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Drivers of Adoption of Integrated Pest Management among Small-scale Vegetable Farmers in Lubumbashi, DR Congo

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Abstract Integrated Pest Management techniques (IPM) have been promoted last decade throughout a large Urban and Periurban Horticulture project (UPH) for a sustainable vegetable production in Congolese cities. However, the drivers of adoption of IPM techniques have not been either studied or identified. Data collected between April and June 2016 throughout field survey from 246 vegetable farmers were analyzed using a logistic regression model to determine the factors influencing the adoption of IPM techniques among vegetable farmers. Results showed that there were no significant differences between gender and the willingness to use IPM ($p>0.05$). However, a high portion of female (46.6%) reported that they would like to test new IPM techniques without any hesitation. Membership to a farmer's group (Association) and previous agricultural training influenced positively and significantly the IPM adoption ($p= 0.000$) and increased highly the probability of adopting IPM respectively 4.2 and 7.7 times. Further, results also highlighted that farmers who previously perceived negative effects of pesticides were likely 5.2 times predisposed ($p<0.05$) to adopt alternative methods of pest control. Findings will allow an increased understanding of the process of IPM adoption and will help provide policy guidance to promote IPM diffusion with a purpose of reducing pesticide issues among farmers.

Keywords: *vegetable production, pesticides, IPM, logistic regression, Lubumbashi*

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1. Introduction

Lubumbashi, located in the southeastern part of DR Congo is one of the fastest growing African cities with annual population growth rate of 5% [1]. Its population growth is accompanied with several environmental, food and employment challenges [1,2]. Vegetable production in that city is considered as a livelihood and entrepreneurial activity for many poor dwellers [2,3]. It plays an important role in term of supplying the local market in various vegetables including amaranth, cabbages, okra, and spinach. Vegetable production also helps growers earn income in short time [4,5,6]. However, farmers face major pest and disease problems in vegetable production and pesticides are sprayed to protect crops and boost their productivity [7].Unfortunately, beside the benefits of increased yields, this may be outweighed by the threats to human health and environment [8,9] as well as indirect economic losses related to the purchase and the application of pesticides [10]. For example, a study conducted by [11] in Northern Tanzania reported that 93% of vegetable farmers have experienced poisoning cases by pesticides in their lifetimes. A previous research mentioned that farmers had to pay up to 116 US dollars for medical bill due to pesticides intoxication [12]. In Lubumbashi, vegetable farmers were found to be likely exposed 36 times (0.022700667 mg/kg/day) to Lambda-cyhalothrin compared to the Acceptable Operator Exposure Level (AOEL:0.00063 mg/kg/day) established by Agritox for the European Union [7]. In this situation, Integrated Pest Management (IPM) is a sustainable approach to reduce pesticide use, costs of production and risks of adverse effects on human health and the environment [13,14,15,16]. IPM techniques are recognized also easy to implement since farmers can combine options from research with traditional farming practices [17]. Furthermore, they are accepted as response to reconcile food security, agrosystem preservation and socio-economic development [18]. They are also attracting the international research community, with a significant increase in the number of publications devoted to the subject [19]. For instance, *Bacillus amyloliquefaciens* has been recently found with interesting potential to be valued as a biocontrol agent against numerous plant fungal pathogens

[20]. Biopesticide spinosad and the entomopathogenic fungi *Beauveria bassiana* seem to be the promising agents against black cutworm [21]. Between 2002-2010, a large Urban and Periurban Horticulture project (UPH) has been set up to extend integrated production and pest management practices (use of pest-resistant varieties, organic inputs, indigenous pesticide plants ,intercropping and crop rotation) for a sustainable vegetable production in Lubumbashi [22,23]. However, despite the favorable results of IPM, its adoption has remained limited in many regions [14,24]. Knowing that conventional pesticides do not provide a solution for future sustainable agriculture also in regions such as Lubumbashi in DR Congo [20], the following questions still need responses: (a) would local vegetable farmers be willing to adopt new IPM techniques? (b) What are the factors that more likely influence the IPM techniques adoption among vegetable farmers?

This study tested the hypothesis that socioeconomic characteristics (gender, age, land size, education, profession, training, membership to an agricultural group, cost of pesticide, perceived problems of pesticides) would influence the adoption of IPM practices among vegetable farmers [24,26,27,28,29]. Through this study, we intended to determine the socioeconomic factors associated with the adoption and use of IPM techniques for promoting a sustainable agriculture in suburban areas of Lubumbashi.

