is one of the most important cereals in Latin America and an important source of energy (Diaz Granados and Chaparro-Giraldo, 2012). In Ecuador, rice occupies a key position in various aspects ranging from its contribution to food security to its performance in the economy (Aldaz *et al*., 2020). In socioeconomic terms, rice is a crucial element of livelihood for numerous populations within the country, generating and providing employment and strengthening their economic base in both rural and urban territories (Fajardo, 2015).

On the other hand, weeds attract pests and diseases affecting rice crops (Amaíz *et al*., 2015; Vigo *et al*., 2018; Demera *et al*., 2023). Therefore, this phenomenon hinders the complete development of the panicle, which translates into an estimated decrease between 24 and 26 % of annual rice production (Bautista *et al*., 2022). These events compromise food security by causing the loss of a considerable part of production, which can lead to increased production costs and demand dissatisfaction (Cruz-Triana *et al*., 2024). Therefore, it is essential to carry out exhaustive monitoring of the crop to control the negative effects, guaranteeing the minimization of losses and the achievement of high quality in production (Aguirre *et al*., 2022).

The damages caused by climatic factors on rice cultivation are variable and are conditioned by the stage of plant development, crop management, climatic conditions, sowing period, varieties, and insect population density (Jiménez, 2021). In contrast to the effects of pests and diseases, weeds compete for resources such as light, water, nutrients, and also as hosts for insects, pests, and pathogens (Mera and Baque, 2023).

From an agronomic perspective, weeds have been defined as native or exotic plants, with an adverse impact on crops of importance to humanity (Ortiz *et al*., 2017). The identification of the specific components of weed varieties in a given location is the initial step to assess the level of affectation and then address its management (Piedrahita *et al*., 2022). In the same sense, an integrated weed management approach proposes to consider various aspects with the aim of executing sustainable and efficient management strategies, ensuring the environmental harmony of agroecosystems (Amaya *et al*., 2018).

The Ecuadorian coast presents optimal climatic and edaphic conditions that favor the vigorous and aggressive development of weeds such as *Cyperus rotundus* L. (coquito), *Panicum maximum* Jacq. (saboya) *Rottboellia exaltata* L.f. (treadmill) (Lovato Echeverría *et al*., 2022). The diversity of weeds in rice production systems demands the implementation of integrated weed management, which is based on the prevention, eradication, and control of weeds (Guzmán and Martínez-Ovalle, 2019). This approach includes the application of various techniques, such as cultural, biological, mechanical, and chemical control (Barcos *et al*., 2024).

In Asia, it is estimated that the direct loss of rice production attributable to the presence of weeds in rice fields reaches approximately 20 % (Torres and Ortiz, 2017). However, these losses can increase significantly, ranging from 40 % to 100 %, in cases where weeds are not managed effectively (Picado-Arroyo and Herrera-Murillo, 2022). Therefore, the objective of the study was to evaluate economic strategies to control weeds in rice cultivation in the rainy and dry seasons in the Samborondón canton of the Province of Guayas, Ecuador.

## Materials and methods

The study was carried out during the rainy and dry seasons of 2020 in the Samborondón canton of the Province of Guayas, Ecuador, an area that has an altitude of 17 meters above sea level, with average annual rainfall of 1400 to 1700 mm, its temperature is temperate and ranges between 30 and 32 °C in winter, and 22 to 25 ºC in the dry season, with a humidity of 61 %. The canton has a population of 85,075 individuals, of which 23.24 % are involved in agricultural work, with rice production standing out as the main activity.

The study was carried out under the quasi-experimental modality, where the main research tool in the assigned context was a draft of a random concession for the outcome, in order to investigate the causal correspondence between the variables. The research approach adopted was descriptive, to examine certain particular characteristics, employing a comparative method through a systematic process of contrasting one or more phenomena to identify similarities and differences between results, and in a methodical way, with the aim of supporting the relationship between variables and the content studied to validate the proposed assumption (Henríquez-Fierro and Zepeda-González, 2004).

In this study, the survey technique with closed questions was used, which were linked to three main areas: socioeconomic, environmental, and agronomic management. In the socioeconomic sphere, the following were considered: age, level of education, origin, place of residence of the producer, income, household possessions, shares, total area, property titles, and production yield. Regarding the environmental and agronomic aspects, the following indicators were used: use of chemical fertilizers, rotation of crops, incorporation of organic matter, organic control, and incidence of pests, and diseases, among others related to this aspect.

