Research Article

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Agro-input dealers' perspectives on the design of a certification scheme for pesticide risk reduction

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Abstract

BACKGROUND: While pesticides are essential for crop protection and food security, they pose serious risks to human health and the environment. Agro-input dealers can play an important role in mitigating pesticide risks, given that they are a major source of pesticides and plant health information for many developing-country farmers. In this article, we assess the willingness of agro-input dealers to offer integrated pest management-based advisory services and promote pesticide risk reduction through a voluntary certification scheme.

RESULTS: Using survey data from 557 agro-input dealers in Uganda and a discrete choice experiment, we find that the proposed certification scheme is significantly valued by agro-input dealers, particularly for its potential to provide training opportunities and ensure safety to human health and the environment. Agro-input dealers have a positive attitude towards a certification scheme that restricts the sale of high-risk pesticide products, especially if it stimulates additional income-generating opportunities. Further analysis shows that preferences for voluntary certification attributes are influenced by certification experience, agro-dealership experience, business ownership status and incidence of acute pesticide poisoning.

CONCLUSION: The study findings demonstrate that agro-input dealers are conscious of pesticide risks to human and environmental health and are keen to participate in a certification scheme promoting safer plant protection products.

Supporting information may be found in the online version of this article.

Keywords: agro-input dealers; certification; pesticide; integrated pest management; environmental sustainability

1 INTRODUCTION

The increasing occurrence of devastating crop pests, such as fall armyworm (*Spodoptera frugiperda*) and tomato leafminer (*Phthorimaea absoluta*), have spurred a rapid increase in pesticide sales and use in many countries worldwide.[1] While pesticides can help reduce crop losses significantly, there is growing evidence pointing to high use of highly toxic products and poor pesticide handling practices among farmers, potentially posing risks to human health and the environment.[2–4] This has stimulated calls for the promotion of integrated pest management (IPM)[†] and safe pesticide use,[3,5] as well as the introduction of several policies to mitigate the environmental and health risks of pesticides.[6]

In many developing countries, including Uganda, agro-input dealers (hereafter referred to simply as agro-dealers[‡]) are the primary conduit of pesticides and a key source of plant health information to farmers.[7–10] Thus, agro-dealers can play an important

[†]IPM involves the management of pests using a combination of cultural, biological and mechanical control methods, pest- resistant varieties, as well as rational use of pesticides, as a last resort.

[‡]Agro-input dealers are retailers who stock and sell agricultural inputs, such as pesticides, fertilisers and seeds. They are the main source of pesticides for farmers in Uganda.

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role in mitigating the risks of pesticides to humans and the environment. While a few previous studies have investigated agro-dealers' role in pesticide risk reduction, they focussed mostly on pesticide knowledge and practices of agro-dealers and the advice they give to farmers.[9–13] For instance, Staudacher *et al.*[9] found that Ugandan agro-dealers have a limited understanding of pesticide active ingredients and frequently sell highly hazardous pesticides to their customers. Similarly, Li *et al.*[10] showed that some agro-dealers in China tend to advise farmers to use more pesticides than recommended, but government regulation can influence the agro-dealers to provide more accurate information on pesticide use to farmers. In the current study, we assess if agro-dealers would be willing to shift from the sale of high- to lower-risk plant protection products and contribute to pesticide risk reduction through a voluntary certification scheme.

We hypothesise that agro-dealers will be keen to participate in a sustainability-oriented voluntary certification scheme because it can contribute to building their capacity to provide appropriate advice on IPM and safe pesticide handling practices, which is often lacking among many agro-dealers in developing economies.[11,14] This can in turn enhance their reputation of providing reliable and environmentally sound products, thereby increasing their competitiveness. Moreover, in addition to a potential increase in product sales, certified agro-dealers could obtain market advantage through the provision of quality plant health diagnostic and advisory services to farmers. Such a business model could help address concerns that profit-seeking pesticide dealers may lack the incentive to shift towards products or give IPM-based advice that might reduce pesticide demand and sales.[15] It is also possible that agro-dealers would be interested in the certification scheme in order to protect their own health, given the health risks associated with the pesticides they sell.

Specifically, this study aims to investigate agro-dealers' attitudes towards the design of a voluntary agro-dealer certification scheme aimed at reducing pesticide risks. It will also analyse the relative importance of different design features, including potential requirements and benefits of the certification scheme. We also explore if preferences for the voluntary certification scheme are influenced by agro-dealer characteristics, such as certification experience, gender, location and prior knowledge of IPM. Finally, we estimate agro-dealers' willingness to pay (WTP) to reduce environmental and health risks posed by pesticides. Our analysis is based on a survey of 557 agro-dealers across all the sub-regions of Uganda.

Our study makes several contributions to the literature. First, we contribute to the literature on individual preferences for pesticide-reduction or agri-environmental schemes. Previous studies have largely focussed on farmers,[20–22] while we examine the preferences of agro-dealers who sell pesticides to farmers. We use a discrete choice experiment (DCE), which is a popular approach for modelling people's choices and preferences. For instance, it has been employed in studies investigating farmer preferences for sustainability standards and consumer preferences for pesticide-free food products.[20,23,24] In this study, we extend the application of DCE to agro-dealers – an important yet often-overlooked group in pesticide risk reduction research. We also contribute to the literature on the uptake of IPM, which is important given the increasing threats of invasive pests and the harmful health and environmental effects of indiscriminate use of pesticides for their control.[3] Thus, exploring the interests of private sector agents (agro-dealers) in providing IPM-based advisory services could have important policy implications for the promotion of environmentally-friendly crop protection strategies.

It should be mentioned that many developing countries, including Uganda, have a mandatory agro-dealer certification scheme, and this is different from the proposed voluntary certification scheme that is aimed at pesticide risk reduction. A mandatory agro-dealer certification scheme is a compulsory training required to be undertaken to be legally registered as an agro-dealer by the national legal entity, the state or national government, while voluntary certification is an optional scheme, which is participatory by choice rather than a compulsory requirement.

