ABSTRACT
Brazil is the third largest market and the eighth largest consumer of pesticides per hectare in the world, with herbicides and insecticides accounting for 60% of the products traded in the country. The use of pesticides has increased worldwide in the last decades, which may represent a risk for several diseases in humans, including cancer. Although in Brazil the research on the impact of the use of pesticides on human health has grown in recent years, it is still insufficient to really know the real dimension of health damage caused mainly by occupational and food exposure, due to the intensive use of pesticides. This article aims to review the use of pesticides by rural workers in Brazil, highlighting the importance of preventive measures for their health.

Keywords: health disorders; occupational health; cancer; genotoxicity; oxidative stress; strategies.

RESUMO
O Brasil é o terceiro maior mercado e o oitavo maior consumidor de agrotóxicos por hectare do mundo, com herbicidas e inseticidas correspondendo a 60% dos produtos comercializados no país. O uso de agrotóxicos tem aumentado em todo o mundo nas últimas décadas, o que pode representar um risco para diversas doenças em humanos, incluindo o câncer. Embora, no Brasil, a pesquisa sobre o impacto do uso de agrotóxicos na saúde humana tenha crescido nos últimos anos, ainda é insuficiente para de fato conhecer a real dimensão dos danos à saúde, causados principalmente pela exposição ocupacional e alimentar, em virtude da utilização de agrotóxicos. Esta revisão tem por objetivo destacar o uso de pesticidas por trabalhadores rurais no Brasil, evidenciando a importância de medidas preventivas para a saúde do trabalhador.

Palavras-chave: transtornos de saúde; saúde ocupacional; câncer; genotoxicidade; estresse oxidativo; estratégias.
INTRODUCTION

Pesticides, according to the World Health Organization (WHO, 2008), is any substance capable of controlling a pest that can have consequences for both the population and the environment. Among the countries with agricultural power involving the consumption of herbicides, fungicides and agricultural insecticides, Brazil ranks first in the Latin American and Caribbean Newsletter, dated 23 of April 2011 (STÉDILE, 2012; NEVES, 2017).

In Brazil, the diversity of agrochemicals is big, about 300 active principles in more than 2 thousand commercial formulations (NEVES, 2017). Humans are often their final recipients, and they can be found in the soil, water, air, in animals and vegetables, being thus considered with great capacity of dispersion (NEVES, 2017). Different symptoms are caused by pesticide poisoning, mainly among farmers, and may even make them stop working and having to look for another type of profession. Among the symptoms, we can highlight anemia, headache, dysthymia, decreased immune defenses, sexual impotence, insomnia, changes in arterial depression and behavioral disorders (LEVIGARD; ROZEMBERG, 2001; SOUZA et al., 2011).

With its effect based on insect neurotoxicity, dichlorodiphenyltrichloroethane (DDT), is a widely known pesticide, mainly because it is sold at a low cost and can act for several years (STOPELLI; MAGALHÃES, 2005). However, it has some limitations: insects have developed resistance to it and experiments with animals showed their carcinogenicity (SMITH; GANGOLLI, 2002; STOPPELLI; MAGALHÃES, 2005). Already in humans, high concentrations of Dieldrin in the blood, for example, have a greater amount of thyroid stimulating hormone (TSH), presenting hypothyroidism. Therefore, this pesticide and other organochlorines act as neurotoxicants, as well as in the endocrine function (RATHORE et al., 2002; STOPPELLI & MAGALHÃES, 2005).

Many studies have presented promising results and made important conclusions beyond the use of pesticides by rural workers, allowing a better understanding of the consequences of its use. Due to the accumulated knowledge, we aimed at conducting a survey on the most important and promising researches on the use of pesticides by rural workers in Brazil until now.

THE BRAZILIAN SITUATION

Because of agricultural practices in the country, around the 1960s the whole scenario underwent modifications leading to a record consumption of agrochemicals and a chemical-dependent context of food production (ABREU; ALONZO, 2014; JACOBSON et al., 2009). In the global context, since 2008 Brazil has become the largest consumer of pesticides (CARNEIRO et al., 2012; AUGUSTO et al., 2012; RIGOTTO et al., 2012), standing out as the world’s largest agricultural producer. Brazil shows growth rates of 10% per year (AGRONEWS, 2014; BRASIL, 2015; GONÇALVES, 2016) and exports food to 180 countries, being the world’s leading exporter of soybeans in grains, sugar, coffee, orange juice, beef and chicken (BRASIL, 2013; GONÇALVES, 2016). According to IBAMA (2002), the states of Mato Grosso, São Paulo, Paraná, Rio Grande do Sul, Goiás, Minas Gerais, Bahia and Mato Grosso do Sul are the main consumer states of agrochemicals (Figure 1).

Especially for the rural worker, along with the evolution of techniques and the use of agricultural inputs, there have been harmful changes in health, mainly related to the loads, ways of working and risks incorporated into these new activities (STOPPELLI & MAGALHÃES, 2005). These risks involve both acute intoxications, with the onset of symptoms fast after excessive exposure, including weakness, vomiting, nausea, seizures, muscle contractions, headaches, difficulty breathing, nasal bleeding and fainting, as well as chronic intoxication. In these, the symptoms are late after months or years, caused by small or moderate exposure to toxic products or multiple products. This type of exposure causes irreversible damage, such as paralysis and neoplasia (PERES, 1999; STOPPELLI & MAGALHÃES, 2005), contact dermatitis, renal and hepatic lesions, delayed neurotoxic effects, chromosomal abnormalities, Parkinson’s disease, cancers and teratogens (WILSON; OTSUKI, 2004; STOPPELLI & MAGALHÃES, 2005). Table 1 shows the main studies carried out to date specifically related to the exposure of the rural worker to pesticides in Brazil. Electronic databases were collected from PUBMED and “Portal de Periódicos” from CAPES/MEC (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior/ Ministério
Impact of the use of pesticides by rural workers in Brazil

Figure 1 – Federation sales of agrochemicals by Unit in 2017.

