



ORIGINAL ARTICLE

Commercialization of hormonal herbicides and proposal for a risk analysis of their use in municipalities in the Rio Grande do Sul State, Brazil

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Abstract - Analysis of the trade of hormonal herbicides in cities in Rio Grande do Sul provides important guidance for regulatory and educational actions. The aim of this study was to carry out a diagnostic of commercialization in municipalities in the Campanha Gaúcha region and to propose a Risk Matrix for the use of hormonal pesticides. Data was extracted from the Integrated Agrotoxics Management System (SIGA-SEAPI RS) using the COGNOS system. The data was collected for the cities of Bagé, Candiota, Caçapava do Sul, Dom Pedrito, Hulha Negra and Lavras do Sul. Data regarding the quantities of products marketed, active ingredients, cities of purchase, and compliance with current legislation was extracted. A Risk Matrix for the use of hormonal herbicides was proposed. A total of 1,098 hormonal pesticides were purchased across the cities analyzed, with 2,4-D the most widely marketed active ingredient. Most of the sales took place in Dom Pedrito. Considering sales, 60 % were not in accordance with legislation. The elaboration of a Risk Matrix concerning the legislation on hormonal pesticides for the development of education and inspection actions resulted in the identification of 36 high-risk producers/rural establishments.

Keywords: Pesticides. Drift. Risk matrix. 2,4D.

Comercializações de herbicidas hormonais e proposta de uma análise de risco do uso em municípios da campanha do Rio grande do Sul, Brasil

Resumo – A realização de uma análise da comercialização de herbicidas hormonais em municípios do Rio Grande do Sul é importante para guiar ações normativas e de educação. O objetivo do estudo foi realizar um diagnóstico da comercialização em municípios da região da Campanha Gaúcha e propor uma Matriz de Risco no uso de agrotóxicos hormonais. Foram extraídos dados do Sistema Integrado de Gestão Agrotóxicos (SIGA-SEAPI RS) por meio do sistema COGNOS. Os dados foram organizados para os municípios de Bagé, Candiota, Caçapava do Sul, Dom Pedrito, Hulha Negra e Lavras do Sul. Foram extraídos as quantidades de produtos comercializados, princípios ativos, municípios da aquisição e concordância com as legislações vigentes. Uma Matriz de Risco no uso de herbicidas hormonais foi proposta. Foram realizadas 1098 comercializações de agrotóxicos hormonais nos municípios, sendo o 2,4D o princípio ativo mais comercializado. A maior parte das comercializações foi realizada no município de Dom Pedrito. Considerando as comercializações, 60 % não estavam de acordo com a legislação. A elaboração de uma Matriz de Risco referente à legislação de agrotóxicos hormonais para a elaboração de ações de educação e de fiscalização resultou na observação de 36 produtores/estabelecimentos rurais de alto risco.

Palavras-chave: Agrotóxicos. Deriva. Matriz de risco. 2,4D.

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Introduction

Although pesticides are of great importance to Brazilian agriculture and are identified as one of the reasons for the increase in agricultural production in the country, they have increasingly become a cause for concern due to the risks they pose to the environment and human health (Souza; Cunha; Pavanin, 2011; Pelaez *et al.*, 2016; Santos *et al.*, 2024). In Rio Grande do Sul, the state with the sixth highest gross agricultural production in the country (Brazil, 2020), the percentage of pesticide consumption ranks fifth nationally (Brazil, 2018).

Incorrect use of hormonal herbicides causes serious social and environmental problems. One of the effects of the incorrect use of pesticides is drift, the dispersion and deposition of the sprayed substance in environments close to the application zones, causing damage to sensitive crops, contamination and the loss of the applied product, as well as economic damage (Marple *et al.*, 2007). Drift on sensitive crops can cause irreversible damage (Brochado *et al.*, 2022), and can also result in the contamination of soil, water, air, and cultivated food, causing damage to the health of humans, animals, and ecosystems. Contact with air contaminated with hormonal herbicide molecules, such as 2,4-D, can cause skin irritation, itching and burning sensations in the airways and various other health problems (Islam *et al.*, 2018; Freisthler *et al.*, 2022).

