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Suicide Mortality Among Agricultural Workers in a Region With Intensive Tobacco Farming and Use of Pesticides in Brazil

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Abstract

Objective—To investigate whether suicide risk among agricultural workers is higher in regions with heavier pesticide use and/or presence of tobacco farming.

Methods—Suicide mortality data were gathered from residents of the Brazilian state of Alagoas. Agricultural census data were used to arrange and classify Alagoas cities into distribution groups on the basis of variables concerning pesticide use and/or tobacco farming. Mortality odds ratio calculations were then used to compare suicide risk among agricultural and nonagricultural workers in different groups.

Results—Suicide risk was higher among agricultural workers than among nonagricultural workers, elevated in regions that used more pesticides, and greatest in regions that produced more tobacco.

Conclusions—This is one of the first studies of its kind to suggest that combined effects of pesticide and tobacco exposure may be linked to higher suicide risk among agricultural workers.

In recent decades, world suicide rates have significantly increased. According to the World Health Organization, more people are dying from suicide than from all armed conflicts around the world, and in some regions equal to or more than those dying from traffic accidents.¹ Reasons for suicide are complex and vary extensively across different regions, populations, and individual cases. Aspects leading to suicide have been partly attributed to socioeconomic factors including stressful life events, social isolation, and limited employment opportunities.^{1–4} Largely influential are also mood disorders, most commonly depression, as well as alcoholism, schizophrenia, and other mental health disturbances.⁵

There has been a growing concern for the rise of mental health disorders and suicide rates in rural areas, particularly in regions where access to health information and services is

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scarce.^{4,6,7} Much of the literature attributes the high suicide rates in rural areas to a combination of socioeconomic, psychological, and cultural factors unique and common to these regions. These include factors such as restricted employment opportunities, high levels of domestic violence, hopelessness about future opportunities, low levels of social integration, and lack of mental health services.^{2,3,4,8,9} Farmers whose income depends on unpredictable factors like the weather can experience high levels of mental stress, and constant exposure to occupational hazards as well as difficult working hours can further exacerbate physical and mental burdens.⁸

Recent studies have begun to explore the effects of neurotoxic pesticides used in the agriculture industry, and whether they may be influencing or contributing to mood alterations and mental health syndromes. A recent study reviewed the literature on epidemiological evidence linking pesticide exposure to depression and/or suicide and identified many studies that suggest this association.¹⁰ Both accidental pesticide poisoning and the availability of pesticides as a tool for suicide are suggested to contribute to the correlation seen between pesticide use and high rates of mood disorders.^{7,11,12} In a study conducted on farmers and their spouses in Colorado, findings indicated that farmers acutely poisoned with pesticides were at a higher risk for depression.¹³ In another case-control study, a history of pesticide poisoning was significantly associated with depression among female spouses of private pesticide applicators.² Behavioral changes, including anxiety and depression, have been observed as sequelae of organophosphate pesticide poisoning in populations exposed to these agents.¹⁴ It is crucial to understand the relationship between exposure to pesticides and neurotoxicity as it can be influential in urging stricter regulations for both governments and agricultural industries to control such exposures.^{12,15} This is especially critical in developing countries where regulation of agricultural activities is scarce and research on possible health effects is limited, increasing the risk of workers to occupational hazards.

Tobacco farming, in particular, involves heavy use of pesticides and several other known occupational hazards for its cultivators. Primarily examined has been green tobacco sickness, an illness in which an overexposure to nicotine from tobacco leaves leads to intense symptoms of vomiting, nausea, dizziness, and headaches.^{16–19} Many studies have also linked tobacco and nicotine exposure to neurobehavioral outcomes including depression.^{20–22} Most research has examined nicotine's modulation of neurotransmitters in cigarette smokers, and many indeed have found direct correlations between smoking and incidence of depression and/or suicide.^{20,22–24}

Although there has been limited research done on the health effects of nicotine through exposures other than tobacco smoke, studies have begun to examine how this toxin may be influencing tobacco agricultural workers. Nonsmoking tobacco harvesters have shown similar cotinine and nicotine levels compared with active smokers in the general population, suggesting that the toxicity to the cardiovascular system and carcinogenicity of chronic dermal nicotine exposure are likely.¹⁸ Nonsmoking tobacco harvesters have been estimated to absorb approximately 0.8 mg of nicotine daily, an amount equivalent to one cigarette per day, 180 per season, and 5000 per working life, and their levels of blood nicotine and urine

cotinine have been found to be significantly higher than that of nonsmoking workers who do not harvest tobacco.²⁵

