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ORIGINAL ARTICLE

Causes and types of health effects during the use of crop protection chemicals: data from a survey of over 6,300 smallholder applicators in 24 different countries

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Abstract
Purpose The present investigation looks in detail at the causes and types of health incidents reported by 6,300 mainly smallholder agrochemical users in 24 countries during 2005 and 2006.
Methods The investigation is based on a questionnaire survey of knowledge, attitude and practice that concentrated on the sequence of events from purchasing the pesticide to disposal. Information was also collected about health problems experienced while using agrochemicals. The survey targeted mainly smallholder knapsack spray operators who were expected to be at a highest risk of exposure.
Results In the 12 months prior to interview, 1.2% of users reported an agrochemical-related incident that required hospital treatment, 5.8% reported an incident requiring at least trained medical treatment but not hospitalisation and 19.8% reported only a minor sign or symptom. Users who had experienced an incident involving agricultural equipment were 3.38 (95% CI 2.29–4.99) times more likely to experience an agrochemical-related health incident, but confident users who felt that their use of personal protective equipment while spraying was best practice were 0.60 (95% CI 0.44–0.84) times less likely to experience such an incident. Over 80% of product-related incidents were caused by insecticides and the incidence rate per spraying time for incidents linked to insecticides was significantly higher than that for fungicides or herbicides. Headache/dizziness and nausea/vomiting, often smell related, were the most common symptoms reported by users who listed agrochemical products that had caused them health problems (52 and 38% of product mentions, respectively).
Conclusions In most countries, the incidence of serious health effects was low; however, there was a high incidence of minor signs and symptoms in a few countries, especially in Africa. A disproportionate number of incidents occurred during insecticide use relative to the time that they were sprayed. Failure to exercise caution as indicated by whether users had incidents involving agricultural equipment or livestock, and lack of confidence in their practices were the most important predictors of agrochemical-related incidents.

Keywords Pesticides · Symptoms · Knowledge attitude practice · Smallholder · Knapsack sprayer · Health survey

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Introduction

In 2004, as part of its stewardship programme, Syngenta Crop Protection commissioned a survey of knowledge, attitude and practice (KAP) amongst 2,431 users of crop protection products in eight countries. The primary purpose of the survey was to focus training and stewardship programmes; in particular, the education and training of smallholders. The 2004 survey showed that 14.0% of users had ever experienced a health effect due to the use of crop protection chemicals, but it also showed that there was a small population of users (1.6%) who reported that they experienced health problems every time that they used certain products. However, the information collected in the 2004 survey about crop protection-related incidents was limited, and did not permit a detailed investigation of the causes and types of health effects. The survey was extended in 2005 and 2006 to a further 6,359 users in 24 countries, including six of the eight countries surveyed in 2004, and the questionnaire was expanded to collect information about the numbers and nature of health incidents experienced by users in the last 12 months, the products that were causing problems, the symptoms experienced by users and the circumstances in which these health incidents were experienced. Syngenta made the data from the survey available to the authors to permit independent analysis and to make the findings accessible to a wider audience. Matthews (2008) has reported on the KAP of users in the 2004, 2005 and 2006 surveys, but only reported briefly on the health effects reported by users. This report presents detailed information on the causes and types of health incidents reported during 2005 and 2006 by users. Syngenta have stated they will be taking into account both reports in the development of their stewardship plans.

The survey was conducted in regions where the use of pesticides is moderate to very intensive and the practices of users were considered to be less well developed. It was largely targeted at smallholders who spray pesticides on smaller than average holdings, as such users are believed to be amongst the least likely to receive training in the use of agrochemicals. Only users of knapsacks and hand held fixed line sprayers were recruited as they are considered to have a higher risk of exposure to pesticides than those using mechanized vehicle (tractor) sprayers (Matthews 2002). Other target groups included contract spray operators and female tropical plantation spray operators who were believed to be intensive users.

One of the principal aims of the survey was to assess the understanding by the surveyed group of pesticide applicators and farmers of five user precautions that Syngenta and other manufacturers consider are key steps to the safe and effective application of pesticides (http://www.croplifeasia.org/ref_library/croplifeAsia/AgroLinksDec2007.pdf). The knowledge gained from the survey was intended to be used to identify gaps in future training programmes. The five key steps of such safe use training are as follows:

1. Awareness of the risks associated with pesticide use and exercising caution at all times.
2. Reading and understanding the instructions provided on the product label.
3. Good personal hygiene.
4. Care and maintenance of application equipment.
5. Knowledge of the personal protective equipment (PPE) needed when using pesticides, and understanding that PPE should be a last line of defence to avoid exposure after taking steps 1 to 4.

Dasgupta et al. (2007) noted that information on the health impact of pesticides is quite limited in many developing countries and much of it is based on surveys of self-reported signs and symptoms. Typically, these investigations have been small in size and have measured health impact and agrochemical relatedness of symptoms in a wide variety of ways (Chitra et al. 2006; Yassin et al. 2002; Kishi et al. 1995; Kishi 2002; Lu 2005; Culp et al. 2007; Ntow et al. 2006; Mancini et al. 2005), making it difficult to compare health impacts in different groups of users. Some surveys have been less reliant on self-reported measures of health impact, but most of those have focused on exposure to organophosphates (Dasgupta et al. 2007; London et al. 1998; Gomes et al. 1999; Ngowi et al. 2001). The survey described in this report collected a wide range of information about the health impact of agrochemicals and the behaviour of large groups of users from a wide variety of developing countries and a number of regions in developed countries where agrochemical practices are less well developed. The survey also targeted users who are expected to be at the highest risk of exposure. Information on self-reported signs and symptoms was collected in the present survey, but it was collected in a uniform manner, although some of the smaller surveys have been able to collect more specific information on incidents and exposure circumstances. Matthews (2008) concluded that most users had a working knowledge of the requirements for safe use and also concluded that a high proportion were able to achieve this as indicated by the low numbers of incidents affecting their health. The present report looks in greater detail at the causes and types of health incidents reported by users and aims to assess whether the five key steps described above do help to prevent such health incidents.

Methods

Survey methodology

The 2005 and 2006 surveys were conducted by a market research company, dmrkynetec and included 6,359 users in 24 countries: four from Europe (Greece, Poland, Portugal and Spain), four from Africa (Cameroon, Morocco, Senegal and Tanzania), ten from Asia (Bangladesh, China, India, Indonesia, Malaysia, Philippines, South Korea, Sri Lanka, Taiwan, Thailand) and six from Central and South America and the Caribbean (Brazil, Colombia, Costa Rica, Guatemala, Martinique/Guadeloupe and Mexico). Approximately, 250 users were sampled from each country except for Martinique/Guadeloupe where a smaller sample was interviewed because of the smaller numbers of users. In Malaysia, an additional group of female users applying pesticides intensively on estates were included because of interest in the health of such workers (Fernandez et al. 2002). India was included in both the 2005 and 2006 surveys.

In each country, a local market research team identified regions where the use of pesticides was moderate to intensive. The survey group included only users of knapsack and hand held sprayers (mainly fixed line) who had sprayed for a minimum of 40 h in the previous year. The selection of respondents was on the basis of quota sampling and targeted users on smallholdings of below average size and contract spray operators in countries where there were significant numbers of such users. The local market research teams defined their target smallholder farmers in terms of farm size and typical crops grown. Screening questions were used to ensure that the sample satisfied the quota requirements. The questionnaire was translated into the relevant language by the local market research team in each country and their staff visited users to conduct the interview.

Respondents were approached in a variety of ways. In some regions, the village head would be contacted first and asked to identify smallholders who satisfied the quota requirements. In other cases, the field team would visit potential respondents on their farms in selected communities or go to a central location such as a local agricultural cooperative to target potential respondents. Snowball sampling was also used to recruit further respondents in some communities. Some respondents were recruited using a telephone interview to screen and arrange an appointment. However, this was not the usual practice because many smallholders did not like to commit to an appointment because of the variability involved in farm work, and because access to a telephone was limited in many of the remote communities targeted in the survey.

Dmrkynetec estimated that the refusal rate in the survey was around 5% based on the information supplied to them by local market research agencies responsible for coordinating the interviews. There was no evidence that there was significant variation in response rates between countries. Feedback from the local agencies indicated that the few individuals who refused to participate mainly did so because they were visited during a busy period for planting, harvesting or other farming activity.

