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Pesticide handling practices by vegetable farmer in Kenya

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Abstract Pesticide handling practices have a strong bearing on the exposure of toxic effects to target and nontarget organism. A clear understanding of determinants of pesticide handling practices is a precondition in the design and implementation of policy intervention. To accomplish this, a household survey of 425 respondents was conducted in 2008. Majority of the farmers (85 %) had inappropriately handled pesticides, mainly through, unsafe storage (23 %), unsafe disposal of leftover in either sprays solutions, or rinsate and empty pesticide containers (40 %), failure to wear the required minimum protective gear (68 %), or overdosed pesticides (27 %). However, majority of those farmers were aware of the risks of pesticide use, with over 81 % expressing the view that pesticides have harmful effects on human health, livestock, beneficial arthropods, and on water. Econometric models showed that pesticide handling practices were significantly influenced by variation in record keeping, main source advice on pesticide use, toxicity of pesticide, and geographical location. Pesticide risk perception and negative impacts experiences had no association with handling practices. The study recommends policy-makers to design effective, participatory, and location targeted outreach programmes, which deal specifically on promotion of record keeping and reduction in use of harmful pesticides.

Keywords Pesticides · Agriculture · Kenya · Handling practices · Risks perception · Farmers

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1 Introduction

Farmers use a wide range of pesticides to prevent crop losses from pest attacks. The ideal situation for pesticides is that it reaches the target organism and, having achieved its intended effect, decomposes rapidly into harmless compounds. However, this is not always the case as most of the pesticides are accompanied by negative side effects. These side effects include impairment of human and animal health, surface and ground water contamination, pest resistance and resurgences, reduction in natural enemy populations, damage to fisheries, fauna, and flora.

In Kenya, some research findings have indicated existence of pesticide-related negative effects, for example, pesticides threatening Lake Naivasha local hippopotamus populations (IUCN 2005) and farmers' health impairment (Ohayo-Mitoko et al. 2000; Okello 2005; Asfaw 2008). Many of these impacts are a direct result of the inappropriate handling of pesticides, often due to deviation from recommended application and handling procedures.

Unsafe handling of pesticides usually due to negligence, lack of information, or lack of training can pose a serious health risk for farmers who are the major pesticide users and are regularly exposed to pesticides (Reeves and Schafer 2003). Several dimensions of unsafe practices in the handling of pesticides include the following: Farmers may apply higher than recommended dosage, store pesticides unsafely, dispose pesticides left over and containers unsafely, or fail to wear the required personal protective equipment (PPE). Extremely unsafe practices include mixing pesticide with bare hands, splashing pesticides onto crops using brushes or twigs and tongue testing to assess concentration strength of the chemical (Dinham 2003). This consequently increases the chances of pesticide side effects on the farmer and the environment as a whole.

Safe handling of pesticides is considered a pivotal aspect in the reduction of health and environmental hazards of pesticides (Keifer 2000). A study conducted by Mancini et al. (2005) demonstrated that handling pesticides unsafely during spraying enhanced health risks of farmers.

Production of vegetables in Kenya is mainly carried out by small-scale farmers targeting local market (Mithöfer et al. 2008; HCDA 2010). The produce is marketed through the informal sector, that is, open markets and kiosks, and currently, only 5 % are sold through supermarkets (Tschirley et al. 2004). Kenya also exports green beans, peas, and Asian vegetables to the European Union (EU) and the Middle East market (Harris et al. 2001). Smallholders are estimated to account for 27 % of exported vegetables (Jaffee 2003).

Insect pests and diseases generally limit production of vegetables. The majority of smallholder vegetable farmers rely heavily on spraying pesticides to reduce the damage caused by pests and diseases. Currently, relatively little is known about pesticide handling practices in Kenya. A clear understanding of how vegetable farmers are handling pesticides and the factors that influence those practices were deemed necessary for the design and implementation of any policy intervention. Thus, the main objective of this study was to identify the determinants for pesticide handling practices and develop recommendations that can reduce the health and environmental hazards associated with those practices. The study offers an opportunity for policy makers to understand the underlying factors related to pesticide handling such that they can target capacity-building efforts in those areas.