Hormonal herbicides are products in the synthetic auxin group, with 2,4-D, Fluroxypyr-meptyl, Quincloraque, Aminopyralid, Halauxifen, Triclopyr-butolithium, Clopyralid, MCPA, Dicamba, Picloram and Florpirauxifen-benzyl as the active ingredients. Herbicides belonging to the synthetic auxin group are systemic and disrupt normal growth patterns, causing plant death, distorted cell division, and the collapse of tissue structure (Johnson *et al.*, 2023).

In the State of Rio Grande do Sul, the Secretariat of Agriculture, Livestock, Sustainable Production and Irrigation (SEAPI) has published regulatory measures, through Normative Instructions (IN 05/2019; IN 08/2019; IN 12/2022; IN 13/2022) intended to regulate the prescription, trade and use of hormonal herbicides (SEAPDR, 2019a; SEAPDR, 2019b; SEAPDR, 2022a; SEAPDR, 2022b). The measures include processes for declaring pesticide applications, warnings indicating the risks of use, limiting sale of pesticides to registered applicators, and registration of sensitive crops.

However, five years on from the announcement of these regulations, the incorrect use of these products persists. In particular, applications without the proper declaration remain prevalent. Such declaration is essential for monitoring and the maintenance of sensitive crops. Cases of drift in the state are frequent. In the 2022/2023 harvest alone, 53 samples were collected with suspected 2,4-D drift, of which 45 were confirmed to be phytotoxic by the herbicide, mainly in grape crops. According to Haring *et al.* (2022), hormone drift causes visible symptoms such as necrosis, chlorosis, and wrinkling of vine leaves.

Procedures for the correct use of hormonal pesticides should be adopted in order to promote rational use and reduce impacts on the different environmental factors (Rocha; Alvarez, 2023). The proposal of a Risk Matrix for the use of hormonal pesticides will be useful in decision-making regarding enforcement actions by public agencies and in mapping sites with a potential risk of damage to sensitive crops. In addition to this, it is important to carry out an analysis of the commercialization of hormonal pesticides in municipalities in Rio Grande do Sul, since this data can guide regulatory processes, preventive inspection, and even market forces. The aim of this study was to carry out a diagnosis of trading in





municipalities in the Campanha region of Rio Grande do Sul and propose a Risk Matrix related to the use of hormonal pesticides.

Materials and Methods

Study Area

The study area comprises the municipalities of Bagé, Caçapava do Sul, Candiota, Dom Pedrito, Hulha Negra and Lavras do Sul. These municipalities are part of the Bagé Regional Supervision, according to the administrative division of SEAPI RS (SEAPDR, 2020). Similarly, the Campanha Regional Development Council (COREDE), created in 1992, is made up of seven municipalities: Aceguá, Bagé, Caçapava do Sul, Candiota, Dom Pedrito, Hulha Negra and Lavras do Sul (SPMDR, 2015). The municipalities of Aceguá, Pedras Altas and Santana da Boa Vista, close to the municipality of Bagé, were not considered in the study, as they were not yet part of the requirements of Normative Instructions No. 12 and No. 13 of 2022, during the period evaluated. The requirements in these municipalities began only on January 1, 2024 (SEAPDR, 2022a; SEAPDR, 2022b).

Obtaining Data and Diagnosing Sales

In order to verify the marketing of hormonal pesticides in 2022, the annual pesticide marketing spreadsheet was acquired by the Agricultural Inputs and Services Division (DISA), via a formal request extracted from the Integrated Agrottoxics Management System (SIGA) using the IBM Cognos Analytics system (SEAPI/RS). All legal sales of pesticides are registered by the companies in this system. All commercial brands with the following active ingredients were considered hormonal herbicides: 2,4-D, Fluroxypyr-meptyl, Quincloraque, Aminopyralid, Halauxifen, Triclopyr-butolytic, Clopyralid, MCPA, Dicamba, Picloram and

Florpirauxifen-benzyl. All marketed products are duly registered with the relevant national regulatory bodies and with the appropriate state-level environmental authority. After purchasing and applying the products, producers must enter the application data (commercial brand of the product, crop, area, date of application, invoice number, agronomic prescription number, applicator's CPF) in the SDA system within a maximum of 10 (ten) days, in accordance with IN 12 of 2022 (SEAPDR, 2022a).

The total quantities of products marketed were extracted and stratified by active ingredients and municipalities of acquisition and use. The frequencies of declarations of use of hormonal pesticide products were checked according to IN 12 of 2022 (SEAPDR, 2022a). Marketing data was expressed in product units. The declarations were transformed into frequencies (percentage) of declarations.