Questionnaire

The questionnaire concentrated on the sequence of events from purchasing the pesticide to disposal including the transport to the farm, storage and application. It included questions about characteristics of the user including region, age, education and responsibility for decision-taking; time spent spraying including the percentage of time spent spraying herbicides, insecticides and fungicides; practices in aspects such as transport, storage, mixing, spraying, personal hygiene, use of PPE, maintenance of spraying equipment, reading of product labels and disposal practices. Users were also asked about their attitudes towards these practices including how confident they felt about them by rating each practice on a 3-point scale: the safest way; an acceptable way, but could be improved; or an unacceptable way, but it is my only option.

The questionnaire was also used to collect the information about whether users had ever experienced incidents related to agrochemicals and to collect specific information about any experienced by the user in the last 12 months. Information was also collected about incidents involving agricultural equipment (agricultural tools, machinery or vehicles) and those involving wildlife or farm animals. Incidents were categorised as serious, moderate or minor. Serious incidents were defined as those requiring hospitalisation and moderate incidents were defined as those requiring trained medical attention, but not resulting in hospitalisation. In the 2005 survey, minor incidents were defined as an incident that had necessitated self-medication but not trained medical attention. The definition of a minor incident was broadened in the 2006 survey to include incidents where the user had not taken any form of medication in order to obtain a more complete picture and because of confusion about the definition of self-medication. The smallholders and spray operators were also asked to name any agrochemical products which had caused them health problems and to list the incidents that they had experienced with these products in the last 12 months. Users were also asked in an unprompted manner about the signs and symptoms that they had experienced when using the product, the tasks they were performing when problems had occurred, the measures taken to remedy the immediate effects on their health and the measures that they had taken to prevent a repetition.

Statistical analysis

Prevalence odds ratios (POR) were calculated for each country to identify factors associated with the incidence of agrochemical-related incidents and to assess the importance of explanatory factors in different countries. POR were calculated using the group of users who experienced no agrochemical-related incidents as the comparison group. Multiple logistic regression analyses were performed to model the probability of a user experiencing an agrochemical-related incident. Models were developed for serious or moderate incidents and incidents of any severity. Models were also developed for serious incidents alone, but results are not presented here as they were similar to those for serious or moderate incidents and which were more stable. POR were used to select factors for inclusion in the multiple logistic regression models and the final model included all factors that were significant in at least one of the models for serious, serious or moderate or any severity incidents. In addition, some factors of interest such as those based on the hours sprayed of the different pesticide types were kept in the final model. Clustering effects for country were incorporated in the model.

Poisson and negative binomial regression models were used to model the numbers of incidents. Negative binomial regression was used when there was evidence that the individual counts were more variable ("overdispersed") than is implied by the Poisson model, i.e., the assumption of equal mean and variance was not met. The negative binomial regression models included an offset term for the logarithm of hours sprayed in the last year and the exponentials of parameter estimates are interpreted as incidence rate ratios (IRR). Clustering effects for country were also incorporated in these models.

The numbers of incidents that could be attributed to the different classes of pesticides were modelled using generalised negative binomial regression. These data also showed evidence of overdispersion, but in this case there was evidence that the degree of overdispersion was not the same for the numbers of herbicide, insecticide and fungicide-related incidents and generalised binomial regression methods were used. Information on symptoms, the frequency that symptoms occurred and the circumstances in which they occurred were provided for each product mention. Analyses of symptoms by product group treated each product mention as the unit of analysis. All statistical analyses were performed using Stata version 9 (Stata Corp., College Station, TX, USA).

Results

Table 1 provides summary information on farm sizes, amount of spraying done, types of pesticides used, sprayer used and type of user for the populations surveyed in different countries. A more detailed description of the demographic characteristics of users, their knowledge and practices is given by Matthews (2008).

Table 2 shows the percentages of users experiencing incidents in the last 12 months and the numbers of incidents that they experienced. Incidents are categorised into three groups: serious; moderate; and minor. The table also shows incidence rates per 10,000 spraying hours. A total of 78 users (1.2%) reported having experienced a serious agrochemical-related incident that required hospital treatment, 370 users (5.2%) reported a moderate incident requiring a trained medical treatment and 1,260 users (19.8%) reported only a minor incident. Some users who reported a serious incident had experienced more than one such incident in the last 12 months (an average of 1.8 serious incidents per user). Users who reported a moderate or worse agrochemical-related incident had experienced an average of 2.5 such incidents and users that reported an incident of any severity had experienced an average of 4.4 incidents of any severity.

There was a wide variation in the incidence of agrochemical-related incidents between countries. No users in six countries (Bangladesh, Brazil, China, Greece, Taiwan and Thailand) had experienced a serious incident in the last 12 months and only one user had experienced a serious incident in four other countries (Indonesia, Mexico, Poland and the Philippines). Over 60% ($n = 47$) of users reporting serious incidents in the last 12 months came from five countries (Colombia, India, Morocco, Senegal and Spain) and these countries also reported 60% of serious incidents ($n = 84$). However, when serious incidents were related to spraying hours, Colombia was barely above average and the highest rates were observed for Morocco, Senegal and Spain. The proportions of users reporting any incident varied from 2% or less users in six countries (Brazil, Greece, Guatemala, Martinique and Guadeloupe, Poland, and Taiwan) to 39–85% in six other countries (Bangladesh, China, Cameroon, Colombia, Morocco and Tanzania). The highest proportion was reported by Moroccan users who also had the highest rate of incidents when adjusted for spraying hours (543 per 10,000 spraying hours) compared with an overall rate of 82 per 10,000 spraying hours. Costa Rica, Cameroon and Tanzania also had rates of more than 200 incidents per 10,000 spraying hours.

Table 3 shows odds ratios (OR) with 95% confidence intervals from the multiple logistic regression models predicting whether a user will have experienced a moderate or worse incident or an incident of any severity in the last 12 months. Users who sprayed more than the overall median number of hours did not have a significantly increased risk of agrochemical-related incidents, but users who sprayed insecticides for more than the median number of hours had a significantly increased OR for incidents of any severity. The strongest predictor of an agrochemical incident was the occurrence of an incident involving agricultural equipment in the last 12 months. Farmers who had experienced such an incident were 2.6 times more likely to experience an agrochemical incident requiring medical treatment and were 3.4 times more likely to report an agrochemical incident of any severity. There was considerable variation between countries and Figure 1 shows POR by country for any agrochemical incident amongst users reporting an incident involving agricultural equipment in the last year. Users aged less than 40 years were also at a significantly higher risk of experiencing any sort of agrochemical incident, but the OR of 1.23 for serious or moderate incidents and 1.34 for any incident were much lower than those for agricultural equipment incidents. The POR

Table 1 Information on farm size, amount of spraying done, types of pesticides used, sprayer used and type of user in different countries