2 MATERIALS AND METHODS

2.1 Context and data

Uganda provides an interesting opportunity to study preferences for a voluntary agro-dealer certification scheme aimed at pesticide risk reduction. There has been an increase in the sale and widespread use of pesticides in the country in recent years.[1,16] Moreover, highly hazardous pesticide products, poor pesticide practices and reports of pesticide-related health problems are common.[17,18] Studies have shown that Ugandan farmers apply pesticides frequently and indiscriminately, including up to 18 times per cropping season.[16,17] Stakeholders in the pesticide supply chain of Uganda have expressed a need for an agro-dealer certification of good practice,[9,19] and some agro-dealers have shown an interest in guiding farmers on sustainable pest management practices.[9]

The data used in this study came from a representative survey of 557 agro-dealers in Uganda, where there are an estimated 3000 agro-dealers.[25] The survey was conducted in November–December 2021 across all the four administrative regions and ten sub-regions of Uganda. With support from the Department of Crop Inspection and Certification (DCIC) of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) of Uganda, we purposively selected representative districts in each sub-region based on the distribution of agro-input shops across the country. In total, the survey covered 50 out of the country's 136 districts (Fig. 1). In each chosen district, between 2 to 30 agro-input shops were randomly selected proportionate to the density of agro-input shops across the districts. Overall, our sample consists of 182, 152, 87 and 136 agro-input shops from central, eastern, northern and western regions of Uganda, respectively.

All selected agro-input shops were visited for face-to-face interviews with agro-dealers who regularly attend to customers. To mitigate potential response bias, the agro-dealers were interviewed individually during periods when they were not busy attending to customers. Moreover, the interviewed agro-dealers were assured of the confidentiality of their responses. The interviews were conducted by a team of 15 local enumerators who were trained by the researchers. Data were collected using a tablet-based questionnaire programmed on Open Data Kit platform and was pre-tested with a sample of agro-dealers in Mukono district. The questionnaire (see Supporting Information Data S1) captured information on agro-dealers' socio-demographic characteristics, shop characteristics, attitudes towards mandatory and voluntary certification, awareness of biopesticides and IPM, membership in agro-dealer associations, and a choice experiment to elicit agro-dealer preferences for voluntary certification attributes.

Our sample is almost evenly divided between male (48%) and female (52%) agro-dealers, with an average age of nearly 33 years

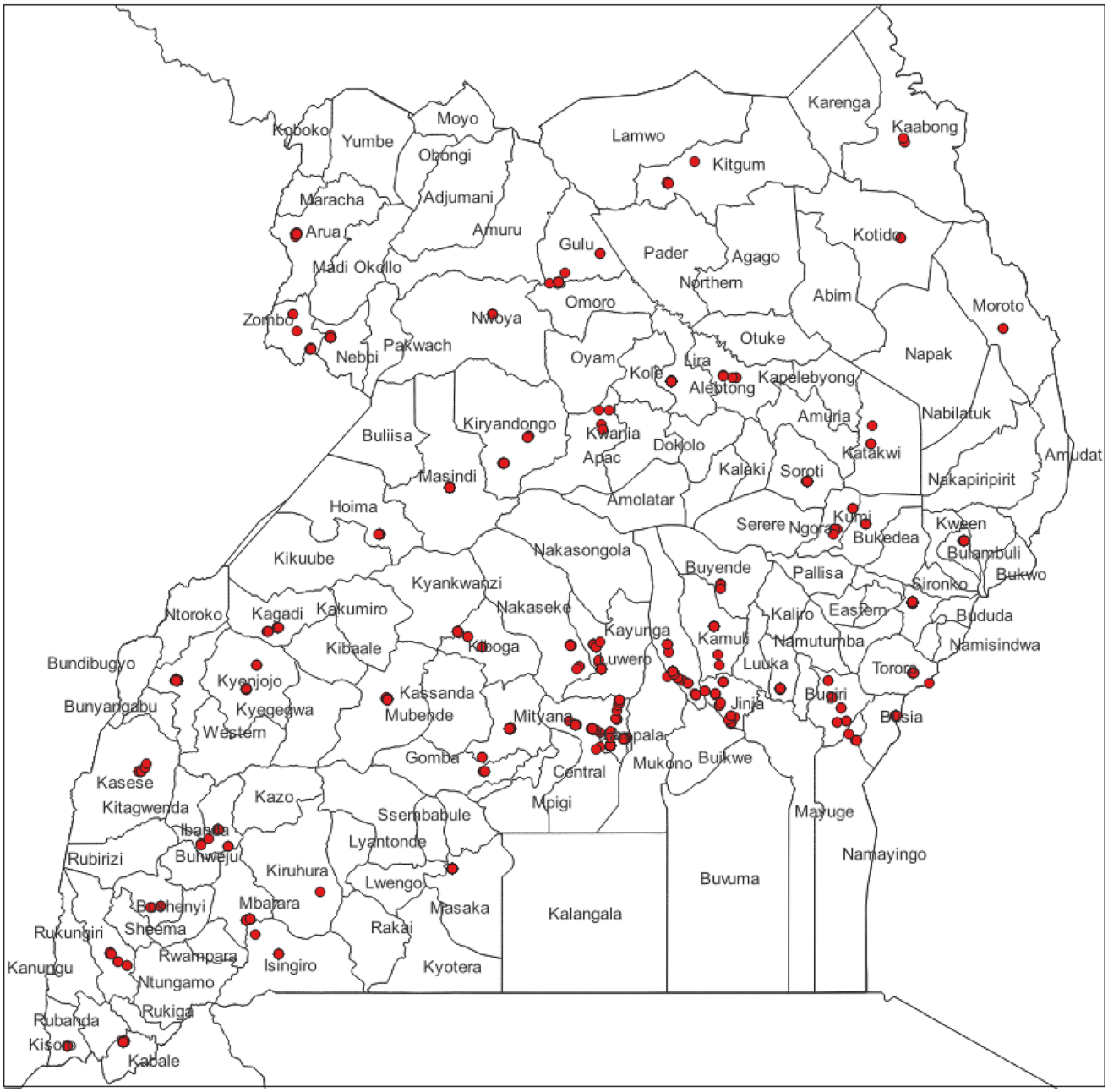

Figure 1. District map of Uganda showing the survey locations.

(Table 1). Half of the interviewed agro-dealers were owners of an agro-input shop, with the other half being managers (9%) or shop attendants (41%) employed by shop owners. On average, the sampled agro-dealers had completed 13 years of formal education and had had 6 years of experience in selling agro-input products, including pesticides. Furthermore, 7% of the agro-dealers had attained less than 11 years of schooling (lower secondary school), and thus do not satisfy the minimum educational requirement necessary to become an agro-dealer in Uganda.[26]

Nearly 40% of the agro-dealers were members of the Uganda National Agro-input and Dealers' Association (UNADA), which obliges its members to abide by codes of conduct concerning the set-up of input shops, registration with authorities, selling of officially registered inputs, and safe use and handling of agro-chemicals.[27] Almost half (45%) of the agro-dealers had not been certified by MAAIF, although it is a requirement under the Uganda's Agricultural Chemicals (Control) Act, 2006.[28] The main reasons given by the agro-dealers for the lack of certification by MAAIF include unawareness of the need to get certified, slow certification process, travel distance to the location of the certification course (usually in the capital Kampala) and cost requirements.

