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Occupational risks associated with the use of pesticides in the green belt of Córdoba, Argentina

Riesgos ocupacionales asociados al uso de plaguicidas en el cinturón verde de Córdoba, Argentina

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Abstract. Horticulture is an activity with high occupational risk and few studies have addressed this problem in Argentina. We studied groups of horticultural workers in the Green Belt of Córdoba City (GBCC) (Argentina) and identified some determinants of occupational accidents caused by the use of pesticides. An observational study was conducted, examining demographic, productive and labor issues in 101 workers. A Multiple Correspondence Analysis (MCA) enabled distribution and covariance patterns to be visualized and typologies of individuals to be established. Logistic regression models were used to identify occupational accidents with pesticides. The MCA identified the more vulnerable groups: those using backpacks to apply pesticides, those who sprayed a great variety of pesticides, those working in small production units, and those living in their place of work. Accidents caused by the use of pesticides were associated with subjects who handle a large number of pesticides and work in small establishments. Determining factors for the occurrence of accidents were found to be higher levels of education (OR 4.23; p = 0.046), the greater number of pesticides used (OR 5.44; p=0.013) and lower PPE level (OR 4.92; p= 0.021). This characterization identifies features of vulnerability to pesticide exposure in certain groups of horticulturists as well as determinants of accidents with pesticides.

Keywords: Accidents; Agricultural workers; Pesticides; Risk.

Resumen. La horticultura constituye una actividad de elevado riesgo ocupacional y en Argentina son escasos los estudios que aborden esa problemática. Se identificaron grupos de trabajadores agrícolas en el cinturón hortícola de Córdoba (Argentina) y algunos condicionantes de accidentes laborales con estos productos. Se llevó a cabo un estudio observacional descriptivo mediante encuestas a 101 horticultores indagando aspectos sociodemográficos, productivos y laborales. Un Análisis Factorial de Correspondencias Múltiples (AFCM) permitió visualizar la distribución y covariación de modalidades y establecer tipologías de individuos. La identificación de los accidentes laborales con plaguicidas se llevó a cabo mediante modelos de regresión logística. El AFCM identificó grupos considerados como vulnerables y dados por sujetos que utilizan mochila para aplicar los plaguicidas, aplican una gran variedad de ellos, trabajan en pequeñas unidades de producción y viven en donde trabajan. Asimismo, los accidentes causados por el uso de plaguicidas se asociaron a sujetos que manipulan mayor número de plaguicidas y trabajan en pequeños establecimientos. Como factores condicionantes de la ocurrencia de accidentes se encontró al mayor nivel de escolaridad (OR 4,23 p=0,046), al mayor número de plaguicidas utilizados (OR 5,44; p=0,013) y al bajo nivel de protección personal (OR 4,92; p=0,021). Esta caracterización identifica atributos de vulnerabilidad frente a la exposición a plaguicidas en determinados grupos de horticultores así como también los condicionantes de accidentes laborales con plaguicidas.

Palabras Clave: Accidentes; Trabajadores agrícolas; Plaguicidas; Riesgo.

Introduction

Pesticides are currently defined as a group of products formulated to control pests, including insects, fungi and weeds. Diverse epidemiological and molecular studies show that pesticides used in agriculture and in the home are associated with chronic diseases (López et al. 2012; Alavanja et al. 2013). Pesticides can induce oxidative stress and are known to participate in the promotion and development of various pathologies including diabetes, neurodegenerative and respiratory disorders, re-

productive diseases and cancer (Lopez et al. 2012), and are a growing public health problem (Ventura et al. 2015).

The ubiquity of these substances is well known (Alavanja and Bonner 2012). Their presence in peri-urban areas has gained importance in recent years and in these places of urban-rural transition the problem becomes more complex. "Green belt" is the term given to the network of primary-intensive farming in the landscape around cities of considerable dimensions. Horticulture in these settings includes agro-ecosystems in which there is intensive use of supplies and environmental resources (Mitidieri and Corbino 2012). They are sectors under great pressure from consumer markets, which entails the necessary use of pesticides, which are also a risk for consumers, workers and the environment (Babbit 2010).

