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Self-reported health effects of pesticides among cotton farmers from the Central-West region in Burkina Faso

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ABSTRACT

Pesticides are chemicals used to control pests with sometime harmful effects on human health. This paper presents results of self-reported health effects experienced by cotton farmers in the Central-West region of Burkina Faso. It was a cross-sectional survey conducted from October to December 2021 among 585 consenting conventional and organic cotton farmers. Data collected included pesticides used, they use conditions, farming practices, experienced health effects. Binary logistic regression was used to find relationships between self-reported health effects and the type of cotton produced. Results showed that all conventional cotton farmers (100%) reported using synthetic pesticides compared to organic ones who using only natural insecticides. Both conventional and organic farmers reported health effects that occurred at least once since they started using pesticides, involving skin effects (85.27% conventional, 65.52% organic), nervous (88.95% conventional, 48,71% organic), respiratory (88.10% conventional, 67.67% organic) systems. 99.72% of conventional farmers vs 46.98% of organic ones reported skin irritation following pesticide use. 69.97% of conventional vs 35.34% of organic cotton farmers reported acute signs such as severe headaches. In univariate and multivariate logistic regressions, severe headaches, dizziness, skin, and ocular effects were significantly associated with conventional farmers compared to organic ones ($p < 0.05$). There was a significant relationship between vomiting ($p = 0.014$), diarrhea ($p = 0.003$) and experience in synthetic pesticide use among conventional farmers. Among organic farmers, there was no significant relationship between health effects reported and experience in organic insecticides use. there was a significant relationship between severe headaches ($p = 0.01$), rhinitis ($p = 0.006$), cough ($p = 0.0001$), skin and ocular irritations ($p = 0.007$) and the frequency of synthetic insecticides use per year by conventional farmers. Study showed that conventional and organic cotton producers experience the same types of health effects. However, these health effects were significantly associated with conventional farmers compared to organic ones.

1. Introduction

Cotton is one of the most important cash crops in sub-Saharan West Africa. Its production contributes substantially to the gross domestic product (GDP) of producing countries as Benin (13%) [1], Mali (15%) [2], Burkina Faso (10.4%) [3], Ivory Coast (7%) [4] and Chad (over 10%) [5]. In Burkina Faso, 2.2 million people earn their income from the production, ginning, weaving or transport of cotton [6–8]. However, the

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cotton sector is increasingly confronted to pests whose the economic effects are compounded by precarious climatic conditions [9,10]. Today, most cotton farmers in Burkina Faso heavily rely on synthetic pesticides to control cotton pest [11,12]. According to studies cotton is a crop which consumes more than 90% of total pesticides used in Burkina Faso despite the health and environmental hazards they involve [13]. Indeed, worldwide estimates of the incidence of pesticide poisoning indicate that there are approximately 300 000 deaths from pesticide poisoning, 3 000 000 cases of severe acute poisoning, and 25 000 000 cases of less severe poisoning per year [14]. Exposure to synthetic pesticides can cause the appearance of toxicological signs and pathologies that affect the digestive, respiratory, nervous, hematopoietic, kidney, and integumentary systems, as well as metabolic disorders [15]. The toxicity of pesticides in humans is related to their potential to interact with the biological supports of the body in case of contact or penetration. This interaction can be the cause of physiological disorders of cellular, tissue or hormonal origin. Several studies have shown that after pesticide use, farmers report health problems involving digestive (vomiting, diarrhea) and neurological (headaches, dizziness, forgetfulness) disorders, eyes and skin effects (eye irritations, rashes, itchy skin, burning eyes/face) and general signs (tiredness, fever) [16,17]. The extent and severity of intoxication depend on the intensity and mode of exposure and on the characteristics of the pesticide(s) used. Health effects related to populations exposure to synthetic pesticides are well documented [18,19]. However, few authors have investigated health effects of natural pesticides. It is therefore important to also document the use conditions of biopesticides that may be responsible for health effects among organic farmers. The objective of the study was to investigate self-reported health effects of pesticides among conventional cotton farmers (using synthetic pesticides) compared to organic ones (using natural pesticides) in the Central-West region of Burkina Faso.

2. Material and methods

2.1. Study area

The study was conducted in the municipalities of Sapouy (11° 33' 00" N; 1° 46' 01" W) and Biéha (11° 03' 26" N; 1° 49' 20" W) in the Central-West region of Burkina Faso (Figure1). These two municipalities are in the Sudanian climatic zone favorable to cotton production [20]. Sapouy is a municipality of the province of Ziro, one of the Burkina Faso country's major cotton-producing province. It produced 13,076.760 tons of conventional and 289.26 tons of organic cotton respectively, during the 2019–2020 cotton campaign. This cotton production comes with a massive use of pesticides in the region, partially fueled by informal pesticide imports from neighboring Ghana [21].

2.2. Study population, sample size determination and sampling

The number of participants to be included in the study was determined according to the Schwartz formula, as follows:

$$(I): n = [\mathcal{E}^2\ p\ (1\ -p)]/(i)^2$$

n: minimum sample size; Ɛ: sampling confidence interval 5% (1.96); p: estimated prevalence of self-reported health effects among cotton farmers (0.50); i: level of precision (5%) [22].

Assuming a 10% non-response rate, with the formula [n/(1–10%)], a total of at least 427 cotton farmers were included in the study. This number was then divided equally between conventional and organic cotton farmers, i.e. 214 participants per group.

