Green tobacco sickness in Indonesia's tobacco heartland: Sociodemographic and environmental determinants among farmers in Bondowoso regency

Dwi Chandra Ramadhani[1], Adistha Eka Noveyani[1], Yunus Ariyanto[1]

AFFILIATION
1 Department of Epidemiology, Faculty of Public Health, University of Jember, Jember, Indonesia

CORRESPONDENCE TO
Adistha Eka Noveyani. Department of Epidemiology, Faculty of Public Health, University of Jember, Jl. Kalimantan Kampus UNEJ No.I / 93, Sumbersari SubRegency, 68121, Jember Regency, East Java, Indonesia
Email: adistha.en@unej.ac.id

ORICID iD: https://orcid.org/0000-0002-1845-2705

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ABSTRACT

INTRODUCTION Green Tobacco Sickness (GTS) is an occupational health problem caused by dermal absorption of nicotine from wet tobacco leaves, posing a significant risk to farmers in Bondowoso Regency, Indonesia. The region's reliance on tobacco cultivation, combined with environmental and socio-cultural factors, increases GTS risk.

METHODS This analytical observational study with a cross-sectional design was conducted in Kembang Village, Bondowoso, from October 2024 to February 2025. A total of 186 tobacco farmers were selected using cluster random sampling. Data were collected via structured interviews, direct observation, and documentation, focusing on sociodemographic (gender, age, education level, smoking status, work duration) and socio-environmental (personal hygiene, PPE use, work activity) factors. GTS was defined by the presence of acute symptoms following contact with wet tobacco leaves. Statistical analysis included univariate, bivariate (chi-squared), and multivariate (Poisson regression) methods.

RESULTS Among 186 farmers, 52.2% experienced GTS, with headache, pruritus, and excessive sweating as the most common symptoms. Most respondents were female, aged 40–49 years, with low level of education and improper personal protective equipment (PPE) use. Bivariate analysis showed that smoking status, PPE use, and personal hygiene were significantly associated with GTS ($p<0.05$). Multivariate analysis identified gender, smoking status, personal hygiene, and tobacco leaf work activity as independent predictors of GTS. Notably, current smokers had a lower GTS risk (adjusted prevalence ratio, APR=0.60; 95% CI: 0.56–0.64), while inappropriate PPE use and poor hygiene increased risk (APR=1.33; 95% CI: 1.19–1.48).

CONCLUSIONS GTS prevalence among tobacco farmers in Kembang Village is high and is significantly influenced by sociodemographic and socio-environmental factors. Targeted interventions to improve hygiene practices and PPE use are essential to reduce GTS risk in this vulnerable population.

INTRODUCTION

Green Tobacco Sickness (GTS) is an occupational health condition primarily afflicting tobacco farmers due to the dermal absorption of nicotine from wet tobacco leaves[1]. This phenomenon is alarming, particularly in Bondowoso Regency, Indonesia, where a combination of environmental, socio-economic, and cultural factors amplifies the risks faced by farmers. Bondowoso Regency is one of Indonesia's tobacco-producing regions, with tobacco farmland increasing from 6347 hectares in 2022 to 8033 hectares in 2023. Tobacco production also rose from 6347 tons to 8033 tons during the same period. One of the tobacco varieties cultivated in Bondowoso is Naa-oogst. Bondowoso has high rainfall, ranging from 1700 to 2100 mm, with humidity levels between 65% and 82%[2]. One of the villages cultivating the Naa-oogst tobacco variety is Kembang Village. Naa-oogst tobacco is harvested in the morning when dew is still present, increasing the risk of GTS. The economic dependence of Kembang Village on tobacco cultivation is profound, with nearly the entire population engaged in this profession. This not only centralizes the economic and social activities around tobacco farming but also enhances

the community's exposure to GTS. The culture of tobacco farming, ingrained over generations, fosters a collective identity that often overlooks the associated health risks, thereby normalizing exposure to hazardous working conditions, including GTS. A preliminary study conducted by researchers in Kembang Village showed that out of 12 farmers, most were unaware of GTS and experienced post-harvest symptoms such as dizziness (41.7%), headaches (50%), nausea (16.7%), and vomiting (8.3%). These symptoms are characteristic of GTS[3].