Fewer than half of the interviewed agro-dealers were aware of biopesticides and had at least a vague idea about IPM. While all the 557 agro-input shops visited across the country sold synthetic pesticides, only 16% of them were also selling biopesticide products, largely due to lack of awareness and access. Almost all (98%) of the agro-input shops were selling at least one high-risk pesticide product, such as dichlorvos, carbofuran and zinc phosphide. These pesticide products are highly hazardous, according to the

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Table 1. Descriptive statistics of agro-dealer characteristics

Variable	Mean	SD
Age of agro-dealer (years)	32.54	9.73
Gender of agro-dealer (1 = male)	0.48	0.50
Ownership of an agro-input shop (1 = yes)	0.50	0.50
Education of agro-dealer (years)	13.10	2.54
Agro-input dealership experience (years)	6.28	5.64
Membership in an agro-dealer association (1 = yes)	0.38	0.49
Certified as an agro-dealer by MAAIF (1 = yes)	0.55	0.50
Aware of IPM (1 = yes)	0.42	0.49
Aware of biopesticides (1 = yes)	0.41	0.49
Sells at least one biopesticide product (1 = yes)	0.16	0.37
Sells at least one high-risk pesticide product (1 = yes)[†]	0.98	0.14
Has suffered pesticide-related illness (1 = yes)	0.29	0.45
Shop's distance to Kampala (km)	218.97	151.28
Number of observations	557	

[†] High-risk products are plant protection products that are extremely or highly acutely toxic (World Health Organisation classes Ia or Ib), can cause cancer and mutations, can cause fertility and reproduction problems, or are banned internationally or nationally, or restricted for health or environmental reasons.
Abbreviations: MAAIF, Ministry of Agriculture, Animal Industry and Fisheries; IPM, integrated pest management; SD, standard deviation.

World Health Organisation's classification of pesticides based on acute oral and dermal toxicity.[29] Nearly 30% of agro-input shops reported that at least one staff member had experienced acute pesticide-related symptoms, such as headache, sneezing, eye irritation, skin irritation, and nausea.

2.2 Choice experiment

We used a DCE method to elicit and analyse agro-dealers' preferences for different attributes of a voluntary sustainability certification scheme. The DCE is a popular approach for studying individual stated preferences for actual or hypothetical products and services.[30] This approach is applicable here because the voluntary certification under discussion is currently not available in the market, therefore limiting the possibility of using a revealed preference approach. The DCE approach draws on the random utility maximisation theory, which assumes that when faced with a choice of several alternatives, rational individuals will prefer the alternative with the highest utility.[31]

In our DCE, agro-dealers were asked to make choices among several alternatives (choice sets) containing a number of attributes with varying attribute levels of the voluntary certification scheme. It is assumed that agro-dealers will evaluate the attributes (requirements and potential benefits) of the voluntary certification scheme when deciding on whether or not to participate in the scheme and choose the combinations of attribute levels that maximise their utility. For practical guidance on DCE design, implementation and data analysis, see Hensher *et al.*,[30] Mandy *et al.*[32] and Mariel *et al.*[33]

2.2.1 Attributes and attribute levels

The first step in conducting a DCE is to identify the attributes and their associated levels through literature reviews and qualitative research, such as key informant interviews or focus group discussions with relevant experts and stakeholders.[33] Several potentially relevant attributes of the hypothetical voluntary certification scheme were identified based on insights from the mandatory certification scheme of Uganda and a review of literature on farmer preferences for voluntary certification and pesticide risk reduction schemes.[20–23] The final set of attributes and attribute levels for inclusion in the DCE were selected after consultation with crop health experts from MAAIF and leaders of UNADA, as well as group discussions with a sample of agro-dealers in Uganda. This helps to ensure that the attributes and attribute levels are contextually relevant, and they reflect the main requirements and potential benefits of the proposed voluntary certification scheme. To reduce the complexities of the choice sets and cognitive overload on the interviewed agro-dealers, the number of attributes was restricted to six. Table 2 presents the six attributes and their corresponding attribute levels.

The first attribute describes the pesticide-related business model that agro-dealers would be required to operate under the voluntary certification scheme. We consider three possibilities: (1) sale of any pesticide product so far as it is registered by national authorities (i.e., no restriction on sale of registered products); (2) sale of only registered lower-risk products; and (3) and sale of only registered lower-risk products and, in addition, having the capacity to provide diagnostic and IPM-based advisory services to farmers. The hypothesis is that agro-dealers might be reluctant to accept to sell only lower-risk products as it would affect sales and profits, but the potential benefits of being accredited to provide other revenue-earning services (such as pest diagnostic services) could help offset any potential loss of income due to the pesticide-sale requirements. In this study, lower-risk products are considered to be those synthetic or biological-based plant protection products which: (1) do not contain substances that are extremely or highly acutely toxic (World Health Organisation classes Ia or Ib);[29] (2) are not currently known to cause cancer, mutations, fertility and reproduction problems; and (3) are not banned internationally or nationally, or restricted for health or environmental reasons.

The second attribute relates to the level of training to be offered as part of the voluntary certification scheme, and it consists of three levels: (1) no training provided; (2) initial training provided; and (3) initial and refresher training provided. Training will enhance agro-dealers' knowledge and skills in crop protection, including pesticide products, pest diagnosis and management, as well as the provision of IPM-based advisory services. While one would expect agro-dealers to have positive preferences for training as it can provide income-earning opportunities, it is possible that the monetary and time costs associated with training may be a disincentive, particularly for agro-dealers who are already certified under a mandatory certification scheme.

The third attribute relates to methods for checking compliance with the quality assurance guidelines of the voluntary certification scheme. The first level requires that participating agro-dealers will keep records of pesticide sales and plant health advice given to their customers, and these records and their agro-input shops will be inspected annually on an agreed date. The first and second levels of this attribute are similar, except that the second level includes annual inspection of agro-input shops and records without prior notice to the agro-dealers.

