*Cultivos Tropicales, Vol. 45, No. 4, October-December 2024, e-ISSN: 1819-4087, p-ISSN: 0258-5936, https://ediciones.inca.edu.cu*

*Cu-ID: https://cu-id.com/2050/v45n4e06*

**Original article**

# Pesticides tendency uses in potato (*Solanum tuberosum* L.) in Mayabeque, Cuba

## Tendencias en el uso de plaguicidas en papa (*Solanum tuberosum* L.) en Mayabeque, Cuba

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**ABSTRACT:** Potato (*Solanum tuberosum* L.) is a high priority crop in Cuba. A technological package is guaranteed for its production, including pesticides application. Mayabeque is one of the most potato productive provinces in Cuba, emphasize the municipalities Batabanó and Quivicán. In Cuba there are a reduction police of pesticides use; however, an update analysis about use pes ticides indicators in these municipalities have not been carry out, to kwon the tendency of pesticide uses in potato crop. The main of this study was to determine the tendency of pesticide usage in potato, in the period 2013-2019, in Batabanó and Quivicán. Application data was obtained from "Estación Territorial de Protección de Plantas" (Territorial Station for Plant Protection), in both municipalities. In the studied period, 52 active ingredients (i.a.) were applied, with a total of 61 993 and 17 103 kg i.a. and a mean of 23 and 16 kg i.a. per hectare in Batabanó and Quivicán, respectively; when fungicides were the most applied (> 80 % of total). Generally, the trend in application between 2013 and 2019, was decrease in both municipalities. The 31 % (n=16) of i.a. applied can produce a harmful human effect and 54 % (n=28) were banned in many countries. In both municipalities, the reduction of pesticide uses in correspondence with the currently police of substitution of highly hazardous pesticides are demonstrated.

**Key words:** fungicides, health, toxicity.

**RESUMEN:** La papa (*Solanum tuberosum* L.) es un cultivo de alta prioridad en Cuba. Para su producción se garantiza un paquete tecnológico que incluye el empleo de plaguicidas. Mayabeque es una de las provincias más productoras de papa en Cuba, destacándose los municipios Batabanó y Quivicán. En Cuba existe una política de reducción del uso de plaguicidas; sin embargo, no se ha realizado un análisis actualizado sobre los indicadores de uso en estos municipios para conocer la tendencia en su empleo en el cultivo de la papa. El objetivo de este trabajo fue determinar la tendencia en el uso de plaguicidas en papa, durante el período 2013-2019, en Batabanó y Quivicán. Los datos de aplicación de los plaguicidas (acaricida, fungicida, herbicida e insecticida) se obtuvieron de la "Estación Territorial de Protección de Plantas" de ambos municipios. En el período estudiado, se emplearon 52 ingredientes activos (i.a.), con un total de 61 993 y 17 103 kg i.a. y un promedio de 23 y 16 kg i.a por hectárea en Batabanó y Quivicán, respectivamente; siendo los fungicidas los más utilizados (>80 % del total). De manera general, la tendencia en el uso entre los años 2013 y 2019, fue a la disminución en ambos municipios. El 31 % (n=16) de los i.a. empleados pueden provocar efectos nocivos a la salud humana y el 54 % (n=28) están prohibidos en muchos países del mundo. En ambos municipios se demuestra la reducción del uso de plaguicidas en correspondencia con la política actual de sustitución gradual de plaguicidas altamente peligrosos.

**Palabras clave:** fungicidas, salud, toxicidad.

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Received: 15/03/2024

Accepted: 15/05/2024

**Conflict of interest:** The authors declare that they have no conflict of interest.

**Author contributions: Conceptualization:** Brizeidi Peña Suárez, Dayana Sosa Pacheco, Nilda Pérez-Consuegra, Arturo C. Escobar Medina. **Data curation:** Brizeidi Peña Suárez. **Research:** Brizeidi Peña Suárez. **Methodology:** Brizeidi Peña Suárez, Dayana Sosa Pacheco, Nilda Pérez-Consuegra, Arturo C. Escobar Medina. **Resources:** Nilda Pérez-Consuegra and Arturo C. Escobar Medina. **Supervision:** Dayana Sosa Pacheco, Nilda Pérez-Consuegra, Arturo C. Escobar Medina. **Writing original draft:** Brizeidi Peña Suárez. **Editing and proofreading:** Dayana Sosa Pacheco, Nilda Pérez-Consuegra, Arturo C. Escobar Medina.

## INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important crops worldwide (1). Its average world production, in the decade 2010-2019, was 449 million tons, which represented 4.2 % of total agricultural production (2). In Cuba, its production in 2021, was 97 300 t (3). Mayabeque province was the largest producer in the country, with a production of 29 200 t in 2021 and a yield of 19.8 t $ha^{-1}$ (4).

Potato is one of the most pesticide-dependent crops and, in many countries, receives the highest amount of agrochemicals per hectare compared to the rest of the crops (5). In Cuba, it is a strategic crop, to which the State guarantees a technological package for its production, which is intensive and depends heavily on the application of pesticides. In the three-year period 2011-2013, this was 53 300 kg of active ingredient (a.i.) and the provinces with the highest consumption in this period were: Artemisa (5.53 kg a.i. $ha^{-1}$), Ciego de Avila (5.14 kg a.i. $ha^{-1}$), Matanzas (4.67 kg a.i. $ha^{-1}$) and Mayabeque (3.52 kg a.i. $ha^{-1}$) (6). In general, the amount of kg a.i.a. $ha^{-1}$ and the types of pesticides used on potatoes in Cuba (6) are similar to other regions of America such as Canada (7), Ecuador (8) and Costa Rica (5).

At the global level, there are international conventions, such as the Stockholm and Rotterdam Conventions, which regulate the treatment of toxic substances. In this sense, the use of some highly hazardous pesticides (HHPs) such as conventional organochlorine and phosphorous pesticides (DDT, aldrin, endrin, heptachlor, methyl parathion and malathion (6), have been banned or replaced by new formulations, considered “safer” as the so-called “pesticides for current use” (PUA) (9) (e.g., neonicotinoids, triazines, azoles and carboxamides). However, some PUAs have also been classified as HHPs because they are toxic, bioaccumulative, persistent in soil, water, and contaminate food (10).

Some HAPs have been banned in countries in the more developed regions of the world, such as those belonging to the European Union (EU). Although their use is illegal in its member states, it is permitted to produce and export them to third countries, including Cuba, where they pose risks to people and the environment (11).

Cuba, as a signatory of these international agreements, has a policy to reduce and substitute the use of pesticides (6). However, there is documented, relevant information on the use of pesticides that is not published, but which is crucial for the evaluation of specific indicators that allow determining the trend of this reduction policy in each region. It is essential to make this information public in order to obtain a complete picture of the impact of pesticide use on the environment and human health. For such reasons, the objective of this study was to determine the trend in the use of pesticides in potato agroecosystems, in the period 2013-2019 in Batabanó and Quivicán municipalities, belonging to Mayabeque province.

## MATERIALS AND METHODS

### Study area

Mayabeque province was selected because it is the largest potato producer in the country. Batabanó and Quivicán municipalities were selected for the study because they have a history of intensive potato production in Mayabeque.

Batabanó and Quivicán are located south-west of Mayabeque, with a latitude of 22°55'41 N, longitude 82°17'38 W and latitude 22°49'29 N, longitude 82°21'21 W, respectively. In both municipalities, more than 70 % of the total area is dominated by Ferrallitic type soils. In Batabanó (12), 50.8 % of the municipality's surface area is considered agricultural, and 85.4 % in Quivicán (13). An average of 391 ha of potatoes were planted in Batabanó in the period 2013 - 2019, with an average yield of 23.3 t ha-1 year (12,14). These values for Quivicán, in the same period, were 196 ha of potato and average yield of 21.8 t $ha^{-1}$ year (13,15).

### Data collection

Data on pesticide use records: technical name, formulation, dosage, area treated and number of hectares planted and harvested of potato, were obtained from the databases of the Batabanó-Quivicán Territorial Plant Protection Station. The collected data were organized in an Excel database (version 2016) for further processing and analysis.

The selection and determination of indicators were made as described (16): amount of a.i. used (kg a.i.), amount of a.i. applied per unit area treated (kg a.i. $ha^{-1}$) (toxic load), class of pesticides and the number of a.i. used. The number and amount of kg a.i. of HHPs applied were also determined. HHPs were identified according to the criteria established in the List of Highly Hazardous Pesticides published by *Pesticide Action Network* (PAN) (17) and FAO-WHO (18).