Table 1 – Update of the main publications related to the use of pesticides by rural workers in Brazil.

<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>High frequency hearing loss; Noise exposure; Quality of life</td>
<td>Pure-tone audiometry, distortion product otoacoustic emissions, and high-frequency audiometry tests were performed. This report is unusual because of the short time of exposure to noise and pesticides and the hearing loss found, indicating a synergy between those agents.</td>
<td>Pure-tone audiometry, distortion product otoacoustic emissions, and high-frequency audiometry tests.</td>
<td>Sena et al.</td>
<td>2018</td>
</tr>
<tr>
<td>ES</td>
<td>Beck Depression Inventory-II (BDI-II); Depressive Symptoms; Mental Health</td>
<td>Pesticide exposure, tobacco use, poor self-perceived health and the presence of chronic disease contribute as risk factors for the appearance of depressive symptoms at a level above ups and downs considered normal in the BDI-II.</td>
<td>Questionnaire</td>
<td>Conti et al.</td>
<td>2018</td>
</tr>
</tbody>
</table>


*No definition: sum of marketed quantities whose companies are not able to specify the territorial distribution of sales, since it is an activity carried out by third parties.
<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC</td>
<td>Artificial Targets; Tractor Cabins; Exposure Evaluation; Fenitrothion; Crop Pulverization</td>
<td>Sealed cabin minimized the exposure of the operator to the pesticides, since all samples analyzed showed fenitrothion values below the limit of detection.</td>
<td>Ultrasonic extraction</td>
<td>Barcellos et al.</td>
<td>2016</td>
</tr>
<tr>
<td>RS</td>
<td>Agrochemicals; Work Environment; Practical Nursing.</td>
<td>Rural workers who apply pesticides present a higher prevalence of dermatological alterations.</td>
<td>Questionnaire</td>
<td>Cezar-Vaz et al.</td>
<td>2016</td>
</tr>
<tr>
<td>RS</td>
<td>Wheezing; Asthma; Tobacco; Rural Health; Prevalence</td>
<td>Pesticides, dusts exposure, and green tobacco sickness were risk factors for wheezing.</td>
<td>Questionnaire</td>
<td>Fiori et al.</td>
<td>2015</td>
</tr>
<tr>
<td></td>
<td>Brazilian micro-region</td>
<td>Suicide rates have increased in middle age (35–64 years) and younger men (15–34 years). Micro-regions with a higher use of pesticides showed higher rates of suicides. Pesticide poisoning effect on suicide rates was stronger than use of pesticide. Reinforces the hypothesis that pesticide use and pesticide poisoning increase the suicide rates.</td>
<td>Crude suicide rates of a 15-year time series (1996–2010) were examined, followed by an ecological study using age-standardized suicide rates for the period 2006–2010.</td>
<td>Faria et al.</td>
<td>2014a</td>
</tr>
<tr>
<td>MG</td>
<td>Health and Epidemiological Surveillance; Health Policies</td>
<td>The conclusion is the pressing need to develop a model for sustainable agriculture, healthy, free of pesticides and that organized society and responsible institutions must undertake actions that meet the needs of the people who work in the farms or consume agricultural products harvested there, especially controlling risks and consequences that can and must be avoided.</td>
<td>Questionnaire</td>
<td>Nasrala Neto, Lacaz and Pignati</td>
<td>2014</td>
</tr>
<tr>
<td>RS</td>
<td>Poisoning; Mental disorders</td>
<td>Reinforces the evidence of the association between pesticide poisoning and mental health disorders. It also points to increased risk of minor psychiatric disorders from low socioeconomic status, dermal pesticide exposure and exposure to organophosphates. Reveals intense nicotine exposure as a risk for tobacco farmers’ mental health.</td>
<td>Characterizing economic indicators of the farms, socio-demographic factors, lifestyle habits and occupational exposures.</td>
<td>Faria et al.</td>
<td>2014b</td>
</tr>
</tbody>
</table>

Table 1 – Continuation.
### Table 1 – Continuation.

<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>Rural Population; Quality of life</td>
<td>Agricultural workers users of pesticides showed the worst levels of quality of life when compared to those who have not handled them. The use of pesticides and their toxicity class interfered in a most striking way in the classification of hearing loss presented by this group.</td>
<td>Audiological evaluation</td>
<td>Sena, Vargas and Oliveira</td>
<td>2013</td>
</tr>
<tr>
<td>RJ</td>
<td>Risk Perception; Risk Communication; Defensive Strategies; Community-Based Participatory Research</td>
<td>Risk perceptions and work practices are strongly influenced by local cultural patterns and, therefore, must be taken into account when developing effective intervention strategies, including risk communication initiatives.</td>
<td>Questionnaire</td>
<td>Peres et al.</td>
<td>2013</td>
</tr>
<tr>
<td>RJ</td>
<td>Small holders; Environment Human health</td>
<td>Do not confirm that the farmers’ apparent careless handling of pesticides is linked to an intentional disregard for intoxication risk. The results point to a more complex set of explanatory variables that include: labor scarcity, inadequacy of protective gear, mixing practices and limited educational effectiveness of labeling standards.</td>
<td>Questionnaire</td>
<td>Pedlowskia et al.</td>
<td>2012</td>
</tr>
<tr>
<td>DF</td>
<td>Knowledge, attitudes, and practices study; Acetylcholinesterase; Butyrylcholinesterase</td>
<td>Although most farmers were aware that pesticides can harm their health, many still use PPDs in an inappropriate manner, or not at all, during pesticide handling. Inhibition of ChE activity during the exposure period for some farmers was higher than the safe, indicating that they might be at risk by the exposure to pesticides during their agricultural activities.</td>
<td>Questionnaire and Blood sample</td>
<td>Pasiani et al.</td>
<td>2012</td>
</tr>
<tr>
<td>RJ</td>
<td>Hearing; Auditory Perception; Adverse Effects.</td>
<td>Workers exposed to pesticide performed below-average on Temporal Auditory Processing tests. There was association between the index of exposure to pesticides and worse performance in Temporal Auditory Processing tests, suggesting that pesticides may be harmful to central auditory pathways.</td>
<td>Questionnaire, meatoscopy, basic audiological evaluation and temporal auditory processing tests.</td>
<td>Bazilio et al.</td>
<td>2012</td>
</tr>
</tbody>
</table>