The cultivation of tobacco in Bondowoso is significantly influenced by its unique geographical and climatic conditions. The region experiences low rainfall and temperatures conducive to tobacco growth, maintaining averages between 21°C and 33°C with humidity levels ranging from 60% to 80%[4,5]. These environmental conditions, while suitable for producing high-quality tobacco, also pose specific health risks, particularly Green Tobacco Sickness (GTS), which occurs due to nicotine absorption through the skin, especially when farmers harvest tobacco leaves early in the morning when they are still wet with dew[6,7]. Moreover, the soil in Bondowoso, beneficial for tobacco cultivation, can increase issues like erosion and drought, complicating farming practices and economic viability for local farmers[5]. This environmental vulnerability, combined with the economic pressures of tobacco farming, contributes to a cycle of health risks and production challenges, as income from tobacco often fails to compensate for the associated health costs and agricultural risks[8,9]. In addition to these environmental concerns, the social context of farming communities significantly influences the prevalence of GTS. Farmers in the Kembang village tend to have a low level of education and limited access to healthcare, which restricts their awareness of occupational health risks and necessary preventive measures. Many farmers may not understand the importance of protective equipment, leading to increased vulnerability for themselves and their families. Research has indicated that a significant percentage of tobacco farmers in Indonesia report symptoms associated with GTS, highlighting a major public health issue within these agricultural communities[5,7].

The situation is further aggravated by inadequate access to information about safe farming practices and health education. Initiatives aimed at improving knowledge and protective practices among tobacco farmers, such as the use of educational videos, have shown promising outcomes[6]. However, without substantial infrastructural support, including better access to educational resources and healthcare services, efforts to mitigate the risks associated with tobacco farming are likely to be insufficient[6]. Given the alarming figures from global contexts such as 37.5% prevalence in South Korea and significant incidences in Brazil and India, there is a clear indication that GTS is an occupational hazard that warrants further investigation[6,10]. Based on the research findings and existing literature, the high potential risk of GTS and the limited research on sociodemographic and socio-environmental factors indicate the need for further analysis to support prevention efforts in Kembang Village. This study aimed to explore the sociodemographic and socio-environmental determinants of Green Tobacco Sickness among farmers in Bondowoso Regency.

METHODS

Study design and settings

This study employed an analytical observational design with a cross-sectional approach to examine the association between sociodemographic and environmental factors and the occurrence of Green Tobacco Sickness (GTS) among tobacco farmers. The study was conducted in Kembang Village, Bondowoso Regency, East Java, Indonesia, a region recognized as a major tobacco-producing area. Data collection took place from October 2024 to February 2025, coinciding with the Naa-oogst tobacco harvesting season, during which farmers typically harvest tobacco leaves in the morning when the leaves are wet with dew, a condition that may increase the risk of GTS[11].

Study participants and sample size calculation

The study population comprised all tobacco farmers in Kembang Village, totaling 288 individuals distributed across 10 farmer groups. The sample size was calculated using the Slovin formula, resulting in a minimum required sample of 186 participants. Cluster random sampling was employed, with clusters defined by farmer group membership. The number of participants selected from each group was proportional to the size of the group relative to the total population. Inclusion criteria were active members of a tobacco farmer group in Kembang Village and not having applied pesticides within the last three days. The exclusion criteria were not a native resident of Kembang Village and having a history of diseases with symptoms similar to GTS (e.g. pesticide poisoning, contact dermatitis, miliaria).

Research instrument

Data were collected through structured interviews, direct observation, and documentation. Dependent variables are GTS occurrence, defined as the presence of one or more symptoms (nausea, vomiting, headache, pruritus, abdominal cramps, excessive sweating) within 24 hours after contact with wet tobacco leaves, as per CDC (2015) criteria[12]. The independent variables are sociodemographic and socio-environmental. The sociodemographic included gender (male or female, based on self-report), age group (<30, 30–39, 40–49, 50–59, and ≥60 years), education level (no schooling, primary school, junior high school, senior high school, diploma, and Bachelor's degree), smoking status (current smoker, ex-smoker, or non-smoker, based on their smoking habits), and duration working with tobacco (<5, 5–10, and >10 years). The socio-environmental included

personal hygiene assessed on observed and reported hygiene practices related to tobacco farming activities (good or poor). Poor hygiene includes behaviors such as not washing hands properly, not showering immediately after work, or reusing contaminated work clothes. Use of personal protective equipment (PPE) is classified as appropriate or inappropriate use, determined by observation and self-report regarding the correct use of gloves, long-sleeved clothing, and other protective gear during tobacco handling. Tobacco leaf work activity is categorized as harvester, collector, sorter, and presser.

