



# Willingness of Kale Farmers to Pay for Vermiliquid Biofertilizer in Bungoma County, Kenya

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## Abstract

Improper management of agricultural wastes can result in adverse environmental, social and economic impacts for both producers and society. Bioconversion of agricultural wastes through composting by worms can turn organic wastes into biofertilizer products thus enhancing the circularity of agricultural systems. Adoption of biofertilizer products requires significant marketing efforts, but there is very little information on farmers' willingness to pay for Vermiliquid organic fertilizer. This study provides insights into the willingness of smallholder farmers to pay (WTP) for Vermiliquid, a relatively new organic bio-fertilizer derived from worm composting. Unlike prior research that focused broadly on organic fertilizers, this study uniquely evaluates Vermiliquid's specific attributes including its safety in use, ability to enhance vegetative growth and yields, pest-repelling potential, and environmental friendliness. The study quantifies WTP and identifies key factors influencing farmers' adoption behavior. Results indicate that 92.19% of sampled farmers expressed willingness to pay for Vermiliquid, with determinants such as access to credit, off-farm income, and access to information significantly influencing their decisions. These findings underscore the critical role of financial capacity and knowledge dissemination in supporting the uptake of emerging sustainable inputs. This study is among the first to assess market demand for Vermiliquid in the Kenyan context and contributes original evidence to inform the design of targeted interventions for organic fertilizer promotion. It recommends strengthening farmer access to organic fertilizers, agricultural information, off-farm income, and supports policies that encourage the scaling up of organic alternatives like Vermiliquid to improve productivity, soil health and sustainability.

## Subject Areas

Consumer Behavior, Environmental Sciences

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## Keywords

Biofertilizers, Worm Composting, Willingness to Pay, Vermiliquid

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### 1. Introduction

Modern agricultural systems rely heavily on the use of mineral fertilizers to replenish soil nutrients. However, their widespread production and application can have harmful environmental impacts [1] [2]. In the mid-eighties, consumers particularly from the developed countries started turning towards organic food because of health concerns [3]. They started believing that organic food is eco-friendly, healthier, safer, cleaner, more nutritious and tastier as compared to conventional food [4]. Today's world is increasingly prioritizing sustainable development [5] [6]. Many studies have been conducted on innovation and the adoption of new technologies and the impact of adopting new technologies in developing countries. However, adoption of new agricultural technologies is often slow and several aspects of adoption remain poorly understood in most of the developing countries [7] [8]. In most cases, adoption of a new technology may take time. This is mainly due to the fact that a producer is rational and therefore prefers to see the benefit of a new technology before adopting [9] [10].

Kenya's Vision 2030, the country's long-term industrialization strategy, advocates for sustainable production through the adoption of clean technologies. It also emphasizes improved waste management by fostering innovation and supporting the development of new business opportunities [11]. The policy framework promotes circular economy principles, including waste reduction, reuse, and recycling. In Kenya, an increase in population in most counties has resulted in extensive land sub-division due to ancestral inheritance, reducing available agricultural land. This pressure has resulted in inappropriate land use, soil degradation, declining soil fertility, ultimately lowering crop yields and farm incomes. To address these challenges and transition the circular economy from policy to practice, efforts have been made by the government and development agencies to promote sustainable land management practices. While Kenya's circular economy is still in its early phases, there are numerous encouraging signals of improvement. Kenya's Green Economy Strategy and Implementation Plan 2016-2030 [12] and The Sustainable Waste Management Act 2022 [13] encourages the transition to a green and circular economy.

Soil forms the foundation of productive agriculture. To ensure its long-term sustainability and productivity, the foremost priority should be enhancing and preserving soil quality [14]. To minimize harmful environmental emissions, promoting nutrient circularity is essential for building sustainable food systems [15]. Organic fertilizers, which are untreated by-products of organic waste, can originate from sources such as crop residues, food scraps, and animal or human excreta [16] [17]. They contain organic matter and micronutrients that contribute to the preservation of soil quality. Farm by-products which are not of immediate use for

human consumption should be recycled back into the food system [17]. They contain carbon and nutrients such as nitrogen and phosphorus that can be incorporated in the soil to improve or preserve soil quality, sequester carbon and mitigate greenhouse gases [14]. Organic fertilizers are derived from animal matter, human excreta or vegetable matter such as vermi-compost manure [16]. On the other hand, inorganic fertilizer also referred to as synthetic fertilizer, is manufactured artificially and contains minerals or synthetic chemicals.

