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RESEARCH ARTICLE

A multifaceted analysis of pesticide utilization in market gardening along the Ruzizi plain: Exploring factors, farmer perceptions & media influence

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Abstract

Along the Ruzizi plain, subsistence agriculture constitutes households' primary food source. Regardless of the environment, the low level of pesticide use ensures less effective disease and pest control. This is why a study was carried out in the Ruzizi plain to identify the main determinants of pesticide use on vegetable crops for effective control of diseases and pests that significantly reduce the yield of these crops, which play an economically important role for producers and the role of the media in this context. The data was collected using a closed-type survey questionnaire on 90 market gardeners distributed equally between localities applying the probit model. The results of the probit model estimation reveal that about nine factors positively influence the use of pesticides: membership in a cooperative (p=0.0012), access to agricultural credit (p=0.0153), experience in agriculture (p=0.0008), experience in market gardening (p=0.0197), standard of living (p=0.0139), yield (p=0.0001), capacity building (p=0.0035), the area exploited (p=0.0011) and the cultivation system (p=0.0233). In addition, tomatoes are the leading vegetable crop grown by many market gardeners (61.1%), followed by amaranth (20%) and onions (18.9%). Also, 67.8% of market gardeners use pesticides compared to 32.2% who do not use them. Thus, considering these factors would contribute to decision-making when carrying out certain activities to improve market gardening, contributing considerably to the fight against food insecurity. Also, it is advised that the media work harder to inform rural residents and areas about the agenda for rural development.

Keywords

pesticides; vegetable crops; media; rural development; awareness

Introduction

On a global scale, market gardening constitutes a significant issue in supplying cities with food, employment and management of the urban and peri-urban environment (1-4). Indeed, they have advantages over other food crops by making an economic and nutritional contribution to poor households because they are rich in minerals and vitamins (5, 6). Leafy and

fruiting vegetables constitute an essential component of daily diets in Africa and essential sources of income, particularly in rural areas (4, 6).

Previous studies have shown that in Sub-Saharan Africa, market gardening appears to be among the main agricultural activities, followed by mini-livestock farming (7, 8). It promotes flood-prone areas unfavourable for other crops; these are fast-growing crops with high nutritional value and capable of generating sufficient income in households with limited resources (9). In East Africa, market gardening and mini livestock often significantly combat food insecurity and malnutrition (10, 11). This would constitute an effective solution in the African Great Lakes region, where around 40% of households suffer from food insecurity (11-14).

Several studies have shown the role of plant protection using pesticides (fungicides, herbicides, insecticides, etc.) in improving yields and reducing family labour in maintenance work (15-18). However, knowledge of the necessary information on the factors of pesticide use by farmers would be an asset in the decision-making of scientists and their suppliers for the sustainable improvement of agriculture (19-22).

In farming environments and particularly in the Ruzizi plain, new agricultural innovations, particularly pesticides on food crops, are of capital importance in sustainable agricultural intensification in the area (23-24). Unfortunately, these innovations still face significant challenges, including the sustainable adoption of these technologies (11, 25). These agricultural innovations are not always transferred in the best affordable socioeconomic conditions for the most significant number of farmers (3, 24). Hence, there is a need to inventory and analyze the factors determining the adoption and use of pesticides in our study environment.

In conducting this research, the following questions were asked: what would be the determining factors for the use of pesticides in market gardening in the Ruzizi plain? What would be the economic implications of the diseases and pests on the different market gardening crops? What would be the impact of farmers' adoption or use of pesticides on the production of market garden crops and on improving the lives of households in the Ruzizi plain? The overall objective of this work was to contribute to improving the productivity of different market garden crops by identifying the factors influencing the adoption of pesticides in the fight against diseases and pests. This is specifically about identifying the main market garden crops grown in the Ruzizi plain and the different types of pesticides used to protect them; identifying the main determinants of pesticide use on market gardening grown in the Ruzizi plain; determining the incidence and severity of diseases and pests on vegetable crops in the Ruzizi plain; and at a lesser extent, to find out on how successfully do media outlets integrate communication, participatory techniques and developmental opportunities. The following hypotheses were formulated: the factors determining the use of pesticides on market gardening in the Ruzizi plain are mainly socioeconomic rather than agronomic; the pesticides applied to the different market garden crops grown in the Ruzizi plain vary from one pest to another and from one crop to another; the incidence and severity of diseases and pests would be influenced using pesticides.

Materials and Methods

Study Area Choice and Characterization

The study was conducted in the Ruzizi Plain in Tanzania's neighbouring Democratic Republic of the Congo. The Ruzizi plain is between 2°42' and 3°24' South latitude and between 29°00' and 29°22' East longitude. Its surface area is of the order of 1750 km ^{2} (4, 11). The Ruzizi plain looks like an almost flat strip stretching from North to South. Its altitude varies from 850 m in the North to 773 m at Lake Tanganyika (11). The map of the study sites is given (Fig. 1).

The choice of this environment was dictated by the importance of market gardening (tomato, onion, amaranth, etc.) in the income of households with limited resources about the different works conducted by Shukuru et al. (11, 14), Shukuru (3, 4) and Shukuru & Archana (24) in the area.

According to the Köppen classification, the Ruzizi plain is generally characterized by a semi-arid climate of type Aw 4 (S), with four months of dry season receiving rainfall varying between 800 and 1000 millimetres per year. The dry period or dry season (June to October), two or three storms bring a little rain. The wet (rainy) period extends from November to May. It is an environment that, in recent times, has been subject to severe climatic disturbances causing a pronounced rainfall deficit and drought (3, 4, 24). The natural vegetation consists of medium-density grassland, shrubs, euphorbias and some Borassus (11, 26).

In general, the soil of the Ruzizi plain is sandy (11). Clay-type soil is recorded in certain areas along the Ruzizi River and the marshes. These soils are sandy, with variable levels of clay, generally poor in organic matter and assimilable phosphorus. The pH is slightly alkaline (7.9) and phosphorus is the most limiting element in this soil, hence the salinity problem near the Ruzizi River (24, 27).

Sampling, Data Collection and Evaluation

To carry out this work, we used a questionnaire and a survey sheet to collect information from market gardeners in the Ruzizi plain. The questions were primarily closed, meaning previously defined assertions guided the debate. An identification key for identifying diseases and pests and facilitating the evaluation of the incidence and severity of these diseases.

Analysis of pesticide use factors in market gardening

The essential data was collected using a closed-ended survey questionnaire. The information collected focused on the socioeconomic characteristics of market gardeners (surface area exploited, land security, access to pesticides, access linked to production factors: labour), the type of market gardening grown and the type of pesticides. Used

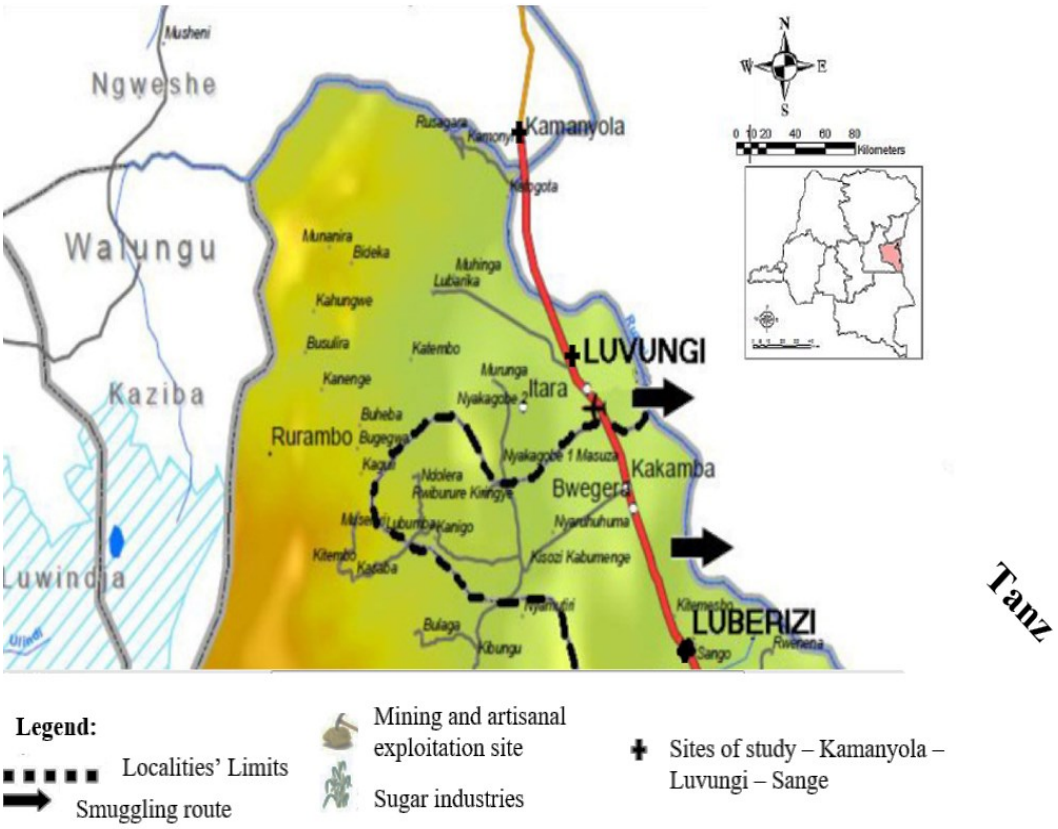

Fig. 1. Map of the Study area

and the factors dictating its use, the production cost for users and non-users of pesticides were estimated considering the context of local markets. The implications for the productivity of different market garden crops and household experiences were also considered. The interviews were individual.

