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Research article

Farmers' preferences for rice bean production traits in western Kenya

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ABSTRACT

Rice bean (*Vigna umbellata*) is an important legume for food and nutritional security. However, the level of its cultivation in western Kenya, where there is a serious malnutrition challenge, is still low due to a lack of insights into its attributes. Hence, to bridge this knowledge gap, this study analyzed smallholder farmers' preferences for production traits. We collected data from 204 farmers through a choice experiment (CE) approach in upper and lower midland agro-ecological zones. Subsequently, we used the random parameter logit (RPL) model to analyze the data. Results showed that farmers preferred all attribute levels presented except 61 % or more pest resistance. The lower midland farmers preferred compensation of Kenya shillings (Ksh) 34.93 for yields of 9 or more bags per acre; Ksh 52.22 for 61 to 79 maturity days and; Ksh 20.24 for 40 %–60 % pest resistance level. In comparison, upper midland farmers preferred compensation of Ksh 66.44 for 6 to 8 bags per acre; Ksh 53.82 for 9 or more bags per acre; no compensation for 50 to 60 maturity days; and Ksh 132.98 for 40 %–60 % pest resistance. However, farmers preferred no compensation for intact pods. The observed differences in farmers' preferences for rice bean attributes are explained by heterogeneity in the agroecological conditions, farmers' socio-economic characteristics, and risk perceptions. The findings should inform targeted extension and breeding programs that fit farmers' diverse environments and resource endowments.

1. Background

Legumes are important for food security and income in many households across the world [1]. In particular, they provide an affordable and nutritious source of protein, vitamins, iron, and micronutrients for resource-constrained households in developing countries [2,3]. [4] estimated the output of legumes worldwide at 77 million tons comprising 32 % dry beans and chickpeas, 10 % cowpeas, and 23 % minor grain legumes; the rest was mainly soybean. Furthermore, out of 27 million hectares (ha) under legumes, 44.6 % was in Asia, while 16 % was in Africa [5]. However, yield gaps of 1.4–2.6 tons/ha persist in Sub-Saharan Africa (SSA), which translates to 25 %–60 % of the potential yields [6,7]. Similarly, legume farms experience field and post-harvest losses due to weather variability, pests and diseases [8]. Moreover, the unreliable nature of rainfall in most places creates a demand for early-maturing, pest-resistant, and drought-tolerant crops in SSA [9].

In Kenya, various research institutions including the Kenya Agricultural and Livestock Research Organization (KALRO) have been

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conducting farm trials of rice bean (a relatively new legume) to determine its acceptability by farmers to guide plant breeding. Rice bean is a potential crop for participatory plant breeding (PPB) [10]. The PPB is an innovative plant breeding approach that targets the improvement of neglected or underutilized crops in marginal areas in developing countries [11]. However, data on rice bean cultivation in Kenya is scant and undocumented because it is not listed in the national crop schedule [12]. Hence, data from the ongoing KALRO field trials will form part of the official database in Kenya. Although rice bean is grown in western Kenya, where beans is the third most important crop, there is a low dietary diversity in this area, where commercial farming has lowered food varieties [13]. In particular, most households feed on starchy foods at the expense of other micro-nutrients found in vegetables [14]. Specifically, there are high cases of hidden hunger and malnutrition; for instance, malnutrition rates in Kakamega County and Siaya County are estimated at 25 % and 20 %, respectively [15].

The outcome of the rice bean farm trials is expected to bridge the shortfalls in the national legume outputs since the rice bean has higher yields per acre than other commonly grown legumes like chickpeas, lentils, cowpeas, and Mung bean or green grams [7,16]. Moreover, besides its nutritional superiority over other legumes, rice bean has a higher tolerance to drought and is resistant to most legume pests and diseases [17]. However, it is paradoxical that only a few farmers in western Kenya have accepted and planted rice bean on their farms. This study therefore sought to identify the production traits that farmers desire and the levels of monetary compensation that they would be willing to accept to plant rice bean on their farms.

While compensation or incentive payments have been shown to stimulate the movement from old to new technologies, it has not been extensively considered for legumes [18,19]. The risks involved in adopting new technologies including fear of crop failure and income losses due to agro-ecological conditions justify compensation of farmers [20]. [21] estimated and compared Chinese landowners' willingness to pay and accept (WTP and WTA) for the use of agricultural land. They found that land titling increased the WTA/WTP ratio and hindered land transfers. Similarly [22],estimated and compared the WTP and WTA for consumers and producers, respectively for animal welfare attributes in Germany. The results showed that while consumers demanded all animal welfare attributes, farmers preferred higher compensation for animal welfare attributes that were expensive to implement.