The conversion of biodegradable materials into nutrient-rich compost can be achieved through the use of earthworms, a process known as vermicomposting [18] [19]. Earthworms feed on raw organic materials and excrete them in a digested form known as worm castings, which are rich in nutrients, growth-promoting compounds, and beneficial soil microorganisms. Vermiculture is a scientific process of breeding worms in controlled conditions vermiliquid [20]. The end products resulting from this process are vermicompost and vermiliquid. Water that flows through the vermiculture system (vermiliquid or vermiwash) washes over live and dead earthworms, soil microbes, and decomposed organic matter, carrying with it all the dissolved substances and can be used as biofertilizer [21] [22]. When applied as foliar feed on the farm, it increases the rate of photosynthesis in crop plants and enhances growth [18]. Vermicompost is generally more stable than conventional composts, has better biological properties and essential mineral nutrients that sustain plant growth [23].

Farmers' knowledge concerning a particular technology has a strong influence on the decision of a producer to adopt the technology or utilize a given product [24]. Awareness refers to an individual's current appraisal of a product or program [25]. People base their judgment on past experience and knowledge thus, if a person has limited knowledge and experience about a topic then he cannot form an opinion on it [26]. Various literature indicates that WTP for a good or service depends on product attributes, institutional factors as well as the socio-economic characteristics of the buyer [27].

While previous studies have highlighted that farmers' knowledge and awareness affect adoption and willingness to pay (WTP) for agricultural technologies, there is still limited empirical evidence that highlights how these factors affect the farmers' willingness to pay for Vermiliquid, a relatively new bio-input. In most of the papers, there has been emphasis on socio-economic and institutional determinants of WTP [28] [29]. Few papers have looked at the role of knowledge and perception, that potentially shaped the demand for the Vermiliquid among small-holder farmers. This gap underscores the need to investigate how knowledge, awareness and perception can shape the demand for Vermiliquid.

## **2. Materials and Methods**

### **2.1. Study Site Description**

A cross-sectional study was conducted in Bukembe East and Bukembe West wards of Bungoma County, Kenya. Bungoma County was selected because it is one of

the counties in Kenya where vermicomposting technology was introduced by development agencies and is practiced on small scale basis. Secondly, the population growth rate is high compared to the land resource available hence there is need to implement strategies that promote sustainable management practices [30].

## 2.2. Sample Size and Sample Selection

The target population consisted of Kale farmers that produced and sold Kale between March 2022 and April 2023. The sample unit consisted of smallholder Kale farmers who were either users or non-users of Vermiliquid in Kanduyi sub-County. The unit of analysis was the individual farmers in the households. To examine farmers' WTP for Vermiliquid and the drivers, a multistage sampling technique was employed. In the first stage, Bungoma County was purposively selected because it is one of the Counties where vermicomposting technology is being promoted. In the second stage Bukembe East and Bukembe West wards in Kanduyi sub-county were purposively selected since it is an area where vermicomposting technology was promoted.

Determination of the household sample size was based on the formula given by Kothari [31] as described;

$$n_0 = \frac{Z^2 pq}{e^2} \quad (1)$$

$$n_0 = \frac{1.96^2 \times 0.5(1-0.5)}{0.0613^2} = 255.6 \quad (2)$$

where;  $n_0$  = desired sample size,  $Z$  = critical value of 1.96 at 95 percent confidence level ( $\alpha = 0.05$ );  $p = 0.5$ ; proportion of the population of interest,  $q =$  weighting variable given by  $1 - p$  and  $e =$  acceptable error. According to Kothari [31] an error of less than 10 percent is allowed thus this study used an error of 0.0613. This resulted to approximately 256 respondents.

## 2.3. Data Collection

The study depended on a set of both closed and open-ended questions packaged in a semi-structured questionnaire to collect primary data. This was done through the face-to-face interviewing method. A stated preference approach using a contingent valuation method was used to elicit households' WTP. Dichotomous choice questions followed by open-ended questions were employed to improve the estimate's precision. The Contingent Valuation Method was used for this study because it shows to what extent a consumer is willing to pay for Vermiliquid. Respondents were asked to report directly their level of willingness to pay for vermiliquid. To determine this, sampled farmers were given a hypothetical scenario in the absence of the real purchasing situation. The benefits of vermiliquid and desirable product attributes were then presented to smallholder farmers.