Continue...
### Table 1 – Continuation.

<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>RJ</td>
<td>Health Indicators; Rural Labor; Public Health</td>
<td>The volume of the determinants identified in the DPSEEA Matrix are related to deficiencies in actions for monitoring and surveillance of pesticide use, as well as the lack of technical assistance provided by the Public Sector.</td>
<td>DPSEEA model (WHO) based on analysis of official public documents.</td>
<td>Araújo-Pinto, Peres and Moreira</td>
<td>2012</td>
</tr>
<tr>
<td>PR</td>
<td>Poisoning; Economy; Health expenditures</td>
<td>Society, especially the population most affected by agrochemicals, would benefit if the risks of acute intoxication associated with the current model of agricultural production were recognized and eliminated.</td>
<td>Information obtained from Pesquisa de Previsão de Safras from 1998 to 1999.</td>
<td>Soares and Porto</td>
<td>2012</td>
</tr>
<tr>
<td>RJ</td>
<td>Mortality rates; Hospitalization rates attributable to suicide attempts; Sales of pesticides</td>
<td>Pesticide exposure may indeed increase the risk of suicide frequency, especially among agricultural workers.</td>
<td>Data on mortality rates, hospitalization rates attributable to suicide attempts, and data on sales of pesticides.</td>
<td>Meyer et al.</td>
<td>2010</td>
</tr>
<tr>
<td>MG</td>
<td>Rural Settlements; Social Conditions; Family Health; Rural Health; Food Security; Rural Population Health; Landless Worker Movement.</td>
<td>The view held by families from the Landless Rural Workers’ Movement was that as they belonged to the Movement and were better organized, their health was better than the temporary rural workers’. The conservative modernization of rural Brazil has led to worse conditions for temporary rural workers, while Agrarian Reform has allowed for a better quality of life and improved health conditions among families in the areas under study.</td>
<td>Questionnaire</td>
<td>Carneiro et al.</td>
<td>2008</td>
</tr>
<tr>
<td>RJ</td>
<td>Environmental Pollution</td>
<td>Discusses several pesticide-related implications for human health and the environment in the mountainous region of the State of Rio de Janeiro, an important farming center. The article presents the results of the research in the area, identifying possible determinants of the current situation and some of the main challenges in dealing with the problem.</td>
<td>Survey</td>
<td>Peres and Moreira</td>
<td>2007</td>
</tr>
</tbody>
</table>

Continue...
These results indicate recurrent multiple overexposures to high concentrations of different chemicals, with serious damage to vital functions, especially considering their young age (average 35 ± 11 years old) and the productive period in their lifetime.

While a few Behavioral Assessment and Research System (BARS) performance measures suggested behavioral impairments for the rural versus the urban participants, a stronger and more consistent association between BARS measures (especially impairment of tapping, digit span, and selective attention) and level of exposure to pesticides was noted when the exposure index was input into a multiple linear regression analysis. Exposure seemed to be especially strong for the youngest participants (10-11 years old).

About 92% of the interviewees had worked directly with pesticides and 59.6% reported typical intoxication symptoms. Only 44.3%, however, believe they had been intoxicated. A significant correlation was found between hand washing after pesticide application and reporting symptoms. Less than 20% used masks, impermeable clothes, or gloves during pesticide application.

Results showed that the inclusion of risk-perception studies in the development of educative and risk-communication campaigns is very important, linking research to action.
<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>RJ</td>
<td>Risk; Rural Population</td>
<td>Results pointed to the importance of risk perception analysis in the process of developing strategies of intervention in rural areas, especially in policies and educational risk communication campaigns.</td>
<td>Questionnaire and assessment of local work processes.</td>
<td>Peres, Rozemberg and De Lucca</td>
<td>2005</td>
</tr>
<tr>
<td>MS</td>
<td>Suicide; Poisoning</td>
<td>Poisonings occurred mostly from October to March and the organophosphate insecticides monocrotophos and methamidophos were the main pesticides involved.</td>
<td>Reports from 1992 to 2002, using data from the Integrated Center for Toxicological Surveillance under the State Health Department.</td>
<td>Pires, Caldas and Recena</td>
<td>2005</td>
</tr>
<tr>
<td>RJ</td>
<td>Agriculture; Pesticide Exposure</td>
<td>Highlights health professionals’ discourse in relation to the association between “nervousness” and pesticides. The authors discuss factors related to this perception and make several suggestions for future research.</td>
<td>Questionnaire</td>
<td>Levigard e Rozemberg</td>
<td>2004</td>
</tr>
<tr>
<td>RS</td>
<td>Pesticide Exposure; Incidence</td>
<td>Based on Poison regression, applying pesticide, reentering crop fields after spraying and working with pesticides in more than one farm were the types of exposure that presented a positive correlation with pesticide poisoning.</td>
<td>Questionnaire</td>
<td>Faria et al.</td>
<td>2004</td>
</tr>
<tr>
<td>MG</td>
<td>Risk Factors; Poisoning; Rural Health</td>
<td>The results emphasize the high level of health risk associated to pesticide use among rural workers.</td>
<td>Questionnaire. Data obtained through the Jorge Duprat Figueirêdo Foundation for Workers’ Safety and Occupational Medicine.</td>
<td>Soares, Almeida and Moro</td>
<td>2003</td>
</tr>
<tr>
<td>MG</td>
<td>Economic Assessment</td>
<td>Points to the need for an extensive investigation on the real benefits of pesticide use and its consequences for the environment and health in Brazil.</td>
<td>Data were obtained from the Fundacentro Ministry of Work agency for the years 1991-2000</td>
<td>Soares, Moro and Almeida</td>
<td>2002</td>
</tr>
</tbody>
</table>