Horticulture is one of the main intensive farming activities in Argentina, with a broad geographic distribution and diversity of crops. Covering approximately 230,000 hectares (ha), a multiplicity of climates and with an annual production of 8-10m tonnes, the horticultural sector contributes significantly to the Gross Domestic Product (Fernández Lozano, 2012). Córdoba is the fifth largest province in Argentina in surface area and the second in population. The green belt around Córdoba City (GBCC) ranks third in volume of horticultural production in the country (Colamarino et al. 2006).

Official statistics from the Argentine Superintendencia de Riesgos del Trabajo (Argentine Labor Risks Office 2014) place agriculture, hunting, forestry and fishing as the second most dangerous activity after construction. This has been the case for several decades. In this sector, the rate of occupational accidents and diseases is 79 cases per thousand workers insured. The International Labor Organization considers agriculture as one of the most dangerous sectors in the world (ILO 2011), which is related to the diversity of tasks and situations that expose horticultural workers to physical demands and that have to be considered in the prevention of injuries and accidents (Mittidieri and Corbino 2012; Paunero et al. 2009).

Previous studies describe the use of pesticides and provide preliminary evidence of their impact on the health of agricultural applicators in the province of Córdoba (Lantieri et al. 2009; 2011; Blanco et al. 2014; Butinof et al. 2014; 2015) and on workers in the GBCC (Machado et al. 2011; Butinof et al. 2014). The latter grow vegetables throughout the year and thus have continuous intense exposure to a wide variety of pesticides. Just as in other green belts in the country, living and working conditions in the GBCC are precarious. Work is casual, with widespread use of obsolete technologies, excessive use of pesticides without any knowledge of personal protection measures, the whole family working, low levels of education and long working journeys. All those situations are associated with the occurrence of accidents in this field (Tártara et al. 2004; Souza-Cazadinho and Bocero 2008; Paunero et al. 2009; Machado et al. 2011; Butinof et al. 2014).

The aim of this study was to explore the sociodemographic, productive and working characteristics of GBCC workers, in order to identify groups that are vulnerable to occupational exposure to pesticides and to determine the factors associated with the occurrence of accidents with pesticides in this population.

Materials and methods

A two-years cross-sectional study was conducted (2012-2013). The GBCC is estimated to have some 300-production units (PU) and 1200 horticultural workers. A random sample, of 101 subjects, was selected from that population, using a 5% sampling error.

A semi-structured questionnaire, divided into modules, was prepared and adapted to examine: 1.sociodemographic composition; 2.horticultural production and employment practices; 3.everyday life; and 4.health. The questionnaires were conducted during the meetings organized by the Córdoba Provincial Ministry of Agriculture within the framework of the granting of pesticide applicator licenses. For the purpose of the current research, only the variables from the first three modules were analyzed.

For the occurrence of accidents it has been taken into account those that involved pesticides manipulation (e.g. spills). This variable was inquired according to a dichotomous response (yes/no). Furthermore, it has been asked which product was specifically involved. In order to evaluate the level of protection, compound categories proposed in an earlier study (Dosemeci et al. 2002) were used and adapted locally (Lantieri et al. 2009; 2011). The categories were established according to the type of elements included in

Personal Protective Equipment (PPE), used alone or combined (*table 1*), and weighting the PPE components based on measurements made from monitoring occupational exposure to pesticides during work. For this study, the level of protection was categorized as unprotected (less than 90% protection) or protected (90% protection).

