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Original Research Article

Willingness to pay for biopesticides for tomato cultivation in Burkina Faso

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Malik Garané[1]*,
Philippe De Leener[4],
Souleymane Ouédraogo[3],
Fréderic Gaspart[2],
Anne Legrève[2], Irenée Somda[1],
and
Patrice Toé[1]

[1]Institute of Rural Development, Nazi Boni University, Burkina Faso,
[2]Faculté d'ingénierie des biosciences, Institut Terre et Vie, Université Catholique de Louvain, Belgium
[3]Institut de l'Environnement et de Recherche Agricole (INERA), Burkina Faso.
[4]Faculty of Economic, Social, Political and Communication Sciences (ESPO), Catholic University of Louvain, Belgium

*Corrresponding Author
Email: garane3@yahoo.fr

This study aims to assess the willingness to pay (WTP) for biopesticides among producers and identify the factors influencing this WTP for the use of biopesticides in tomato farms in the provinces of *Houet, Sourou, Oubritenga* and *Passoré* in Burkina Faso. A survey was conducted among a random sample of 904 producers using a semi-structured questionnaire and the referendum method to reveal the producers' preferences for biopesticides. Data analysis shows that producers are highly aware of the dangers associated with heavily agrochemical-based production methods. More than 80% of the sampled producers consent to paying for biopesticides, but with a relatively low average WTP of 14,180 FCFA. The estimation of a logistic model indicates that factors influencing producers' decision to pay include gender, household size, producer experience, income from vegetable farming, and the amount of the proposed bid. Additionally, perception variables such as the perceived effectiveness of biopesticides and the level of information about biopesticides positively influence the willingness to pay. However, contextual differences and significant heterogeneity among producers may introduce biases in estimating the average WTP and identifying these determinants.

Keywords: Willingness to pay, contingent valuation method, logit model, biopesticides, Burkina Faso

INTRODUCTION

In Burkina Faso, strategies for managing parasitic risks that were previously used are now predominantly replaced using chemical pesticides, with results that are not always satisfactory (Dabiré et al., 2016). The agrochemical products sector represents approximately 18 billion CFA francs in turnover (WFP, 2010). Particularly in the field of vegetable farming, producers have a strong preference for these chemical products. This is due to the fact that the cultivated areas are becoming larger, and chemical pesticides are easily accessible (Son, 2017).

Lack of knowledge about phytosanitary products, insufficient information about alternative methods or products, ignorance of regulatory requirements, and a lack of risk assessment capabilities also prevent appropriate and sustainable solutions from being provided to producers. For instance, several studies have reported that the most pesticides used in vegetable farming are not approved for use on vegetables by the Sahelian Pesticides Committee (CSP) (MASA, 2014). This abusive and inappropriate use of chemical products leads to the pollution of agroecosystems, resistance of pests to biocontrol methods, their resurgence and contamination of plant products with residues, resulting in sometimes fatal intoxications and unsuitable products for export markets as they fail to meet standards (Son, 2017a). Given these health-related issues, it is important to find solutions.

In this regard, alternative options to chemical pesticides, such as integrated pest management or biological control, and more recently, the use of transgenic plants, represent an alternative, developing countries (Yovo, 2010). Nowadays, the desire to implement actions in favor of agroecological transition leads stakeholders to focus on the use of biopesticides as a more viable alternative for human health, the environment, and agricultural sustainability. Indeed, certain plants, such as neem, garlic, cotton, orange, marigold, and clove, are known to have insecticidal, fungicidal, and even nematicidal properties and can be used as solutions for crop protection (MASA, 2014). Several studies have proven that these biopesticides have a better cost-effectiveness ratio and generate positive externalities in terms of health and the environment. Biopesticides provide healthy vegetable products for consumers and allow producers to sell their produce at more favorable prices (Dhaliwal et al., 2004; Julie Bourgeault, 2009). Barret et al. (2004) also add that biological solutions allow for the development of agriculture that builds harmony between ecology, human factors, and the economy. This preference for products derived from biopesticides increases the profitability of this alternative method of pest control. In Burkina Faso, the use of biopesticides could contribute reduce the chemical pesticides importations and develop local expertise in the diagnosis and treatment of plant diseases and pests. This also the possibility of producing organic products that meet the Maximum Residue Limit (MRL) standards required for agricultural products exported to the European market and allows for penetration into these markets with local productions (Yovo, 2010).

Despite the various benefits (agricultural, breeding, land, environmental, health, and economical) resulting from the use of these agroecological pest control methods, their adoption rate by producers remains low, particularly in vegetable farming. The observation in the field is that producers are aware of the situation and are willing to change practices, which is manifested by the use of crop protection methods based on biological extracts (Son, 2018). Indeed, although biopesticides are known to producers, their use is marginal in vegetable farming, especially in tomato production. This situation could be explained by several factors, one of the most significant is the availability of labor. The analysis of the results of several empirical studies indicates that labor availability is one of the main constraints affecting the adoption of new agricultural technologies. The analysis of the results of several empirical studies indicates that labor availability is one of the main constraints affecting the adoption of new agricultural technologies. Sanogo et al. (2020), show that the application of microdose fertilization technology generates additional labor costs due to the greater effort required to bury the fertilizer compared to traditional practices. The same applies to the use of biopesticides, which require more work on the part of the producer compared to the use of synthetic chemical pesticides. As pointed out by Jovana Deravel et al. (2014), the use of synthetic chemical phytosanitary products has significantly reduced the labor intensity of fieldwork for producers, who show less enthusiasm for agroecological protection solutions that require much more working time.

Despite this low penetration of biopesticides of the agriculture, some producers nevertheless use plant extracts, such as aqueous extracts of neem seeds and leaves, neem oil, etc. In the case of implementing an agroecology program for vegetable farmers, one of the chances of success and sustainability of such an alternative is the commitment of producers to pay the necessary price to cover the production costs of biopesticides. Given the harmful effects of the use of synthetic chemicals in crop protection, on human health and the environment, we assume that growers develop a desire to access other, more environmentally friendly crop protection alternatives. This work aims to assess growers' willingness to pay for biopesticides and to identify the factors influencing this WTP for biopesticide use on tomato farms in the provinces of *Houet*, *Sourou*, *Oubritenga* and *Passoré* in Burkina Faso.

MATERIALS AND METHODS

Theoretical foundations and biases of the contingent valuation method

The evaluation of individuals' willingness to pay (WTP) is based on the method known as contingent valuation (CV) or stated preference method. This method is used to assess the monetary value of the environment based on the values individuals attribute to it.

Theoretical foundations of the Contingent Valuation Method

The economic literature highlights two major factors that gave rise to the contingent valuation method: the emergence of the concept of non-use value and the recognition of the need to evaluate the impact of economic activities on the environment. The non-use value concept is based on the idea that the value of environmental assets depends not only on their immediate use but also on their potential future use (Weissbrod, 1964; Krutilla, 1967). The economic value of the environment is thus intrinsically linked to the concepts of use value and non-use value. An economic agent attributes a value to the environment based on the utility or level of satisfaction the environmental asset provides. This utility considers various possible uses, including the direct value of the asset to the economy (or use value), the option value (potential future use), and the intrinsic value (existence value) of the asset. The contingent valuation method, as a direct method of revealing individuals' preferences, aims to elicit their willingness to pay for the benefits provided by a good or service in the absence of a market price. This is done through a hypothetical market (contingent market) created in surveys. From an economic standpoint, rational decision-making seeks to maximize net benefits, and therefore, an individual's willingness to pay for an environmental asset corresponds to its total economic value (TEV) that the individual attributes to the asset. Thus, we can note that:

WTP = TEV = use value + option value + existence value. (1)

From its theoretical foundations, the contingent valuation method is an economic evaluation tool used in Cost-Benefit Analyses (CBA), providing useful information on the desirable and undesirable effects of public sector interventions. CBA is a valuable decision-making tool as it provides information on whether a specific public sector activity is advantageous or constitutes a misuse of productive resources within the community (Traoré, 2012). CBA is inspired by welfare economics, which seeks to determine how a community can allocate its scarce resources to maximize general welfare. Therefore, CBA helps to address two concerns: first, to decide whether an action should be carried out or not (for example, whether it is more judicious to use biopesticides or synthetic chemical pesticides in tomato production, whether to pay for biological protection in the farms, etc.), and second, to choose among different actions or projects the one that is likely to bring a net positive gain for the individual economic agent and the entire community.