The fourth and fifth attributes highlight the expected benefits from the voluntary certification scheme. The fourth attribute (income effect) refers to the financial benefits that could be derived from additional crop protection business, which may

Table 2. Voluntary certification attributes and attribute levels

Attributes	Attribute levels
Pesticide-sale model	Sale of any registered products
	Sale of only registered lower-risk products (LRPs)
	Sale of only registered LRPs + providing diagnostic and advisory services
Training requirement	No training provided
	Initial training on crop protection provided
	Initial and refresher training on crop protection provided
Quality control	Scheduled annual inspection + mandatory record keeping
	Unannounced annual inspection + mandatory record keeping
Income effect	Same as your current income from crop protection business
	2% increase over your current income from crop protection business
	4% increase over your current income from crop protection business
	6% increase over your current income from crop protection business
	8% increase over your current income from crop protection business
	10% increase over your current income from crop protection business
Health and environmental risks	Low risks to humans and the environment
	High risks to humans and the environment
Investment costs	200 000 UGX
	300 000 UGX
	400 000 UGX
	500 000 UGX

Note: UGX denotes Uganda Shilling. 1 USD = 3550 UGX at the time of the survey.

incentivise profit-driven agro-dealers to participate in the scheme. This could stem from a potential increase in product sales [pesticides, and personal protective equipment (PPE)] due to enhanced reputation of selling quality and reliable lower-risk products, and direct payments for providing quality plant health diagnostic and advisory services to farmers. The income effect is defined by six levels, starting with no change in current income and varying in increments of 2 percentage points up to 10% increase over current income from crop protection business. These income percentages were determined based on a group discussion with selected Ugandan agro-dealers on the range of additional income they could earn from the voluntary certification scheme, given its features and their current profit margins from agro-input business.

The fifth attribute captures the potential risks of pesticides to human health and the environment and is defined by two levels: low and high risks to humans and the environment. Achieving the former is among the main goals of sustainability-oriented certification schemes. The health and environmental risks of pesticides include food and water contamination, acute and chronic health problems, soil pollution, poisoning of pollinators and natural enemies, and loss of biodiversity.

The final attribute relates to the initial investment costs, including training and inspection costs, that an agro-dealer would have to incur in order to participate in the voluntary certification scheme. The investment costs attribute has four levels, ranging from 200 000 UGX to 500 000 UGX. These cost levels were set around the amount an agro-dealer needs to pay (i.e., 250 000 UGX or about 70 USD) to participate in training under the mandatory certification scheme of Uganda. We also verified that these amounts are realistic and acceptable during a meeting with representatives from MAAIF and UNADA.

2.2.2 *Experimental design*

Given the number of attributes and their levels, a full factorial design will generate 864 (i.e., $3 \times 3 \times 2 \times 6 \times 2 \times 4$) combinations. Thus, theoretically, the sampled agro-dealers have to choose from 864 possible combinations of attribute levels, with each combination representing a specific voluntary certification profile. To create a more feasible experiment, we used a D-efficient design with zero priors to generate a subset of voluntary certification profiles.[34,35] We developed 18 choice sets, with each choice set having different combinations of the certification attribute levels. We checked that none of the 18 choice sets had an unrealistic or a dominant certification profile. For example, it is unlikely to achieve a reduction in pesticide risks if agro-dealers receive no pesticide-related training and there is no restriction on the types of pesticides sold, including high-risk products.

The 18 choice sets were divided into three blocks of six choice sets each. The surveyed agro-dealers were randomly assigned one block, and thus, each respondent was asked to complete six choice sets that were presented to them in a random order by an enumerator. The choice sets were presented on choice cards, an example of which is illustrated in Fig. 2. Each card shows three options, labelled A, B and C. Options A and B always reflect voluntary certification with variations in attributes, while Option C reflects the situation in the agro-input business without voluntary certification (i.e., a status quo option). Respondents were asked to choose their most preferred option from the three options on each of the six choice cards.

It is well-known that choice experiments tend to be prone to hypothetical bias (i.e., choices made in an experiment may differ from actual choices in real-life settings), which can influence WTP estimates.[36] To mitigate such bias, we explained the hypothetical nature of the experiment and emphasised on the importance of giving truthful responses.[37] In addition, the respondents were reminded of the opt-out (status quo) alternatives on the choice cards.[38] The status-quo option captures agro-dealers' preferences that are unobservable, and also prevent the bias of forcing respondents to choose a voluntary certification profile even if they dislike it. Another potential source of bias in our DCE is attribute non-attendance (ANA), which occurs when respondents do not consider all the six attributes when making their choices. Following Geussens *et al.*[39] and Oyinbo *et al.*,[40] self-reported information on ANA were collected from each respondent after the experiment, and the results (see Table S1 in the Supporting Information) show that almost all (96%) the respondents stated that they considered all the attributes, and even the few who reportedly ignored some attributes did ignore mostly only one attribute. Thus, the influence of ANA on our DCE results is likely small or insignificant, which is to be expected

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	OPTION A	OPTION B	OPTION C
Pesticide-sale model 	Sale of any registered products	Sale of only registered lower-risk products	I don't want Option A or Option B
Training requirement 	Initial training on pesticides provided	Initial and refresher training on pesticides provided	
Quality control 	Scheduled annual inspection + mandatory record keeping	Unannounced annual inspection + mandatory record keeping	
Expected income 	10% increase	6% increase	
Health and Env. risks 	High	Low	
Investment costs 	300,000 UGX	400,000 UGX	

Figure 2. An example of a choice card.

given that all the six attributes significantly affect agro-dealers' utility (Table 3).

2.2.3 *Estimation methods*

We used mixed logit models (also known as random parameter logit models) to estimate agro-dealers' preferences for voluntary certification scheme attributes. Unlike alternative models such as conditional or multinomial logit models that assume that respondents have the same preferences, the mixed logit models account for heterogeneity in preferences across respondents and also relax the restrictive assumption of independence of irrelevant alternatives (IIA).[41] We estimated the mixed logit models using maximum simulated likelihood.[42] We ran several model specifications. Initially, we estimated a utility function that only includes the voluntary certification attributes as covariates:

$$U_{ijt} = \vartheta_0 \mathrm{ASC} + \vartheta_1 \mathrm{PM}_{ijt} + \vartheta_2 \mathrm{TR}_{ijt} + \vartheta_3 \mathrm{QC}_{ijt} + \vartheta_4 \mathrm{IE}_{ijt} + \vartheta_5 \mathrm{HE}_{ijt} + \vartheta_6 \mathrm{IC}_{ijt} + \mu_{ijt} \quad (1)$$

where U is the utility that agro-dealer i derives by choosing alternative j on choice set t; PM, TR, QC, IE,HE, and IC represent the attributes pesticide-sale model, training requirements, quality control, income effect, health and environmental risks, and investment costs, respectively; ϑs are the coefficients to be estimated; and μ denotes a random error term. ASC is the alternative specific constant, and is equal to 1 for the status quo alternative and 0 for the two certification profiles in each choice set. Income and investment costs were treated as continuous attributes, and we used dummy coding (instead of effects coding) for the other attributes.[33,43]

In further specifications, we introduced different sets of interaction terms to explore preference heterogeneity among agro-dealers. Given that some of the agro-dealers in our sample were already certified under a mandatory scheme, we first examined if preference heterogeneity is related to certification experience by estimating the following model:

$$U_{ijt} = \vartheta_0 \mathrm{ASC} + \vartheta_1 \mathrm{PM}_{ijt} + \vartheta_2 \mathrm{TR}_{ijt} + \vartheta_3 \mathrm{QC}_{ijt} + \vartheta_4 \mathrm{IE}_{ijt} + \vartheta_5 \mathrm{HE}_{ijt} + \vartheta_6 \mathrm{IC}_{ijt} + \vartheta_7 (\mathrm{ASC} \times C_i) + \mu_{ijt} \quad (2)$$

where C is a dummy variable that measures whether or not an agro-dealer has the necessary certification to sell pesticides in Uganda. Thus, a statistically significant ϑ_7 coefficient will mean that attitudes towards the voluntary certification scheme differ between certified and uncertified agro-dealers.