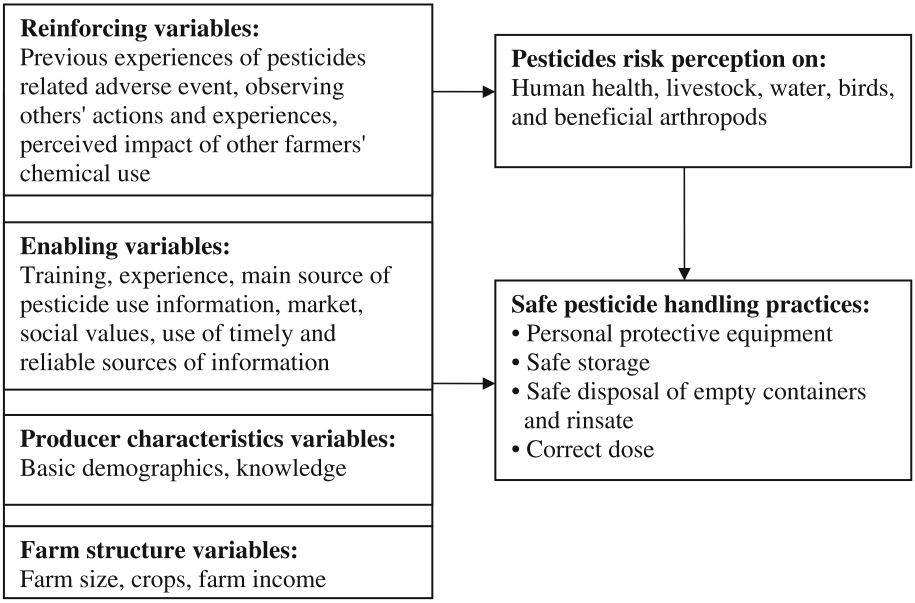

Fig. 1 Factors associated with risk perception and pesticide handling practices. *Source*: Own presentation

2 Materials and methods

2.1 Conceptual framework

The conceptual framework for the analysis of factors associated with farmers' pesticide risk perception and the determinants of their pesticide handling practices is presented in Fig. 1. This framework is a combination of two existing analytical tools: the farm structure theory developed for agricultural studies (Tucker and Napier 2001) and the psychometric paradigm framework used in risk perception research (Slovic 2000). These tools incorporated farm-specific factors such as farm size and crops; individual features such as age, gender, knowledge, training; and psychometric factors such as risk perception and who are trusted sources for providing pesticide risk information. Within the psychometric paradigm, people make quantitative judgments about the current and desired riskiness of diverse hazards and the desired level of regulation of each. It is thus hypothesized that farmer risk perception is influenced by socioeconomic and demographic factors, and in turn drives farmer's decisions on how to handle pesticides among the other factors.

2.2 Surveys and data

This paper uses cross-sectional data collected through a survey carried out in seven major vegetable producing districts of Central province (Kiambu, Kirinyaga, Murang'a, Nyandarua and Nyeri North) and Eastern province (Makueni and Meru Central) of Kenya in 2008.

The sample was a random subsample[1] of 425 farmers, sampled by probability proportional to size (PPS) from two previous surveys conducted in 2005 by the International Centre of

[1] Follow up survey but due to resource constraints the sample was reduced.

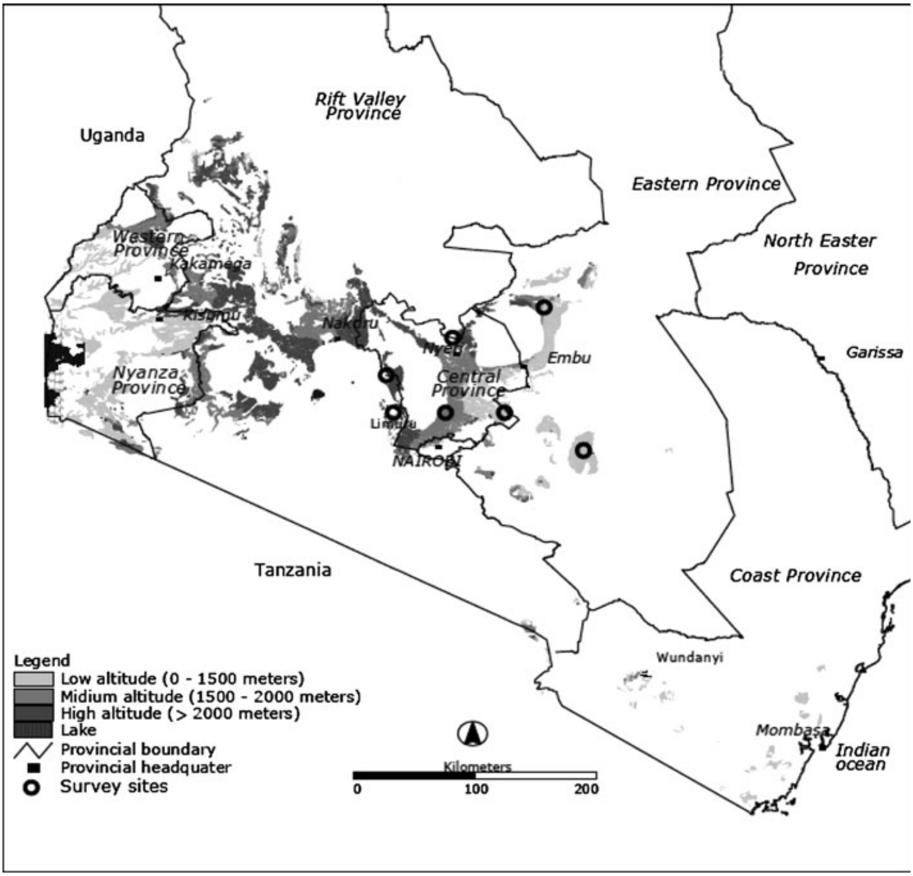

Fig. 2 Study sites. *Source*: Own presentation based on GIS mapping of potential vegetable production areas

Insect Physiology and Ecology (ICIPE), that is, the Diamondback moth biological control impact assessment survey ('DBM' with 295 farmers) and the Global Good Agricultural Practices ('GLOBALGAP' with 544 farmers) assessment survey. GLOBALGAP (formerly known as EUREPGAP) is a private sector body that sets voluntary standards for the certification of agricultural products around the globe. The aim is to establish one standard for good agricultural practice (GAP) by translating consumer requirements into agricultural production.

