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Description of the application method in technical and scientific work on insecticides

Marcelo Gonçalves Balan[1*], Otavio Jorge Grigoli Abi Saab[2], Arney Eduardo do Amaral Ecker[1] and Gustavo de Oliveira Migliorini[2]

*[1]Departamento de Agronomia, Universidade Estadual de Maringá, Avenida Colombo, 5790, 87020-900, Maringá, Paraná, Brazil. [2]Departamento de Agronomia, Universidade Estadual de Londrina, Londrina, Paraná, Brazil. *Author for correspondence. E-mail: mgbalan2@uem.br*

ABSTRACT. Chemical control is a viable and practically indispensable tool in the control and management of cultivated plant pests, but insufficient detail in documenting the methods used for applying phytosanitary products has been reported in the majority of scientific publications dealing with insecticide application. A survey of 200 scientific studies was conducted to examine how much basic information was provided on the application method. The amount of descriptive detail concerning the insecticide application method was found to be below the minimum requirements. In particular, there was insufficient detail concerning the spray droplet spectrum (no information in 173 studies evaluated – 86.5%), operating pressure (38 studies – 19%), solution concentration (52 studies – 26%), distance and position of spray nozzles in relation to the target (114 studies – 57%), temperature (128 studies - 64%), relative humidity (134 studies - 67%) and wind speed (145 studies – 72.5%). All the studies evaluated contained information on the application rate used (L ha^{-1}). To change this situation and reestablish the importance of the application method, we propose a simplified method description for the application of phytosanitary chemicals. Use of the proposed minimum methodological description is practicable for insecticide treatments and will also enable them to be accurately repeated.

Keywords: spray nozzles, droplet spectrum, operating pressure.

Descrição metodológica para trabalhos técnico-científicos que tratam da aplicação de inseticidas

RESUMO. O controle químico é ferramenta viável e praticamente indispensável no manejo e controle de pragas das plantas cultivadas, mas detalhes insuficientes sobre os métodos de aplicação de produtos fitossanitários têm sido reportados na maioria das publicações científicas que tratam da aplicação de inseticidas. Através de levantamento em 200 trabalhos científicos fez-se o apontamento da presença ou ausência de informações básicas sobre o método de aplicação. Observou-se que as descrições mínimas requeridas sobre a técnica de aplicação de inseticidas não tem sido atendidas. Destacam-se a insuficiência de descrição sobre o espectro de gotas formado pela pulverização, com ausência de informação em 86,5% dos trabalhos avaliados; pressão de trabalho: 19%; concentração da calda: 26%; distância e posição das pontas de pulverização em relação ao alvo: 57%; temperatura: 64%; umidade relativa do ar: 67% e velocidade do vento: 72,5%. Para todos os trabalhos foi informada a taxa de aplicação utilizada (L ha^{-1}). Para alterar a realidade observada e resgatar a devida importância da técnica de aplicação, propõe-se uma descrição metodológica simplificada para a aplicação de produtos fitossanitários. A utilização da proposta de descrição metodológica mínima é plausível para os tratamentos inseticidas, permitindo sua repetibilidade.

Palavras-chave: pontas de pulverização, espectro de gotas, pressão de trabalho.

Introduction

Chemical control is a viable alternative for the management and control of cultivated plant pests. Chemical control has made a valuable contribution to agriculture and helped boost the potential yield, provided that it is used rationally, minimizing environmental contamination, human health problems, and the appearance of resistant pests.

Phytosanitary defense strategies over the last 30 years have seen significant changes and technological innovations in response to an increase in the number of important pests. In the period from 1992 to 2005, insecticides used for pest management and control represented an average of 25.73% of the total volume of phytosanitary products commercially available in Brazil, in commercial terms amounting to US$ 7.80 billion (Sindicato Nacional da Indústria de Produtos para a Defesa Agrícola [Sindag], 2008).

According to Zambolim, Conceição and Santiago (2008), since the discovery of organochlorine and organophosphate insecticides in the 1940s, the dosage of the active ingredient and the persistence of the insecticides recommended for use in Brazil during the 1960s, 1970s, 1980s and 1990s decreased significantly by approximately 88.69%. Also of note is the development of insecticide molecules. These molecules used to be thought of as highly toxic but are now available at lower toxicity and with different levels of selectivity.