This study had three objectives: (1) to describe the socioeconomic characteristics of the vegetable farmers and their pest management practices (2) Analyze gender willingness to use IPM techniques (3) Identify factors that would increase the probability of using the IPM among farmers. The identification and discussion of these factors will allow an increased understanding of the process of IPM adoption and will help provide policy guidance to promote adoption with a purpose of reducing the risks of pesticides for farmers, consumers and local biodiversity [30].

2. Materials and Methods

2.1. Description of the Study Area

The current study was conducted within five vegetable sites in Lubumbashi: Kimilolo (11°43'007"S, 27°25'66"E); Kilobelobe (11°40'306"S, 27°30'974"E), Maendeleo (11°42'615"S, 27°27'976"E), Naviundu (11°37'825'S, 27°31'266"E) and Tingi-Tingi (11°36'540"S, 27°28'433"E). The choice of those sites was motivated by the fact that they were identified among the largest vegetable production sites in Lubumbashi and have experienced the UPH project between 2002-2008 with the implementation of field farmer's school [4,22]. The mean annual temperature is about 20°C; the coolest month is July (15.6°C), and the warmest month is October (23°C). The mean annual rainfall is 1270 mm, with a rainy season that lasts 118 days on average, from November to March [31]. Profitable vegetable production takes place during the dry season from March to September [6]. Soil of those sites is poor and highly contaminated with heavy metals including copper, cobalt, lead, cadmium, and zinc, arsenic [32]. Pollution and high human exposure to metals have been exacerbated the last decades by the increasing of mining activities [33,34,35]. The use of organic inputs (organic matter) is therefore a mandatory to increase crop yield and restrict the transfer of trace metals from the soil to plant edible organs [32].

2.2. Data Collection

A list of vegetable farmers per site was obtained from a National Service of Urban and Periurban Horticulture (SENAHUP) that provides a technical assistance to urban and periurban vegetable famers. A survey was conducted in the selected sites mentioned above from April to June 2016. A sample of 246 farmers was randomly interviewed using a structured questionnaires and participatory approach as well as observations during farmer's activities related to crop protection. The questionnaire was designed in French and most of the interviews were in Kiswahili, a local language spoken by the majority of farmers met. The content of the questionnaire included farmer's informations related to the gender, age, education, profession, experience in vegetable production (years), previous training in farming, membership to an agricultural association, access to land, land size, vegetable grown, market orientation, pest management practices and cost of pesticides as well as famers' perception of chemical pesticides. The IPM techniques considered in this study included crop rotation, intercropping, and insect collection, use pesticidal plants, use of natural products, field inspection and use of resistant seeds.

2.3. Modeling IPM Techniques Adoption among Farmers

The adoption of IPM is a choice between two alternatives (1, if adopt at least one or more IPM techniques, 0, otherwise) [28]. A new IPM technique will be likely adopted if its perceived utility is higher than the perceived utility of the old technology. In this context, vegetable growers are assumed to make their decisions by choosing the alternative that maximizes their perceived utility [30]. The variables tested in logit model and effects expected are recorded in Table 1.

2.4. Data Analysis

Data were encoded into Microsoft Excel and crosschecked to clean errors and analyzed using IBM SPSS Statistical Package Version 21.0. Data analysis was performed using frequencies and percentages of all socioeconomic variables. Since strong variabilities were observed among farmers, quantitative variables (age, experience, land size, and cost of pesticides) were broken into categories (ranging) for a good description. A chi square test ($\chi 2$) was used to determine if significant differences existed between gender and willingness to use new IPM techniques. The same test ($\chi 2$) was used to investigate if farmers who experienced pesticide concerns were more likely willing to adopt IPM than those who did not. The logit model was performed to identify the socioeconomic factors associated with the adoption of IPM techniques. This study considered $\alpha < 0.05$ as a criterion for statistical significance.

Table 1. Lists of explanatory variables used in logistic regression

Variables	Description	Expected effects
Gender	Gender (1= male, 0 = female)	+
Age	Age of farmers (years)	- /+
Prof	Farmer's main Profession (1= farmer, 0 = Other)	+
Educ	Farmer's education (1= primary, 2= high school, 3= university, 4= professional)	+
Train	Farmer attended training (Yes =1, 0= no)	+
Associat	Membership to a farming association (Yes =1, 0 = no)	+
Expe	Farmer's Years in farming(years)	+
Landac	Land access(1= location , 0 = other modes)	+
Lansize	Land size in are	+
Pestipro	Experienced pesticide problems (yes= 1 ; 0 = no	-
MarkR	Market requierement (yes= 1 ; 0 = no)	+
Pestcost	Pesticide cost in US Dollar	-/+