## 2.4. Theoretical Framework

This study uses the concept of utility theory, which forms the foundation of con-

sumer choice behavior and highlights that individuals can make their purchasing decisions based on the perceived satisfaction, or utility, derived from purchasing a commodity. In the cases, where Vermiliquid is considered, farmers are able to assess the satisfaction by evaluating the potential benefits, which include improved soil health, improved yields, as well as reduced chemical use against the cost of acquiring these inputs. If the farmers think that the utility they will get from using Vermiliquid will be more than the utility of using alternatives, then they will indicate a higher willingness to pay (WTP). Thus, utility is not determined only by the physical attributes of Vermiliquid but also brought about by farmers' knowledge, experience, and perceived reliability of the product.

The willingness of farmers to pay (WTP) for Vermiliquid was analyzed using Contingent Valuation Method (CVM). This was used in the study to show to what extent the consumer is willing to go in order to utilize vermiliquid [32]. Consumers' WTP was evaluated in the absence of a real purchasing situation. This method suits the case of Vermiliquid whose market is not yet developed in Bungoma County. Farmers were given a hypothetical scenario where the benefits of using Vermiliquid were highlighted to farmers who were not aware of the product [33]. Farmers' fertilizer purchase and application behavior can be influenced by a combination of personal, institutional and economic factors [34].

Farmers are the main force in agricultural production thus understanding the underlying determinants of farmers' purchasing behavior plays a big role for successful promotion of organic fertilizers [29]. The choice to utilize new agricultural products may depend on consumers' gender, age and even education level which greatly play a big role in influencing adoption [35]. Although there is advocacy in the adoption of organic fertilizer, the economic linkage between farmers' socio-economic factors and willingness to pay (WTP) remains under explored in Kenya. This is also confirmed by Zondo and Baiyegunhi [32] in the study that investigated the determinants of WTP for a price premium for organic fertilizer among small-holder farmers fertilizer.

One major limitation of Contingent Valuation Method is hypothetical bias which occurs when respondents overstate or understate their WTP, given that they are not required to make actual financial commitments. To minimize this bias, respondents were explicitly reminded to consider the scenario as if they were making a real monetary decision regarding the purchase of Vermiliquid. Future research could complement stated preference methods with revealed preference approaches or field experiences to validate the robustness of WTP estimates.

## 2.5. Econometric Specification

To understand the factors influencing farmers WTP for Vermiliquid, the study employed the ordered logit regression model [36]. This choice was appropriate because the dependent variable (WTP) is ordinal, taking discrete values from 0 to 3, corresponding to increasing levels of willingness to pay. Unlike the binary logit model, which is restricted to two outcomes, the ordered logit model accommo-

dates the ordered nature of WTP categories while estimating the probability of a farmer falling into each category as a function of explanatory variables.

The latent continuous variable is expressed below:

$$Y_i^* = \sum_{i=1}^n \beta X_i + \varepsilon_i \quad (3)$$

where:  $Y_i^*$  represents the unobserved (latent) variable,  $Y_i$  represents the observed WTP category (0-3),  $X_i$  is the vector of explanatory variables,  $\beta$  = unknown parameters to be estimated, and  $\varepsilon_i$  = is the error term.

The double bounded dichotomous choice elicitation resulted in four mutually exclusive outcomes:

$Y_0 = 0$ ; not willing to pay (n/n WTP)

$Y_1 = 1$ ; "No" to the first bid but "Yes" to the second lower bid (n/y WTP)

$Y_2 = 2$ ; "Yes" to the first bid but "No" to the higher second bid (y/n WTP)

$Y_3 = 3$ ; "Yes" to both bids (y/y WTP)

These outcomes are expressed in the equations below:

$Y_0 = 0$  if  $Y_0^* \leq 0$  for zero WTP

$Y_1 = 1$  if  $Y_0 < Y_1^* \leq Y_1$  for n/y WTP

$Y_2 = 2$  if  $Y_1 < Y_2^* \leq Y_2$  for y/n WTP

$Y_3 = 3$  if  $Y_2 < Y_3^* \leq Y_3$  for y/y WTP (4)

It is presumed that the error term  $\varepsilon_i$  is normally distributed across observations. By normalizing the mean and variance of  $\varepsilon_i$  to zero and one, the following probabilities are obtained:

$$\begin{aligned} \text{Prob}(Y_i = 0 / X_i) &= F(-X_i\beta) \\ \text{Prob}(Y_i = 1 / X_i) &= F(Y_1 - X_i\beta) - F(-X_i\beta) \\ \text{Prob}(Y_i = 2 / X_i) &= F(Y_2 - X_i\beta) - F(Y_1 - X_i\beta) \\ \text{Prob}(Y_i = 3 / X_i) &= F(Y_3 - X_i\beta) - F(Y_2 - X_i\beta) \\ &\vdots \\ \text{Prob}(Y_i = J / X_i) &= 1 - F(Y_{J-1} - X_i\beta) \end{aligned} \quad (5)$$