Empirically, the use of stated preference methods in environmental economics helps reveal the weight of various pecuniary and non-pecuniary attributes, both objective and subjective. These methods refer, from a theoretical standpoint, to the existence of a hypothetical market for the provision of a public good. Based on direct surveys, the method consists of estimating the willingness to pay for specific changes in the supply of this good. The approach to evaluating the willingness to pay of agricultural producers for changes in agricultural practices is based on considering them as households-producers (Dupraz et al., 2000). They are characterized by a multi-attribute utility function that values both the marketable product derived from agricultural activities and the public good produced through changes in practices, under the constraint of implementing the technology; the public good is then a joint product of agricultural activity (Aude Ridier, 2014). This is the case with the use of biopesticides, which generate positive externalities for the environment, mitigating the harmful effects of synthetic chemical pesticides. The marketable product derived from agricultural activities is tomatoes, the public good is the environment and health, and the change in practice is the substitution of biopesticides for synthetic pesticides.

Biases of the Contingent Valuation Method

As mentioned earlier, the contingent valuation method lacks a real market where the price of the good or service could be determined through the interaction of supply and demand. The method relies on hypothetical or contingent markets, and as such, it may be subject to certain biases that can affect the quality of the estimates of willingness to pay and its determinants (Willinger, 1996). These measurement errors lead to observed willingness to pay (WTP_o) differing from the true willingness to pay (WTP_v), which remains unknown. We note WTP_v as the true WTP, WTP_o as the observed WTP, and E as the mathematical expectation operator. In the absence of bias, we have $E(WTPo - WTP_v) = 0$, or $WTP_o = WTP_v + \varepsilon$, *where* $E(\varepsilon) = 0$. In other words, if the estimation of WTP is unbiased, the divergence between the true value and the observed value is solely due to random error (Willinger, 1996). This error can be minimized by increasing the number of observations, improving the sampling technique, or implementing the recommendations of the National Oceanic and Atmospheric Administration (NOAA) panel (Arrow et al., 1993). However, if there is bias, i.e., $E(WTP_o - WTP_v)$ significantly different from zero, the error is inherent to the observation method itself, and in this case, the method itself must be modified. Several types of biases have been identified for the contingent valuation method. We will address the most common and significant biases here.

Instrumental Bias: This bias is related to the instrument used to collect individuals' WTP. Various payment methods can be used in a contingent valuation survey (payment card, auction, open-ended method, etc.), and depending on the chosen method, the results may deviate from the true WTP. This bias can be easily avoided by using, for example, the referendum method, as recommended by the NOAA panel. However, the existence of this bias clearly demonstrates that the choice of the instrument is not neutral and should be taken into account in the preparation of a contingent valuation study.

Strategic Bias or ***Free-Rider Bias***: A frequent criticism of the contingent valuation method is the possibility of "strategic responses" given by respondents. This bias is related to the fact that respondents may not want to reveal their true willingness to pay if they anticipate how their responses will be used. For example, if respondents believe that their revealed willingness to pay will be used to calculate an additional tax or levy on their income, they may tend to disclose a lower willingness to pay than their actual willingness to pay. In the case of our study, for example, producers may think that they are being asked to pay for things they should not pay for, leading them to hide their true willingness by providing biased responses. In such a situation, they behave like free riders, wanting to benefit from the service or good funded by others (Willinger, 1996).

Hypothetical Bias: This bias arises from the fact that respondents participating in the questionnaire are not faced with a real market but with a hypothetical or contingent market. In such a situation, respondents know in advance that there is no actual payment involved. Therefore, the stated willingness to pay differs from what would be expressed in a real market (Cumming et al., 1995). This bias resulting from individuals' inability to accurately reveal their preferences is difficult to avoid because it is inseparable from the method itself and, therefore, irreducible. As François Bonnieux (2007) argues, individuals have likely not previously translated their preferences into monetary terms, so even if they genuinely want to do so, lack of experience becomes a handicap. Attempts to control the hypothetical bias include providing a clear and precise description of the scenario to enable respondents to accurately assess their WTP. In reality, different experiments show that individuals subject to the survey tend to underestimate their WTP, and there is a significant reduction in the dispersion of values (reduction of WTP variance). Experiments also indicate that once subjects become familiar with the environmental asset being evaluated, their psychological perception is altered (Greene et al., 1995). To reduce this bias of overestimating WTP due to respondents' lack of familiarity with the contingent market, McClelland et al. (1991) propose a logarithmic transformation to de-bias the mean, and the distribution of errors becomes closer to a normal distribution.

Inclusion Bias (***Embedding Effect***): This is one of the most important biases that researchers must control in a contingent valuation study (Bonnieux, 1998). Inclusion bias occurs when the WTP for a particular good is influenced by the degree to which this good is included in a broader set of goods (Hanemann, 1994). In such cases, the effect of WTP may not change with the size or dimension of the evaluated good. For example, the WTP to protect 10 hectares of tomatoes and the WTP to protect 2 hectares would have practically the same values. This difficulty arises when the definition of the good lacks precision or realism, casting doubt on the significance of the contingent valuation results (François Bonnieux, 1998). The selection bias particularly arises when the good to be valued is vague and at a high level of aggregation (Kahneman et al., 1992). Three different notions of inclusion bias are generally used. The "scope effect" or scope effect is the situation where agents do not take into account the quantity, size, and volume of the good being evaluated in their willingness to pay. The sequence effect occurs when multiple assets are evaluated in the same survey. In such a situation, the value assigned to a particular asset may depend on the order in which questions about the evaluation of that asset are asked, leading to variation in WTP based on the order of evaluating different assets. Several economists argue that the anomaly associated with the sequence effect is related to the income effect and the substitution effect. If an agent is willing to pay for a given asset, their available income for other assets decreases, leading to lower willingness to pay for subsequent assets. Similarly, according to the substitution effect, an agent who is willing to pay M1 for a particular asset will be willing to pay M2, such that M2 < M1, because the two assets are substitutes. The sub-additivity effect is the situation where the overall value attributed to a group of assets may be lower than the sum of the values revealed for each component of this group of assets. In this case, aggregating the WTP of the same person for different independently evaluated goods results in abnormally high values that do not respect the budget constraint of the individual, resulting in overestimations of WTP (François Bonnieux, 1998) if a producer is willing to pay for a given technology package.

In addition to the biases mentioned above, there are other biases often highlighted in willingness-to-pay evaluations. We will not address them here. For example, a poorly specified scenario can lead to a gap in understanding between the interviewer and the interviewee. The problem then lies in the perception gap between the two, which can be controlled by conducting preliminary pilot studies to assess the questionnaire's comprehension, question order, information provided during the questionnaire, and the relationship between the interviewer and the interviewee, all of which are sources of biases that are difficult to control (Willinger, 1996).

Econometric modeling

Theoretical model

This part provides additional information to aid in a better understanding of the formation of WTP (Willingness to Pay) for biopesticides among tomato producers. As previously mentioned, the contingent valuation method serves as the methodological basis for this study, evaluating the producers' willingness to pay for the use of biopesticides. The modeling in this study refers to Hanemann's model (1984). This model assumes that an individual's random utility depends on the improvement in the environmental good's quality, their income, and observable characteristics. To convert the responses (yes/no) to the referendum question, we introduce the random utility function U (j, y, s), where *j* is an indicator variable (*j=1* if the individual accepts to pay and *j=0* otherwise), y is the income, and s is a vector of individual socio-economic characteristics of the producer. As prices are assumed to be constant, we can omit the price vector in the utility function (François Bonnieux, 1998).