Brazil has a relatively low suicide rate, most recently ranked 70th by the World Health Organization, with a suicide rate per 100,000 of 7.7 for males and 2.0 for females.²⁶ Yet, certain regions of Brazil are experiencing abnormally high rates of mood disorders and suicide, particularly among rural populations.^{27,28} Brazil is currently the world's third largest consumer of pesticides,²⁸ and third largest producer of tobacco.²⁹ In 2012 alone, Brazil produced an estimated 810,550 metric tons of tobacco, over double the amount produced in the United States, the next largest ranked tobacco-producing economy in the world.²⁹ Research has begun to show that in certain regions in Brazil with heavy use of pesticides, agricultural workers are at greatest risk of hospitalization for mood disorders and suicide attempts.²⁸ Brazilian mortality data also reveal that suicide rates among agricultural workers are highest in states that produce tobacco.³⁰ Unpublished data from our research group show that in the tobacco-producing states of Rio Grande do Sul, Parana, and Santa Catarina, regions with higher tobacco production and pesticide use experienced higher suicide rates among agricultural workers.

Most studies up to date have focused separately on the effects of either pesticides or nicotine on workers' health, and some authors have begun to point to the need to investigate their synergistic effects on workers who experience simultaneous exposures.^{17,18,27,31,32} In this study, we have chosen to explore the synergic effect of tobacco farming and exposure to pesticides in the northeastern state of Alagoas, the fourth largest producer of tobacco in Brazil. The study examines suicide rates among agricultural workers in all Alagoas cities, with a particular focus on the primary tobacco-producing city of Arapiraca. By analyzing publically available data on mortality patterns and on agricultural production in the region, we tested whether the presence of pesticides and/or specifically tobacco farming increased the risk of death by suicide among agricultural workers in the region. This study also compared these suicide patterns with those of nonagricultural workers living in the capital city of Maceió and other cities of Alagoas. To the best of our knowledge, no other study thus far has examined the association between pesticide use, tobacco farming, and suicide incidence.

MATERIALS AND METHODS

Study Area and Population

An ecological study was designed to compare the suicide mortality patterns of agricultural workers and nonagricultural workers living in the state of Alagoas. Alagoas is located in the northeastern region of Brazil and borders the states of Bahia, Sergipe, and Pernambuco. Alagoas spans an area of 27,779,343 km² and has a population of about 3,120,494 people (Population Census 2010).³⁰ Alagoas was chosen as the region of interest because Brazilian mortality data reveal high suicide rates in this region. Alagoas has an abundant agricultural economy in which about 451,742 individuals (14% of the general population) are regularly engaged in agricultural activities (Census of Agriculture 2006).³⁰ Alagoas is the fourth largest producer of tobacco in Brazil, after directly behind the southern states of Rio Grande do Sul, Santa Catarina, and Parana, producing about 48,461 tons of tobacco per year on an

estimated 40,707 hectares of tobacco plantations (Census of Agriculture 2006).³⁰ The most striking suicide rates are observed in Arapiraca, which is the second largest city of Alagoas and contains 59% of the tobacco production of Alagoas state (Census of Agriculture 2006).³⁰ Arapiraca spans an area of 356,179 km² and has a population of about 214,000 people (Population Census 2010).³⁰

Suicide Mortality Data

Deaths attributed to suicide in Alagoas were obtained from the Brazilian National Mortality System, which is implemented by the Ministry of Health and classifies death causes according to the International Classification of Diseases.³³ Information on death by suicide and other causes among residents of Alagoas older than 20 years was collected for the years 1996 to 2005 (the International Classification of Diseases, 10th Revision, codes X60–X84).³³ Data specifically on agricultural workers were obtained using occupation codes 600 to 621. A total of 122,036 deaths were analyzed from which 15,671 were of agricultural workers and 106,365 were of nonagricultural workers. These years and groups were selected on the basis of the latest mortality data made available by Brazil's Ministry of Health. Mortality data from certain cities were excluded in the cases that information on desired variables was not available for that city.