Conventional and organic cotton farmers at least 18 years old were included in the study. They are organized in cotton producer groups (CPGs), and the study area accounts 60 GPCs of conventional cotton producers and 7 CPGs of organic cotton farmers. Participants were selected from 1/4 of the 60 conventional GPCs and from all the 7 organic GPCs. The choice of these two sub-groups of farmers can be explained on the one hand, by their membership of separate and regulated sectors. Conventional cotton farmers use synthetic pesticides to control cotton pests, while organic ones do not use them.

2.3. Survey

Data were collected from October to December 2021. The survey consisted in administering individual questionnaires to study participants through personal interviews [23]. The questionnaire, which included closed and open questions, was tested, and adjusted during a pilot phase. The questionnaire included questions about the types of pesticides used, their conditions of use, and about health effects experienced. Each participant was asked if they had ever been in contact with one or more of pesticides they use at least once in their career. In the event of a positive answer, the cotton farmer was asked to specify health effects experienced during contact or during the week following contact. The interviews were conducted either in one of the three national languages (Moore, Dioula, Gourounsi) or in French. Answers were recorded through KoboCollect, a smartphone-based questionnaire tool. Data collected was then stored on the KoboToolbox platform.

2.4. Statistical analysis

Data were analyzed with SPSS software version 20 (SPSS Inc., Chicago, IL, USA). Continuous variables were presented as mean ± standard deviation. Categorical variables were summarized as numbers and percentages. The mean values of continuous variables and the proportions were compared through T-test and Chi-square test respectively. Binary logistic regression was used to find relationships between self-reported health effects and the type of cotton produced, setting having no health effects and being an organic cotton farmer as references. Chi-square or Fisher's exact tests was used to find relationships between Self-reported health effects and risk factors. For more precision, statistical analysis of the study was performed with a 95% confidence interval and different relationships observed were indicated with their associated p-value. Differences were considered statistically significant for $p < 0.05$.

2.5. Ethics

The research protocol was approved by the institutional ethics committee on health research of Burkina Faso's Health Sciences Research Institute (IRSS/CNRST) under the number 009–2022/CEIRES of 20/01/2022. The participants were included in the study after their free and informed consent was signed. The information collected was kept confidential and anonymous.

3. Results

3.1. Characteristics of the study population

A total of 585 adults including 353 conventional and 232 organic cotton farmers were surveyed. Participants came from 23 CPGs in 20 villages included in the study (Fig. 1). The average age of conventional cotton farmers is higher (40.78 ± 11.43) compared to organic ones (37.66 ± 12.51) ($p < 0.05$). Most conventional cotton farmers were mainly males (100%), while organic ones where predominantly females (54.31%). 76.49% and 68.10% of conventional and organic cotton farmers respectively did not receive formal schooling. Most of conventional farmers (95.18) and organic ones (89.65%) are married. The number of smokers is higher among conventional cotton farmers (18.13%) compared to organic ones (6.90%) (Table 1).