### Statistical analysis

Data processing was performed with Microsoft Excel version 2016 and statistical analysis with R version 4.2.0. Analysis of variance with factorial arrangement (ANOVA) was performed to compare the amounts of kg i.a. $ha^{-1}$ used (dependent variable) between municipalities and pesticide classes (independent variables). The ANOVA was performed by selecting the data kg a.i. $ha^{-1}$ in all years. The RStudio *aov* function was used for this purpose. A t-test was performed adjusting the “Bonferroni” correction for p-value, using the *pairwise.t.test* function of RStudio. P-value ≤ 0.05 indicated that there were significant differences.

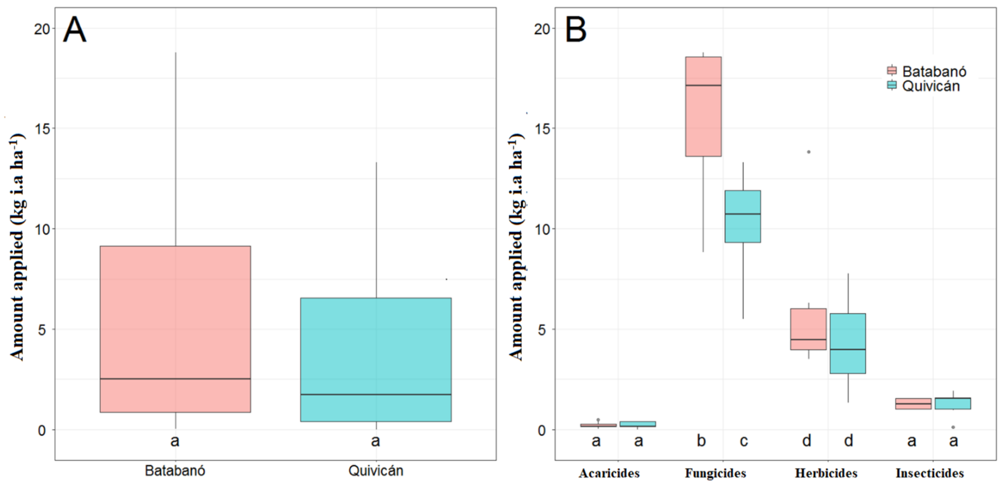
## RESULTS AND DISCUSSION

### Classes of pesticides used per hectare treated (kg a.i. ha$^{-1}$) in the period 2013-2019 in Batabanó and Quivicán

Figure 1 shows the dose applied (kg a.i. ha$^{-1}$) according to each pesticide class (acaricide, fungicide, herbicide and insecticide) in Batabanó and Quivicán. The dose range was 0.01 - 18.8 kg a.i. ha$^{-1}$ in Batabanó and 0.12 - 13.3 kg a.i. ha$^{-1}$ in Quivicán. The means of these values were 5.8 kg a.i. ha$^{-1}$ in Batabanó and 4.0 kg a.i. ha$^{-1}$ in Quivicán, and no significant differences were found between doses in the two municipalities (p-value = 0.254) (Figure 1 A). Fungicides were the pesticide class with the highest dose of use, followed by herbicides; with significant differences with respect to the other pesticide classes (p-value < 2xe-16, Figure 1 B). The mean fungicide dose per hectare treated was higher in Batabanó (15.6 kg a.i. ha$^{-1}$) than in Quivicán (10.2 kg a.i. ha$^{-1}$), with significant differences between these two municipalities (p-value=0.0167, Figure 1 B). Doses in the other pesticide classes showed no differences between the municipalities studied (p-value = 0.935 for acaricides, p-value = 0.323 for herbicides and p-value = 0.932 for insecticides) (Figure 1 B).