Technology is used in the application of phytosanitary products to deposit the appropriate quantity of the active ingredient on the target with maximum efficiency, in the most economical way and with the lowest possible impact on the environment (Matthews, 2002). The skilled use of this technology is essential to increase insecticide efficiency and minimize contamination of the application operators and the environment, as well as cutting application costs.

Today, there is a tendency to reduce the volume of spray solution to cut costs and increase spraying efficiency. Matthews (2004; 2008) highlights a reduction in spray application rates from 500 to less than 200 L ha^{-1}, underlining the urgent need for improvements in the field application technology.

For Matthews (2008), although phytosanitary products are applied in various situations, each situation must be treated individually to achieve maximum precision and optimum dosage, as well as minimum operator exposure to the active ingredient. He notes that developing new spray nozzles provides users with greater flexibility, improving the distribution of phytosanitary products while reducing spray volumes and influencing the dose transfer.

The author affirms that the dosages of phytosanitary products recommended by the molecule patent-holders are high, based on the results of rigorous and prolonged field trials to ensure that the product is successfully registered with the regulatory agencies. In many cases, the significant drop in the application rates currently used is the result of the end user's decision because, in most cases, the volume to be applied is determined by the user.

The droplet spectrum formed at the hydraulic nozzle is determined by the type of nozzle, orifice size (nominal flow rate), spray discharge angle, operating pressure and formulation of the phytosanitary product. These factors therefore affect the target coverage by the spray because once the volume to be applied and the crop area to be covered have been determined, the coverage can be modified by altering the droplet spectrum, subject to the limits imposed by drift and the run-off point. As a result, it is very important to select appropriate spray nozzles because doing so is crucial in determining the quantity applied per unit area, uniformity of application, coverage obtained and potential drift risk (Lan, Hoffmann, Fritz, Martin & Lopes Jr., 2008; Matthews, 2004, 2008; Zande et al., 2008).

The international classification system for droplet spectra and spray nozzles is based on two components: droplet size distribution and drift risk (Miller, Ellis & Gilbert, 2002). This classification, including the spray nozzle color code, is given in the Asabe/Asae standard S-572 (American Society of Agricultural and Biological Engineers [Asabe], 2004).

The great challenge of research in this field is to obtain ideal coverage of the target, distributing the droplets produced in a uniform way. If the droplets are too large, then there are problems with insufficient coverage of the target, lack of uniformity in the distribution and excess mass, which interferes with adhesion to the target and results in run-off to the soil. However, although using very small droplets would solve all these problems, they are likely to evaporate in low humidity conditions or be carried off by the downwind, aggravating the phenomenon of drift with increased risk of environmental contamination (Fritz, Hoffmann, Martin & Thomson, 2007; Jamar, Mostade, Huyghebaert, Pigeon & Lateur, 2010; Wolf & Daggupati, 2009; Zhu, Dorner, Rowland, Derksen & Ozkan, 2004). There is a strict correlation between the evaporation of the droplet spectrum produced and the weather conditions, such as temperature and relative humidity. Ramos and Pio (2008) reported that an air temperature above 30°C and a relative humidity below 55% are factors that favor this phenomenon and should therefore be monitored. Fritz (2006) and Yu et al. (2009) demonstrated the importance of meteorological factors in the spray and efficacy performance.

Matthews (2002) affirmed that each nozzle has its own volumetric distribution characteristics, specific to the height of the nozzle in relation to the target and the spacing between nozzles on the boom. If the volume applied is not adequate and uniform, then there is a risk that further applications will be needed to compensate for irregular application or untreated swathes (Peressin & Perecin, 2003). In Brazil, the spacing used between nozzle sets is usually 50 cm. Based on knowledge of the spray nozzle to be used and the jet emitted, it is possible to find the best relationship between spacing and minimum boom height over the target to set the parameters so that, depending on the swathe and operating pressure, the spray solution is deposited as uniformly as possible, with the lowest coefficient of variation (Cunha & Ruas, 2006; Peressin & Perecin, 2003).