Table 1 – Continuation.
## Table 1 – Continuation.

<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>RJ</td>
<td>Communication; Health Education; Interview; Communication and Health.</td>
<td>This study pointed out to the historical misinformation on pesticides in rural areas.</td>
<td>Questionnaire</td>
<td>Peres et al.</td>
<td>2001</td>
</tr>
<tr>
<td>RJ</td>
<td>Insecticides; Organophosphate; Poisoning; Socioeconomic Factors; Carbamates; Cholinesterase Inhibitors; Blood.</td>
<td>A result of 3.0 % was found for the BChE values, and 41.8 %, according to AChE. Individuals with at least one positive enzymatic indicator result were considered as “intoxicated”. When these data were compared to the social-economic and pesticides use factors, the importance of the educational level in the prevalence of intoxication was highlighted.</td>
<td>AChE and BChE activities</td>
<td>Oliveira-Silva et al.</td>
<td>2001</td>
</tr>
<tr>
<td>PE</td>
<td>Tomatoes; Environment Impacts; Health Surveillance.</td>
<td>There is a lack of effective policies to protect the health of rural workers who must deal with pesticides and the environment which has already been severely damaged.</td>
<td>Questionnaire</td>
<td>Araújo, Nogueira and Augusto</td>
<td>2000</td>
</tr>
<tr>
<td>RS</td>
<td>Pesticide Poisoning; Occupational Accidents; Agriculture</td>
<td>The high prevalence of health problems identified in the study calls attention to the need for measures to promote and protect rural workers’ health.</td>
<td>Questionnaire</td>
<td>Faria et al.</td>
<td>2000</td>
</tr>
<tr>
<td>RS</td>
<td>Mental Health; Poisoning; Educational Status.</td>
<td>The results call attention to the problem’s dimension and to the importance of adopting new policies to protect farm workers’ mental health.</td>
<td>Questionnaire</td>
<td>Faria et al.</td>
<td>1999</td>
</tr>
<tr>
<td>RJ</td>
<td>Ddt; Dieldrin; Occupational Exposure</td>
<td>Serum concentrations of organochlorine pesticides found in this study are comparable to the levels reported for the non-occupationally exposed population in Brazil and elsewhere.</td>
<td>Blood samples, Serum levels of organochlorine pesticides measured.</td>
<td>Paumgartten et al.</td>
<td>1998</td>
</tr>
<tr>
<td>BA</td>
<td>Occupational and Environmental Exposure</td>
<td>Rural workers and public health authorities must become aware of the importance of protective equipment, periodic health examinations and reduced environmental pollution in order to lessen occupational risks of field workers and promote improved conditions of life for the rural population.</td>
<td>Parameters of biochemistry, hematology, and organochlorine pesticide residues in the blood.</td>
<td>Carvalho</td>
<td>1991</td>
</tr>
</tbody>
</table>

Continue...
### Table 1 – Continuation.

<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>CNS Magnese Intoxication</td>
<td>Occupational exposure to pesticides containing Mn is a possible source of Mn intoxication of the CNS.</td>
<td>Mn intoxication</td>
<td>Ferraz et al.</td>
<td>1988</td>
</tr>
<tr>
<td>SP</td>
<td>Machine Learning; Genotoxicity Micronucleus; Smoking; Agriculture</td>
<td>Exposing agricultural workers to pesticides and/or tobacco had genotoxic potential, but concomitant exposure to xenobiotics did not lead to additive or potentiating effects.</td>
<td>Oral mucosa cells, cytogenetic analysis</td>
<td>Tomiazzi et al.</td>
<td>2018</td>
</tr>
<tr>
<td>SC</td>
<td>DNA Damage; Oxidative Stress</td>
<td>Exposed individuals, participants of this study, are more subject to suffer genetic damage and, consequently, more susceptible to diseases resulting from such damages</td>
<td>Blood samples, comet assay and the cytokinesis-block micronucleus technique and thiobarbituric acid reactive substance and catalase activity.</td>
<td>Hilgert Jacobsen-Pereira et al.</td>
<td>2018</td>
</tr>
<tr>
<td>MG</td>
<td>Genotoxicity Test; Bioindicators and Clinical Evaluation</td>
<td>The group exposed to organophosphates presented significant changes in all these parameters compared to the control group and showed significant changes in budding, condensed chromatin and karyolytic cells compared to the group non-exposed to organophosphates. Data from clinical evaluation showed significant changes in the central nervous, respiratory and auditory systems.</td>
<td>Blood, urine and buccal samples, activities of cholinesterases, levels of urinary dialkyl phosphates, genotoxicity data, from a comet assay.</td>
<td>Silvério et al.</td>
<td>2017</td>
</tr>
<tr>
<td>RS</td>
<td>Skin Neoplasms; Occupational Risks; Oncology Nursing; Clinical Competence; Health Communication</td>
<td>This study’s results allowed to clarify the combination of clinical knowledge and risk communication regarding skin cancer to rural workers.</td>
<td>Observational-exploratory study</td>
<td>Cezar-Vaz et al.</td>
<td>2015</td>
</tr>
<tr>
<td>RS</td>
<td>Oxidative stress, TBARS, protein carbonyls.</td>
<td>The results demonstrated a change in the oxidative status of rural workers compared to the control group, mainly by possible inhibition of AChE activity and the occurrence of oxidative stress without showing changes in biochemical parameters.</td>
<td>Questionnaire and blood sample</td>
<td>Murrussi et al.</td>
<td>2014</td>
</tr>
</tbody>
</table>