Country	Users	Farm size		Spraying sessions and hours in last 12 months [Median (IQR)]			Time spent spraying pesticides in different categories (%)[a]			Type of sprayer used[b]			Type of user[c]	
		≤1 ha %	>10 ha %	Number of days spraying	Average spraying hours per day	Total spraying hours	Herbicide	Insecticide	Fungicide	Knapsack (%)	Fixed line (%)	Both (%)	Farm owner (%)	Contract sprayer (%)
2005														
Brazil	250	0	16	50 (40–96)	2 (2–3)	128 (90–204)	7	42	43	26	52	25	70	0
China	250	94	0	21 (15–30)	4 (3–5)	71 (50–146)	17	54	27	96	4	3	100	0
Greece	250	0	67	10 (6–20)	3 (2–4)	30 (15–50)	29	47	19	86	17	11	98	0
Guatemala	250	56	0	24 (6–47)	4 (1–8)	47 (40–96)	32	42	26	100	<1	<1	85	9
India	259	10	7	20 (15–30)	5 (4–6)	96 (60–160)	20	54	26	61	53	14	48	19
Korea	250	65	<1	15 (12–20)	4 (3–5)	52 (42–69)	14	40	40	18	97	15	99	0
Malaysia	256	7	3	20 (12–48)	4 (3–4)	60 (48–120)	67	23	9	95	33	28	72	10
Malaysian females	87	–	–	276 (27–312)	6 (5–6)	1,560 (208–1,728)	66	24	10	98	16	15	1	0
Mart & Guad	153	3	38	24 (15–60)	4 (3–4)	72 (48–194)	73	16	11	90	36	29	75	0
Mexico	266	14	0	10 (8–16)	6 (5–8)	60 (45–100)	65	27	7	100	0	0	91	<1
Philippines	250	0	0	20 (12–24)	4 (3–5)	63 (48–96)	21	56	17	100	4	4	65	10
Poland	258	0	45	15 (9–24)	3 (2–4)	45 (40–54)	33	35	30	66	43	16	89	<1
Sri Lanka	262	23	0	10 (9–14)	5 (4–6)	50 (48–72)	48	31	20	100	0	0	98	<1
Taiwan	250	74	0	24 (15–35)	3 (2–5)	60 (48–92)	16	57	27	67	80	47	91	<1
Thailand	250	0	0	48 (48–60)	2 (1–2)	93 (50–120)	16	58	25	56	50	20	94	<1
2006														
Bangladesh	258	100	0	30 (23–85)	3 (2–3)	86 (60–229)	10	60	23	33	5	<1	85	11
Cameroon	261	33	5	24 (12–54)	5 (4–7)	105 (60–256)	6	40	54	90	8	<1	80	2
Colombia	251	41	0	48 (30–48)	8 (8–8)	384 (216–450)	23	36	35	99	19	18	78	9
Costa Rica	250	100	0	9 (7–12)	6 (5–7)	54 (45–64)	70	13	13	98	9	7	32	61
India	259	17	3	30 (15–60)	5 (3–6)	120 (72–200)	14	65	18	75	30	20	75	21
Indonesia	290	27	18	15 (10–192)	5 (4–6)	70 (48–960)	73	25	2	99	<1	0	58	13
Morocco	250	3	0	7 (5–10)	7 (6–8)	48 (40–64)	39	44	10	88	17	8	62	<1
Portugal	250	14	6	25 (20–30)	2 (2–3)	50 (45–60)	37	45	17	94	8	6	88	2
Senegal	249	2	3	23 (17–40)	3 (2–4)	54 (45–74)	27	49	19	90	21	14	45	18
Spain	250	38	0	15 (10–20)	5 (4–5)	75 (48–100)	23	36	37	76	42	20	90	<1
Tanzania	250	39	0	14 (10–22)	4 (4–6)	60 (48–80)	7	63	30	98	<1	<1	81	15
Total	6,359	28	9	20 (10–40)	4 (3–6)	60 (48–120)	37	39	22	80	25	12	77	8

[a] The categories are not mutually exclusive as mixtures are sprayed and some products do not fall into these categories

[b] Only knapsack and fixed-line hand held sprayer use shown (used by 93% of respondents)

[c] Other users were relatives of the smallholder or paid employees

Table 2 Percentages (number) of users experiencing incidents by highest severity of incident and numbers and rates of incidents per 10,000 spraying hours in different severity categories

	Total	Spraying hours	Serious			Moderate			Minor		
			Users (%) (*n*)	Incidents	Per 10,000 h	Users (%) (*n*)	Incidents	Per 10,000 hours	Users (%) (*n*)	Incidents	Per 10,000 h
2005											
Brazil	250	45,532	0.0 (0)	0	0.0	0.0 (0)	0	0.0	0.0 (0)	0	0.0
China	250	26,789	0.0 (0)	0	0.0	1.2 (3)	7	2.6	38.0 (95)	422	157.5
Greece	250	9,552	0.0 (0)	0	0.0	0.0 (0)	0	0.0	1.6 (4)	24	25.1
Guatemala	250	20,057	0.8 (2)	11	5.5	0.8 (2)	5	2.5	0.4 (1)	2	1.0
India	259	36,337	5.4 (14)	24	6.6	6.2 (16)	48	13.2	18.9 (49)	166	45.7
Korea	250	15,032	1.6 (4)	4	2.7	2.0 (5)	9	6.0	16.4 (41)	107	71.2
Malaysia	256	29,792	0.4 (1)	2	0.7	2.7 (7)	27	9.1	5.5 (14)	85	28.5
Malaysian females	87	98,530	1.1 (1)	1	0.1	12.6 (11)	17	1.7	13.8 (12)	51	5.2
Mart & Guad	153	28,268	1.3 (2)	2	0.7	0.0 (0)	0	0.0	0.7 (1)	5	1.8
Mexico	266	25,587	0.4 (1)	1	0.4	2.3 (6)	16	6.3	3.4 (9)	18	7.0
Philippines	250	19,819	0.4 (1)	1	0.5	0.0 (0)	0	0.0	4.8 (12)	29	14.6
Poland	258	11,906	0.4 (1)	1	0.8	0.0 (0)	0	0.0	0.0 (0)	0	0.0
Sri Lanka	262	17,254	1.1 (3)	5	2.9	2.7 (7)	8	4.6	13.0 (34)	67	38.8
Taiwan	250	21,155	0.0 (0)	0	0.0	0.0 (0)	0	0.0	1.2 (3)	7	3.3
Thailand	250	26,133	0.0 (0)	0	0.0	2.4 (6)	21	8.0	7.2 (18)	234	89.5
2006											
Bangladesh	258	48,529	0.0 (0)	0	0.0	9.3 (24)	37	7.6	33.3 (86)	285	58.7
Cameroon	261	49,096	1.9 (5)	12	2.4	10.3 (27)	82	16.7	46.7 (122)	1,324	269.7
Colombia	251	10,7686	3.2 (8)	17	1.6	13.9 (35)	88	8.2	46.2 (116)	752	69.8
Costa Rica	250	14,297	1.6 (4)	8	5.6	6.4 (16)	30	21.0	24.0 (60)	301	210.5
India	259	41,890	1.2 (3)	5	1.2	6.6 (17)	58	13.8	31.3 (81)	321	76.6
Indonesia	290	12,4066	0.3 (1)	1	0.1	7.6 (22)	68	5.5	20.3 (59)	136	11.0
Morocco	250	15,903	3.2 (8)	12	7.5	18.8 (47)	126	79.2	63.2 (158)	726	456.5
Portugal	250	15,126	0.8 (2)	2	1.3	6.0 (15)	47	31.1	27.2 (68)	236	156.0
Senegal	249	18,199	2.8 (7)	13	7.1	15.3 (38)	111	61.0	12.4 (31)	119	65.4
Spain	250	19,167	2.8 (7)	13	6.8	14.8 (37)	104	54.3	12.4 (31)	118	61.6
Tanzania	250	20,550	1.2 (3)	5	2.4	11.6 (29)	86	41.8	62.0 (155)	760	369.8
Total	6,359	90,6252	1.2 (78)	140	1.5	5.8 (370)	995	11.0	19.8 (1,260)	6,295	69.5

for an agrochemical-related incident amongst users aged less than 40 showed less variability between countries than those for agricultural equipment incidents (see Figs. 1, 2). Confident users who considered that their practices were the safest (mixing, PPE use while mixing and PPE use while spraying) were significantly less likely to experience a serious or moderate incident. However, these three variables were highly correlated and only confidence in PPE use while spraying was kept in the multiple logistic regression models as it was usually the strongest predictor. Users who took all decisions on the farm and users who cleaned contamination from spillages immediately were significantly less likely to experience serious or moderate severity incidents while users whose sprayers leaked occasionally or all the time were significantly more likely to experience serious or moderate severity incidents.