Despite all these considerations and efforts towards safer and more efficient spraying practices for phytosanitary products, a great deal of importance is still attached to the insecticide but little to the application method (Cunha, Teixeira, Coury & Ferreira, 2003; Hislop, 1991).

The lack of knowledge of the basic concepts involved in applying phytosanitary products is evident in the scientific literature, which frequently indicates that the volume of solution applied is considered an adequate parameter to characterize and allow for repeatability of an application.

Even with the important mission and objective of making a name in the scientific world through publication in high-impact scientific periodicals (Slafer, 2008), insufficient details concerning phytosanitary product application methods have been reported in most of these publications, according to Matthews (2004). In his work ('How was the pesticide applied?'), he notes that the majority of scientific studies do not sufficiently detail the application methods used. Apart from the volume of water used for dilution, which is indicated in all publications, the author highlights a lack of information concerning the types of nozzle used, the application angle, the droplet spectrum category, the spray concentration, the operating pressure and how pressure is maintained, the nozzle position in relation to the crop and information on the weather conditions at the time of application. This lack of information makes it more difficult to judge whether the result of inefficient phytosanitary treatment was caused by the insecticide applied or by an inadequate application method.

The objective of this study was to verify the presence or absence of a basic methodological description, based on the suggestions made by Matthews (2004), of how insecticides were applied in the scientific papers published in Brazil and other countries. We also propose minimum requirements for an application method description to verify the adequacy of the conditions under which the experiments were performed and to afford technical assistance in repeating the insecticide application methods.

Material and methods

Based on the work of Matthews (2004) and bearing in mind his affirmation that scientific documentation contains insufficient basic methodological information on the phytosanitary product application method, we performed a survey of the bibliographical database available for consultation at the periodicals portal of Capes – the Brazilian Higher Education Coordination Agency (Qualis, 2006), journals and bibliographical databases freely accessible over the Internet, and periodicals, journals, and scientific magazines available at the libraries of the State University of Londrina (UEL), the State University of Maringá (UEM), the 'Luiz de Queiroz' Agricultural College (ESALQ/USP) and the Campo Mourão Integrado Faculty. We selected 200 studies involving the application of insecticides, 100 of which were published in Brazil and 100 published abroad. The studies examined were all published after 1990.

In choosing the studies examined, preference was given to those classified during the 2004/2006 triennial period (level A publications) by Qualis, a body that classifies publication media for intellectual output (bibliographical) from post-graduation programs and is used by Capes in its post-graduate assessment process.

We verified the presence or absence of the following information in the methodological description of the scientific work evaluated. Spray nozzle: description (type/model) - Spray discharge angle and droplet spectrum - Operating pressure used and how it was maintained - Application rate: volume of solution applied per unit area - Concentration of solution applied: dosage of the active ingredient used at the application rate - Air temperature at the time of application - Relative humidity at the time of application - Wind speed at the time of application.

The results for the national and international bibliographic databases examined were annotated by a simple 'yes' (present) or 'no' (absent) and presented as charts indicating percentages, arranged to give an overview that could be easily described and analyzed. We chose not to identify the studies evaluated because our objective was simply to indicate the publication medium and the quantitative data (Table 1).

Table 1. Bibliographic database examined and quantitative distribution.

Source	Number of issues evaluated	
	National	International
Agronomy Journal	-	12
Arquivos do Instituto Biológico	9	-
Ciência Rural	18	-
Crop Protection	-	10
Engenharia Agrícola	10	-
International Journal of Agriculture Science	-	12
Journal of Applied Entomology	-	9
Journal of Economic Entomology	-	15
Journal of Stored Products Research	-	4
Neotropical Entomology	-	7
Pesquisa Agropecuária Brasileira	14	-
Pesticide Science	-	6
Phytoparasitica	-	7
Planta Daninha	4	-
Revista Brasileira de Agrociência	8	-
Revista Brasileira de Entomologia	18	-
Revista Brasileira de Fruticultura	8	-
Revista Brasileira de Oleaginosas e Fibrosas	2	-
Scientia Agricola	9	-
Transactions of the American Entomological Society	-	15
Weed Technology	-	3
TOTAL	100	100

Results and discussion

The results for descriptions of the nozzles used (model), the spray angle and the droplet size are shown in Figure 1.