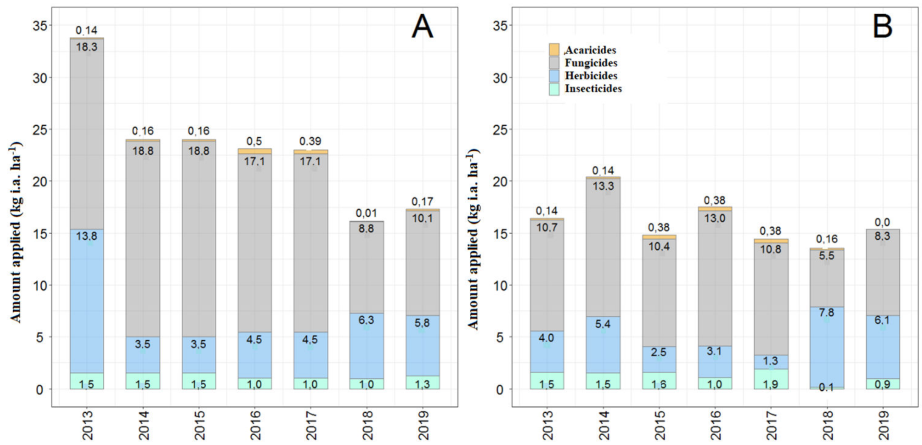
The total sum of kg a.i.a. ha$^{-1}$ used ranged from 16.1 - 33.7 kg a.i.a. ha$^{-1}$ in Batabanó and 13.6 - 20.3 kg a.i.a. ha$^{-1}$ in Quivicán (Figure 2 A and B). Overall, a 48.6 % decrease in the sum of the dose in 2019 (17.3 kg a.i.a. ha$^{-1}$) compared to 2013 (33.7 kg a.i.a. ha$^{-1}$) was observed in Batabanó (Figure 2 A). In these years, it was observed that the highest value of the indicator was reached in 2013 (33.7 kg a.i.a. ha$^{-1}$) and then a decrease of 29.0 % was evidenced in 2014 (23.9 kg a.i.a. ha$^{-1}$), a value that remained approximately constant between 2014 and 2017 (22.9 kg a.i.a. ha$^{-1}$). However, a decrease of 29.7 % in the sum of the dose appears again from 2018 (16.1 kg a.i.a. ha$^{-1}$) with respect to 2017, a value that has, subsequently, a slight increase (7.4 %) in 2019 (17.3 kg a.i.a. ha$^{-1}$). On the other hand, in Quivicán (Figure 2 B), the trend between 2013 and 2019 was variable and, in general, only a decrease of 6.7 % was appreciated; behavior that was different from that observed in Batabanó. The highest value of the indicator in Quivicán was observed in 2014 (20.4 kg i.a. ha$^{-1}$), where an increase of 24.3 % was evident with respect to 2013 (16.4 kg i.a. ha$^{-1}$). Subsequently, the value decreased by 27.4 % in 2015 (14.8 kg i.a. ha$^{-1}$) with respect to 2014 and again increased by 18.2 % in 2016 (17.5 kg i.a. ha$^{-1}$) with respect to the previous year. In the rest of the years, the behavior was similar, although with some fluctuations (14.4 kg a.i.a. ha$^{-1}$ in 2017, 13.6 kg a.i.a. ha$^{-1}$ in 2018 and 15.3 kg a.i.a. ha$^{-1}$ in 2019).

Although fungicides were the most used class of pesticides (Figure 2 A and B), their use decreased between 2013 and 2019, by 44.8 and 22.4 % in Batabanó and Quivicán, respectively. Herbicides and insecticides in Batabanó also showed a decrease between 2013 and 2019 of 58.0 and 13.3 %, respectively, as well as insecticides in Quivicán (40 %). However, herbicides in Quivicán showed variations between the different years, although an increase of 52.5 % was observed in the period in 2019 with respect to 2013. In the case of acaricides, very low doses were applied and the trend was variable in both municipalities. However, in general, in the period an increase in acaricides of 21.4 % between 2013 and 2019 was seen in Batabanó, and an increase in Quivicán of 14.3 % between 2013 and 2018, since no acaricides were applied in 2019.




According to ANOVA, different letters indicate that there are significant differences (p-value < 0.05) between the means of the amount applied kg a.i. ha$^{-1}$ of all years by municipality (A) and by pesticide class (B). Boxes represent the 25$^{th}$ and 75$^{th}$ percentile, black bars the 10$^{th}$ and 90$^{th}$ percentile. Dots out of place indicate extreme values and the black line inside the box indicates the median of the values

**Figure 1.** Amount of active ingredients used (a.i.) per hectare treated (kg a.i. ha$^{-1}$) in Batabanó and Quivicán municipalities (A) and by class of pesticide (acaricide, fungicide, herbicide and insecticide) (B)




The stacked bar signifies the total sum of kg a.i. ha$^{-1}$ treated in that year. The color division of the stacked bar and the value on the bar signify the sum of kg a.i. ha$^{-1}$ treated according to each pesticide class: acaricide (mustard yellow bar), fungicide (gray bar), herbicide (light blue bar) and insecticide (green-blue bar)