Sampling

Only farmers practising market gardening were concerned by the surveys. Given the difficulty of determining the exact number of market gardeners in the study area, a sample of 90 market gardeners was surveyed in the three study sites (Kamanyola, Luvungi and Sange), with 30 market gardeners per group.

Assessment of the incidence and severity of diseases and pests of vegetable crops with or without the use of pesticides

Data on the severity of diseases and pests were collected according to the rating scale of the International Institute of Tropical Agriculture (IITA); 1 to 5 was used to assess the level of damage, where 1 means no visible symptoms (apparently healthy plants), 2: symptoms on approximately 25% of all plants, 3: symptoms cover 50% of plants, 4: symptoms on all plants, but there is no stunting or deformation, while five stands for symptoms on all plants followed by deformation and death of infected plants (4, 11). To do this, a sample frame according to the area of the field was randomly placed in the vegetable crop field to collect data on the incidence and severity of diseases and pests.

The incidence (I) corresponds to the number of plants destroyed out of the total number of plants observed multiplied by one hundred (17). It is expressed as a percentage (%) and was calculated by the following formula: $I = \frac{\sum_{t-1}^{n} Pt}{N} \times 100$ where Pt = Number of plants destroyed and N = Total number of plants observed. A total of plants affected by the decameter was observed according to the area of each field and the length of the decameter.

Determinants of adoption of pesticide use in market gardening

The logistic regression makes it possible to predict the values taken by a categorical variable, most often binary (0 and 1), from a series of continuous and categorical explanatory variables (3, 14). In this study, the probit approach was used.

$E(Y_i) = P(Y_i) = \frac{e^{\alpha+\beta X i}}{1+e^{\alpha+\beta X i}}$ Consequently, the probability that the market gardener does not use a pesticide becomes:

$P(\text{non-use}) = 1 - P(Yi) = \frac{1}{1+e^{\alpha+\beta Yi}}$ where P(Yi) is the probability for a market gardener i to use a pesticide; P(Yi) =1 if the pesticide is used and 0 if the pesticide is not used; e is the exponential function; Yi represents the explained variable; the use of pesticides Xi is characteristic of market gardener i; it represents the vector of explanatory variables (age, level of education, membership of a market gardener group, etc.); β is the vector of parameters to be estimated, the sign of which allows the interpretation of the results; and α is the constant.

Dependent Variables

This study aims to explain the adoption of pesticide use in market gardening. To adequately describe this problem, the adoption variable (Y) distribution was constituted by the two modalities, including 0 and 1, which means non-adoption and adoption of pesticide use in market gardening.

Explanatory variables

The explanatory variables or independent variables for adopting pesticide use in market gardening were taken in two dimensions: the socioeconomic variables linked to the farmer and the variables related to the farm. Therefore, this study assumes that the use of pesticides on market gardening in the Ruzizi plain depends on the following variables: sex of the market gardener, market gardening experiences, member of a peasant association, level of education, the distance between input store and field, area exploited, participation in specific training in the field of pesticide use, share of market gardening in household income, no knowledge on pesticide application, standard of living, market garden crops practised, cultivation system, method of control, land security, presence of diseases and pests, access to credit, sales market, profitability, household size, occupation other than agriculture, age of respondents, main production objective.

Among the explanatory variables identified, few were selected and defined (Tab. 1).

Table 1. Explanatory variables for adoption of pesticide use in market gardening

Explanatory variables	Description
Field acquisition mode	
Age	Digital
Membership of an association	1=belonging to an association 0=not belonging
Belonging to a cooperative	1=belonging to a cooperative 0 =not belonging
Agricultural credit	1=access to agricultural credits, 0=does not have access to credits
Main crop	1=tomato, 2=onion, 3=amaranth
Experience in agriculture	Digital
Experience in market gardening	Less than 5=0 super 5=1
Group	Luvungi=1, sange=2, kamanyola =3
Level of study	0=illiterate, 1= primary 2 =secondary
Quality of life	0= low 1 =acceptable
Objective of culture	0=self-consumption, 1=sale, 2= sale+consumption
Yield	0= low , 1=medium, 2=high
Capacity building	0=never trained 1=trained
Gender	0=woman and 1=man
Available area	
Area exploited	0= less than 0.5ha, 1= greater than 0.5ha
Cultivation system	0=monoculture, 2=association
Household size	0= less than 5, 1= greater than 5
Other activities	1=other activity 0 = no other activity

Data Analysis

The data collected after the surveys were encoded using Microsoft Excel Package 2013 and then submitted for econometric analyses using the R program language and EViews 9 software. The Jarque-Bera (JB) test was carried out to determine the econometric model adapted to our data. The result of the latter showed that the Probit model is adapted to our data. The JB test is used to test the normality of the distribution. The distribution is expected if the probability value associated with the JB statistic exceeds the significance threshold (5% for example). This test is used when the sample size exceeds 88 (n > 88). The distribution follows the normal law when its probability is more significant than 5.99. Therefore, the model to use is the probit. A descriptive analysis (mean and frequency) carried out using RStudio was used to identify the primary market garden crops and the different types of pesticides used on these crops and describe the socioeconomic characteristics of the farmers.

Results

Socioeconomic characteristics

The market gardening is more practiced by men (72.2%) than women (27.8%). The majority (78.9%) of market gardeners are aged between 30-50 years while the minority (8.9%) are less than 30 years old. Indeed, the majority (73.3%) of market gardening households have a household size of more than 5 members while 26.3% of these households have less than 5 members. Market gardening is more practiced by farmers with a primary level of education (40%), followed by those with a secondary level (32.2%) and those who have not been to school (without level) practice less market gardening (27.8%). Most farmers (36.7%) have less than 5 years in this activity while the minority (13.3%) has seniority of between 11 and 20 years. on the other hand, 25.6% of farmers have more than 20 years in agriculture. The majority (51.1%) of market gardeners have less than 5 years in their activity while 48.9% have more than 5 years in their activity. In addition, the experience in agriculture and market gardening which influences the use of pesticides is around 5 years (Fig. 2).

Tomato is the most cultivated vegetable crop (61.1%) followed by amaranth (20%) and onion (18.9%). In Kamanyola, tomatoes are the main market garden crop (73.3%) (Fig. 3a). Furthermore, in Sange, tomatoes are grown by 53.3% of market gardeners surveyed, this crop is followed by amaranth (36.7%) and onions (10%). In Luvungi, tomatoes are grown as the main cultivation by 56.7%, followed by amaranth which is practiced in second place by 36.7%. In addition, the results show that these main crops are those on which pesticides are used the most. Tomatoes are the main market garden crop in the Ruzizi plain and seem to be the crop that is treated with pesticides (Tab. 4).

The use of different pesticides present in the environment varies from one market gardener to another (Fig. 3b). The proportion of Dudu users is higher (65.2%); it is also 55.6% for Dithane users. While the lowest is (16.7%) For the use of Lava. Furthermore, the proportion of Dudu, Lava, Ratox and Rocket used is much more observed in Kamanyola, while Dithane is used much more in Luvungi.