Binomial regression models predicting the numbers of incidents in the last 12 months gave similar results to the multiple logistic regression models and the strongest predictors were also an agricultural equipment incident in the last 12 months and the confidence of the user about their spraying practices (Table 4). Users who cleaned contamination from spillages immediately were significantly less likely to experience serious or moderate severity incidents, although this term was not quite significant in models for incidents of any severity. A sprayer leaking occasionally or all the time was also an important predictor of numbers of moderate or serious incidents, but also not quite significant

Table 3 Odds ratios (95% confidence interval) from multiple logistic regression models for moderate or worse incidents and incidents of any severity

	Serious or moderate incident OR (95% CI)	Any severity incident OR (95% CI)
Age <40	1.23 (1.04–1.47)*	1.34 (1.12–1.61)**
No formal education	1.23 (0.86–1.76)	0.97 (0.64–1.47)
Experienced a machinery incident in last 12 months	2.60 (1.26–5.38)**	3.38 (2.29–4.99)***
Experienced a livestock incident in last 12 months	1.22 (0.67–2.22)	1.99 (1.31–3.02)**
Sprayed more than median hours	1.11 (0.79–1.56)	1.05 (0.78–1.40)
Sprayed more than median insecticide hours	1.19 (0.84–1.67)	1.59 (1.09–2.32)*
Sprayed more than median herbicide hours	1.35 (0.87–2.08)	1.08 (0.64–1.82)
Sprayed more than median fungicide hours	1.37 (0.94–2.00)	1.39 (0.87–2.20)
Takes all decisions on farm	0.61 (0.41–0.91)*	0.79 (0.60–1.04)
Measures using graduated device	1.06 (0.75–1.51)	0.61 (0.45–0.83)**
Wears 3 key items of PPE for spraying	1.16 (0.81–1.65)	1.26 (0.79–2.00)
User considers spraying PPE to be the safest	0.56 (0.43–0.73)***	0.60 (0.44–0.84)**
Clean water supply always available	1.04 (0.72–1.51)	0.88 (0.66–1.16)
Cleans contamination immediately	0.70 (0.50–0.99)*	0.79 (0.57–1.11)
Sprayer leaks occasionally or all the time	1.53 (1.12–2.07)*	1.64 (0.99–2.71)
Uses good nozzle cleaning practices	1.17 (0.78–1.76)	0.87 (0.57–1.32)

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

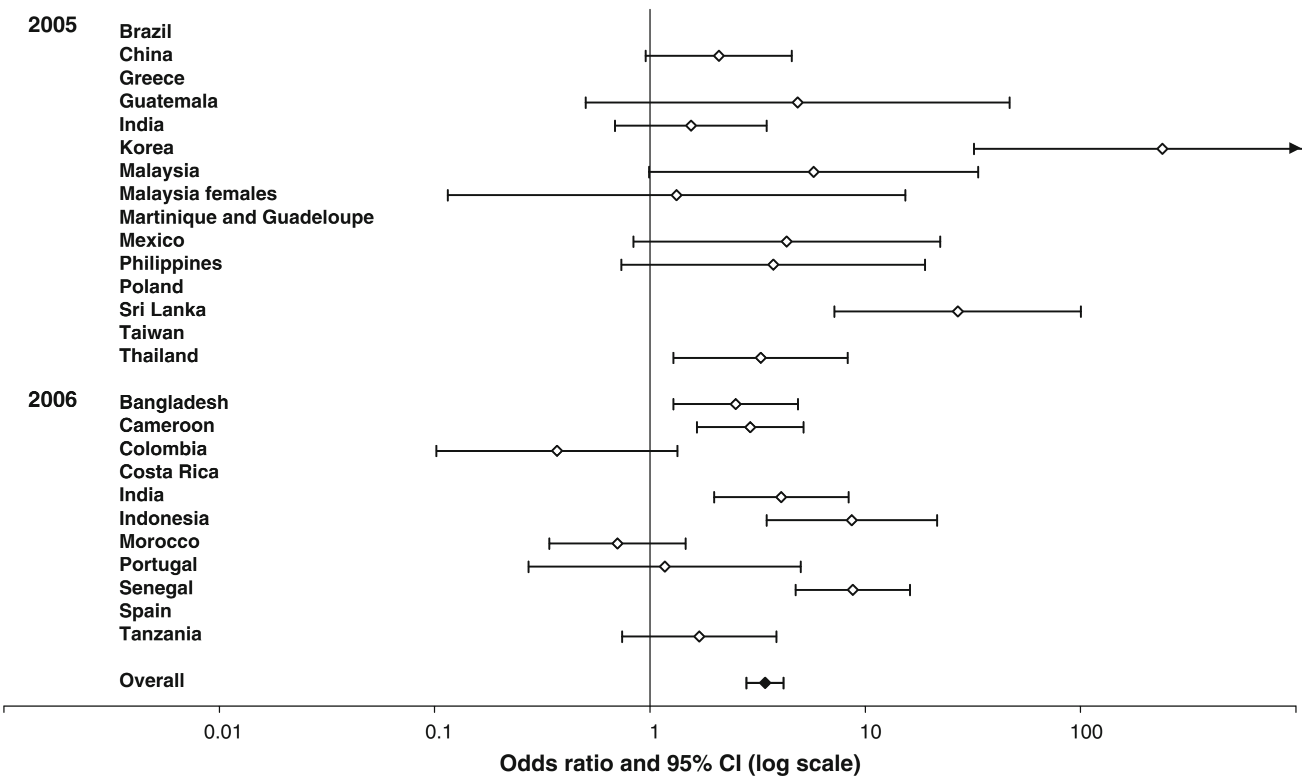

Fig. 1 Prevalence odds ratios and 95% confidence intervals for any agrochemical incident among users experiencing an agricultural equipment incident

in models for incidents of any severity. The measure of good nozzle cleaning practices gave conflicting results. As expected, users who employed good nozzle cleaning practices were at a lower risk of incidents of any severity, although the OR was not statistically significant. However, the direction of the association reversed for serious or moderate incidents and was of borderline significance. Being aged less than 40 was less important in models for the number of incidents, although close to significance. Times spent spraying the three different types of pesticides were not a statistically significant factor in regression models for the number of incidents.

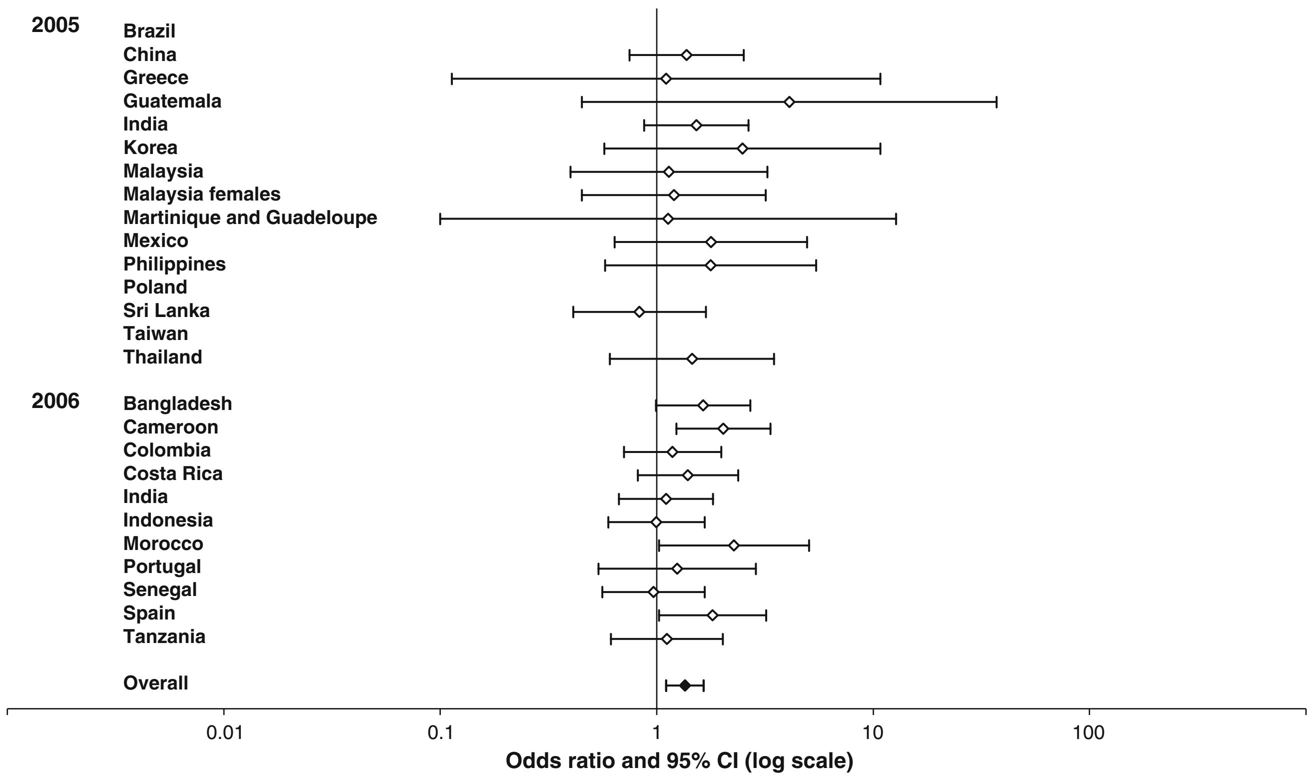

Fig. 2 Prevalence odds ratios and 95% confidence intervals for any agrochemical incident amongst users aged less than 40 years