Data collection tools included a validated questionnaire for interviews and an observation checklist for PPE use and work activities. Prior to data collection, ethical clearance was obtained from the Health Research Ethics Committee (KEPK) of the Faculty of Dentistry, University of Jember, with approval number 2862/UN25.8/KEPK/DL/2024.

Statistical analysis

All collected data were first coded and edited for completeness and consistency before being entered into Stata version 16.1 for analysis. Univariate analysis was performed to describe the characteristics of each study variable, both dependent and independent. The results are presented using descriptive statistics such as frequencies and percentages, means and standard deviations, as appropriate for each variable type. Bivariate analysis was then conducted to examine the association between each independent variable and the occurrence of GTS (the dependent variable). The chi-squared test was used for categorical data to determine whether there was a statistically significant association between variables. Associations were considered statistically significant at $p<0.05$. Independent variables with a $p<0.25$ in the bivariate analysis were included in a multivariate Poisson regression model to control for confounding factors and to identify the most dominant factors associated with GTS occurrence. The multivariate analysis is presented in two models. In the full model, all selected sociodemographic and socio-environmental variables were entered and controlled simultaneously. Variable selection was then performed using the backward elimination method, where variables with $p>0.05$ were sequentially removed, starting with the variable with the highest p-value, until the final fixed model was obtained. All statistical analyses were performed using Stata version 16.1.

RESULTS

Table 1 presents the distribution of sociodemographic characteristics among tobacco farmers in Desa Kembang, Bondowoso. Most respondents were female (58.1%), aged 40–49 years (33.3%), had no schooling (32.3%), and were non-smokers (47.8%). The distribution of symptoms among tobacco farmers experiencing green tobacco sickness (GTS) in Bondowoso reflects the classic clinical picture of acute nicotine poisoning due to skin contact with wet tobacco leaves. The most frequently reported symptoms were headache, itchy skin (pruritus), and excessive sweating.

Table 2 presents the distribution of socio-environmental characteristics among tobacco farmers, and shows that most farmers reported improper use of personal protective equipment (PPE) (87.1%), poor personal hygiene (64.5%), had <5 years of work experience (79%), and the largest proportion worked as leaf pickers (42.5%). These findings highlight key occupational and behavioral risk factors relevant to green tobacco sickness in this population.

The bivariate analysis explored the relationship between

Table 1. Green tobacco sickness (GTS) among tobacco farmers according to sociodemographic characteristics (N=186)

Characteristics	n	%
Age (years)		
<30	12	6.5
30–39	45	24.2
40–49	62	33.3
50–59	42	22.6
60	25	13.4
Sex		
Male	78	41.9
Female	108	58.1
Education level		
No schooling	60	32.3
Primary school	48	25.8
Junior high school	35	18.8
Senior high school	19	10.2
Diploma	13	7.0
Bachelor's	11	5.9
Smoking status		
Smoker	82	44.1
Ex-smoker	14	8.1
Non-smoker	89	47.8
Green tobacco sickness (GTS)		
Yes	97	52.2
No	89	47.8
Symptoms of GTS		
Nausea	18	9.7
Abdominal cramps	5	2.7
Headache	68	38.2
Skin itching	26	14.0
Vomiting	9	4.8
Excessive sweating	35	18.8

Table 2. Green tobacco sickness (GTS) among tobacco farmers according to socio-environment (N=186)

Characteristics	n	%
Use of PPE		
Inappropriate	161	87.1
Appropriate	25	12.9
Personal hygiene		
Poor	120	64.5
Good	66	35.5
Time working with tobacco (years)		
>10	64	34.4
5–10	43	23.1
<5	79	42.5
Tobacco leaf work activity		
Harvester	79	42.5
Collector	28	15.1
Sorter	59	31.7
Presser	20	10.8

PPE: personal protective equipment.