Table 1. Level of personal protection of GBCC workers. 2012-2013

Type of protection	% of protection	Measure adopted
PPE 0	0%	None
PPE 1	20%	Glasses for face protection (Face shields or glasses) Other protective clothing: safety footwear, helmet or cap.
PPE 2	30%	Gas mask. All-weather clothing.
PPE 3	40%	Chemical-proof rubber gloves.
PPE 4	50%	PPE 1 -2
PPE 5	60%	PPE 1 -3
PPE 6	70%	PPE 2 3
PPE 7	90%	PPE 1, 2 and 3

Ethical considerations

This study was approved by the Ethics Committee of the Hospital Nacional de Clínicas (Universidad Nacional de Córdoba), through resolution Nº 135/12. All participants have given their respective informed consent.

Statistical analysis

Univariate and bivariate analysis was performed to describe sociodemographic characteristics, labor and technological practices. A Multiple Correspondence Analysis (MCA) was conducted in order to differentiate groups by similarity and to determine the risk groups in relation to pesticide exposure. Multiple Logistic Regression Models were developed to identify the factors determining labor accidents with pesticides, using the occurrence of accidents as the dependent variable. The co-variables were the quantity of pesticides used, the level of personal protection during the application and mixing of pesticides, the practice of burning pesticide packaging (dichotomous), educational level (low, medium and high), and the land ownership status (owner/tenant and sharecropper/employee). Statistical analyses were performed with SPAD V3.5 (CISIA-CERESTA, 1998, Saint-Mandé, France) and STATA 13.0 (Statacorp LP. CollegeStation, TX, USA) softwares.

Results

The horticultural workers were all male with an average age of 42.94 ± 13.34 years old. Forty eight percent were aged 45 or over and 52% had a low educational level (incomplete or complete primary school). The majority of workers (77%) were married or in a domestic partnership. 77% of workers lived in the same farm where they work and 31% are in family enterprises. 71% of the workers are from Argentina and the others from Bolivia. Sociodemographic characteristics of the sample analyzed are described in *table 2*.

Table 2. Socio-demographic characteristics of GBCC workers 2012-2013

Sociodemographic characteristics	Number	Valid (%)[1]
Age (years old)		
Average	42.94	
Standard deviation	13.34	
≤ 25	13	13
26 – 34	20	20
35 – 44	19	19
45 – 54	26	26
> 55	22	22
Education		
Primary (incomplete)	24	24
Primary (complete)	28	28
Secondary (incomplete)	18	18
Secondary (complete, tertiary or higher education)	31	30
Marital status		
Married or in a domestic partnership	75	77
Single, separated, divorced or widower	22	23
Other members who live in the same house and work in the fields		
Yes	33	31
Country of origin		
Bolivia	29	29
Argentina	71	71
Internal Migration		
Born in Cordoba	62	87
Internal migrants	9	13

[1]Percentage considering the total of responses.

This population has more than 20 years in this activity, with an average of 21.34 ± 14.58 years old. The average age of starting to work with pesticides was 16.3 ± 5.6 years old. *Table 3* summarizes the working, productive and technological aspects of the horticultural workers in the GBCC. The distance from the house to the nearest crop in 38% of cases does not exceed 100 meters and in 49% is not more than 500 m. 58% of the production units are small (≤ 10 ha) and these are the most diversified. The medium-sized establishments share characteristics of small and large establishments, but differ in producing potatoes and carrots. The large holdings (≥ 41 ha) produce potatoes. 71% of the enterprises are small, with an area of up to 10 ha. The type of technology that is typically used for fumigation is the backpack (77%), followed by the trailed crop sprayer with 31%. With respect to the quantity of pesticides used, 45% use between 11 and 20 and 19% of the workers use more than 20 different products.

Groups of workers with specific differentiating characteristics were identified through MCA (*Table 4*). The first factor characterized subjects who use backpack as a method for applying pesticides, spray with a greater variety of pesticides, work in small production units, and live on site, differentiated from those who do not use backpack, use a smaller variety of products and work in larger production units. In the second factor, accidents with pesticides are linked to subjects who use a large number of pesticides and work in relatively small production units, differentiated from those that did not have any accidents, use less quantity of pesticides, are younger and work in larger production units. The third factor distinguishes younger workers who use a greater quantity of pesticides, differentiated from those who use fewer pesticides and have spent more years as horticultural workers.