Risk Matrix

Based on the producers' purchase data, a search was carried out in the Agricultural Defense System (SDA) for each declaration of use that should have been made, within a period of up to 10 (ten) days. Producers were categorized and their declarations separated into "COMPLETE" - all purchase notes were declared in the SDA, "PARTIAL" - at least one purchase note was not declared in the SDA, and "ABSENT" - no purchase note was declared in the SDA.

Information on the technical responsibility of the agronomic recipe used for each hormonal agrochemical product purchase was linked manually, by consulting the agronomic recipes sent to SIGA. In addition, companies were contacted and asked for copies of agronomic recipes that were not available on the system.

In order to draw up a Risk Matrix, the following





criteria were developed (Table 1):

1. Volume of hormonal herbicides purchased: To calculate the volume of herbicides purchased, the volume of products on the purchase invoices was summed. For the risk scale, producers were assigned scores for the quantities, on the following scale: 0 to 99 liters/kilo, score 1; 100 to 999 liters/kilo, score 2; above 1000 liters/kilo, score 3. Returned volumes were not taken into account.

2. Location of the crop at a distance equal to or less than 10 km from sensitive crops declared in the SDA: By checking the geographical coordinate registered in the SDA, it was ascertained whether it is at a distance equal to or less than 10 km from any active sensitive crop (registered crop and harvest declared in the current year) in the SDA. If there were sensitive crops, the producer received a score of 3. If not, the score was zero. In the case of producers with more than one property, the area with the greatest restriction for the criterion was considered, i.e. the presence of sensitive crops (score 3). Greater weight was given to this criterion because of the increased risk of hypothetical drift due to the proximity of sensitive crops. It is known that, excluding situations such as thermal inversion and convective currents, the chance of off-target product deposit due to incorrect applications occurs over shorter distances.

3. Partial or absent declaration of hormonal herbicide application: Producers who made their application declarations “COMPLETE” - all purchase notes were declared in the SDA - received a score of 1. Producers who made their application declarations “PARTIAL” - at least one purchase note was not declared in the SDA - received a score of 2. Producers categorized in “ABSENT” declaration status - no purchase notes were declared in the SDA - received a score of 3.

4. History of inspections in the area of application: Inspections are an important tool for instruction, and it is a valuable consideration that producers who have already been inspected are better informed about the legislation in force. Producers who have not yet been inspected should therefore be prioritized and given a score of 1, while those who have already been inspected receive a score of zero.

To calculate the index guiding the Risk Matrix, the scores for each of the criteria were added up using the Microsoft Excel 2010 software. The indices varied on a scale from 2 (minimum risk) to 10 (maximum risk), and were divided into four risk groups: “low” (scores 3 to 4), “medium” (scores 5 and 6) “high” (score 7) and “high” (scores 8 to 10).

Table 1. List of the criteria used for the risk matrix and the scores assigned to each item.

Criteria			
Scale of scores	Volume of products purchased (l/kg)		
	0 a 99	100 a 999	> 1000
	Score 1	2	3
Score	Location of the crop at a distance of 10 km or less from sensitive crops		
	Yes	No	
	Score 3	0	
Score	Declaration of hormonal herbicide application		
	Complete	Partial	Absent
	Score 1	2	3
Score	Inspection history in the application area		
	Yes	No	
	Score 0	1	

Results and Discussion

There were 1098 sales of hormonal pesticides in the municipalities of Campanha do Rio Grande do Sul, including Bagé, Candiota, Caçapava do Sul, Dom





Pedrito, Hulha Negra, and Lavras do Sul (Figure 1). Analysis indicates that approximately 6,000 kg of solid hormonal pesticides and 292,000 liters of liquid hormonal pesticides were sold to these municipalities in 2022. Brazil has a major global consumer market for pesticides and the use of pesticides provides many benefits to agricultural producers in controlling pests and diseases, increasing crop productivity, but control over their use is necessary in order to avoid health risks and environmental contamination (Ritter; Silva; Russini, 2018). The trade in herbicides is increasing globally, mainly due to their ease of use in response to the scarcity of labor in weed removal and the need to increase crop yields (Gianessi, 2013). Weed resistance

to an herbicide necessitates an increase in the use of alternative molecules. For example, the use of synthetic auxins is necessary because of the fewer reports of resistance to this group (Busi *et al.*, 2018), and because it is an option for managing glyphosate-resistant weeds. It is important to note that the use of alternative controls and management techniques, such as integrated management, can reduce the need for chemical weed control (Tinoco; Silva; Rocha, 2023). In addition, the active engagement of those involved in production, such as producers, cooperatives, educational institutions and supervisory bodies is essential for more sustainable weed control practices and the sustainable use of herbicides.