Data Analysis

Various comparisons of suicide mortality between groups were carried out using mortality odds ratios (MOR), according to Miettinen and Wang.³⁴ To calculate MOR, total suicide deaths were divided by total deaths by all other causes, generating a death-by-suicide rate ratio. Dividing each noted death-by-suicide rate ratio by that of reference group death-by-suicide rate ratios generated comparative MOR. For each MOR calculation, statistical significance was assessed using 95% confidence intervals. The mathematical relationship between the standardized mortality ratio, the paradigm measure in mortality studies, and MOR has been previously described by Meyer et al.³⁵

Distributions and Reference Groups

The first set of MOR calculations compared suicide rates between agricultural workers and nonagricultural workers in Alagoas as well as specifically in Arapiraca. For each remaining calculation, data on agricultural activities in each city were obtained from the 2006 agricultural census (Agricultural Census 2006).³⁰ These data were used to group and order cities by the existence or abundance of a variable of interest related to pesticide use and/or level of tobacco farming. For analyses based on the abundance of a variable, median was used as a cutoff point to divide cities into two equal distribution groups on the basis of the higher and lower levels of the variable being observed. Mortality odds ratio was used to compare suicide rates between agricultural workers in different distribution groups using those in the group lacking or with a lower level of the variable of interest as the reference group. Suicide deaths were also compared against those of two additional reference populations. The second reference groups were nonagricultural workers living in the capital city of Maceio, and the third reference groups were nonagricultural workers living in other Alagoas cities.

Distribution by Percentage of Establishments That Use Pesticides

To compare suicide rates on the basis of amount of pesticides used, all 102 cities were ordered by their percentage of agricultural establishments that used pesticides. Median was used as a cutoff point to divide cities into two groups on the basis of their abundance of pesticide-using establishments; the 51 cities with a higher percentage of agricultural establishments that used pesticides were classified as “above median” and the 51 cities with a lower percentage of agricultural establishments that used pesticides were classified as “below median.” Mortality odds ratio was used to compare suicide rates among agricultural workers using those in cities “below median” as the first reference group. These categories were then compared with the second and third reference groups of nonagricultural workers.

Distribution by Presence of Tobacco Production

To compare suicide rates on the basis of tobacco production, cities were divided into two categories: 77 cities were grouped as having “no tobacco production” and 16 cities were grouped as having “tobacco production.” Nine cities were excluded because of the unavailability of data on tobacco production. Mortality odds ratio was used to compare suicide rates among agricultural workers using those in cities with “no tobacco production” as the first reference group. These categories were then compared with the second and third reference groups of nonagricultural workers.

Distribution by Concentration of Tobacco Farmers

To compare suicide rates on the basis of concentration of tobacco farmers, cities were ordered by their ratio of tobacco agricultural workers to all agricultural workers. Of these, 83 cities were grouped together as having “no tobacco agricultural workers” and cities with tobacco agricultural workers were divided into two equal groups using median as a cutoff point; the 10 cities with a higher ratio of tobacco workers were classified as “above median,” and the nine cities with a lower ratio of tobacco workers were classified as “below median.” Mortality odds ratio was used to compare suicide rates among agricultural workers using those in cities with “no tobacco agricultural workers” as the first reference group. These categories were then compared with the second and third reference groups of nonagricultural workers.

Distribution by Tobacco Production Controlling for Pesticide Use

To compare suicide rates on the basis of tobacco production while controlling for pesticide use, cities were ordered by the ratio of establishments within each city that used pesticides in the production of tobacco to those that used pesticides in the production of all crops. This allowed us to only compare agricultural establishments that used pesticides and observe whether tobacco production, in particular, correlated with higher suicide rates. The 85 cities that had “no tobacco production” were grouped together and those with tobacco production were divided into two equal groups using median as a cutoff point; the nine cities with a higher percentage of pesticides used for the production of tobacco relative to pesticides used for the production of all crops were classified as “above median” and the nine cities with a lower percentage of pesticides used for the production of tobacco relative to pesticides used for the production of all crops were classified as “below median.” Mortality odds ratio was

used to compare suicide rates among agricultural workers using those in cities with “no tobacco production” as the first reference group. These categories were then compared with the second and third reference groups of nonagricultural workers.

Arapiraca MOR Data

For all sets of data in which the above variables were compared, a separate set of MOR calculations was performed excluding the city of Arapiraca. Mortality odds ratio was calculated separately for Arapiraca to assess its agricultural workers’ suicide mortality patterns relative to those of agricultural workers and nonagricultural workers in other cities. Distribution groups remained unchanged other than the removal of Arapiraca, and new MORs were calculated for each distribution group as compared with the set reference groups.