However, according to Ref. [23], there are differences between WTA and WTP. Therefore, in some instances, compensation studies are more relevant than those on demand. Except for a few studies like [24,25], most studies in developed countries have estimated acceptance without compensation for crop attributes. Likewise, in developing countries, few studies [for example, [26,27]] analyzed farmer acceptance of crop attributes in Rwanda and Ethiopia, respectively but excluded the preferred compensation. [28], who analyzed smallholder farmers' demand for planting and consumption attributes in rice in Nepal as an exception. They found that farmers demanded improved consumption qualities, yields, drought tolerance, and short maturity. However, subsequent studies, for example [29], identified two distinct groups of farmers, who focused on nutritional and commercial attributes, respectively. Yet, few studies utilized this binary approach in the analysis of cooking and planting attributes. For instance, even though [30] investigated the acceptance of grain using the binary approach in France, they excluded compensation preferred by farmers.

In our study, other than including compensation, we modified the "rotational effect of pesticide" from Ref. [30] into three pest resistance levels. Also [31], analyzed consumption quality traits and their effect on the acceptance of gene-edited fruits, which are under trial in the United States, like rice beans in our case. They found that consumers would forego compensation to accept the gene-edited fruits. However, there were likely to be differences in the post-improvement and pre-improvement compensation of planting attributes. Although [32] assessed farmers' post-improvement preference for crops in the Mediterranean region, rice bean in western Kenya were at the pre-improvement stage. The results from the study of [32] showed a higher preference and acceptance for intercrops, which were perceived to lower the risks and expected compensation due to total crop failure. Likewise [19], analyzed Malawian farmers' preferences for agroforestry as an option for improved soil fertility and climate change resilience. They found a preference for packages, which had an intercrop that provided food and income. Additionally, they found that farmers required no compensation for favorable climatic resilience packages; attributes that require no compensation are not exhaustively analyzed in rice bean.

In contrast [33], estimated the effect of land property rights on the acceptance and preferred compensation by rice and/or maize farmers for climate-smart activities. They found that farmers with secure property rights were willing to accept compensation for climate-smart activities [24]. included opportunity and transaction costs as attributes in the acceptance of energy crops in Germany. Hence, they noted that farmers preferred a higher compensation for long-term crops on secured land [25]. also included the opportunity cost of utilizing rice straws as an attribute in the analysis of farmers' acceptance of rice straws in China. They found that farmers required the highest compensation for straws used for feeds and fuels than crop residues. Although [16] noted that the splitting of pods hindered the commercialization of rice beans, they did not proceed to determine the compensation preferred by farmers for the splitting of pods nor any opportunity and transaction costs.

The current study aimed to address the identified gaps in the literature by analyzing farmers' preferences for rice bean attributes and estimating their WTA compensation. The study hypothesized that: (1) There is no difference in farmer preference for rice bean attributes and (2) There are no differences in farmer WTA compensation for rice bean attributes. The rest of the paper is organized as follows. Section 2 describes the methods that were applied in the study. Section 3 discusses the results while Section 4 provides conclusions and recommendations.

2. Materials and methods

2.1. Choice experiment design

This study applied the choice experiment (CE) approach since it is appropriate for measuring monetary values attached to non-market goods or services [34]. The CE technique is appropriate for eliciting preferences for products that are in the trial or development stage such as the rice bean which is still in the pilot trial stage. Following [24] the rice bean attributes for the CE design were identified through a review of the literature and two focus group discussions (FGDs). The FGDs comprised 3 elderly farmers (2 men and 1 woman), 3 youthful farmers (2 male and 1 female), and 3 legume value chain actors (trader, nutritionist, and extension officer). We included women and youth since legumes are gendered crops [35]. During the FGDs, a ranking exercise similar to that applied by Ref. [31] was used to determine the relevance of the chosen attributes to farmers. Therefore, we asked the FGD participants to list the common legume attributes they considered when planting. Then we asked them to score each of the attributes. Subsequently, we used the ranking scores to choose the five most important attributes. Subsequently, we validated them through key informant interviews (KIIs) with legume experts including experienced farmers and researchers.

The identified attributes had different levels as shown in Table 1. First, yield was measured by the number of 90-kg (Kg) bags of legume harvested per unit acre, which is critical for food security and income. We adopted a 90 Kg bag per acre for uniformity; legumes are not typically weighed in kilograms but are sold in containers of different sizes. This attribute was important since most smallholder farmers in western Kenya were subsistence-oriented. Second, the maturity period refers to the number of days it requires from planting until a legume produces seeds in the pod for harvesting. This period was important due to land scarcity from the high population in western Kenya [36,37]. Therefore, farmers were sensitive to the period that a crop was in the field due to land constraints. The splitting of pods refers to the bursting of mature legume pods due to environmental conditions. In particular, pods split frequently in areas with high temperatures, which causes on-farm losses as birds can easily eat the grains if the pods split when farmers are away [10]. Pest resistance refers to the number of legume plants not destroyed after a pest attack. It was measured on a scale of 1–10 plants. Then, we converted them into percentages and categorized them as; low, medium, and high resistance. This attribute was important since most farmers could not afford pesticides due to low incomes [38]. Also, most farmers had a negative perception of the use of excessive pesticides on their farms. Finally, payment refers to the amount of money a farmer expects as compensation for growing a kilogram of rice beans. This is an important attribute since it enables the estimation of the monetary value of each attribute. We varied price levels by 25 % of the average market price of rice beans in western Kenya. These represent two scenarios of rice bean improvement and their expected compensation; market prices include unit production costs and a markup. Moreover, these price levels are within the current price range for legumes in western Kenya.