In both surveys, a multistage sampling procedure was employed to select districts, sub-locations, and farmers. First, districts were purposely sampled according to intensity of vegetable production and agroecological zone. Figure 2 shows the study sites.

Lists of farmers that were compiled by extension workers at the sub-location level, served as a sampling frame from which the farmers were randomly sampled using the PPS procedure. Table 1 displays the distribution of farmers in the sampled districts.

Structured questionnaires were used to collect information on pesticide use and practices, risk perceptions, knowledge and experiences of pesticide negative impacts (health effects, intoxication of livestock, mortality of beneficial arthropods and birds). For all the pesticide-related impacts listed above, only the effects observed during the spraying operation or within 24 h after spraying were considered. In addition, the number of empty pesticide container lying around the farm was also assessed and counted to further confirm and ascertain farmers'

Table 1 Regional distribution of survey respondents

Province	District	Main vegetable crops		Previous surveys (2005)	No. of farmers sampled (2008)
		Domestic	Export		
Central	Kiambu	Cabbages, kales, spinach		48	27
	Kirinyaga	Peas, tomatoes	French beans	155	74
	Muranga	Tomatoes, kales	French beans	51	24
	Nyandarua	Cabbages, potatoes		119	52
	Nyeri North	Peas, cabbage, onions, carrots	French beans	277	116
Eastern	Makueni	Cabbages, kales	Asian vegetables[a]	49	22
	Meru Central	Peas, tomatoes, cabbage, onions	French beans	140	110

Source: Own presentation

[a] Brinjals, karella, dudhi, okra, turia, valore and aubergine

pesticide containers disposal methods. To test farmers' recognition of the natural enemies and soil biota known to them, a self-made arthropods zoo (clear plastic jar containing the most common—natural enemies: ladybird beetles, praying mantis, spiders, dragonflies, fire ants and soil biota: earthworms, millipedes, and crickets) was shown to them. Respondents were also asked to show samples of pesticide containers or labels they had used to facilitate the accurate recording of the names of pesticide products applied.

Ten pictograms used on pesticide labels in Kenya for instructions on appropriate pesticide use were also shown to farmers in order to assess farmers' understanding of them and their link with actual pesticide handling practices. Interviewers were instructed to record all responses in the exact words of the farmer, which were later compared with the correct instruction and scored 1 if it was right or zero when it was wrong. To measure farmer risk perception of the harmful effects of pesticides on human health and the environment, five questions were asked. 'In your opinion, what is the effect of pesticide used in vegetable production on (1) human health (2) livestock (3) beneficial arthropods (bees, natural enemies, soil biota), (4) water, frogs and fish (5) birds?' Farmers could choose one from the following answers: (1) beneficial (2) somewhat beneficial (3) no effect (4) somewhat harmful (5) harmful, and (6) do not know.

2.3 Model

To model determinants of the degree of pesticide risk perceptions and pesticide handling practices, we used a count data model (Poisson regression). Poisson regression model is commonly applied in the analysis of count data (Wooldridge 2006). The count of risk perceptions or the counts of handling practices y_i were assumed Poisson distributed and can be expressed as:

$$\mathrm{prob}(Y_i = \lambda_i) = \lfloor e^{-\lambda i} \lambda_i^{yi} \rfloor / y_i! \tag{1}$$

where $y_i = 0, 1, 2\ldots.$

The expected parameter λ_i is assumed both the mean and the variance of the count data (y_i). This property is called equi-dispersion. The distribution is extended to obtain a regression model by allowing each observation y_i to have a different value of λ. The popular formulation is an exponential relationship between the expectation rate and a set of regressors, expressed as:

$$E[y_i|x_i] = \text{var}[y_i|x_i] = \lambda_i = \exp(\beta' x_i + \mu_i) \tag{2}$$

where x_i is the vector of regressors, β is the vector of estimated parameters, which captures the effect of the regressors on the dependent variables (i.e., pesticide risk perceptions and pesticide handling practices), and μ is the error term.

We used maximum likelihood estimation procedure for the estimation of the parameters β and μ in Stata Version 10 statistical package. For the empirical model, we began by specifying the risk perception equation as Eq. 3 below and handling practices as the fourth equation.