		Value	Asymptotic meaning (two-sided)
Gender	Pearson chi-square	3.102a	0.212
	Likelihood ratio	3,237	0.198
Age	Pearson chi-square	13.460 *	0.009
	Likelihood ratio	18,905	0.001
Household size	Pearson chi-square	0.341a	0.843
	Likelihood ratio	0.342	0.843
Level of Study	Pearson chi-square	13.350 *	0.010
	Likelihood ratio	14,415	0.006
Seniority in agriculture	Pearson chi-square	10.559 *	0.103
	Likelihood ratio	10,844	0.093
Seniority in market gardening	Pearson chi-square	0.089a	0.957
	Likelihood ratio	0.089	0.956

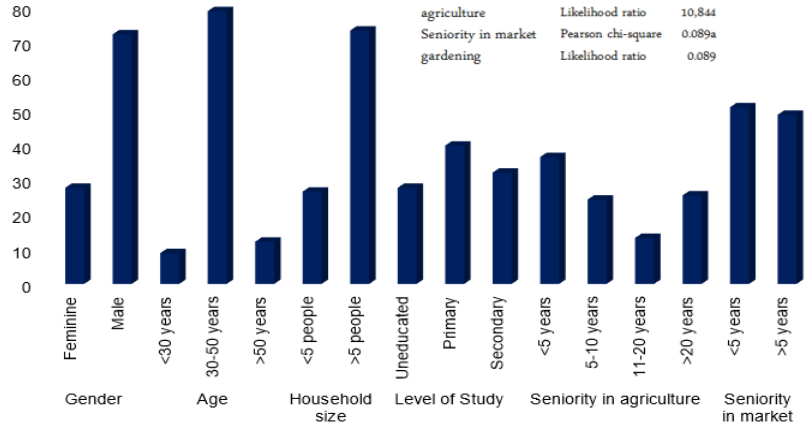

Fig. 2. Identification of the market gardeners surveyed in Ruzizi plain

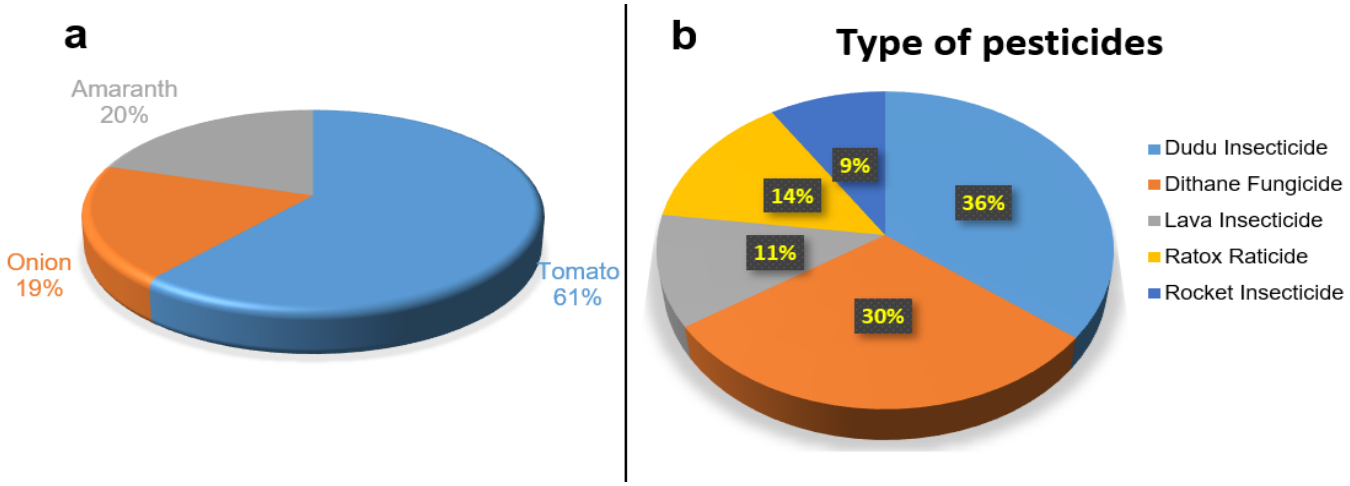

Fig. 3. Main market garden crops practised (a) and pesticides (b) used in the Ruzizi plain

Identification of the factors determining the use of pesticides

It appears that the distribution function of the residuals follows a normal law. It is therefore governed by a Gaussian process (p=0.8307) (Fig. 4). Therefore, the appropriate method to estimate the main determinants of pesticide use in the Ruzizi plain is the probit (Tab. 2).

The model is adjusted and significant (p<0.001). It shows that the different factors contribute to the use of pesticides in the Ruzizi plain, with an order of 82.53%, as shown in the table above. Indeed, the results show that 11 variables significantly influence the use of pesticides on

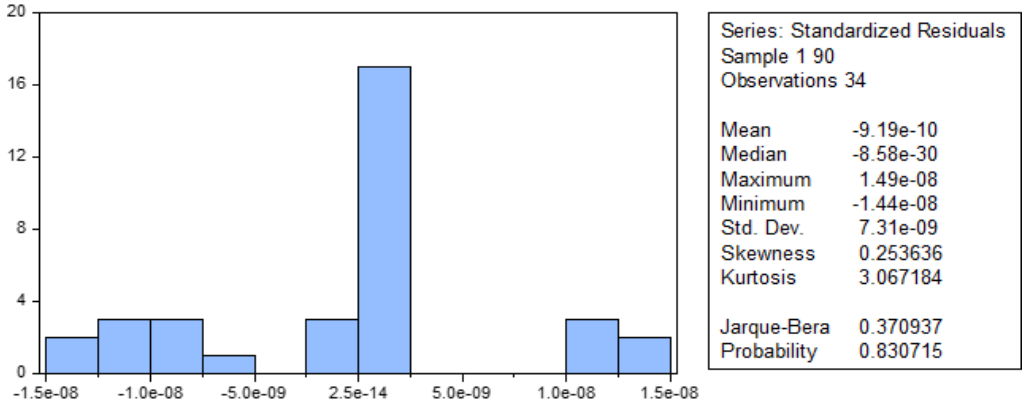

Fig. 4. Statistics of main determinants of pesticide use on market gardening in the Ruzizi plain.

Table 2. Probit model of the main determinants of pesticide use on market gardening in the Ruzizi plain.

Variable	Coefficient	Std. Error	z- Statistic	Prob.	Sign.
Other economic activity	0.267204	0.300114	0.890342	0.3733	
Field acquisition mode	-0.065298	0.252286	-0.258823	0.7958	
Age	0.419036	0.358411	1.169151	0.2423	
Membership of an association	-0.085461	0.316303	-0.270186	0.7870	
Belonging to a cooperative	1.109142	0.343594	3.228062	0.0012	**
Agricultural credit	0.881283	0.363291	2.425831	0.0153	*
Main crop	-1.034503	0.198290	-5.217112	0.0000	***
Experience in agriculture	0.452066	0.134657	3.357179	0.0008	***
Experience in market gardening	0.661284	0.283571	2.331989	0.0197	*
Group	2.158147	1.970357	1.095308	0.2734	
Level of study	-0.425317	1.349299	-0.315214	0.7526	
Quality of life	0.695025	0.282491	2.460344	0.0139	*
Objective of culture	4.442337	3.179936	1.396989	0.1624	
Yield	0.773323	0.192882	4.009302	0.0001	***
Capacity building	1.038323	0.355074	2.924240	0.0035	**
Gender	1.659946	0.419542	3.956568	0.0001	***
Available area	-0.942013	0.623476	-1.510905	0.1308	
Area exploited	1.694285	0.521136	3.251138	0.0011	**
Cultivation system	0.919620	0.405367	2.268614	0.0233	*
Household size	-0.322339	0.407517	-0.790982	0.4290	
Constant	-1.185167	0.404544	-2.929637	0.0034	**
McFadden R-squared: 0.825301					
LR statistic: 93.37126					
Restr. Deviation: 113.1360					

market garden crops. These variables are among others: membership in a cooperative, access to agricultural credit, main crop, experience in agriculture, experience in market gardening, standard of living, yield, strengthening of capacity, gender, area exploited (sown) and cropping system. These variables had a positive or negative influence on the use of pesticides in market gardens.

Belonging to a cooperative significantly and positively influences at the 5% threshold the probability of using pesticides in the face of disease and pest attack (Fig. 7). Market gardeners who are part of a cooperative tend to use pesticides more than others who are not part of cooperatives. Access to credit positively influences the use of pesticides at the 10% threshold. The more market gardeners have access to agricultural credit, the more they have enough means to pay for good quality agricultural inputs which will facilitate the use of pesticides for pest control. The main crop had a significant effect on the probability of pesticide use at the 1% threshold. Experience in agriculture is a variable that had a significant and positive influence on the use of pesticides at the 1% threshold. This shows that those with more farming experience have a greater understanding of the risks of diseases and pests on yield reduction. Experience in market gardening significantly and positively influences the use of pesticides on market garden crops at a threshold of 10%. This shows that the more experience we have in the activity, the more we control the risks linked to the non-use of pesticides on market garden crops which are more sensitive to attacks by diseases and pests, and which reduce the yield up to 100% if the products are not effective or if the control is not carried out. The standard of living had a significant and positive influence on the use of pesticides at the 10% threshold. This is linked to the price that new technologies cost. Yield positively and highly significantly influenced pesticide use at the 1% threshold. This shows that the more effectively pesticides control pests and allow crops to express their potential; the more market gardeners tend to use pesticides to enable plants to give good yields. Improving crop productivity would allow market gardeners to earn more to purchase pesticides for the next use. Capacity building had a significant influence on the use of pesticides at the 5% threshold.

