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# Herbicides Assesment for Weed Control and Cost Analysis in a Tomato (*Solanum lycopersicon* L.) Crop in the State of Yucatan Mexico

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## Abstract

The tomato is very sensitive to weed competition, especially in the early stages after transplanting. In the state of Yucatan Mexico, weed control is carried out with the application of several herbicides such as *glyphosate* in pre-transplantation. Currently, the use of *glyphosate* is prohibited, in the country, since 2020. For this reason, new herbicides are to be searched to replace it. A study was carried out in 2022 in the municipality of Muna, Yucatan, Mexico with the objective of assessing the effectiveness of various herbicides and their phytotoxicity in the crop. Four herbicides were selected and applied in combination with a contact herbicide (*Bentazon*): *Pendimethalin*, *Clorthal Dimethil*, *Trifluralin* and *Ethalfluralin* which were compared with a combined control treatment (*Glyphosate* + *Manual Control* + *Paraquat*). The cost reduction ($) of each treatment was calculated when the production cost of the producer was taken as 100%, against the production cost of each treatment. All herbicides were more effective to reduce the incidence of all kind of weeds. Only T1 (*Pendimethalin* + *Bentazon*) reduced the cost marginally by 2.69%, the other treatments were more expensive than the Control. When excluding the Bentazon *Pendimethalin*, *Ethalfluralin* and *Trifluralin* the costs can be reduced by 79.12, 64.91 and 61.86.

## Subject Areas

Agricultural Engineering

## Keywords

Vegetables, Weed Control, Phytotoxicity, Herbicides

## 1. Introduction

Current regulations at the international and national level are driving to a gradual reduction and prohibition of the herbicide *Glyphosate* aiming to promote healthier agri-food systems in order to avoid soil and water contamination. Under this context, Mexico has launched agroecological transition policies; the reduction and eventual elimination of *Glyphosate* by 2024 being the main objective [1].

In December 2020, Mexico established a presidential decree for the institution of the Federal Public Administration to carry out actions to gradually replace the use, acquisition, distribution, promotion and import of *Glyphosate* and all other pesticides containing its active ingredient. The replacement must be toward the use of sustainable and culturally appropriate alternatives to maintain crop production and be safe to human health, amicable to the biocultural diversity of the country and the environment [2].

However, this is not an easy task since *Glyphosate* has gained popularity due to its cheaper acquisition by producers. Unfortunately, the economic analysis of the herbicide is limited, since the negative effects on human health and nature are not taken into account [3].

In the particular case of tomato production (*Solanum lycopersicum* L.) in the state of Yucatan, weed control is carried out by applying several herbicides, including *Glyphosate*, as the principal one, applied in pre-transplanting. Weed competes with the crop for space, light, nutrients, and water; and also serves as an alternate host for begomoviruses and important biological vectors [4].

In the state of Yucatán Mexico, the farmers control weeds based on a combination of hand weeding in crop lines, application of *Glyphosate* in pre-transplant and *paraquat* in post-transplant. This is ineffective for being a high cost and highly-labor demanding practice that needs to be repeated two or three weeks, depending on the environmental conditions.

Due to the foregoing, the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) of Mexico, launched in 2022 a strategy, based on the project: "*Alternatives to the use of glyphosate for weed control in Mexico.*" to control weeds from germination to emergence of different crops, such as tomatoe, but keeping in mind the cost/benefit ratio ($).

In accordance with the strategy, this work aimed to assess the effect of different commercial herbicides to control weeds and their phytotoxic effects in tomato, considering the cost-benefit ($) of each treatment.

## 2. Materials

### 2.1. Location

The research was carried out in the Agricultural Unit "José López Portillo Pozo 3", in the municipality of Muna, Yucatán, Mexico; located at the coordinates 20˚25'10'' north latitude and 89˚29'41'' west longitude in a soil classified as K'ankab lu'um in Mayan terms and *Luvisol* in the World Soil Reference Base

(WRB) [5].

### 2.2. Identification of Weed Species

The weed species were identified under field conditions a week before the establishment of the treatments, using 12 squares of 1.0 $m^2$ (1.0 × 1.0 m) to record the coverage and frequency of appearance of each species.