Continue...
<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>RJ</td>
<td>Brain Cancer; Age-Period-Cohort; Agriculture; Trend</td>
<td>There is an increasing trend in brain cancer mortality rates in the rural Serrana Region in Brazil. At the ecological level, different environmental factors, especially the use of pesticides, may explain regional disparities in the mortality patterns from brain cancers.</td>
<td>Descriptive study examined brain cancer mortality who died between 1996 and 2010.</td>
<td>Miranda Filho <em>et al.</em></td>
<td>2014</td>
</tr>
<tr>
<td>GO</td>
<td>Occupational Exposure; DNA Damage; MN Comet Assay</td>
<td>Occupational exposure to pesticides could cause genome damage in somatic cells, representing a potential health risk to rural workers that constantly deal with agrochemicals without adequate personal protection equipment.</td>
<td>Micronucleus and the comet assay.</td>
<td>Khayat <em>et al.</em></td>
<td>2013</td>
</tr>
<tr>
<td>GO</td>
<td>Polymorphism GST; Biomarkers</td>
<td>The authors could not associate a null GSTT1 or null GSTM1 polymorphisms or both to intoxication events caused by pesticides, but instead they presented the importance of using Personal Protection Equipment to prevent such harm.</td>
<td>Blood sample</td>
<td>Godoy <em>et al.</em></td>
<td>2014</td>
</tr>
<tr>
<td>CE</td>
<td>Biomonitoring; Human Lymphocytes; Comet Assay; Chromosomal Aberrations</td>
<td>Damages caused by pesticides in our study area were not great enough to induce permanent mutations or to interfere with mitotic apparatus formation; minimal pesticide damages could have undergone cellular repair, explaining the absence of structural and numerical chromosome aberration.</td>
<td>Alkaline comet assay and the chromosome aberration test.</td>
<td>Paiva <em>et al.</em></td>
<td>2011</td>
</tr>
<tr>
<td>PE and AL</td>
<td>Carcinogenesis; Analysis of Principal Components</td>
<td>Both endosulfan and its metabolites are electrophilic and have carcinogenic potential.</td>
<td>Electronic parameters (Electron affinity, dipole moments, electrostatic attraction, formation heat and permeability of the cell membrane).</td>
<td>Bedor <em>et al.</em></td>
<td>2010</td>
</tr>
</tbody>
</table>

Table 1 – Continuation.
### Table 1 – Continuation.

<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>Cancer; Agriculture;</td>
<td>Cancers of the skin and digestive system were the most prevalent.</td>
<td>Database containing records of Amaral Carvalho Hospital.</td>
<td>De Brito Sá Stopelli and Crestana</td>
<td>2005</td>
</tr>
<tr>
<td>SP</td>
<td>Chromosome Aberrations; Toxicology; Contamination.</td>
<td>Although workers used protection against the pesticide’s fog, the results revealed that they were contaminated with the pesticides.</td>
<td>Toxicological dosages of copper, zinc and manganese, hepatic enzyme dosage and acetylcholinesterase activity</td>
<td>Brega et al.</td>
<td>1998</td>
</tr>
</tbody>
</table>

**REPRODUCTIVE HORMONES, SPERM QUALITY**

<table>
<thead>
<tr>
<th>State</th>
<th>Target</th>
<th>Major findings</th>
<th>Methodology</th>
<th>Reference</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS</td>
<td>Agricultural Workers; Anogenital Distance; Fungicides; Herbicides; Reproductive Hormones; Sperm Quality</td>
<td>Chronic occupational exposure to modern pesticides, particularly herbicides and fungicides, may adversely affect semen quality in young male farmers, potentially leading to poorer morphology. Also, exposure to agricultural pesticides may acutely increase prolactin and chronically alter sex hormone levels acting at the pituitary level through prolactin and LH suppression, hampering compensatory responses to testicular dysfunction.</td>
<td>Reproductive hormones, semen quality, and genital measures</td>
<td>Cremonese et al.</td>
<td>2017</td>
</tr>
</tbody>
</table>

| RJ    | Endocrine disruptors; Estrogenic compounds; Organochlorines; Testosterone | Seem to support the known capacity of organochlorines pesticides to exert estrogenic and anti-androgenic activity, affecting sex hormone systems through mechanisms of action that may be different for each individual compound. | Interviews and blood sample. | Freire et al. | 2014 |

da Educação). The majority of the articles are related to health disorders and occupational health, such as mental disorders, asthma, hearing, suicide, and poisoning.