various sociodemographic and socio-environmental factors and the occurrence of green tobacco sickness (GTS) among tobacco farmers (Table 3). The results revealed that smoking status, PPE use, and personal hygiene were significantly associated with GTS among tobacco farmers, while other sociodemographic and occupational variables were not found to be significant predictors in this context. Smoking status was strongly associated with GTS. Farmers who smoked had a significantly lower risk of experiencing GTS compared to non-smokers, with a prevalence ratio (PR) of 0.55 (95% CI: 0.40–0.76, p<0.001). This indicates a statistically significant protective effect of smoking status in this population. The use of PPE emerged as an important factor. Farmers who used PPE inappropriately, were found to have twice the risk of developing GTS compared to those who used PPE appropriately (PR=2.0; 95% CI: 1.05–3.80, p=0009). This relationship was statistically significant, highlighting the critical role of proper PPE use in preventing GTS. Personal hygiene was also significantly associated with GTS. Farmers with poor personal hygiene had a 43% higher risk of GTS than those with good hygiene practices (PR=1.43; 95% CI: 1.03–1.97, p=0.023). This finding underscores the importance of maintaining good personal hygiene to reduce the risk of GTS. In contrast, other variables such as age, sex, education level, duration of work, and tobacco leaf work activity did not show statistically significant associations

Table 3. The association between sociodemographic and socio-environmental factors and the occurrence of green tobacco sickness (GTS) among tobacco farmers (N=186)

Variables	Total n	Green tobacco sickness				p	PR (95% CI)
		Yes		No			
		n	%	n	%		
Sex							
Female	108	55	50.9	53	49.1	0.694	0.95 (0.71–1.24)
Male ®	78	42	53.8	36	46.2		1
Age (years)							
≥60	25	16	64.0	9	36.0	0.199	1.54 (0.74–3.20)
50–59	42	25	59.5	17	40.5	0.272	1.43 (0.70–2.91)
40–49	62	36	58.1	26	41.9	0.296	1.39 (0.69–2.80)
30–39	45	15	23.5	30	21.5	0.590	0.80 (0.36–1.75)
<30 ®	12	5	41.7	7	58.3		1
Education level							
No schooling	60	36	60.0	24	40.0	0.241	1.44 (0.71–2.90)
Primary school	48	25	52.1	23	47.9	0.519	1.25 (0.60–2.57)
Junior high school	35	19	54.3	16	45.7	0.450	1.30 (0.62–2.72)
Senior high school	19	7	36.8	12	63.2	0.788	0.88 (0.36–2.16)
Diploma	13	5	38.5	8	61.5	0.870	0.92 (0.35–2.41)
Bachelor's ®	11	5	45.5	6	54.5		1

Continued

Table 3. Continued

Variables	Total n	Green tobacco sickness				p	PR (95% CI)
		Yes		No			
		n	%	n	%		
Smoking status							
Smoker	82	30	36.7	52	53.4	<0.001	0.55 (0.40–0.76)
Ex-smoker	15	8	53.3	7	46.7	0.332	0.81 (0.49–1.32)
Non-smoker ®	89	59	66.3	30	33.7		1
Use of PPE							
Inappropriate	161	90	55.9	71	44.1	0.009	2.00 (1.05–3.80)
Appropriate ®	25	7	2.8	18	7.2		1
Personal hygiene							
Poor	120	70	58.3	50	41.7	0.023	1.43 (1.03–1.97)
Good ®	66	27	40.9	39	59.1		1
Time working with tobacco (years)							
>10	64	30	46.9	34	53.1	0.097	0.77 (0.56–1.06)
5–10	43	19	44.2	24	55.8	0.079	0.72 (0.50–1.06)
<5 ®	79	48	60.8	31	39.2		1
Tobacco leaf work activity							
Harvester	79	44	55.7	35	44.3	0.098	1.59 (0.85–2.98)
Collector	28	15	53.6	13	46.4	0.202	1.53 (0.76–3.05)
Sorter	59	31	52.5	28	47.5	0.174	1.50 (0.79–2.86)
Presser ®	20	7	3.5	13	6.5		1

PR: prevalence ratio. PPE: personal protective equipment. ® Reference categories.