The frequency of appearance, abundance and dominance of each species were recorded and the Importance Value Index (IVI) of each weed was calculated adapting the methodology described by Gámez López *et al.* (2011) [6]. The Importance Value Index (IVI) was developed by Curtis & McIntosh (1951) [7]. It is a synthetic structural index, developed mainly to rank the dominance of each species in mixed stands and was calculated as follows: IVI = Relative dominance + Relative density + Relative frequency [8] [9]. According to Campo and Duval (2014) [10], these three parameters are calculated as follows:

1) $\text{Relative dominance} = \frac{\text{Dominance of each species}}{\text{Dominance of all species}} \times 100$

2) $\text{Relative Density} = \frac{\text{Number of individuals of each species}}{\text{Total Number of individuals}} \times 100$

3) $\text{Relative frequency} = \frac{\text{Frequency of each species}}{\text{Frequency of all species}} \times 100$

## 3. Methods

### 3.1. Management and Herbicides Application

The study was carried out from August to December 2022 (autumn-winter cycle) starting with the land preparation by passing a heavy harrowing twice. In the second week of August, the contact herbicide *Paraquat* (200 g of active ingredient $L^{-1}$) was applied at a dose of 10 mL of commercial material per liter of water, to eliminate the first vegetation.

Five treatments were evaluated in five repetitions: in the first four treatments, pre-emergent herbicides (*Pendimethalin*, *Clorthal Dimethi*, *Trifluralin* and *Ethalfluralin*), mixed each one with the contact herbicide *Bentazon*, were applied three days before the transplanting (2/Sep). Subsequently, two more applications of *Bentazon* alone were made at 10 (September 15) and 29 days after transplantation (Oct 4).

Treatment five was the Producer's Control, based on *Glyphosate* before transplanting, plus hand weeding in the crop line and application of contact Paraquat in the streets after transplanting. In this control treatment, *Glyphosate* was applied, in post-emergence of weeds, three days before transplanting the tomatoe (Sep 2). Hand weeding was carried out in the crop lines (40 cm wide band) and *Paraquat* applied on the streets, 29 days after transplanting (4/Oct).

The doses used (**Table 1**) were determined using the herbicides manufacturers and those suggested by INIFAP [11]. Legal authorization for Mexico and USA for other vegetable crops, was also considered. Crop management was carried

**Table 1.** Herbicide treatments for weeds control in a tomato crop (Autumn-Winter period 2021-2022).

| Treatment (N°) | Herbicide | g of active ingredient (a·i) $Kg^{-1}$ or $L^{-1}$ | Commercial Dose (L or $Kg \cdot ha^{-1}$) | Dose of a·i (Kg a·i $Kg^{-1}$ or $L^{-1}$) | Chemical Group (HRAC) | TC |
|---|---|---|---|---|---|---|
| 1 | *Pendimethalin* + *Bentazon* | 328 + 480 | 2.5 + 6.25 | 0.82 + 3.0 | Dinitroanilines<br>Benzothiadiazine | V<br>IV |
| 2 | *Clorthal Dimethil* + *Bentazon* | 750 + 480 | 6.25 + 6.25 | 4.7 + 3.0 | Benzoic Acids<br>Benzothiadiazine | IV<br>IV |
| 3 | *Trifluralin* + *Bentazon* | 600 + 480 | 5.0 + 6.25 | 3.0 + 3.0 | Dinitroanilines -<br>Benzothiadiazine | IV<br>IV |
| 4 | *Ethalfluralin* + *Bentazon* | 371 + 480 | 3.75 + 6.25 | 1.39 + 3.12 | Dinitroanilines -<br>Benzothiadiazine | IV<br>IV |
| 5 | *Glyphosate* + *Hand weeding* + *Paraquat* (***Control***) | 360 + 200 | 5.0 + 3.66 | 1.8 + 0.732 | Glycines<br>Pyridiniums | V<br>II |

*Weight percentage of main components; (HRAC) = Herbicides Resistance Action Committee 2020; TC = Toxicological Category.

out according to recommendations of Avilés *et al.* (2010) [11] for Yucatan Mexico conditions

## 3.2. Experimental Design and Statistical Analysis

Five treatments with five replications were established, under drip irrigation conditions, and the information was analyzed in a randomized complete block design. The experimental units were of 375 $m^2$ (50 m long by 7.5 m wide).