To simplify counts of the farmer risk perception on human health, livestock, water, birds, and beneficial arthropods, responses with the following: (1) beneficial (2) somewhat beneficial, and (3) no effect were grouped together and coded as 0 and were referred to as pesticide are 'harmless' whereas responses with (4) somewhat harmful and (5) harmful were grouped and coded as 1 and referred as 'harmful'.

Theoretically, farmers' pesticide risk perception (PERCEPTION) can be shaped by a variety of independent factors, including the potential health implications, formal education, and experience[2] (Warburton et al. 1995). The perception equation considered these factors along with the gender, main source of pesticide use information, being the primary pesticides applicator, target markets, toxicity levels of pesticide handled, and location. Variable definitions and summary statistics are shown in Table 2.

$$\text{PERCEPTION} = f\begin{pmatrix} \text{IMPACT, EDUCATION, EXPERIENCE, EXPERIENCESQ, GENDER,} \\ \text{GLOBALGAP, APPLICATOR, RECORD, EXTENS, FARMER, RADIO,} \\ \text{TRADER, EXPORT, LOCAL, NPEST, PWHOIab, PWHOII, PWHOIII,} \\ \text{PWHOU, District Dummies} \end{pmatrix} \tag{3}$$

The pesticide handling practices (HANDLING) was constructed as a count of each of the responses for overdose, unsafe storage of pesticides, unsafe disposal of pesticides rinsates and containers, and failure to wear of the minimum PPE (long-sleeved shirt, long trousers or overalls, gloves, and gumboot). Each was coded as 1 and referred to as inappropriate handling practices and 0 otherwise. The equation was then specified as a function of farmer's pesticide risk perception, gender, level of education, experience in agricultural production, farm size, main source of pesticide use information, target markets, toxicity levels of pesticide handled, being the primary pesticide applicator, and location.

$$\text{HANDLING} = f\begin{pmatrix} \text{PERCEPTION, IMPACT, EDUCATION, EXPERIENCE, EXPERIENCESQ,} \\ \text{GENDER, GLOBALGAP, APPLICATOR, RECORD, FARMSIZE,} \\ \text{EXTENS, FARMER, RADIO, TRADER, EXPORT, LOCAL, NPEST,} \\ \text{PWHOIab, PWHOII, PWHOIII, PWHOU, District Dummies} \end{pmatrix} \tag{4}$$

All variables were cross-checked for problem of multicollinearity, through the simple correlation matrix between all the variables and the highest correlation coefficient was

[2] Experience squared (EXPERIENCESQ) was added in the equation as there exist a concave relationship between experience and returns to experience (Mincer 1974). Applied in our case it means that the more experienced the farmers are, they may be expected to perceive pesticide to be risky and handle them safely. However, this expectation may decline after a certain point due to depreciation effects of human capital.

Table 2 Definition and summary statistics of variables used in empirical estimations

Variable	Definition	Mean[a]
Dependent variables		
PERCEPTION	Farmer perceive pesticides to be harmful to human health, livestock, water and fish, beneficial arthropods and birds (count)	4.00 (1.23)
HANDLING	Farmer overdose pesticides, unsafely stored pesticides, unsafely disposed of pesticides containers and failed to wear the minimum PPE (count)	1.57 (0.98)
Reinforcing independent variables		
IMPACT	Farmer experienced/witnessed a pesticide associated human health impairment, livestock poisoning, mortality of beneficial arthropods and birds (count)	2.16 (1.72)
Farmer characteristics independent variables		
EDUCATION	None (%)	1.6
	Primary school (%)	47.8
	Secondary school (%)	39.5
	College (%)	10.8
GENDER	1, if farmer is a male; 0, otherwise	0.70 (0.45)
Enabling independent variables		
EXPERIENCE	Farming experience in agriculture production (years)	20.85 (12.03)
EXPERIENCESQ	Farming experience in agriculture production (years squared)	579.30 (634.73)
GLOBALGAP	1, if farmer has ever been GLOBALGAP certified (proxy for pesticide use training); 0, otherwise	0.21 (0.40)
APPLICATOR	1, if the farmer is the primary pesticides applicator; 0, otherwise	0.86 (0.35)
EXTENS	1, if extension officers are the main source of advice on pesticide use; 0, otherwise	0.23 (0.42)
FELLOW	1, if other farmers are the main source of advice on the pesticide use; 0, otherwise	0.05 (0.21)
LABEL	1, if label is the main source of information on the pesticide use; 0, otherwise (base in estimation)	0.20 (0.40)
RADIO	1, if radio is the main source of information on the pesticide use; 0, otherwise	0.29 (0.45)
TRADER	1, if pesticide traders including agro-vets are the main source of advice on the pesticide use; 0, otherwise	0.23 (0.22)
BOTH	1, if farmer producing for domestic as well as export market; 0, otherwise (base in estimation)	0.46 (0.50)
EXPORT	1, if farmer produce exclusively for the export market; 0, otherwise	0.04 (0.19)
LOCAL	1, if farmer produce exclusively for the local market; 0, otherwise	0.50 (0.50)
Farm management and other independent variables		
RECORD	1, if the farmer keep records of the pesticide use activities; 0, otherwise	0.31 (0.46)
FARMSIZE	Total farm size (hectares)	1.01 (0.96)
NPEST	Number of pesticide products farmer handled (count)	4.06 (2.40)
PWHOIab	Amount of pesticides applied and classified as WHO Ia or Ib (extremely or highly hazardous) (g)	32.96 (227.77)