where  $F(\cdot)$  is the cumulative logistic distribution function. All probabilities are positive under the condition:

$$0 < Y_1 < Y_2 < Y_3 < \dots < Y_{J-1}$$

The final ordered logit model estimated in this study was specified as:

$$\begin{aligned} \text{WTP} = & \beta_0 + \beta_1 \text{gender} + \beta_2 \text{age} + \beta_3 \text{educlevel} + \beta_4 \text{hhsz} \\ & + \beta_5 \text{groupmembership} + \beta_6 \text{totlandundersukuma} \\ & + \beta_7 \text{creditaccess} + \beta_8 \text{trainingaccess} \\ & + \beta_9 \text{offarmincome} + \beta_{10} \text{infoaccess} + \epsilon \end{aligned} \quad (6)$$

#### Bid Design and Double-Bounded CVM Procedure

To elicit willingness to pay (WTP) for Vermiliquid, the study adopted a double-bounded contingent valuation method (CVM). After confirming whether respondents were willing to purchase Vermiliquid given its described agronomic

and environmental benefits, they were first asked an open-ended valuation question: “How much would you be willing to pay for one litre of Vermiliquid?” This provided each respondent’s stated maximum WTP and served as the initial reference point for subsequent bids.

Following this, a structured bidding game was introduced, using discrete price offers of KES 100, 200, 300, 400, and 500 per litre. To minimize starting-point bias, the initial bid was randomly assigned from among these five amounts. Depending on the respondent’s answer to the first bid, the follow-up bid was adjusted upward along the sequence under the assumption that lower bids would be accepted if higher bids were already acceptable. Each respondent therefore faced at most two dichotomous choices, generating four possible outcomes (Yes-Yes, Yes-No, No-Yes, No-No), consistent with the double-bounded CVM framework.

### 3. Results and Discussion

#### Determinants of Willingness to Pay for Vermiliquid

The results establish how household and socio-economic factors influence the likelihood of farmers falling into different willingness to pay (WTP) categories (0, 1, 2, 3). Since the dependent variable is ordinal, the model appropriately captures the increasing levels of WTP. **Table 1** presents the estimated coefficients, standard errors (S.E.), and marginal effects (dy/dx) for each WTP level. The marginal effects indicate how a unit change in each explanatory variable alters the probability of a farmer being in a particular category (WTP = 0, WTP = 1, WTP = 2, WTP = 3).

**Table 1.** Maximum likelihood estimates of WTP for vermiliquid used in logit model.

Variable	Coefficient		Marginal Effects (dy/dx)			
	Value	S. E	WTP = 0	WTP = 1	WTP = 2	WTP = 3
Age	0.0150	0.143	0.001	0.003	-0.002	-0.001
Gender	-2.530	0.292	0.009	0.050	-0.037	-0.021
Educ level	0.029	0.113	-0.001	-0.006	-0.004	0.002
HH size	-0.016	0.062	0.001	0.003	-0.002	-0.001
Land ownshp	0.625	1.078	-0.023	0.122	0.095	0.050
Info Access	-0.644	0.362	0.024	0.126	-0.097	0.052*
Acc to credit	-0.3	0.271	0.011	0.058	-0.045	-0.024
Grp mshp	0.48	0.39	-0.018	-0.094	0.073	0.039
Tland (Kales)	-0.002	0.583	0.000	0.012	0.023	0.031***
Offfarm income	-1.008	0.292	0.037	0.107	0.153	0.181***
cut1	-3.436	1.231			-5.849	-1.023
cut2	-0.141	1.156			-2.407	2.125

## Continued

cut3	2.352	1.152	0.095	4.609
Mean dependent var		1.563	SD dependent var	0.711
Pseudo r-squared		0.038	Number of obs	256
Chi-square		19.386	Prob > chi2	0.036
Akaike crit. (AIC)		551.273	Bayesian crit. (BIC)	597.360

## Farmers Willingness to Pay for Vermiliquid

The distribution of smallholder farmers' responses shows a strong demand for Vermiliquid. A vast majority (92%) indicated willingness to pay for the product, while only 8% were not willing to pay. The analysis of these open-ended bidding responses revealed that farmers were, on average, willing to pay KES 150 per litre, with the highest stated amount being KES 500 and the lowest KES 50. This wide range demonstrates both the potential market value of Vermiliquid and the heterogeneity in farmers' purchasing power.