Table 4 Incidence rate ratios (95% confidence interval) from negative binomial regression models for numbers of moderate or worse incidents and incidents of any severity

	Serious or moderate incident IRR (95% CI)	Any severity incident IRR (95% CI)
Age <40	1.23 (0.95–1.61)	1.15 (0.96–1.38)
No formal education	1.66 (0.93–2.95)	1.10 (0.74–1.65)
Experienced a machinery incident in last 12 months	2.46 (1.32–4.57)**	2.33 (1.71–3.18)***
Experienced a livestock incident in last 12 months	1.02 (0.63–1.65)	1.27 (0.95–1.71)
Sprayed more than median insecticide hours	1.24 (0.92–1.66)	1.38 (0.89–2.12)
Sprayed more than median herbicide hours	1.33 (0.81–2.21)	0.93 (0.58–1.50)
Sprayed more than median fungicide hours	1.24 (0.80–1.92)	1.48 (0.97–2.27)
Takes all decisions on farm	0.68 (0.42–1.10)	0.83 (0.62–1.11)
Measures using graduated device	0.91 (0.65–1.27)	0.65 (0.48–0.88)**
Wears 3 key items of PPE for spraying	1.33 (0.85–2.06)	1.35 (0.92–1.99)
User considers spraying PPE to be the safest	0.55 (0.39–0.77)***	0.64 (0.45–0.89)**
Clean water supply always available	1.05 (0.74–1.48)	0.94 (0.67–1.33)
Cleans contamination immediately	0.60 (0.42–0.87)**	0.83 (0.60–1.13)
Sprayer leaks occasionally or all the time	1.88 (1.26–2.81)**	1.23 (0.92–1.65)
Uses good nozzle cleaning practices	1.47 (1.01–2.12)*	0.71 (0.45–1.10)

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

Of the 1,708 users experiencing an agrochemical-related incident of any severity in the last 12 months, 63% (1,081) named at least one pesticide that they claimed had had an adverse effect on their health in the last 12 months. This group of 1,081 users listed an average of 1.5 products (1,633 pesticide mentions) which they claimed had caused incidents in the last 12 months. Users also mentioned a further 80 products which they claimed had caused incidents in the last 12 months, but three were not recognised, three were fertilisers and the user did not know either the type or name of the remainder. Table 5 shows the numbers of users that reported product-related incidents by the highest severity of incidents and numbers and the rates of product-related incidents per 10,000 h sprayed for different

Table 5 Users experiencing product-related incidents by highest severity of incidents and numbers and rates of product-related incidents per 10,000 h sprayed for different types of pesticide

Type of pesticide	Spray hours	Serious			Moderate			Minor		
		Users	Incidents	Incidents per 10,000 spray hours	Users	Incidents	Incidents per 10,000 spray hours	Users	Incidents	Incidents per 10,000 spray hours
Herbicide	333,839	3	6	0.2	49	117	3.5	135	306	9.2
Fungicide	196,699	6	10	0.5	13	26	1.3	185	628	31.9
Insecticide	352,001	32	75	2.1	133	334	9.5	664	3,233	91.8

Note that some users experienced incidents with more than one type of pesticide

Table 6 Incidence rate ratios for herbicide and fungicide incidents relative to insecticide incidents

	Serious incident IRR (95% CI)	Serious or moderate incident IRR (95% CI)	Any severity incident IRR (95% CI)
Herbicide relative to insecticide	0.08 (0.02–0.30)	0.27 (0.11–0.64)	0.11 (0.04–0.27)
Fungicide relative to insecticide	0.16 (0.08–0.34)	0.10 (0.06–0.16)	0.20 (0.11–0.36)

types of pesticide. The lowest rates for both users and incidents are seen for herbicides and the highest rates for insecticides. In addition, users who experienced health incidents with herbicides in the last 12 months averaged 2.3 herbicide-related incidents compared with 3.3 per user for fungicides and 4.4 per user for insecticides. Regression modelling showed no evidence of differences between the incidence rates for herbicides and fungicides for all severities of incidents, but there were significant differences between the incidence rates for herbicides and fungicides and those for insecticides. Table 6 shows the IRR for herbicides and fungicides relative to insecticides for incidents of different severities. The IRR varied with the severity of incident, but incidence rates for insecticides were generally about 5–10 times higher than those for herbicides and fungicides.

Figure 3 shows the symptoms reported by users who listed agrochemical products which had caused them health

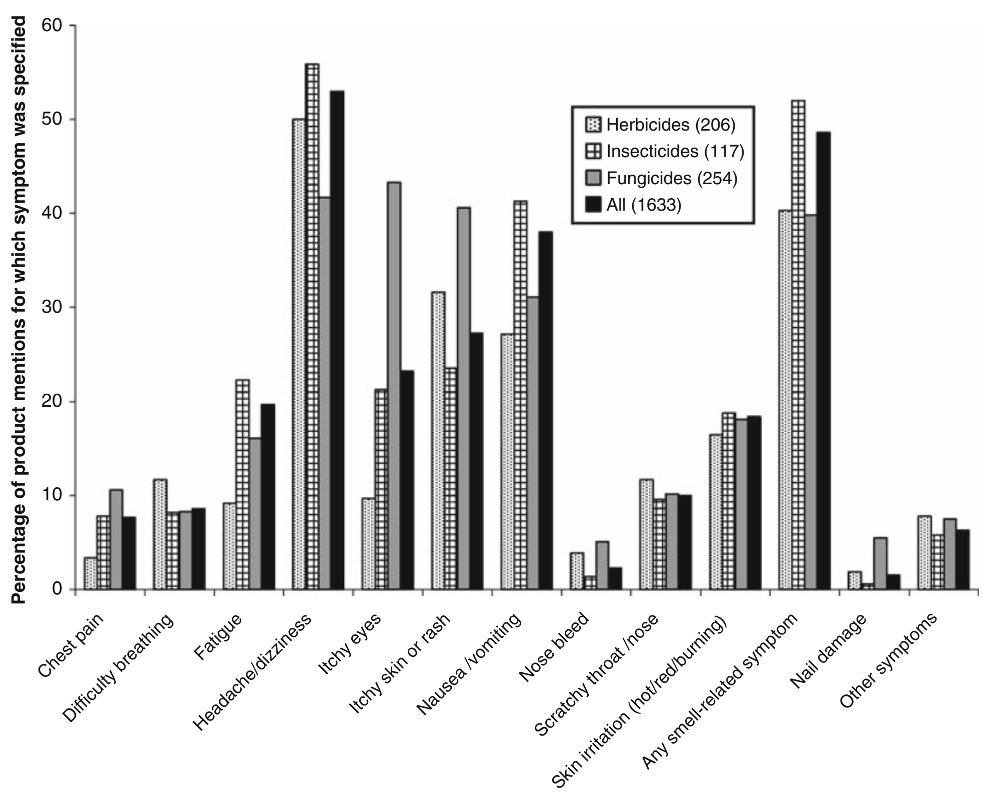

Fig. 3 Symptoms reported by users who listed agrochemical products which had caused them health problems by pesticide group