As a phytometer the tomatoe *hybrid DRD 8551* was used, transplanted at 21 days old as seedlings, after being germinated under controlled conditions. Each experimental plot had 625 seedlings (16,750 plants $ha^{-1}$). Data were subjected to an Analysis of Variance (ANOVA), Mean Comparison Test by Tukey's method ($p \leq 0.05$) using the Statgraphics Centurión program, version 16.1.2.0.

## 3.3. Total Coverage of Weeds (%)

The percentage of coverage was measured visually, adapting the methodology described by Rodríguez *et al.* (2008) [12] and Gámez López *et al.* (2011) [6] for weed populations. 15 quadrants of 50 × 50 cm (0.25 $m^2$) were used per treatment (three quadrants per repetition) at 15, 30 and 45 days after herbicide application (**da**). Subsequently, the data were transformed to arc sine root of x for statistical analysis (ANOVA) [13].

## 3.4. Evaluation of Phytotoxicity Height of Plants

For phytotoxicity, the percentage of mortality and the symptomatology of herbicide damage were evaluated using the method proposed by the European Weed Research Society (EWRS) cited by Pérez *et al.* (2014) [14] (**Table 2**).

**Table 2.** Reference values suggested by the European Weed Research Society (EWRS) for weeds control and crop phytotoxicity.

| Grades | Effect on the weeds | Effect on the crop |
|---|---|---|
| 2 | Very high control | Very light symptoms |
| 3 | Good control | Light symptoms |
| 4 | Sufficient control | Yields are not affected |
| | **Acceptability limits** | |
| 5 | Medium control | Medium damage |
| 6 | Regular | High damage |
| 7 | Poor | Very high damage |
| 8 | Very poor | Severe damage |
| 9 | No effect on weeds | Total damage until die |
| **Grades** | **Weed control (%)** | **Phytotoxicity on crop** |
| 1 | 99.0 - 100.0 | 0.0 - 1.0 |
| 2 | 96.5 - 99.0 | 1.0 - 3.5 |
| 3 | 93.0 - 96.5 | 3.5 - 7.0 |
| 4 | 87.5 - 93.0 | 7.0 - 12.5 |
| 5 | 80.0 - 87.5 | 12.5 - 20.0 |
| 6 | 70.0 - 80.0 | 20.0 - 30.0 |
| 7 | 50.0 - 70.0 | 30.0 - 50.0 |
| 8 | 1.0 - 50.0 | 50.0 - 99.0 |
| 9 | 0.0 - 1.0 | 99.0 - 100.0 |

Source: Urzúa (2001), cited by Pérez *et al.*, 2014.

### 3.5. Cost Analysis ($)

A preliminary analysis of profitability per treatment was carried out considering the costs of the products and the application days per hectare as compared to the estimated cost of the producer (combination of manual and chemical control). The cost reduction ($) of each treatment was calculated when comparing the production cost of the producer, as 100%, against the production cost of each treatment.

## 4. Results

### 4.1. Identification of Weeds

Eight dominant weed species were detected: Nutsedge (*Cyperus ligularis*), Xtes (*Amaranthus dubius*), Pants' iil (*Boerhavia erecta*), White yew (*Urochloa panicoides*), Guinea grass (*Megathyrsus maximus*), Tsi' tsi' n (*Artemisa vulgaris*), Crow's foot (*Digitaria sanguinalis*), Purslane (*Portulaca oleracea*). 65.9% of the weeds were narrow-leaf species (*Cyperus ligularis*, *Urochloa panicoides*, *Megathyrsus maximus* and *Digita-ria sanguinalis*) and 34.1% broad-leaf species (*Amaranthus dubius*, *Boerhavia erecta*, *Artemisa vulgaris* and *Portulaca oleracea*).