To explain the different effects of explanatory variables on farmers WTP, the coefficient estimates, as well as the marginal effects which represent changes in the probability of WTP for Vermiliquid, are presented. The model fits the data well because the Likelihood ratio Chi-square test of the hypothesis is at 0.036 thus statistically significant at 5% level. Variables relating to information access, land under *Sukumawiki* and off farm income were found to be statistically significant at 10%, 1% and 1%, respectively.

The findings in **Table 1** show that access to information plays a significant role in shaping farmers' willingness to pay (WTP) for Vermiliquid. Interestingly, farmers with greater access to agricultural information were more likely to fall into the lower WTP category (WTP = 1), but access also had a modest positive effect at the highest WTP level (WTP = 3). Specifically, a 1% increase in information access increased the likelihood of being in the lowest WTP category by 13%, reduced the likelihood of being in the middle category (WTP = 2) by 9.7%, and raised the probability of being in the highest WTP category by 5.2%. This suggests that informed farmers do not simply settle at the middle level of payment. Rather, they are polarized: some adopt cautiously at lower levels, while those who fully appreciate Vermiliquid's value are willing to pay at higher levels [37]. This implies that information empowers farmers to make more deliberate and differentiated decisions on agricultural inputs, depending on their needs, resources, and risk preferences. Regarding land size under *Sukuma wiki* (Kale) production, the results indicate that larger production areas strongly increase WTP for Vermiliquid. A 1% increase in land size raised the likelihood of belonging to the lowest WTP category by 12%, the middle category by 23%, and the highest category by 31%. This pattern highlights that farmers with larger kale plots are more willing to invest in Vermiliquid. The likely reason is that pest and disease management becomes a greater priority on larger farms, making Vermiliquid a more attractive

and cost-justifiable investment. Overall, these findings imply that access to information and land size are critical determinants of WTP for Vermiliquid [32]. Information access drives more informed and strategic decision-making, while larger landholdings amplify the economic rationale for investing in pest and disease management through organic solutions like Vermiliquid [37].

The results indicate that off-farm income significantly influence farmers' willingness to pay (WTP) for Vermiliquid. A 1% increase in off-farm income raised the likelihood of being in the lowest WTP category (WTP = 1) by 11%, the middle category (WTP = 2) by 15%, and the highest category (WTP = 3) by 18%. These results imply that farmers with higher off-farm earnings are more likely to belong to the higher WTP category (WTP = 3). A plausible explanation is that access to additional income relaxes household liquidity constraints, enabling farmers to allocate more resources toward farm innovations such as Vermiliquid [38]. In this way, off-farm income serves as a complementary financial buffer that enhances farmers' capacity and willingness to invest in Vermiliquid and other organic pest and disease management technologies.

#### **4. Conclusion and Recommendations**

This study demonstrates a strong demand for Vermiliquid among smallholder farmers, with 92.19% expressing willingness to pay. The findings highlight Vermiliquid's commercialization potential and its role in advancing sustainable agriculture by improving soil health and reducing reliance on synthetic inputs. The analysis reveals that access to credit, agricultural information, and off-farm income significantly increase willingness to pay. Larger landholdings further amplify demand, as farmers with more land are motivated to invest in effective pest and disease management. These results emphasize that both financial capacity and information access are critical enablers of technology adoption. To enhance uptake of organic fertilizers, interventions should focus on expanding farmers' access to credit facilities, strengthening the dissemination of agricultural information, and supporting diversified income opportunities. Extension services should also prioritize awareness creation on the benefits and correct use of Vermiliquid, thereby improving acceptance and sustained use. These measures will not only improve farm productivity and resilience but also contribute to national and regional goals of advancing climate-smart agriculture, supporting environmental sustainability, and shaping evidence-based agricultural policy. Beyond its practical implications, this study contributes to the growing literature on willingness to pay for organic fertilizers by providing empirical evidence from smallholder kale producers in Kenya.

#### **Ethics Approval**

This study was approved by the Egerton University Research Ethics Committee (EUREC) approval number EUISERC/APP/374/2024 and the National Commission for Science Technology, and Innovation (NACOSTI) license number (NACOSTI/P/23/30613).

## Credit Author Statement

**Maureen Elegwa:** Conceptualization, Writing - original draft, Writing - review & editing, Methodology and Formal analysis. **Prof. Margaret Ngigi:** Supervision **Dr. Florence Opondo:** Supervision

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## Data Availability

To protect the confidentiality of the respondents, the authors do not have permission to share data.

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## Conflicts of Interest

The authors declare no conflict of interest.

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