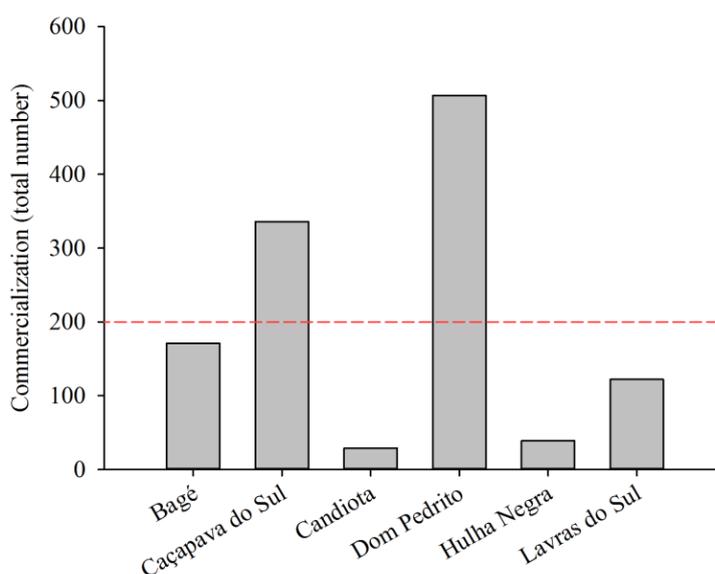


Figure 1. Marketing of hormonal pesticide products in the municipalities of the Bagé region. Dashed line indicates the average number of sales in the Bagé region of Rio Grande do Sul State, Brazil, in 2022.

Regarding the products marketed, the two with the largest volumes have 2,4-D as their active ingredient. Of the ten most marketed, only two products have Fluroxypyr-meptyl as their active ingredient, all the others have 2,4-D in their composition. 2,4-D was

one of the first synthetic herbicides to be developed and currently approximately 600 products contain its molecule (Song, 2014).

According to Normative Instructions No. 12 and 13 of 2022, rural producers must inform SEAPI,



through the SDA, of data relating to the application of hormonal pesticides on their farm, within ten days of their use (SEAPDR, 2022a; SEAPDR, 2022b). However, there is still a high frequency of pesticide applications without proper declaration. In the municipalities evaluated in the Bagé Regional Supervision, the average number of applications with a declaration is 40 % (Figure 2). The municipality with the highest percentage of declarations is Dom Pedrito (60 %), while the municipalities of Candiota, Caçapava do Sul and Hulha Negra had declaration rates of less than 20 %.

In the qualitative analysis, in which producers are separated into groups according to whether they made a “complete”, “partial” or “absent” declaration, a greater number of producers complied than the absolute numbers in relation to the purchase invoices in the quantitative analysis (Figure 3). When analyzing the

municipality of Dom Pedrito, there was a 67 % percentage of producers with at least one declaration of use of hormonal herbicides in the SDA, showing the wider reach of legal enforcement within the municipality. The higher incidence of producers, cooperatives, and technical managers, combined with the greater likelihood of inspection action, results in a higher proportion of declarations. In general, inspection actions increase in line with the increase in cultivated areas, resulting in greater compliance with the normative instructions by producers (Rocha; Alvarez, 2023). Cooperatives and technical managers also help to guide producers in making declarations in accordance with current legislation. For producers, the information provided by the technical managers is of great importance in the use of pesticides (Müller; Tavares, 2020).