Besides certification experience, we examined other sources of heterogeneity in agro-dealers' preferences for the voluntary certification scheme by including interaction terms between the ASC and some agro-dealer characteristics as follows:

$$U_{ijt} = \vartheta_0 \mathrm{ASC} + \vartheta_1 \mathrm{PM}_{ijt} + \vartheta_2 \mathrm{TR}_{ijt} + \vartheta_3 \mathrm{QC}_{ijt} + \vartheta_4 \mathrm{IE}_{ijt} + \vartheta_5 \mathrm{HE}_{ijt} + \vartheta_6 \mathrm{IC}_{ijt} + \vartheta_n (\mathrm{ASC} \times \boldsymbol{S_i}) + \mu_{ijt} \quad (3)$$

Table 3. Mixed logit model estimates of agro-dealer preferences for voluntary certification

	(1) Full sample	(2) Certified	(3) Non-certified	(4) Full sample	(5) Full sample
Parameters					
ASC (no voluntary certification)	−0.944*** (0.243)	−1.101*** (0.343)	−0.877** (0.355)	−0.555** (0.269)	−0.125 (0.384)
Investment costs	−0.002*** (0.001)	−0.003** (0.001)	−0.001 (0.001)	−0.002** (0.001)	−0.002** (0.001)
Only registered low-risk products (LRPs)[†]	0.791** (0.307)	0.241 (0.417)	1.417*** (0.458)	0.776** (0.307)	0.745** (0.305)
Only registered LRPs + diagnostic services[†]	1.289*** (0.327)	0.806* (0.440)	1.837*** (0.488)	1.267*** (0.326)	1.223*** (0.325)
Initial training on pesticides[‡]	1.210*** (0.225)	1.474*** (0.313)	0.937*** (0.330)	1.219*** (0.225)	1.225*** (0.222)
Initial and refresher training on pesticides[‡]	1.242*** (0.241)	1.201*** (0.338)	1.298*** (0.355)	1.259*** (0.242)	1.281*** (0.280)
Unannounced inspection[§]	−0.277*** (0.088)	−0.181 (0.115)	−0.427*** (0.142)	−0.272*** (0.088)	−0.244*** (0.086)
Expected income	0.169*** (0.033)	0.188*** (0.047)	0.166***(0.048)	0.166*** (0.032)	0.146*** (0.032)
Low health and environmental risks[¶]	1.376*** (0.370)	1.887*** (0.503)	0.953* (0.556)	1.371*** (0.369)	1.262*** (0.364)
ASC interactions					
ASC × Mandatory certification				−0.867*** (0.274)	
ASC × Gender					0.446 (0.293)
ASC × Experience					−0.094*** (0.034)
ASC × Shop owner					−1.074*** (0.311)
ASC × UNADA member					−0.161 (0.305)
ASC × Aware of IPM					−0.245 (0.300)
ASC × Suffered pesticide-related illness					−0.908** (0.361)
ASC × Distance to Kampala					0.001 (0.001)
Log likelihood	−2168.885	−1001.903	−1114.176	−2163.84	−2150.959
Chi squared	868.38***	304.06***	571.61***	854.84***	785.47***
Observations	10 008	4779	5229	10 008	10 008

Note: Numbers in parentheses are standard errors. The full results with standard deviations are presented in Table S2 in the Supporting Information. Abbreviations: ASC, alternative specific constant; IPM, integrated pest management; UNADA, Uganda National Agro-input and Dealers' Association. ***, **, and * denote 1%, 5%, and 10% statistical significance levels, respectively.
[†] Reference category is sale of any registered product.
[‡] Reference category is no training provided.
[§] Reference category is scheduled annual inspection.
[¶] Reference category is high health and environmental risks.

where $\boldsymbol{S}$ is a vector of agro-dealer characteristics, including gender, years of agro-dealer experience, shop ownership status, UNADA membership, IPM awareness, experience with pesticide-related illness and distance to Kampala. Additionally, we interacted the agro-dealer characteristics with specific attribute levels to assess whether and which socioeconomic factors influence attitudes towards particular voluntary certification attributes.

Finally, we use the coefficients estimates of Eqn (1) to compute agro-dealers' WTP for the various voluntary certification attributes as follows:

$$\text{WTP}_{\text{attribute}} = \frac{\vartheta_{\text{attribute}}}{-\vartheta_6} \tag{4}$$

where $\vartheta_{\text{attribute}}$ is the coefficient of the attribute for which the WTP is computed and ϑ_6 is the coefficient of the investment costs attribute. Thus, the agro-input dealers' WTP for the certification attributes is estimated as the marginal rate of substitution between the various attributes and the investment costs attribute. The WTP estimates translate the utilities that agro-dealers derive from the voluntary certification attributes into monetary terms.

3 RESULTS

3.1 Preferences for voluntary certification attributes

Table 3 reports the mixed logit model estimation results regarding agro-dealers' preferences for voluntary certification attributes. Focussing first on the model results for the full sample (column 1), we find that all the mean parameters are statistically significant at least at the 5% level, suggesting that all the attributes are important and affect agro-dealers' utility. The negative and significant coefficient on the status quo (ASC) variable suggests that the agro-dealers have positive attitudes towards the proposed voluntary certification scheme. Thus, there is a strong preference for an agro-dealer certification scheme aiming at sustainable pest management and pesticide risk reduction rather than maintaining the status quo.

The investment costs coefficient is also negative and significant, indicating that agro-dealers prefer a voluntary certification scheme that does not require high upfront costs, which include training and inspection costs. The coefficients on the two pesticide-sale model attributes are positive, suggesting that agro-dealers would gain utility from shifting from the sale of registered products (including high-risk products) to selling only registered lower-risk products and providing pest diagnostic and advisory services to their customers. The marginal utility obtained from selling registered low-products only is lower than the utility derived from a combination of selling lower-risk products and offering plant health diagnostic services, implying that agro-dealers derive additional positive utility from providing pest diagnostic services. This seems reasonable, as agro-dealers who are uniquely equipped to provide quality plant health diagnostic and advisory services can earn extra income through direct payments from customers or indirectly by attracting more customers to their agro-input shops.