It is observed that the expression of the individual's indirect utility function includes an observable component v(.) and a second component part $\in_j$ ($j=0,1$) which is random and unobservable.

$$U(j, y, s)=v(j, y, s) + \in j \text{ with } j=0, 1. \quad (2)$$

An individual then agrees to pay if :

$$v(1, y-C;s)+\in 1 > v(0, y, s) + \in 0. \quad (3)$$

Where C is the proposed bid. By agreeing to pay amount C, the individual's residual income is then y-C. The probability of the individual answering yes to the referendum is given by the expression:

$$P=P[\eta+v(1, y-C;s)-v(0, y, s)] \quad (4)$$

where $\eta = + \in_0 \in_1$. We then deduce that:

$$P = F_{\eta}(\,)\,\Delta v$$

and $P\,(accept\ bid\ C) = P(CAP>C) = 1-G(C)$

$$F_{\eta}(\Delta v)=1-G(C) \quad (5)$$

Where $F_{\eta}(.)$ is the distribution function and $G(C)$ gives the probability of refusing the bid. Bonnieux (1998) shows that we can get around the constraint of estimating $G(.)$, which is both the CAP distribution function and a random variable, by using the term η.

The econometric model can be derived by specifying a functional form for the observable component of utility and a probability distribution for the random component. For modeling such decisions, models with qualifying dependent variables are adequate (Greene, 2012), and from a logistic distribution, we deduce a Logit model that we know how to estimate. We then have :

$$P=F_{\eta}(\Delta v)=\frac{1}{1+e^{-\Delta v}}, \quad (6)$$

with $\Delta v = \gamma_0 + \gamma_1 \log C + X\Sigma\gamma_{j\,j}$

Regarding the estimation approach, the implementation of the CVM (Contingent Valuation Method) required the development of a questionnaire, conducting surveys, and the use of statistical and econometric techniques to assess preferences. In selecting these tools, we considered the recommendations established by the NOAA panel. Additionally, we followed the research protocol proposed by Carson and Mitchell (1989) and Loomis (1990), which have shown satisfactory results for contingent valuation evaluations with validity tests of WTP on individuals' preference stability. The dichotomous choice closed-ended method, strongly recommended by the aforementioned panel due to its ability to minimize various biases and provide better WTP estimates, was used to elicit preferences. This mechanism of preference revelation resembles a perfectly competitive market since the person being surveyed is in the position of a buyer facing a displayed price (Lucinio et al., 1998).

The FCFA values of the WTP offered in the surveys correspond to a vector of values (7500, 10000, 12500, 15000). The values in this vector were empirically determined based on information gathered during a survey conducted in 2021 among tomato producers and biopesticide-producing entities. An analysis of the prices of different biopesticides and chemical pesticides used by tomato producers led to the establishment of an average price. This average price was considered a reference to create the list of prices offered to producers during the WTP revelation survey.

To collect producers' WTP, they were asked the following question: "To avoid using chemical pesticides on your tomato field, would you be willing to pay Ci FCFA to acquire biopesticides?" The value Ci corresponded to a value randomly selected from the elements of the previously mentioned vector. In addition to the WTP question, the survey collected socio-economic characteristics of the respondents, their preferences, and their opinions on biopesticides.

In general, two methods can be used to model willingness to pay in a contingent valuation: Heckman's method (two-step method with a selection equation) and the dichotomous method. The Heckman method estimates only positive WTP values, but the introduction of Mills ratios in the equation corrects this selection bias. The dichotomous method, on the other hand, takes into account the zero values of WTP by distinguishing "true zeros" from "false zeros" based on an analysis of the reasons for refusal to pay given by the surveyed individuals. The dichotomous method also has the advantage, in addition to identifying factors explaining WTP, of facilitating the calculation of the average WTP value.

Technically, the Heckman method is not very different from the dichotomous method. Both methods proceed through two relatively similar steps, one qualitative and the other quantitative. The difference lies in the introduction in the quantitative model of the Mills ratio, which is directly derived from the qualitative model concerning the principle of paying (PDP) under specific circumstances (Jean-Yves Godard, 2010). By considering the principle of PDP, the Heckman method preserves the continuity of the decision-making process and, therefore, seeks to predict not the stated value, as the dichotomous model does, but the value that would have been declared if a refusal to pay had not come to censor the actual willingness to pay (Jean Yves Godard, 2010).

In this study, we chose to use the dichotomous method to evaluate the willingness to pay, which allows estimation of mean and median WTP values that will facilitate potential cost-benefit analyses of using biopesticides in Burkina Faso. The mean WTP value is an essential outcome of any contingent valuation (Champ et al., 2003) and can be considered the ultimate purpose of the study in some cases. In the case of a cost-benefit analysis, it is this value that allows us to approach the total benefit of a project by multiplying it by the number of beneficiaries of the said project (Bateman, 2002; Desaigues et al., 2003).

Finally, we specify that in this study, we assumed that producers act as individuals free to make an autonomous and rational decision based on their situation. However, we know that in reality, active producers are most often linked, in one way or another, to the opinions, reasoning, postures and beliefs expressed by other producers with whom they are sometimes in close contact and, in particular, with whom they are regularly in conversation (what Jean-Pierre Darré calls a "talking group"). As a result, the decisions they take to adopt or not, or to pay one price rather than another, can be made independently of any price or availability factor.

Specification of the econometric model

As mentioned earlier, we can deduce a Logit model that can be easily estimated from a logistic distribution. This model captures the probability that a tomato producer agrees to pay the amount C of the bid to access biopesticides on their farm. The surveyed producer i agrees ($Y = 1$) to pay for biopesticides with the aim of achieving a more economically profitable and environmentally friendly production if the proposed amount C is less than their Willingness to Pay (WTP). Otherwise, they refuse ($Y = 0$). Since the error terms follow a logistic distribution, the estimation of the probability that individuals agree to pay the proposed amount in the referendum can be done using the equation below. Based on pseudo-R2, the best form of logistic regression is obtained by transforming the amounts proposed to the respondents using the natural logarithm (Wooldridge, 2018).

$$P(accept\ bid\ C) = P(CAP>C) = 1- G(C)= P\ (Y_i =1/X_j\ ,\ C) = \frac{1}{1+e^{-\alpha-\beta_1 \ln(Ci)-\sum \beta j Xj-\mu i}} \quad (7)$$

- Y_i is the dichotomous variable specifying the choice of producer i and takes the values 0 and 1;
- βj ($j = 1, 2, ...n$) are the parameters of the model to be estimated;
- C_i is the amount of the bid proposed to producer i in the referendum;
- Xj is the vector of explanatory variables (socio-economic characteristics of the grower, grower's perceptions and knowledge of biopesticides, etc.);
- μi the error term that follows a logistic distribution.

From the estimation of this equation, we can identify the factors that influence producers' willingness to pay for biopesticides and also the direction and intensity played by any given factor on this willingness (Kitoto, 2018). This information would allow us to formulate policy measures.