In most cases, any innovation has technical risks whose impact on life delays adoption and/or acceptability. Technical supervision by extension workers or other specialists in the field reduces technical risks and promotes the use or adoption of an innovation. Farmers who are not in contact with support services are unaware of the advantages of innovation and their existence and/or the techniques of use. Gender significantly influences at the 1% threshold on the probability of using pesticides on market gardening in the Ruzizi plain. Like all field work, applying pesticides requires a lot of energy; therefore, the less weak women are, the less likely they are to use pesticides on crops. The exploited surface area had a significant and positive influence on the use of pesticides at the 5% threshold. Land rental is an abundant activity among market gardeners in the Ruzizi plain. As for the area exploited, the average area was 1 square (25 mx 25 m), which shows that in this area, the use of pesticides can be possible and/or considered regardless of the crop grown. The cropping system significantly and positively influences the probability of using pesticides on market garden crops at the 10% threshold. Generally, market

Fig. 7. Images showing diseases and pests on tomatoes (1a-e, 3), onion root (2) and amaranth (4), including pesticides (5) inventoried during the survey.

gardeners who practice monoculture tend to use pesticides much more to protect crops against diseases and pests (Fig. 7).

About 67.8% of Kamanyola, Luvungi and Sange market gardeners use pesticides to protect their crops against diseases and pests. On the other hand, 32.2% of the latter do not use pesticides (Fig. 5). In Luvungi, 70% of market gardeners use pesticides while 30% of the latter do not use them. The same results show that 53.3% of market gardeners in Sange use pesticides while 46.4% do not use them. And, in Kamanyola, a large percentage (80%) of market gardeners apply pesticides to their crops while 20% do not apply any pesticides to protect their crops against diseases and pests.

The use of pesticides on vegetable crops was influenced positively or negatively by the 11 variables presented in the table above (Tab. 3). Indeed, the use of pesticides by market gardeners who are members of an agricultural cooperative was 38.9%. As for access to agricultural credit, 26.7% have access to credit. Tomato growers are the largest users of pesticides (61.1%). Agricultural experience positively influences the use of pesticides on vegetable crops. Market gardeners with less than 5 years in agriculture use more pesticides (36.7%) than those with more than 20 years (25.6%). For those with experience between 5-10 years and 11-20 years, the utilization rate is 24.4% and 13.3%. The rate of pesticide use among market gardeners who have less than 5 years of experience is 51.8% compared to those with more than 5 years of experience which is 48.9%. This shows that the use of pesticides among less expert market gardeners is higher (51.8%) than among the most expert, which is lower (48.9%). The use of pesticides was significantly influenced by the standard of living of market gardeners (Tab. 3). The rate of pesticide use is higher (60%) among market gardeners who have an acceptable standard of living and lower (40%) among those who have a low standard of

Table 3. Rate of use of pesticides according to the different factors having significantly influenced their use

Variables		Use of pesticides		Overall
		Non-	User	
Belonging to a cooperative	No	86.20	49.20	61.10
	Yes	13.80	50.80	38.90
Agricultural credit	No	89.70	65.60	73.30
	Yes	10.30	34.40	26.70
Main crop	Tomato	24.10	78.70	61.10
	Onion	24.10	16.40	18.90
	Amaranth	51.70	4.90	20.00
Experience in agriculture	<5 years	55.20	27.90	36.70
	5-10 years	27.60	23.00	24.40
	11-20 years	13.80	13.10	13.30
	>20 years	3.40	36.10	25.60
Experience in market gardening	<5 years	69.00	42.60	51.10
	>5 years	31.00	57.40	48.90
Quality of life	Weak	58.60	31.10	40.00
	Acceptable	41.40	68.90	60.00
Yield	Weak	48.30	16.40	26.70
	Average	41.40	31.10	34.40
	High	10.30	52.50	38.90
Capacity building	No	89.70	59.00	68.90
	Yes	10.30	41.00	31.10
Gender	Feminine	65.50	9.80	27.80
	Male	34.50	90.20	72.20
Area exploited	≤0.5ha	86.20	36.10	52.20
	>0.5ha	13.80	63.90	47.80
Cultivation system	Monoculture	82.80	47.50	58.90
	Association	17.20	52.50	41.10

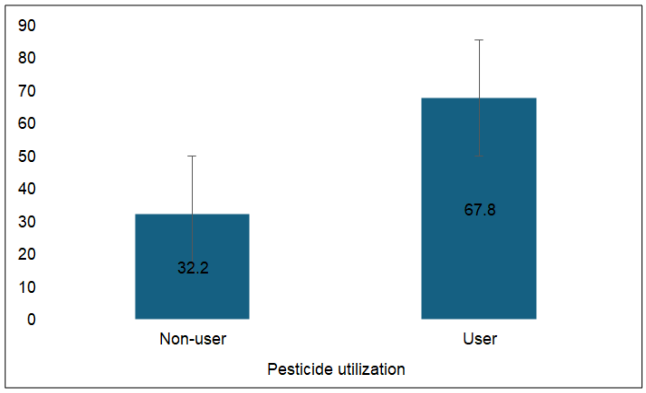

Fig. 5. Rate of pesticide use in the Ruzizi plain

living. Furthermore, it was high (38.9%) among market gardeners who obtained average yields and lower (26.7%) among those obtaining low yields. The rate of pesticide use was significantly influenced by capacity building (training). It was higher (68.9%) among market gardeners who had not received any training on the use of pesticides and lower (31.1%) among market gardeners who had followed at least one training on the use of pesticides. pesticides. It is also higher (72.2%) among men and lower (27.8%) among women. Pesticide use was significantly influenced by the area sown. The rate of use of the latter is higher (52.2%) among market gardeners operating areas less than or equal to 0.5 ha and lower (47.8%) among those operating areas greater than 0. 5 ha. The cropping system also influences the use of pesticides on market garden crops; however, its rate of use is higher (58.9%) in monoculture than in combination of crops where it is lower (41.1%).

Effect of pesticide use in disease and pest control

About 80% of market gardeners using pesticides find that this use is profitable while 20% of the latter show that this use is not (Fig. 6). In fact, 91.8% of market gardeners using pesticides say that this use is profitable while 8.2% of the

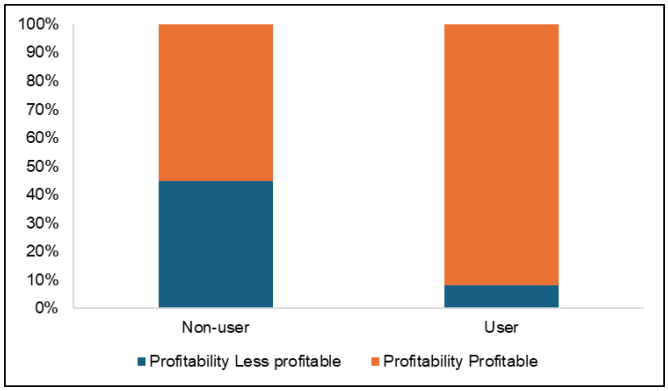

Fig. 6. Share of pesticide use on improving the productivity of market gardening through the management of diseases and pests

latter showed that this use is less profitable. On the other hand, 55.2% of non-users say that their crops are profitable despite not using pesticides while 44.8% of the latter show that their crops are less profitable.

The incidence and severity of diseases and pests vary from one disease to another and from one pest to another. Although Downy mildew and damping off present the same severity value (2), their incidence values show that damping off is the most devastating disease (23.15%) than downy mildew (17, 51%). In addition, the same severity value is present on all the frequent tomato pests in the Ruzizi plain, i.e. the value (2) but the incidence varies from one pest to another, including the rat. 18.81%, the caterpillar 13.63 and the aphid 14.92%. Therefore, the rat is the most pest of tomatoes with an incidence of 18.1% although it obtained rating 2 like the other pests (Tab. 4).

The incidence and severity of onion diseases and pests varies from one disease to another and from one pest to another. Downy mildew is a common disease in onions with less sappy effects (2) and a low incidence of 11.27%. Only in Kamanyola, downy mildew is present in onions, with severe cases. The rat which is the main pest of this crop has an incidence of 18.39% with rating 2. The caterpillar and the aphid also have less severe damage with rating 2 for severity and incidences of 9.98% and 12.08% (Tab. 5).