Table 4. Multivariate analysis of Poisson regression with backward elimination methods

Variables	Full model		Fixed model	
	p	APR	p	APR
Sex	0.070	0.93 (0.87–1.53)	<0.001	0.86 (0.56–0.64)
Age (years)				
≥60	<0.001	3.41 (2.59–4.51)		
50–59	<0.001	1.99 (1.57–2.55)		
40–49	0.011	1.30 (1.06–1.60)		
30–39	0.855	1.02 (0.81–1.28)		
Education level				
No schooling	<0.001	2.49 (1.61–3.58)		
Primary school	0.002	1.99 (1.30–3.07)		
Junior high school	0.003	1.89 (1.23–2.88)		
Senior high school	0.480	1.16 (0.77–1.73)		
Diploma	0.445	1.14 (0.81–1.60)		
Smoking status				
Smoker	<0.001	0.73 (0.67–0.80)	<0.001	0.60 (0.79–0.93)
Ex-smoker	0.305	1.15 (0.87–1.53)	<0.001	1.46 (1.28–1.66)

Continued

Table 4. Continued

Variables	Full model		Fixed model	
	p	APR	p	APR
Use of PPE	0.763	0.98 (0.87–1.10)		
Personal hygiene	0.037	1.10 (1.07–1.21)	<0.001	1.33 (1.19–1.48)
Time working with tobacco (years)				
>10	0.029	0.86 (0.76–0.92)		
5–10	0.001	0.84 (0.76–0.99)		
Tobacco leaf work activity				
Harvester	<0.001	1.58 (1.22–2.06)	<0.001	1.59 (1.42–1.78)
Collector	<0.001	1.59 (1.23–2.05)	<0.001	1.39 (1.20–1.55)
Sorter	0.007	1.34 (1.08–1.66)	<0.001	1.44 (1.31–1.59)

APR: adjusted prevalence ratio. Full model: adjusted for all variables. Fixed model: adjusted for age, smoking status, personal hygiene, tobacco leaf work activity; variables with p>0.05 were excluded from the full model one by one starting from the highest p-value, to obtain the fixed model. PPE: personal protective equipment.

with GTS in the bivariate analysis (p>0.05). This suggests that, within this sample, these factors were not major determinants of GTS risk.

The multivariate Poisson regression analysis identified several independent predictors of GTS among tobacco farmers in Bondowoso. After controlling for potential confounders, four variables remained significantly associated with GTS (Table 4). Sex was a significant factor. Female farmers had a 14% lower risk of experiencing GTS compared to male farmers (adjusted prevalence ratio, APR=0.86; 95% CI: 0.79–0.93, p<0.001). This suggests that either the work activities performed by women or biological differences may contribute to their lower risk. Smoking status showed a strong association. Current smokers had a 40% lower risk of GTS compared to non-smokers (APR=0.60; 95% CI: 0.56–0.64, p<0.001), while ex-smokers had a 46% higher risk than non-smokers (APR=1.46; 95% CI: 1.28–1.66, p<0.001). Although this protective association among smokers is notable, it may be influenced by physiological adaptation, behavioral patterns, or unmeasured confounding, and does not imply that smoking should be promoted for prevention.

Personal hygiene was also independently associated with GTS. Farmers with poor personal hygiene had a 33% higher risk of GTS compared to those with good hygiene (APR=1.33; 95% CI: 1.19–1.48, p<0.001). Lastly, the type of work activity was a significant predictor. Compared to leaf pressers, leaf harvesters had a 59% higher risk of GTS (APR=1.59; 95% CI: 1.35–1.86, p<0.001), leaf sorters had a 48% higher risk (APR=1.48; 95% CI: 1.26–1.74, p<0.001), and leaf collectors had a 39% higher risk (APR=1.39; 95% CI: 1.18–1.64, p<0.001). These results indicate that direct and prolonged contact with wet tobacco leaves in these roles substantially increases GTS risk. Other variables, such as age, education level, and duration of work, were not significantly associated with GTS in the multivariate model (p>0.05).

DISCUSSION

The primary type of tobacco grown and processed in Kembang Village is used to make kretek cigarettes, which are distinctive for their high nicotine content, about 3–5 times higher than regular cigarettes. Each kretek cigarette contains approximately 1.9–2.6 mg of nicotine. Most local farmers are also kretek smokers, which has led to a unique adaptation: long-term smokers develop a tolerance to nicotine, making them less likely to experience acute symptoms of GTS, although this does not eliminate the risk entirely. This high-nicotine tobacco and the prevalence of kretek smoking among farmers create a distinctive health dynamic in the village, where nicotine tolerance alters the pattern of GTS symptoms compared to non-smoking populations. Tobacco farming in Kembang Village involves unique routines shaped by the local environment and traditional practices. Farmers begin harvesting early, during 5:30–7:00 a.m., when tobacco leaves are still wet with dew, which increases the absorption of nicotine through the skin. Sorting follows during 7:30–11:00 a.m., prolonging contact with tobacco leaves and exposure to nicotine. The work is typically managed individually, and the land is cultivated without formal oversight, leading to inconsistent safety practices. Personal hygiene practices are often lacking; many farmers do not wash their hands or work clothes properly after handling tobacco. Economic factors and limited access to hygiene facilities further contribute to this issue. Most farmers do not use PPE properly, often due to discomfort, lack of awareness, economic constraints, and the absence of strict regulations. Improvised PPE, such as gloves made from old socks, is common, and many farmers work without any protection at all.