Following [39], we used the attributes in Table 1 to generate choice sets that were presented to respondents in the survey. The choice sets designed fulfilled the recommended limits of the number of alternatives (≥3) and attributes (4–7), respectively [40,41]. The attributes and their respective level resulted in 162 (3^4 *2) possible combinations. Hence, to reduce respondents' cognitive burden, these combinations were reduced through a fractional factorial design that was generated in Ngene software [42]. The resultant 36 choice sets were well-balanced and satisfied the criteria for D-efficiency of 70 % that was used in previous studies [43]. Then, we randomly placed the choice sets into 6 blocks with 6 choice tasks in each block. A choice set had three options; two unlabeled and an opt-out option. The opt-out option was included to reduce hypothetical bias common in a forced choice if the options presented do not have a respondent's preferred attribute combinations [18]. An illustration of one of the choice sets (options) presented to respondents is shown on the right side of Table 1. The order of presentation of the options was randomized to prevent the effect of ordered choices. Likewise, we included a "cheap talk" that emphasized the importance of accurate responses and lower biases [28,44]. Likewise, we included follow-up questions to confirm if respondents were sure of their choices.

2.2. Study area, sampling, and data collection

The study was conducted in Kakamega and Siaya County in western Kenya, which have suitable agro-climatic conditions for planting rice beans (Fig. 1a and b). According to Pattanayak et al. (2019), rice beans grow well in areas with an annual rainfall of 1000 mm–1500 mm, and temperature ranges of 18 °C–30 °C. Kakamega County has a mean annual temperature of 21 °C–23 °C and an

Table 1
Description of rice bean production attributes, levels, and choice options presented to respondents.

Attributes	Description of attributes	Levels of attributes	Example of choice options		
			Rice bean type A	Rice bean type B	Neither A nor B
Yield	Number of 90 Kg bags of rice beans per acre	Low* (≤5), average (6–8 bags), high (≥9 bags)	≥9	≤5	
Splitting of pods	Splitting of rice bean pods in the field	No; Yes*	Yes	No	
Maturity period	Number of days from planting to harvest	Short (50–60 days), moderate (61–79 days), Long* (≥80 days)	50–60	≥80	
Disease resistance	Proportion of crop left after pest attack	Low* (≤39 %), moderate (40–60 %), High (≥61 %)	≤40 %	≥61 %	
Compensation (Ksh)	Required compensation in Ksh	152, 190, 228	228	152	
Which one would you accept?					

Note: * denotes the base/reference level, which indicates the unimproved status of the attribute; USD1 was equivalent to Ksh 110 at the time of the survey.

annual rainfall of between 1,250 mm and 1,750 mm [45]. Likewise, Siaya County has an annual temperature range of 21 °C–25 °C and an annual rainfall range of 1,000 mm to 1,750 mm [45].

Furthermore, according to Ref. [48], Kakamega County is a "high potential zone" with humid upper midland and sub-humid midland zones. On the other hand, Siaya County is a "mid potential zone" with lower midland. Moreover, it is drier, has unreliable rainfall patterns, and a low to moderately fertile soils. In our subsequent discussions, we use the words upper midland and lower midland to refer to Kakamega and Siaya counties, respectively.

The survey used a multi-stage sampling technique. First, we purposively selected Kakamega County and Siaya County from rice bean-producing areas. This was because they had suitable agroecological conditions for rice bean production. Second, we randomly selected Mumias East and Butere sub-counties from a list of sub-counties in Kakamega County with rice bean farmers. Likewise, we selected Ugenya and Bondo sub-counties from a list of sub-counties in Siaya with rice bean farmers. Third, we selected Makunga and Wanga East wards from Mumias East sub-county then Marama North and Marenyo wards from Butere sub-county. Similarly, we selected Ukwala and West Ugenya wards from Ugenya sub-county then central Sakwa and East Yimbo wards from Bondo sub-county.