**Figure 2.** Trend in the application of pesticide classes according to kg of active ingredient (a.i.) per hectare (ha) (kg a.i. ha$^{-1}$) between 2013 and 2019 in Batabanó (A) and Quivicán (B) municipalities

## Trend in the amount of active ingredients (kg a.i.) applied in the period 2013-2019 in Batabanó and Quivicán

Figure 3 shows the active ingredients used and the number of kg used in the period 2013 to 2019. In this period, 52 a.i. were used, of these, 43 in the two municipalities and the rest were only used in one of the two (five in Batabanó and four in Quivicán). The total amount of a.i. consumed in the seven years was 61 993 kg a.i. in Batabanó and 17 103 kg a.i. in Quivicán. Fungicides represented 84.4 and 83.6 % of the total applied in Batabanó and Quivicán, respectively. Overall, there was a 55 % decrease in the amount used in Batabanó, which went from 14 351 kg a.i. in 2013 to 6 452 kg a.i. in 2019. On the other hand, in Quivicán, there was an increase of 263 % when comparing 2014 (4 024 kg a.i.) with respect to 2013 (1 109 kg a.i.). Subsequently, there was a decrease of 62 % in 2019 (1 514 kg i.a.) in Quivicán.

More than 80 % of the total used in both municipalities was represented by 10 types of a.i.: mancozeb, chlorothalonil, potassium phosphite, azoxyestrobin, propineb, glyphosate, sulfur, metribuzin, spirotetramat and diafenthiuron. The two most used a.i. were the fungicides mancozeb and chlorothalonil, with 33.7 and 22.7 % of the total in Batabanó and 42.3 and 19.0 % in Quivicán, respectively. In the use of these 10 a.i., fluctuations were also found in the two municipalities studied in the period 2013 to 2019, influencing the variations discussed above according to the class of pesticides. For example, as shown in Figure 3, in Batabanó, the a.i.: mancozeb, chlorothalonil, potassium phosphite, propineb and diafenthiuron showed a decrease in their application. While the a.i., azoxyestrobin, glyphosate, spirotetramat and metribuzin, showed an increase. On the contrary, in Quivicán, six of the 10 most used a.i. (mancozeb, chlorothalonil, potassium phosphite, metribuzin, spirotetramat and diafenthiuron) showed a tendency to increase in 2014 with respect to 2013 and, subsequently a decrease until 2019. In addition, the use of propineb and glyphosate presented variations in the period studied in this municipality. On the other hand, sulfur was only used in one year in both municipalities.

## Quantity of Highly Hazardous Pesticides (HHPs) used in the period 2013-2019 in Batabanó and Quivicán

Table 1 shows the a.i.s. used that can cause harmful effects to human health according to the data of the List of Highly Hazardous Pesticides (HHP) (17) and the a.i.s. whose use has been prohibited worldwide. Of the 52 a.i.s. used in Quivicán and Batabanó, a total of 33 a.i.s. are listed, according to the aforementioned classifications. Thirty-one percent (n=16) of the 52 a.i.s. present some acute or chronic toxic effect on human health (acute toxicity, possible or probable carcinogen, endocrine disruption, and reproductive harm, among others). The amount of a.i. that can cause harmful effects was 44 420 kg a.i. in Batabanó and 13 491 kg a.i. in Quivicán, representing 71.6% and 78.8% of the total applied, respectively (Table 1). Among the pesticides that can cause harmful effects, fungicides were used in the greatest number (n=9). They were followed in order by herbicides (n=4) and insecticides (n=3). The amount of fungicides that can cause harmful effects was higher than the other classes of pesticides, being 39 682 kg a.i. in Batabanó and 12 219 kg a.i. in Quivicán. This amount represented 89.3 and 90.6 % of the total a.i. that can cause harmful effects in Batabanó and Quivicán, respectively (Table 1).

On the other hand, 54 % (n=28) of the a.i.s used in Batabanó and Quivicán have been banned in at least one country (17); except in Cuba, where all the a.i.s used are allowed (6). The amount applied of a.i. banned in other countries was 46 536 kg a.i. in Batabanó and 13 783 kg a.i.