According to the Importance Value Index (IVI), the outstanding species were: *Cyperus ligularis* (Cyperaceae), *Amaranthus dubius* (Amaranthaceae) and *Boerhavia erecta* (Nyctaginaceae) with values of 82.1%, 37.6% and 30.3%, respectively (Figure 1).

## 4.2. Total Coverage of Weeds (%)

The Analysis of Variance (ANOVA) detected highly significant differences between treatments at 15, 30 and 45 days after application (**daa**). At 15 **daa**, Tukey's test ($p \leq 0.05$) showed that the best treatments were T4 (Ethalfluralin + Bentazon) and T3 (Trifluralin + Bentazon) with 4.50% and 5.70% coverage respectively, compared to the Control of the producer with 31.40% (Table 3).

At 30 and 45 **daa**, all treatments were better than the Control; with a weed cover range from 2.05% to 3.13% *vs.* 32.0% of the Control at 30 **daa.** At 45 **daa** the cover ranged from 2.10% to 3.50% against 12.60% of the Control (Table 3).

Due to the dominance of *Cyperus ligularis* (nutsedge), the analysis of weed cover was divided into both "*broadleaf and grass weeds*" and "*nutsedge*" in order to know the effects of the treatments to control that specific kind of weeds.

In relation to the presence of broadleaf weeds and grasses, the evaluations (Table 3) at 15, 30 and 45 **daa** showed that all treatments were most effective than the Control with values of 0.06%, 0.06%, 0.14% and 0.12% for T1, T2, T3 and T4 respectively *vs.* 3.6% of the Control at 15 **daa**.

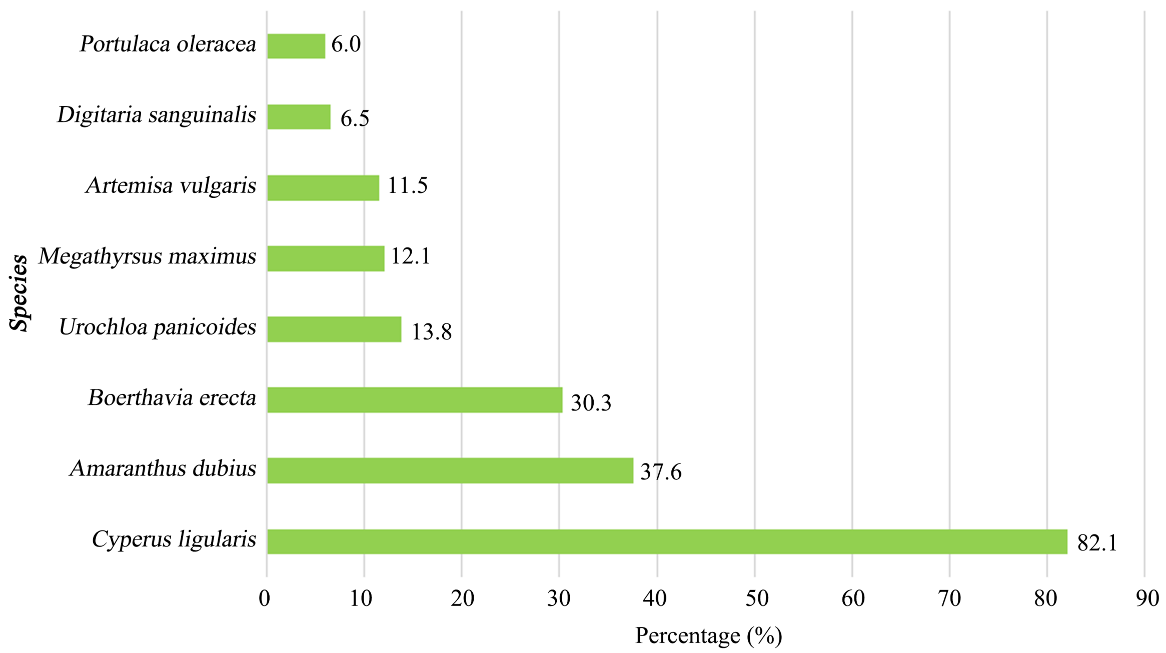


Figure 1. Relative Importance Values (RIVs) of weeds in percentage.