Reflecting the importance of agriculture to the country’s economy, Brazil has a vast legislation specifically designed to regulate the stages of the agrochemicals’ life cycle at Federal and State level (GONÇALVES, 2016). All states have a pesticides register and authorization in their territory, but it also left some open controversial points regarding evaluation parameters and the attribution of inspection to the public power (GONÇALVES, 2016). Consequently, according to Pelaez, Terra and Silva (2010) there is a conflict of interests due to the ability of regulators, regulated companies and the companies themselves in adapting to the more stringent criteria for registering toxic substances (PELAEZ; TERRA; SILVA, 2010; GONÇALVES, 2016). There are studies that prove the contamination caused by the indiscriminate use of pesticides in different regions of Brazil (ALBUQUERQUE et al., 2016; CALDAS; ZANELLA; PRIMEL, 2011; RISSATO et al., 2007; LAABS et al., 2002; CALDAS et al., 1999; Laabs et al., 2002; Alho; VIEIRA, 1997); however, this gap between Brazilian and state legislation leads to a panorama of uncertainties about the extent and degree of environmental contamination, as well as the dimension of effects to the human health and to the environment. Since there are no equal control procedures throughout the national territory, there are vulnerabilities associated with the use of agrochemicals. The European Union, one of the world’s largest food producers and holding the position of the world’s largest wheat producer, is in the process of implementing the world’s most rigorous plan to reduce the use of pesticides. It culminated in the adoption of the Directive 2009/128/CE on the sustainable use of pesticides, whose complete implementation is planned for 2020 (GONÇALVES, 2016).

**Health disorders and Occupational health**

As a result of the analysis of the selected articles, four thematic categories emerged, the first three being linked to the problems that the use or misuse of pesticides generate to the environment and human health and a category linked to the appropriate practices:

- Health disorders and Occupational health;
- Genotoxicity of pesticides;
- Reproductive hormones and Sperm quality;
- Practices to reduce exposure.

Using AChE and BChE analysis, Oliveira-Silva et al. (2001), evaluated the exposures of rural workers of Rio de Janeiro State to anticholinesterasic pesticides. According to the authors’ results and to the enzymatic indicator used, data were distinct concerning the incidence of excessive exposure. In the studied sample, a result of 3.0% was found for BChE values, and 41.8% according to AChE. Individuals with at least one positive enzymatic indicator result were considered as “intoxicated”. Considering these data and comparing them to the social-economic and pesticides use factors, the importance of educational level in the prevalence of intoxication was showed. The other indicators studied did not show any significant and evident correlation (OLIVEIRA-SILVA et al., 2001). In the same way, Pasiani et al. (2012) conducted a knowledge, attitudes, and practices (KAP)/biomonitoring study in an agricultural setting in Midwestern Brazil. For this purpose, they assessed the knowledge, attitudes, and practices regarding the use of pesticides by farmers in two rural settings and calculated the farmers and residents’ levels of exposure to organophosphorous and carbamate pesticides through red cells (AChE) and plasmatic butyrylcholinesterase (BChE) analysis. In relation to these last analyses, for some farmers, the authors found higher activity of cholinesterase inhibition during the exposure period compared to what is considered safe. This may indicate that they might be at risk by the exposure to pesticides during their agricultural activities. AChE activity depletion was also found in family farming settings, and thus may also be at risk from secondary exposure to pesticides (PASIANI et al., 2012).

From an epidemiological, clinical and laboratory aspects study of multiple exposure to pesticides in a representative sample of 102 small farmers, Araújo et al. (2007), brought some light to moderate episodes of acute intoxication by organophosphorates either described by the farmers or observed during clinical examination. Thirteen cases of delayed neuropathies were diag-
nosed and 29 cases of neural behavioral syndromes and psychiatric disorders associated to the continued use of pesticides. From these results, they found recurrent multiple overexposures to high concentrations of different chemicals that may cause serious damage to vital functions, if considered their young age (average 35 ± 11 years old) and the productive period in their lifetime (ARAUJO et al., 2007).

Genotoxicity of pesticides

The harmful effects on the health of rural workers, who are chronically exposed to mixtures of agrochemicals, are still little elucidated. In Brazil, Antonucci e Syllas (2000) found a positive relationship between genotoxicity and farmers in Parana, and Silva et al. (2008) in winery workers in Rio Grande do Sul, being observed chromosomal aberrations as genotoxicity markers (SILVA, 2012).

Among the most serious damage caused by pesticides, genotoxicity or genetic toxicology seeks to identify the action of agents that produce toxic and genotoxic effects on the genetic material. From the interaction between our genetic material and genotoxic agents, the formation of adducts, oxidative alterations or even the breakdown of DNA molecules can happen (SILVA, 2012). The elimination of this cell or its repair by the organism usually occurs, however, if the lesion is fixed it will probably cause mutations, that is, hereditary alterations. Thus, there will be a mutagenic effect, where during the replication process the perpetuation of the mutation in the daughter cells will take place (OBE et al., 2002; SILVA, 2012).

The mutagenic potential is common between the pesticides, being extremely toxic to mammals. Because they inhibit the enzyme acetylcholinesterase, Organophosphorus insecticides, for example, cause an accumulation of acetylcholine in nervous tissues, impairing neurotransmission. Therefore, a reaction with DNA molecules occurs, being able to generate substitutions of bases (GRISOLIA, 2005; SILVA, 2012). In 2006, the International Agency for Research on Cancer (IARC) came to consider the organophosphate Dichlorvos as potentially carcinogenic to man (SILVA, 2012). Important and recent articles involving this area are from Tomiazzi et al. (2018), Hilgert Jacobsen-Pereira et al. (2018) and Silvério et al. (2017), performed in SP, SC and MG, respectively. In Tomiazzi et al. (2018), the authors study the relationship between the exposure to two xenobiotics with possible carcinogenic potential. In the exposed groups, the total number of cytogenetic abnormalities and MN were higher and the exposure to pesticides proved to be more deleterious than smoking. This finding is consistent with the exposure to a mixture of pesticides in the workplace, including compounds that are potentially carcinogenic in humans, as reported by pesticide group and smoking + pesticide group participants (TOMIAZZY et al., 2018).