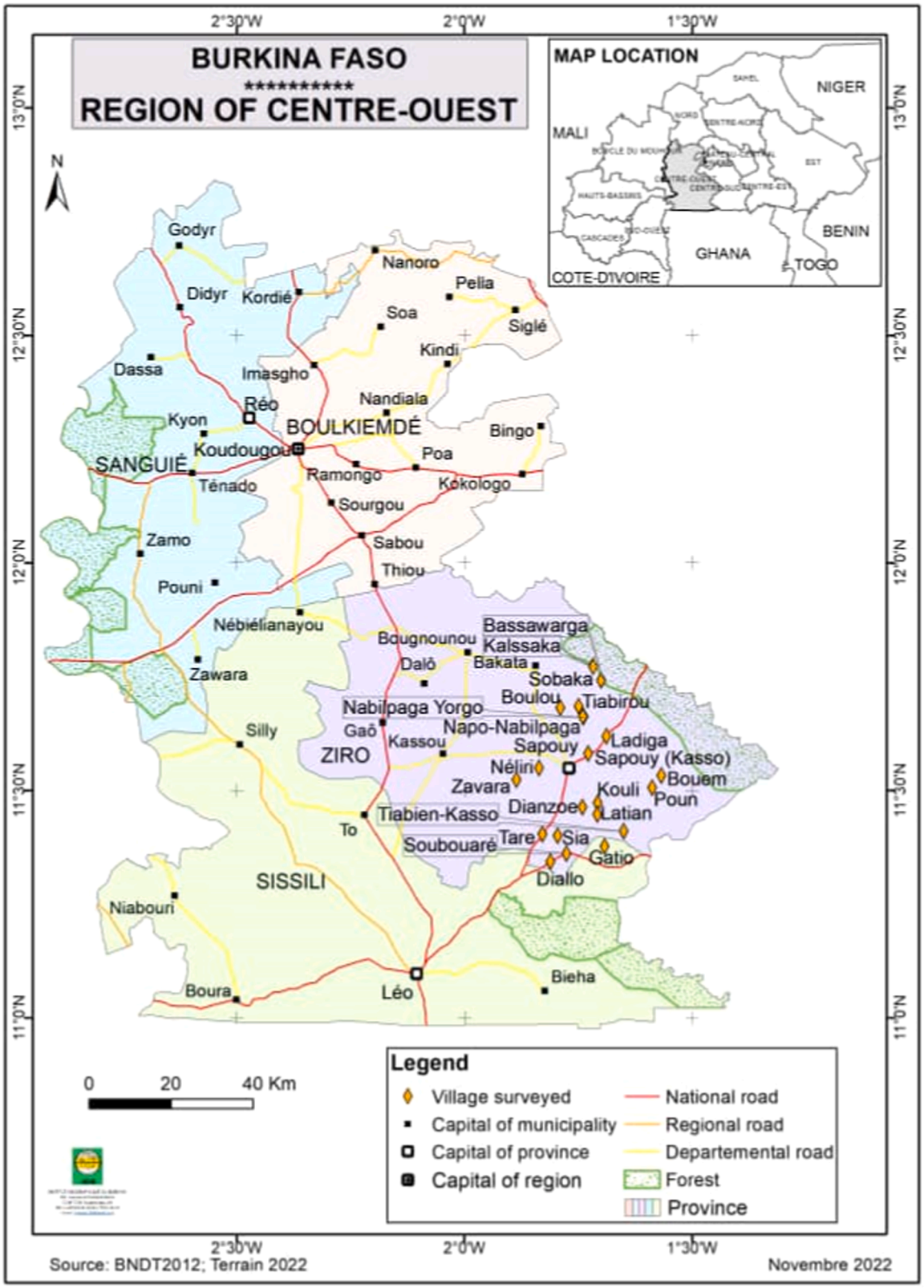

Fig. 1. Map of study villages surveyed (
Source: IGB, BNDT2012, adapted in 2022).

Table 1
Descriptive characteristics of conventional and organic cotton producers.

		Conventional (n = 353) Mean ± SD	Organic (n = 232) Mean ± SD	Statistical analysis
Age		40.78 ± 11.43	37.66 ± 12.51	T-test p = 0.026 *
		n (%)	**n (%)**	
Gender				n/a
Male		353 (100.00)	106 (45.69)	
Female		0 (0.00)	126 (54.31)	
Level of education				Chi-square test
No formal school education		270 (76.49)	158 (68.10)	p = 0.4159
Primary		60 (17.00)	49 (21.12)	
Secondary or higher		23 (6.51)	25 (10.78)	
Marital status				
Married	Yes	336 (95.18)	208 (89.66)	Fisher's exact test p = 0.2828
	No	17 (4.82)	24 (10.34)	
Consumption of psychoactive substances				
Cigarette	Yes	64 (18.13)	16 (6.90)	Fisher's exact test p = 0.0309 *
	No	289 (81.87)	216 (93.10)	
Alcohol	Yes	41 (11.61)	16 (6.90)	Fisher's exact test p = 0.3350
	No	312 (88.39)	216 (93.10)	
Narcotics	Yes	2 (0.57)	0 (0.00)	n/a
	No	351 (99.43)	232 (100.00)	

n: frequency; n/a: not applicable; *Significant level at p-value < 0.05

3.2. Health effects experienced by cotton farmers

3.2.1. Cotton farmers's self-reported health effects during or after pesticides use

Table 2 shows results of health effects reported by cotton growers after at least one contact with pesticides since they started using them. More than eighty-eight percent (88.95%) of conventional cotton farmers vs 48.71% of organic ones reported health effects involving nervous system, after at least one contact with one or more pesticides since they started using them. Over eighty-eight percent (88.10%) of conventional cotton farmers vs 67.67% of organic ones reported health effects involving respiratory system after contact. Among conventional cotton farmers, 85.27% reported health effects involving skin, compared to 65.52% among organic ones. Regarding health effects involving eyes, 79.60% of conventional cotton producers reported health effects involving ocular effects, compared to 54.31% of organic ones.

3.2.2. Signs associated with type of cotton cultivated

In univariate and multivariate logistic regressions, neurological signs such as headaches and dizziness were significantly associated with conventional cotton farmers ($p < 0.05$) compared to organic ones (Table 3). Skin and ocular effects such as skin irritations and burns, and eye irritations are also significantly associated with conventional cotton farmers ($p < 0.05$) compared to organic ones. In multivariate logistic regression, conventional cotton farmers have a higher risk losing balance after contact with synthetic pesticides compared to organic ones after contact with bioinsecticides [OR = 12.172 (95% CI: 0.913–162.328)] (Table 3).

3.3. Main pesticides used in the study area

Table 4 shows pesticides inventoried and used in cotton production in the study area. To control cotton pests, all conventional cotton farmers use synthetic insecticides and herbicides, while organic cotton producers use only natural insecticides. Among conventional cotton farmers, most herbicides are unregistered. Only one bioinsecticide out of four is registered. The synthetic pesticides used by conventional cotton farmers are classified in the following toxicological classes II (Moderately hazardous), III (Slightly hazardous), U (Unlikely to present acute hazard), according to WHO classification [24]. However, for organic cotton producers, the toxicological class of only one organic insecticide

Table 2
Health effects experienced during and after farmers' exposure to pesticides.