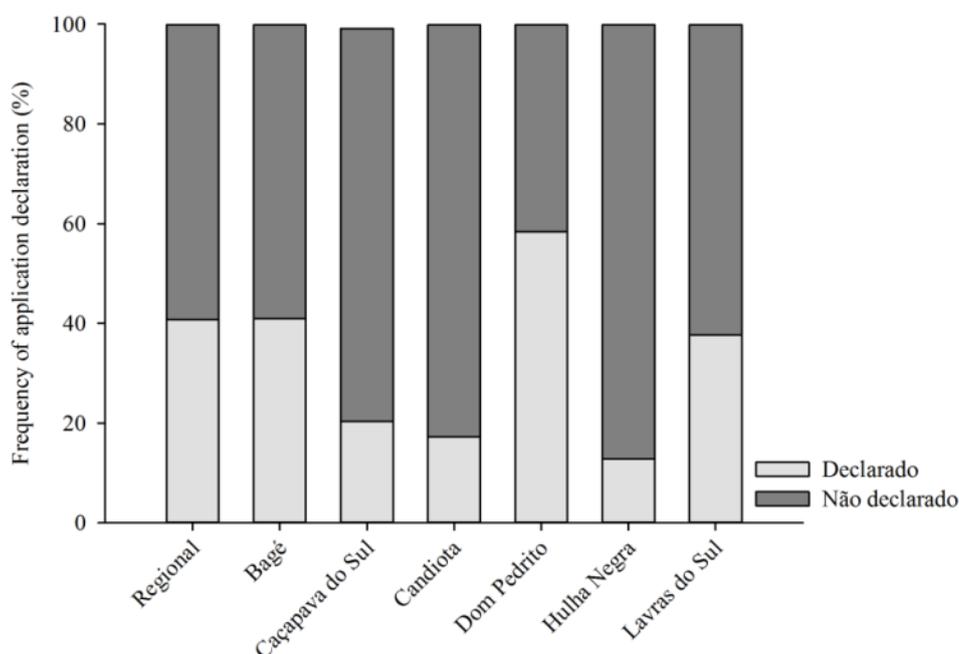


Figure 2. Frequency of producers who did or did not declare the application of hormonal pesticides in the SIGA system in areas of the municipalities belonging to the Bagé regional of Rio Grande do Sul State, Brazil.

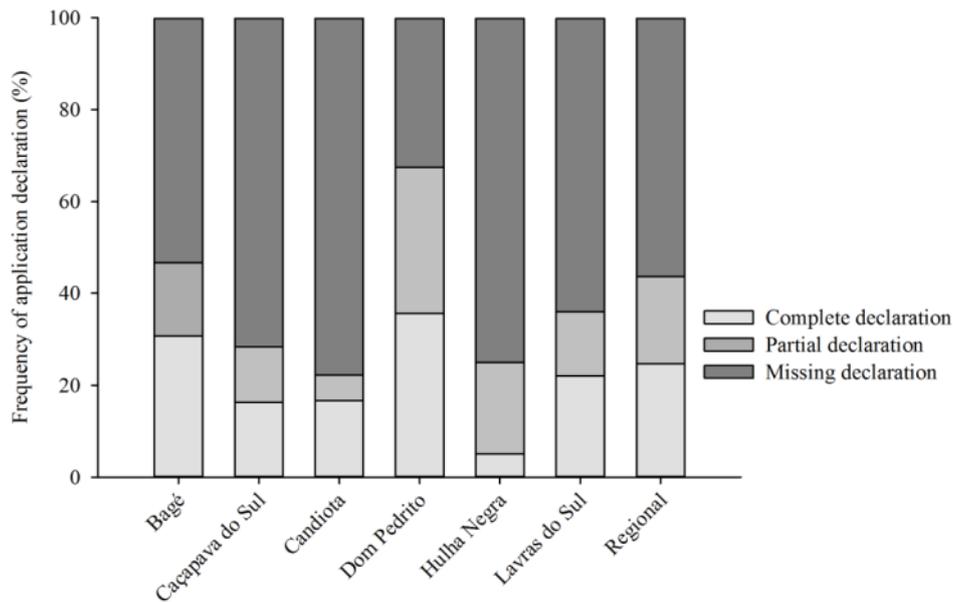


Figure 3. Frequency of producers who made a complete, partial or absent declaration of hormonal pesticide application in the SIGA system in areas of the municipalities belonging to the Bagé of Rio Grande do Sul State, Brazil.