Table 2 continued

Variable	Definition	Mean[a]
PWHOII	Amount of pesticides applied and classified as WHO II (moderately hazardous) (g)	654.20 (1,244.38)
PWHOIII	Amount of pesticides applied and classified as WHO III (slightly hazardous) (g)	177.96 (495.60)
PWHOU	Amount of pesticides applied and classified as WHO U (unlikely to present any acute hazard use) (g)	301.44 (772.83)
KIAMBU	1, if the farmer is located in Kiambu; 0, otherwise	0.06 (0.24)
KIRINYAGA	1, if the farmer is located in Kirinyaga; 0, otherwise	0.18 (0.02)
MAKUENI	1, if the farmer is located in Makueni; 0, otherwise	0.05 (0.22)
MERU CENTRAL	1, if the farmer is located in Meru Central; 0, otherwise	0.26 (0.44)
MURANGA	1, if the farmer is located in Muranga; 0, otherwise (base in estimation)	0.06 (0.23)
NYANDARUA	1, if the farmer is located in Nyandarua; 0, otherwise	0.12 (0.33)
NYERI NORTH	1, if the farmer is located in Nyeri North; 0, otherwise	0.27 (0.45)

Source: Own survey

[a] Figures in parenthesis are standard deviations

0.38. Likewise, for endogeneity, none of the independent variables was suspected to be explained within the equation in which it appeared. To check the robustness of the model, we also fitted a negative binomial regression model, which is preferred when there is over-dispersion (Long and Freese 2003). The likelihood ratio test and the statistical evidence did not indicate over-dispersion.[3] In addition, to check the robustness of all the models, other restricted models were estimated in which subsequently insignificant variables were dropped. The statistical quality of the models and the direction of the signs did not change, and the coefficients deviated only marginally.

3 Results and discussion

3.1 Descriptive statistics

3.1.1 Farmer and vegetable production characteristics

The average age was calculated to be 46 years with nearly 23 % of the sample being under the age of 35 and 29 % older than 50 years. Most farmers were literate, and only 2 % of the farmers had not attended any formal school. Almost, half (47 %) of the farmers had received formal primary education, whereas about 40 % had received secondary education, and about 11 % had earned at least a diploma. The female farmers were approximately 30 %, and the average years of experience in agricultural activities by all the farmers were 21 years. Vegetable plot sizes varied between 0.02 ha to 10.1 ha with a median of 0.30 ha per farmer. Farms varied in size from 0.02-18 ha and comprised five general cropping

[3] Over-dispersion normally occurs when the mean < variance.

Table 3 Pictograms presented to farmers and level of understanding i.e. knowledge and their practices (%)

Pictogram	Meaning	Know	Practice		p value[a]
			Yes	No	
	Keep in a safe place out of reach of children	Yes	47	13	0.41
		No	29	10	
	Protect your feet/wear gumboots boots	Yes	80	12	0.35
		No	8	0	
	Wear protective clothing/apron	Yes	59	24	0.34
		No	10	6	
	Wear gloves	Yes	32	61	0.56
		No	2	5	
	Harmful to farm animals[b]	Yes	3	49	0.38
		No	1	42	
	Harmful to aquatic animals like fish[c]	Yes	33	18	0.25
		No	28	22	
	Wash hand after use	Yes	80	0	–
		No	20	0	
	Cover your face/use a face shield	Yes	32	50	0.43
		No	8	10	

Source: Own survey

[a] From Fisher's exact test

[b] Practice: do not feed livestock with freshly sprayed vegetable residue

[c] Practice: do not dispose of leftover spray solutions, rinsates or empty pesticide containers into pond, rivers or dams

systems, that is, cereals, legumes, fruit crops, fodder crops for dairy, and intensive vegetable plots, with a median of 0.80 ha.

3.1.2 Pesticides use

Farmers used 66 pesticide products comprising of 44 active ingredients. These included insecticides (52 %), fungicides (42 %) herbicides (5 %) and 1 % acaricides. The commonly used products included dimethoate (WHO II), used by 48 % of farmers, lambda cyhalothrin (WHO II—27 %), cymoxanil (WHO II—22 %) cypermethrin (WHO II—22 %), cyfluthrin (WHO Ib—20 %), mancozeb (WHO U—18 %), and deltamethrin (WHO II—14 %). The total amount of pesticides used was estimated at 570 metric tonnes for the whole year (Macharia et al. (2009) estimation method). Forty-one percent of the volumes belong to the group of carbamates, 19 % to pyrethroids, 16 % to organophosphates, 13 % to acetamides, and 5 % to inorganics.