3. Results

3.1. Socioeconomic Characteristics of Respondents

This part presents the socioeconomic characteristics of 246 vegetable farmers surveyed in urban and suburban areas of Lubumbashi (Table 2). Over half of the respondents (52%) were male, and female represented 48%. The proportion of young farmers in vegetable production was important (35.8%) and the number of aged people was low (26.8%). A good part (62.6%) of farmers attended the high school and 13.8% were students from local universities. As observed, 65.8% had farming experience ranging between 1-10 years and 40% were members of local farmer's groups (associations). Only half of respondents (50.4%) reported having attended previously the training provided by local and international organizations to extend IPM techniques. Half of farmers cultivated small plot (2-3 ares) on which they grew Chinese cabbage (100%) and amaranth as well as spinach (48%). The cost of pesticides for most of farmers (90.7%) ranged between 0.5 to 4 US Dollars per crop cycle. Over 84% of farmers reported having previously health problems linked to pesticide application in vegetable farms.

3.2. Gender and Willingness to Use New IPM Techniques

There were no statistically significant differences between gender and the willingness to adopt IPM techniques ($p>0.05$) (Table 3). A good portion of vegetable growers (42.3%) was willing to adopt IPM techniques. Female (46.6%) reported that they were favorable in adopting new IPM techniques without any hesitation and 36.4% would prefer testing first their effectiveness. However, 19.9% would not want to adopt. In other hand, 38.3% among male were willing to adopt new IPM, 32% would like also to test new IPM techniques. Almost the farmers reported having heard, and knowing some IPM techniques.

Table 2. Socioeconomic characteristics of surveyed farmers (n=246)

Variables	**Category**	**N^{ber} of farmers**	**Percentage**
Gender	Male	128	52
	Female	118	48
Farmer's age	17-35	88	35.8
	36-54	92	37.4
	>55	66	26.8
Education level	Primary	54	22
	High school	154	62.6
	University	34	13.8
	Professional	4	1.6
Farmer's experience (years)	1-10	162	65.8
	10-20	84	34.2
Member of agricultural association		98	40
Training and farmer's field school		124	50.4
Land size	≥ 1are	85	34.6
	2-3 ares	123	50
	>3 ares	38	15.4
Main vegetable crops	Cabbage (Chinese c.)	246	100
	Amaranth and spinach	118	48
Pesticide cost /crop cycle	0.5- 4 USD	223	90.7
	5-9 USD	12	4.9
	≥ 10 USD	4	1.6
Report of pesticide concerns		207	84.1

Table 3. Gender and willingness to use IPM

Gender	Would adopt IPM innovations		Would like to test		Would not adopt	
	Freq.	(%)	Freq.	(%)	Freq.	(%)
Female	55(46.6)		43(36.4)		20(19.9)	
Male	49(38.3)		41(32)		38(29.7)	
All farmers	104(42.3)		84(34.1)		58(23.6)	
*Number of observation= 246, Chi square=5.583, p=0.61**						

* No significant.

Table 4. Report of pesticide concerns among farmers and adoption of IPM

Previous problem with pesticides	Would like to test		Would not adopt		Would adopt IPM innovation	
	Freq.	(%)	Freq.	(%)	Freq.	(%)
Yes	75(36.2)		45(21.7)		87(42)	
No	9(23.1)		13(33.3)		17(43.6)	
*Number of observation = 246, Chi square =3.553, p=0.169**						

***** No significant.

Table 5. Current IPM techniques used by vegetable farmers (n=246)

Curent IPM practices	**Number of farmers**	**Percentage**
Intercropping	128	52,0
Rotation of crops	145	58,9
Weeding	246	100
Collecting pest insects,	153	62,2
Use of ash	193	78.5
Ash + insecticide + Weeding+ Rotation	240	97.6
Pepper and field inspection	28	11,4
Tobacco and *Titonia diversifolia*	1	0,4
Use of garlic	1	0,4