The data indicate that the majority of the surveyed farmers were aged 40–49 years. This demographic trend aligns with previous studies, which highlight that age serves as an essential indicator of occupational health risks, with

older individuals typically experiencing a higher burden of diseases like GTS due to prolonged exposure to tobacco farming conditions[13,14]. Additionally, the gender distribution suggests a notable female majority. Previous study showed that women also play dual roles as housewives and tobacco farmers[15]. It has implications for understanding gender-specific risks, as studies have shown that women may experience different symptoms and severity levels of occupational illnesses compared to men[10]. In this study, the majority of farmers had no schooling. Higher level of education allows farmers in Kembang Village to choose jobs in other sectors with better economic opportunities, while farmers with low level of education have limited job opportunities, making farming their main choice, which was also mentioned by a previous study[16]. This lack of formal education may hinder awareness and understanding of the health risks associated with tobacco farming. Education plays an important role in promoting health literacy, impacting farmers' willingness to engage in preventive health measures against GTS[17]. The majority of farmers in Kembang Village do not smoke, despite the prevalence of smoking-related behaviors in their community. This phenomenon reflects a complex interplay of cultural, economic, and social dynamics surrounding tobacco cultivation. Based on interviews, it is indicated that while many farmers do not smoke, those who do often view it as a means to cope with fatigue and stress during labor-intensive tasks. Smoking among agricultural workers commonly serves as a form of respite and can be facilitated by socio-economic structures, such as the provision of cigarettes during breaks[18,19]. The association of smoking with societal status within farming communities underscores the entrenched cultural norms that dictate tobacco use behaviors, resonating with research showing that tobacco use often correlates with sociocultural factors in similar demographic groups[20]. Among the farmers who choose to smoke, they consume kretek cigarettes, which are a blend of tobacco and clove. The use of kretek is prevalent in Indonesia and is often linked to specific cultural practices and preferences that differ from those observed in other regions. Moreover, the occupational hazards associated with handling tobacco manifest in various health symptoms, such as headaches, itchy skin, and excessive sweating; these symptoms are notably exacerbated during or immediately after wet tobacco processing[21,22]. Research indicates that skin irritations can facilitate nicotine absorption, potentially amplifying the health risks associated with tobacco exposure in agricultural settings[21]. The health impacts reported among these farmers can be substantial. Chronic health issues, including musculoskeletal disorders and respiratory problems, have been documented among tobacco workers due to the physical demands and exposure to tobacco leaf particulates[21,23]. Furthermore, the intersection of economic necessity and tobacco cultivation complicates potential cessation efforts, as financial reliance on tobacco farming can lead to resistance against public health initiatives aimed at reducing tobacco use[18].

Socio-environmental variables show concerning trends in protective measures and hygiene practices among tobacco farmers. This study found inappropriate use of personal protective equipment (PPE) and poor personal hygiene. This lack of proper protective measures has been linked to increased susceptibility to GTS, as inadequate PPE significantly heightens exposure to nicotine and other harmful substances during harvesting[24]. The study conducted by Fassa et al.[25] emphasizes the risks attributed to inadequate PPE in agricultural settings, including increased nicotine absorption and subsequent GTS symptoms. The results of the study show that the majority of tobacco farmers in Kembang Village do not use PPE properly. The main cause is economic limitations, where low daily incomes (IDR 25000–35000, about US$1.5–2.1) make it difficult for them to buy proper PPE, so they use whatever alternatives they can find, such as used socks as gloves. In addition, comfort is also a consideration, as PPE is often perceived as uncomfortable and hindering productivity. There is a need to introduce PPE designed for comfort and breathability suitable for hot, humid working conditions, such as lightweight, moisture-wicking fabrics and ergonomic designs that do not hinder movement. This can help overcome discomfort and reluctance to wear PPE. Moreover, the high percentage of farmers working more than ten years in tobacco cultivation could lead to cumulative health risks, reinforcing the need for enhanced protective strategies and educational initiatives surrounding the hazards of prolonged exposure to tobacco leaf handling. Personal hygiene among tobacco farmers is very important, considering that they are often directly exposed to wet tobacco leaves, tobacco dust, and chemicals such as pesticides and fertilizers[26]. The majority engaged in tobacco leaf harvesting, an activity known for its intense exposure to nicotine and physical demand. Harvesting was consistently associated with higher prevalence rates of GTS among farmers[5].

