Newcastle University ePrints

Remoundou K, Brennan M, Hart A, Frewer LJ.

[Pesticide Risk Perceptions, Knowledge, and Attitudes of Operators, Workers, and Residents: A Review of the Literature.](#)

Human and Ecological Risk Assessment: An International Journal 2014, 20(4), 1113-1138.

Copyright:

This is an Accepted Manuscript of an article published by Taylor & Francis in *Human and Ecological Risk Assessment: An International Journal* on 6 February 2014, available online:

<http://www.tandfonline.com/10.1080/10807039.2013.799405>

Date deposited: 29th September 2014 [made available 6th February 2015]

This work is licensed under a

[Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Unported License](#)

ePrints – Newcastle University ePrints

<http://eprint.ncl.ac.uk>

Pesticide Risk Perceptions, Knowledge and Attitudes of Operators, Workers, and Residents: A Review of the Literature

Kyriaki Remoundou,¹ Mary Brennan,¹ Andy Hart,² and Lynn J. Frewer¹

¹School of Agriculture, Food and Rural Development, Centre for Rural Economy, Newcastle University, Newcastle upon Tyne, UK; ²Food and Environment Research Agency, Sand Hutton, York, UK

Address correspondence to Lynn J. Frewer, School of Agriculture, Food and Rural Development, Centre for Rural Economy, Agriculture Building, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK. E-mail: Lynn.Frewer@Newcastle.ac.uk

Running Head: Pesticide Risk Perceptions, Operators, Workers and Residents

Received 22 January 2013; revised manuscript accepted 16 April 2013

ABSTRACT

The literature on the risk perceptions, knowledge levels, and attitudes of operators, workers, and residents in relation to non-dietary exposure to agricultural pesticides is reviewed. No literature was identified in relation to bystander exposure. Research has primarily been conducted on participants in developing countries and migrant workers in the U.S. For operators and workers, illiteracy, poverty, and a perception that exposure to pesticides is an inevitable part of their work results in limited adoption of safety precautions while using and storing pesticides. As a result, risk communication activities aimed at operator and workers need to take account of the wider socio-economic and cultural conditions in which workers and operators are working and living. There is less research focused on residents' and bystanders' perceptions, attitudes, and behaviours. The lack of European data in general, and residents' and bystanders' data in particular, represents a knowledge gap that is pertinent to emerging EU legislation requiring residents' and bystanders' inclusion in pesticide risk assessment. This review provides a comprehensive overview that can assist policy-makers, and risk communicators in the development of targeted training and awareness-raising material for operators, workers, bystanders, and residents. Areas for future research are suggested.

Key Words: agricultural pesticides; risk perceptions; operators; workers; residents.

INTRODUCTION

Pesticides are a significant source of mortality and morbidity worldwide, especially in developing countries where economies are heavily reliant on agriculture (WHO 2003; Pimentel 1996). The acute health problems associated with pesticide exposure include headaches, nausea, eye irritation, skin rashes, and flu-like symptoms. Long-term chronic health problems include neurological and reproductive disorders and various forms of cancer (Salazar 2004). Concerns about the potential adverse health effects of pesticides have driven the development and publication of the recently revised EU Directive on the sustainable use of pesticides (European Union Parliament and Council 2009). The Directive aims to reduce the risks to human health and the environment from the use of pesticides, and requires EU member states to implement training for all professional pesticide users, along with awareness-raising programmes targeting the wider public. These include, in particular, “residents”, who live in areas adjacent to those where pesticides are applied, and “bystanders”, who are inadvertently exposed to agricultural pesticides through non-agricultural activities. As a consequence of the sustainable use directive, member states are required to develop training materials to minimise occupational exposure to pesticides (operators and workers), as well as risk communication programs aimed at raising awareness amongst residents and bystanders about the risks of pesticide exposure, and provide advice on how exposure risks can be minimised (Pasiani *et al.* 2012; Sam *et al.* 2008).

Nearly 50% of the world’s labour force is employed in agriculture (Maroni *et al.* 2006). In developing countries, agricultural employment predominates across the workforce. Modern agriculture relies on the use of pesticides to increase crop yields and sustain food safety and

security for the global population (Cooper and Dobson 2007). Most pesticides, however, are toxic to non-target species and can result in substantial health risks, especially if not used in accordance with safety advice (Pimentel *et al.* 1992). Occupational exposure occurs either through acute intoxication due to accidents while mixing, loading, or applying pesticides or through contact with treated crops (Damalas and Eleftherohorinos 2011). Exposure risk increases when operators and workers ignore safety instructions on how to properly use pesticides, and guidelines on the use of personal protective equipment and adoption of sanitation practices (Damalas and Eleftherohorinos 2011). It is argued that engagement in unsafe pesticide use and disposal practices is the result of a lack of knowledge and misperceptions of the risks associated with pesticides amongst operators and workers (Obopile *et al.* 2008; Koh and Jeyaratnam 1996).

Recent years have witnessed an increase in awareness from policy-makers on the adverse effects of passive exposure to pesticides from residents and bystanders (Butler-Ellis 2012; The Royal Commission on Environmental Pollution 2005). Epidemiological data have also become available that provide evidence for a direct causality between morbidity and pesticides exposure in these groups (Galea *et al.* 2011). As a consequence, many countries have enacted legislation to protect residents and bystanders and minimize their exposure. In the UK, for example, the Royal Commission on Environmental Pollution (2005) published a report on crop spraying that raised concerns about the pesticides approval process and arguing that there is a need for clearer communication and provision of information to the public about pesticide spraying. In response, the government recognized the need to develop a better understanding of residents' and bystanders' exposure to pesticides, along with the need to revise the current model for their exposure.

Central to the development of effective training and risk communication materials is an understanding of how different stakeholders perceive the risks associated with pesticide exposure, and how these perceptions are shaped by socio-economic, cultural, environmental, and/or institutional factors. Seminal research originating in behavioural decision-making by Slovic and colleagues (see, *inter alia*, Fischhoff *et al.* 1978; Slovic 2000) have demonstrated that how people perceive risks may differ from expert risk assessments. Moreover, these differences have explanatory value regarding why people react negatively to risks that are judged acceptable by technical risk assessors (see, *inter alia*, Frewer *et al.* 2012; Slovic 1987; Hinman *et al.* 1993; Whitfield *et al.* 2009; MacGregor and Fleming 1996; McCauley *et al.* 2002). Alternatively, individuals may discount risks to themselves by applying a cognitive mechanism such as optimistic biases, where people perceive that they are personally at less risk than an average member of their society, or relative to an individual who engages in riskier behaviours (Weinstein 1982; Helweg-Larsen and Shepperd 2001; Klein and Helweg-Larsen 2002). Potential cultural differences in risk perceptions and communication preferences also need to be considered (Renn and Rohrman 2000). It is generally assumed that risk perceptions need to be taken into account when developing risk communication, as informational content needs to address people's concerns and existing beliefs about potential hazards as well as technical risk estimates (Fischhoff 1995; Sandman *et al.* 2006). The need to take risk perceptions into account when developing intervention-based policies to reduce exposure to potentially hazardous events has been noted in the literature (*e.g.*, see Slovic 2000; Frewer *et al.* accepted).