The survey indicates that, regardless of the main focus of the publication, this information, together with the spray angle, must be considered essential in scientific work. Although it may not seem significant because manufacturers' manuals are available for consultation and there is specific work on the development and operation of spray nozzles, the information on the spray droplet spectrum and the correct nozzle set-up in relation to the target is essential because each type of spray nozzle has its own characteristics, as noted by Matthews (2002). The most worrying aspect is the lack of information on the droplet size formed by the spray nozzles. Despite technological advances in the development of spray nozzles and international efforts to standardize them, seeking methods of application that are more technical, accurate, and safe in terms of the environment and human health and economical for phytosanitary products (reduction of potential drift), progress continues to be merely a trend, as affirmed by Matthews (2004). This lack of real progress is highlighted by the fact that 173 (86.5%) of the 200 studies evaluated did not contain this information.

Information on the operating pressure, the basic principle of hydraulic spraying, and the fundamentals for forming and maintaining droplet distribution (Figure 2) were not methodologically described in 19% (38) of the studies evaluated. This situation must be changed, and this information must be made mandatory without exception in studies dealing with the spray application of phytosanitary products. Because these factors vary considerably from one set of equipment to another, improper settings can render the application of insecticides non-viable.

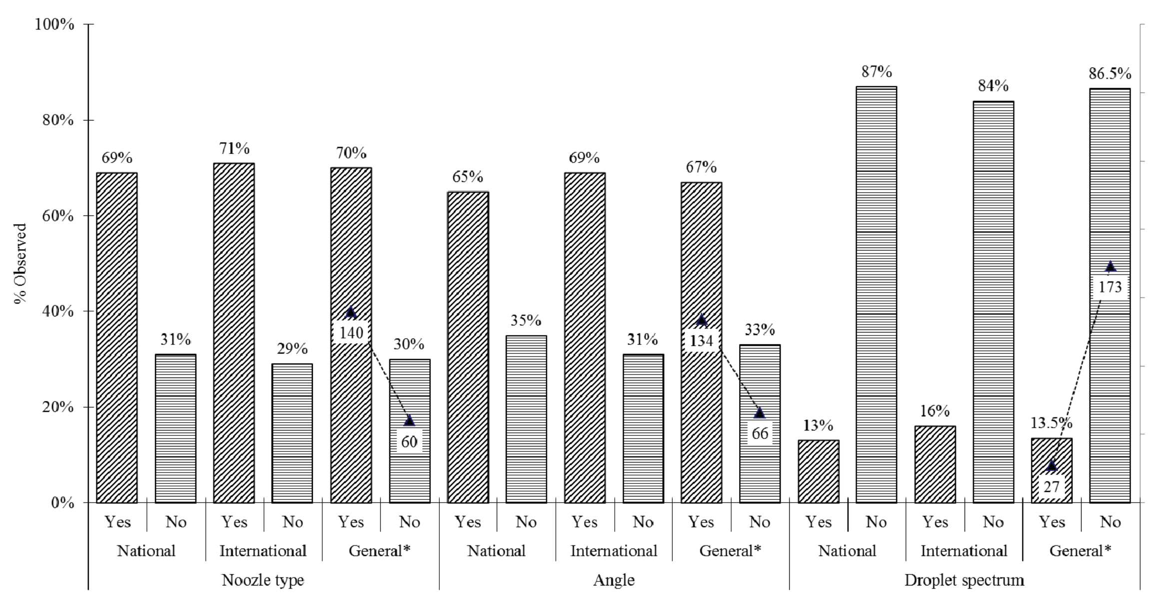

Figure 1. Percentage distribution and total amount of information on the type of spray nozzle used, spray angle and droplet spectrum for 100 national and international scientific studies concerning the application of insecticides.