The price of the main crops grown in the Ruzizi Plain varies from one crop to another and from one pesticide user to another. The average price of tomatoes is 5168.75 ± 1124.93 CDF (Congolese Franc) per 20 liter can, that of onions is 40333.33 ± 1372.61 per 50 kg load and that of amaranth 7400 .00 ± 1183.22 CDF per 100 kg bag. Using pesticides increases and/or influences the price of products because untreated products have pest bites or disease symptoms, for example, mildew. Then, these stains and/or bites will affect the quality of the products by making them

Table 4. Effect of pesticide use on the incidence and severity of diseases and pests in tomato cultivation

Adoption level	Mildew		Damping off		Rat		Caterpillar		Aphid	
	INC	SEV	INC	SEV	INC	SEV	INC	SEV	INC	SEV
Luvungi	18.25	2	25.00	2	15.25	2	19.26	2	12.70	2
Not used	27.40	3	25.00	2	15.54	2	30.24	3	-	-
Use	9.11	2	-	-	13.63	2	8.29	2	12.70	2
Sange	18.12	2	29.67	3	15.13	2	8.62	2	14.24	2
Not used	24.81	2	29.67	3	20.97	2	12.27	2	14.24	2
Use	11.44	2	-	-	11.23	2	4.98	2	-	-
Kamanyola	16.16	5	14.80	2	23.43	2	13.03	2	17.84	2
Not used	26.18	3	14.80	2	25.11	3	17.30	2	23.50	2
Use	6.15	2	-	-	19.23	2	10.59	2	15.66	2
Overall mean	17.51	2	23.15	2	18.81	2	13.63	2	14.92	2

INC: incidence; SEV: severity, The different severity levels: 1=0 %, 2=1 to 25%, 3=25.1 to 50%, 4=50.1 to 75%, 4=75.1 to 100%, 5= >100% .

Table 5. Effect of pesticide use on the incidence and severity of diseases and pests in onion cultivation

Adoption level	Mildew		Rat		Caterpillar		Aphid	
	INC	SEV	INC	SEV	INC	SEV	INC	SEV
Luvungi	-	-	15.20	2	1.63	2	4.91	2
Not used	-	-	17.48	2	-	-	4.91	2
Use	-	-	8.33	2	1.63	2	-	-
Sange	-	-	26.66	3	-	-	-	-
Not used	-	-	26.66	3	-	-	-	-
Use	-	-	-	-	-	-	-	-
Kamanyola	11.27	2	19.89	2	11.17	2	12.98	2
Not used	16.61	2	26.00	3	12.05	2	23.60	2
Use	5.94	2	16.83	2	5.90	2	11.46	2
Total	11.27	2	18.39	2	9.98	2	12.08	2

Table 6. Effect of pesticide use on the price of vegetable crops

	Tomato Price (CDF)	Onion Price (CDF)	Amaranth Price (CDF)
Non-user	4785.71 ± 1778.84	40285.71 ± 1704.34	7200.00 ± 1032.80
User	5305.08 ± 748.66	40352.94 ± 1271.87	7800.00 ± 1483.24
Total	5168.75 ± 1124.93	40333.33 ± 1372.61	7400.00 ± 1183.22

		Levene 's test for equality of variances		t-test for equality of means						
		F	Sig .	T	ddl	Sig . (bilateral)	Average difference	Difference standard deviation	95% confidence interval of the difference Lower	Superior
Tomato Price	Assumption of equal variances	6,216	0.015	-1,844	78	0.069	-519,370	281,599	-1079.992	41,251
	Assumption of unequal variances			-1,298	22,570	0.207	-519,370	400,225	-1348.172	309,431
Onion Price	Assumption of equal variances	0.287	0.598	-0.107	22	0.916	-67,227	630,115	-1374.005	1239,551
	Assumption of unequal variances			-0.094	8,892	0.927	-67,227	714,228	-1685.923	1551,469
Amaranth Price	Assumption of equal variances	0.073	0.791	-0.921	13	0.374	-600,000	651,625	-2007.751	807,751
	Assumption of unequal variances			-0.812	6,017	0.448	-600,000	739,369	-2407.911	1207,911

unfit for consumption and marketing (sale) compared to treated products which will not present any symptoms of disease or any bite, no crushing and/or damage by insects or other pests (Tab. 6). Indeed, the cooperativeness of products in the markets will also be influenced by the presence or absence of pest bites which affect the quality of foodstuffs by making them unfit for consumption and sale.

The incidence of diseases was influenced by applying pesticides on different market garden crops (Tab. 7). Indeed, the incidence of caterpillars on the onion was significantly influenced (p=0.006) by the application of Roket. In addition, the application of Ratox influences rat incidence in a very highly significant manner (p=0.0000) on tomato. Regarding the application of Lava, the incidence of aphids in tomatoes is significantly influenced (p=0.045) by the application of the latter. The incidence of Downy Mildew on tomatoes (p=0.012) and caterpillars (p=0.004) on this same crop are significantly influenced by the application of Dithane. Finally, the application of Dudu significantly influences the incidence of downy mildew (p= 0.012) and caterpillar (p=0.043) on tomatoes.

Contribution of weeds inventoried in the individualization of level of soil fertility level in farmer fields

In the villages surveyed, the farmer fields considered having high fertility level included the presence of species such as *Commelina benghalensis*, *Digitaria vestida var scalarum, Bidens pilosa*, *Conyza sumatrensis, Cyperus rotondus* and *Eragrotis aspera.* Fields with medium or average fertility comprehend species like *Eragrotis tenuifolia, Imperata cylindrica*, *Gallinsoga palviflora*, *Cyperus distans*, *Brothiocline longipes* and *Sida rhombifolia*. They are

Table 7. Influence of different products on the incidence of crops. With R^2: coefficient of determination; IMT: tomato late blight incidence; IFST: incidence of tomato damping-off; IMO: onion late blight incidence; IRT: tomato rat incidence; IRO: onion rat incidence; ICT: tomato caterpillar incidence; ICO: onion caterpillar incidence; IPT: tomato aphid incidence

Pesticides		IMT	IFST	IMO	IRT	IRO	ICT	ICO	IPT
	R^2	0.002	0.022	0.008	0.001	0.018	0.010	0.084	0.020
Rocket	F	0.199	1,986	0.701	0.087	1,570	0.908	8,076	1,826
	Pr > F	0.657	0.162	0.405	0.768	0.214	0.343	**0.006**	0.180
	R^2	0.011	0.004	0.005	0.141	0.020	0.012	0.009	0.000
Ratox	F	0.979	0.326	0.486	14,447	1,823	1,082	0.819	0.004
	Pr > F	0.325	0.569	0.487	**0.000**	0.180	0.301	0.368	0.948
	R^2	0.016	0.049	0.010	0.001	0.004	0.041	0.018	0.045
Lava	F	1,432	4,559	0.905	0.075	0.387	3,754	1,646	4,146
	Pr > F	0.235	0.036	0.344	0.785	0.536	0.056	0.203	**0.045**
	R^2	0.055	0.021	0.024	0.001	0.042	0.091	0.004	0.003
Dithane	F	5,119	1,872	2,123	0.082	3,869	8,775	0.358	0.302
	Pr > F	**0.026**	0.175	0.149	0.775	0.052	**0.004**	0.551	0.584
	R^2	0.070	0.012	0.003	0.000	0.018	0.046	0.005	0.003
Dudu	F	6,582	1.031	0.281	0.000	1,617	4,221	0.437	0.277
	Pr > F	**0.012**	0.313	0.597	0.983	0.207	**0.043**	0.510	0.600