Table 6. Drivers of adoption of IPM among farmers

Variables	**Coefficient**	**Std. error**	**Sig.**	**Exp(B)**	**[95% Conf.Interval]**	
					<	>
Gender	.004	.385	.991	1.004	.472	2.138
Age	-.021	.016	.186	.979	.949	1.010
Prof	.222	.155	.152	1.249	.921	1.692
Educ	-.345	.282	.222	.709	.408	1.231
Train	2.044***	.373	.000	7.722	3.718	16.037
Associat	1.435***	.361	.000	4.200	2.071	8.518
Expe	.012	.023	.602	1.012	.968	1.058
Landac	.087	.172	.612	1.091	.779	1.529
Lansiz	-.539*	.272	.048	.583	.342	.994
Pestipro	1.654*	.671	.014	5.226	1.404	19.448
MarkR	.332	.532	.533	1.393	.491	3.954
Pestcost	.000	.000	.264	1.000	1.000	1.000
Constant	-5.250	2.014	.009	.005	-	-
Number of observation : 246, -2log- *likelihood* =220.307, Nagelkerke R^2 =0.498						

*******= significant at 1 %.; *****= significant at 10 %.

3.3. Farmers ‘Perception of Pesticide Problems and Adoption of IPM

The chi-square test revealed that having experienced pesticide concerns was not significantly associated to the willingness to adopt IPM techniques among farmers surveyed (p>0.05) (Table 4). Results showed that 42% and 36.2% among farmers who were willing respectively to adopt and test new IPM techniques had previously pesticide concerns (eye and skin irritation, sneezing). Result also highlighted 43.6% who did not notice pesticide problems before were also favorable to adopt IPM techniques.

3.4. Current Pest Management Practices Used by Farmers

Vegetable farmers surveyed used a range of IPM techniques as reported in Table 5. IPM techniques used included intercropping (52%), crop rotation (58.9%), collection of insect pests (62%), weeding (100%), application of ash (78.5%) and 97.6% reported spraying insecticides (Lambda-cyhalothrin and Diclorvos).

3.5. Drivers of Adoption of IPM among Vegetable Farmers Surveyed

The logit model identified 4 significant factors (Train = training on vegetable production practices, Associat = membership to an agricultural association, Pestipro= perceived problem of pesticides, Landsiz = land size). The three first factors increased highly the probability of adopting IPM techniques with confident interval of 95% (Table 6).

Results showed that both membership to a farmer's group (association) and previous training on vegetable production practices influenced positively and significantly the IPM adoption (p= 0.000) and increased the probability of using IPM respectively of 4.2 and 7.7 times. Perceived concerns of pesticides among vegetable farmers influenced also positively and significantly the IPM adoption (p=0.014). Indeed, farmers who had previously experienced pesticide issues (skin and eyes irritation, sneezing, fatigue) were more than 5 times likely predisposed to adopt IPM techniques. However, the land size was negatively correlated to IPM adoption among farmers surveyed. The factors used in logit model solely could explain 49.8% of variation in level of vegetable farmers' adoption of IPM practices.

4. Discussion

The current study aimed at identifying the factors that can promote the use of IPM techniques among vegetable growers. IPM techniques were extended in Congolese cities as a part of UPH project (2002-2010) for reducing possible unnecessary chemical inputs [22,23]. However, like in many developing countries there are very few studies assessing the extend of adoption and long term impact [36]. Factors tested explained the level of adoption at 49.8%. This rate was low compared to the results reported in Iran (58.9%) [37].This suggests that there are other factors that need to be considered in IPM adoption process, such as farmer's perception, conviction, time, and effectiveness that need to be evaluated.

4.1. Gender and Willingness to Use IPM Techniques

There were no significant differences between male and female (p>0.05) regarding IPM adoption. This is probably because farmers observed tend to imitate mutually one another as for the choice of agricultural practices. Results found are consistent with a survey conducted in Kenya where [38] did not find significant differences between men and women in adoption of push-pull pest management technology. The same observation was done in Uganda where gender did not influence pest management decision [39]. In this study, a large proportion of female was predisposed to adopt IPM techniques. This can be explained by two following raisons: (i) the increasing price of chemical inputs on local market can lead women to use IPM techniques that are easy to use, safe and affordable and available. (ii) Women have greater knowledge of dimensional attributes of IPM than men, particularly awareness of potential harmful effects of synthetic agricultural inputs such as pesticides [39]. Since all farmers have the same perception of IPM techniques, its promotion and dissemination can be supported equally for male and female [38]. However, the effort to use IPM is challenged actually by the perceived benefit of chemical pesticides. The benefits include less labor compared to IPM techniques, high yields and good quality of crops [40,41]. Nevertheless, the experience from Kenya reveals that IPM-adopting farmers can also get good results by using lower quantities of insecticides [28].