This population presents an estimated accident rate of 17%. Among the factors identified as associated with the occurrence of accidents, there was a greater number of pesticides used (OR 5.44; p = 0.013), a higher educational level of workers (OR 4.23; p = 0.046), as well as lower PPE level (OR 4.92; p = 0.021) (*Table 5*).

Discussion

Horticultural workers of the GBCC are immersed in a complex risk scenario (Butinof et

Table 3. Labor and technological practices used by GBCC workers. 2012-2013

Labor characteristics	Number	Valid (%)[1]
Area of production units (hectares)		
≤ 5	15	17
6-10	13	14
11-15	8	9
16 - 20	14	16
> 20	40	44
Distance from the house to the nearest crop (meters)		
≤ 50	16	25
51 - 100	8	13
101 - 500	7	11
≥ 501	32	51
Extension of production unit (hectares)		
Small (≤ 10 ha)	57	58
Medium (11 to 40 ha)	34	33
Large (≥ 41 ha)	9	9
Area cultivated by the worker (ha)		
≤ 10	70	73
11-20	11	11
21 - 40	9	9
≥ 41	7	7
Equipment used for the application of pesticides[2]		
Backpack sprayer	77	77
Engine-powered backpack sprayer	7	7
Trailed crop sprayer	28	31
Number of pesticides used		
≤ 10	36	36
11-20	46	45
21-30	14	14
≥ 31	5	5

[1]Percentage considering the total of responses.
[2]The categories of this variable are not excluding each other (a single worker can use one or more methods of application).

Table 4. Description of the axis factoring 1-3 with active and explanatory nominal variables associated with practices, working conditions and the use of pesticides by GBCC horticultural workers, 2012-2013

Significant types	Test value[1]	Significant types	Test value[1]
Factor 1		**Factor 1**	
Backpack use	-6.94	No backpack use	6.77
Use of 11 - 20 pest.	-5.04	Use of < 10 pest.	6.25
Work in < 10 ha	-3.75	Work 21 - 49 ha	3.00
Live in the land	-2.19	Work> 50 ha	3.03
Factor 2		**Factor 2**	
Accidents with pesticides	-6.32	No accidents with pesticides	4.15
Use of 21 - 30 pest.	-5.87	Use of 11–20 pest.	4.83
Work 11 - 20 ha	-2.04	Work > 50 ha	2.41
----		Age < 35 years old	2.51
Factor 3		**Factor 3**	
Age < 35 years old	-2.00	Use of < 10 pest.	3.19
Use of > 31 pest.	-6.45	Seniority > 20 years	3.27

[1]Significant categories for the axis (Z score >1.96 in absolute value)

Table 5. Measures of association estimate (Odds Ratios, OR), their confidence and value intervals- p, for accidents occurring with pesticides taken from the Logistic Regression Model of GBCC workers, 2012-2013

Variables		O.R.	Confidence intervals (95%)		P-value
			Lower	Higher	
Number of pesticides used	Up to 15 pesticides	Reference			
	Between 16 and 30 pesticides	5.446	1.420	20.882	0.013
	31 or more pesticides	2.773	0.211	36.352	0.437
Level of protection	More than 90%	Reference			
	Less than 90%	4.928	1.271	19.106	0.021
Burning of pesticide packaging	No	Reference			
	Yes	3.018	0.723	12.591	0.130
Educational level	Low	Reference			
	Mid and high	4.230	1.029	17.391	0.046
Ownership status of the land	Owner	Reference			
	Tenants	1.072	0.277	4.142	0.919
	Sharecropper/ employee	0.329	0.033	3.274	0.343

al. 2014). There are few studies that analyze the occupational risk involved in horticultural activity, although there are clear attempts to understand the effects of pesticides on the health of these populations. This work identifies horticultural production systems differentiated in terms of the occupational risk they present. The workers associated with small production units are more exposed, given their living and working conditions. Recognizing and evaluating the determinant factors of work exposure to and accidents with pesticides in these production subsystems is fundamental for the formation of preventive policies.