	Health effects reported by farmers	Conventional (n = 353)		Organic (n = 232)		Statistical analysis
Systems	Signs experienced and reported by cotton farmers after at least one contact with one or more pesticides since they started using them	Frequency and percentage (%) of cotton farmers experiencing at least one sign	Frequency and percentage (%) of each sign	Frequency and percentage (%) of cotton farmers experiencing at least one sign	Frequency and percentage (%) of each sign	Chi-square test
Nervous system	Severe headaches	314 (88.95)	247 (69.97)	113 (48.71)	82 (35.34)	p = 0.0005 *
	Dizziness		233 (66)		74 (31.90)	
	Temporary impotence of a limb or specific part of body		79 (22.37)		0 (0.00)	
	Trembling or shaking		57 (16.15)		2 (0.86)	
	Hearing difficulties (up to 48 h or more)		51 (14.45)		0 (0.00)	
	Slowness or weakness in performing routine tasks		49 (13.88)		5 (2.16)	
	Difficulty walking or keeping balance		44 (12.46)		4 (1.72)	
Respiratory system	Rhinitis (Stuffy or runny nose)	311 (88.10)	248 (70.25)	157 (67.67)	118 (50.86)	p = 0.015*
	Persistent cough for more than 48 h		119 (33.71)		62 (26.72)	
	Feeling of tightness in the chest		86 (24.36)		10 (4.31)	
Skin effects	Skin irritations	301 (85.27)	352 (99.72)	152 (65.52)	109 (46.98)	p = 0.085
	Body burns		37 (10.48)		7 (3.02)	
Ocular effects	Eye irritations	281 (79.60)	278 (78.75)	126 (54.31)	124 (53.45)	p = 0.007*
	Blurred vision		15 (4.25)		1 (0.43)	
Cardiovascular system	Irregular heartbeat	233 (66.00)	233 (66.00)	58 (25.00)	58 (25.00)	p = 0.011*
Digestive system	Abdominal pain	206 (58.36)	139 (39.38)	114 (49.14)	49 (21.12)	p = 0.118
	Nausea		95 (26.91)		94 (40.52)	
	Vomiting		38 (10.76)		7 (3.02)	
	Diarrhea		27 (7.65)		1 (0.43)	
Urinary system	Urinary pain	142 (40.23)	108 (30.59)	37 (15.95)	32 (13.79)	p = 0.069
	Abnormally foamy urine		29 (8.21)		2 (0.86)	

* Significant level at p-value < 0.05

Table 3
Relationships between some health effects reported by conventional cotton farmers compared to organic ones.

	Binary logistic regression			
	Univariate (CI=95%)		Multivariate (CI=95%)	
Health effects reported by farmers (Reference = No)	p-value	OR (CI 95%)	p-value	OR (CI 95%)
Neurological				
Severe headaches	0.0001 *	4.211 (2.963 – 5.986)	0.005 *	2.412 (1.306 – 4.455)
Dizziness	0.0001 *	4.090 (2.876 – 5.817)	0.005 *	2.503 (1.315 – 4.764)
Trembling or shaking	0.0001 *	22.242 (5.374 – 92.059)	0.098	4.011 (0.772 – 20.835)
Slowness or weakness in performing routine tasks	0.0001 *	7.350 (2.883 – 18.742)	0.180	0.187 (0.016 – 2.163)
Difficulty walking or keeping balance	0.0001 *	8.152 (2.888 – 23.012)	0.059	12.172 (0.913 – 162.328)
Respiratory				
Rhinitis (Stuffy or runny nose)	0.0001 *	2.263 (1.605 – 3.190)	0.273	0.680 (0.342 – 1.354)
Persistent cough for more than 48 h	0.752	1.056 (0.753 – 1.480)	0.210	0.662 (0.348 – 1.262)
Feeling of tightness in the chest	0.0001 *	7.183 (3.644 – 14.147)	0.013 *	3.490 (1.296 – 9.401)
Throat irritation	0.515	1.116 (0.801 – 1.556)	0.013 *	0.406 (0.200 – 0.824)
Skin				
Skin irritations	0.049 *	1.426 (1.001 – 2.032)	0.006 *	0.409 (0.217 – 0.770)
Body burns	0.0001 *	4.569 (3.201 – 6.520)	0.0001 *	4.216 (2.291 – 7.758)
Ocular				
Eye irritations	0.0001 *	3.203 (2.229 – 4.601)	0.017 *	2.138 (1.149 – 3.979)
Cardiovascular				
Irregular heartbeat	0.0001 *	6.370 (4.399 – 9.222)	0.0001 *	2.889 (1.639 – 5.092)
Digestive				
Abdominal pain	0.0001 *	2.410 (1.647 – 3.527)	0.290	1.411 (0.745 – 2.673)
Nausea	0.0001 *	0.535 (0.376 – 0.760)	0.0001 *	0.279 (0.153 – 0.511)
Vomiting	0.001 *	3.895 (1.708 – 8.879)	0.585	0.698 (0.192 – 2.540)
Diarrhea	0.004 *	19.215 (2.593 – 142.408)	0.255	3.944 (0.372 – 41.838)
Urinary				
Urinary pain	0.0001 *	2.561 (1.676 – 3.914)	0.719	1.124 (0.595 – 2.124)

OR: Odds ratio; CI: confidence interval; n = 585 (types of cotton farmers: 353 conventionals and 232 organics); *Significant level at p-value < 0.05

is known (classe III). All conventional cotton farmers declared using insecticides whose active ingredients belong to the carbamate and anthranilic diamide families. All of them also use herbicides whose active ingredients belong to the phosphonoglycin family. Organic cotton producers all declared to be using neem extract and potassium salts of fatty acids, at times complemented by two other organic insecticides.

3.4. Cotton cultivation practices, pesticide use conditions and risk factors

Information's in Table 5 show pesticides use conditions and exposure risk factors for cotton growers. Conventional cotton farmers have more experience in pesticides use in years (14.01 ± 12.02) compared to organic ones (5.63 ± 4.42) ($p < 0.05$). Most organic cotton farmers (82.33%) received training on biopesticide use, while only slightly over a third (35.69%) of conventional cotton farmers received pesticide training. Conventional cotton famers farm larger areas in hectares (2.80 ± 1.67 ha) compared to organic farmers (1.19 ± 0.82). While most organic cotton farmers (51.29%) spray their cotton field in one single session per treatment, the vast majority of conventional cotton farmers (87.25%) need two or more spraying sessions per treatment to spray the whole field. Conventional cotton farmers use insecticides at a higher frequency per year (10.58 ± 3.26) compared to organic ones (5.55 ± 1.88). Most of conventional (98.87%) and organic (97.84%) cotton farmers use backpack sprayer (16 L) to treat cotton. Results show that conventional and organic cotton farmers use a variety of personal protective equipment (PPE) to protect themselves during cotton spraying sessions. However, there was no significant difference between the proportion of conventional and organic cotton producers using at least a type of PPE.