Table 3. Weed coverage (%) as related to weeds herbicides in a tomato crop at 15, 30 and 45 daa.

| Treatment (N˚) | Herbicide | Commercial dose (L or Kg·ha$^{-1}$) | Coverage (%) | | | Broad leaf weeds and grasses | | | Nutsedge | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 15 DAA | 30 DAA | 45 DAA | 15 | 30 | 45 | 15 | 30 | 45 |
| | | | | | | DAA | | | | | |
| 1 | *Pendimethalin + Bentazon* | 2.5 + 6.25 | 33.20 b | 3.13 a | 3.00 a | 0.06 a | 0.45 a | 0.00 a | 33.20 b | 3.13 a | 3.00 a |
| 2 | *Clorthal Dimethil + Bentazon* | 6.25 + 6.25 | 23.40 b | 2.20 a | 3.50 a | 0.06 a | 0.45 a | 0.24 a | 23.40 b | 2.20 a | 3.50 a |
| 3 | *Trifluralin + Bentazon* | 5.0 + 6.25 | 5.70 a | 2.05 a | 2.10 a | 0.14 a | 1.23 a | 1.40 a | 5.70 a | 2.05 a | 2.10 a |
| 4 | *Ethalfluralin + Bentazo* | 3.75 + 6.25 | 4.50 a | 2.60 a | 2.70 a | 0.12 a | 0.64 a | 0.20 a | 4.50 a | 2.60 a | 2.70 a |
| 5 | *Glyphosate – Hand weeding + Paraquat* (***Control***) | 5.0 + 3.66 | 31.40 b | 32.00 b | 12.60 b | 3.60 b | 62.00 b | 11.60 b | 31.40 b | 32.00 b | 12.60 b |

Note: Different letters mean statistical significant differences (p < 0.05, Tukey).

At 30 **daa** the values for the same above-mentioned treatments were: 0.45%, 0.45%, 1.23% and 0.64% against 62.0% for the Control; and again, at 45 **daa** very low weed cover were found with 0.00%, 0.20%, 0.24% and 1.40% *vs.* 11.6% of the Control (Table 3).

In the particular case of *Cyperus liguralis*, at 15 **daa**, the best treatments, were: T4 (*Ethalfluralin* + *Bentazon*) and T3 (*Trifluralin* + *Bentazon*) with 4.50% and 5.70% coverage, being statistically similar to each other and different from the Control with 31.40%. At 30 and 45 **daa**, all treatments were better to eliminate weeds than the Control and the cover values ranged very low. At 30 **daa** the cover values ranged from 2.05% to 3.13% *vs.* 32% of the Control and at 45 **daa** the ranges were from 2.1% to 3.5% *vs.* 12.64% of the Control (Table 3).

### 4.3. Cost Analysis ($)

Regarding the cost analysis, two different analyzes were carried out; one considering the costs for the exclusive control of *Cyperus ligularis* (*nutsedge*) and the second one without the use of the herbicide *Bentazon* used to control *C. ligularis*. This was done because the costs increased considerably when controlling only the nutsedge.

Table 4 describes the unit costs of herbicides and treatments as of September 2022, according to the doses per hectare used. All treatments cost were compared to the estimated costs of the combined control used by the producer in the first 30 days after transplanting. It is observed that only T1 (*Pendimethalin* + *Bentazon*) reduced the cost marginally by 2.69%, while the other treatments were more expensive than the Control. Applying T4 (*Ethalfluralin* + *Bentazon*) the cost increased 6.34% while applying T2 (*Clorthal Dimethil* + *Bentazon*) the cost increased quite a bit with 72.36%.

However, when excluding the herbicide *Bentazon* it was observed that using *Pendimethalin*, *Ethalfluralin* and *Trifluralin* the costs can be reduced by 79.12%, 64.91% and 61.86% with respect to the Control (T5); the mixture of *Clorthal Dimethil* + *Bentazon* only reduced the cost by 4.07% (**Table 5**).