4.2. Drivers of Adoption of IPM among Vegetable Farmers

Some of the variables tested had positive and significant effects on the probability of adopting of IPM techniques among sampled vegetable farmers. Previous training on agricultural practices, membership to an agricultural association and problem perceived of chemical pesticides were found influencing factors of IPM adoption. Factors identified were in agreement with some findings in previous studies carried out in developing countries, as discussed below.

4.2.1. Influence of Famers' Group and Agricultural Training in Adopting IPM

Both farmers 'group (association) and training in farming practices influenced positively and significantly the IPM adoption (p= 0.000) and increased the probability of using IPM respectively of 4.2 and 7.7 times. The plausible explanation for these results is that vegetable growers who belong to farmer's network increase also their knowledge of pest management and improve their skills by attending training in group through Field Farmer 'Schools program. A recent study conducted in Lubumbashi mentioned that Associative Networks created by vegetable farmers increased their capacity in terms of cooperation with other local institutions [6] also members adopted some of the IPM practices promoted by the UPH project [22]. Rural institutions (farmer's groups) influenced significantly the use of a bundle of IPM practices in Kenya [29]. The membership to a rural social group enhances social capital allowing trust, idea and information exchange [27]. According to [42], farmers within a social group learn from each other the benefits and usage of a new technology. As many studies highlight the role of the farmers 'group in adopting IPM, actions supporting and strengthening the leadership of members will help these organizations to become a real pathway for the promotion of IPM. As for the training, previous training in pest management influenced positively and significantly the probability of a farmer using IPM practices. Previous researches indicated that an individual already trained in IPM was more likely aware of the benefit of IPM and increased awareness on harmful effects of pesticides and enhanced capacity for safe handling[43,44]. This is also in agreement with [41] who indicated that knowledge obtained during training, shapes farmers' attitudes and practices regarding pest control method selection and use.

A survey conducted in Iran among olive growers confirms that farmers who participate in extension and educational activities, they gain more knowledge of olive fly integrated [24]. In Sri Lanka, 85% of farmers who participated in IPM training programs had better understanding on IPM, compared to others [45].

4.2.2. Farmers ‘Perception of Pesticide Concerns and Adoption of IPM

Perceived concern of pesticides among vegetable farmers influenced positively and significantly IPM adoption (p=0.014). Vegetable farmers who had previously experienced pesticide issues (headache, sneezing, irritation of eyes and skin) were likely more than 5 times predisposed to adopt IPM techniques. This was contrary to our expectation since almost the farmers believed that chemical pesticides were important in vegetable production and effective to control pests. Significant and positive correlation observed can be explained by the increasing awareness of pesticide hazards among farmers. This is consistent with [39] and [43] who reported that awareness of the harmful effects of pesticides on human health was linked to adoption of IPM practices. In Lubumbashi, Vegetable farmers reported previously self-pesticide discomforts such as nostril irritation accompanied with sneeze (94%), eyes irritation (76%) and 30% complained of headache after spraying pesticides [7]. A survey conducted in Nicaragua [26] concluded that experience of pesticide poisoning led farmers to change their behavior and search for alternative pest control options, resulting in increased testing of IPM practices. Since small farmers cannot afford protective and spraying equipment and pesticides due to their increasing price in developing countries [46], the IPM is an opportunity to minimize chemical pesticide risks in vegetable production. Findings from two surveys of [43] and [47] indicate that the possible strategy of relieving farmers from the health risks associated with pesticide exposure is to deploy a program of awareness and information. Studies conducted by [25,48] recommend field farmers school because it focuses on teaching farmers how to think critically about production problems on fields. It also enables small-scale farmers to investigate and learn together in small groups the skills required for adapting integrated pest management practices to their fields [49].

5. Conclusion

The current study aimed at determining the drivers of IPM techniques adoption among vegetable farmers and their willingness to test and adopt new IPM techniques for sustainable vegetable production. Both male and female were willing to adopt and test new IPM techniques for reducing possible unnecessary insecticide sprays in vegetable production. The econometric analysis (logit model) performed indicated that previous training in vegetable production, membership to an association (farmer’s group) and perceived concerns of pesticides influenced positively and significantly farmer’s decision to use IPM. Farmers who had previously experienced negative effects of pesticides and those who had attended training on vegetable production practices were likely favorable to adopting IPM respectively 5.2 and 7.7 times. Since the training is considered as a source of information for farmers and help to increase their awareness regarding pesticide issues, this study pleads for actions strengthening farmers’ technical knowledge of IPM techniques through their groups with a participative approach. Field farmer’s school is strongly recommended because it empowers farmers to take initiative in solving production challenges by themselves into their fields.

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