Correlation and Interaction Analyses

A Spearman correlation analysis was performed between all four independent variables related to pesticide and/or tobacco presence to identify correlations between variables. These variables were also included in a multiple linear regression model, with each being placed as a dependent variable at a time. Multicollinearity was considered to be present if the variance inflation factor was greater than 5. To test the interaction between simultaneous pesticide and tobacco exposure on risk of suicide among agricultural workers, an interaction test was performed using the variables “percentage of agricultural establishments that used pesticides” and “tons of tobacco produced.” Variables were first centered, by subtracting each value from the variable mean, to avoid possible multicollinearity. The product of the centered variables was calculated, and a multiple linear regression analysis was performed, including the product of the centered variables and each individual centered variable, to evaluate their influence on agricultural workers’ risk of suicide.

RESULTS

Mortality odds ratios comparing the suicide mortality risk among agricultural workers and nonagricultural workers in Alagoas and specifically in Arapiraca are presented in Table 1. Overall, agricultural workers in all Alagoas cities had a 2.96-times higher risk of death by suicide than nonagricultural workers in Alagoas. Agricultural workers in Arapiraca had a 3.8-times higher risk of death by suicide than nonagricultural workers in Arapiraca.

Mortality odds ratios comparing suicide mortality risk among agricultural workers according to distribution by percentage of agricultural establishments in cities that used pesticides are presented in Table 2. Agricultural workers in cities above the median cutoff point had a 1.91-times higher risk of death by suicide than those in cities below the median cutoff point, a 3.5-times higher risk of death by suicide than nonagricultural workers in the capital city, and a 4.01-times higher risk of death by suicide than nonagricultural workers in all other cities. When Arapiraca was excluded and compared, Arapiraca agricultural workers showed an even greater risk of death by suicide that was 3.24-times higher than that of agricultural workers in cities below the median cutoff point, 5.83-times higher than that of

nonagricultural workers in the capital city, and 6.71-times higher than that of nonagricultural workers in all other Alagoas cities.

Mortality odds ratios comparing suicide mortality risk between agricultural workers in cities with tobacco production and agricultural workers in cities with no tobacco production are presented in Table 3. Agricultural workers in cities with tobacco production had a 2.39-times higher risk of death by suicide than agricultural workers in cities without tobacco production, a 4.73-times higher risk than that of nonagricultural workers in the capital city, and a 5.45-times higher risk than that of nonagricultural workers in all other Alagoas cities. When Arapiraca was excluded and compared with other cities, a similar pattern occurred and Arapiraca agricultural workers had a 2.9-times higher risk of death by suicide than agricultural workers in cities without tobacco production.

Mortality odds ratio comparing suicide risk among agricultural workers according to distribution by ratio of tobacco agricultural workers to all agricultural workers in cities are presented in Table 4. Agricultural workers in cities above the median cutoff point had a 2.51-times higher risk of death by suicide than agricultural workers in cities with no tobacco workers, a 4.9-times higher risk than that of nonagricultural workers in the capital city, and a 5.64-times higher risk than that of nonagricultural workers in all other Alagoas cities. Again, when excluded and compared with other cities, Arapiraca agricultural workers had a 2.99-times higher risk of death by suicide than agricultural workers in cities with no tobacco workers.

Mortality odds ratios comparing suicide risk among agricultural workers according to distribution by ratio of establishments that use pesticides in the production of tobacco to those that use pesticides in the production of all crops are presented in Table 5. Even when controlling for pesticides, agricultural workers in cities above the median cutoff point and with more tobacco production had a 2.41-times higher risk of death by suicide than agricultural workers in cities with no tobacco production, a 4.9-times higher risk than that of nonagricultural workers in the capital city, and a 5.64-times higher risk than that of nonagricultural workers in all other Alagoas cities. After the usual pattern, when Arapiraca was excluded and compared with other cities, Arapiraca agricultural workers had a 2.87-times higher risk of death by suicide than agricultural workers in cities with no tobacco production.

DISCUSSION

Our first findings demonstrate that in Alagoas, working in agriculture might lead to an increased risk of suicide. Throughout this study, agricultural workers consistently experienced higher rates of suicide than nonagricultural workers. As presented in Table 1, MORs comparing suicide rates among agricultural and nonagricultural workers in all Alagoas cities demonstrated that overall agricultural workers were almost three times more likely to die from suicide than nonagricultural workers in Alagoas. In Arapiraca, the risk of death by suicide was exacerbated and agricultural workers were almost four times more likely to die from suicide than nonagricultural workers. Similar patterns were noted when

suicide rates of agricultural workers in the variable-based distribution groups were compared with those of nonagricultural workers, as seen in Tables 2 to 5.