The MCA identified a group of workers who live in small production units, which is typical of this working context. The place where they live provides constant exposure (Quandt et al. 2006; Arcury et al. 2014). The close proximity of the dwellings to the crops entails the non-occupational exposure of the worker after working hours (and para-occupational exposure of the family) and there is growing evidence of the importance of these routes (Quandt et al. 2006; Deziel et al. 2015). In this study, the small production units (with an area of less than 10 ha) constitute 70% of the enterprises. There are other characterizations (Sánchez and Barberis 2013) that consider small production units to be those with less than 20 ha, and it is to be expected that there are shared characteristics between both distinctions. Among small producers, there is more diversification of crops as, not having enough land for large-scale production or access to large-volume marketing, the farmer must work with those crops that are more profitable and require intensive labor (Tártara et al. 2004), which naturally involves larger amounts of agricultural xenobiotics.

The high use of backpacks to apply pesticides among GBCC workers increases health risks (Dosemeci et al. 2002, Ramos et al. 2010; Oliveira Pasiani et al. 2012). Physical exposure due to the use of the backpack sprayer, the lack of maintenance of the equipment, the lack of use of PPE, the size of the fields sprayed, the frequency of pesticide application, and entering recently treated fields, among others, intensify the group's exposure. In contrast,

a group of workers was observed who are judged to have less exposure because they do not use the backpack as application technology but, as workers in medium or large production units, use trailed crop sprayers. There are more of this group in the southern part of the GBCC where there is greater mechanization and larger areas cultivated with less diversification (Tártara et al. 2004), which means that fewer pesticides are used.

The second axis of multidimensional analysis contrasts two scenarios typical of intensive production. Although "medium-sized" (11–20 ha) production units were observed, the characterization mentioned before (Sánchez and Barberis 2013) regards them as small, "… these are family-type, generally diversified, and have less than 20 ha cultivated..." The results of this study indicate that poor working conditions added to the greater number of pesticides used increase the feasibility of accidents with these products. There are prior reports that an increased use of pesticides in areas with intensive agriculture may lead to adverse effects, since the farmers may use excessive quantities without adequate protective measures (Damalas and Hashemi 2006; Palis et al. 2006).

A distinct group characteristic in the analysis is the use of a greater amount of chemicals reported in small production units where there is a higher likelihood of accidents. Our results indicate that those using between 16 and 30 pesticides have approximately 5 times higher chances of having accidents with these products. Several studies have reported health risks in employment practices associated with the use of a broad spectrum of pesticides (Tártara et al. 2004; Paunero et al. 2009; Butinof et al. 2015). From a preventive perspective, it is essential to highlight that the people who have suffered accidents while handling pesticides may have permanent consequences which, far beyond the time it takes them for them to show, could impact their future social and work performance (Souza-Cazadinho and Bocero 2008).