In relation to agronomic management, established doses were applied, approximately 15 days after sowing. Specifically, the application was carried out during the initial stages using a manual backpack sprayer with a capacity of 20 L and 40 PSI, equipped with a fan nozzle for a two-meter amplitude, with the respective calibration of the device to guarantee the spraying of 200 $L.ha^{-1}$ volume of water.

Weeds were identified in areas every 10 m² within the rice crop, and data was taken 10 days after sowing. Seventy (70) sites were also randomly analyzed to observe the most frequent weed species according to the season (rainfall and drought) at 10 $m^2$, 15 days after sowing.

For weed control, mechanical control, manual weeding, and herbicide treatments were evaluated; T1: Quinclorac at a dose of 1.50 $L.ha^{-1}$ + Pyrazosulfuron-ethyl at a dose of 350 $g.ha^{-1}$ for narrow leaf; T2: Quinclorac at a dose of 1.50 $L.ha^{-1}$ + Metsulfuron-methyl at a dose of 20 $g.ha^{-1}$ for narrow leaf; T3: Quinclorac at a dose of 1.50 $L.ha^{-1}$ + Pyrazosulfuron-ethyl at a dose of 350 $g.ha^{-1}$ for broadleaf; T4: Quinclorac in doses of 1.50 $L.ha^{-1}$ + Metsulfuron-methyl in doses of 20 $g.ha^{-1}$ for broadleaf. Herbicide treatments were applied with two application frequencies on days 10 and 20 after sowing, by foliar application.

To estimate the profitability of weed control in rice crops, only plantations under incursion of mechanized systems were considered within the study (Plaza *et al*., 2022). Likewise, the efficiency (E) of weed management was determined at 10, 20, and 30 days after rice planting, applying the formula , Where: PM corresponds to the number of species located on the properties of rice farmers; Mt: Number of species located in mechanized properties (López-Urquídez *et al*., 2020).

The statistical design was executed under the student's T-test, where data collected from the farms under study were compared with weed control by herbicides. The economic analysis was verified by applying the partial budgeting system proposed by Vera-Rodriguez *et al*. (2020a) and Vera-Rodríguez *et al*. (2020b). For the calculation of profitability, the yield in 4 quintals of 100-pound paddy was considered, and the average price established for the cost of milled rice was USD 35.00 according to the price established by the MAG Ministry of Agriculture and Livestock of Ecuador for the period 2020, following the methodology proposed by Vera-Rodríguez *et al*. (2021).

## Results and discussion

Table 1 shows the percentage of weeds found in the area under study.

**Table 1. Percent proportion of weed species (%) per rice fields (Rcto) in Samborondón.**

| Scientific name | Rcto La Palma | Rcto Barranca | Rcto Bellavista – Rcto El Rosario | Rcto Boca de caña | Rcto El Zapan-Rcto Quevedo |
|---|---|---|---|---|---|
| *Ageratum conyzoides* | 10 | 12 | 4 | 13 | 3 |
| *Digitaria sanguinalis* | 12 | 8 | 5 | 15 | 3 |
| *Echinochloa colonum* | 9 | 6 | 7 | 12 | 2 |
| *Echinochloa crus galli* | 13 | 7 | 4 | 14 | 7 |
| *Eclipta* | 10 | 6 | 4 | 11 | 6 |
| *Eleusina indica* | 9 | 7 | 5 | 7 | 6 |
| *Euphorbia heterophylla* | 7 | 7 | 0 | 0 | 7 |
| *Tiliácea* | 7 | 9 | 7 | 7 | 8 |
| *Leptochloa filiformis* | 0 | 7 | 5 | 5 | 9 |
| *Leptochloa virgata* | 7 | 10 | 7 | 4 | 7 |
| *Portulaca oleracea* | 5 | 0 | 4 | 6 | 8 |
| *Rottboellia exaltata* | 4 | 7 | 6 | 0 | 10 |
| *Sesbania exaltata* | 3 | 9 | 11 | 3 | 0 |
| *Vigna vexillata* | 4 | 7 | 31 | 3 | 24 |

It is important to note that the incidence of a weed in a field can vary depending on the region, the type of crop, and other specific factors. For Espinoza-Hernandez *et al*. (2021) weeds cause serious economic losses, resulting in low yields in rice crops.

Table 2 shows the weed species that occur most frequently at different times of the year.