The relationship between sociodemographic and socio-environmental factors with Green Tobacco Sickness (GTS)

This study showed that socio-demographic factors, such as educational background and smoking habits, play a significant role in the incidence of GTS, reaffirming findings from previous studies[27,28]. Furthermore, the observation that smoking appears to confer a protective effect against GTS in this study deviates from traditional perceptions that associate nicotine exposure with heightened risk[29-31]. The PR value shows that farmers who smoke are more protective against GTS incidents. Individuals who smoke for a long period of time experience adaptation in the central nervous system due to continuous exposure to nicotine. This adaptation is known as nicotine tolerance, a condition in which nicotinic acetylcholine receptors (nAChR) become less responsive to nicotine stimuli. As a

result, active smokers develop tolerance to nicotine and are less likely to experience nicotine poisoning symptoms even when exposed to certain amounts of nicotine. However, this tolerance does not mean that smoking completely protects against GTS. If nicotine accumulation in the body exceeds the tolerance threshold, the symptoms that arise can become more severe and dangerous. The sensitivity of nAChR receptors gradually increases again when smoking is stopped. Normalization of receptor sensitivity can occur within a few weeks to several months after smoking cessation, depending on the duration and intensity of previous smoking history. As tolerance diminishes, individuals who have quit smoking become more susceptible to the acute effects of nicotine[32]. This aligns with research findings indicating that tobacco farmers who have smoked do not have a significant association with GTS incidents. This suggests that workers who have smoked but have quit smoking for a certain period no longer have nicotine tolerance which could reduce GTS symptoms. Education level among farmers varies, but it does not directly correlate with the risk of GTS or the proper use of personal protective equipment (PPE). Farmers with higher level of education are not necessarily more compliant with PPE use, as comfort, work habits, and local culture often override formal knowledge. Many farmers, regardless of education, neglect PPE due to discomfort or a lack of awareness about its importance for GTS prevention[13].

The study shows that there is a relationship between personal hygiene and the occurrence of GTS. Poor personal hygiene increases the risk of GTS because it allows more nicotine from wet tobacco leaves to be absorbed through the skin[17]. This is supported by the research results, which show that farmers with poor personal hygiene have a 1.43 times higher risk of experiencing GTS compared to farmers with good personal hygiene. Farmers who rarely wash their hands, do not shower immediately, or continue to wear contaminated work clothes after harvesting are at higher risk of experiencing GTS. Sweat and humidity also accelerate nicotine absorption, especially if farmers do not clean themselves properly. Additionally, a lack of awareness about the dangers of nicotine exposure leads farmers to overlook the importance of maintaining cleanliness after work[17]. Research findings indicate that 52.6% of farmers do not wash their work clothes after use, causing nicotine residues on the clothing to continue contacting the skin and increasing exposure. Furthermore, most farmers do not wash their hands properly, such as not using soap, only rubbing the palms of their hands with coconut husks and water, not scrubbing the backs of their hands, not cleaning between their fingers, and not properly scrubbing their nails, which can cause nicotine to remain on the skin's surface for a longer period. Another risky habit is that farmers do not shower immediately after work but instead continue with other tasks or rest, such as sleeping, thereby prolonging the duration of nicotine exposure on the body.