Results obtained by Hilgert Jacobsen-Pereira et al. (2018) indicate the presence of genotoxic and mutagenic effects in the exposed group. Continuous and low dose exposure to complex mixtures of pesticides is associated to single and double strand breaks of DNA, oxidative stress and crosslinks. It is important to highlight that DNA damage, when incorrectly or not repaired, can persist and accumulate, triggering mutagenic processes and causing important cytogenetic changes (BENEDETTI et al., 2013; HILGERT JACOBSEN-PEREIRA et al., 2018).

From a study in southern Minas Gerais, Silvério et al. (2017) showed that workers had a hazardous exposure to organophosphates and afforded valuable data to es-
timate the risk to cancer development. The biomarkers used in this study are useful to assess and distinguish the occupational and environmental exposure to pesticides (SILVÉRIO et al., 2017).

Reproductive hormones and Sperm quality

It is interesting to highlight two studies approaching reproductive hormones and sperm quality (CREMONESE et al., 2017; FREIRE et al., 2014). Cremonese et al. (2017) investigated reproductive hormone levels, sperm quality, and genital measures in rural compared to urban young men in the South of Brazil, examining their association with occupational exposure to agricultural pesticides. According to their results, the main findings were:

- the linear dose-response relationship’s poorer sperm morphology and life time use of all pesticides, fungicides, insecticides, herbicides, OP insecticides, dithiocarbamates and other chemical lass- es, mancozeb, glyphosate, and paraquat;
- the association of lifetime use of pesticides, particularly herbicides and fungicides, with reduced levels of LH and prolactin;
- the association of rural living and maternal farming during pregnancy with larger anogenital distance and testicular volume, but poorer sperm morphology.

The authors suggest that chronic occupational exposure to modern pesticides, particularly herbicides and fungicides, may adversely affect semen quality in young male farmers in the South of Brazil, potentially leading to poorer morphology (CREMONESE et al., 2017).

On the other hand, Freire et al. (2014) aimed to examine the association between serum concentrations of organochlorine pesticides and levels of sex hormones in adult population in a rural area of Brazil heavily contaminated with these pesticides. The authors found an inverse association between organochlorine pesticide concentrations and testosterone in men and LH and FSH in peri-/postmenopausal women, together with the high proportion of women with elevated prolactina. Based on their findings, the authors suggest that, in this population, these organochlorine compounds may have triggered anti-androgenic effects in men and estrogenic effects in women (FREIRE et al., 2014).

Practices to reduce exposure

According to the World Health Organization, accidental poisoning kills about 355,000 people every year. Two thirds of these deaths happen in developing countries and are strongly associated with overexposure and inappropriate use of toxic chemicals, including pesticides (WHO, 2008; GONÇALVES, 2016). The use of pesticides has increased worldwide in the last decades, representing a risk for several diseases in humans, including cancer. As previously mentioned, genotoxicity underscores the importance of increasing studies that seek to detect cytogenetic damage caused by pesticides. It is among the most serious damage caused by pesticides, as there’s a strong association between occupational exposure to pesticides and different types of cancer.

The inappropriate use of pesticides is of vital importance and is considered one of the main public health problems, mainly in the interior of Brazil. There are few, however, valuable studies related to the characteristics of their occupational use in order to identify the effects of the agrochemicals’ use by rural workers from basic science with enough relevance to give a return to society’s health. Therefore, it is necessary to obtain a profile of the rural worker through the study on the use of agrochemicals’ impact, as well as the possible genetic and cytological modifications that can be triggered by these treatments.

According to Abreu & Alonzo (2014), the chemical industries encourage the expansion of the use of their products through aggressive marketing and commercialization practices, supported by the Brazilian legislation on agrochemicals (PORTO & SOARES, 2012; MIRANDA et al., 2007). They disregard the health impacts on farmers by promoting “safe use” (ABREU & ALONZO, 2014). The safety manuals prepared by the Associação Nacional de Defesa Vegetal (IWAMI et al., 2010; ASSOCIAÇÃO NACIONAL DE DEFESA VEGETAL, 2006) credit the hazards and accidents involved in the handling of pesticides to the “incorrect use” by the worker and not to the toxicity of the formulations and to the imposition of the agrochemical model of production in the Country (BREIHL, 2003; ABREU & ALONZO, 2014).
Quite common for rural workers, mainly by poor communication of risks to the population, is mixing active substances with the objective of achieving a potent effect, the so-called cocktail effect (REFSTRUP; LARSEN; MEYER, 2010; HERNÁNDEZ et al., 2013; GONÇALVES, 2016). Individually, these active substances can be approved but mixed imply greater risks. Brazilian legislation does not provide tests on the effects of that, which are frequent and rarely punished. Although already regulated in several States, there is an urgent need to spread the information about the risks of using agrochemicals to the population and gain national dimension (GONÇALVES, 2016).

Stoppelli & Magalhães (2005), cited some strategies to minimize negative impacts to the producer and consumer: greater inspection of manufacturing, import, export and quality, as well as products sales; greater control over use, including correct disposal of empty packaging and waste; application only when necessary, in the correct dose and preferring less toxic formulations; greater control in commercialized foods; restrictions by the responsible organs of those products without full epidemiological and environmental studies; banning, when necessary, classes of pesticides; simplifying labels on packaging; risk communication; changes in the production and labor model; greater adequacy of protective equipment to excessive heat in tropical countries. Also incentive to government policies that incorporate, before crediting these products, an earlier structuring of the system, such as the preparation of labor, certification of Good Agricultural Practices and compliance with laws and improvements in inspection (STOPPELLI & MAGALHÃES, 2005).