According to World Health Organization (WHO 2009) risk classification, 7 % of the pesticide pesticides commonly used are extremely hazardous (WHO Ia and WHO Ib e.g., Methomyl (Lannate 90SP, Agrinate 90SP, Methomex 90) and Dichlorvos (Phosvit)) and 36 % moderately hazardous (WHO II e.g., dimethoate, cyhalothrin, cypermethrin). Approximately 61 % are indicated by Pesticides Action Network North America (PAN) to be bad actor chemicals.[4] Comparing the products to the Environmental Impact Quotient[5] (EIQ) following Mazlan and Mumford (2005) classification showed that 11 % were rated as low (EIQ = 0–20), 61 % as medium (EIQ = 21–40) and 27 % as high (EIQ $\geq$ 41).

3.1.3 Knowledge and handling practices

Table 3 summarizes the farmers' knowledge of the safety measures pictograms normally found on pesticide labels on the Kenyan market and how they responded to them (practiced). Though the majority (63 %) of farmers stated that they read and understand pesticide labels, a sizeable percentage (65 %) did not know the correct meaning of all the main and simple pictograms used in pesticide labeling with only 4 farmers adhering to all.

A sizeable proportion (23 %) stored the pesticides unsafely in places such as in the kitchen, bedrooms, and farm store together with farm produce and other equipment without any safety precaution. Approximately 32 % reported wearing the required minimum protective gear. By cross-observation a clear under use of PPE, particularly the use of gloves was revealed. Only 1 out of 7 farmers was seen in gloves during spraying, strengthening the validity of farmers' responses. Low use of PPE has also reported among farmers in other countries like in Ethiopia and the United States (Carpenter et al. 2002; Mekonnen and Agonafir 2002). In most cases, use of PPE was very low despite the availability of PPE and farmer awareness of the potential impact of pesticides on their health. The farmers disposed empty pesticide containers within the farm by burying or throwing into the latrine (56 %), disposal pit (28 %), dumping by the field (13 %), or washed and reused (2 %). By cross-checking, an average of 2 pesticide containers was observed lying either in or near the vegetable field, water ponds, and near homestead of 33, 2, and 13 % of the sample farmers, respectively. Hurtig et al. (2003) Ntow et al. (2006) and Recena et al. (2006) reported similar unsafe disposal methods of empty pesticide containers. The majority of the farmers also indicated that they continuously sprayed the leftover pesticide solutions on the same crop the same day (60 %), 12 % emptied the leftover spray solutions nearby wells or ponds. Equipments used to apply the pesticides were washed with a water hose near the homestead (44 %) or in the field using water from ponds, streams or from the wells with 17 % releasing the rinsates into pond or stream.

The majority of the farmers (91 %) stated that they followed the label instructions when determining the application rates. However, the comparison between the farmers' application rates to the existing recommended rates, (i.e., the application rates indicated on pesticide labels, which were also cross-referenced with those conventionally put in

[4] Chemicals that are highly acutely toxic, cholinesterase inhibitor, known/probable carcinogen, known groundwater pollutant or known reproductive or developmental toxicant.

[5] The EIQ calculation developed by Kovach et al. (1992) uses active ingredients of pesticides and applies a rating system in ten categories to identify a single value of the environmental impact rating. The ten categories include: (1) action mode of pesticides, (2) acute toxicity to birds, (3) fish, (4) bees, (5) acute dermal toxicity, (6) long term health effects, (7) residue half-life in soil and (8) plant surface, (9) toxicity to beneficial organisms, and (10) groundwater and runoff potential.

Table 4 Farmers experience and perception of harmful effects of pesticides (%), 2008

Category	Impact		Perception		
	Experienced	Witnessed from neighbors	Harm-less	Harmful	Don't know
Human health	35	50	5	93	2
Livestock	12	30	8	85	7
Beneficial arthropods	54	57	25	70	4
Water, frogs and fish[a]	–	–	10	80	10
Birds	6	9	14	74	12
Average	27	37	12	81	7

Source: Own survey

[a] It was difficult for farmers to associated pesticide use with fish mortality or notice contamination of water by pesticides apart from the smell, which is subjective

company catalogs), showed that only three farmers actually sprayed the recommended rates[6] for all the pesticide sprayed. Even allowing an error of 25 % for the total number of pesticides sprayed did not change the number of farmer. Approximately 27 % of the farmers had overdosed pesticides with an average overuse rate of 0.42 kg/application. However, only 10 % overdosed pesticides on the export crops as compared to 17 % on the domestic crops. Overdose results in financial losses because of waste of pesticides, and decreased yields due to phytotoxicity (Asogwa and Dongo 2009). However, the biggest risk of overdose is the increased likelihood for the development of resistance against pesticides, which can have devastating large-scale effects on crop production (Meijden 1998). It also increases the chances of pest resurgence due to destruction of natural control organisms (Meijden 1998).