The relationship between sociodemographic and socio-environmental factors with Green Tobacco Sickness (GTS) after controlling for potential confounders

The findings of this study reveal a significant relationship between various sociodemographic and socio-environmental factors and the occurrence of GTS. Notably, gender differences emerged, showing that female farmers exhibited a lower GTS risk compared to their male counterparts. This finding is key, suggesting that gender may influence exposure levels and physiological responses to nicotine[10]. Furthermore, poor personal hygiene and smoking status were also identified as critical risk factors, with poor hygiene correlating with increased GTS risk[17], which underscores the need for enhanced health education in this population. This is in line with previous studies[30,33]. Inadequate personal protective equipment (PPE) and high exposure tasks as critical contributors to GTS outcomes, emphasizing the importance of workplace safety interventions. Importantly, the current study presents a unique perspective regarding smoking behavior, suggesting that farmers who smoke may develop adaptations that mitigate their GTS risk. The results of this study are consistent with previous research on the first reported outbreak of GTS in Brazil, which showed that smoking status was significantly associated with the risk of GTS, with active smokers having a lower risk than non-smokers[25]. This is due to the development of nicotine tolerance as a result of chronic exposure in active smokers. This tolerance reduces the nervous system's sensitivity to nicotine, so that symptoms of poisoning, such as those occurring in GTS, do not easily appear even when exposed through the skin. Conversely, among farmers who had previously smoked, this tolerance had decreased due to cessation of smoking. This made them once again vulnerable to the toxic effects of nicotine when exposed to large amounts, such as during the harvesting of wet tobacco leaves. However, this aspect needs further investigation[29].

The findings highlight the necessity for tailored interventions aimed specifically at enhancing understanding and compliance with personal hygiene practices and proper PPE use among tobacco farmers. Recognizing how gender influences health outcomes allows for the development of gender-sensitive health promotion programs, potentially leading to a greater impact on reducing GTS incidence in male-dominated agricultural practices[34]. As the field of agricultural health continues to evolve, the findings of this study underline the importance of integrating sociodemographic factors into health risk assessments. By building on previous research and reinforcing the significance of demographic factors, a path towards innovative practices that prioritize both farmer safety and health can be developed. This could lead to the formation of national policies aimed at protecting vulnerable populations in agricultural sectors.

Strengths and limitations

The present statistical approach not only enhances the reliability of the findings but exemplifies the necessity for such methodologies in public health research to systematically address occupational hazards associated with farming[5,20,27,35,36]. The findings of this study offer crucial insights for public health initiatives aimed at tobacco farmers. By elucidating the socio-environmental risk profiles associated with GTS, health policymakers and agricultural health organizations can better design interventions that address the specific needs of tobacco farming communities, ultimately promoting safer agricultural practices and reducing GTS incidence[37].

The study is not without limitations. The reliance on self-reported data may introduce biases, and the cross-sectional design limits causal inferences regarding GTS development over time.

Implications

Our recommendations are that the related authorities should provide regular training and counseling to farmers about the risks of GTS, the importance of personal hygiene, and correct PPE usage. The establishment and optimization of Occupational Health Posts (Pos UKK) can further support health education and the prevention of occupational diseases and accidents, ultimately raising farmers' awareness of workplace health risks. There needs to be continuous monitoring to ensure tobacco farmers' compliance with the use of personal protective equipment.

Moreover, future studies should conduct more detailed analyses of risk factors, including exposure duration and harvesting techniques. Exploring mechanisms that may explain the protective effects of smoking and the role of socio-economic factors, which were not directly addressed in this analysis, but warrant further investigation. Different methods can also be used, such as cohort studies.

CONCLUSIONS

This study on the relationship between sociodemographic and socio-environmental factors and the incidence of Green Tobacco Sickness (GTS) among tobacco farmers in Kembang Village, Bondowoso, reveals several important findings. Most tobacco farmers in this village are women aged 40–49 years, with most having no formal education and being non-smokers. Socio-environmental observations indicate that improper use of personal protective equipment (PPE), poor personal hygiene, work experience of less than five years, and primary involvement in leaf-picking. The prevalence of GTS among these farmers is notably high, with 52.2% (97 individuals) affected. Bivariate analysis indicates that among sociodemographic factors, only smoking status is significantly associated with GTS, while age, gender, and education level are not. For socio-environmental factors, both PPE use and personal hygiene are significantly related to GTS, whereas work duration and type of work activity are not. Multivariate analysis further highlights four variables, gender, smoking status, personal hygiene, and type of work activity, as being significantly associated with GTS incidence.

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DATA AVAILABILITY
The data supporting this research are available from the authors on reasonable request.

AUTHORS' CONTRIBUTIONS
DCR and AEN: study design. DCR: data collection. DCR and AEN: formal analysis, writing of original draft, writing, reviewing, and editing of the manuscript. YA: supervision. All authors read and approved the final version of the manuscript.

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