problems. The symptoms are shown for all product mentions and broken down by the type of pesticide. Headache/dizziness was the most common symptom (52% of all identified pesticides) followed by nausea/vomiting (38% of all product reports). Over half of the product reports listing headaches/dizziness and nausea/vomiting noted that the symptoms were smell related. A small proportion of product reports mentioned strong smell and no other sign or symptom (3%), and a further 8% of product reports did not mention any sign or symptom other than ones which were smell related. The biggest differences between the symptom distributions for product mentions in the three sectors were seen for itchy eyes and itchy skin which were much more commonly reported for fungicides. Insecticides were more likely to cause smell-related problems, especially nausea and headache. Fatigue also appeared to be associated with insecticides, but this resulted from the high proportion of insecticide mentions made by Bangladeshi users that listed fatigue as a symptom (82%). Figure 4 shows a breakdown of symptoms for four classes of insecticides; organophosphates, synthetic pyrethroids, carbamates and others (including mixtures of organophosphates and synthetic pyrethroids). Organophosphates were more likely to be associated with smell-related symptoms while the synthetic pyrethroids were associated with itchy skin or rash and itchy eyes. Figure 5 shows a breakdown of symptoms for four classes of fungicides; inorganics, triazoles, dithiocarbamates and others. Itchy eyes were much more commonly reported by users of inorganics and triazoles (57 vs. 15% all other fungicides) but the difference was much smaller for itchy skin or rash (46 vs. 29%). Chest pain was also more likely to be reported by users who mentioned problems with inorganics and triazoles (15 vs. 2%). A similar breakdown is given in Fig. 6 for four classes of herbicides; bypyridylium, phenoxyacetic acid, glycine and others. Two major differences in symptoms were the absence of skin irritation for phenoxyacetic herbicides (23% for all other herbicides) and the low proportion of headache mentions for bypridilium herbicides (33 vs. 55% for all other herbicides).

The frequency distributions of symptoms caused by pesticides in the three groups were significantly different ($P = 0.001$) and herbicides that users stated had caused them health problems were more likely to have caused problems only once or rarely (51%) than fungicides (36%) or insecticides (40%). A high percentage of product reports mentioned at least one symptom that the user experienced every time that product was used (32%), but this fell to 24% when smell-related symptoms were excluded. After strong smell, itchy skin or rash was the symptom most

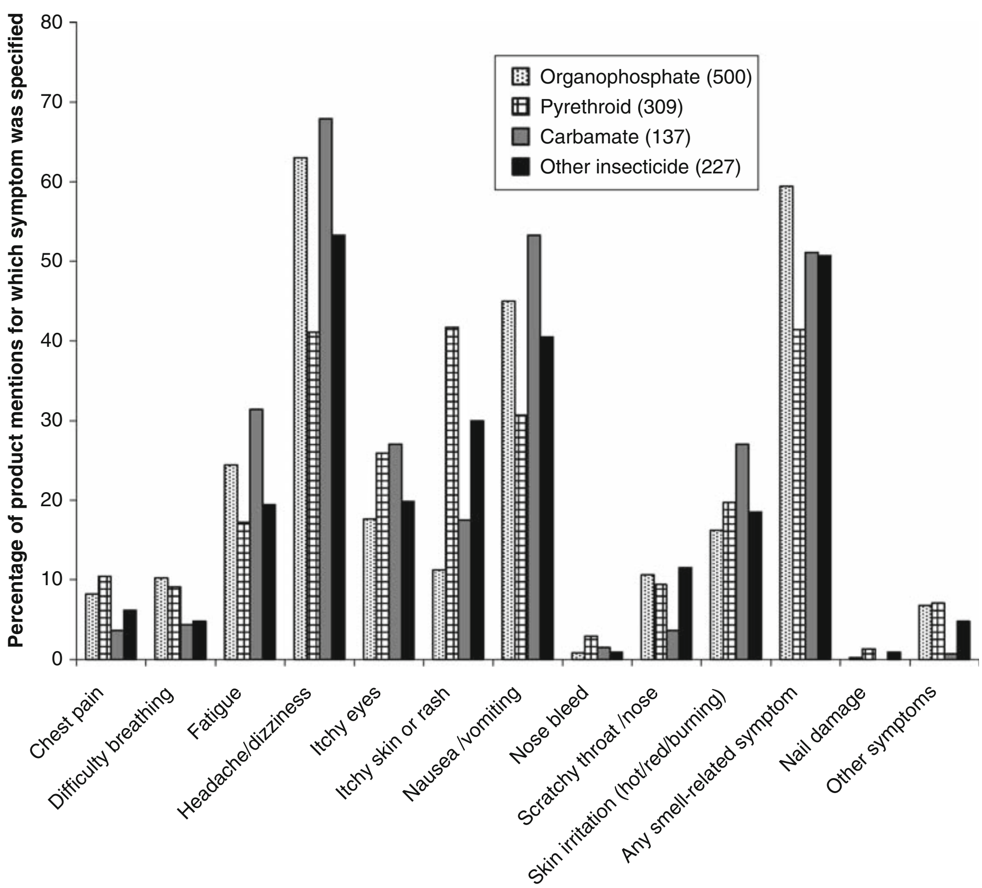

Fig. 4 Symptoms reported by users who listed insecticides which had caused them health problems by insecticide group

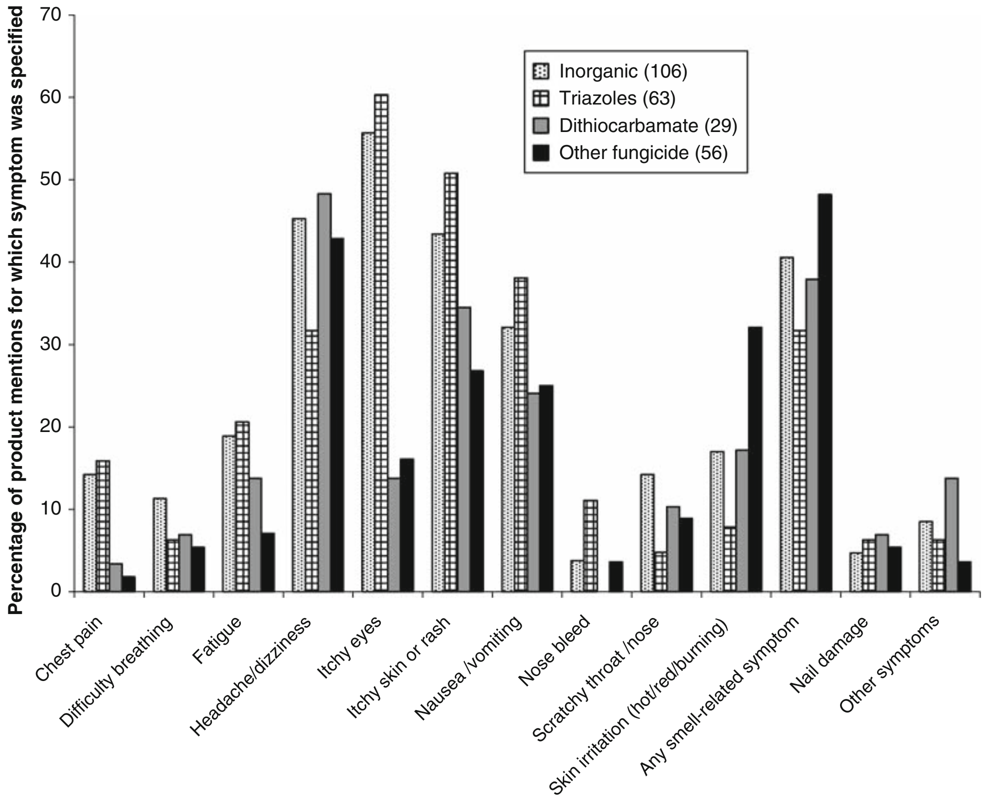

Fig. 5 Symptoms reported by users who listed fungicides which had caused them health problems by fungicide group