Calculation of the Mean Willingness to Pay

The mean value of the Willingness to Pay is among the essential results of any contingent valuation (Champ, 2003). This value will allow us to approximate the total benefit of substituting biopesticides for chemical pesticides (Bateman, 2002). It can also be useful for legal decisions to assess damages (Desaigues et al., 2003). Therefore, after identifying the variables that significantly influence producers' willingness to pay based on our sample, we seek to estimate the mathematical expectation of the WTP, considering that it is a random variable. Taking into account the discrete nature of the dependent variable data, we can use the following utility function:

$$v(q,y,s)=\alpha_y+\beta y+\gamma s+\epsilon_q q=0.1. \quad (8)$$

From this equality, we can capture the variation in the producer's utility induced by the use of the biopesticide with a willingness to pay a cost *C*. This differential is:

$$\Delta v = \alpha_1 + \beta\,(y-C) + \gamma\,s - \alpha_0 - \beta\,y - \gamma\,s = (-\alpha_1\ \alpha_0\ ) - \beta\,C = -\alpha\beta\,C \quad (9)$$

Defining P0 as the probability that individuals agree to pay the amount C proposed to acquire biopesticides and use them on their farm, replacing synthetic chemical pesticides, and if F is the cumulative distribution function of a logistic distribution, this probability P0 becomes:

$$P_0=F_\eta\ (-\alpha\beta\ \ C) = \frac{1}{1+e^{-\alpha+\beta C}} = \frac{e^{\alpha-\beta C}}{1+e^{\alpha-\beta C}} \quad (10)$$

From this equation, we can deduce the average WTP defined by :

$$E(CAP) = \int_{t1}^{t2} F\eta\,(\alpha - \beta C)\,dC = \int_{t1}^{t2} \frac{e^{\alpha-\beta C}}{1+e^{\alpha-\beta C}}\,dC = -\frac{1}{\beta}[\ \ln(1+e^{\alpha-\beta C})\ ]_{t1}^{t2} \quad (11)$$

To calculate this value, we need to choose a relevant cut-off or truncation point t_1 and t_2 . To address this constraint, we use the truncated mean to estimate the average WTP, whose expression retains the truncation of the questionnaire's maximum offer. Mitchell and Carson (1989) recommend the use of this truncated measure in contingent valuation, as it brings the mean closer to the median. Furthermore, Kitoto (2018) indicates that the best form of regression is obtained by transforming the proposed amounts by the natural logarithm. In view of the above, the expression for the corresponding average WTP is as follows:

$$Mean\ CAP = -\frac{1}{\beta 1}[\ \ln(1+e^{\alpha-\beta 1\ln(C)})]_0^{C*} = -\frac{1}{\beta 1}\ \ln\left(\frac{1+e^{\alpha-\beta 1\ln(C*)}}{1+e^{\alpha}}\right) \quad (12)$$

Kitoto (2018) shows that the arguments of the other variables are not explicitly apparent in the above equation, but that their influence is exerted on the values of the parameters α and β_1 corresponding to the coefficients of the constant and the amount *C* of the offer respectively.

Treatment of Null Values (False Zeros)

Before proceeding with the model estimation, one point needs to be clarified: the data related to the dependent variable (false zeros).

The consideration of false zeros in the model estimation and the calculation of the mean Willingness to Pay can be done in two ways (Jean-Yves Godard, 2010). The first approach involves excluding false zeros from the calculations. In other words, they are discarded because a direct and indiscriminate modeling of the CAP, including all values, both zeros and non-zeros, would yield poor results (Jean-Yves Godard, 2010). However, this approach is justified only if the excluded observations, i.e., the population of false zeros, do not exhibit a selection bias compared to the population that declared non-zero amounts (Grappey, 1999; Bateman et al., 2002). Therefore, it is essential to verify this condition by ensuring that the two sub-populations do not show significant differences with respect to the variables found to be significant for determining the CAP. To do this, we will perform a chi-square test of difference between the characteristics of the two groups to ensure that there is no significant difference between them. This test will lead us to adjust the size of our sample to a final size and proceed with the modeling by excluding the data of producers who did not respond at all to the question and those who clearly cited financial constraints preventing them from contributing to the access to biopesticides.

Explanatory Variables of the Model

Based on the literature review, we consider that the variables likely to influence the probability that a producer is willing to pay for biopesticides are of socio-demographic, agro-economic, and psychosocial nature.

Sociodemographic factors may include various aspects such as age, gender, producer's experience, household size, and level of education. Institutional factors related to the producer's environment and social network include membership in producer organizations, contact with agricultural extension services, contact with NGOs, and previous information and/or use of biopesticides. Agro-economic factors encompass variables like plot size, access to credit, tenure mode of the plot, distance from the village to the tomato fields, distance between the point of sale of phytosanitary products, and the tomato field, as well as the producer's horticultural income.

The producer's age, as a continuous variable, is an intrinsic factor that significantly influences their willingness to pay for agrotechnologies. Yovo (2010) demonstrated in their study on the analysis of willingness to pay for biopesticides by vegetable growers that young operators are more inclined to adopt biopesticides than older vegetable growers. Similarly, Bekouanan (2018) showed that the age of the producer significantly influences their willingness to pay for the use of neem extracts in vegetable production in Burkina Faso.

Gender, a binary variable, may be a key determinant of willingness to pay. According to the results of several previous studies, being male increases the probability of willingness to pay for biopesticides. However, some studies present contrary results, suggesting that the relationship between gender and willingness to pay is indeterminate.

The level of formal education of the producer could influence their willingness to pay. In general, education positively influences the adoption of new technologies due to increased capacities, skills, and risk aversion. Son (2018) specifically demonstrated that the level of education has a positive influence on the adoption of good plant disease and pest control practices in Burkina Faso, attributed to the ability to read and use technical documents.

The size of the producer's household may have different effects on the decision to adopt a given technology, depending on the characteristics of the technology and the institutional context. Particularly for the adoption of biopesticides, the household size serves as a proxy for the availability of the producer's family labor and, in turn, influences their decision to invest in biopesticides. Previous studies have identified the high demand for labor as one of the key constraints to the non-adoption of biopesticides by producers. This factor may also have a positive effect on willingness to pay for biopesticides. The number of household members is included in this study to measure the effect of labor availability on household production and consumption decisions.

The size of the producer's plot is a continuous variable that could influence their willingness to pay. We expect that producers with relatively large plots may be less willing to pay for biopesticides and may opt for synthetic chemical solutions instead.

Membership in a producer organization is a binary variable taking the value 1 if the producer is a member and 0 otherwise. One of the key dimensions of the adoption of agricultural technologies is fundamentally dialogue and learning from peers. Producer organizations can be considered as incubators in this process (Darré, 1985).

Contact with extension services is also a key factor in the adoption of agricultural technology. According to the results of Sissoko's analysis (2019), there was a significant difference between adopters who had been in contact with state and private institutions and non-adopters of agricultural technologies. This factor could undoubtedly affect both the decision to adopt and the decision after adoption.

NGOs play a crucial role in supporting and strengthening the capacities of farmer organizations. These NGOs implement programs in the field to fill the gaps left by the state. It is expected that the presence of these organizations enhances the knowledge of producers about biopesticides, which will increase the probability of accepting to pay for them.

To analyze the effect of access to phytosanitary products, the distance from the producer's residence to an input sales point will be used as a proxy. Studies assume that the longer the distance, the lower the probability that the producer has access to fertilizers or applies mineral fertilizers. This variable is expressed in kilometers (km) between the producer's residence and the rural market or the nearest city market.

Experience, measured by the number of years in tomato production, is decisive, especially in the continuous application decision (Tura et al., 2010). As the producer's experience increases, the probability of adopting biopesticides and being willing to pay may also increase.

Additionally, the information received by the producers through capacity-building sessions on the production and use of biopesticides impacts their knowledge about the technology, its advantages, disadvantages, characteristics, and conditions of use, all of which influence their willingness to pay.

The mode of acquiring plots is a binary variable, taking the value 1 for inheritance and 0 for other modes of acquisition. It is considered that households that acquired their plot through inheritance have absolute property rights. Thus, they can make investments with a relatively long return on investment period. On the other hand, those who acquired their plot through rental or donation may be reluctant to make certain investments, as the plot could be returned to its owner if the need arises.

The horticultural income serves as an incentive for the producer and may influence their investment in the use of biopesticides. Bakouanan (2018) showed that income from horticulture has a significant positive impact on the use of neem extracts in horticulture in Burkina Faso. We expect that the producer's horticultural income will have a positive impact on the probability of accepting to pay for biopesticides.