3.5. Relationships between health effects reported by cotton farmers and associated factors

Among conventional cotton farmers, analysis of associated factors shows a significant relationship between reported digestive signs such as vomiting ($p = 0.014$), diarrhea ($p = 0.003$) and the experience (in years) in synthetic pesticide use. However, among organic cotton farmers, there was no significant relationship between signs reported by farmers and experience in bioinsecticides use (Table 6). Among conventional cotton farmers, analysis of associated factors shows a significant relationship between neurological signs such as severe headaches ($p = 0.01$), dizziness ($p = 0.001$), slowness or weakness in performing routine tasks ($p = 0.0001$), difficulty maintaining balance ($p = 0.0001$) and the frequency of chemical insecticide use per season in general. There was a significant relationship between respiratory signs reported by conventional cotton farmers such as rhinitis ($p = 0.006$), cough ($p = 0.0001$), tightness in the chest (0.0001), throat irritation ($p = 0.0001$) and the frequency of synthetic insecticides use per season in general. The skin and eye effects reported by conventional cotton farmers (skin and eye irritations) are significantly associated with the frequency of chemical insecticides use ($p = 0.007$). However, among organic cotton farmers, only abdominal pain was significantly associated with the frequency of bioinsecticide application per season in general ($p = 0.033$). Severe headaches are significantly associated with time of return to the cotton field after spraying in both conventional and organic cotton producers ($p < 0.05$). Rhinitis ($p = 0.023$) and throat irritation ($p = 0.047$) are significantly associated with the time taken by conventional cotton farmers to return to the cotton field after spraying, compared with organic ones, where only throat irritation is significantly associated with the time of return to the organic cotton field after spraying ($p = 0.039$). Results of Table 6 show also that Skin burns are significantly associated with the time that conventional farmers return to the cotton field after spraying ($p = 0.040$), while skin irritations are significantly associated with the time that organic farmers return to the cotton field after spraying ($p = 0.026$).

4. Discussion

Pesticides, through their toxic potential, are the source of various health effects among users exposed to these substances. This study allowed describing the use conditions of pesticides and determining factors which would favor the occurrence of health effects. Results show that, in the study area, conventional cotton was predominantly cultivated by males, while most organic cotton producers were females. The low percentage of females among conventional cotton farmers could be related to social constraints that do not favor females' free access to large cultivable surface [25]. This can also be explained by the fact that the treatment of conventional cotton fields with synthetic pesticides is mainly reserved for males. However, the high proportion of females in organic cotton cultivation in the study area could be explained by the fact that organic cotton is cultivated on small areas. Organic cotton

Table 4
Inventory of pesticides used for cotton production in the study area.

N°	Trade name	Active ingredients	Chemical family	Number and percentage (%) of users on a total of 353 conventional and 232 organic farmers	Type of pesticide	WHO acute toxicity class	Registration status (CSP)	Type of formulation	Manufacturer country	Supplier
		Synthetic pesticides inventoried among conventional cotton farmers								
1	AVAUNT 150 EC	Indoxacarb (150 g/L)	Carbamates	353 (100)	Insecticide	II	Registered	EC	Burkina Faso	SAPHYTO SA
2	CORAGEN 20 SC	Chlorantraniliprole (200 g/L)	Anthranilic diamides	353 (100)	Insecticide	U	Registered	SC	Burkina Faso	SAPHYTO SA
3	K-OPTIMAL	Lambda-cyhalothrin (15 g/L); Acetamiprid (20 g/L)	Pyrethroids; Neonicotinoids	213 (60.34)	Insecticide	II	Registered	EC	Switzerland	Solevo Burkina Faso
4	THALIS 56 EC	Emamectin benzoate (24 g/L); Acetamiprid (32 g/L)	Avermectins; Neonicotinoids	140 (39.66)	Insecticide	II	Registered	EC	Ivory Coast	AF-CHEM SOFACO
5	SUNPHOSATE 360 SL	Glyphosate (360 g/L)	Phosphonoglycins	353 (100)	Herbicide	III	Registered	SL	Ghana	WYNCA SUNSHINE AGRIC PRODUCTS AND TRADING CO., (GH) LTD.
6	GAGNANT SUPER 412,5 EC	-	-	42 (11.90)	Herbicide	-	Unregistered	EC	Ivory Coast	KETALON CI
7	GRAMOQUAT SUPER	Paraquat chloride (200 g/L paraquat ion)	Pyridines	42 (11.90)	Herbicide	II	Unregistered	EC	Ghana	Kumark Trading Ent.
8	GANORSATE	Glyphosate (480 g/L)	Phosphonoglycins	353 (100)	Herbicide	III	Unregistered	-	Ghana	GANORMA AGRO CHEMICALS LTD
9	HERBEXTRA 720 SL	Salt of 2,4-D-amine (720 g/L)	Aryloxyacids	68 (19.26)	Herbicide	II	Registered	SL	Ghana	Kumark Trading Ent.
10	POWER	Diuron (800 g/kg)	Phenylamines	262 (74.22)	Herbicide	III	Registered	WG	Mali	TOGUNA SARL
11	ADWUMA WURA	Glyphosate (360 g/L); Isopropylamine salt (480 g/L)	Phosphonoglycins	68 (19.26)	Herbicide	U	Unregistered	SL	Ghana	KUMARK COMPANY LTD.
		Organic pesticides inventoried among organic cotton farmers								
1	PIMENT	Mixture of peppers, Batik® and plant extracts	Plant extracts; Bacteria	70 (30.17)	Bioinsecticide		Unregistered	-	Burkina Faso	Personal manufacturing
2	BATIK® WG	*Bacillus thuringiensis var Kurstaki* (32000 UI/mg)	Bacteria	123 (53.02)	Bioinsecticide	III	Registered	WG	France	SAPHYTO (Burkina Faso); MPC (Mali); AGRIMEX-SA (Niger); Spia (Senegal); Calivoire (Ivory Coast)
3	H-N	Neem extract	Plant extracts	232 (100)	Bioinsecticide	-	Unregistered	-	Burkina Faso	BIOPROTECT
4	E-CODAOLEO K	Potassium salts of fatty acids	Plant extracts	232 (100)	Bioinsecticide	-	Unregistered	-	Spain	SAPHYTO SA