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The coefficients on the two training attribute levels (initial training on pesticides and initial training combined with refresher courses) are both positive and statistically significant at 1%, indicating that agro-dealers strongly prefer a voluntary certification scheme that provides training. This result is expected, since training can enhance the capacity of agro-dealers to provide quality services to farmers, which in turn can lead to an increase in customers and product sales. This is comparable to Meemken *et al.*[20] who observed positive preferences for agricultural training in voluntary sustainability certification schemes designed for farm households in Uganda. We find a negative and significant coefficient for the quality inspection attribute, indicating that agro-dealers dislike unannounced inspection of shops for checking compliance with quality requirements. Thus, they would prefer scheduled inspection visits with mandatory record keeping, and would only accept unannounced inspection if compensated, for example through a reduction in investment cost. This is not surprising as many Ugandan agro-dealers fail to comply with mandatory requirements, such as shop set-up and pesticide safety practices.[9]

As expected of rational economic agents, agro-dealers have a positive preference for a voluntary certification scheme that increases their income. This means that the agro-dealers would have to be compensated if the certification scheme generates environmental and health benefits but does not lead to additional financial gains from crop protection business. However, the estimation results show that the agro-dealers have a much stronger preference for low health and environmental risks from pesticides, indicating that reducing pesticide-related health and environmental risks through a voluntary agro-dealer certification scheme is possible and highly valued.

Overall, the results in Table 3 column 1 suggest that agro-dealers would generally prefer a voluntary certification scheme that provides trainings in crop protection, generates financial, health and environmental benefits, and requires scheduled visits to shops for inspection and the sale of registered lower-risk products, particularly when combined with the provision of plant health diagnostic and advisory services. Almost all the standard deviation parameters are statistically significant (see column 1 of Table S2), indicating the existence of heterogeneity in preferences for the attributes. In columns 2–5 of Table 3, we explore some of the sources of preference heterogeneity, which are discussed in the next section.

3.2 Heterogeneity in preferences

We first test whether there is heterogeneity in preferences for voluntary certification and its attributes due to prior experience with certification by estimating separate mixed logit models for certified and non-certified agro-dealers. The results are presented in columns 2 and 3 of Table 3. The significantly negative ASC coefficients indicate that both certified and non-certified agro-dealers have a positive general attitude towards the voluntary certification scheme. However, the significant interaction effect of the ASC and mandatory certification (Table 3, column 4) suggests that certified agro-dealers show a stronger general preference for voluntary certification than their non-certified counterparts. A plausible explanation is that certified agro-dealers are familiar with the advantages of the mandatory certification scheme and are thus more likely to appreciate the potential benefits from participating in the voluntary scheme. Moreover, they are probably more likely to be able to afford the costs associated with voluntary certification, especially after having been able to meet the cost requirements of the mandatory scheme.

Columns 2 and 3 of Table 3 show negative coefficients on the investment costs attribute for both the sub-sample of certified and non-certified agro-dealers but is statistically significant only in the case of certified agro-dealers. This means that certified agro-dealers prefer lower investment costs (most likely because they already have the mandatory certificate), whereas non-certified agro-dealers are indifferent towards the required investment costs. Both certified and non-certified agro-dealers expressed strong preferences for participating in training and refresher courses on pesticides, but non-certified agro-dealers appear to be more receptive towards dealing in either only registered lower-risk products or in combination with providing pest diagnostic services as against selling any registered pesticide products. In fact, the results show that certified agro-dealers are indifferent between selling either registered products or only lower-risk registered products, but would only accept trading in lower-risk products when combined with having the capacity to provide plant health diagnostic and advisory services. This suggests that to be able to attract already certified agro-dealers to participate in a voluntary certification scheme requiring a restriction on the sale of high-risk products, it would be critical for the scheme to include additional income-generating opportunities, such as the provision of pest diagnostic and advisory services, which could cover potential income loss owing to not selling high-risk products.

We also find that the certified agro-dealers are indifferent towards unannounced or scheduled inspection of shops for compliance purposes, whereas their non-certified counterparts have a negative attitude towards unannounced inspection. The point estimate on the health and environmental risks attribute for certified agro-dealers is strongly significant and is about twice that of the non-certified agro-dealers, indicating that certified agro-dealers would gain a much higher utility from protecting human and environmental health from pesticide risks than their uncertified counterparts. Perhaps this is because certified agro-dealers have a better understanding of human and environmental effects of pesticides, as it forms part of the training contents of the mandatory certification scheme.[44]

Next, we examine differences in preferences for voluntary certification by introducing interaction terms between the ASC and several agro-dealer characteristics, including gender, experience, shop ownership, UNADA membership, IPM awareness and location (Table 3, column 5). The interaction of the ASC with gender is insignificant, indicating that female and male agro-dealers have similar preferences for the voluntary certification scheme. Years of experience as an agro-dealer is negatively and significantly correlated with the ASC, meaning that experienced agro-dealers have positive attitude towards voluntary certification than their less-experienced counterparts. Our data show that experienced agro-dealers are more likely to have the mandatory agro-dealer certificate, which could have influenced their perception about voluntary certification. Our results also indicate that shop owners have a greater preference for voluntary certification than employees, which may be related to differences in decision-making power or resourcefulness. Preference for voluntary certification is not correlated with membership in UNADA or agro-dealer awareness of IPM. However, agro-dealers who had suffered pesticide-related illness have a positive preference for a voluntary certification scheme aimed at pesticide risk reduction, which is expected. The ASC has no significant interaction effect with

distance to Kampala, suggesting that agro-dealer preference for voluntary certification is not influenced by remoteness.

While we have shown earlier that some agro-dealer characteristics shape general preference for the voluntary certification scheme, it is also possible that the agro-dealer characteristics may influence attitudes towards the different certification attributes. We explore this by interacting the agro-dealer characteristics with the certification attributes, and the results are presented in Table 4. Focussing on the results on the interaction terms in the middle part of Table 4, column 1 shows significant gender differences in terms of only the training attribute, albeit the effect is significant at 10% level. The negative coefficients suggest that female agro-dealers attach more importance to training and refresher courses on pesticides than their male counterparts, probably because they are more information-constrained. This is noteworthy as there is a good proportion of female agro-dealers in Uganda (52% in our sample). Agro-dealers working in shops where a staff member had ever suffered from pesticide-related health problems also show a higher preference for training (column 6 of Table 4).