Subsequently, we followed a similar procedure used by Ref. [9] and randomly selected 30 households in each of the 8 wards from a list provided by county extension agents in Kakamega and Siaya County. However, due to non-response from some of the targeted farmers, we interviewed 204 farmers. This sample size satisfied the minimum sample size required for a CE based on the formula from Ref. [49] shown in equation (1), which is a rule of thumb in CE. According to the formula, $D = 3$, is the maximum level of attributes; C = 3, is the number of alternatives in choice situations, and T = 6, is the number of choice situations. Hence, we got a minimum target of 83 respondents. Following [43], we categorized the sample into 6 balanced blocks of 34 respondents, which is consistent with the sample range used in previous studies of this nature [22,43,50].

$$n \geq 500^{*}\frac{D}{CT} \tag{1}$$

The pretested survey questionnaire included farmer socio-economic characteristics and was administered by trained enumerators in a face-to-face interview. The data collection was done from 30th November to December 16, 2021. This coincided with a period of the Covid-19 pandemic. Hence, for the health and safety of the enumerators and respondents, all prescribed health protocols were observed and enumerators collected data using electronic devices. Moreover, in remote areas and those without electricity and poor internet connections, questionnaires were filled with pen on paper.

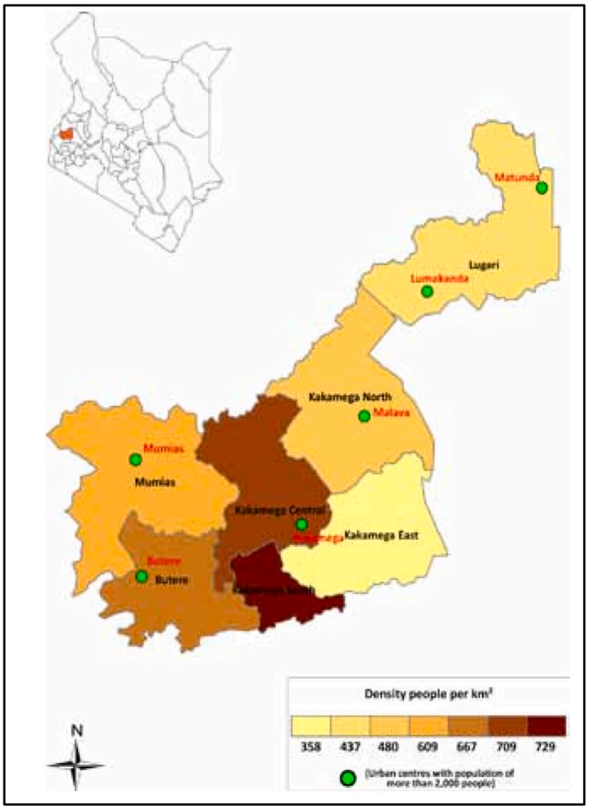

Fig. 1a. Map of study sites Kakamega County.
Source: Adapted from Ref. [46].

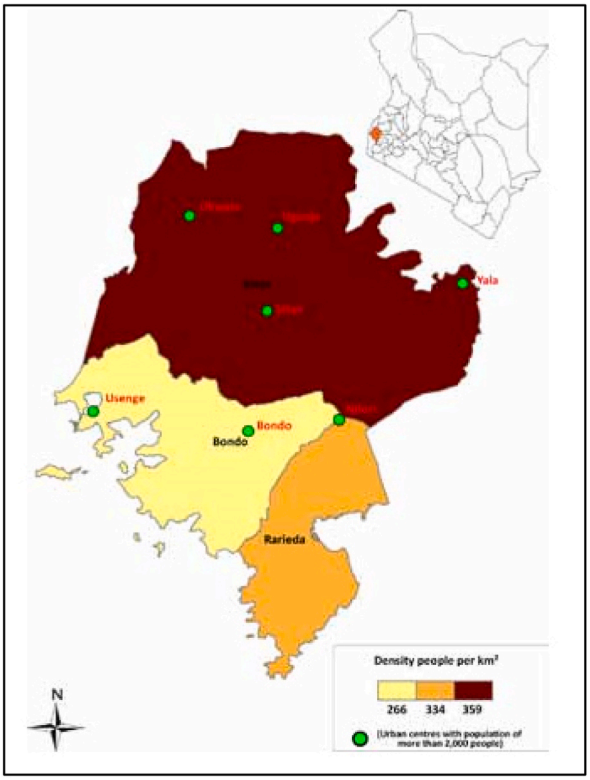

Fig. 1b. Map of study sites in Siaya County.
Source: Adapted from Ref. [47].