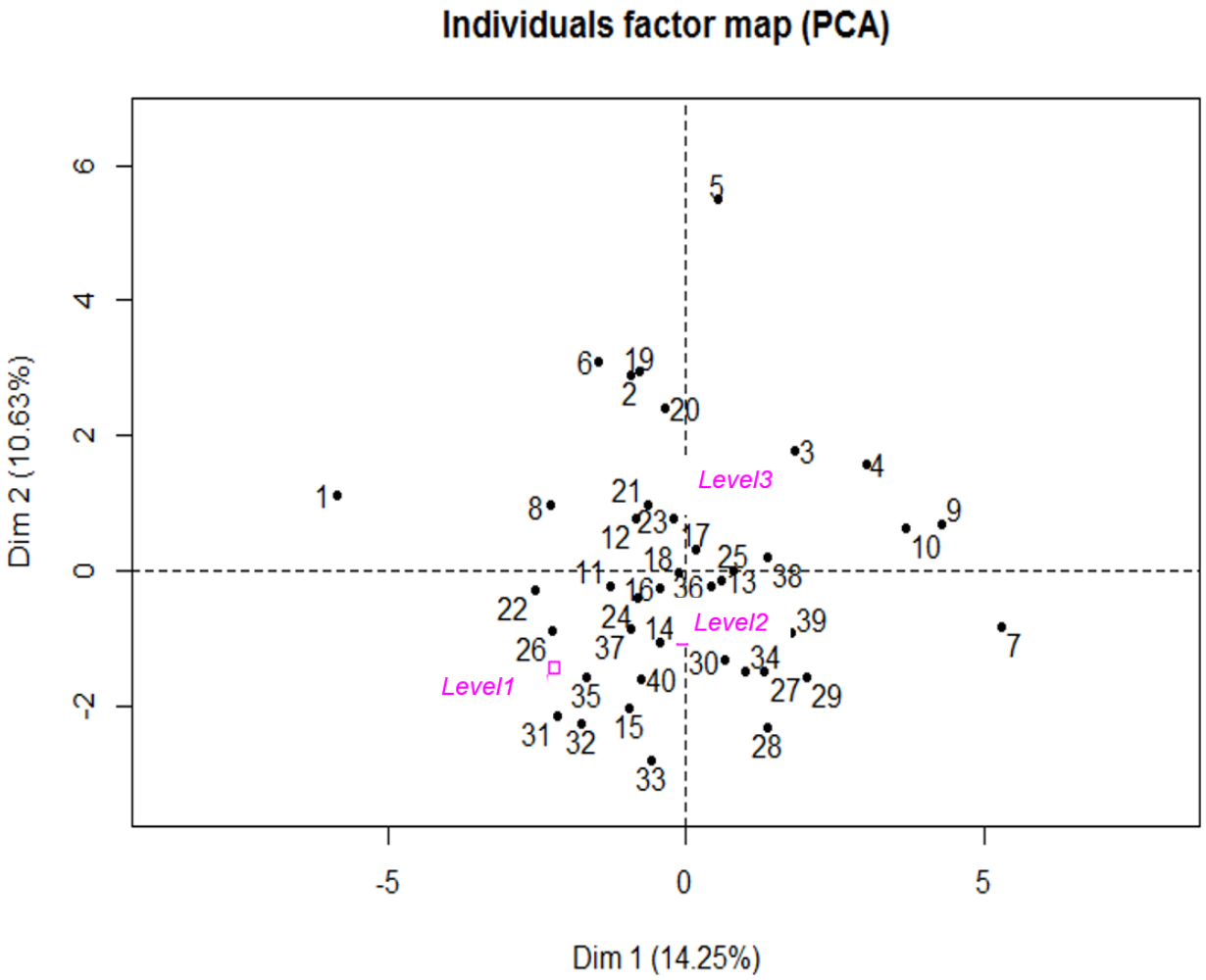

Fig. 8. Degre of closeness and fertility level. Whenever a species is close to a given level, it characterizes it very well. Legends : 1-*Oxalis corniculata*, 2-*Digitaria vestida* var. *scalarum*, 3-*Bidens pilosa*, 4-*Conyza sumantrensis*, 5-*Gallisonga palviflora*, 6-*Digitaria vestida* var. *scalarum*, 7-*Dioscorea bulbifera*, 8-*Imperata cylindrica*, 9-*Eragrotis aspera*, 10-*Digitaria vestida* var. *scalarum*, 11-*Bidens pilosa*, 12. *Digitaria vestida* var. *scalarum*, 13-*Bidens pilosa*, 14-*Sonchus oleraceus*, 15-*Spermacocae princea*, 16-*Stylosanthes graculus*, 17-*Eragrotis aspera* 18-*Sporobolus pyramidalis*, 19-*Digitaria vestida* var. scalarum 20-*Digitaria vestida* var. *scalarum* 21-*Digitaria vestida* var. *scalarum*, 22-*Oxalis corniculata*, 23.*Conyza sumatresis*, 24-*Digitaria vestida* var. *scalarum*, 25-*Digitaria vestida* var. *scalarum*, 26-Ntakayula (local name), 27.*Eragrotis tenuifolia*, 28-*Eragrotis tenuifolia*, 29-*Eragrotis tenuifolia*, 30-*Eragrotis tenuifolia*, 31-*Spermacocae ruelliae*, 32-*Spermacocae ruelliae*, 33-*Spermacocae ruelliae*, 34-*Digitaria vestida* var. *scalarum*, 35-*Spermacocae ruelliae*, 36-*Digitaria vestida* var. *scalarum*, 37-Ntakayula, 38-*Eragrotis aspera*, 39-*Digitaria vestida* var. *scalarum*, and 40-Ntakayula. Level1 : Field with low fertility ; Level2 : Field with medium fertility et Level3 : Field with high fertility

identified as the more cited species by farmers in this category. Finally, fields associated with low level of soil fertility were dominated by species that include *Oxalis corniculata*, *Spermacocae princeae*, *Ntimuka*, *Spermacoce ruelliae*, *Brachiaria lata* and *Pennisetum polystachia* as per farmer responses (Fig. 8).

Farmer perceptions on media participation in rural development

More than a half of farmers who were selected as a sample in this research (58.07%) do not know if media do broadcast the information about the development of the rural area's budget, this might be the time to present the mention agenda farmers are busy on something else so they miss the chance to hear it then media should broadcast it on conducive time for farmers in rural areas so that the information can reach majority of the rural areas people who are the targeted one (Fig. 9a). Few

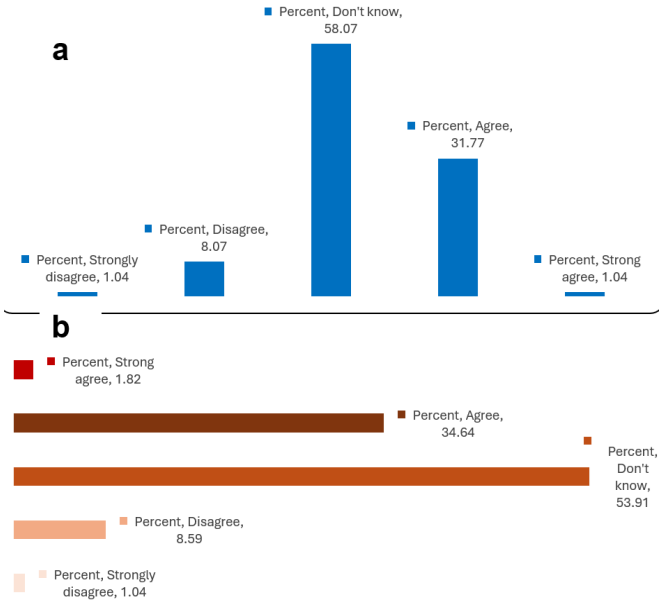

Fig. 9. (a) Media presents information about the development budget for rural areas; (b) Media take the rural development projects to the people's doorsteps.

farmers (34.64%) agreed that the media do take the rural development projects to the doorsteps of the people especially to the rural areas because of the time when the media reach to them then they are busy at farm working, so they do miss each other. Now, the media should find the time to meet and educate the farmers on rural development projects (Fig. 9b).

Discussion

Unlike our results and those of Mushagalusa et al. (28), Ntumba's study et al. (29) showed that market gardening in Lubumbashi is practiced much more by women than men. They also showed that women spend more time in the fields than men and children, which is why they are considered more active. Although women spend more time in the field than men, they only perform lighter tasks. Cishesa (30) found that a large proportion (38%) of tomato farmers have less than 10 years of experience in the activity. It shows that this insufficient experience would negatively affect the development of market gardening, which contributes significantly to food security and increased income for producers, especially in family farming. Our results agree with those of Temple et al., (31); Kasanda et al. (32) who showed that the large household size on market gardening farms is explained by the abundance of field work mainly carried out by family labor.

Adopting an innovation depends on several factors linked to the adopters' physical environment and socioeconomic conditions. The use of pesticides for effective control of diseases and pests is a function of dependent and independent variables.

Indeed, the results of the estimation of the probit model showed that membership in a cooperative, access to agricultural credit, main crop, experience in agriculture, experience in market gardening, level of life, the yield obtained, capacity building, the area exploited and the cultivation system have significantly influenced the use of pesticides among the market gardeners of Kamanyola, Luvungi and Sange in the Ruzizi plain.

Age has always been considered the key factor influencing the adoption of a new agricultural innovation (33). Our results are contrary to those of these others because, in our study area, age had no influence on the use of pesticides, however, Folefack et al. (34) and Moumirou (35) who showed that age greatly influences the probability of adopting an innovation because older farmers are wary of new innovations which influence the improvement of farm production compared to older farmers. Young people who have access to the media (social networks, television, radio) try their luck by adopting new innovations.

These results are similar to those of Ngondjeb et al. (33) who showed that membership in any group significantly and positively influences the decision to use and/or adopt a new agricultural innovation. They showed that belonging to a group positively influenced the decision of members to adopt techniques to combat water erosion in the cotton zone of Cameroon. This use is linked to the membership of a group because members share the same group exchange experiences, which, in return, influences the management of agricultural operations within a rural community.

According to Mabah et al. (36), members of the same cooperative discuss their production constraints, the solutions tested by each other, the effects of new technologies and production techniques with the members of their entourage. Furthermore, gender and access to agricultural credit significantly and positively influence the use of pesticides on market gardening grown in the Ruzizi plain. These results are in agreement with those of Xaba et al. (37) who showed that access to agricultural credit positively influences the improvement of agricultural production in Swaziland. This is explained by the fact that access to agricultural credit empowers the farmer who purchases quality inputs himself to maximize yield. In addition, gender positively and significantly influences the use or adoption of agrarian innovation since men are more informed and have access to several production factors than women.