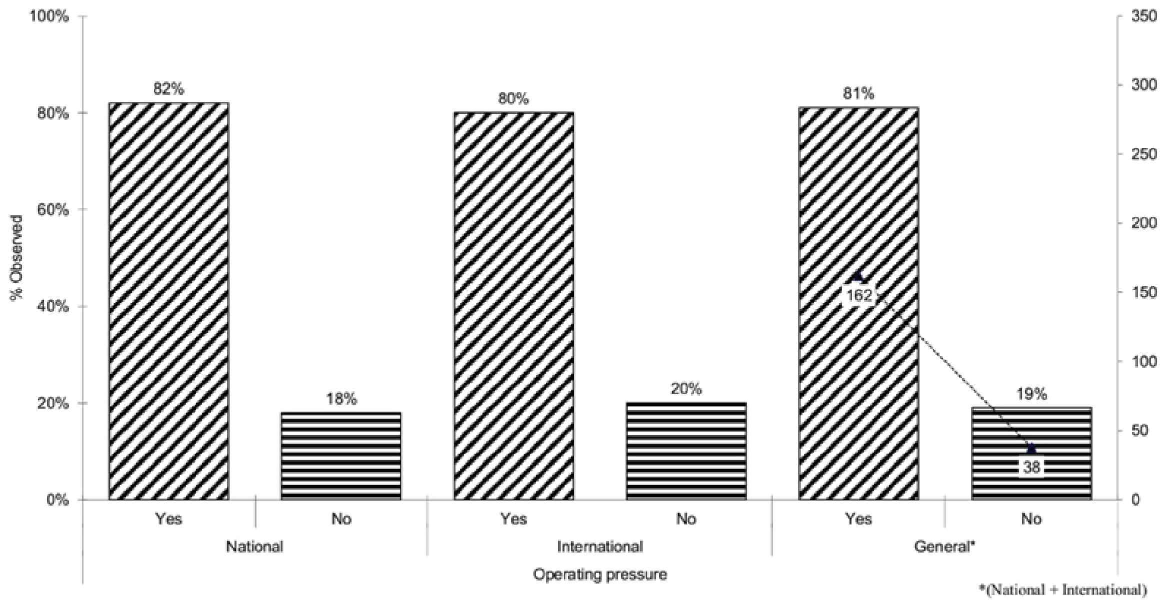

Figure 2. Percentage distribution and total amount of information on operating pressure in 100 national and international scientific studies involving the application of insecticides.

In general, the use of excessive pressure or unsuitable spray nozzles is the greatest cause of drift (Matthews, 2004). In his observations, Matthews affirmed that the volume of solution applied per unit area (application rate) is indicated in the majority of studies, as we ourselves confirmed in the studies we evaluated (Figure 3). However, the insecticide dosage (solution concentration) was not indicated in 26% (52) of the studies evaluated because, in practice, there is a tendency for low rates to be applied (200 L ha^{-1}) and taking into account recommended doses of insecticide per unit area (ha), it is important and indeed essential to indicate the concentration of the active ingredient (dosage) per unit volume applied. Although recommended doses are high, if the application method is unsuitable, then the effect can be attenuated or reinforced to the detriment of dose transfer, and losses are incurred in both cases (Matthews, 2008).