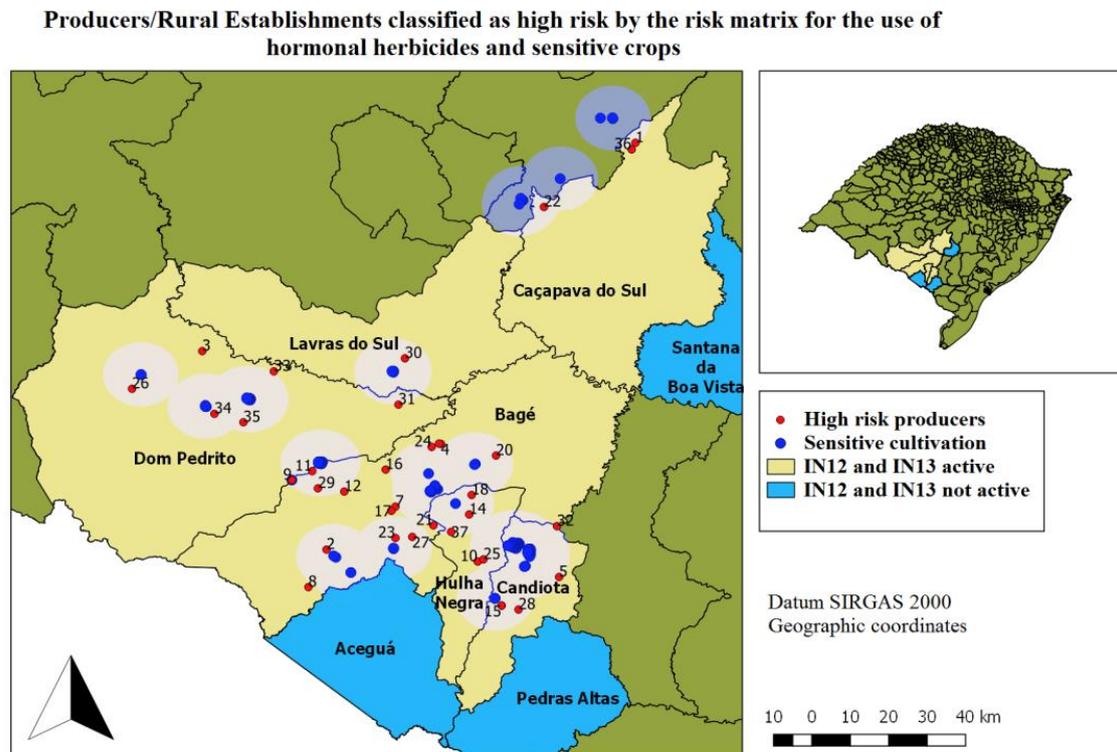


Figure 4. Producers and rural establishments classified as high risk by the risk matrix for the use of hormonal herbicides and sensitive crops in the Bagé of Rio Grande do Sul State, Brazil.



Table 2. List of technical managers who issued agronomic prescriptions to producers who did not declare the application. The ten technical managers who had the highest frequency of non-declaration in relation to the number of agronomic prescriptions for hormonal herbicides issued for the Bagé Regional of Rio Grande do Sul State, Brazil, in 2022 were selected.

Technical managers	City	Total	Undeclared	Declared	Undeclared (%)
A	Cachoeira do Sul	23	0	23	100.00
B	Caçapava do Sul	83	12	71	85.54
C	Bagé	12	2	10	83.33
D	Bagé	73	13	60	82.19
E	Caçapava do Sul	111	23	88	79.28
F	Caçapava do Sul	86	27	59	68.60
G	Ibirubá	14	5	9	64.29
H	São Gabriel	20	8	12	60.00
I	Dom Pedrito	9	13	22	59.09
J	Alegrete	8	11	19	57.89

The number of producers who made no declaration to the SDA in the municipalities of Caçapava do Sul (71.63 %), Candiota (77.78 %) and Hulha Negra (75 %) was high when compared to producers in Dom Pedrito (Figure 3). It is worth highlighting the important role of agrochemical retailers in advising producers on the requirements laid down in Normative Instruction 12/2022 (SEAPDR, 2022a), which deals with the targeted sale of hormonal herbicides. When a retailer sells hormonal herbicides, it requires the rural producer to provide a document declaring who will be the applicator responsible for applying the product purchased and their respective Declaration of Registration of Active Pesticide Applicators with SEAPI-RS, making the purchaser aware of the regulations in force on the subject. In addition, it is not uncommon for retailers to offer to make the declaration pesticide system and to prepare a

model field notebook as a way of building customer loyalty and contributing to an increase in the number of declarations. The lack of agrochemical retailers in the municipalities of Candiota, Hulha Negra, and Lavras do Sul also implied the existence of less local education for producers, leading to lower rates of declarations in the system. In Dom Pedrito, according to data from the SDA, in 2022 there were 12 (twelve) registered pesticide retailers, as well as two agricultural aviation businesses.