2.3. Data analysis

Analysis of CE data follows Lancaster's random utility theory (RUT) [51,44], which postulates that a rational decision-maker derives satisfaction from individual attributes of a good and not from the whole good. Subsequently, an individual (*n*) may be required to choose from alternative (*j*) in a choice situation (*t*) to maximize their utility (*U*) as shown in equation (2).

$$U_{int} = \beta X_{int} + e_{int} \tag{2}$$

The utility function in equation (2), which is assumed to have a multivariate normal distribution, comprises a deterministic component (βX_{int}) and a random or stochastic part (e_{int}) [44]. The error term is assumed to have an independent identical distribution (IID) with an extreme value. On the other hand, β represents the coefficient of a vector of socio-economic characteristics and taste preferences. Consequently, they are interpreted as the marginal elasticities and part-worth utilities in WTA compensation [24].

A conditional logit shown in equation (3) is mainly applied to the RUT. However, it has a restrictive assumption on the distribution of the error term. Hence, most WTA compensation studies apply the random parameter logit (RPL), which is an integral of the product of the standard conditional logit and density function (β|θ), where θ represents the normal distribution of the random parameters shown in equation (4). Although studies like [25,33,52] applied multinomial logit models, Heckman models, and finite mixture model (FMM), respectively, the RPL allows for heterogeneity in the preferences and the error term to vary over individual choices. Moreover, other studies have used the RPL in combination with other models or used different models in the analysis of WTA compensation [22,23,33].

$$L_{int=} \frac{\exp(\beta_n X_{int})}{\sum_j \exp\left(\beta_n x_{jint}\right)} \tag{3}$$

$$P_n(\theta) = \int K_n(\beta_n) f(\beta_n|\theta) d\beta_n \Big) \tag{4}$$

Moreover, RPL allows for estimation of β through maximum log-likelihood as shown in equation (5).

$$LL(\theta) = \sum_n \ln P_n(\theta) \tag{5}$$

The WTA compensation is expressed as a ratio of the individual attributes' coefficients to that of price as shown in Equation (6).

This is equivalent to the marginal rate of substitution between the attributes and the compensation or the trade-offs the farmers would make for the attributes [42]. The compensation variable is assumed to be log-normally distributed, while all other parameters had a normal distribution. Therefore, since compensation represented the amount of money farmers requested to grow rice beans the coefficient is expected to be positive.

$$WTA = \frac{\beta_n}{\beta_c} \tag{6}$$

3. Results

3.1. Farmer characteristics

The average age of household heads in the pooled sample was 50 years and 75 % were male (Table 2). The households in the upper midland were further from all-weather roads than those in the lower midland. However, their household heads had more years of schooling. In contrast, households in the lower midland had larger land size; a larger area planted with rice beans; and more years of planting rice beans.

Approximately a third of all households had an average income level between Ksh 10,000 to 30,000 (Fig. 2). Moreover, over a third of them had members of the women groups. However, 70 % of all households accessed information from combined sources. Surprisingly, over 60 % had not sought legume information in the past year. And about 72 % of households relied on other farmers for legume seeds.

3.2. Farmers' preferences for rice bean attributes in western Kenya

The RPL model results on farmer preferences for rice bean attributes are presented in Table 3 and discussed in this section. A large number of the attribute levels were statistically significant with the expected signs. Moreover, the tests of model fitness including the *pseudo* R^2 were within the acceptable limits [22,43]. According to Ref. [43], differences in socioeconomic characteristics can explain the heterogeneity in preferences. We proceeded with the RPL model without interaction terms since it was more robust than the other models; however, results from interaction variables are shown in the appendix for completeness of the analysis. Moreover, the standard deviations were statistically significant for splitting pods; 50 to 60 maturity days; 40 %–60 % pest resistance; and 61 % or more pest resistance. This confirmed the presence of heterogeneity or variation in the farmers' preferences for these traits.

Farmers in the upper midland had a higher marginal utility for 6 to 8 bags than those in the pooled sample. Likewise, it was higher than the marginal utility for 9 or more bags per acre for all the farmer categories. This means that compared to 5 or less bags per acre, the upper midland farmers preferred 6 to 8 bags per acre. However, compared to 5 or less bags per acre, farmers in the upper midland and pooled sample preferred 9 or more bags per acre. As expected, compared to intact pods, farmers had a low preference for splitting pods across all the samples. Likewise, upper midland farmers disliked 50 to 60 compared to 80 maturity days. However, lower midland farmers and the pooled sample had a significant marginal utility for 61 to 79 maturity days. This means that compared to 80 or more maturity days, upper midland farmers did not prefer 50 to 60 maturity days. On the other hand, compared to 80 or more maturity days, farmers in the lower midland and pooled sample preferred 61 to 79 maturity days. Finally, farmers across all the samples had a marginal utility for 40 %–60 % pest resistance. This means that compared to a 39 % or less pest resistance, upper midland farmers preferred 40 %–60 % pest resistance than other farmers.