In addition to socio-economic and agronomic characteristics, willingness to pay is also influenced by the perceptions that producers have of the technologies. These perceptions, expressed through opinions about biopesticides, are subjective in nature. Perceptions are subjective, and producers may base their decisions on what they perceive or imagine rather than objective reality (Adesina and Zinnah, 1993; Bennani and Saad, 2018). For example, for some producers, the impression or perception of the efficacy of biopesticides or their high demand for labor may be a concern for them, despite a probable relative advantage in terms of economic profitability compared to chemical control methods. Given the subjective nature of perceptions and the heterogeneity of producers, these perceptions are intrinsic to each producer and may be endogenous. Indeed, as emphasized by Roussy et al. (2015), perceptions depend on unobservable and specific factors due to the heterogeneity of producers and the different production contexts in which they are embedded. Omitting these perception variables in the analysis of determinants of willingness to pay for biopesticides will lead to a biased estimation of the effects of other explanatory variables that would be correlated with producers' perceptions on adoption and use probabilities (Wooldridge, 2012) (cited by Sanogo, 2021). In this case, we face a bias of omitted variables related to the fact that we did not consider producers' perceptions of biopesticides in determining their willingness to pay for them. This omission of perceptions in the explanatory variables would lead to a biased estimation of the model parameters (bias of the omitted variable, which in this case is the producer's perception of biopesticides). Since perceptions have a partial but nevertheless significant

Table 1. Description of Explanatory Variables

Variables	Description	Expected signs
Ln(auction)	Neperian logarithm of the amount proposed in the referendum	-
Age	Age of producer (years)	_
Gender	Sex of producer (1=male, 0=female)	+/-
Experience	Number of years in tomato production (years)	+
Household size	Number of individuals in producer's household (number)	+
Education	Producer's level of education (1=No level, 2=Primary, 3=Secondary and 4=Higher)	+
Market garden income	Grower's market garden income for last season (FCFA)	+
Group member	The producer is a member of a producer group (1=yes, 0=no)	+
Extension access	Producer receives advice from government technical services (1=yes, 0=no)	+
NGO contact	The producer is in contact with NGOs (1=yes, 0=no)	+
Credit	The producer has had access to credit in the last three years for his activity (1=yes, 0=no)	+
Dvillage	Distance between plot and grower's concession (in km)	+/-
Dphyto	Distance from point of sale of crop protection products to producer's dealership (in Km)	+
Efficiency	Grower's perception of biopesticide effectiveness against pests and diseases (1=effective, 0=not effective)	+
Environment	Producer's perception of whether the biopesticide is harmful to the environment (1=yes, 0=no)	-
Infobio	Grower information/knowledge of biopesticide (1=yes; 0=no)	+
Usagebio	Producer's use of biopesticides (1=yes, 0=no)	+/-
Health	Grower's perception of whether the biopesticide is good for his health (1=yes, 0=no)	+

effect on the producer's willingness to pay, and they are correlated with other socio-economic characteristics of the producer already included in the explanatory variables, this situation violates the assumption of exogeneity of the explanatory variables when the explanatory variables matrix is endogenous (if we do not include perception variables in the explanatory variables). The difficulty in considering these perception variables is that perceptions are endogenous as they depend on the characteristics of the producers and especially because it is not possible to instrument these perceptions, which are by nature unobservable. One possible solution is to find a proxy that would attenuate the bias for these perception variables (Wooldridge, 2012). The proxy used to analyze perceptions is generally introduced into the model based on a binary variable if the producer perceives the interest of the innovation or not (Roussy et al., 2015). This is the approach we have adopted in this study.

The perception variables considered in this study are: the producer's perception of the effectiveness of biopesticides, the producer's perception of the harmful effect of biopesticides on the environment, and the producer's perception of the toxic effect of biopesticides on their health. The perception of the effectiveness of biopesticides, a binary variable, assesses the producer's belief in the ability of biopesticides to eliminate plant diseases and pests compared to other control techniques, notably chemical control. The variable takes the value 1 if the producer considers the biopesticide effective and 0 otherwise. We expect a positive effect in the case of a positive perception. The perception of the benefits of biopesticides for the environment mainly concerns the perceived advantages of biopesticides for environmental protection compared to chemical pesticides, which are toxic and have harmful effects on the environment. A binary variable takes the value 1 if the producer believes that the application of biopesticides protects the environment and 0 otherwise. The producer's perception of the benefits of biopesticides for their own health is a binary variable, taking the value 1 when the producer believes that the technique better protects their health compared to chemical pesticides, and 0 otherwise.

Table 1 above summarises the explanatory variables in the model, together with their descriptions and expected signs.

Study area and data used

The data used in this study were collected through a survey of producers in four (4) regions of the horticultural basin of Burkina Faso, namely *Hauts-Bassins* (*Houet*), *Boucle du Mouhoun* (*Sourou*), *Plateau Central* (*Oubritenga*), and *Nord* (*Yatenga*). The provinces of *Sourou*, *Oubritenga* and *Passoré* are located respectively in the *Boucle du Mouhoun*, *Plateau Central* and *North* regions in the Sudano-Sahelian climatic zone, with isohyets of between 700mm and 900mm. The province of *Houet* is located in the *Hauts-Bassins* region in the Sudanian zone, with isohyets between 800 and 1100mm. These four regions alone account for 48% of the national tomato production and 50% of the total tomato acreage in the country. In 2021, an initial survey was carried out on a sample of 50 villages with high tomato production (in terms of area sown and number of growers) in the targeted zone. This work allowed us to compile a list of all tomato producers in these villages, which served as the sampling frame for the WTP survey in 2022. From the

Table 2. Breakdown of selected amounts by sample

Proposed bid	7 500	10 000	12 500	15 000	Total
Workforce	227	214	211	219	871
Proportion	26%	25%	24%	25%	100%