Established by Normative Instruction nº 08/2019 (SEAPDR, 2019b), the sensitive crop register is an extremely important tool for mitigating the risk of drift. According to this normative act, sensitive crops are those that, when exposed to pesticides from the synthetic auxin group, show symptoms of phytotoxicity. Examples of such sensitive crops include: apple trees, grapevines, olive trees, pecans, yerba mate, tomatoes





and vegetables. The location of sensitive crops helps neighboring producers take greater care when applying hormonal herbicides (Figure 4). By registering production areas such as orchards, grapevines and olive groves, it is possible for rural producers who intend to use hormonal herbicides to know where these crops are located and make more assertive decisions about whether or not to use the product and the application technology used at the time of application. Applying hormonal herbicides requires winds of more than 3 km/h and less than 10 km/h, relative humidity of more than 55% and a temperature of less than 30°C, and the use of sprayers with appropriate settings and tips (Ferreira; Ferreira, 2020). Wind direction, a crucial factor in helping to avoid damage in the event of drift, can be assessed by considering the direction in which the crops registered with the SDA are facing. Although it is not compulsory, registration has been widely encouraged by inspection bodies, as it is a tool for analyzing drift.

To create the Risk Matrix, 423 producers and rural establishments that purchased hormonal pesticides in the Bagé region in 2022 were listed. These producers and rural establishments should therefore have met all the criteria set out in current State legislation, in addition to making declarations regarding pesticide use in the SDA. The Risk Matrix is intended to serve as a preventative tool for environmental and inspection bodies, since it will not be used to apportion blame for damage caused by drift that has already occurred, but rather to propose inspection and health education actions in places where there is a potential risk of drift. Hupffer, Figueiredo and Weyermüller (2020) cited several cases of problems, such as drift, in the use of hormonal herbicides on properties located in the same region as this study. According to the authors, there have already been several discussions about problems

with the use of hormonal herbicides between producers of soybeans, sensitive crops (vines, olive trees, apple trees, vegetables, etc.), public authorities and other associations.

After submitting the data from producers purchasing hormonal herbicides according to the established criteria, the producers and rural establishments were categorized based on their indices, separated by municipality, and categorized into risk groups. Thus, two producers were found to be at the minimum level, 107 at the low level and 250 at the medium level. In addition to these, 27 producers/rural establishments were classified as high risk (score 7) and could be included in the planned tax actions. In addition, 37 producers were considered high risk (Figure 4). These producers can be prioritized in health education and inspection actions, and these actions can be combined in Task Forces by municipalities and nearby regions, before the period of greatest use of hormonal herbicides (pre-planting of the soybean crop) in order to minimize drift problems resulting from incorrect application.

There was a relationship between technical managers issuing agronomic prescriptions and producers not declaring the use of hormonal herbicides (Table 2). It is noteworthy that only one professional out of the ten (10) responsible technicians works directly in the municipality with the highest note versus declaration conversion (Dom Pedrito), while all the others work elsewhere.

In the municipalities of Bagé, Caçapava do Sul, Candiota, Dom Pedrito, Hulha Negra and Lavras do Sul, 1098 trade of hormonal herbicide pesticides to 427 producers were observed. Of the total number of sales, 60% were declared in noncompliance with current legislation. The city of Dom Pedrito had the lowest number of producers and establishments with missing



declarations. Drawing up a Risk Matrix for the legislation on hormonal pesticides for education and inspection actions resulted in the identification of 36 high-risk producers/rural establishments.

Conflict of Interests

The authors declare that the research was conducted in the absence of any potential conflicts of interest.

Ethical Statements

The authors confirm that the ethical guidelines adopted by the journal were followed by this work, and all authors agree with the submission, content and transfer of the publication rights of the article to the journal. They also declare that the work has not been previously published nor is it being considered for publication in another journal.

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