The proportion of farmers with a positive preference for attributes with statistically significant standard deviations is shown in Table 4. Approximately 13.89 % of farmers in the upper midland had a positive preference for splitting pods compared to 28.23 % in the lower midland. This means more farmers in the lower midland could tolerate or cope with the splitting of pods. Moreover, 89.14 % of farmers in the upper midland had a positive preference for 61 to 79 maturity days compared to 86.2 % in the lower midland. This can be interpreted as the presence of risk-seeking farmers in the upper midland preferred moderate maturity. Likewise, 93.32 % of farmers

Table 2
Description of the farmers' socio-economic characteristics.

Variable	Upper midland (n = 102)	Lower midland (n = 102)	Pooled sample (n = 204)
Average age of household head	49.80(15.98)	49.78(46.81)	49.79(47.64)
Sex of household head	0.80(0.40)	0.69(0.46)	0.75(0.43)
Average land size	2.32(2.00)[b]	3.18(0.32)[)a]	2.74(2.69)
Average distance to all weather road	5.65(2.98)[a]	1.68(2.21)[b]	3.65(2.18)
Average distance to market	4.58(3.99)	4.69(4.40)	4.64(4.20)
Average years of schooling	10.11(5.19)[a]	9.03(5.45)[b]	9.56(5.34)
Average years of rice bean planting	5.41(5.10)[b]	6.71(8.54)[a]	6.05(7.03)
Average area planted with rice beans	0.53(0.67)[b]	0.70(1.04)[a]	0.62(0.88)
Average daily wages (Ksh)	272.28(284.91)	269.42(95.55)	270.83(211.13)
Average quantity harvested (Kg)	34.73(62.46)	47.16(98.60)	40.88(82.39)
Average quantity of rice beans eaten (Kg)	16.41(1.77)	20.79(5.46)	18.62(2.89)
Social group membership (% yes)	0.87(0.34)	0.83(0.38)	0.85(0.36)

Note: Standard deviations are shown in parentheses and different superscript letters indicate statistical significance at 5 % or better.

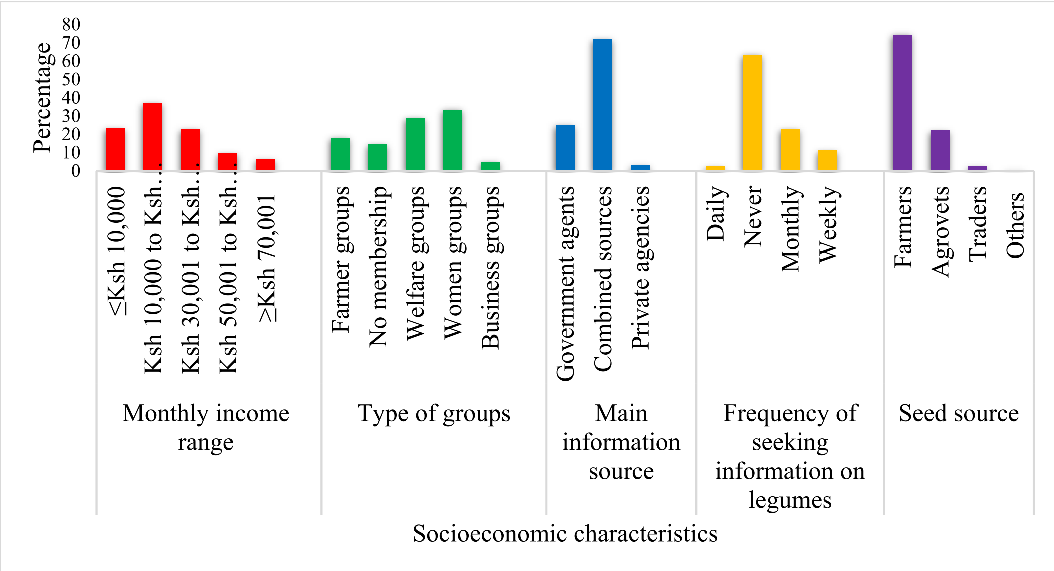

Fig. 2. Farmers' socio-economic characteristics and information-seeking habits.

Table 3
Random parameter logit results on rice bean attribute preferences.