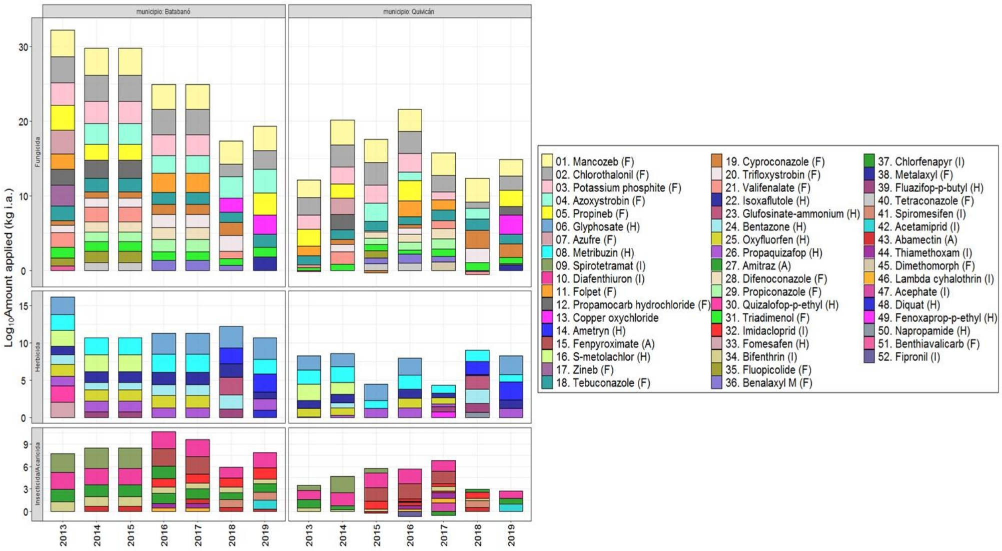



**Figure 3.** Quantity of active ingredients (kg a.i.) used in Batabanó and Quivicán (Mayabeque) in the period 2013-2019. 52 active ingredients are listed

in Quivicán, representing 75.1 and 80.6 % of the total, respectively (Table 1). Fungicides were also the pesticide class with the highest number of bans (n=11), followed by herbicides (n=9), insecticides (n=7) and acaricides (n=1). The amount used of fungicides that have been banned was 40 436 kg a.i. in Batabanó and 11 901 kg a.i. in Quivicán, which represented 86.9 and 86.3 % of the total banned a.i., respectively.

Five of the ten most used pesticides in both municipalities (mancozeb, chlorothalonil, propineb, glyphosate and metribuzin) have some of the harmful effects mentioned above. Four of these pesticides (mancozeb, chlorothalonil, propineb and glyphosate) and diafenthiuron are banned in at least one country (17).

## Comparison of the results with other studies in Cuba and in the Latin American and Caribbean region

In tropical countries, the diseases that most affect potato crops are early blight caused by the fungus *Alternaria solani* Sorauer and late blight caused by the oomycete *Phytophthora infestans* (Mont.) de Bary (1). Therefore, in Latin America and the Caribbean, fungicides are the most widely used pesticides, among which mancozeb and chlorothalonil stand out. In Cuba, these two pesticides are approved for the control of foliar fungal diseases in potato, tomato, vegetables and beans, among others (19).

The results of this study are similar to those reported for other regions of Latin America and the Caribbean, where the most commonly used pesticides were: mancozeb, paraquat, propineb, chlorothalonil, fosetyl aluminum, cartap, methamidophos, and endosulfan (19). Of the 10 a.i. that were most applied in Batabanó and Quivicán in the period 2013-2019, seven are also used on potato crops in Peru (mancozeb, chlorothalonil, azoxyestrobin, propineb, sulfur, metribuzin, and spirotetramat) (20) and Chile (mancozeb, chlorothalonil, azoxyestrobin, glyphosate, sulfur, metribuzin, and spirotetramat) (21).

These results are in correspondence with those reported in Costa Rica, where fungicides were 77 % of the total of pesticides used in potato, and the most used were: mancozeb, chlorothalonil, cymoxanil and propineb (5) and, in Ecuador, where mancozeb represented 80 % of the total of pesticides used in potato (22).

The number and amount of kg a.i. reported in this study were similar to those reported in the period 2011-2013 in Cuba; where 52 a.i. and a total of 53 263 kg a.i. were used on potato. As in this study, 76 % of the pesticides used on potato in Cuba were fungicides, the most frequent being mancozeb and chlorothalonil. In addition, 16 a.i. were classified as having an effect on human health in Cuba in the period 2011-2013, and the amount used of these represented 47 % of the total applied. However, the trend in the use of pesticides on potato in Cuba between 2011 and 2013 showed an increase of 110 %, led by an increase in the use of fungicides (6). This behavior was different from what was reported in the present study. However, the author found an increase in the use of herbicides (6), results that are similar to those reported here.