Many farmers recognized the major natural enemies' found in the vegetable crops with over 90 % identifying 3 out of the 4 insects that they were asked to identify (ladybird beetles 90 %, spiders 99 %, fire ants 99 %), while only 66 % clearly identified dragonflies. However, they were uncertain of their role.

3.1.4 Experience and perception of pesticide negative impacts

Over 35 % of the farmers reported at least one of a variety of acute illness symptoms of pesticide poisoning within 24 h after spraying pesticides, with half indicating that they witnessed a fellow farmer intoxicated by pesticides (Table 4). The most common symptoms reported were sneezing, headache, stomach pains, dizziness, burning skin/rash, eye irritation, shortness of breath, backache, vomiting, blurred vision, and coughing in the order of most frequently reported. These symptoms are associated with pesticide acute poisoning (Extension Toxicology Network 2004). In addition, a sizable number had also observed/witnessed livestock poisoning, mortality of beneficial arthropods, and birds during or 24 h after spraying pesticides, and all attributed to the pesticide sprayed. Many (81 %) farmers also regarded pesticides as harmful for their health and environment.

[6] The amount the farmer exceeded from recommended dose indicated on the label of the pesticide container for each of the individual pesticides was first calculated. If the farmer used more than the recommended dose, over-dose was coded as 1 and if it was less than the recommended dose under-dose likewise coded 1. This calculation was performed for all the pesticide products used in each application, then summed across each farmer.

Table 5 Estimation results of farmer risk perception and pesticide handling model, 2008

	Risk perception		Pesticide handling	
	Coefficient[a]		Coefficient[a]	
	Unrestricted	Restricted	Unrestricted	Restricted
IMPACT	0.01 (0.01)		0.03 (0.02)	
PERCEPTION			0.01 (0.03)	
EDUCATION	0.00 (0.02)		−0.05 (0.04)	
EXPERIENCE	0.01 (0.00)		0.01 (0.01)	
EXPERIENCESQ	−0.00 (0.00)		−0.00 (0.00)	
GENDER	0.06 (0.03)*	0.06 (0.03)*	0.05 (0.07)	
GLOBALGAP	0.13 (0.04)***	0.13 (0.04)***	−0.04 (0.09)	
APPLICATOR	−0.09 (0.04)**	−0.09 (0.04)***	−0.04 (0.08)	
RECORD	0.02 (0.03)		−0.17 (0.07)**	−0.18 (0.07)**
FARMSIZE			−0.00 (0.03)	
EXTENS	0.06 (0.04)		0.03 (0.11)	
FARMER	0.14 (0.06)**	0.13 (0.05)***	0.07 (0.14)	
RADIO	0.04 (0.04)		0.05 (0.09)	
TRADER	−0.06 (0.05)		0.15 (0.09)*	0.09 (0.06)*
EXPORT	−0.21 (0.09)**	−0.26 (0.08)***	−0.11 (0.15)	
LOCAL	0.08 (0.03)**	0.08 (0.03)***	−0.01 (0.07)	
NPEST	0.02 (0.01)***	0.02 (0.01)***	0.02 (0.01)*	0.02 (0.01)*
PWHOIab	0.00 (0.00)		0.00 (0.00)	
PWHOII	−0.00 (0.00)		0.00 (0.00)***,[c]	0.00 (0.00)***
PWHOIII	0.00 (0.00)		−0.00 (0.00)	
PWHOU	−0.00 (0.00)**,[b]	−0.00 (0.00)**	−0.00 (0.00)	
KIAMBU	−0.41 (0.11)***	−0.36 (0.08)***	−0.32 (0.22)	
KIRINYAGA	−0.21 (0.09)**	−0.19 (0.04)**	0.40 (0.13)***	0.34 (0.06)***
MAKUENI	0.05 (0.09)		0.32 (0.16)**	0.22 (0.11)**
MERU CENTRAL	−0.09 (0.09)		−0.29 (0.15)***	−0.34 (0.09)***
NYANDARUA	0.01 (0.09)		0.10 (0.15)	
NYERI NORTH	−0.02 (0.08)		−0.00 (0.14)	
Constant	1.23 (0.11)***	1.31 (0.05)***	0.22 (0.23)	0.36 (0.06)***
Observations	411	416	411	415
Log likelihood	−729.92	−743.51	−567.46	−577.99
Wald χ^2	142.34***	110.37***	108.12***	80.55***

Source: Own survey

[a] Figures in parenthesis are robust standard errors, statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

[b] z value = −1.89 and [c] z value = 2.61

3.2 Models estimation results

The results of the two models are presented in Table 5. Starting with the risk perception model (Column 2, unrestricted), the results indicate that the probability of risk perception significantly increases with male farmers, GLOBALGAP certification, fellow farmers as the main sources of advice on pesticide use, production of vegetable geared exclusively for domestic market as well as the number of pesticides handled. Farmers as the primary pesticides applicator, growing vegetables targeting export markets, handling pesticide in WHO U, and being located in the districts of Kirinyaga and Kiambu reduces the probability of pesticide risks perception. Neither experience/witness of pesticide-related negative impact[7] nor education had any significant effect on risk perceptions. The restricted model reestimated by dropping insignificant variables, shows the estimates of the coefficients, and their directions were robust.