	Upper midland (n = 102)	Lower midland (n = 102)	Pooled sample (n = 204)
Attribute	Coefficient	Coefficient	Coefficient
Medium yield (6–8 bags/acre)	0.72***(0.20)	0.29(0.20)	0.33***(0.13)
high yield (≥9 bags/acre)	0.58**(0.27)	0.52***(0.19)	0.43***(0.14)
Splitting pods	−0.43*(0.23)	−0.50***(0.17)	−0.48***(0.13)
Short maturity (50–60 days)	−0.43**(0.21)	0.33(0.25)	0.01(0.15)
Moderate maturity (61–79 days)	0.39(0.48)	0.82**(0.34)	0.74***(0.26)
Moderate pest resistance (40 %–60 %)	1.43***(0.25)	0.31*(0.19)	0.79***(0.14)
High pest resistance (≥61 %)	0.33(0.28)	0.05(0.23)	0.12(0.16)
Payment	0.01***(0.002)	0.02***(0.001)	0.01***(0.001)
Standard deviations			
Nsmedium yield	0.03(0.47)	0.09(0.46)	0.01(0.39)
Nshigh yield	0.30(0.94)	0.04(0.32)	0.05(0.32)
Nssplitting pods	0.80**(0.36)	0.52*(0.29)	0.49**(0.22)
Nsshort maturity	0.03(0.59)	0.59(0.48)	0.19 (0.55)
Nsmoderate maturity	0.87*(0.51)	1.65***(0.43)	1.35***(0.30)
Nsmoderate resistance	1.25***(0.31)	0.57*(0.34)	0.88***(0.17)
Nshigh resistance	0.37(0.77)	1.10(0.32)	0.85***(0.26)
Pseudo-R^2	0.35	0.34	0.33
Log-likelihood	−450.19	−444.31	−901.50
Number of observations	612	612	1224
Sample size (*n*)	102	102	204
X^2	444.32***	453.47***	886.41***

*. **, *** represent statistical significance at 10 %, 5 % and 1 %, respectively. Standard errors are shown in parentheses.

in the upper midland and 87.65 % in the lower midland had a positive preference for a 41–60 % pest resistance. This implied more upper than lower-midland farmers had a positive preference for moderate pest resistance. Additionally, this was the proportion of risk-averse farmers, who were cautious of high pest resistance in crops. However, 88.31 % of farmers in the lower midland compared to

Table 4
Distribution of the positive preference of rice bean attributes.

Variable	Upper midland (n = 102)	Lower midland (n = 102)	Pooled sample (n = 204)
Splitting pods	13.89 %	28.23 %	11.51 %
Moderate maturity	89.14 %	86.20 %	71.31 %
Moderate pest resistance	93.32 %	87.65 %	81.62 %
High pest resistance	51.90 %	88.31 %	57.35 %

51.9 % had a positive preference for 61 % or more resistance. This indicated that the lower midland farmers had more risk-seeking farmers than those in the upper midland. Therefore, as a whole, this indicates that the variables had other sources of heterogeneity outside the model. We used interaction terms as shown in Appendix 1 to detect sources of heterogeneity.

3.3. Farmers' willingness to accept compensation for rice bean attributes

Results on farmers' WTA compensation for rice bean attributes are presented in Table 5. This was the preferred compensation to shift from the old rice bean varieties with base attribute levels in Table 1. For a shift from 5 or less to 6 to 8 bags per acre, upper midland farmers would prefer a compensation of Ksh 66.44. However, they would prefer a compensation of Ksh 58.82 for a shift from 5 or less to 9 or more bags per acre. On the other hand, for a shift from 5 or less to 9 or more bags per acre in the lower midland, farmers would prefer a compensation of Ksh 34.93. However, farmers preferred no compensation for a shift from varieties with splitting pods to those with intact pods.

A negative WTA can be interpreted as a willingness to forego compensation or as a WTP (see Ref. [54]). Although farmers in the upper midland were cautious of 50–60 maturity days, they were willing to forego their compensation. Hence, to shift from 80 or more to 50 to 60 maturity days, they preferred no compensation. On the contrary, farmers in the lower midland preferred a compensation of Ksh 54.22 for a shift from 80 or more to 61 to 79 maturity days. This means unlike in the upper midland, these farmers were cautious and avoided drastic shifts. In the event of a shift from 39 % or less to 40 %–60 % pest-resistance, upper midland farmers would prefer a compensation of Ksh132.98; those in lower midland would prefer a compensation of Ksh 20.24 and; those in the pooled sample would require Ksh 61.65. This meant that an introduction of new rice bean varieties with 40 %–60 % pest resistance in the upper midland had more risks than in the lower midland or the pooled sample.

To fully mimic the real segments of society that would require different combinations of attributes in rice bean, we estimated compensating surplus measures for the three policy scenarios that depict categories of farmers; large-scale, medium-scale farm, and small-scale (Table 6). Ideally, a large-scale farmer would require a high-yielding, fast-maturing, and high pest-resistant seed described in scenario 1 [6]. This is important to supply the quantity demanded in the markets and to cover production costs. Also, it frees up land space faster while minimizing the costs of pesticides and field losses [28,34,46]. A medium-scale farm is a transitional or moderate zone between a large-scale and a small-scale farmer; they produce for commercial and subsistence [20]. Their moderate resource endowment corresponds to moderate yields, maturity periods, and resistance to pest attacks. This is because medium-scale farmers have budget constraints that limit their access to expensive inputs; the higher attribute levels are normally expensive [7,52]. Although they avoid lower attribute levels, they trade off higher attribute levels for moderate attribute levels [15,49]. Their ideal rice bean seed is represented in scenario 2. In contrast, the small-scale farmers, who are the most budget-constrained, use seeds with minimum improvements that retain some undesirable traits such as splitting of pods. Although they occasionally sell, they are mostly subsistence and are described in scenario 3. Small-scale farms required the lowest compensation in the pooled sample, while large-scale farms required the highest compensation. Also, the required compensation was higher in the upper than lower midland.