## 5. Discussion

Tomatoes are very sensitive to weed competition especially in the early stages after transplanting [15]. Singh and Twpathi (1988) [16] showed that competition can reduce yield by 42% to 70% when it occurs during the first 15 to 45 days after transplanting.

It has been proven that when the predominant weed is *nutsedge* (*Cyperus spp*), as in the present study, underground interference with this species reduces

**Table 4.** Profitability of different herbicides applied for weed control in a tomato crop (Autumn-Winter period 2021-2022).

| Treatment (N˚) | Herbicide | Commercial dose (L or Kg·ha$^{-1}$) | Price ($ L or Kg·ha$^{-1}$) (mexican pesos) | Total Cost ha$^{-1}$ ($)** | Cost Reduction (%)*** |
|---|---|---|---|---|---|
| 1 | *Pendimethalin* + *Bentazon* | 2.5 + 6.25 | $405.8 - $425.0 | $7527.00[1] | **2.69** |
| 2 | *Clorthal Dimethil* + *Bentazon* | 6.25 + 6.25 | $1091.3 - $4 25.0 | $13333.12[1] | **−72.36** |
| 3 | *Trifluralin* + *Bentazon* | 5.0 + 6.25 | $470.0 - $425.0 | $8862.50[1] | **−14.56** |
| 4 | *Ethalfluralin* + *Bentazo* | 3.75 + 6.25 | $457.0 - $425.0 | $8226.25[1] | **−6.34** |
| 5 | *Glyphosate* − *Hand weeding* + *Paraquat* (***Control***) | 5.0 + 3.66 | $261.5 - $103.8[2] | $7735.56[2] | - |

[1]Treatments 1 - 4: One pre-emergent herbicide application and two of *Bentazon*. [2]Treatment 5: One application of *Glyphosate*, one hand weeding and one application of *Paraquat*. **Total Cost: Cost of herbicides and three wages per application during first 30 days after transplanting. ***Calculation expression: (T5 − TN˚)/T5 * 100.

**Table 5.** Profitability of different herbicides applied for weed control in a tomato crop eliminating the Bentazon herbicide (Autumn-Winter period 2021-2022).

| Treatment (N˚) | Herbicide | Commercial dose (L or Kg·ha$^{-1}$) | Price ($L or Kg·ha$^{-1}$) (mexican pesos) | Total Cost ha$^{-1}$ ($)** | Cost Reduction (%) |
|---|---|---|---|---|---|
| 1 | *Pendimethalin* | 2.5 | $405.8 | $1614.50[1] | 79.12 |
| 2 | *Clorthal Dimethil* | 6.25 | $1091.3 | $7420.62[1] | 4.07 |
| 3 | *Trifluralin* | 5.0 | $470.0 | $2950.00[1] | 61.86 |
| 4 | *Ethalfluralin* | 3.75 | $457.0 | $2713.75[1] | 64.91 |
| 5 | *Glyphosate* − *Hand weeding* + *Paraquat* (***Control***) | 5.0 + 3.66 | $261.5 - $103.82 | $7735.56[2] | - |

[1]Treatments 1 - 4: One pre-emergent herbicide application. [2]Treatment 5: One application of *Glyphosate*, one hand weeding and one application of *Paraquat*. **Total Cost: Cost of herbicides and three wages per application during first 30 days after transplanting.

the accumulation of dry matter in tomato shoots from 18% to 19%, while space competition aboveground the reduction is from 9% to 19%.

When both types of competition occurs, at the same time, a decrease of 28% to 34% in the dry matter is presented and the nitrogen content, as nitrate ($NO_3$), in the sap can be reduced more than 18% [17].

According to Johnson (1975) [18], the management of *nutsedge* can be highly effective through the application of *Bentazon*, with an effectiveness of 98% to 100% without damaging the crop.