Risk perception has been shown to influence pesticide exposure. For example, Koh and Jeyaratnam (1996) argued that occupational poisoning episodes in developing countries can

largely be attributed to the erroneous beliefs of workers that impair their capacity and motivation to protect themselves from the associated risks. It is argued that the number of cases of occupational poisoning can be significantly reduced if appropriate training is provided on pesticide use and associated potential health risks. To be successful, such training must build on existing perceptions, attitudes, and beliefs held by operators and workers about: 1) how to handle and use pesticides and 2) the risks to human health from pesticide exposure.

In recent years, a significant body of literature has emerged that has examined how risk perceptions held by different stakeholders are linked to exposure to pesticides. These studies have mainly focused on addressing occupational hazards associated with the mixing, loading, and application of pesticides (operators), or working in treated fields or with treated crops (workers). Less research has examined how residents and bystanders living in agricultural areas perceive the risks from inadvertent pesticide exposure. The aim of this study is to review existing research that has linked perceptions to self-protective behaviours associated with pesticide exposure in four key stakeholder groups potentially exposed to pesticides through agricultural application: operators, workers, residents, and bystanders.

METHODS

Studies are included if they consider risk perceptions, knowledge, and associated attitudes, associated with pesticide exposure, independent of geographical location or the type of crops being treated. Only studies published in peer-reviewed journals have been reviewed to ensure the quality of the research. Due to linguistic constraints, the articles included are restricted to English language publications.

The databases searched included Scopus, Google Scholar, and the bibliographic database PubMed. The search strings applied were: ‘pesticides’ AND ‘risk perceptions OR knowledge OR attitudes’ AND ‘residents OR bystanders OR neighbours OR operators OR workers OR farmers’.¹ The review focuses on studies on risk perception and related attitudes associated with 1) occupational exposure for operators and workers (Part 1); and 2) residents’ and bystanders’ exposure (Part 2). Papers were excluded from the review if they did not assess perceptions and attitudes towards pesticide exposure (for example, if they dealt *only* with exposure).

RESULTS

Presented in Table 1 is a summary table outlining the key findings from the literature and maps these against the stakeholder groups investigated, the country/region in which research has taken place, the methods and sample size used, and the number of papers and key references. The geographical distribution of the studies is graphically depicted in Figure 1.

Occupational Hazards for Operators and Workers²

---

¹Consumption of food and water contaminated with pesticide residues can represent a significant route for exposure, and have been extensively addressed in the existing risk perception literature. However, these data are excluded from this review unless exposure occurs as part of daily working practices, or through residents’ or bystanders’ exposure. The ecological impacts of pesticide use are also out of the scope. For the same reason, risk perceptions associated with the domestic use of pesticides are also excluded.

²The studies reviewed in this paper are not following the official definition of workers as developed by the European Food Safety Authority (EFSA). Instead, the term workers often refers to people performing operator and re-entry tasks, whereas a ‘worker’ in the EFSA (2010) definition is defined as a person who, as part of his/her employment, enters an area that has previously been treated with pesticides or who handles a crop that has been treated with pesticides.

The literature on risk perceptions and attitudes of operators and workers draws primarily on studies in developing countries and studies examining migrant and seasonal farmworkers in the U.S. (see also Figure 1 on the case study areas). These groups are considered to be more vulnerable to pesticide exposure since they have limited access to societal institutions and resources necessary to promote awareness and self-protection (Parrott *et al.* 1999). Furthermore, high illiteracy rates, poverty and language barriers within these groups may represent significant barriers to the development of risk communication and training materials (Salameh *et al.* 2004).

Developing countries

Illiteracy levels

An important finding from the studies conducted in developing countries is that high illiteracy rates contribute to farmers' (and farmworkers') difficulties in understanding and following pesticide use instructions and safety advice. This is considered to be a significant impediment to risk communication efforts. Ibitayo (2006) reported a 55% illiteracy rate amongst the Egyptian farmers included in their research, and Kimani and Mwabthi (1995) reported that 24% of their Kenyan participants are illiterate. Similar findings were reported for farmworkers in Brazil (Recena *et al.* 2006; Pasiani *et al.* 2012), Tanzania (Stadlinger *et al.* 2011), Lebanon (Salameh *et al.* 2004), Ethiopia (Karunamoorthi *et al.* 2011), and for Mexican operators and workers (Blanco-Muñoz and Lacasaña 2011). In Ghana, the majority of farmers had received only basic education (Ntow 2006). Two exceptions were found in Gaza (Yasin *et al.* 2002) and Kerala, India (Devi 2009), where higher literacy rates amongst agricultural workers were identified. Gender differences in the level of education are also evident. Atreya (2007) examined

gender differences in pesticide use, knowledge, attitude, and practices for Nepalese farmworkers and reported that female workers had lower literacy rates than male workers. Consequently the female workers were less likely to be able to read and understand pesticides labels. Participants across the studies were found to have difficulty in understanding the toxicity level indicated on pesticide labels and few reported having attended any training on pesticide use and storage. In Bangladesh, only 4% of farmers reported receiving any training on how to use and handle pesticides (Dasgupta *et al.*, 2007). Hashemi *et al.* (2012) found that almost none of the Iranian participants in their study had received any special training in pesticide safety.

Unsafe pesticides practices

The prevalence of unsafe pesticide practices among farmworkers and operators in developing countries is also identified as a potential risk factor. Ibitayo (2006) reported that, in Egypt, almost all participants admitted storing pesticides in their bedroom. Storage in bedrooms was also widespread in Kenya (Kimani and Mwabthi 1995). Farmworkers in Palestine admitted unsafe practices, including the preparation of pesticides in kitchens, inadequate disposal of empty pesticide containers, and eating and drinking during pesticide application (Zyoud *et al.* 2010). Use of pesticide containers for drinking and food storage was reported in Ethiopia (Karunamoorthi *et al.* 2011). Inadequate use of protective equipment is also a cause of concern. In studies by Dasgupta *et al.* (2007) and Salameh (2004), participants (87% - Bangladesh; 50%: Lebanon, respectively) stated that they did not take any protective measures when using pesticides. In Tanzania, more than 50% of the farmers did not use any protective equipment during mixing or application of pesticides. Poor adoption of protective equipment was also

identified amongst farmworkers in Gaza (Yasin *et al.* 2002), Ghana (Ntow 2006) and Brazil (Pasiani *et al.* 2012). The reasons commonly stated for misusing protective equipment were the cost and discomfort associated with their use (Ntow 2006; Devi 2009). In Ghana, the great majority of farmers further admitted disposal of sprayer wash water and empty pesticide containers by throwing them on the field or nearby waterways (Ntow 2006).