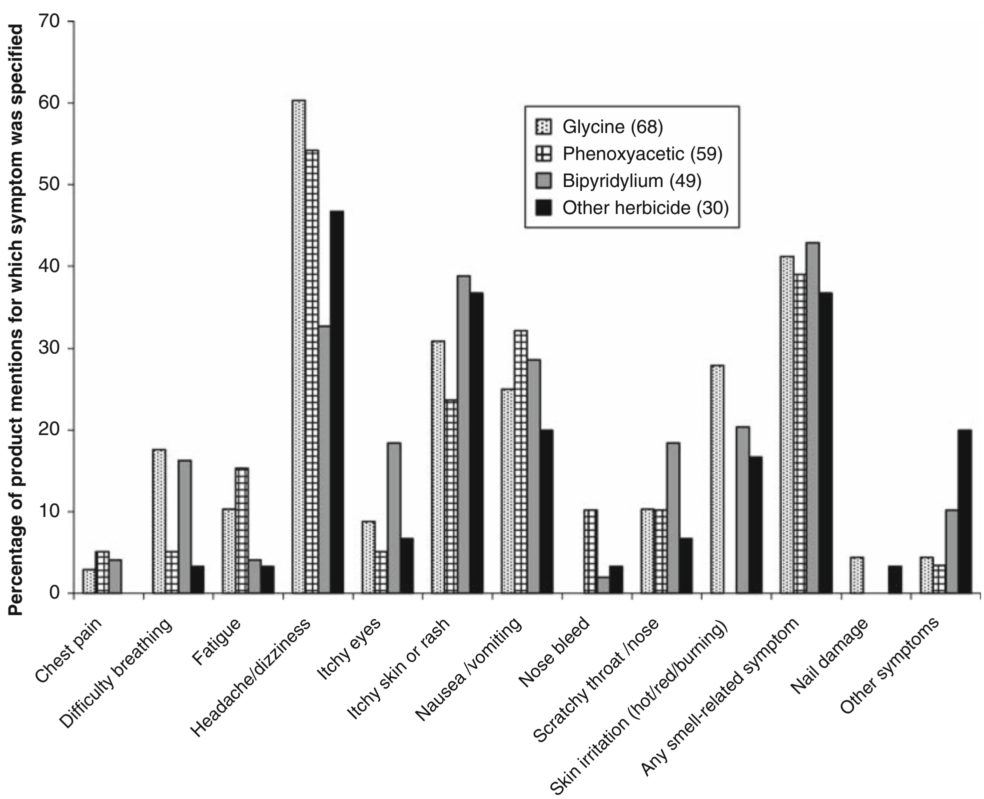

Fig. 6 Symptoms reported by users who listed herbicides which had caused them health problems by herbicide group

likely to be experienced by a user every time that product was used. Synthetic pyrethroids and fungicides were the most likely to be associated with a sign or symptom every time used. The median number of incidents attributed to different types of pesticides were also significantly different ($P < 0.01$) with herbicides having the lowest median.

Discussion

The survey was conducted primarily to gather information on KAP amongst groups of agrochemical users considered to be at highest risk of exposure. Nevertheless, it provides valuable information about health effects related to agrochemicals amongst users considered to be at the highest risk of exposure in a wide variety of geographical regions and about the products causing health problems. Information collected on health effects in the 2004 survey was not as comprehensive as that collected in 2005/2006 and consequently the analysis was restricted to the 2005/2006 surveys.

The definition of a minor health incident was modified in 2006 because there were differences in the way it had been interpreted in different countries. The incidence of agrochemical-related incidents was higher in the 2006 survey than in 2005, but it did not appear to be a result of this change because there was a comparable increase in the incidence of serious and moderate incidents from 2005 to 2006 to that in minor incidents. The proportion of users who reported a minor incident at worst in 2006 was approximately five times higher than in 2005 (34.3 vs. 8.3%, respectively) but almost five times as many users reported a serious or moderate incident in 2006 as in 2005 (12.6 and 2.6%, respectively). It is unclear why incidence rates were higher in 2006 than 2005, although the 2006 survey included four African countries and three of the four countries with the highest proportions of users reporting an agrochemical region came from this region. However, two European countries were included in the 2006 survey and 12.2% of their combined users reported an incident requiring medical treatment in the last 12 months which is a higher figure than reported by any country in the 2005 survey. Indian users were surveyed in both years, but the regions surveyed were different. Although a higher proportion of Indian users reported minor incidents in 2006 than 2005 (31.3 vs. 18.9%), a lower proportion reported an incident requiring medical treatment in 2006 than 2005 (7.7 vs. 11.6%).

Another limitation of the survey was incomplete information on the identity of pesticides that the users thought had caused their health problems. It is unsurprising that some users could not identify the pesticides that they were using when incidents occurred because of the complex tank mixtures used and decanting after purchase (although this practice was not common). However, almost 2/3 of users that had experienced an agrochemical-related incident in the last 12 months listed at least one product that had had an adverse effect on their personal health. Surprisingly, the proportion of users that were able to identify a product that had had an adverse effect on their health was slightly lower for those who reported a serious or moderate severity incident (57%, $n = 256$) than for users who reported a minor incident (65%, $n = 825$). However, this was largely due to the fact that many of the minor incidents were reported by users in Tanzania and Cameroon where very high proportions of users who reported health problems were able to identify the products that they felt had caused health problems (98 and 92%, respectively). The use of complex tank mixtures may have resulted in over-reporting of the numbers of incidents as some users reported the same numbers of incidents in all severity categories for more than one product. In some cases, the numbers of incidents were sufficiently unusual to suggest that the user had not been able to identify the product that they thought was responsible.

Caution is also required when comparing the results between countries in this survey because the wide variations in the frequencies of agrochemical health incidents of different severities will also reflect different cultural attitudes towards the symptoms and the pesticides themselves. Other explanatory factors include the availability and cost of treatment and the types of pesticides being used. Evidence of other cultural influences is provided by users from Bangladesh who were much more likely to list fatigue as a symptom than users from other countries (80% of product mentions made by Bangladeshi users listed fatigue as a symptom compared to only 14% of product mentions by other users). Organophosphorous and carbamate insecticides comprised almost three quarters of product mentions by Bangladeshi users and almost 90% of these listed fatigue as a symptom. However, users in other countries who mentioned these same insecticides were no more likely to list fatigue as a symptom for these products than for other products mentioned. Differences in refusal proportions between countries may also have explained some of the variability in the reported incidence of agrochemical incidents, but there was no indication from the local market research agencies who performed the fieldwork that this was a significant factor.

Some analyses in this paper are based on spraying time as a surrogate for exposure time. This clearly underestimates the time that a user is exposed and incidents could occur during all phases from transport to spraying and after. However, there is no reason to expect that the opportunity for exposure would be greatly different for the different pesticide sectors, although many of the insecticides were sprayed in combination and the potential for exposure during mixing and measuring might be greater. In addition, over 80% of product-related incidents occurred while spraying (Matthews 2008).

It is of concern that 1.2% of users reported an agrochemical incident that resulted in hospitalisation in the last 12 months and a further 5.8% reported an incident that required medical treatment. The incidence rate for incidents requiring medical treatment in the last 12 months was 17.8 per 100 users. However, nine countries in this survey (Brazil, China, Greece, Korea, Martinique and Guadeloupe, Philippines, Sri Lanka and Taiwan) had an incidence rate for agrochemical incidents requiring medical treatment that was less than 5.8 per 100 users which equates to the 2006 all illness and accident rate for crop production workers in the USA of 5.8 per 200,000 h (US Bureau of Labor Statistics 2006). The limited information available on machinery and livestock-related incidents in this survey suggests that this would also have been true for the majority of these countries if it had been possible to calculate a rate for all incidents requiring medical treatment.

Wesseling et al. (2001) reported on acute pesticide-related illness amongst banana plantation workers in Costa Rica in 1996 and reported an overall rate of 2.6 per 100 workers per year for topical injuries and systemic poisonings. The incidence rate for incidents requiring hospital treatment amongst Costa Rican farmers in the present survey was similar at 3.2 per 100 (8.0 per 100 for medically treated incidents). However, only 3 of the 16 Costa Rican farmers in the present survey who were able to identify a product responsible for their incident cited paraquat as the cause of their agrochemical-related incident, whereas Wesseling et al. (2001) reported that paraquat was the pesticide most frequently associated with injuries, mostly skin and eye lesions.