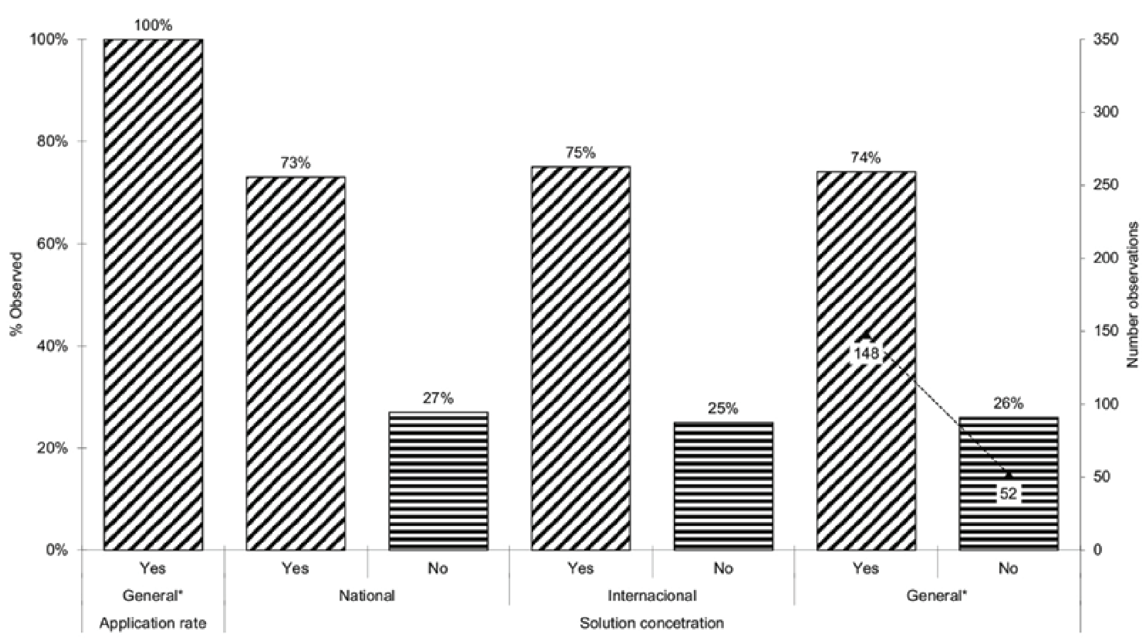

Figure 3. Percentage distribution and total amount of information on application rate and spray solution concentration for 100 national and international scientific studies involving the application of insecticides.

The information on the distance and position of the nozzle relative to the target (Figure 4) was little appreciated in the publications examined, except in specific studies. The fact that this information was omitted in 57% (114) of the studies examined is worrying. The spraying method, with various possibilities in terms of nozzle spacing and the relationship between the spacing and the height (distance) to the target (depending on the nozzle model, technology, operating pressure, type of solution, jet angle, topography, leaf density and crop architecture) can significantly affect the results of spraying, leading to excessive coefficients of variation and the consequent lack of uniformity in the deposition of the insecticide applied. This lack of uniformity can mean that it is necessary to respray some areas (new treatment), which can be directly attributed to the application method, as affirmed by Peressin and Perecin (2003).

The prospects for making progress in the field of science generate significant enthusiasm and concern regarding the objectives and results to be obtained. In some cases, this focus on results can lead to carelessness and negligence in the basic description of the method used in publishing notes, reports and technical and scientific papers in periodicals and journals with significant impact on the scientific community. Slafer (2008) notes the importance for agronomy journals of the number of scientists seeking to publish their most relevant hypotheses in high-impact journals. However, the importance of publishing this work in the most basic plant science journals should not be underrated.

Following this line of argument, we should have a goal of publishing our work without ignoring the basic methodological aspects. When we evaluated temperature, relative humidity and wind speed (Figure 5), we found the results to be alarming because the results of our survey showed how little importance was attached to them. No fewer than 64 (128), 67 (134) and 72.5% (145) of the studies evaluated contained no information at all concerning temperature, relative humidity and wind speed (in that order). Regarding the use of insecticides, although systemic products can be used with fine, medium and possibly coarse droplets, it is an acknowledged fact that the results do not always match expectations, and notwithstanding the technological options available, inefficient control is the end result (Matthews, 2008). The observations and descriptive criteria for this information are fundamental to safety and efficacy in the application of phytosanitary products, with ample potential for significantly altering application methods in the ongoing search for optimum, homogeneous and safe transfer of the required dose to the direct or indirect target we are attempting to control.