EC: emulsifiable concentrated; SC: concentrated suspension; SL: soluble concentrate; WG: granules to disperse in water; II: Moderately hazardous; III: Slightly hazardous; U: Unlikely to present acute hazard (WHO classification)

Table 5
Pesticides use conditions and exposure risk factors.

	Conventional (n = 353)	Organic (232)	
	n (%)	n (%)	Statistical analysis
Experience in pesticide use (years)			
< 5	48 (13.60)	112 (48.27)	
5–10	94 (26.63)	93 (40.30)	
10–15	65 (18.41)	18 (7.73)	
15–20	68 (19.26)	5 (2.15)	
> 20	78 (22.09)	4 (1.72)	
Mean ± SD	14.01 ± 12.02	5.63 ± 4.42	T-test p = 0.0001 *
Cultivated area (ha)			
< 1	8 (2.27)	84 (36.05)	
1–2	174 (49.29)	127 (54.94)	
2–3	80 (22.66)	16 (6.87)	
3–4	39 (11.05)	2 (0.86)	
4–5	27 (7.65)	2 (0.86)	
> 5	25 (7.08)	1 (0.43)	
Mean ± SD	2.80 ± 1.67	1.19 ± 0.82	T-test p = 0.0001 *
Spray sessions per treatment to treat the entire crop area			
One session	45 (12.75)	119 (51.29)	Chi-square test
Two sessions	176 (49.86)	84 (36.21)	p = 0.0001 *
More than two sessions	132 (37.39)	29 (12.5)	
Frequency of insecticide treatments per season in general			
≤ 6 times	65 (18.41)	182 (78.45)	T-test
> 6 times	288 (81.59)	50 (21.55)	p = 0.0001 *
Mean ± SD	10.58 ± 3.26	5.55 ± 1.88	
Training in pesticide use	126 (35.69)	191 (82.33)	Chi-square test p = 0.008 *
Time to return to the field after treatment			
Immediately after treatment	64 (18.13)	12 (5.17)	
1 – 7 days	237 (67.14)	158 (68.10)	
7 – 14 days	48 (13.60)	58 (25.00)	
≥ 14 days	4 (1.13)	4 (1.72)	
Mean ± SD	2.60 ± 2.66	4.00 ± 3.60	T-test p = 0.0001 *
Type of device used for treatments			
Backpack sprayer (16 L)	349 (98.87)	227 (97.84)	n/a
Portable battery-operated sprayer (5 L)	4 (1.13)	1 (0.43)	
Automatic battery sprayer (16 L)	0 (0.00)	4 (1.72)	
Use of any PPE	289 (81.87)	187 (80.60)	Chi-square test p = 0.470
Type of PPE used			
Dust masks	266 (92.04)	180 (96.26)	
Boots	100 (34.60)	90 (48.13)	
Gloves	62 (21.45)	64 (34.22)	
Glasses	58 (20.07)	31 (16.58)	
Personal clothing	22 (7.61)	3 (1.60)	
Headset	8 (2.77)	0 (0.00)	
Combinations	7 (2.42)	3 (1.60)	
Cartridge masks	2 (0.69)	1 (0.53)	

n: frequency; *Significant level at p-value < 0.05

reduce also the production cost, as it eliminates the cost of using agrochemicals [26]. More than seventy percent (70.82%) and 66.38% of conventional and organic cotton farmers respectively had no formal school education. These results confirm those of other studies which found that 81.5% of pesticide users had no formal schooling [18].

Health effects reported by farmers after their contact with pesticides showed that neurological, respiratory, ocular, cardiovascular signs were significantly higher among conventional farmers compared to organic ones ($p < 0.05$). Some synthetic pesticides as AVAUNT 150 EC (carbamates), CORAGEN 20 SC (Anthranilic diamides) and SUNPHOSATE 360 SL (phosphonoglycins) were used by all conventional cotton farmers. The same observation applies to organic farmers, all of them using H-N and E-CODAOLEO K. These practices also expose farmers to a diversity of molecules. This multiple exposure may also be the cause of health effects known as "cocktail effects" involving neurological, respiratory, cardiovascular systems and eyes [27]. Results showed that 5 out of 11 synthetic pesticides used were class II toxicity. Class II substances being moderately hazardous according to WHO classification, this could explain health effects observed among conventional cotton farmers [28]. Previous studies have shown that synthetic pesticides of the carbamate and pyrethroid families cause toxic effects with acute signs involving neurological, digestive, respiratory, cardiovascular systems, skin and eyes [29,30]. The types and frequency of health signs reported were consistent with findings of similar studies in African contexts [31, 32].