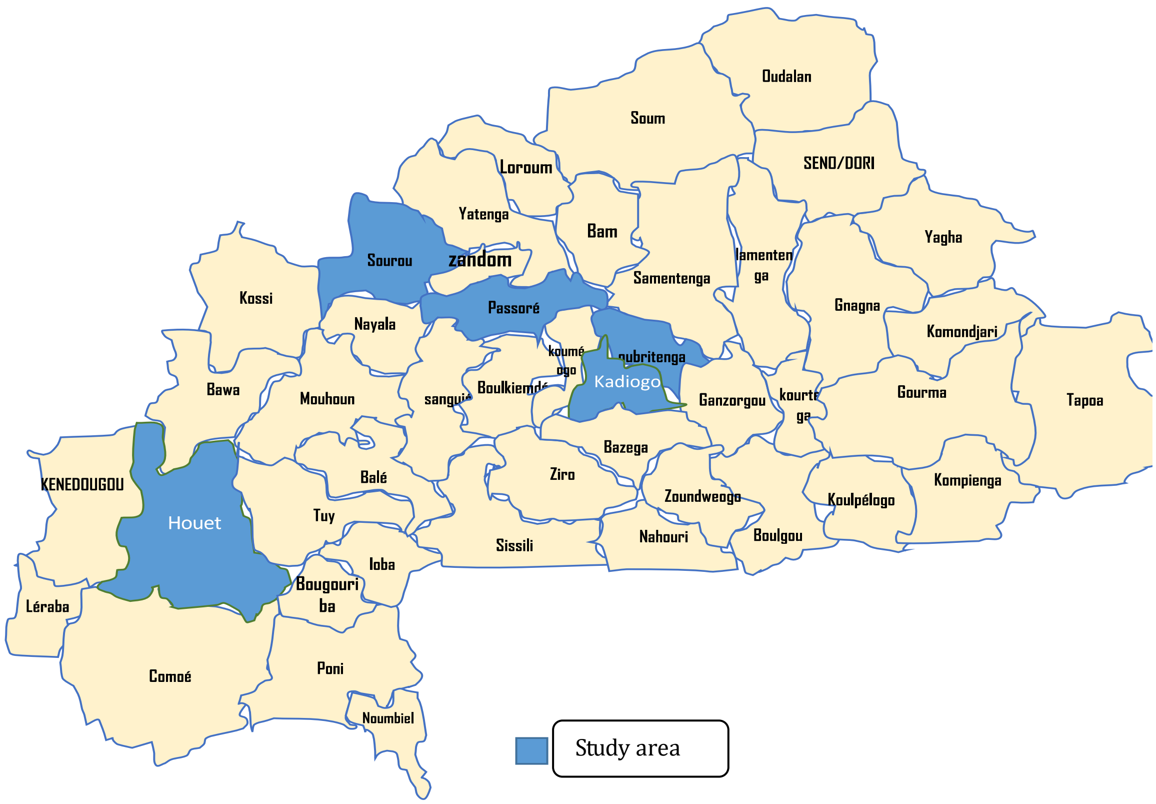

Figure 1: Map showing study provinces

Source: PRD-PRoDuIRe, 2021

list of tomato producers in these selected villages, a random sample of twenty (20) producers per village was drawn. In total, 904 producers were asked to reveal their willingness to pay for biopesticides as a phytosanitary solution for tomato crop protection. The closed-ended question with a simple dichotomous choice (yes/no) and voluntary contribution were used in this survey as means of formulating and eliciting the willingness to pay. The question posed, to which the surveyed producer had to respond with either yes or no, was as follows: "Would you be willing to pay Ci FCFA to have a biopesticide for your tomato plot instead of chemical pesticides?" The amount Ci proposed to a respondent was randomly chosen from the elements of a vector of four defined bids mentioned above. Stata software was used for analysis.

In order to follow the recommendations of the NOAA panel (Arrow et al., 1993), each amount was distributed equitably in the total sample. After the data collection, a sorting of the questionnaires allowed us to discard those with missing or incomplete information, resulting in only 871 questionnaires that could be used for our work. The distribution of the treated sample according to the values of the price vector is presented in Table 2.

In addition to their WTP, data collection also involved information on the socio-economic characteristics of growers, their preferences and their levels of knowledge about biopesticides.

Figure 1 shows the geographical location of the provinces covered by this study.

RESULTS

Socio-economic Characteristics and Knowledge of Producers about Biopesticides

The results show that our sample is predominantly composed of men (82.72%) with an average age of 41.63 years, ranging from 18 to 68 years. This reflects the relatively young age of the surveyed producers. These results are consistent with those of the National Agricultural Census (2020), which indicates that producers

Table 3. Proportion of acceptances

Proposed amount (Fcfa)	7500	10000	12500	15000	**Total**
Proportion of acceptances (%)	84.58	86.87	76.44	74.62	**80.69**

between the ages of 18 and 35 represent 41.8% of all vegetable producers in the country. Regarding education, the data reveals that nearly half of the surveyed producers have no formal education (44.72%), 41.29% have primary or basic literacy, 09.14% have secondary education, and only 4.82% have higher education. In terms of experience in tomato production, the average number of years in activity for the producers in our sample is 12.57 years, indicating a relatively good knowledge of the activity they are engaged in. Only 28.33% of the producers had access to credit during the past five years for their activities, indicating a relatively limited access to credit for producers. The average maraicher income for the surveyed producers is 372,190 Fcfa (West African CFA franc) for a production campaign. More than half of the producers (69.63%) believe that biopesticides (neem extracts) are effective in controlling diseases and pests. 67.21% acknowledge that biopesticides are better for their health compared to chemical pesticides. However, only 13.34% are aware that biopesticides are beneficial for the environment. This suggests that the damages caused by chemical pesticides to the environment are not well known among the producers. Moreover, only 41.42% of the producers reported having received information about biopesticides, their benefits, and the need to use them for sustainable production. This highlights the importance of awareness-raising, training, and information dissemination in promoting these agroecological solutions.

Regarding the producers' reaction to the contingent scenario presented to them, it appears that more than 80% of the 871 surveyed producers accepted to pay the proposed amount to access biopesticides (Table 3). Only 19.31% of the producers refused to pay the proposed amount.

Reasons for Producers' Refusal to Pay

A common difficulty in conducting contingent surveys arises from the presence of zero responses. The practice in such surveys involves asking an additional question to distinguish between true zeros, which represent a genuine refusal to pay, and protest zeros, which are associated with issues such as the difficulty of evaluating the good or service. To better understand the reasons for the refusal to pay (CAP=0), producers who expressed a refusal to pay for the use of biopesticides were invited to freely express the reasons for their refusal (appendix 1). The analysis of the reasons for refusal based on 236 observations indicates that 36.39% of the cases correspond to "protest zeros," where the refusal to pay is primarily motivated by general considerations rather than specific reasons related to the use of biopesticides. These cases were excluded from our sample. Therefore, it is important to verify if there is a notable difference between the two subpopulations concerning the variables found to be significant in determining CAP using a chi-square test.

We conducted a chi-square test to check if there is a significant difference between the characteristics of the two groups. The test showed that there is no significant difference between the two groups. This result allows us to proceed with the modeling, excluding the data from producers who did not respond to the question and those who clearly cited financial constraints preventing them from contributing to access biopesticides. Taking this into account, our sample has been adjusted to a final size of 787 producers, whose results were considered in the econometric model.

Determinants of Willingness to Pay for Biopesticides

As already mentioned, the contingent valuation method employs a hypothetical market. Therefore, one of the necessary conditions to ensure the theoretical validity of the results of this valuation is the observation of consistent relationships between certain characteristics of the respondents and their declaration of willingness to pay (WTP). These pieces of information, along with the marginal effects, are provided by the results of the Logit model and are presented in Table 4.

The results of the logistic regression model presented in Table 4 shows that the model is statistically significant overall (Prob > Chi-squared = 0.0000) at the 1% significance level. The estimation of the regression model yielded a predictive power (pseudo-R2 of McFadden) of 41%. This indicates that 41% of the variation in willingness to pay for biopesticides is explained by the introduced variables in the model. McFadden (1974), indicates that Pseudo R2 values between 20% and 40% indicate an excellent model fit in logistic regression.

Table 5 below presents the contingency table, which shows the actual structure of observed choices and the choices predicted by our estimated model.

This Table 5 shows that among the 678 producers who accepted to pay (WTP=1), 614 responses were correctly predicted, and for the producers who did not accept to pay (WTP=0), 88 out of 109 responses were correctly predicted. The total number of correct predictions is then 702 cases (614+88=702). If we relate this number to the total number of observations in our sample (787), we obtain a correct prediction rate of 89.20%. This indicates that our model has a satisfactory explanatory power. Based on the results, we can conclude that our model is statistically significant overall and has a satisfactory explanatory power for the willingness to pay of tomato producers for biopesticides.

The estimation of the model shows that, at the level of economic variables, the producer's maraicher income and the proposed bid amount have a significant effect at the 1%

Table 4. Econometric model estimation results

Explanatory variables	Coefficient	z-stat	P>z	Marginal effects
Ln(auction)	-2.480***	-4.92	0.000	-0.216
Age	-0.010	-0.62	0.533	-0.001
Gender	-0.306	-0.87	0.387	-0.027
Formal education	-0.056	-0.33	0.738	-0.005
Experience	-0.043**	-2.30	0.021	-0.004
Household size	0.076**	2.29	0.022	0.007
Parcel area	-0.968	-1.50	0.133	-0.084
Distance field-Concession	0.029	0.46	0,643	0.002
Distance from crop protection products	0.076	1.12	0.263	0.007
Credit	-0.412	-1.37	0.172	-0.036
Market garden income	2.618***	8.91	0.000	0.229
Group member	0.568**	2.10	0.036	0,049
Extension contact	-0.056	-0.22	0.823	-0.005
NGO contact	-0.391	-1.41	0,159	-0.034
Type of plot ownership	-0.097	-0.77	0.443	-0,008
usagebio	-0.248	-0.51	0.610	-0.022
infobio	1.795***	3.57	0.000	0.157
Efficiency	1.697***	6.15	0.000	0.148
Health	0.530*	1.94	0.052	0.046
Environment	-1.091**	-2.15	0.032	-0.095
_cons	1.90*	2.73	0.084*	--
R2 username	0.4083	Prob>chi2		0.0000
Log likelihood	-228.51756			787

*** p<1%, ** p<5%, * p<10% (significance thresholds)

Table 5. Predicted and observed numbers of the dependent variable

		Observed "CAP" values		
		1	0	**Total**
CAP" predicted values	1	614	64	**678**
	0	21	88	**109**
	Total	**635**	**152**	**787**

NB: This matrix has been constructed on the basis of an arbitrary probability significance threshold set at 0.5.

level on the probability that producers are willing to pay for biopesticides. In terms of marginal effect, an increase in the proposed bid amount would reduce this probability by 0.216 points. The maraicher income of the producer, on the other hand, has a positive and significant influence at the 1% level on the probability of accepting to pay for biopesticides.