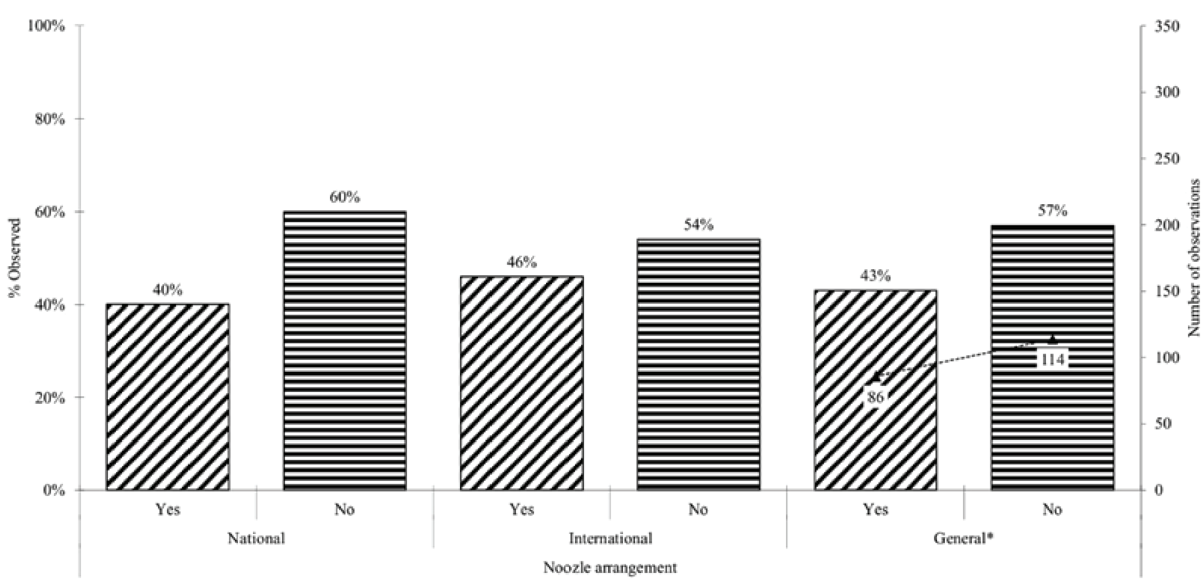

Figure 4. Percentage distribution and total amount of information on the nozzle distance and position in relation to the target in 100 national and international scientific studies on application of insecticides.

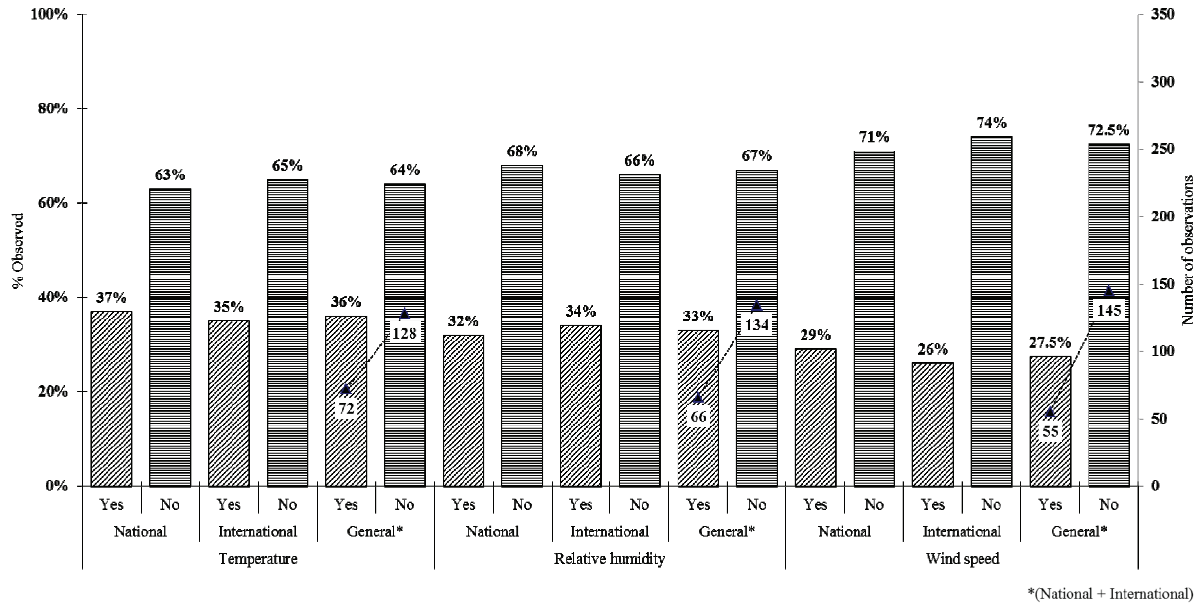

Figure 5. Percentage distribution and total amount of information on weather conditions in 100 national and international scientific studies involving the application of insecticides.