It is likely that the high suicide rates among agricultural workers can partially be attributed to the socioeconomic and psychological stresses often affecting rural populations.^{3,4,8,36} The high incidence of depression and/or suicide among rural populations has long been observed and noted. Studies comparing urban and rural populations in Brazil, Scotland, England, Wales, New Zealand, and Australia all concluded that suicide is higher in rural than in urban areas, and that suicide rates in rural regions have been increasing in recent decades.^{3,28,36,37}

Alagoas has a large rural resident population of about 823,000 (26% of residents) and is one of the poorest states of Brazil (Population Census 2010).³⁰ In 2007, Alagoas had an infant mortality rate of 41.3 deaths per 1000 live births, which was over twice that of the national infant mortality rate that year. The average monthly household income from work in Alagoas for the years 2008 to 2009 was 846 Reais, which was about half of that of the national average that year (Consumer Expenditure Survey 2008 to 2009).³⁰ Illiteracy in the region is also high at approximately 32% (Population Census 2010).³⁰ Despite the difficult socioeconomic state of many residents of Alagoas, it is unlikely that the high levels of suicide rates observed can be explained by such factors alone. When suicide rates in Alagoas cities were compared by distribution according to the Brazilian Human Development Index, which takes into account income level, educational level, and longevity, there was no association between cities with poorer socioeconomic conditions and suicide rates (data not shown). In addition, many nonagricultural workers of Alagoas live in rural and poor cities in which they experience similar living conditions as their agricultural worker counterparts. Yet, consistently throughout this study, agricultural workers showed at least three times higher suicide rates than nonagricultural workers. Nonagricultural workers from Maceió, the capital and most urbanized city of Alagoas, experienced higher incidences of suicide than nonagricultural workers in other Alagoas cities. This provides evidence that rural living conditions alone cannot explain suicide patterns in Alagoas, and emphasizes that other elements must be taken into account.

The results of this study may support the assumption that a risk factor for suicide in this region is the abundant presence of toxic pesticides. As shown in Table 2, agricultural workers in cities with a higher percentage of agricultural establishments that use pesticides were almost twice as likely to die from suicide than workers in cities that had a lower percentage of agricultural establishments that use pesticides.

Organophosphates are one the most commonly used and toxic class of pesticides, and are known occupational health hazards for workers who are exposed to them.^{2,7,38}

Organophosphates can be absorbed directly through the skin, mucous membranes, gastrointestinal tract, or respiratory tract.¹³ The toxicity of organophosphates is initiated through their inhibition of acetylcholinesterase, the enzyme responsible for degrading acetylcholine in the synapse.^{15,39,40} Accumulation of acetylcholine can lead to excessive stimulation of acetylcholine receptors in postsynaptic cells or in end organs, which can in turn lead to autonomic dysfunction, involuntary movements, muscle fasciculation, and respiratory depression.⁴⁰ Evidence suggests that exposure to organophosphates and

excessive consequential stimulation of receptors in the brain may also lead to serotonin alterations.^{12,41–14} Modified serotonin function in the brain has been associated with many mood disorders including depression, anxiety, and aggression.^{21,45,46} In fact, even low doses of methamidophos, a pesticide shown to have been actively used by Arapiraca tobacco agricultural workers in 2010,³¹ has shown to lead to depressive-like behavior in mice.⁴⁷ It is important to consider that both acute and chronic exposure to organophosphates and other toxic pesticides may be influencing the high levels of suicide evident among agricultural workers.

This study also presents data supporting the correlation between tobacco production and suicide risk. In the results presented in Table 3, agricultural workers living in cities that produced tobacco were almost two and a half times more likely to commit suicide than workers in cities that did not produce tobacco. In the results presented in Table 4, agricultural workers living in cities with a higher concentration of tobacco workers were two and a half times more likely to commit suicide than workers in cities with agricultural activity but a lower concentration of tobacco workers. Both these sets of data suggest that agricultural workers, particularly in cities with a more significant tobacco industry, were at higher risk of death by suicide.

An interesting fact was observed when suicide rates among nonagricultural workers were compared between cities with tobacco production and cities without tobacco production. Nonagricultural workers in cities with tobacco production were one and a half times more likely to die from suicide than nonagricultural workers in cities without tobacco production (results not shown). In many of the surveyed cities, the tobacco industry accounts for a large portion of the local economy. It is thus plausible that workers involved with the tobacco industry in occupations other than agriculture might also be affected by the toxins in tobacco and by other factors and stressors brought about by the presence of this industry.