Regarding sociodemographic variables, the size of the household and the experience of the producer significantly affect their willingness to pay for biopesticides. The coefficient associated with the size of the producer's household is positive and significant at the 5% level. In terms of marginal effect, an increase in the size of the producer's household by one unit increases the probability that the producer accepts the proposed bid by 0.007 points. The producer's experience in tomato production negatively influences the probability of accepting to pay for biopesticides at the 5% level.

As for variables related to producers' perceptions and knowledge of biopesticides, the results indicate a significantly positive relationship at the 1% level between WTP and being informed about these technologies, especially the perception they have of the effectiveness of these biopesticides and their impact on health and the environment. Additionally, the coefficient associated with access to information on biopesticides is positive and significant at the 1% level. Furthermore, the willingness of producers to pay for biopesticides is also positively linked to institutional factors such as membership in producer organizations (prob=0.036).

Values of the Average Willingness to Pay (WTP) and Induced Benefits Based on the coefficients obtained from the econometric estimation of the model, we can calculate the average WTP of our sample. The constant α is 1.90, and the bid coefficient β is -2.480. The numerical application using these coefficients and the formula for the average WTP gives ln (average WTP) equal to 9,560 FCFA per hectare and per producer. From this formula, we obtain the value of the natural logarithm of the average WTP, from which we deduce the real average WTP by applying the exponential function. As a result of this transformation, we find that the estimated average WTP is 14,180 FCFA per producer and per hectare of tomatoes, which is approximately 21.61 euros.

Our contingent scenario involves replacing synthetic chemical pesticides with biopesticides in tomato production and more generally in other vegetable productions. In 2020, the total area exploited for vegetable farming was estimated at 60,354 hectares, with a total of 337,691 farmers. However, 678 out of 787 producers are willing to pay to acquire biopesticides, representing 80.69% of the producers in our sample. The value of the average WTP, aggregated to all producers willing to pay for biopesticides and for the entire vegetable farming area of the country, allows us to obtain the theoretical benefits associated with the abandonment of chemical pesticides in favor of biopesticides.

Based on this, the social gain associated with the use of biopesticides is obtained by multiplying the average WTP by the area exploited by the 80.69% of all vegetable farmers in the country, resulting in a monetary value estimated at 690,566,000 FCFA per production cycle. This value represents what vegetable farmers would be willing to give to replace chemical pesticides with biopesticides. This extrapolation is based on the very strong assumption of the homogeneity of preferences and choices of individuals (Blackorby and Donaldson, 1988).

DISCUSSION

The evaluation of farmers' willingness to pay indicates that they are well aware of the negative effects of synthetic chemical pesticides on their health and the environment. In fact, more than 80% of the interviewed farmers are willing to pay an amount to substitute biopesticides for the widely used chemical pesticides in tomato production, not only to achieve better yields but also to protect their health and the environment. These results are consistent with those of Son (2017) and Coulibaly et al. (2006), which show that vegetable farmers in Burkina Faso are aware of the dangers posed by the (especially uncontrolled) use of chemical pesticides in their fields. However, this rate is lower than the one obtained by Yoro (2010), who found a 93% rate of farmers willing to pay a premium to buy biopesticides in his study on the evaluation of willingness to pay for biopesticides by vegetable farmers in the coastal region of South Togo. The majority of farmers are willing to pay a premium of 10,000 FCFA, likely due to their financial constraints.

However, the question remains as to why this awareness among farmers of the benefits of biopesticides compared to chemical pesticides does not yet translate into widespread use of biopesticides in Burkina Faso. Such an observation suggests that emphasis should be placed on awareness-raising and widespread dissemination of knowledge about biopesticides, which are essential factors in the decision to pay for and adopt biopesticides.

The willingness to pay for biopesticides is influenced by several factors, including socio-demographic, economic, and institutional ones.

The maraicher's income has a positive effect on the probability that farmers are willing to pay for biopesticides. This would mean that farmers who earn a higher income from vegetable farming are more willing to pay the proposed amount than those who earn relatively less. This result highlights the importance of the profitability of tomato production for the farmer in their decision to accept paying a price for the use of biopesticides. This result is consistent with that of Jean-Yves Badart (2018) but contradicts that of Yovo (2010), who, using a Tobit model, found a non-significant relationship between income and the probability of accepting to pay for biopesticides. Moreover, Patrice Toé and Dominique Dulieu (2007) argue that any innovation aimed at conserving natural resources can only be favorably received by farmers if they see benefits from it, as currently, farmers prioritize monetary gain over environmental conservation. These results indicate the importance of giving due consideration to financial incentives in measures aimed at accelerating the use of biopesticides and, more broadly, in accelerating the agroecological transition.

The proposed bid amount negatively impacts the probability of acceptance to pay. Thus, the probability of responding positively to the WTP evaluation question decreases as the bid amount increases. This observation has been established by several empirical studies on willingness to pay, which show a significant inverse relationship between the proposed bid amount and the willingness to pay. Pearce et al. (2006) argue that in a contingent valuation, the signs of economic variables somewhat reassure the rationality of farmers in their responses, aligning with the expectations of economic theory. The price of biopesticides becomes a key factor in the farmer's behavior in choosing phytosanitary solutions. Generally, the proportion of farmers willing to pay a higher price decrease as the proposed prices increase, in accordance with the law of demand.

The size of the producer's household has a positive effect on their willingness to pay for biopesticides. This indicates that the probability of accepting the bid increases with the size of the household. This result likely reflects the consideration by farmers of the labor constraint required for the use of biopesticides. As we know, using biopesticides requires a considerable amount of work, and only farmers with sufficient labor resources are more inclined to adopt this protective technology. This result is consistent with most studies on the adoption of agricultural technologies, particularly in developing countries, where one of the constraints limiting the adoption of new agricultural technologies is labor. In practice, the farmer allocates their work time among multiple tasks, so to fully understand the labor needs of a local or improved technology, the seasonal and specialized labor demand of all the farmer's needs must be taken into account (Karen Dvorak, 1995). Using family labor to apply techniques aimed at conserving natural resources comes at a cost to rural families, and in many production systems in Africa, labor represents 90% of production costs (Dvorak, 1995). This result is consistent with that of Belloumi and Matoussi (2002) and Yovo (2010) regarding the positive significance of household size in explaining the probability of accepting the proposed bid. In Burkina Faso, Sanogo et al. (2020) show that one of the key constraints to the adoption of microdose fertilization is the availability of labor. Similarly, Claude et al. (2019) find that the number of agricultural workers positively influences the adoption of agroecological practices in vegetable farming in the Niger Valley and Benin. In our case, the same observation applies to the use of biopesticides in tomato cultivation, as reflected in the results of the estimation of determinants of willingness to pay. Using biopesticides requires a significant amount of labor for various operations (collecting raw materials such as neem leaves, water-intensive processing, access to appropriate processing equipment, and the need for repeated treatments to achieve efficacy equivalent to chemical pesticides, etc.). All these operations require a lot of work from the farmer, and they will only accept to acquire biopesticides if they have sufficient labor resources to carry out these various operations. Having a large family is then an indication of the availability of able hands to perform the various tasks related to the use of biopesticides.