As reported by Maroni, Fait and Colosio (1999), in the European Union a set of tests is required and designed to identify a toxicological profile of the substance. This profile includes: acute toxicity (oral, inhalation, dermal), skin and eye irritation, skin sensitization, short-term toxicity (28–90 days), mutagenicity, long-term toxicity (2 years), carcinogenicity, reproductive toxicity and other special effects (MARONI; FAIT; COLOSIO, 1999). According to the same author, developed countries’ stringent requirements have to be satisfied before a product is authorized and the costs of meeting these requirements are very high. With the lack of legislation and adequate control’s infrastructure to enforce legislation mainly in developing countries, the rural worker, often misinformed, starts to use pesticides that contain dangerous compounds which do not have controlled adverse effects both to humans and to the environment (MARONI; FAIT; COLOSIO, 1999).

The production of organic products through price reduction policies is also worth highlighting as a possible measure to be taken. According to Soares (2010), as it is done with alcohol and cigarettes in Brazil, making the production of pesticides less attractive by charging the products with high toxicity could be done. Having less than 1% of accredited establishments, the organic market in Brazil is considered very shy (IBGE, 2006; SOARES, 2010). Already in Europe, mainly due to the implemented policies encouraged the expansion of this market. About 11% of the land used for agriculture in Austria is occupied by certified organic producers, 7 to 10% in the Czech Republic, Greece, Italy, Sweden and Switzerland, 4 to 6% in Denmark, Estonia, Germany, Finland, Lithuania, Portugal, Slovakia, Slovenia, Spain and the United Kingdom, and less than 3% in other countries (PADEL; RÖCKLINSBERG; SCHMID, 2009; SOARES, 2010).

CONCLUSION

Rural workers and planting care are associated with a variety of occupational health hazards, both by physical factors and extreme weather conditions, and by exposure to hazards arising from the use of toxicological chemicals, such as pesticides and fertilizers. There are also biological and mechanical risks. Farmers are involved in different farming activities, so they are susceptible to numerous work-related health disorders. In many cases, producers do not give adequate attention to preventing and controlling occupational health problems. For the rural environment, comprehensive occupational health programs are adequately developed for this public, involving both preventive, curative and rehabilitation aspects. Studies such as Chaudhuri (2000), Cavalheiro et al. (2014) and Rempel, Haetinger and Sehnem (2013) demonstrate that there are health problems related to the occupational health of rural producers and that they demonstrate that specific programs can improve their quality of life.
Several studies report and describe the genotoxic effect of pesticides on farmers who use them, including a study by Doğanlar et al. (2018), which shows that populations of areas close to sites that use agrotoxic, even if they are not in contact with them, present an increase in the genotoxicity verified in blood test. These same authors suggest that biological monitoring efforts should be made to control non-occupational exposure to pesticides and thus safeguarding the health of agricultural residents. Despite the possible immediate benefits of using pesticides, it is important to stress that they are toxic substances and that their uncontrolled use causes severe damage to environmental and human health (GONÇALVES, 2016). Many countries encourage sustainable agricultural practices and have restrictions on importing products without proven food security. Therefore, even if the elimination of pesticide use in agriculture is still far away, its use in a rational manner and respecting quantity, application, environmental legislation and with appropriate PPE use, make the genotoxic risks smaller.

Most articles that relate the change in reproductive hormones and sperm quality to the prolonged use of pesticides in agriculture also mention that pregnant women exposed to pesticides accumulate active ingredients and pass them to the fetus. In a study carried out with rural producers in a city in the interior of Rio Grande do Sul, they do not relate the inadequate use of pesticides to their health status, even though they know the problems that pesticides can have on their health (WAHLBRINCK; BICA; REMPEL, 2017).

Many countries, mainly from the European Union, have adopted targets to reduce the use of agrochemicals, but countries that have their agriculture heavily dependent on pesticides must follow the regulations of the US EPA, which is the agency that regulates the amount of pesticide residues considered to be reliable in food. These sustainable environmental measures and practices, such as crop rotation and crop diversity, are necessary to ensure that even using only pesticides, there is less risk of generating health problems. Also, the measures adopted by the EU can be adapted to the Brazilian reality, improving the Brazilian agrochemicals’ management system and for the Brazilian products to be certified and accepted in the European market.

This review made it possible to understand the current situation of the association between the exposure to pesticides and their possible effects caused to Brazilian rural workers. Considering the size of the country and although the research on the impact of the use of pesticides on human health has grown in recent years, it is still insufficient to really know the dimension of their damage on human health, caused by occupational exposure and by the intensive use of agrochemicals. It is fundamental to identify the presence of genotoxic and mutagenic effects of the use of pesticides in rural workers, considering the strong relationship between mutagenesis and carcinogenesis in pesticide users, as well as other damages involving health disorders and reproductive hormones.

Brazil has been growing in relation to the consumption of agrochemicals as well as in the production and export of agricultural products. It is up to us, and mainly to the governments, the search for the disciplining of their use, preventive actions and change to an agriculture aware of the environmental health, the consumer and the rural worker (STOPPELLI & MAGALHÃES, 2005).

**CONFLICT OF INTERESTS**

The authors confirm that this article content has no conflicts of interest.

**FUNDING SOURCES**

This study was financed in part by the Brazilian Coordination for the Improvement of Higher Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—CAPES), Finance Code 001.

**ACKNOWLEDGMENTS**

The first author is grateful for the Postdoctoral grant from CAPES.
REFERENCES


Impact of the use of pesticides by rural workers in Brazil


Majolo, F.; Rempel, C.


NEVES, F. R. M. *Efeito dos agrotóxicos e seus metabólitos em células sanguíneas*. Dissertação (Mestrado) – Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, 2017.


SOARES, W. L. *Uso dos agrotóxicos e seus impactos à saúde e ao ambiente: uma avaliação integrada entre a economia, a saúde pública, a ecologia e a agricultura*. Tese (Doutorado em Ciências) – Fundação Oswaldo Cruz, Rio de Janeiro, 2010.