Analysis of associated factors showed a significant relationship between headaches, dizziness, skin irritations, body burns, eye irritations and conventional cotton farming in univariate and multivariate logistic regressions ($p < 0.05$). These results show that conventional cotton farmers have a higher risk having reported health effects compared to organic ones. For difficulty walking or keeping balance after contact with synthetic pesticides, the OR was 12.172 (95% CI: 0.913–162.328) in multivariate analysis. This means that a conventional cotton farmer has a high-risk losing balance in the event of contact with synthetic pesticides, and that this risk varies from 0.913–162.328. However, this risk is low for an organic farmer using biopesticides. Among conventional cotton farmers, a significant relationship was observed between vomiting ($p = 0.014$), diarrhea ($p = 0.003$) and the experience in synthetic pesticide use. However, among organic cotton farmers, there was no significant relationship between digestive signs and experience in pesticide use. These results show that as experience with pesticides increases, conventional cotton farmers are more exposed to health effects than organic ones. These results could be explained by the use of highly toxic synthetic pesticides by conventional farmers such as GRAMOQUAT SUPER witch is formulated with paraquat chloride, an herbicide banned due to its high toxicity [33]. Previous studies have also reported acute signs such as headaches, unbalance, dizziness, vomiting, diarrhea, skin irritations, body burns and eye irritations after farmer' exposure to synthetic pesticides [28,34]. There was a significant relationship between neurological signs such as severe headaches ($p = 0.01$), dizziness ($p = 0.001$), slowness or weakness in performing routine tasks ($p = 0.0001$), difficulty maintaining balance ($p = 0.0001$) and the frequency of synthetic insecticide use per season in general among conventional cotton farmers. Neurological effects associated with the annual use of synthetic insecticides by conventional cotton farmers could be explained by the use of pesticides from the carbamate family, such as AVAUNT 150 EC, known for their toxic effects on the central and peripheral nervous systems [29]. There was a significant relationship between respiratory signs reported by conventional cotton farmers such as rhinitis ($p = 0.006$), cough ($p = 0.0001$), tightness in the chest (0.0001), throat irritation ($p = 0.0001$) and the frequency of synthetic insecticides use per season in general. Throat and respiratory tract irritations reported by conventional cotton farmers could be related to the use of herbicides containing respectively glyphosate (SUNPHOSATE 360 SL) and paraquat chloride (GRAMOQUAT SUPER) as these molecules are known for their highly irritating properties [35–37]. Anthranilic diamides (Chlorantraniliprole), organophosphate and carbamate insecticides are also known to be involved in the onset of respiratory symptoms [38,39]. Previous study has also shown that synthetic pesticides can alter respiratory function by inducing pulmonary ventilatory troubles [40]. There was also a strong relationship between skin and eye irritations ($p = 0.007$) and the frequency of synthetic insecticides use among conventional cotton farmers. These results may be explained by the failure to observe insecticide use frequencies by most of conventional cotton farmers. Study showed that most of conventional cotton farmers (81.59%) used insecticides more than 6 times per year compared to organic ones (21.55%). However, the para-statal company,

Table 6
Factors associated with some self-reported health effects among conventional and organic cotton farmers.

	Associated factors															
	Experience in pesticide use (years)		Frequency of insecticide treatments per season in general		Spray sessions per treatment to treat the entire crop area		Cultivated area (ha)		Time to return to the field after treatment		Personal protective equipment (PPE)		Training in pesticide use		Level of school education	
Health effects reported by farmers	Conventional p-value‡	Organic p-value‡	Conventional p-value‡	Organic p-value‡	Conventional p-value‡	Organic p-value‡	Conventional p-value‡	Organic p-value‡	Conventional p-value‡	Organic p-value‡	Conventional p-value‡	Organic p-value‡	Conventional p-value‡	Organic p-value‡	Conventional p-value‡	Organic p-value‡
Neurological system																
Severe headaches	0.076	0.617	0.010 *	0.076	0.632	0.337	0.477	0.329	0.017 *	0.014 *	0.491	0.056	0.469	0.206	0.748	0.173
Dizziness	0.286	0.381	0.001 *	0.928	0.960	0.140	0.562	0.392	0.216	0.001	0.145	0.013 *	0.005 *	0.069	0.762	0.511
Trembling or shaking	0.827	0.319	0.333	0.986	0.421	0.180	0.185	0.0001 *	0.774	0.775	0.588	0.274	0.091	0.510	0.344	0.333
Slowness or weakness in performing routine tasks	0.721	0.362	0.0001 *	0.921	0.393	0.715	0.007 *	0.554	0.020 *	0.169	0.417	0.266	0.017	0.375	0.546	0.170
Difficulty walking or keeping balance	0.350	0.413	0.0001 *	0.884	0.114	0.721	0.112	0.360	0.015 *	0.052	0.393	0.321	0.015 *	0.457	0.750	0.429
Respiratory system																
Rhinitis (Stuffy or runny nose)	0.169	0.397	0.006 *	0.211	0.996	0.219	0.621	0.169	0.023 *	0.277	0.597	0.020 *	0.001 *	0.011 *	0.911	0.081
Persistent cough for more than 48 h	0.114	0.541	0.0001 *	0.110	0.832	0.566	0.552	0.321	0.106	0.014	0.181	0.033 *	0.011 *	0.012 *	0.762	0.608
Feeling of tightness in the chest	0.559	0.796	0.0001 *	0.892	0.344	0.859	0.165	0.949	0.164	0.067	0.677	0.966	0.062	0.134	0.977	0.050
Throat irritation	0.544	0.730	0.0001 *	0.667	0.367	0.026 *	0.904	0.564	0.047 *	0.039 *	0.656	0.006 *	0.0001 *	0.087	0.930	0.792
Skin																
Skin irritations	0.553	0.822	0.007 *	0.239	0.784	0.353	0.137	0.833	0.149	0.026 *	0.128	0.085	0.0001 *	0.083	0.706	0.433
Body burns	0.226	0.054	0.109	0.357	0.134	0.010 *	0.190	0.553	0.040 *	0.322	0.127	0.952	0.906	0.003	0.198	0.516
Ocular																
Eyes irritation	0.553	0.474	0.007 *	0.084	0.784	0.439	0.137	0.586	0.149	0.001 *	0.967	0.004 *	0.0001 *	0.024 *	0.488	0.714
Cardiovascular system																
Irregular heartbeat	0.082	0.305	0.169	0.687	0.086	0.039	0.516	0.264	0.184	0.757	0.816	0.381	0.597	0.004 *	0.381	0.532
Digestive system																
Abdominal pain	0.249	0.381	0.054	0.033 *	0.397	0.725	0.545	0.876	0.616	0.577	0.751	0.009 *	0.067	0.024 *	0.719	0.394
Nausea	0.271	0.203	0.185	0.074	0.636	0.394	0.329	0.276	0.358	0.193	0.961	0.400	0.615	0.402	0.285	0.139
Vomiting	0.014 *	0.595	0.896	0.981	0.009 *	0.916	0.375	0.898	0.402	0.752	0.568	0.725	0.617	0.213	0.422	0.143
Diarrhea	0.003 *	0.895	0.762	0.980	0.153	0.410	0.412	0.756	0.366	0.990	0.824	0.622	0.329	0.823	0.111	0.142
Urinary system																
Urinary pain	0.489	0.061	0.001 *	0.661	0.465	0.008 *	0.587	0.147	0.190	0.335	0.734	0.312	0.025 *	0.574	0.546	0.054