The incidence of minor agrochemical-related incidents in the present survey seems very high in some countries, especially Morocco and Tanzania, but it is difficult to compare these figures with those reported by other investigators because of the variability in the definitions of health effects used in other studies and the ways that other investigators have related incidents to agrochemical use. The study by Chitra et al. (2006) has reported one of the highest figures for the proportion of farmers suffering from pesticide-related signs and symptoms. Chitra et al. (2006) reported that 86.1% of farmers spraying predominantly insecticides in Southern India had experienced signs or symptoms related to pesticide exposure. In the present survey, 85.2% of Moroccan farmers reported a minor health effect in the last year suggesting a problem comparable to that reported by Chitra et al. (2006). However, Chitra et al. (2006) asked farmers whether they experienced these signs and symptoms during or immediately after spraying pesticides, implying that the sign or symptom was experienced regularly. In contrast, the proportion of Moroccan farmers experiencing the regular problems described by Chitra et al. (2006) is likely to be much lower than 82.5% as only a third of the products listed by Moroccan farmers in the present survey were stated to cause health problems often or every time used. In addition, excessive sweating and burning/stinging/itchy eyes were the most common symptoms reported by Chitra et al. (2006) and these are more severe and specific to insecticides than the symptoms most commonly reported by insecticide users in the current survey.

Yassin et al. (2002) also reported a high prevalence (83.2%) of self-reported toxicity symptoms related to pesticides in the last 3 months amongst farm workers in the Gaza strip who used insecticides predominantly. However, the symptoms were very different to those reported by users in this survey. Burning sensation in the eyes/face was by far the most common symptom experienced by 64.3% of the Gaza strip farm workers but headache and dizziness were also commonly experienced. The definition of a minor health effect in the present survey is probably broader than in other surveys and 11% of the product reports only listed smell-related symptoms. In addition, the most commonly reported symptoms in the present survey such as headaches/dizziness and nausea/vomiting may have been heat related in many cases (US EPA 1994) and a high proportion of product reports (40%) listed symptoms that had only caused a problem once or rarely in the last 12 months.

Concern has been expressed about female sprayers working in Malaysian plantations (Fernandez et al. 2002). It is clear that some female sprayers spend large amounts of time spraying pesticides and many of the Malaysian female plantation sprayers surveyed in the present study sprayed pesticides almost every day of the year (median 276 days). This figure is considerably higher than the median of 20 days for all users in the survey. In addition, the median hours that they sprayed each day was also much higher than that for all users in the survey (6 vs. 4 h), and the median hours sprayed in the last year by the Malaysian females was 1,560 h compared with 60 h for all users. A higher proportion of the Malaysian female plantation workers had experienced a serious or moderate health incident in the last year than the full group of users (13.7 vs. 7.9%). Nevertheless, the proportions of Malaysian female users experiencing a serious incident or an incident of any severity were close to the average for the survey and reflected their generally good working practices.

Although the survey collected a considerable amount of information about the KAP of users, information about exposure to pesticides is not very specific. Nevertheless, the logistic regression models to predict which farmers would experience incidents and the negative binomial regression models for incidence rates were informative and consistent.

Farmers who experienced agricultural equipment and livestock incidents were much more likely to experience agrochemical-related incidents and this was a much stronger predictor than the practices adopted by the user when measuring, mixing and spraying agrochemicals. It was an especially strong factor in a number of countries and in Korea only 1 out of 50 users who had experienced an agrochemical-related incident had not had an incident involving agricultural equipment in the last 12 months. In some cases, the agricultural equipment incidents may have involved the spraying equipment, but the association with livestock incidents suggests that the association indicates a failure to exercise caution.

Younger farmers were more likely to experience agrochemical-related incidents than older users, a finding also reported by Yassin et al. (2002), but this factor was less important in models for the number of incidents, although close to significance. The confidence of the user was a key factor, especially the confidence of users about their practices when spraying. Those who felt that their practices were the safest were much less likely to experience incidents even if their practices were not the best. Users who sprayed more than the median insecticide spraying hours were at a significantly increased risk of agrochemical-related incidents but, a stronger association might have been expected given that most of the brands that users stated had caused incidents were insecticides.

The regression modelling was able to confirm the value of some of the steps in the five key steps approach towards safe handling of pesticides, such as caution (demonstrated by not experiencing machinery or livestock incidents) and equipment maintenance. Personal hygiene (the user and their spraying clothes) had been expected to be more strongly associated with incidents, but cleaning contamination immediately after spillages was an important factor. The use of recommended PPE was also not a strong predictor of health incidents, but the use of PPE could be seen as being secondary to the other four key steps which focus on minimising opportunities for exposure. In addition, there was confusion amongst users in some countries about whether items of clothing such as a long sleeved shirt, long trousers or boots could be described as items of PPE. It is not surprising that the regression models were unable to confirm the value of certain practices as there is a considerable variation between countries in the importance of various factors as indicated in figures 1 and 2. For example, Mexican users were the least confident in the survey (only 5% of Mexican users felt that their use of PPE for spraying was the safest practice), but their agrochemical incident rates were amongst the lowest. Atkin and Leisinger (2000) also noted this variation and the difficulty of measuring the "impact of isolated interventions in a dynamic social environment".

Far more incidents were attributed to insecticide usage than to fungicide or herbicide usage, but information was not collected about all the agrochemicals used by respondents and the quantities used. Users were asked to estimate the proportion of time spent spraying pesticides in the different sectors and relative to this measure, the data suggested that the incidence rate for insecticide-related incidents was 5–10 times higher than that for herbicides or fungicides. Users may have disliked insecticides more because of their smell and been more inclined to think that they were the cause of their health problems, but other pesticides such as paraquat have a very strong smell. Other investigators have reported a high proportion of incidents attributed to insecticides. Das et al. (2001) noted that a few categories of insecticides accounted for over half of the acute illnesses reported by migrant workers in California and Calvert et al. (2004) reported that insecticides were responsible for almost half of acute pesticide-related illnesses reported to the US SENSOR surveillance scheme. In addition, the studies that have reported some of the highest rates of pesticide-related signs and symptoms, e.g., Chitra et al. (2006) and Yassin et al. (2002), have studied populations that predominantly sprayed insecticides.

The results of the survey, although not as clear as had been hoped, do highlight some important messages such as the importance of caution. The strong association observed between other types of accident on the farm and agrochemical incidents suggests that agrochemical use training needs to be set in a wider safety context of identifying unsafe acts and managing risks. The sponsor company is addressing this by putting more emphasis on straightforward overall safety messages such as the five key steps of safe use described above, and has worked with global experts to develop improved training materials. More than three million users were trained in these practices in 2008 by the sponsor company and its cooperators.

It is also clear that the majority of health incidents in the survey resulted from spraying, but the regression analyses were less helpful in this respect. Matthews (2008) reported problems with the use of leaking lances especially in the African countries, and the regression analyses in this study indicate that this is a factor linked to health incidents. Matthews (2008) also noted that the proportion of users wearing the minimum recommended wear for spraying (long sleeved shirt, long trousers and boots/shoes) was low in some countries, especially some Asian countries where many users did not wear any form of foot protection in muddy fields. However, not wearing three key items of PPE was not shown to be associated with an increased risk of health incidents, even though it must increase the risk of exposure when users do not take other measures to protect themselves such as spraying downwind (encouragingly, almost 80% of users were aware of the need to do this).

The full survey (Matthews 2008) also indicated a need for better education about secure storage and disposal, and this is being addressed as part of a wider approach to accidental and deliberate misuse of crop protection products. The survey did not focus specifically on the sale of crop protection products, but the survey has shown that the distributor/supplier is the main source of information about safe use. It is clear that greater emphasis needs to be placed on their training as in the UK where those involved in the sale, advice or supply of crop protection products are required to possess certification of training.

In conclusion, the survey indicates that the incidence of agrochemical-related incidents in some countries is high, especially in the African countries that were surveyed. The symptoms were often minor but about a third of brands that users said caused health effects, gave problems every time they were used. However, the survey also suggests that agrochemical-related incidents requiring medical or hospital treatment amongst high risk groups of users in many of the countries were no more common than would be expected amongst users in a developed country such as the US. Insecticide-related health problems were 5–10 times more common than would be expected on the basis of the spraying time. Time spent spraying insecticides was significantly associated with the risk of an agrochemical-related incident of any severity, but the association was weaker than expected given that almost 80% of incidents were blamed on insecticides. The most important factors influencing whether an individual reported one or more agrochemical incidents were failure to exercise caution measured by whether users had incidents involving agricultural equipment or livestock and lack of confidence in their practices.

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