Knowledge levels, risk perceptions, and safety practices

Correlations between knowledge levels about pesticide-related health risks and adoption of safety practices have been reported in various studies. The findings are mixed. In the Gaza, for example, almost 60% of farmworkers are not in favour of the use of pesticides for pest control. Furthermore, they reported high levels of knowledge on the potential health impacts of pesticides and routes of exposure. However, use of protective measures was reported to be poor, since the majority believed that their body has developed resistance to pesticides (Yasin *et al.* 2002). Similarly, Ghanaian farmers have high risk perceptions regarding hazards from pesticides but fewer than 30% wear full protective covering (Ntow 2006). Perceived resistance to pesticides is also reported by Palis *et al.* (2006) in their research on Pilipino farmers' knowledge and attitudes, where about a quarter of the participants take no special precautions to protect themselves from pesticide exposure. Knowledge was not found to influence practices in Brazil. Recena *et al.* (2006) note that almost all the participants included in the study considered pesticides to be poisonous, with the majority also expressing concerns regarding the adverse effects on the environment. However, the use of personal protective equipment during pesticide application was not found to be common practice.

In a more recent Brazilian study, the majority of participants admitted having received information about pesticides from the government and claimed to be reading the instructions and warnings on the products' labels. However, many did not take adequate protective measures. This inconsistency was attributed to the low mean educational level of study participants. Ethiopian farmers were also aware of the adverse effects of pesticides on human health. However their reported safety practices and use of PPE were found to be inadequate (Karunamoorthi *et al.* 2011). Similarly, high risk perceptions did not significantly influence the extent to which Turkish farmers adopt safety practices (Isin and Yildirim 2007) nor did they increase the use of personal protective equipment in Mexico (Blanco-Muñoz and Lacasaña 2011) and Lesotho (Mokhele 2011). Salameh *et al.* (2004) noted that more experience of pesticide application did not translate into higher adoption of protective equipment in Lebanon. However, having experience of pesticide related education increased both the likelihood of participants adopting preventative measures and risk perceptions, despite the low educational level of study participants. Dasgupta *et al.* (2007) reported that approximately 47% of their sample of farmworkers in Bangladesh overused pesticides. Over usage was, in turn, positively correlated with low perceptions of pesticide risk by the farmers. Similarly, knowledge about pesticide related health risks positively correlates with the adoption of safety practices in Palestine (Zyoud *et al.* 2010).

Determinants of risk perceptions

Socio-economic and cultural determinants of risk perceptions and practices have also been examined. Isin and Yildirim (2007) report that, in Turkey, younger and better-educated

individuals, as well as those having less farming experience, have higher perceptions of the health risks associated with pesticide exposure. Similarly, younger and less-experienced farmers report higher risk perceptions in Iran (Hashemi *et al.* 2012). Blanco-Muñoz and Lacasaña (2011) find that, in Mexico, the perceived risk of pesticides is positively correlated with educational level but is not influenced by age or gender. Atreya (2007) did not report significant differences in perceived risks for an individual's own health or to the environment among male and female farmworkers in Nepal. However, the characteristics of the risk "target" may influence risk perceptions. For example, Barraza *et al.* (2011) report higher risk perceptions among mothers in Costa-Rica, compared to fathers and other stakeholders, when it comes to pesticide-related health risks for children.

Heong *et al.* (2002) note that influence from reference groups is highly correlated with behaviour. Farmers in Laos were asked what they thought was expected of them with respect to the frequency of insecticide spraying by different reference groups, including neighbours, village heads, spouses, and extension technicians. Farmers rated technicians as the most influential reference group. Palis *et al.* (2006) also stressed the role of associated beliefs in shaping risk perceptions. For example, Pilipino farmers tended to view pesticides as a "medicine" for the plants rather than a "poison" for pests, and therefore saw no point in investing in protective equipment.

Almost all of the studies in the developing world highlighted the need for targeted training and awareness raising programs. Palis *et al.* (2006) emphasised the need to assess belief systems and perceptions before training and awareness-raising material are developed. Atreya (2007) also stressed the need for such programmes to be gender-sensitive, given potential

gender-related differences in attitude and perceptions, although research is needed *a priori* to establish what these are.

Immigrant workers in the U.S.

Safety practices

Some of the earlier evidence from the U.S. comes from research that aimed to reduce farmworker pesticide exposure by developing an education program targeting specific cultural groups (Arcury *et al.* 2002; Austin *et al.* 2001). These studies examined the knowledge levels, attitudes, and risk perceptions of North Carolina Latino and Hispanic farmworkers. Participants were reported as not being able to understand English, the language in which training materials were provided. The majority reported that they perceived having no control over reduction of personal pesticide exposure. Salazar *et al.* (2004) reported that the majority of immigrant workers in Oregon tended to perceive adverse health effects as an inevitable by-product of their work, or believed that only weaker individuals were vulnerable to the effects of pesticide exposure. Both lines of reasoning were found to lead to participants' adopting limited precautions. Arcury *et al.* (2002) and Austin *et al.* (2001) further reported very limited use of protective equipment by immigrant workers, and attributed this to the absence of protective equipment in the workplace and work pressure. These findings are reinforced by recent studies with immigrant workers in the U.S. These demonstrated that stress at work and an inability to access equipment limited workers' use of protective equipment (Salazar *et al.* 2004; Parrot *et al.* 1999; Flocks *et al.* 2012). McCauly *et al.* (2002), noted that 40% of their sample (from Oregon, USA) considered themselves as never having been exposed to pesticides, or having limited

control in being able to protect themselves if they were exposed. As a result, only half the sample reported using protective equipment regularly while working with pesticides.

Illiteracy rates

Another common finding among studies of immigrant workers in the U.S. (and similar to the situation in developing countries) was the high illiteracy rates associated with those who were the recipients of pesticide application training. McCauly *et al.* (2002) noted that only a third of the farmworkers in Oregon received pesticide safety training. Similarly, in California, Cabrera and Leckie (2009) reported that the majority of the participants could not speak or read in English, and only half received any type of training in pesticide use.

Determinants of risk perceptions

Some demographic differences in risk perceptions amongst the U.S. farmworker population have been identified. For example, Cabrera and Leckie (2009) noted that risk perception scores are higher for women in California's Salinas Valley, and they are able to identify a wider range of long- and short-term health effects associated with pesticide exposure. Higher risk perceptions have also been reported among female farmworkers in Florida (Flocks *et al.* 2012). Focus group discussion reveals that female farmworkers were aware of the health hazards associated with pesticide exposure, in particular during pregnancy, and could recall incidents of illness affecting them and their children. Strong *et al.* (2009) further examined attitudes and knowledge of immigrant female farmworkers (or mothers in farm-working households). Using in-depth interviews, they reported that female workers could describe how

pesticides could enter their homes (take-home pathway) but were less able to connect it to exposure of children. The study argues that existing health beliefs play a role in determining safety practices. Strong *et al.* (2009) found that the majority of farmworkers reported delaying showering after work in order to cool down. Family dynamics, as well as community and worksite characteristics, were also found to influence the adoption of behaviours aimed at reducing the “take-home” pathway of pesticide exposure.