Specifically in Batabanó, between 2004 and 2009, the use of 57 646 kg a.i. on potato was reported, where fungicides and herbicides were the most used class of pesticides (6). As in this study, the authors found that of the ten most commonly used substances, five had a recognized harmful effect on health and the environment (mancozeb, glyphosate, methamidophos, endosulfan and methyl parathion) (6). But the trend in Batabanó showed an increase of 132 % in 2009 (11 496 kg a.i.) with respect to 2004 (4 944 kg a.i.) (6), which was different from what was reported here. Data in Quivicán on the amount of a.i. used and the toxicity to human health of pesticides applied on potato have not been reported previously, according to the available literature.

**Table 1.** Active ingredients applied in Batabanó and Quivicán that are highly hazardous (HHP) according to their acute, chronic and environmental toxicity, as well as the number of countries where their use is prohibited. None of these a.i.s. are prohibited in Cuba

| No. | Active ingredient | Class[a] | Acute toxicity[b] | | Chronic toxicity[b] | | | | | Amount of effects | No. Countries where use is prohibited[b] | kg i.a. used | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | WHO Ib | H330 | IARC prob carc | EPA prob likel carc | GHS+ repro (1A, 1B) | EU EDC | GHS+ C2 & R2 | | | Batabanó | Quivicán |
| 1 | Mancozeb | F | | | | 1 | 1 | 1 | 1 | 4 | 29 | 20 872 | 7 232 |
| 2 | Chlorothalonil | F | | 1 | | 1 | | | | 2 | 32 | 14 048 | 3 243 |
| 3 | Propineb | F | | | | 1 | | | | 1 | 29 | 3 167 | 939 |
| 4 | Glyphosato | H | | | 1 | | | | | 1 | 3 | 3 030 | 771 |
| 5 | Metribuzin | H | | | | | | | 1 | 1 | | 1 163 | 360 |
| 6 | Diafentiuron | I | | | | | | | | | 30 | 1 082 | 322 |
| 7 | Folpet | F | | 1 | | | | | 1 | 2 | 2 | 836 | 195 |
| 8 | Amethrin | H | | | | | | | | | 29 | 408 | 326 |
| 9 | S-metolachlor | H | | | | | | | | | 30 | 499 | 177 |
| 10 | Zineb | F | | | | | | | | | 35 | 640 | |
| 11 | Tebuconazole | F | | 1 | | | | | 1 | 2 | 1 | 370 | 146 |
| 12 | Ciproconazole | F | | | | | 1 | | | 1 | | 124 | 360 |
| 13 | Isoxaflutol | H | | | | 1 | | | | 1 | 1 | 242 | 61 |
| 14 | Glufosinate de amonium | H | | | | | | | | | 28 | 220 | 62 |
| 15 | Oxifluorfen | H | | | | 1 | | | | 1 | 1 | 202 | 51 |
| 16 | Amitraz | A | | | | | | | | | 35 | 160 | 19 |
| 17 | Diphenoconazol | F | | | | | | | | | 1 | 126 | 42 |
| 18 | Propiconazol | F | | | | | 1 | | | 1 | 28 | 126 | 42 |
| 19 | Triadimenol | F | | | | | 1 | | | 1 | 28 | 116 | 45 |
| 20 | Imidacloprid | I | | | | | | | | | 28 | 79 | 21 |
| 21 | Bifenthrin | I | | | | | | | 1 | 1 | 29 | 77 | 14 |
| 22 | Fluopicolide | F | | | | | | | | | 1 | 72 | 12 |
| 23 | Chlorfenapyr | I | | | | | | | | | 29 | 71 | 7 |
| 24 | Metalaxil | F | | | | | | | | | 1 | 65 | 6 |
| 25 | Fluazifop-p-butyl | H | | | | | | | | | 1 | 23 | 20 |
| 26 | Tetraconazole | F | | | | | | | 1 | 1 | | 24 | 17 |
| 27 | Abamectin | I | 1 | 1 | | | | | | 2 | | 18 | 8 |
| 28 | Tiamethoxam | I | | | | | | | | | 28 | 8 | 9 |
| 29 | Lambda cyhalothrin | I | | 1 | | | | | 1 | 2 | | 6 | 6 |
| 30 | Acephate | I | | | | | | | | | 35 | | 12 |
| 31 | Fenoxaprop-p-ethyl | H | | | | | | | | | 1 | | 6 |
| 32 | Napropamida | H | | | | | | | | | 1 | | 5 |
| 33 | Fipronil | I | | | | | | | | | 36 | | 0,2 |