We find substantial heterogeneity in preferences for voluntary certification attributes by agro-dealership experience and shop

Table 4. Mixed logit estimates with interactions between attributes and agro-dealer characteristics

	(1) Gender	(2) Experience	(3) Shop owner	(4) UNADA member	(5) Aware of IPM	(6) Pesticide illness	(7) Kampala distance
Parameters							
ASC (no voluntary certification)	−0.94*** (0.25)	−0.99*** (0.24)	−0.99*** (0.24)	−0.93*** (0.24)	−0.93*** (0.24)	−0.96*** (0.25)	−0.97*** (0.24)
Investment costs	−0.00*** (0.00)	−0.00** (0.00)	−0.00** (0.00)	−0.00*** (0.00)	−0.00*** (0.00)	−0.00** (0.00)	−0.00** (0.00)
Only registered low-risk products (LRPs)[†]	0.77* (0.40)	1.60*** (0.44)	1.14*** (0.41)	1.10*** (0.38)	1.00*** (0.38)	0.65* (0.35)	0.68 (0.51)
Only registered LRPs + diagnostic services[†]	0.96** (0.42)	2.17*** (0.46)	1.76*** (0.43)	1.34*** (0.40)	1.34*** (0.40)	1.22*** (0.36)	1.26** (0.52)
Initial training on pesticides[‡]	1.51*** (0.27)	0.68** (0.28)	0.92*** (0.26)	1.31*** (0.25)	1.31*** (0.25)	1.06*** (0.24)	1.46*** (0.30)
Initial and refresher training on pesticides[‡]	1.57*** (0.30)	0.66** (0.31)	0.85*** (0.29)	1.32*** (0.28)	1.32*** (0.28)	1.04*** (0.26)	1.31*** (0.00)
Unannounced inspection[§]	−0.36*** (0.12)	−0.49*** (0.13)	−0.50*** (0.12)	−0.18* (0.11)	−0.19* (0.11)	−0.22** (0.10)	−0.14 (0.15)
Expected income	0.19*** (0.04)	0.18*** (0.04)	0.16*** (0.04)	0.16*** (0.04)	0.16*** (0.04)	0.17*** (0.04)	0.16*** (0.04)
Low health and environmental risks[¶]	1.28*** (0.46)	0.73 (0.50)	0.78*(0.47)	1.16*** (0.44)	1.16*** (0.44)	1.21*** (0.41)	1.44** (0.56)
Attribute interactions							
× Only registered LRPs	0.06 (0.56)	−0.14*** (0.05)	−0.74 (0.56)	−0.62 (0.58)	−0.62 (0.58)	0.54 (0.67)	0.00 (0.00)
× Only registered LRPs + diagnostic services	0.68 (0.57)	−0.15*** (0.05)	−1.04* (0.57)	−0.25 (0.58)	−0.25 (0.58)	0.26 (0.69)	0.00 (0.00)
× Initial training on pesticides	−0.56* (0.29)	0.09*** (0.03)	0.59** (0.29)	−0.23 (0.29)	−0.23 (0.29)	0.59* (0.36)	−0.00 (0.00)
× Initial and refresher training on pesticides	−0.61* (0.34)	0.10*** (0.03)	0.82** 0.34)	−0.18 (0.35)	−0.18 (0.35)	0.83** (0.41)	−0.00 (0.00)
× Unannounced inspection	0.15 (0.17)	0.04** (0.02)	0.46*** (0.16)	−0.22 (0.17)	−0.22 (0.04)	−0.26 (0.19)	−0.00 (0.00)
× Expected income	−0.05 (0.04)	−0.00 (0.00)	−0.00 (0.04)	0.03 (0.04)	0.03 (0.04)	−0.00 (0.05)	−0.00 (0.00)
× Low health and environmental risks	0.21 (0.60)	0.10* (0.05)	1.14* (0.60)	0.69 (0.61)	0.69 (0.61)	0.45 (0.70)	−0.00 (0.00)
Log likelihood	−2161.53	−2159.36	−2158.98	−2165.71	−2165.71	−2154.61	−2166.48
Chi squared	859.55***	862.83***	849.16***	870.26***	870.26***	837.66***	858.36***
Observations	10 008	10 008	10 008	10 008	10 008	10 008	10 008

Note: Numbers in parentheses are standard errors. The full results with standard deviations are presented in Table S3 in the Supporting Information. Abbreviations: ASC, alternative specific constant; IPM, integrated pest management; UNADA, Uganda National Agro-input and Dealers' Association. ***, **, and * denote 1%, 5%, and 10% statistical significance levels, respectively.
[†] Reference category is sale of any registered product.
[‡] Reference category is no training provided.
[§] Reference category is scheduled annual inspection.
[¶] Reference category is high health and environmental risks.

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Table 5. Willingness to pay (WTP) estimates (1000 UGX)

Attribute	WTP	95% Confidence interval	
Only registered lower-risk products (LRPs)	406.19	3.86	808.51
Only registered LRPs + diagnostic services	666.02	39.41	1284.64
Initial training on pesticides	621.16	230.84	1011.47
Initial and refresher training on pesticides	637.95	241.40	1034.50
Unannounced inspection	−142.44	−275.41	−9.48
Expected income	86.82	36.92	136.72
Low health and environmental risks	706.49	147.32	1265.67

ownership (Table 4, columns 2 and 3). The more experienced agro-dealers have negative attitudes towards the requirement of shifting from the sale of registered pesticide products to the sale of only registered lower-risk products, but they have more positive attitudes towards attending training and refresher courses on crop protection and protecting human and environmental health. Interestingly, they have no problem with unannounced visits to their shops for inspections. These results suggest that experienced agro-dealers would prefer a voluntary certification scheme that contributes to pesticide risk reduction through training and compliance with safety recommendations rather than through restricting the sale of high-risk products. Like experienced agro-dealers, shop owners are more receptive than employees to training, unannounced inspections and pesticide risk reduction. All the interaction terms in columns 4, 5 and 7 are not statistically significant, indicating that agro-dealers have similar preferences for the voluntary certification attributes, irrespective of their proximity to the capital city and whether or not they are members of UNADA or have prior knowledge of IPM.

3.3 Willingness to pay for certification attributes

The mixed logit estimates in column 1 of Table 3 were used to compute agro-dealers' WTP for the different attributes of the voluntary certification scheme. Specifically, we estimated WTP in preference space by dividing the coefficient of each attribute by the negative of the coefficient of the cost attribute.[45] The results are presented in Table 5. Given that our cost attribute is investment costs, a positive (negative) WTP value can be interpreted as the amount of money agro-dealers are willing to invest (accept as compensation) in order to follow specified attributes of the voluntary certification scheme.