Europe

Risk perceptions and behaviours

Less research was identified that dealt with the risk *perceptions* associated with pesticide application of European operators and workers, when compared to developing countries and immigrant worker populations in North America. It is also possible that the relatively lower exposure risks due to more effective legislation and training in Europe has resulted in less research being done on risk perceptions for different stakeholder groups. The available data do not indicate a different pattern of perceptions and behaviours to those identified elsewhere. Damalas and Hashemi (2010) examined pesticide risk perceptions and the use of personal protective equipment among cotton growers in Northern Greece. They compared the attitudes and perceptions of younger and older farmers. The results suggest that younger farmers perceived higher levels of risk associated with pesticide use, and that they were less likely to agree that the benefits from pesticides outweighed the risks. Furthermore, younger farmers were more positive towards the adoption of integrated pest management (IPM) practices, although adoption scores were generally low. The frequency of use of protective equipment was also

found to be considerably lower for older farmers. Damalas *et al.* (2006) reported high levels of awareness regarding the potential health risks associated with handling pesticides amongst Greek tobacco farmers. However, these did not translate into high levels of adoption of safety precautions, with almost half of the sample reporting not using any personal protective equipment (PPE) when spraying pesticides.

Emerging evidence on European farmers' perceptions comes from a small but growing literature that applies non-market valuation techniques to investigate the welfare costs associated with pesticide use. These costs mainly refer to risk to the farmers' health from acute and chronic exposure to pesticides and more recently the effects on the environment and biodiversity, which are out of the scope of the current review.

Residents' and Bystanders' Exposure

Risk perceptions and behaviours

Little research on the perceptions of, and attitudes towards, non-dietary exposure as a result of pesticide drifts from treated areas has been published in peer-reviewed journals to date. In part, this may be a problem of definition, in particular in relation to who is represented by the term "bystanders", and collecting perceptual data from these individuals. There is a literature on people's valuation of negative environmental effects associated with pesticide use (see Cuyno *et al.* 2001 and Foster and Mourato 2000 among others), although this does not equate directly with assessment of the perceptions and attitudes of residents and bystanders, and associated behaviours in relation to agricultural pesticide use.

Ahmed *et al.* (2011) studied the risk perceptions of residents living close to agricultural fields in Sweden, and compared residents' perceptions of risk and attitudes towards pesticides with those of local farmers. The residents were found to perceive pesticides to be more harmful to the environment, and in general expressed more negative attitudes towards pesticide use than the farmers. Women and older residents expressed higher concerns regarding the potential risks of pesticides.

DISCUSSION

Pesticide use may be associated with health risks as a result of occupational (operator/worker) and passive (resident/bystander) exposure. Understanding how different “at risk” group, perceive the risks associated with pesticides, and how these vary between different socio-demographic and stakeholder groups is necessary to assist policy-makers and other interested actors in designing effective risk reduction measures and risk communication materials and activities (*e.g.*, Slovic 2000). This review aimed to summarize the limited though growing body of literature that considers the perceptions, attitudes, and levels of knowledge of pesticide risk and exposure across different “at risk groups”.

The research reported in this review was collected primarily in developing countries, or in the U.S. (particularly in regard to immigrant populations). The body of evidence suggests that, for populations where data are available, operators and workers rarely wear protective equipment, thereby exposing themselves to direct contact with pesticides. A significant finding is that higher risk perceptions and better levels of knowledge about the associated risk do not always translate into better use of, and adherence to, protective advice, guidelines, and protective

equipment use, suggesting that the relationship between risk perception and behaviour is not direct. Other factors, such as economic and employment pressures, and those related to peer group influences, may also influence risk-related behaviours. As a consequence, many workers and operators do not adopt protective practices nor use protective equipment.

There is some evidence to suggest that potential gender differences can be identified. For example, female workers tend to perceive higher levels of health risks associated with pesticides, and engage in more self-protective behaviours, although they also tend to receive less training (Cabrera and Leckie 2009). However, this finding needs to be corroborated in other geographical regions and cultures, in particular in Europe. This is in line with research in other areas (for example, see Gustafsod 1998), who reported that higher risk perceptions associated with a particular issue are experienced by women, possibly because they perceive that they are excluded from the risk management decisions that have imposed the same risks upon them in the first place. In addition, the low rates of literacy among farmers are a particular concern in developing countries and amongst U.S. migrant workers, in particular amongst female workers. Again, further research is needed to confirm that this is the case in other regions, in particular in Europe, as this has direct implications for the design and implementation of training and communication materials.

High levels of knowledge and perception of risk are not enough to influence workers' and operators' self-protective behaviour. This must be considered when designing training programs to increase safety. Other economic and socio-cultural pressures may also need to be addressed. These might include economic and employment pressures. The influence of potentially influential peer groups may also need to be addressed in risk communication initiatives directed

at both employers and workers, or as part of other interventions targeting the implementation of self-protective behaviour associated with pesticide use.

Gaps in knowledge have also been identified that need to be addressed in future research. In particular, research is needed to better understand the risk perceptions and related attitudes and knowledge levels about pesticide exposure associated with agricultural application for members of the public considered to be at significant risk of exposure. These include, in particular, residents living and/or working in close proximity to agricultural fields, and bystanders who visit rural areas for leisure/work and who find themselves in close proximity to agricultural fields. Such research is necessary if, as now required by EU legislation, effective targeted risk communication and awareness-raising material for residents and bystanders is to be developed.

As research into the risk perceptions and attitudes of operators and workers has primarily been centred on those of developing countries, equivalent research in Europe is needed to inform the development of effective training and awareness material targeting these groups in line with the EU directive on the sustainable use of pesticides. The evidence suggests that it may be necessary to take gender differences into account, as women are widely involved in agricultural activities in many parts of the world and can be extremely vulnerable to adverse health effects of pesticide exposure (Murphy *et al.* 1999), and also potentially have different levels of risk perception, training, and education compared to men. In developing countries, in particular, accumulated epidemiological evidence shows that women are more sensitive to adverse effects from exposure whilst at the same time have limited opportunities to control their exposure given

that production is organized in a gender-specific way (London *et al.* 2002). At the same time, the evidence for a causal relationship between risk perceptions and related attitude is equivocal.