**Table 2. Weed species with higher frequency according to the season.**

| Weed | Rainfall (%) | Drought (%) |
|---|---|---|
| *Rottboellia exaltata* | 23 | 19 |
| *Cyperus rotundus* | 24 | 16 |
| *Momordica charantia* | 10 | 6 |
| *Panicum fasciculatum* | 13 | 11 |
| Other species | 30 | 49 |

The weed with the highest incidence corresponded to *Rottboellia exaltata* (23 %) in the rainy season, while its existence decreased by 19 % in the dry season. For Coquito (*Cyperus rotundus*) 24 % in the rainy season and 16 % in the dry season. Achochilla (*Momordica charantia*) 10 % in the rainy season and 6 % in the dry season; then Granadilla (*Panicum fasciculatum*) with an incidence of 13 % in the rainy season and low in the dry season to 11 %. Other uncharacterized species affect 30 % in the rainy season and increase to 49 % in the dry season. This information coincides with that described by Ortiz and González (2001) who argued that the incidence of a weed at the time of year, whether in the dry or rainy season, could depend on factors such as the dormancy and germination of the seeds, the specific climatic conditions of each season, soil management practices and the control of weeds used in agriculture.

Table 3 shows the frequency of weed control techniques in rice cultivation (mechanical, manual, and herbicides). The limited use of mechanical control is evident since producers make use of this mechanism when preparing the soil to start a new planting. Manual weeding is carried out using a scythe and machete, while herbicide control is carried out by crop period during the pre-emergent and post-emergent periods of the weed.

It is important to highlight, that weed monitoring in rice fields can be challenging due to the competition for nutrients that these undesirable plants represent for the crop. For Gastesi *et al*. (2024), it is essential to implement integrated weed control practices that combine different agronomic, mechanical, biological, and chemical methods

The efficiency of weed control in rice cultivation according to the time of year is shown in table 4.

As for mechanical control, it has been noted that, on average, this method starts with 76 % of E at 10 days in the rainy season and with 73 % in the dry season. However, after 30 days of application, E reaches 43 % for both seasons.

With manual weeding, it was observed that the E of this control method in the rainy season begins with 88 % after 10 days, while in the dry season, it obtains 86 %. However, after 30 days of application, in the rainy season, it reaches 49 %, while in the dry season it reaches 42 %.

In the mixture of herbicides for narrow-leaved weeds, it was observed that the T1 treatment had an effective result of 96 % throughout the rainy season. At 10 days after its application during the dry season, it obtained an E of 93 %, and after 30 days its effectiveness reached 84 %. It is perceived that the weeds begin to recover their natural green color, which indicates the presence of resistance. For the T2 treatment in the rainy season, an E percentage of 92 % is shown at 10 days after sowing, reaching 94 % after 30 days, while for the dry season, its E is 90 % at 10 days and 82 % at 30 days.

**Table 3. Frequency of weed control techniques (%) in systems (mechanical, manual, and herbicides) in the rainy and dry seasons.**

| Frequency | Mechanical | | Manual | | Herbicides | |
|---|---|---|---|---|---|---|
| | Rainy season | Dry Season | Rainy season | Dry Season | Rainy season | Dry Season |
| Once a week | - | - | 17 | 14 | - | - |
| 2 times a week | - | - | 4 | 6 | - | - |
| 2 times per month | - | - | 3 | 2 | 10 | 3 |
| 1 time per month | - | - | 10 | 12 | 20 | 27 |
| 1 time each growing period | 100 | 100 | 36 | 34 | 39 | 24 |
| 2 times per growing period | - | - | 30 | 32 | 31 | 46 |

**Table 4. Efficiency (%) of weed control in rice cultivation according to the rainy and dry seasons.**

| | Rainy season | | | Dry season | | |
|---|---|---|---|---|---|---|
| Control Type | 10 days | 20 days | 30 days | 10 days | 20 days | 30 days |
| **Mechanical control** | 76 | 63 | 43 | 73 | 54 | 43 |
| **Manual weeding** | 88 | 71 | 49 | 86 | 70 | 42 |
| **T1** | 95 | 95 | 96 | 93 | 94 | 84 |
| **T2** | 92 | 94 | 94 | 90 | 93 | 82 |
| **T3** | 96 | 95 | 96 | 94 | 94 | 84 |
| **T4** | 96 | 93 | 97 | 94 | 92 | 84 |

T1: Quinclorac + Pyrazosulfuron-ethyl for narrow leaf; T2: Quinclorac + Metsulfuron-methyl for narrow leaf; T3: Quinclorac + Pyrazosulfuron-ethyl for broadleaf; T4: Quinclorac + Metsulfuron-Methyl for broadleaf

For the control of broadleaf weeds with herbicide mixture, an E of 96 % was maintained during the rainy season until 30 days after sowing. In the dry season, it started with an E of 94 % and after 30 days of application, it reached 84 %, with the T3 treatment. The same happened with T4, in addition, resistance was observed in this type of weed. It is important to note that after 30 days, the phenological stage of tillering of the rice plant begins, so no product is applied due to its adverse effects on production.