| **Number of a.i. used** | **WHO Ib** | H330 | IARC prob carc | **EPA prob likel carc** | **GHS+ repro (1A, 1B)** | **EU EDC** | **GHS+ C2 & R2** | **Total number of a.i. with effects** | **Total number of a.i. banned in the world (not in Cuba)** | **kg i.a. used in Batabanó** | | **kg i.a. used in Quivicán** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | **Harmful effects** | **Banned in the world (not in Cuba)** | **Harmful effects** | **Banned in the world (not in Cuba)** |
| **Total** | **1** | **5** | **1** | **5** | **4** | **1** | **7** | **16** | **28** | **44 420** | **46 536** | **13 491** | **13 783** |
| **Acaricides** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **160** | **0** | **19** |
| **Fungicides** | **0** | **3** | **0** | **3** | **4** | **1** | **4** | **9** | **11** | **39 682** | **4 0436** | **12 219** | **11 901** |
| **Herbicides** | **0** | **0** | **1** | **2** | **0** | **0** | **1** | **4** | **9** | **4 637** | **4 624** | **1 243** | **1 478** |
| **Insecticides** | **1** | **2** | **0** | **0** | **0** | **0** | **2** | **3** | **7** | **101** | **1 316** | **29** | **386** |

[a]**Class of pesticides: acaricides** (A), fungicides (F), herbicides (H) and insecticides (I). b **Classifications according to the PAP List (PAN-International, 2021) ( 17 ). WHO Ib**: highly hazardous (Class 1b) according to the World Health Organization. **H330**: “Lethal by inhalation” hazard classification according to the European Union (EU) or Japan's Globally Harmonized System (GHS). **IARC prob carc**: Probable carcinogen according to the International Agency for Research on Cancer (IARC). **EPA prob likel carc**: probable/possible carcinogen (including “possibly causes cancer in humans: at high doses” according to the U.S. Environmental Protection Agency (EPA)). **GHS+ repro (1A, 1B):** known or suspected to exhibit reproductive toxicity in humans according to EU or GHS. EU EDC: known to be an endocrine disruptor according to EU assessment following Commission Regulation (EU) 2018/605. **GHS+ C2 & R2:** classification as carcinogen category 2 and reproductive concern category 2 by EU and **GHS. No**. Countries where use is banned: number of countries where the active ingredient (a.i.) has been banned

The tendency observed in this study to decrease the use of pesticides can be related to the measures established by the Cuban government several years ago to reduce the use of these toxic chemical substances (6). These measures include the use of Integrated Pest Management programs, the adoption of agroecological practices and the availability of biological alternatives. These measures allow the application of biological control in potato (example: use of the entomopathogenic bacterium Bacillus thuringiensis Berliner strain 13 and 24, the antagonistic fungus Trichoderma spp. and other biological control agents) (23); since in Cuba the paradigm of ecological or agroecological pest management is applied (6). Not to mention that, in the last years, the main cause of the reduction in the use of pesticides is due, in part, to the reduction of its importation; because of the intensification of the economic, commercial and financial blockade imposed to Cuba by the government of the United States of America. This also limits the possibilities of accessing foreign financing and direct foreign investment, the acquisition of technologies, inputs and agricultural means (6).

## CONCLUSIONS

- Fungicides were the most widely used pesticide class in both municipalities, with mancozeb and chlorothalonil standing out. These results were similar to those reported for other regions of Latin America and Cuba.
- In general, it was observed that the trend in pesticide use decreased in both municipalities. Although there were fluctuations in the behavior, according to the classes of pesticides and the a.i. applied, this being more accentuated in Quivicán municipality.
- Five active ingredients (mancozeb, chlorothalonil, propineb, glyphosate and metribuzin), which are among the most widely used in potato cultivation in both municipalities, may have harmful effects on human health. The use of most of these is prohibited in several countries, but in Cuba they are authorized.
- In both municipalities, the reduction in the use of pesticides is demonstrated in correspondence with the current policy of gradual substitution of highly hazardous pesticides.

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