Some limitations of this review can be identified. The authors acknowledge that the inclusion of only English languages publications may have excluded articles of interest published in non-English language journals. The authors suspect that such a literature may be available in languages published in Europe and beyond, for example in Chinese or Spanish. However, it is clearly not possible to include all languages of potential relevant publications in a review due to first of all the impossibility of systematically identifying all such articles, (even if abstracts are published in English translation of the article is required), and because of the linguistic limitations of the databases accessed. A further limitation to identification of studies for inclusion may relate to the databases utilised, as not all journals are included in all data-bases. In this study, we have included those most normally used for research in the area of study (Scopus and Biomed central) and Google Scholar (which has broader inclusion of publications). We are reasonably certain, therefore, that the review has included the range of scholarly English language publications available, although there may be some omissions related to the data-bases selected.

Several studies have reported increased risk of toxicity when an individual spends more time involved in pesticide application, unless greater attention is simultaneously paid to implementation of protective measures (Bell *et al.* 2006; Jensen *et al.* 2011; Jors *et al.* 2006). Research within the EU Framework 7 funded BROWSE project is currently assessing the relationship between exposure and frequency of application for different crops and European climatic conditions, as both crop type and climate may influence this relationship. Of course,

research is also needed outside Europe, as socio-cultural, climatic, and crop-related variation will potentially influence pesticide exposure. An alternative strategy may be to reduce the frequency of application through adoption of alternative agricultural practices, such as integrated pest management and precision agriculture approaches, which might usefully represent a topic for future research.

Consumer perceptions of risks associated with consumption of pesticide residues on food has been reviewed elsewhere (*e.g.*, see Aertsens *et al.* 2009; Yiridoe *et al.* 2005). This issue has been excluded from the current review, which has focused only on collating information relevant to developing effective interventions aimed at promoting the protection of operators, workers, bystanders, and residents exposed to pesticide through their agricultural applications, but not through consumption of foods obtained within (for example) retail environments. Raymond *et al.* (2005) present a meta-analysis of the economic literature eliciting Willingness to Pay (WTP) values to hedge against negative effects of pesticides use on individual health and the environment. Other researchers have considered consumers' perceptions of risk associated with domestic pesticide use, such as in the garden (*e.g.*, see Schutz and Wiederman 1998; Templeton *et al.* 1998; Nieuwenhuijsen *et al.* 2005), and it is possible that perceptions of risk associated with different types of pesticide use are related to, or determine, each other. This may be particularly relevant in relation to resident and bystander perceptions and behaviours, and this may represent useful topic for future research.

The use of meta-analysis on risk perception data has previously allowed the “mapping” of changes with time, and between geographical regions (Frewer *et al.* 2013). This type of analysis would require identification of appropriate dependent variables in a range of studies that

could be aggregated in the process of meta-analysis. This, *a priori*, would require the implementation of “standard operating procedures” or comparable dependent variables across studies, which would limit the geographical range of the review as the numbers of studies would be much reduced. The adoption of comparable dependent variables in future research would facilitate formal meta-analysis and allow significance testing of differences in time and between different geographical regions (Ronteltap *et al.* 2011).

CONCLUSIONS

Research regarding the perceptions and attitudes of vulnerable populations is required to inform the development and implementation of effective risk communication strategies. In Europe, where there are few available data, this information is required by the EU Sustainable Use Directive. An international gap in knowledge relates to the perceptions and attitudes of residents and bystanders. The development of risk communication and training presents additional challenges given low educational attainment, low literacy rates, ethnic and cultural diversity, and language barriers for many agricultural workers in the developing world. Low rates of literacy among farmers are a particular concern in developing countries and amongst U.S. migrant workers, an issue potentially of greater concern for female workers. The association between risk perceptions and behaviours is not direct, as other factors (work, economic and peer group pressures, and cultural factors) may also influence the extent to which operators and workers and potentially residents and bystanders adopt self-protective behaviours.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge funding under the BROWSE FP7 project (Bystanders, Residents, Operators and WorkerS Exposure models for plant protection products. Seventh Framework Programme, Theme: Environment (including climate change) Project Number: 265307 www.browseproject.eu).

REFERENCES

- Aertsens J, Verbeke W, Mondelaers K, *et al.* 2009. Personal determinants of organic food consumption: A review. *Brit Food J* 111:1140-67
- Ahmed N, Englund JE, Åhman I, *et al.* 2011. Perception of pesticide use by farmers and neighbours in two periurban areas. *Sci Total Environ* 412-413:77-86
- Arcury TA, Quandt SA, and Russell GB. 2002. Pesticide safety among farmworkers: Perceived risk and perceived control as factors reflecting environmental justice. *Environ Health Persp* 110:233-40
- Atreya K. 2007. Pesticide use knowledge and practices: A gender differences in Nepal. *Environ Res* 104:305-11
- Austin C, Arcury TA, Quandt SA, *et al.* 2001. Training farmworkers about pesticide safety: Issues of control. *J Health Care Poor U* 12:236-49
- Barraza D, Jansen K, van Wendel de Joode B, *et al.* 2011. Pesticide use in banana and plantain production and risk perception among local actors in Talamanca, Costa Rica. *Environ Res* 111:708-17
- Bell EM, Sandler DP, and Alavanja MC. 2006. High pesticide exposure events among farmers and spouses enrolled in the Agricultural Health Study. *J Agric Saf Health* 12:101-16

- Blanco-Muñoz J and Lacasaña M. 2011. Practices in Pesticide handling and the use of personal protective equipment in Mexican agricultural workers. *J Agromedicine* 16:117-26
- Butler-Ellis C. 2012. Bystander and resident exposures to pesticides used in agriculture: Recent work to update the model used to assess exposure of the public in the UK. *Outlook Pest Manage* 23:7-12
- Cabrera NL and Leckie JO. 2009. Pesticide risk communication, risk perception, and self-protective behaviors among farmworkers in California's Salinas Valley. *Hispanic J Behav Sci* 31:258-72
- Cooper J and Dobson H. 2007. The benefits of pesticides to mankind and the environment. *Crop Prot* 26:1337-48
- Cuyno LCM, Norton GW, and Rola A. 2001. Economic analysis of environmental benefits of integrated pest management: A Philippine case study. *Agr Econ* 25:227-33
- Damalas CA and Eleftherohorinos EG. 2011. Pesticide Exposure, Safety Issues, and Risk Assessment Indicators. *Internat J Environ Res Public Health* 8:1402-19
- Damalas CA and Hashemi SM. 2010. Pesticide risk perception and use of personal protective equipment among young and old cotton growers in northern Greece. *Agrociencia* 44:363-71
- Damalas CA, Georgiou EB, and Theodorou MG. 2006. Pesticide use and safety practices among Greek tobacco farmers: A survey. *Internat J Environ Health Res* 16:339-48
- Dasgupta S, Meisner C, and Huq M. 2007. A pinch or a pint? Evidence of pesticide overuse in Bangladesh. *J Agr Econ* 58:91-114