Extensive research has been done on the neurotoxic effects of nicotine. When nicotine is absorbed into the body, it activates nicotinic receptors that can modulate many different neurotransmitters including dopamine, serotonin, norepinephrine, acetylcholine, aminobutyric acid, and glutamate, and can result in alterations and fluctuations of mood.⁴⁸ Several associations have been noted between smoking tobacco and incidence of depression and/or suicide. One study found a significant association between cigarette smoking and depression, in which current smokers had a higher risk of depression than ex-smokers and an even higher risk than never-smokers.²² Current daily smoking, but not past smoking, has been observed to predict the subsequent occurrence of suicidal thoughts or attempts,²³ and heavier smoking habits have correlated with more impaired serotonin function and more serious suicidal behavior.²¹ Certain studies argue that smoking does not merely correlate with depression and suicide, but that it is also a direct and causal risk factor.^{20,24}

Much of the research on the link between tobacco and mood disorders has been done on cigarette smokers, but there is evidence that nicotine and other toxins can enter the body through channels other than smoking such as the skin.^{16–19,25} Tobacco harvesters may be exposed to similar risks of mood alterations through contact with tobacco during work. More research is needed to understand different modes of nicotine intake as well as its

mechanisms of neurotransmitter modulations with both temporary and long-term effects on the nervous system.

As there are no pesticides used exclusively for tobacco farming, and pesticides are used heavily and applied to tobacco several times over the growing season,³² it is difficult to differentiate between the effects of heavy pesticide use typical of tobacco production, the effects of exposure to toxins found in tobacco plants, and the combination of both. The Brazilian Ministry of Agriculture cites 11 types of pesticides used specifically for tobacco production, including organophosphates, (Z)-9-tetradecenyl acetates, tetranortriterpenoids, biopesticides, pyrethroids, dinitroanilines, and carbamates.⁴⁹ Indeed, our multicollinearity analyses between variables showed an expected moderate to high degree of correlations (data not shown) between cities with heavy pesticide use and those with more tobacco production.

We attempted to control for the simultaneous presence of tobacco and pesticides by comparing only establishments that use pesticides and seeing whether workers in cities who use more pesticides specifically for tobacco farming experience more suicide than those in cities who use pesticides to grow other crops. These results, presented in Table 5, show that agricultural workers in cities with a higher ratio of establishments that grow tobacco were almost two and a half times more likely to die from suicide than agricultural workers in cities with less establishments that grow tobacco, despite the use of pesticides in establishments in all cities compared. Yet, when we performed an interaction test between the variables “percentage of agricultural establishments that used pesticides” and “tons of tobacco produced,” to look for possible collective effects of pesticide and tobacco exposure, we found no explicit synergic effect on risk of suicide (data not shown). Because these two distinct approaches lead to contradictory outcomes, results of this study could not support the hypothesis that pesticide and tobacco exposure synergistically act to increase the risk of suicide in this group of workers, and should be readdressed in a larger sample in future studies.

Throughout this study, the city of Arapiraca was examined as a case study exemplifying especially high rates of suicide. Because Arapiraca, known as the tobacco capital of Alagoas, contains 59% of Alagoas tobacco production, it is an important city for analysis of suicide incidence as related to tobacco farming. A recent study in Arapiraca reported on the first recorded outbreak of green tobacco sickness in Brazil during August to September of 2007, highlighting some of the common health hazards experienced by its tobacco agricultural workers.¹⁶ Throughout our study, Arapiraca agricultural workers showed consistently higher rates of suicide than other groups. Arapiraca agricultural workers were over twice as likely to die from suicide than agricultural workers in all other cities (results not shown). When MORs were calculated against groups of agricultural workers in cities with lower tobacco production and lower pesticide use, Arapiraca agricultural workers showed an even higher relative risk of suicide. When compared with the reference groups of nonagricultural workers in the capital as well as in other Alagoas cities, Arapiraca agricultural workers were up to six and seven times more likely to die from suicide than each of these groups, respectively. These figures highlight that Arapiraca agricultural workers are experiencing abnormal suicide rates that must be investigated. These data also

exemplify that despite these high rates, Arapiraca is not the only city that demonstrates these correlations; in every set of data, all other cities excluding Arapiraca still experience higher rates of suicide in cities with more tobacco production and pesticide use. It is important to further explore the factors leading to such high suicide rates among agricultural workers in all Alagoas cities with a particular focus on Arapiraca's striking suicide patterns.