‡ Chi square or Fishers's exact test; *Significant level at p-value < 0.05; n = 585 (353 conventionals and 232 organics)

the ″Société burkinabè des fibres et textiles (SOFITEX)″ recommends 6 insecticide treatments, with an interval of 14 days, and 2 herbicide treatments per year for synthetic pesticides. This raises the issue of non-compliance with recommended pesticides application frequency which could be explained by the increasing resistance of cotton pests to pesticides [41], and which substantially increases farmers' contact time with pesticides. Past studies found similar results regarding the non-compliance of producers with the recommended frequencies of pesticide application [42]. Skin and eye irritations reported by conventional cotton farmers could be related to the use of herbicides containing glyphosate, molecule with a high irritant property [35–37]. Among organic farmers, irritation signs reported could be related to capsaicin, a hot pepper molecule used in the formulation of most bioinsecticides [43]. Skin and ocular health effects reported by both types of cotton farmers could also be explained by the inefficiency of PPEs used. PPEs used by both conventional and organic farmers is mainly dust masks, sometimes boots, gloves, and glasses. All of which generally offer inappropriate protection and contribute to increase the risk of pesticides exposure through skin or ocular contact [44]. Severe headaches were significantly associated with time of return to the cotton field after spraying among both conventional and organic cotton producers ($p < 0.05$). Rhinitis ($p = 0.023$) and throat irritation ($p = 0.047$) were significantly associated with the time to return to the field after pesticides application among conventional cotton farmers, compared to organic ones, where only throat irritations were significantly associated with the time of return to the organic cotton field after spraying ($p = 0.039$). These results can be explained by the fact that 15.86% vs 4.31% of conventional and organic cotton farmers respectively returned immediately to the cotton field after spraying. These practices further increase the risk of acute and chronic poisoning to farmers as the recommended time to return to the field after spraying is on average 14 days according SOFITEX.

Both types of cotton farmers use registered and unregistered pesticides. Unregistered pesticides have not received marketing authorization from the competent authorities of the countries where they are used. Among conventional cotton farmers, herbicides are less often registered compared to insecticides. This is due to the fact that insecticides are supplied to conventional cotton farmers at relatively low cost by SOFITEX. However, many bioinsecticides are not registered because they are manufactured individually or by cooperatives that promote organic crops. Moreover, compared to organic cotton farmers, conventional cotton farmers have more experience in pesticides use. Organic cotton producers generally farm small areas, while conventional cotton producers farm larger areas. The latter therefore tend to have more days, per cotton season, on which they apply pesticides. These results echo those of a recent study showing that organic cotton cultivation accounts for only 1% of the total land occupied by cotton cultivation in Burkina Faso [45].

5. Conclusion

From our findings, health effects related to pesticide use were observed in both conventional and organic cotton farmers in the Central-West region of Burkina Faso. In addition to skin and ocular, health effects reported concerned neurological, respiratory, cardiovascular, digestive, and urinary systems. These different health effects were significantly associated with conventional cotton farmers, considering associated factors such as experience and frequency of pesticides use, time to return to the cotton field after pesticide application. It concluded that banned synthetic pesticides are still used in conventional cotton production in the study area. Conventional cotton farmers don't respect the application frequency of synthetic pesticides. Both organic and conventional cotton farmers use inappropriate personal protective equipment's. These practices expose cotton farmers to higher risks of poisoning, resulting in health effects. However, health effects inventoried among cotton farmers after contact with pesticides are based only on self-reports. It is therefore necessary to carry out additional tests, such as biological ones, to assess pesticide's exposure biomarkers among these farmers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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