Under adverse weather conditions, with high temperatures, low relative humidity and high wind speed, there is a higher risk of environmental contamination due to drift. The quantity of droplets blown off-course (drift) is directly proportional to the wind speed and the smallness of the spray droplets. On one hand, because water is the dilution medium for most commercially available insecticides, evaporation also plays an important role and should be avoided. On the other hand, producing a spray with larger droplets reduces the risk of drift; however, because of the weight of the droplets, they may not adhere to the leaf surface and end up running off into the soil (Ellis, Webb, & Western, 2004).

In view of our findings, we propose a simplified method description that we hope will help those who are producing scientific work or competing to publish in the scientific periodicals and journals.

Our suggestion is based on the basic principle of the scientific method: repeatability. By providing the information proposed (Table 2), it will be easier to judge and acknowledge whether the application method was efficient or not. Some pieces of information merely give credence to and highlight the importance of the information that is normally provided.

Table 2. Proposed list of items that should be followed and expanded when describing a methodology in technical or scientific articles involving the application of insecticides.

		Product description		
Toxicological category	Formulation	Mode of action, selectivity and phytotoxicity	Adjuvant(s)	Recommended dose x Dose used
Toxicology category of the product to be applied	Formulation of the product applied	Systemic or contact – selective or not – phytotoxicity conditions	Description, concentration and characterization (if used)	Indicate the dose recommended by the manufacturer (registered). Indicate the dose used in the application
		Application		
Application phase	Recommended application rate (L ha^{-1})	Application rate used (L ha^{-1})	Operating pressure	Dilution agent
Pre-planting; pre-emergence; post-emergence	Solution volume recommended by manufacturer	Solution volume effectively applied	Operating pressure used (kPa)	If possible, describe the quality of the water used (hardness and pH)
		Applications performed		
Date and time	Number of applications	Interval between applications	Description of target	Description of protected crop
Date and time of each application	Number of applications	Interval (days) between applications	Age, phenological stage and height of target	Age, phenological stage and height
		Spray nozzle		
Model	Spray discharge angle	Flow rate (L $min.^{-1}$)	Droplet spectrum*	Average volumetric diameter (AVD)
Model of nozzle (manufacturer)	If available (degrees)	Nominal flow rate of spray nozzle	Droplet spectrum category at operating pressure used	If available

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Equipment				
Model	Type of boom	Nozzle spacing	Nozzle angle	Boom operating height / air assistance
Type of equipment, capacity to produce and maintain operating pressure	Length and type of mounting	Nozzle spacing used for application	Nozzle angle relative to the vertical.	Distance between spray nozzles and target. Type of air assistance used
Weather conditions				
Temperature	Relative humidity	Wind speed	Mist conditions	Rainfall
Temperature at time of application	Relative humidity at time of application	Wind speed at time of and during application	Mist conditions at time of application	If any (before, during and after application)
Safety				
Suggestion: information on the use of individual protective equipment (IPE) when preparing and applying the solution could be given to lay emphasis on the need for operator safety.				

*The international droplet spectrum classification lists droplet categories as very fine, fine, medium, coarse, very coarse and extremely coarse. This classification and the spray nozzle color code are given in Asabe/Asae standard S-572 (Asabe, 2004).

When this minimum information is provided, the researcher is in a better position to address challenges and discuss the results obtained, helping master and improve the techniques used for applying phytosanitary products. In this sense, the production of scientific work will benefit, and it will take less time to reach the professionals and disseminators of technology, who will put the work into practice in the field, thereby benefitting all segments of the production chain.

Conclusion

Currently, the minimum requirements for describing the methods used for applying insecticides are not being met. There are deficiencies in basic information concerning the spray nozzles used and their technical characteristics, spray solution concentration, operating pressure and how pressure is maintained, nozzle position in relation to the target, and information concerning weather conditions at the time of application. The use of the proposed minimum method description is practical for insecticide treatments, facilitating scientific verification through repeatability.

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