The second equation for the pesticide handling model in Table 5 (column 3, unrestricted) clearly shows that the probability of inappropriate handling of pesticides is lower with record keeping and being in the district of Meru Central. In general, record keeping of pesticide products handled, their application dosage, application techniques, and production activities enables a farmer to increase profits through better pesticide use planning. With records, a farmer can also see how well she/he is managing production operations and can identify the strengths and weaknesses in those activities. The positive significant coefficient on pesticide traders as the main sources of advice on pesticide use, numbers of pesticides handled, and handling of pesticides in WHO II, suggests a probability of inappropriate handling of pesticides association. In the Philippines, increased pesticide misuse was found to be strongly associated with visits by chemical company representatives or by agricultural technicians (Tjornhom et al. 1997). Furthermore, pesticides dealers particularly the companies have an incentive to push pesticides use by advertising and promotion, and this creates a bias in favor of their use (Tisdell et al. 1984).

Analysis further shows that farmer located in the districts of Kirinyaga and Makueni have higher probability of inappropriate handling of pesticides. Contrary to theoretical expectations, pesticide risk perceptions and previous experience/witness of a negative pesticide impact had no significant influence on pesticide handling practices.[8] Kishi et al. (1995) reported that farmers take pesticides poisoning symptoms as normal effects so they get used to them. Similarly, the study in Côte d'Ivoire by Ajayi (2000) also showed that pesticide applicators tended to accept a certain level of illness as an expected and normal part of farming. This could be the reason why farmers did not handle pesticide safely even after experiencing a negative impact. In addition, most farmers do not keep records of their pesticides related losses, as they do not appreciate its importance. Furthermore, the lack of diagnosis attributed to pesticide exposure make farmers also to ignore the dangers of pesticide use as the long-term effect is not easy to prove (Pimentel and Greiner 1997).

Similar findings on lack of association between handling practices and risk perceptions were reported in studies that showed that knowledge of the pesticide negative effects was not directly reflected on the use of PPE (Martinez et al. 2004) or did not influence or change farmers crop production practices (Ecobichon 2001). Tucker and Napier (2001) also found that although some Midwestern US farmers were aware of potential negative effects of pesticides use, they still relied heavily on chemical control.

Though the coefficients of farmer as the primary applicator, farm size, and GLOBALGAP certification are insignificance, they had the expected negative sign. Close check

[7] In an alternative model specification, with set of dummies for impacts on health, livestock, beneficial arthropods, and birds yielded no statistical significance.

[8] Even after controlling for specific impact and risk perceptions, i.e. on health, livestock, beneficial arthropods, and birds no statistical significance was found.

on GLOBALGAP certification showed that many of the farmers (69 %)[9] who were earlier certified did not maintain their certification at the time of survey. Probability of these farmers not following the recommended practices as required might offer a partial explanation of this apparently perverse result.

When the model was reestimated (restricted) by dropping insignificant variables, the estimates of the coefficients were again robust.

4 Conclusions and recommendations

The study shows that most farmers are aware of the pesticide side effects; however, they do not handle them appropriately. The PPE gear in most cases was inadequate, and there exist no regulations that require the use of protective gear during pesticide handling.

The regression results showed that record keeping, play a significant role in the reduction of inappropriate pesticides handling practices, highlighting the need for encouraging farmers on record keeping of their vegetable production activities. Handling pesticides in WHO II and receiving advice on pesticides use from pesticide traders significantly increase inappropriate pesticides handling practices.

It is remarkable that pesticide risk perceptions and previous experience/witness of a negative pesticide impact have no direct influence on farmer's pesticides handling practices. Hence, the learning effect of experience is very little. Such a trend is very worrying because not only are the health of farmers affected, but the whole household also suffer. Furthermore, the effect on entire society is likely to be considerable since water sources and the entire environment are affected.

The results further suggest widespread inappropriate handling of pesticides in Kirinyaga and Makueni districts. The district of Meru appears to be less prone to these practices, perhaps due to record keeping.

The study ultimately recommends policymakers to design effective, more participatory and targeted outreach programmes, which deal specifically on promotion of record keeping and reduction on use of pesticides particularly in WHO II.

Farmer should be enlightened of the broader long-term negative effects of pesticides as most farmers seems not to learn after experiencing the short-term pesticide negative impact. Similarly, the results also point to specific district of Kirinyaga and Makueni experiencing higher prevalence of inappropriate handling of pesticides, targeting these areas may have the most measurable effects on reduction of inappropriate handling of pesticides.

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[9] It has been argued that smallholder vegetable farmers can achieve GLOBALGAP certification, but continuous maintenance is a problem due to the high costs of compliance.

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