The MCA shows fewer accidents occurring in production units larger than 50 ha. The previous classification (Sánchez and Barberis 2013) showed that there are systems with areas greater than 20 ha that base their production on the cultivation of potatoes and other vegetables, in business-style establishments, with little diversification and with high technology (Tártara et al., 2004; Sánchez and Barberis 2013). Our results showed that in this sector, with a higher technological level, workers are generally younger and the range of pesticides used is less varied than in the first scenario, which goes along with the lesser crop diversification. They also show that younger workers (< 35 years old) suffer fewer accidents. Other publications (Tártara et al. 2004), report that the farmer's age is negatively related with the adoption of new technologies (ANT) in the GBCC. It was thus interpreted that the ANT has a protective effect against the occurrence of accidents. This is supported by the fact that the level of adoption depends on the size of the farm, since as the larger the area, the more innovative is the behavior, which accounts for the lower occurrence of accidents in larger farms. Likewise, research in Greece found that young farmers showed higher levels of risk perception concerning potential adverse health effects of pesticides, higher levels of adoption of some practices and more frequent use of PPE (Damalas and Hashemi 2006). The higher educational level in the younger population (Lantieri et al. 2009; 2011; Blanco et al. 2014; Butinof et al. 2014; 2015) seems to have a protective effect against accidents occurring with pesticides. Educational level is an indicator associated with better health conditions, and a protective effect against poisoning with pesticides (Oliveira-Silva et al. 2001; Moreira et al. 2002; Faria et al. 2004; Gomide 2005).

Our results also show two well-defined groups in terms of technological innovation. Current trends in technology seem to be mostly assimilated by the younger population who have a higher level of education than the older population and consume more of the technology available in the market. A study divided Córdoba province into agro-ecological areas and found that the northwest area, with a recent technological boom, had a higher percentage of young subjects with higher levels of PPE use (Blanco et al. 2014). The sub-group of those who have been working more than 20 years in horticulture, according to findings from other studies, maintains habits and traditions inherited from their families (Machado et al. 2011). These are the older subjects,"... the older ones are traditionalists and the young ones tend to be more innovative (Tártara et al. 2004)…", which may account for the lesser variety of pesticides used. Furthermore, as men-

tioned earlier, the older workers have low levels of education (Butinof et al. 2014). A study in Brazil showed that the large number of illiterate people hindered the change from beliefs to opinions (Gomide 2005). Both groups in this factor show protective as well as risk characteristics in relation to work with pesticides. For the first, although young workers use a great number of pesticides, they have a higher level of education and more innovative behavior, and as a result, better working conditions. In the other, although they may use less variety of pesticides, their number of years in the job increases the effect of accumulated exposure over time.

A higher educational level does not necessarily activate mechanisms protective of health in work with pesticides (Machado et al. 2011). This finding was evidenced here by means of a logistic regression analysis (*Table 5*). The logistic model also showed that the occurrence of accidents is associated with low levels of personal protection. There is profuse evidence of the mitigating character of the use of PPE in relation to exposure to pesticides (Weng and Black, 2015). In the Córdoba population of agricultural applicators, it has been noted that workers who use less PPE are more exposed to pesticides (Lantieri et al. 2009; 2011; Butinof et al. 2014; 2015). The elements found in the second factor confirm the higher incidence of accidents among those who use more quantities of pesticides. The co-variables of ownership status of the land and burning of pesticide packaging were included in the analysis because of their known role as risk determinants in this sector (SAyDS, OPS and AAMMA 2007) although no statistically significant associations were found.

One limitation of this work is that it was difficult to have access to immigrant workers due to their hidden status (Machado et al. 2014), which implies that their labor status is probably underrepresented. This group seems to have less favorable working conditions than those analyzed in this work. However, this work presents substantial evidence on differences by type of production, which is of great importance when characterizing labor risks in horticultural settings.

Growing efforts are currently being made to deal with poor working and living conditions and the excessive use of pesticides in horticulture sector. This study identifies shared and differential attributes of horticultural workers, helping to build complex scenarios of occupational risk. Factors associated with the occurrence of accidents with pesticides in the workplace were identified, which provides some tools for the development of preventive measures.

The strength of this work is that it supplies objective and reliable information about the situation of GBCC workers who are immersed in a complex setting influenced by multiple factors. This is undoubtedly a high risk situation that highlights the role of chronic exposure to pesticides. The determinant factors of exposure and of occupational accidents with pesticides differ according to the different production scenarios within horticulture in Córdoba. These differences must be recognized when conducting studies on health damage due to exposure to pesticides.

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