The experience in tomato production negatively influences the probability of accepting to pay for biopesticides. This result is contrary to our expectations and could be explained by the relatively recent introduction and use of biopesticides in vegetable production. It is important to remember that the use of biopesticides is part of the new trends in agroecological transition that have been popular in recent decades, encouraging more sustainable production methods. Farmers with extensive experience in vegetable production may not have always used these protective technologies and may stick to traditional or chemical protection methods with which they are familiar. In fact, several studies have highlighted a positive relationship between the farmer's experience and the adoption of agricultural technologies (Adétonah et al., 2011; Kpadenou et al., 2019). In our case, it is worth noting that the use of biopesticides, while being an ancient practice, is part of the new trends in agroecological transition that have been popular in recent decades, encouraging more sustainable production methods. Indeed, in Burkina Faso, organic agriculture was formally introduced in 2011 (Martin, 2017), particularly with the creation of the National Organic Agriculture Council (CNABIO). It is through this structure that a local certification mechanism is put in place through the Participatory Guarantee System (SPG). The operationalization of this system only dates back to 2015, and the first vegetable farms were certified as organic starting from 2016. Farmers with extensive experience in tomato production may not have used biopesticides yet and may not be familiar with them. It is true that vegetable farmers have long used their local practices and knowledge regarding the use of biological extracts in vegetable farming, but the inertia of the current agrochemical model has relegated traditional knowledge to the background. This is certainly pointed out by Blandine Sankara (2022), who argues that the implementation of the agrochemical model has swept away traditional knowledge and diverted Burkinabé farmers from sustainable alternatives. In reality, extensive experience in tomato production does not always indicate a good understanding and experience of the farmer in using biopesticides.

There is a positive and significant relationship between willingness to pay and the perception of the effectiveness of biopesticides against tomato pests. Farmers who believe that biopesticides are effective as treatments are more likely to accept the offered bid. These results are consistent with those obtained by Hebié (2014), who, in their study in Burkina Faso, show that farmers' choice or willingness to acquire biopesticides and other treatment products is based solely on effectiveness and cost criteria. In this study, the analysis of the reasons for refusal to pay reveals that about 14% of farmers who refuse to pay cite the inefficiency of biopesticides against crop pests.

Psychoecological variables arise from environmental concern. The probability of consenting to pay increases with the perception of a positive impact of biopesticides on the health of the producer and the environment. This result is consistent with the work of Beaumais et al. (2008), who found a significant and positive relationship between willingness to pay and the perception of a positive impact of the technology on the environment. Similarly, Bonnieux et al. (1985) show that environmental sensitivity has a positive effect on willingness to pay for an environmental good. Kitoto (2018) also found in his work that environmental perception positively and significantly influences the willingness of residents to pay for the protection of Lake Chad. However, ecological awareness has not yet curbed the exploitation of natural resources, nor has it altered individual behaviors (Jean-Yves Godart, 2011). All these results indicate that farmers are concerned about environmental protection. They suggest that there should be a focus on environmental education for farmers to establish the "systematic" use of biopesticides in their practices.

Access to information on biopesticides significantly promotes acceptance of paying for the technologies. Informed, sensitized, or trained farmers on biopesticides are more willing to pay for this agroecological solution than others. This result is consistent with Toé (2010), who showed that farmers who were trained or sensitized on alternative control methods are more willing to use biopesticides in Burkina Faso. This result suggests that strengthening farmers' capacities in the production and use of biopesticides is an effective lever to boost their utilization. It also highlights the need for training and sensitization of farmers on diseases, pests, and the use of biopesticides, particularly for agroecological and sustainable production. It can be concluded that experience and information allow farmers to have a more accurate representation of the contingent good (Yovo, 2010).

The farmer's membership in a peasant organization positively influences their decision to pay for biopesticides. This result is consistent with those found by Kpadenou et al. (2019) in Benin, showing the positive influence of a farmer's membership in a group on their decision to accept biological production practices. It testifies to the role of the producer network in forming their opinions and decisions. Producer organizations are "dialogue groups" that facilitate the dissemination of knowledge about agricultural technologies (Darré, 1985). Within these groups, they share information (technical itineraries, technology effectiveness, pitfalls to avoid, etc.). For farmers to be willing to pay a phytosanitary insurance premium, they must be well informed about the potential and availability of the proposed control products (phytosanitary, agronomic, and economic performance of the product).

The average willingness to pay (WTP) of the farmers is estimated at 14,180 FCFA per farmer per hectare of tomatoes, equivalent to 21.61 euros. This value is higher than those obtained in other studies conducted in West Africa using Contingent Valuation Method (CVM) with dichotomous choices. Using a Tobit model, Yovo (2010) obtained slightly lower results in Burkina Faso and Togo. Coulibaly et al. (2006) obtained values ranging from 11,093 to 11,439 FCFA in Benin and Ghana. An analysis of the prices of biopesticides produced by local units and sold on the local market (Burkinabè) gives an average price of about 40,000 FCFA/ha, well above the average WTP of our sample. The analysis of the production costs structure of biopesticides shows the predominance of costs related to the homologation of the product. Local biopesticide-producing companies pass on these costs to the selling price per kilogram to the farmer. This result suggests the need to put in place incentives for the use of biopesticides if significant adoption of these agroecological technologies is expected. If subsidies for these biopesticides are not feasible due to financial constraints, public authorities could consider reducing or completely eliminating the homologation fees for biopesticides and lowering import duties on imported biopesticides as alternatives.

CONCLUSION

This study conducted in the vegetable-growing areas of Burkina Faso aimed to assess tomato producers' willingness to pay for the use of biopesticides as a substitute for chemical pesticides and the determinants of this willingness. It clearly highlights farmers' awareness of the harmful effects of chemical pesticides on the environment and human health. This is reflected in over 80% of the farmers in our sample being willing to contribute financially to access biopesticides instead of chemical products, with an average willingness to pay (WTP) of 14,180 FCFA, which is relatively low. The demands of the agroecological transition, coupled with increasing consumer preferences for organic products, are calling on farmers to shift towards less chemical inputs, particularly biopesticides, in vegetable production.

To encourage farmers to abandon the use of chemical pesticides and replace them with biopesticides while paying a price to access them, it seems necessary for policymakers to be put in place through the creation of an appropriate incentive framework for the adoption of these biopesticides. Additionally, the establishment of an information system on biopesticides should be a prerequisite for disseminating "bio-solutions" to farmers. Institutional and regulatory actions should also be taken to facilitate the homologation procedures of biopesticides, making their production, availability, and access to farmers more straightforward.

Due to the low level of WTP and the small size of the farms, the introduction of biopesticides to farmers, in the current state of their production system, could lead to mixed success. The study yields valuable results for decision-making, but they cannot be generalized to all cases due to the unobserved heterogeneity of farmers. Further evaluation of stated preferences is required on a large sample of farmers to understand the diversity of determinants and heterogeneity of behaviors concerning the adoption of innovative practices. Additionally, considering the role of farmers' perceptions on the acceptance of biopesticides, it is essential to take them into account in future studies on their willingness to pay for these control solutions.

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Appendix 1. Reasons given for refusing to pay the proposed amount

Public financing	**13**	**5.51%**
It's up to projects to give biospescides to growers free of charge	8	
It's up to the government to give biopesticides to growers free of charge.	5	
Charging other producers	**7**	**2.97%**
Make the big cotton growers pay for biopesticides	3	
I'm afraid to use biopesticides (my neighbor may not use them)	4	
Unnecessary use of biopesticides	**32**	**14%**
Chemical pesticides are already good for us	15	
Doubts about the efficacy and usefulness of biopesticides	17	
Financial problems	**110**	**47%**
Biopesticides don't sell more tomatoes	38	
Your financial means are insufficient to buy biopesticides	72	
It's up to the State to subsidize biopesticides		
Against the principle of using biopesticides to protect the environment and health	**5**	**2.12%**
Information on biopesticides	**22**	9%
Request for further information on biopesticides	10	
Do you have doubts about the effectiveness and usefulness of biopesticides?	12	
Other	**5**	**2%**
No information	**42**	**17.80%**
TOTAL	236	**100%**