Our results showed that the priority or primary or exclusive crop negatively and significantly influences the use of pesticides in market gardening in the Ruzizi Plain. These results are similar to those of Moumirou (35) and Shukuru (3), who showed that the priority or exclusive cultivation of agricultural production does not improve the perception of adopting technical innovations. This could be explained by new technologies' effects on a given culture.

Strengthening the capacities of market gardeners in the Ruzizi plain has had a positive and significant influence on the use of pesticides on market garden crops. These results are similar to those of Adekambi et al. (38), Shukuru and Archana (24) and Shukuru et al. (14, 17), who estimate that the supervision of farmers positively affects the adoption of agricultural technologies. A producer supervised and monitored by the extension services changes his decision favouring the new technology. Capacity building improves the knowledge and skills of individuals and leads them to adopt favourable behaviour towards innovations.

Also, capacity building (training) that puts farmers in contact with extension services positively influences the probability of adopting a new agricultural innovation. Our results are similar to those of Mabah et al. (39), Johnson et al. (40) and Shukuru et al. (11), who showed that capacity building by extension workers increases the decision-making process for adopting new agricultural innovation. This positive relationship is explained by the fact that when new technologies are introduced into an environment, there is often intense uncertainty about their effectiveness in local conditions; the uncertainty decreases over time when certain Farmers in the region adopt and gain experience with the new technology, they then serve as a reference for other farmers in the area (39).

The effect of the area operated and experience as a factor influencing the probability of adopting pesticides on market garden crops could be explained by the fact that in rural areas, most farmers operate small areas of less than 1.5 ha, mainly rented. Furthermore, the number of years in an activity positively influences the use of any technology, given that the more people practice the same activity, the more experience they acquire and become aware of technical risks. These results are similar to those of Alabi et al. (41), who found that area sown and experience positively affected decision-making regarding agrochemical energy use in Nigeria. Ojo and Ogunyemi (42) also showed that cultivated areas significantly and positively influenced the adoption of new technologies in cassava production in Nigeria. Although experience in agriculture and cassava production influences the adoption of cassava production technologies, these same authors found that these variables had adverse effects.

Indeed, our results showed that after estimating the model, the standard of living of market gardeners had a positive and significant influence on the use of pesticides against the control of diseases and pests of market garden crops in the Ruzizi plain. These results are similar to those of Abdoulaye et al. (43), who showed that farmers' living standards significantly influenced the adoption of improved cassava varieties and processing technologies.

The yield obtained from crops positively and significantly influences the use of pesticides to effectively control diseases and pests. In our study, the improvement in the productivity of market gardening depends on the use of pesticides. These results are similar to those synthesized by the book of Shukuru (4), who showed that the yield or performance of a crop in giving better yield for consumption and sale is the variable that pushes any farmer to adopt a new technology that would allow them to harvest more.

According to Ngongo and Lunze (44) findings, it has been demonstrated that, like *Gallinsoga parviflora*, *Bidens pilosa* is considered as an excellent indicator of soil fertility in each site, indicateing the value of the soil use in agriculture. In addition, other species from Asteraceae family in which belong *Gallinsoga parviflora*, *Bidens pilosa*, *Conyza sumatrensis* and others, are nostly find in banana fields and lower with an excellent fertility of the soil (4). The difference is that *Pennisetum polystachia* grows in poor soils, meaning with very low fertility, but *Conyza sumatrensis* and *Digitaria vestida* show a high naturally productive soil when there are presents at a given agricultural area (44).

The focus of rural development today is not exclusively on farms, and more attention has been given to the increasingly interconnected continuum of urban and rural areas (4, 11, 45, 46). The relationship between the ordinary natural resources and the development of rural areas is still significant (4). It is imperative to verify that programs fulfil their goals in every rural development initiative (4, 47). Even detrimental outcomes require a long- and short-term perspective on development for the given field. Results in which the societies get benefits more broadly (that means the support of multiple latent plans, improve the infrastructure, and increase a place's marketability) can occasionally be explained using qualitative methods, such as focus groups, as opposed to quantitative methods, which are suitable in metropolitan settings (4, 14). Telling the story of the project's history and the community's development and future goals is crucial. Nevertheless, Gruchow (48) said it is a strange irony that the places we fill up become increasingly empty while the places we call empty should hold several memories of different kinds of life.

Conclusion

Market gardening in the Ruzizi plain is crucial for food security and economic stability. Our study examined factors affecting pesticide use in this sector, revealing challenges and opportunities for sustainable intensification. Through surveys and analysis, we identified vital determinants: cooperative membership, access to credit, farming experience, living standards, yield and cultivation practices. Notably, prioritizing certain crops reduced pesticide usage, with tomatoes dominating. This highlights the need for targeted pest management. Socioeconomic factors intricately shape agricultural practices, emphasizing tailored strategies for the region.

Enhanced information dissemination, cooperative strengthening and skill development can boost resilience and productivity. Media is pivotal in rural development, offering avenues for knowledge dissemination and participatory engagement. Scientists and development agents should consider these variables to improve pesticide adoption rates, unlocking agricultural potential while controlling pests and diseases.

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Authors' contributions

Kasonta, A.A: Conceptualization, methodology, investigation/ survey, data collection, data analysis, writing and preparation of the manuscript, and production of the first format. Birindwa J-CM: methodology, supervision, data analysis, resources, writing and preparation of the manuscript, and production and editing of the first format. Thakur, S.S.: incorporation of necessary corrections until final submission, supervision.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. Nabahat B, Soumaya B, Mebrouk K, Djamel E. Aggressiveness and morphological variability of small spore Alternaria species isolated from Algeria, Journal of Experimental Biology and Agricultural Sciences.2014;2(2S):266-78.
2. Kouassi F, Koffi J, N'Goran S, IpouIpou J. Fodder production potential of a grazed area threatened with destruction: case of the Port-Bouët and Grand-Bassam coastal barrier, Journal of Applied Biosciences.2014; 82:7403-410. https://doi.org/10.4314/jab.v82i1.13
3. Shukuru BN. Analysis of profitability and the level of agronomic and economic efficiencies among small-scale producers of rice in Ruzizi plain, eastern D.R. Congo. Asian Journal of Plant and Soil Sciences. 2022a;7(1):185-95. https://doi.org/10.56557/ajopss/2022/v7i171 .
4. Shukuru, B.N. (2022b). Current trends in rice production and consumption: rice cultivation and traits and analysis of agronomic and economic efficiencies for sustainable rural development. Lambert Academic Publisher, Chisinau: Moldova; 2022b.Available at https://www.morebooks.shop/shop-ui/shop/product/9786205518991
5. Dossou J, Soulé I, Montcho M. Evaluation of the physicochemical and sensory characteristics of local tomato puree produced on a small scale in Benin, Tropicultura.2009; 25 (2):119-25.
6. James B, Atcha-Ahowé C, Godonou I, Baimey H, et al. Integrated management of pests in market gardening: Guide for extension agents in West Africa. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria;2010.
7. Fall A, Ba Diao M, Bastianelli D, Naniogo A, 2004. Concerted and sustainable management of urban animal sectors. In Olanrewaju B, Moustier P, Mougeot LJA, Fall A. Sustainable development of urban agriculture in Francophone Africa. Issues, concepts and method. Montpellier, France: CIRAD - CRDI, 96-22.
8. Moustier P, Moumbélé M, Huat J. Concerted and sustainable management of urban market gardening sectors. In Olanrewaju B, Moustier P, Mougeot LJA, Fall A. Sustainable development of urban agriculture in French-speaking Africa. Issues, concepts and method. Montpellier, France: CIRAD - CRDI; 2004. 66-95.
9. Mfoukou-Ntsakala A, Bitémo M, Speybroeck N, Huylenbroeck G, Thys E. Urban agriculture and household livelihoods in a post-conflict zone in Central Africa, Biotechnol . Agron . Soc. Approximately.2010;10(3):237-49.
10. Nchoutnji I, Fofiri E, Olina JP, Temple L, Kameni A. Market gardening systems in urban and peri-urban environments in the Sudano-Sahelian and Sudano-Guinean zones of Cameroon: case of Garoua and Ngaoundéré, Tropicultura.2009; 27(2):98-104.
11. Shukuru BN, Archana TS, Bisimwa EB, Birindwa DR, et al. Screening of cultivars against cassava brown streak disease and molecular identification of the phytopathogenic infection-associated viruses. Archives of Phytopathology and Plant Protection. 2022;55(16):1899-29. https://doi.org/10.1080/03235408.2022.2123590.
12. Hillocks RJ. Cassava virus disease and their control with special reference to southern Tanzania. Integrated Pest Management Reviews. 1997;2:125-38. https://doi.org/10.1023/A:1018449017411.
13. Legg JP, Raya MD. Survey of cassava virus diseases in Tanzania. International Journal of Pest Management. 1998; 44(1),17-23. https://doi.org/10.1080/096708798228473.
14. Shukuru BN, Sharma S, Birindwa JC. Characterization of the 31 genotypes cultivated under the threat of cassava brown streak disease. IOSR Journal of Agriculture and Veterinary Science. 2021; 14(12), 45-53. http://ssrn.com/abstract=3995371.
15. Hillocks RJ, Raya MD, Mtunda K, Kiozia H. Effects of brown streak virus disease on yield and quality of cassava in Tanzania. Journal of Phytopathology. 2001; 149(7-9):389-94. https://doi.org/10.1111/j.1439-0434.2001.tb03868.x.
16. Ouédraogo M, Tankoano A, Ouédraogo T., Guissou I. Study of risk factors for poisoning among pesticide users in the cotton-growing region of Fada N'Gourma in Burkina Faso, Environment, Risks & Health. 2009; 8(4):343-47.
17. Shukuru BN, Archana TS, Kangela AM. Rapid screening for resistance of maize inbred and hybrid lines against southern corn leaf blight. Journal of Phytopathology. 2023a; 171(9):452-69. https://doi.org/10.1111/jph.13202.
18. Shukuru BN, Archana TS, Ghosh P, Kumar A, Kumar D, Kumar V. Breeding for resistance in vegetables against meloidogyne species causing root gall disease. In: Ahmad F, Blázquez G.N. (eds) root-galling disease of vegetable plants. Singapore, Springer; 2023b.253-71. https://doi.org/10.1007/978-981-99-3892-6_10.
19. Mamadou A, Ahmed MR, Alzouma I. The impact of pesticides used to combat the desert locust (schistocerca gregaria Forskål, 1775) (orthoptera, acrididae) on two species of pimelia (coleoptera, tenebrionidae) in Niger", VertigO - the electronic journal in environmental sciences. 2005;6(3). https://doi.org/10.4000/vertigo.3665
20. Pedlowski M, Canela M, Costa Terra M, de Faria R. Modes of pesticides utilization by Brazilian smallholders and their implications for human health and the environment, Crop Protection. 2009; 31(201):112-18. https://doi.org/10.1016/j.cropro.2011.10.002