Results show that agro-dealers are willing to invest about 406 000 UGX to acquire the capacity to trade in only registered lower-risk products, and 666 000 UGX if they are equipped to provide plant health diagnostic and IPM-based advisory services in addition to selling lower-risk products to their clients. This suggests that agro-dealers perceive a gain in competitive advantage if they are professionally trained to provide pest diagnostic and advisory services, as these services are hardly offered by Ugandan agro-dealers.[9] Agro-dealers are willing to invest 621 000 UGX to receive trainings related to pesticides, pest diagnosis and management and how to give plant health advice, and they are willing to increase the amount to about 638 000 UGX if the initial training is complemented with refresher courses.

As highlighted earlier, agro-dealers have a strong preference for scheduled inspection as against unannounced inspection of shops for quality control purposes. Results in Table 5 show that they would need a cost reduction of about 142 000 UGX if their agro-input shops must be inspected without prior notice. We also observe that agro-dealers would be willing to invest roughly 87 000 UGX for a 1% increase in income from agro-input business. The highest WTP estimate is observed for the health and environmental risks attribute, implying a high interest in an agro-dealer certification scheme aiming at pesticide risk reduction. Specifically, agro-dealers are willing to invest about 706 000 UGX to achieve a reduction in pesticide risks to human and environmental health.

It should be noted that some caution is warranted when interpreting the exact WTP values, given that stated preferences data tend to be plagued by hypothetical bias.[30] For instance, a 5-day training programme under the mandatory certification scheme in Uganda costs 250 000 UGX, which is considered to be prohibitive. Hence, it may be challenging for agro-dealers to pay more than twice this amount (about 600 000 UGX) for training under the voluntary certification scheme. It is possible that the mandatory certification training fee is government-subsidised, and that the WTP estimates actually reflect the value agro-dealers attach to the voluntary certification scheme, given its advantages over the mandatory scheme. Nonetheless, the WTP estimates should be taken as indicative, and are better reflective of the relative importance of the different voluntary certification attributes.

Our results are generally comparable to previous studies showing that the willingness of farmers to pay to avoid pesticide risks or to adopt safer alternatives to pesticides is greatly influenced by concerns about the health and/or environmental risks of pesticides.[21,46–48] For instance, Chèze *et al.*[21] found that French farmers are willing to pay to reduce the health and environmental impacts of pesticides only if they perceive that pesticides affect the environment. Khan and Damalas[46] also observed that cotton farmers in Pakistan who perceived major pesticide-related health risks expressed WTP a higher premium for lower-risk pesticides.

4 CONCLUSION

In this article, we used DCE method to study the willingness of agro-dealers to provide sustainable IPM-related services to farmers and reduce pesticide risks to the environment and human health through a hypothetical voluntary certification scheme. The study was based on survey data from 557 agro-dealers in Uganda. We contribute to the literature on pesticide risk reduction by focussing on the perspectives of agro-dealers, rather than the often-studied farmers. The findings are useful for designing pesticide risk reduction schemes for private-sector input suppliers and for promoting lower-risk crop protection products.

The analysis showed that agro-dealers consider the concept of a voluntary certification scheme to promote lower-risk plant protection products relevant, as it can help improve their business while

ensuring safety for people and the environment. Agro-dealers have a positive attitude towards a shift from the sale of registered products to selling only registered lower-risk products, particularly when combined with having the capacity to provide plant health diagnostic and advisory services to their customers. They also strongly value a certification scheme that provides training opportunities, but dislike unannounced inspection of shops for checking compliance with quality requirements. In addition, they have a positive preference for a voluntary certification scheme that provides income benefits, but they demonstrate a much stronger preference for reducing the health and environmental risks associated with pesticides. We also found evidence that included additional income-generating opportunities, such as the provision of pest diagnostic and advisory services, would be essential to be able to attract already certified agro-dealers to participate in a voluntary certification scheme aimed at restricting the sale of high-risk products. Further results showed that preferences for voluntary certification attributes are influenced by certification experience, agro-dealership experience, business ownership status and incidence of acute pesticide poisoning.

Overall, our findings imply that the concept of a voluntary sustainability certification for agro-dealers is greatly valued, particularly for its potential to provide training opportunities and ensure safety to human health and the environment. Thus, the design of an agro-dealer certification scheme to promote safer crop protection products and achieve pesticide risk reduction goals is worth pursuing. Given that the promotion of lower-risk pesticide products can generate positive externalities, agro-dealers could be nudged to participate in the IPM-oriented certification scheme through monetary incentives, as is the case of agri-environment and payments for environmental services schemes for farmers.[49] In the case of Uganda, it would be useful to explore the possibility of incorporating some desirable attributes of the voluntary certification scheme, such as training on lower-risk plant protection products and IPM into the country's mandatory certification course for agro-dealers, as these are currently missing in the training curriculum.[44]

The study findings also highlight the need to strongly engage other actors in the agro-input supply chain (besides agro-dealers) in the design and implementation of a certification scheme aimed at pesticide risk reduction. For instance, given that the limited sale of lower-risk pesticide products is partly due to lack of accessibility, input supply companies would have to be motivated to increase the availability of safer plant protection products (such as biopesticides), if the aspect of restricting the sale of high-risk products is to be successful. Another important stakeholder is pesticide regulators (e.g., MAAIF in the case of Uganda), considering the fact that some of the high-risk pesticide products that could be restricted under the voluntary sustainability certification scheme (such as dichlorvos) are officially registered and widely sold across the country. Moreover, enhancing farmers' knowledge about pesticide hazards, for example through public education campaigns, would be useful to drive demand for lower-risk crop protection products, which can in turn encourage input suppliers and agro-dealers to increase the prevalence of such products.

A limitation of this study is that other relevant certification attributes were not captured in the choice experiments in order not to make them too cognitive challenging for the agro-dealers. For instance, it would be interesting to examine agro-dealer preferences for different modes of training (such as face-to-face, digital or self-guided learning materials) and training duration, and how they influence willingness to invest in the scheme. In addition, it would be useful to conduct further subgroup analysis to examine how agro-dealer preferences differ by other factors, such as regions, given that agricultural characteristics of a region could influence the preferences of agro-dealers. Thus, future research in different settings and exploring other certification attributes and subgroup analysis will contribute to improving the design of voluntary sustainability certification schemes for agro-dealers. Furthermore, it would be necessary to conduct a detailed analysis of potential loss of income from limiting the sale of high-risk pesticide products and whether potential new business opportunities associated with the scheme can compensate for any loss of income or the level of compensation needed to incentivise participation in the scheme, given the public good nature of pesticide risk reduction. This requires an assessment of the most appropriate business models for the voluntary certification scheme.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

SUPPORTING INFORMATION

Supporting information may be found in the online version of this article.

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