In essence, the nature of this ecological study limits the scope of its conclusions because it cannot provide causality ascertainment. Because secondary sources were used to obtain data, we were not able to assess the accuracy of census information, determine the chemical nature of the pesticides involved, or control for discrepancies in publically available data. Because the IBGE agricultural census is carried out in certain years that are not always consistent with those in which data are available for suicide mortality data, the correlation between tobacco production, pesticide use, and suicide mortality on a yearly basis could not be obtained. Furthermore, we were not able to attain information from the census on home pesticide application or other types of occupational pesticide exposure from nonagricultural jobs, which may play a significant role in pesticide exposure and/or access among nonagricultural workers. Because of the limited size of the population of Alagoas state, comparisons could not take into account ages and sexes of the persons examined in this study or create several distribution groups for cities. The size of Alagoas and the difficulty of separating the presence of tobacco and pesticides did not allow us to measure with statistical significance whether there was a synergistic effect of co-pesticide and tobacco exposure on suicide mortality. Despite these limitations, MORs were pronounced and consistent throughout this study, and almost all correlations between observed variables and suicide risk were statistically significant.

The results of this study suggest the possibility that continuous exposure to tobacco and/or pesticides may exert a unique neurotoxic effect on workers, aggravating their risk of suicide. To the best of our knowledge, this is the first study of its kind that compares suicide rates on the combined variables of tobacco production and pesticide use. As suicide is becoming a growing health problem in Brazil and other parts of the world, particular attention should be dedicated to better understanding the biochemical mechanisms of toxins present in pesticides and tobacco and how they may be altering mood and mental health. In the future, controlled studies should be designed to assess the link between chronic tobacco and pesticide exposure and suicide. Arapiraca, which exhibits a strong association between these exposures and suicide, could be a suitable region for further studying this relationship.

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TABLE 1

Suicide Mortality Risk Among Agricultural Workers Compared With Nonagricultural Workers

	Suicide Deaths	Other Deaths	MOR (95% CI)
All Alagoas cities			
Nonagricultural workers	441	105,924	1
Agricultural workers	191	15,480	2.96 (2.50–3.51)
Arapiraca			
Nonagricultural workers	55	7,901	1
Agricultural workers	31	1,172	3.80 (2.44–5.93)

CI, confidence interval; MOR, mortality odds ratio.

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Suicide Mortality Risk Among Agricultural Workers According to the Percentage of Agricultural Establishments That Used Pesticides

TABLE 2

Distribution of Cities	First Reference Population: Agricultural Workers			Second Reference Population: Nonagricultural Workers in the Capital City			Third Reference Population: Nonagricultural Workers in All Other Cities		
	Suicide Deaths	Other Deaths	MOR (95% CI)	Suicide Deaths	Other Deaths	MOR (95% CI)	Suicide Deaths	Other Deaths	MOR (95% CI)
All cities									
Below median	59 [*]	7,121 [*]	1	180 [†]	39,671 [†]	1.83(1.36–2.45)	261 [‡]	66,253 [‡]	2.10 (1.58–2.79)
Above median	132	8,348	1.91 (1.40–2.60)			3.48 (2.78–4.37)			4.01 (3.25–4.95)
Isolating Arapiraca									
Below median	57 [*]	6,979 [*]	1	180 [†]	39,671 [†]	1.80 (1.33–2.43)	261 [‡]	66,253 [‡]	2.07 (1.56–2.76)
Above median	103	7,318	1.72 (1.25–2.39)			3.10 (2.43–3.96)			3.57 (2.84–4.49)
Arapiraca	31	1,172	3.24 (2.08–5.04)			5.83 (3.96–8.57)			6.71 (4.61–9.79)

^{*} Number of cases used as the first reference population for MOR.

[†] Number of cases used as the second reference population for MOR.

[‡] Number of cases used as the third reference population for MOR.

CI, confidence interval; MOR, mortality odds ratio.

TABLE 3
Suicide Mortality Risk Among Agricultural Workers From Cities With Tobacco Production

Distribution of Cities	First Reference Population: Agricultural Workers			Second Reference Population: Nonagricultural Workers in the Capital City			Third Reference Population: Nonagricultural Workers in All Other Cities		
	Suicide Deaths	Other Deaths	MOR (95% CI)	Suicide Deaths	Other Deaths	MOR (95% CI)	Suicide Deaths	Other Deaths	MOR (95% CI)
All cities									
No tobacco production	85*	9,467*	1	180 [†]	39,671 [‡]	1.98 (1.53–2.56)	261 [‡]	66,253 [‡]	2.28 (1.78–2.91)
Tobacco production Isolating Arapiraca	95	4,425	2.39 (1.78–3.21)			4.73 (3.68–6.08)			5.45 (4.30–6.91)
No tobacco production	85*	9,467*	1	180 [†]	39,671 [‡]	1.98 (1.53–2.56)	261 [‡]	66,253 [‡]	2.28 (1.78–2.91)
Tobacco production	64	3,253	2.19 (1.58–3.04)			4.34 (3.25–5.78)			4.99 (3.79–6.58)
Arapiraca	31	1,172	2.95 (1.94–4.46)			5.83 (3.96–8.57)			6.71 (4.61–9.79)

* Number of cases used as the first reference population for MOR.