21. Anang B, Amikuzuno J. Factors influencing pesticides use in Smallholder rice production in Northern Ghana, Agriculture Forestry and Fisheries. 2015; 4(2):77-82. https://doi.org/10.11648/j.aff.20150402.19
22. Shukuru BN, Archana TS, Kumar D, Singh S, Kumar G. Chapter 15: Phyllosphere endophytic bacteria: Diversity and biotechnological potential. In: Kumar, G. et al. (Editors), Plant endophytes and secondary metabolites. Microbiome research in plants and soil. Academic press, Elsevier; 2024.269-94. https://doi.org/10.1016/B978-0-443-13365-7.00019-1
23. Van den Berg J. Socioeconomic factors affecting adoption of improved agricultural practices by small scale farmers in South Africa, African Journal of Agricultural Research. 2013; 8(35):4490 -500. https://doi.org/10.5897/AJAR12.1025
24. Shukuru BN, Archana TS. Effectiveness of transplant date and sowing density related to tillering capacity of rice (*Oryza sativa* L.). Journal of Global Agriculture and Ecology. 2021; 12(4):31-42. https://ikprress.org/index.php/JOGAE/article/view/7401
25. Mafikiri T. Impact of the introduction of an innovation on the development of peasant farms in the mountainous areas of Kivu (Zaire), Tropicultura. 1993; 11(1):11-15.
26. Njangwe B, Henrard C, Dubois M, Malaisse F. Traditional phytotherapy of cattle on livestock farms in the Ruzizi plain, Biotechnol. Agron. Soc. Approximately. 2000; 4(3):135-56.
27. Lunze L. Possibilities for managing soil fertility in South Kivu Montagneux. Cahiers du CERPRU. 2000;14,23-26.
28. Mushagalusa A, Baraka P, Lenga A, Madi D, Ilunga F, Nkulu J. Gender and family farming in rural Katanga: case study of Kipushi, International Journal of Innovation and Applied Studies. 2015; 11(2):367-75.
29. Ntumba F, Tshomba J, Muyombo E, Kirika A, Nkulu M. Market gardening and access to production factors in the socioeconomic context of Lubumbashi, International Journal of Innovation and Applied Studies. 2015; 13(3):527-37.
30. Cishesa T. Tomato production, constraints and opportunities in Walungu territory , South Kivu, Eastern DR Congo, International Journal of Innovation and Scientific Research. 2016; 23(1):15-27.
31. Temple L, Marquis S, Simon S. Is peri-urban market gardening in Yaoundé an innovative localized production system? Economies and Societies agri-food series. 2008;30,2309-28. https://doi.org/10.3406/esag.2008.970
32. Kasanda N, Mushagalusa A, Kitsali H, Nukulu J, Bogaert J. Peri-urban market gardening in Lubumbashi: modes of access to land and management of agricultural areas, International Journal of Innovation and Applied Studies. 2016; 14(1):27-36.
33. Ngondjeb Y, Nje P, Havard M. Determinants of the adoption of techniques to combat water erosion in the cotton-growing area of Cameroon, Revue d'livestock and veterinary medicine of tropical countries. 2011; 64(1-4):9-19. https://doi.org/10.19182/remvt.10120
34. Folefack P, Sale A, Wakponou A. Factors affecting the use of organic manure on farms in the Sahelian zones of Cameroon, Afrique Science. 2012; 8(2):22-33.
35. Moumirou I. Perception and adoption of agricultural technical innovations in the Banikoara cotton basin in Benin, African Journal of Agricultural and Resource Economics. 2015; 10(2):87-102.
36. Mabah G, Havard M, Temple L. Socioeconomic and institutional determinants of the adoption of technical innovations concerning maize production in Western Cameroon, Tropicultura. 2013; 31(2):137-42.
37. Xaba B, Masuku M. Factors affecting the productivity and profitability of vegetables production in Swaziland, Journal of Agriculture Studies. 2013; 1(2):37-52. https://doi.org/10.5296/jas.v1i2.3748
38. Adekambi S., Adegbola P, Arouna Y. Farmer's perception and agricultural technology adoption. The case of botanical extracts and biopesticides in vegetable production in Benin, Contributed Paper presented at the Joint 3 rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23;2010.
39. Mabah L, Temple L, Havard M. The determinants of the adoption of technical innovations on corn in Cameroon, a contribution to food security. 2015;283-91.
40. Johnson A, Lakoh A, Saidu E, Kobba F. An assessment of early adoption of improvement in Bo district, Southern Sierra Leone, International Journal of Agriculture and Food Science Technology. 2013; 5(3):135-40.
41. Alabi O, Lawal A, Coker A, Awoyinka Y. Probit model analysis of smallholder's farmers decision to use agrochemical inputs in Gwagwalada and Kuje area councils of federal capital territory, Abuja, Nigeria, International Journal of Food and Agricultural Economics. 2014; 2(1):85-93.
42. Ojo S, Ogunyemi A. Analysis of factors influencing the adoption of improved cassava production technology in Ekiti State, Nigeria. International Journal of Agricultural Sciences and Natural Resources. Flight. 2014; 1(3):40-44.
43. Abdoulaye T, Abass A, Maziya-Dixon B, Okechukwu R, et al. Awareness and adoption of improved cassava varieties and processing technologies in Nigeria, Journal of Development and Agricultural Economics. 2014; 6(2):67-75. https://doi.org/10.5897/JDAE2013.006
44. Ngongo M, Lunze L. Espèce d'herbe Dominante comme Indice de la Productivité du Sol et de la Réponse du Haricot Commun à l'application du Compost. African Crop Science Journal. 2000;8 (3):251-61. https://doi.org/10.4314/acsj.v8i3.27690
45. Scott K, Rowe F, Pollock V. Creating the good life? A wellbeing perspective on cultural value in rural development. J Rural Stud. 2016;1-10. http:// doi.org/10.1016/j.jrurstud.2016.07.001
46. Usadolo SE, Caldwel M. A stakeholder approach to community participation in a rural development project. SAGE Open; 2016. https://doi.org/10.1177/2158244016638132
47. Townsend L, Wallace C, Fairhurst G, Anderson A. Broadband and the creative industries in rural Scotland. J Rural Stud. 2016; 1-8. http:// doi.org/10.1016/j.jrurstud.2016.09.001
48. Gruchow P. The necessity of empty places. St. Martin's Press, New York; 1988