- Devi PI. 2009. Health risk perceptions, Awareness and handling behaviour of pesticides by farm workers. *Agr Econ Res Review* 22:263-8
- EFSA (European Food Safety Authority). 2010. Scientific opinion on preparation of a guidance document on pesticide exposure assessment for workers, operators, bystanders and residents. *EFSA J* 8:1-65
- European Union Parliament and Council Directive 2009. 2009/128/EC of 21st Oct 2009 establishing a framework for community action to achieve the sustainable use of pesticides. *Official J EU*, L309/71, 24.11.09
- Fischhoff B. 1995. Risk perception and communication unplugged: Twenty years of process. *Risk Anal* 15:137-45
- Fischhoff B, Slovic P, Lichtenstein S, *et al.* 1978. How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Policy Sci* 9:127-52
- Flocks J, Kelley M, Economos J, *et al.* 2012. Female farmworkers' perceptions of pesticide exposure and pregnancy health. *J Immigr Minor Health* 14:626-32
- Foster V and Mourato S. 2000. Valuing the multiple impacts of pesticides use in the UK: A contingent ranking approach. *J Agri Econ* 51:1-21
- Frewer LJ, Fischer ARH, Brennan M, *et al.* Risk/benefit communication about food – a systematic review of the literature. *Crit Rev Food Sci* (*accepted*)
- Frewer LJ, van der Lans IA, Fischer ARH, *et al.* 2013. Public perceptions of agri-food applications of genetic modification – A systematic review and meta-analysis. *Trends Food Sci Tech* 30:142–52

- Galea KS, MacCalman L, Jones K, *et al.* 2011. Biological monitoring of pesticide exposures in residents living near agricultural land. BMC Public Health doi: 10.1186/1471-2458-11-856
- Gustafsson PE. 1998. Gender Differences in risk perception: Theoretical and methodological perspectives. Risk Anal 18:805-11
- Hashemi SM, Rostami R, Hashemi KM, *et al.* 2012. Pesticide Use and Risk Perceptions among Farmers in Southwest Iran. Hum Ecol Risk Assess 18:456-70
- Helweg-Larsen M and Shepperd JA. 2001. Do moderators of the optimistic bias affect personal or target risk estimates? A review of the literature. Pers Soc Psychol Rev 5:74-95
- Heong KL, Escalada MM, Sengsoulivang V, *et al.* 2002. Insect management beliefs and practices of rice farmers in Laos. Agr Ecosyst Environ 92:137-45
- Hinman GW, Rosa EA, Kleinhesselink RR, *et al.* 1993. Perceptions of nuclear and other risks in Japan and the United States. Risk Anal 13:449-55
- Ibitayo O. 2006. Egyptian farmers' attitudes and behaviors regarding agricultural pesticides: Implications for pesticide risk communication. Risk Anal 26:989-95
- Isin S and Yildirim I. 2007. Fruit-growers' perceptions on the harmful effects of pesticides and their reflection on practices: The case of Kemalpaşa, Turkey. Crop Prot 26:917-22
- Jensen HK, Konradsen F, Jørs E, *et al.* 2011. Pesticide Use and Self-Reported Symptoms of Acute Pesticide Poisoning among Aquatic Farmers in Phnom Penh, Cambodia. J Toxicol doi:10.1155/2011/639814
- Jors E, Morant RC, Aguilar GC, *et al.* 2006. Occupational pesticide intoxications among farmers in Bolivia: A cross-sectional study. Environ Health doi: 10.1186/1476-069X-5-10

- Karunamoorthi K, Mohammed A, and Jemal Z. 2011. Peasant association member's knowledge, attitudes, and practices towards safe use of pesticide management. *Am J Indust Med* 54:965-70
- Kimani VN and Mwanthi MA. 1995. Agrochemicals exposure and health implications in Githunguri Location, Kenya. *E Afr Med J* 72:531-5
- Klein CT and Helweg-Larsen M. 2002. Perceived control and the optimistic bias: A meta-analytic review. *Psychol Health* 17:437-46
- Koh D and Jeyaratnam J. 1996. Pesticides hazards in developing countries. *Sci Total Environ* 188:78-85
- London L, de Grosbois S, Wesseling C, *et al.* 2002. Pesticide usage and health consequences for women in developing countries: Out of sight out of mind? *Internat J Occ Environ Health* 1:46-59
- MacGregor DG and Fleming R. 1996. Risk perception and symptom reporting. *Risk Anal* 16:773-83
- Maroni M, Fanetti AC, and Metruccio F. 2006. Risk assessment and management of occupational exposure to pesticides in agriculture. *Med Lav* 97:430-7
- McCauley LA, Sticker D, Bryan C, *et al.* 2002. Pesticide knowledge and risk perception among adolescent Latino farmworkers. *J Agri Safety Health* 8:397-409
- Mokhele T. 2011. Potential health effects of pesticide use on farmworkers in Lesotho. *S Afr J Sci* 107 doi:10.4102/ sajs.v107i7/8.509
- Murphy HH, Sanusi A, Dilts R, *et al.* 1999. Health effects of pesticide use among Indonesian women farmers: Part I: Exposure and acute health effects. *J Agromedicine* 6:61-85

- Nieuwenhuijsen MJ, Grey CN, and Golding G. 2005. Exposure misclassification of household pesticides and risk perception and behaviour. *Ann Occup Hyg* 49:703-9
- Ntow WJ, Gijzen HJ, Kelderman P, *et al.* 2006. Farmer perceptions and pesticide use practices in vegetable production in Ghana. *Pest Manag Sci* 62:356-65
- Obopile M, Munthali DC, and Matilo B. 2008. Farmers' knowledge, perceptions and management of vegetable pests and diseases in Botswana. *Crop Prot* 27:1220-4
- Palis FG, Flor RJ, Warburton H, *et al.* 2006. Our farmers at risk: Behaviour and belief system in pesticide safety. *J Public Health* 28:43-8
- Parrott R, Wilson K, Buttram C, *et al.* 1999. Migrant farm workers' access to pesticide protection and information: Cultivando buenos habitos campaign development. *J Health Commun* 4:49-64
- Pimentel D. 1996. Pest management in agriculture. In: Pimentel D (ed), *Techniques for Reducing Pesticides: Environmental and Economic Benefits*. John Wiley & Sons, Chichester, England
- Pimentel D, Acquy H, Biltonen M, *et al.* 1992. Environmental and economic costs of pesticide use. *Bioscience* 42:750-60
- Pasiani JO, Torres P, Silva JR, *et al.* 2012. Knowledge, attitudes, practices and biomonitoring of farmers and residents exposed to pesticides in Brazil. *Internat J Environ Res Public Health* 9:3051-68
- Raymond J, Florax GM, Travisi CM, *et al.* 2005. A meta-analysis of the willingness to pay for reductions in pesticide risk exposure. *Eur Rev Agric Econ* 32:441-67