The *Bentazon* can control *C. liguralis* without damaging the soybeans, unlike *Glyphosate* and *Perfluidone*, which severely affect this crop [19]. In both cases, a slow acropetal translocation of *Bentazon* induced to an effective elimination of the original reproductive tubers. The present study also supports these findings, since no phytotoxic effects were detected after transplanting when using *Bentazon* in combination with pre-emergent herbicides.

## 6. Conclusions

Tomato is a very sensitive crop to weed competition, especially after transplanting. In the state of Yucatan Mexico, weed control is carried out with the application of several herbicides such as *Glyphosate* in pre-transplantation. Currently, *Glyphosate* is prohibited. Therefore, new effective and low-cost herbicides need to be recommended.

In this research the main findings were that:

1) All treatments exhibited high efficacy in controlling broadleaf weeds, grasses, and nutsedge up to 45 days after application: *Pendimethalin* + *Bentazon*, *Clorthal Dimethil* + *Bentazon*, *Trifluralin* + *Bentazon*, *and Ethalfluralin* + *Bentazon.* Furthermore, none of the treatments induced phytotoxicity in the tomato plants.

2) Only T1 (*Pendimethalin* + *Bentazon*) reduced the cost marginally by 2.69%. The other treatments were more expensive than the Control (T5) of the producer.

3) When excluding the herbicide *Bentazon*, in the combining treatments, applying *Pendimethalin*, *Ethalfluralin* and *Trifluralin* can reduce costs by 79.12%, 64.91% and 61.86% respectively.

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## Conflicts of Interest

The authors declare no conflicts of interest.

## References

[1] Monroy-Sais, S., García-Frapolli, E., Casas, A., Mora, F., Skutsch, M. and Gerritsen,

P.R. (2022) Relational values and management of plant resources in two communities in a highly biodiverse area in western Mexico. *Agriculture and Human Values*, **39**, 1231-1244. https://doi.org/10.1007/s10460-022-10313-6

[2] Diario Oficial de la Federación (DOF) (2020) Acciones para sustituir gradualmente el uso, adquisición, distribución, promoción e importación de la sustancia química denominada glifosato y de los agroquímicos utilizados en nuestro país que lo contienen como ingrediente activo. https://www.dof.gob.mx/nota_detalle.php?codigo=5609365&fecha=31/12/2020#gsc.tab=0

[3] Tovar, L.G., Cruz, M. and Ángel, G. (2022) Sustitución de glifosato en la producción de naranja orgánica en el Norte de Veracruz, México: Glyphosate substitution in organic orange production in northern Veracruz, Mexico. *Studies in Environmental and Animal Sciences*, ***3***, 103-117. https://doi.org/10.54020/seasv3n1-007

[4] Vaca-Vaca, J.C., Rivera-Toro, D.M., Morales-Euse, J., Jara-Tejada, F. and López-López, K. (2020) Nuevas arvenses hospederas de Begomovirus colectadas en cultivos de tomate (*Solanum lycopersicum* L.) en Cundinamarca. *Revista de Investigación Agraria y Ambiental*, **11**, 29-39. https://doi.org/10.22490/21456453.3019

[5] Bautista, F., Maldonado, D. and Zinck, A. (2012) Clasificación maya de los suelos. *Ciencia y Desarrollo*, **260**, 65-70. https://www.cyd.conacyt.gob.mx/archivo/260/articulos/clasificacion-maya-suelos.html

[6] Gámez López, A., Hernández, M., Díaz, R. and Vargas, J. (2011) Caracterización de la flora arvense asociada a un cultivo de maíz bajo riego para la producción de jojotos. *Agronomía Tropical*, **61**, 133-140. https://ve.scielo.org/pdf/at/v61n2/art04.pdf

[7] Curtis, J.T. and McIntosh, R.P. (1951) An Upland Forest Continuum in the Pariré-Forest Border Region of Wisconsin. *Ecology*, **32**, 476-496. https://doi.org/10.2307/1931725 https://www.jstor.org/stable/1931725