[†] Number of cases used as the second reference population for MOR.

[‡] Number of cases used as the third reference population for MOR.

CI, confidence interval; MOR, mortality odds ratio.

TABLE 4
 Suicide Mortality Risk Among Agricultural Workers According to the Ratio of Tobacco Agricultural Workers to the Total Number of Agricultural Workers

Distribution of Cities	First Reference Population: Agricultural Workers			Second Reference Population: Nonagricultural Workers in the Capital City			Third Reference Population: Nonagricultural Workers in All Other Cities		
	Suicide Deaths	Other Deaths	MOR (95% CI)	Suicide Deaths	Other Deaths	MOR (95% CI)	Suicide Deaths	Other Deaths	MOR (95% CI)
All cities									
No tobacco workers	96 [*]	10,846 [*]	1	180 [†]	39,671 [†]	1.95 (1.52–2.5)	261 [‡]	66,253 [‡]	2.25 (1.78–2.84)
Below median	22	1,339	1.86 (1.16–2.96)			3.62 (2.32–5.66)			4.17 (2.69–6.45)
Above median	73	3,284	2.51 (1.85–3.41)			4.90 (3.72–6.45)			5.64 (4.34–7.33)
Isolating Arapiraca									
No tobacco workers	96 [*]	10,846 [*]	1	180 [†]	39,671 [†]	1.95 (1.52–2.50)	261 [‡]	66,253 [‡]	2.25 (1.78–2.84)
Below median	21	1,278	1.86 (1.16–2.96)			3.62 (2.30–5.71)			4.17 (2.66–6.53)
Above median	43	2,173	2.24 (1.85–3.41)			4.36 (3.12–6.10)			5.02 (3.63–6.95)
Arapiraca	31	1,172	2.99 (1.98–4.50)			5.83 (3.96–8.57)			6.71 (4.61–9.79)

^{*} Number of cases used as the first reference population for MOR.

[†] Number of cases used as the second reference population for MOR.

[‡] Number of cases used as the third reference population for MOR.

CI, confidence interval; MOR, mortality odds ratio.

Suicide Mortality Risk Among Agricultural Workers According to the Ratio of Establishments That Used Pesticides in Tobacco Production to Those That Used Pesticides in Any Crop Production in 2006

TABLE 5

Distribution of Cities	First Reference Population: Agricultural Workers			Second Reference Population: Nonagricultural Workers in the Capital City			Third Reference Population: Nonagricultural Workers in All Other Cities		
	Suicide Deaths	Other Deaths	MOR (95% CI)	Suicide Deaths	Other Deaths	MOR (95% CI)	Suicide Deaths	Other Deaths	MOR (95% CI)
All cities									
No tobacco production	102*	11,052*	1	180 [†]	39,671 [†]	2.03 (1.59–2.60)	261 [‡]	66,253 [‡]	2.34 (1.86–2.95)
Below median	16	1,133	1.53 (0.90–2.60)			3.11 (1.86–5.21)			3.58 (2.16–5.96)
Above median	73	3,284	2.41 (1.78–3.26)			4.90 (3.72–6.45)			5.64 (4.34–7.33)
Isolating Arapiraca									
No tobacco production	102*	11,052*	1	180 [†]	39,671 [†]	2.03 (1.59–2.60)	261 [‡]	66,253 [‡]	2.34 (1.86–2.95)
Below median	16	1,133	1.53 (0.90–2.60)			3.11 (1.86–5.21)			3.58 (2.16–5.96)
Above median	42	2,112	2.15 (1.50–3.10)			4.38 (3.12–6.15)			5.05 (3.63–7.01)
Arapiraca	31	1,172	2.87 (1.91–4.30)			5.83 (3.96–8.57)			6.71 (4.61–9.79)

* Number of cases used as the first reference population for MOR.

[†] Number of cases used as the second reference population for MOR.

[‡] Number of cases used as the third reference population for MOR.

CI, confidence interval; MOR, mortality odds ratio.