- Recena MCP, Caldas ED, Pires DX, *et al.* 2006. Pesticides exposure in Culturama, Brazil: Knowledge, attitudes, and practices. *Environ Res* 102:230-6
- Renn O and Rohrmann B. 2000. Cross-cultural risk perception: A survey of empirical studies, pp 240. Volume 13 of Technology, Risk, and Society Series. Kluwer Academic Publishers, The Netherlands
- Ronteltap A, Fischer AR, and Tobi H. 2011. Societal response to nanotechnology: Converging technologies—converging societal response research? *J Nanopart Res* 13:4399-410
- Salameh PR, Baldi I, Brochard P, *et al.* 2004. Pesticides in Lebanon: A knowledge, attitude, and practice study. *Environ Res* 94:1-6
- Salazar MK, Napolitano M, Scherer JA, *et al.* 2004. Hispanic adolescent farmworkers' perceptions associated with pesticide exposure. *Western J Nurs Res* 26:146-75
- Sam KG, Andrade HH, Pradhan L, *et al.* 2008. Effectiveness of an education program to promote pesticides safety among pesticides handlers of South India. *Internat Arch Occ Environ Health* 81:787–95
- Sandman PM, Miller PM, Johnson BB, *et al.* 2006. Agency communication, community outrage, and perception of risk: Three simulation experiments. *Risk Anal* 13:585-98
- Schütz H and Wiedemann PM. 1998. Judgements of personal and environmental risks of consumer products—Do they differ? *Risk Anal* 18:119-29
- Slovic P. 1987. Perception of risk. *Science* 236:280-5
- Stadlinger N, Mmochi AJ, Dobo S, *et al.* 2011. Pesticide use among smallholder rice farmers in Tanzania. *Environ Dev Sustain* 13:641-56

- Strong LL, Starks HE, Meischke H, *et al.* 2009. Perspectives of mothers in farmworker households on reducing the take-home pathway of pesticide exposure. *Health Educ Behav* 36:915-29
- Templeton SR, Zilberman D, and Yoo SJ. 1998. An economic perspective on outdoor residential pesticide use. *Environ Sci Technol* 32:416-23
- The Royal Commission on Environmental Pollution. 2005. Crop Spraying and the health of residents and bystanders .Available at http://webarchive.nationalarchives.gov.uk/20060214071948/http://www.rcep.org.uk/crop_spraying.htm
- Weinstein ND. 1982. Unrealistic optimism about susceptibility to health problems. *J Behav Med* 5:441-60
- Whitfield SC, Rosa EA, Dan A, *et al.* 2009. The future of nuclear power: Value orientations and risk perception. *Risk Anal* 29:425-37
- WHO (World Health Organization). 2003. The World Health Report 2003 – Shaping the Future. Geneva, Switzerland
- Yassin MM, Mourad ATA, and Safi JM. 2002. Knowledge, attitude, practice and toxicity symptoms associated with pesticide use among farm workers in the Gaza. *Occup Environ Med* 59:387-94
- Yiridoe EK, Bonti-Ankomah S, and Martin RC. 2005. Comparison of consumer perceptions and preference toward organic versus conventionally produced foods: A review and update of the literature. *Renew Agr Food Syst* 20:193-205

Zyoud SH, Sawalha AF, Sweileh WM, *et al.* 2010. Knowledge and practices of pesticide use among farm workers in the West Bank, Palestine: Safety implications. *Environ Health Prev Med* 15:252-61

Table 1: Summary of the studies included in the review

Reference	Countries /Regions	Sample Size	Stakeholder group	Methods used	Key findings
Ahmed et al. (2011)	Sweden	617	Residents and Farmers	Face to face interviews	Residents perceived pesticides more harmful for the environment and expressed more negative attitudes towards pesticide use compared to farmers. Women and older residents showed higher concerns about pesticides harmfulness. Education was not found to significantly influence risk perceptions.
Arcury et al. (2002)	North Carolina	293	Farmworkers	Face to face interviews	Most participants did not understand the language of risk communication materials. The majority reported having no personal control over reducing pesticide exposure. No relationship between farm-worker background characteristics and perceived risk/control. Increased access to pesticide safety information associated with higher perceived control scores and lower risk scores.
Atreya (2007)	Nepal	434	Farmworkers	Face to face interviews	Higher literacy rate for males. Pesticide knowledge and practice differed among genders. More women could not read and pesticide labels compared to men. Women reported greater perceived risks to own health and the environment. Gender-sensitive awareness and training programs required.
Austin et al. (2001)	North Carolina	270	Farmworkers	Face to face interviews	Participants reported lack of control over pesticide exposure in the workplace. Perceived lack of control is not attenuated with training

					or educational information. Inability to speak the same language was a barrier to training farm-workers. Very limited use of protective equipment. Absence of protective equipment and pressure at work resulted in low levels of self-protection.
Barraza et al. (2011)	Costa Rica		Farmers, NGOs industries, NGOs, farmers unions	Focus groups and Face to face interviews	Participants expressed little and diverse knowledge on pesticides exposure routes and chronic effects. Mothers perceived higher risks in particular for their children. Aerial spraying considered by most participants as the main source of exposure for residents.
Blanco-Munoz and Lacasana (2011)	Mexico	99	Operators and workers	Face to face interviews	Low rate of correct usage of personal protective equipment. Storage of pesticides at home was frequent implying an exposure risk for family members. The majority of participants regarded pesticide handling as hazardous to their health. Perceiving pesticides as risky not associated with the use of personal protective equipment. Pesticide risk positively correlated with educational level but not influenced by age or gender.
Cabrera and Leckie (2009)	California	50	Farmworkers	Face to face interviews	Most participants could not understand the language in which training materials were provided. 50% of participants had received no pesticide training. Participants reported high risk perception scores which were more elevated among women. Participants identified a range of long and short term health effects linked pesticides exposure. Most participants did not engage in self-protective behaviours.
Damalas and Hashemi (2010)	Greece	148	Farmers	Face to face interviews	Educational levels were higher among younger, compared to older, farmers. Older farmers perceived lower risks and higher benefits from pesticide use, and tended to be less risk averse than to young farmers.