[8] Zarco-Espinoza, V.M., Valdez-Hernández, J.I., Ángeles-Pérez, G. and Castillo-Acosta, O. (2010) Estructura y diversidad de la vegetación arbórea del parque estatal Agua Blanca, Macuspana, Tabasco. *Universidad y Ciencia*, **26**, 1-17. https://www.scielo.org.mx/scielo.php?pid=S0186-29792010000100001andscript=sci_arttext

[9] Soler, P.E., Berroterán, J.L., Gil, J.L. and Acosta, R.A. (2012) Indice valor de importancia, diversidad y similaridad florística de especies leñosas en tres ecosistemas de los llanos centrales de Venezuela. *Agronomía Tropical*, **62**, 25-37. https://dialnet.unirioja.es/servlet/articulo?codigo=5254691

[10] Campo, A.M. and Duval, V.S. (2014) Diversidad y valor de importancia para la con-servación de la vegetación natural. Parque Nacional Lihué Calel (Argentina). *Anales de Geografía*, **34**, 25-42. https://doi.org/10.5209/rev_AGUC.2014.v34.n2.47071

[11] Aviles-Baeza, W., Dzib-Echeverría, R. and Pereyda-Pérez, G. (2010) Manual para la producción de chile habanero (*Capsicum chinense* Jacq.) a campo abierto y bajo estructuras de protección. Campo experimental Mocochá. Mocochá, Yucatán, México. *Folleto Técnico*, **7**, 26 p.

[12] Rodríguez, M., Plaza, G., Gil, R., Chaves, F. and Jiménez, J. (2008) Reconocimiento y fluctuación poblacional arvense en el cultivo de espinaca (*Spinacea oleracea* L.)

para el municipio de Cota, Cundinamarca. *Agronomía Colombiana*, **16**, 87-96. https://expeditiorepositorio.utadeo.edu.co/bitstream/handle/20.500.12010/12645/Reconocimiento%20y%20fluctuación%20poblacional%20arvense%20en%20el%20cultivo%20de%20espinaca.pdf?sequence=1&isAllowed=y

[13] Barrera, F.M., Cervera, D.G.J., Peña, R.L., Cobas, E.A., Peña, P.M. and Barquié, P.O. (2019) Poblaciones de arvenses en suelos tratados con diferentes técnicas de manejo en caña de azúcar. *Centro Agrícola*, **46**, 76-85. http://scielo.sld.cu/pdf/cag/v46n3/0253-5785-cag-46-03-76.pdf

[14] Pérez-Moreno, L., Castañeda-Cabrera, C., Ramos-Tapia, M. and Tafoya-Razo, J.A. (2014) Control químico preemergente de la maleza en tomate de cáscara. *Interciencia*, **39**, 422-427. https://www.redalyc.org/pdf/339/33931213011.pdf

[15] Mennan, H., Jabran, K., Zandstra, B.H. and Pala, F. (2020) Non-Chemical Weed Management in Vegetables by Using Cover Crops: A Review. *Agronomy*, **10**, 257. https://doi.org/10.3390/agronomy10020257

[16] Singh, P.P. and Twpathi, S.S. (1988) Effect of Herbicides and Time of Weeding on Weed Control and Fruit Yield of Tomato. *Indian Journal of Weed Science*, **20**, 39-43. https://www.indianjournals.com/ijor.aspx?target=ijor:ijws&volume=20&issue=4&article=008

[17] Morales-Payan, J., Stall, W., Shilling, D., Charudattan, R., Dusky, J. and Bewick, T. (2003) Above- and Belowground Interference of Purple and Yellow Nutsedge (*Cyperus* spp.) with Tomato. *Weed Science*, **51**, 181-185. https://doi.org/10.1614/0043-1745(2003)051[0181:AABIOP]2.0.CO;2

[18] Johnson, B. (1975) Purple Nutsedge Control by Bentazon and Perfluidone in Turfgrasses. *Weed Science*, **23**, 349-353. https://doi.org/10.1017/S0043174500062640

[19] Stoller, E., Wax, L. and Mathiessen, R. (1975) Response of Yellow Nutsedge and Soybeans to Bentazon, Glyphosate, and Perfluidone. *Weed Science*, **23**, 2015-2021. https://doi.org/10.1017/S0043174500052899