An aspect of interest to highlight is that integrated weed control involves combinations of different methods, adapted to the specific conditions of each crop area. The choice of the most appropriate method will depend on several factors, such as environmental conditions, water surface according to the phenology of the crop, and other available factors (Luna *et al*., 2024).

Table 5 shows the destination of rice production for 70 people surveyed, 90 % stated that rice production during the rainy season is used for marketing (intermediaries, direct sales, or markets). Similarly, 94 % provided the same answer for the dry season.

**Table 5. Destination of rice production (*%)* in the rainy and dry seasons.**

| Destination of production | Rainy season | Dry season |
|---|---|---|
| 50 % sale - 50 % consumption | 3 | 1 |
| 25 % sale - 75 % consumption | 4 | 3 |
| 75 % sale - 25 % consumption | 3 | 1 |
| 100 % sales | 90 | 94 |

It is important to consider that the destination of rice production can vary depending on the country and market conditions. This coincides with what was referred to by Cobo *et al*. (2020), where factors such as domestic demand, trade agreements, and agricultural policies also influence the destination of rice production.

Concerning profitability, it obtained the highest value with USD 0.09 for each USD 1.00 invested for the control of herbicide weeds in the rainy season (table 6). As can be seen in table 6, the profitability is higher for the rainy season, it can be stated that it is due to the amount of water available at different seasons.

It is important to note that the profitability of rice cultivation depends not only on the weed control method used but also on other factors such as planting date, soil preparation, number of seeds, fertilization, and the variety of rice, these factors must be maximized to achieve adequate weed control and ensure efficient rice production (Maldonado and Reyes, 2023).

## Conclusions

Rice producers in the rural area of Samborondón in the Province of Guayas use manual weeding with a monthly frequency of 40 % during the rainy season and 44 % in the dry season. Regarding the application of herbicides, it is carried out by both pre-emergent and post-emergent crop periods, representing 39 % in the rainy season and 46 % in the dry season.

The efficiency with mechanical control for weeds is less than 30 % within 30 days in the rainy season, while in drought it reaches 43 %. On the other hand, manual weeding achieves an efficiency of up to 49 % in the rainy season and 42 % in the dry season in the same period of 30 days. On the other hand, the control with the herbicide mixture shows an (E) greater than 80 % after 30 days, for both seasons (rainy and dry).

When evaluating the economic effect of applying weed control, variations were shown, with a higher yield in dry seasons, being the case of the herbicide mixture (costing USD 0.09 during the rainy season and USD 0.07 for the dry season), manual weeding (costing USD 0.10 for the rainy season and USD 0.06 in the dry season) and for mechanical control (costing USD 0.09 in the rainy season and USD 0.04 during the dry season) for every USD 1.00 invested in rice cultivation.

Manual weeding and herbicide application are common in weed control in rice cultivation in Samborondón, Guayas. The efficiency of mechanical control is low compared to manual weeding and herbicide application. It is recommended to use the herbicide mixture for more effective control, consider the cost-benefit, adjust strategies according to climatic conditions, and conduct additional research.

**Table 6. Profitability according to weed control method at different seasons.**

| DESCRIPTION | | Cmc- Ll | Cmc-S | Dm- Ll | Dm-S | Ch- Ll | Ch-S |
|---|---|---|---|---|---|---|---|
| Paddy yield (B) | | 42 | 42 | 42 | 42 | 42 | 42 |
| Sack of paddy rice (USD $) (C) | | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 |
| Gross income (US$) (D) | BXC | 1470 | 1470 | 1470 | 1470 | 1470 | 1470 |
| Direct costs (A) | | 1390 | 1410 | 1340 | 1385 | 1350,0 | 1370 |
| Net income (USD $) (E) | D-A | 80.0 | 60.0 | 130.0 | 85.0 | 120.0 | 100.0 |
| Cost/benefit ratio | | 1.06 | 1.04 | 1.10 | 1.06 | 1.09 | 1.07 |
| Profitability (%) | E/A*100 | 5.76 | 4.26 | 9.70 | 6.14 | 8.89 | 7.30 |
| Production cost (USD $/200 lb bag) | A/B | 33.10 | 33.57 | 31.90 | 32.98 | 32.14 | 32.62 |

Cmc: Mechanical control; Dm: Manual weeding; Ch: Herbicide control; Ll: rainy season, S: dry season

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