					Young farmers showed more favourable attitudes towards IPM practices. Older farmers used personal protective equipment less frequently
Damalas et al. (2006)	Greece	223	Farmers	Face to face interviews	Almost all farmers thought that pesticides can have serious adverse effects on users' health. Despite high awareness rates, 46% of participants reported not using any special protective equipment when spraying pesticides. The reasons for not using protective equipment were that it is uncomfortable (68%), too expensive to buy (17%), time-consuming to use (8%), unavailable (6%) or unnecessary (2%).
Dasgupta et al. (2007)	Bangladesh	820	Farmers	Face to face interviews	Approximately 47% of the sample overused pesticides, which was positively correlated with the degree of misperception of risk by the farmer. 4% of farmers reported having received training on the use and handling of pesticides 87% admitted not taking any protective measures when using pesticides.
Devi (2009)	India	280	Pesticide applicators	Face to face interviews	Higher literacy levels reported compared to other studies. Almost all participants reported being unable to understand toxicity levels on pesticides labels Participants had not attended any training on pesticide use and care. Operators admitted not using protective equipment due to concerns about the cost and discomfort associated with their use. Most participants aware of the health risks and impacts of pesticides and could recall episodes of severe health damage after application.
Flocks et al. (2012)	Florida	35	Female Farm-workers	Focus groups	Female farm-workers aware of health hazards associated with pesticide exposure, in particular during pregnancy, and recollected incidents of illness to themselves and their children. Participants stressed the absence of protective equipment at work as the main barrier to adopting self-

					protective behaviours
Hashemi et al. (2012)	Iran	155	Farmers	Face to face interviews	Most farmers included not able to interpret the signs on the pesticide labels, discriminate the degree of pesticide toxicity or identify the exposure path for the operator. The majority admitted not using any special protective equipment when spraying pesticides. Few participants had received any special training in pesticide safety. Younger and less experienced farmers reported higher risk perceptions.
Heong et al. (2002)	Laos	600	Farmers	Face to face interviews	Farmers considered pests a significant problem that needed to be solved with pesticides. Farmers rated technicians as the most influential reference group Peer pressure was highly correlated with actual behaviour.
Ibitayo (2006)	Egypt	188	Farmers	Face to face interviews	Illiteracy rate was 55%. Almost no study participants wore protective equipment while mixing or applying pesticides. Knowledge about pesticides was limited. Almost all participants reported storing pesticides in their bedroom.
Isin and Yildirim (2007)	Turkey	61	Fruit growers	Face to face interviews	Most participants perceived pesticides harmful to human health. Younger, better educated participants, and those having less experience in fruit-growing, expressed higher risk perceptions. Farmers did not take sufficient precautions when using pesticides, used more than recommended, or did not use appropriate pesticides. Perceptions did not significantly influence the behaviour of farmers.
Karunamoorthi et al. (2011)	Ethiopia	291	Farmers	Face to face interviews	Most farmers had some knowledge about the adverse effects of pesticides on human health. Most farmers reported applying pesticides without the use of any protective clothing. 75% of farmers used empty pesticide containers for food storage or drinking.

					20% of famers applied pesticides in a hazardous manner.
Kimani and Mwabthi (1995)	Kenya	1797	Farmers	Face to face interviews	More than 97% of the participants reported year-long pesticide use. Limited farmer knowledge and awareness regarding handling and storage of agrochemicals. Storage of pesticides in bedrooms was widespread. High illiteracy rates/ difficulty understanding instructions and safety procedures on product labels
McCauly et al. (2002)	Oregon	102	Farmworkers	Face to face interviews	33% of the farm-workers were trained for pesticide safety. 50% stated that they used protective equipment while working with pesticides. 40% believed either that they had never been exposed to pesticides or that they had limited control in protecting themselves from pesticides. Knowledge about pesticide-related health effects was positively correlated with the adoption of safety practices.
Mokhele (2011)*	Lesotho	27	Farmworkers	Structured interviews	Lack of training and education increases health risks Labelling difficult to understand by poorly educated High risk perceptions about pesticides not translated into self-protective behaviours
Ntow et al. 2006	Ghana	137	Farmers	Face to face interviews, Field observations and game	The majority of farmers had only basic education A high level of pesticide use was evident Knowledge of pesticide selection, application rates and re-entry timing was poor. Farmers used very little personal protection during spraying although the majority had high risk perceptions regarding pesticide health hazards. Due to budget constraints farmers bought less expensive products, even if less suited to the pests they want to control
Palis et al. (2006)	Philippines	162	Farmers	Face to face interviews	25% of participants took no special precautions to protect themselves from pesticide exposure. Not taking precautions linked to the perception of being immune to negative effects Pesticides were perceived as

					a medicine for plants not a poison for pests Inhalation and not dermal absorption was regarded as hazardous by most participants Most participants saw no point in spending on protective equipment.
Parrott et al. (1999)	South Georgia	279	Farmworkers	Face to face interviews	Workers generally unaware of the risks associated with pesticides. Lack of protective equipment to purchase was the main reason for not taking precautions. Risk information was only available in the language of vulnerable workers.
Pasiani et al. (2012)	Brazil	112	Farmers	Face to face interviews	Low mean educational level. Most worker participants were aware of the risks associated with the use of pesticides and declared having received information about pesticides from government. The majority read the product labels with instructions and warnings. But, many did not take adequate protective measures.
Recena et al. (2006)	Brazil	250	Farmworkers	Face to face interviews	Low literacy level. Almost all the interviewees considered pesticides to be poisonous The use of personal protective equipment during pesticide application was infrequent.
Salameh et al. (2004)	Lebanon	89	Farmworkers, Pesticides distributors	Face to face interviews	Low levels of training regarding pesticides use among workers. Pesticide risk knowledge was substantially higher among pesticides distributors. Workers and distributors had better knowledge about pesticides than the general population. Long experience with pesticide application resulted in adoption of fewer prevention measures. Pesticide related education increased risk perceptions and i the likelihood of adopting risk mitigation measures.
Salazar et al. (2004)	Oregon	33	Farmworkers	Focus groups	Participants were aware of the risks associated with pesticide exposure. Workers perceived adverse health effects as an inevitable by-product of their work or thought that only the

					weaker workers were vulnerable to risks Limited precautions were taken. Participants referred to stress during work and inability to access protective equipment as the main reason for engaging in unsafe work practices.
Stadlinger et al. (2011)	Tanzania	106	Farmers	Face to face interviews	Low knowledge about the chemicals they used. More than 50% of farmers did not use any protective equipment during mixing or application Pesticides were often being mixed with bare hands. Safety instructions were often in English and could not be understood by the (illiterate) farmers,
Strong et al. (2009)	Washington State	37	Female Farm-workers or mothers in farm-worker households	In-depth Interviews	Women could describe the pesticide "take-home" pathway but were less able to connect it with their family's susceptibility to pesticide exposure. Women experienced difficulty integrating the prevention behaviors into their everyday lives because of competing responsibilities, conflicts with their husbands' intentions and with cultural health beliefs, perceived lack of control, and community barriers.
Yasin et al. (2002)	Gaza	189	Farmworkers	Face to face interviews	High levels of knowledge on the health impact of pesticides and routes of exposure. High mean educational level. Almost 60% of participants were negative about pesticides use. The majority believed that their body had developed resistance to pesticides The use of protective measures was poor.
Zyoud et al. (2010)	Palestine	388	Farmworkers	Face to face interviews	Prevalence of unsafe behaviours. Knowledge about health risks positively correlated with the adoption of safety practices.

*not identified in the original search but recommended for inclusion by the reviewer.

FIGURE CAPTION**FIGURE LEGEND**

Figure 1: Map of countries covered by the studies included in the review.

Note: Each red dot corresponds to a different study.