4. Discussion

The empirical results showed that the average age of rice bean farmers was about 50 years. This is consistent with earlier findings that few youths were involved in agriculture [37]. The differences in land sizes, land planted with rice beans, and rice bean yields were because of demographic and agroecological factors [37]. Generally, most farmers relied on combined sources of agricultural information; they rarely searched for information on legumes. According to respondents in the FGDs, public extension was inconsistent and inaccessible in most areas. Likewise, over 60 % of farmers accessed seeds from farmers in their social networks. These findings are consistent with [2], who showed low access by farmers to formal bean seed supply in western Kenya.

The upper midland had fewer agroecological advantages in planting rice beans than the lower midland (see Table 2). Therefore, upper midland farmers preferred 6 to 8 bags per acre; these minimized the chances of total crop failure. Moreover, it was realistic since rice bean was mainly planted for subsistence. In contrast, 9 bags or more bags per acre were likely to cover the production costs and give a surplus. Hence, a higher preference for 9 bags or more than 8 bags in the lower midland and pooled sample. The preferences of the upper midland farmers were consistent with the preference for moderate yield under constrained environments [55]. Likewise, those from the lower midland were consistent with a preference for high yields under optimal conditions [56].

Table 5
Willingness to accept compensation estimates for rice bean attributes.

Attribute	Upper midland (n = 102)	Lower midland (n = 102)	Pooled sample (n = 204)
Medium yield (6–8 bags/acre)	66.44*** (23.41–109.46)	19.40 (−6.61 to 45.41)	26.02** (5.27–46.78)
high yield (≥9 bags/acre)	53.82** (2.49–105.14)	34.93*** (9.75–60.10)	33.36*** (11.14–55.58)
Splitting pods	−40.13** (−76.63 to −3.63)	−33.21*** (−53.06 to −13.36)	−37.67*** (−55.17 to −20.17)
Short maturity (50–60 days)	−40.17** (−75.96 to −4.39)	22.03 (−11.73 to 55.79)	1.15 (−21.62 to 23.93)
Moderate maturity (61–79 days)	36.60 (−41.33 to 114.52)	54.22** (7.54–100.90)	57.58*** (14.69–100.46)
Moderate pest resistance (40 %–60 %)	132.98*** (72.85–193.11)	20.24* (−5.05 to 45.53)	61.65*** (37.61–85.69)
High pest resistance (≥61 %)	30.87 (−24.08 to 85.82)	3.16 (−26.97 to 33.31)	9.41 (−15.98 to 34.80)

*. **, *** represent statistical significance at 10 %, 5 % and 1 %, respectively. Confidence intervals estimated through the delta method [53] are shown in parentheses.

Table 6
Compensating surplus estimates for different rice bean policy scenarios.

Scenario	6 to 8 bags	≥9 bags	Splitting pods	50 to 60 maturity days	61 to 79 maturity days	40 %–60 % pest resistance	≥61 % pest resistance	Upper midland (n = 102)	Lower midland (n = 102)	Pooled sample (n = 204)
(1) Large-scale farm		✓		✓			✓	284.74*** (146.79–422.78)	102.35*** (50.26–154.44)	163.19*** (111.26–215.13)
(2) Medium-scale farm	✓			✓	✓	✓		155.39** (29.34–281.44)	76.92*** (18.63–135.22)	103.48*** (49.78–157.18)
(3) Small-scale farm		✓	✓	✓		✓		82.00 (−37.87 to 210.88)	48.96* (5.54–103.47)	59.73** (8.56–110.90)

*. **, *** represent statistical significance at 10 %, 5 % and 1 %, respectively. Confidence intervals estimated through the delta method [53] are shown in parentheses.

The differences in dislike for splitting pods were mainly due to agro-ecological factors. This was because farmers picked rice bean pods early in the morning or late afternoon. The lower temperatures during these periods reduced the splitting of pods. However, the higher temperatures in the lower midland accelerated the splitting of pods and the risk of crop losses [45]. Hence, the additional costs, time, and inconveniences caused a larger disutility for the splitting of pods in the lower midland [10]. Although [16] assessed the splitting of pods in rice bean qualitatively, our findings are consistent in disutility for splitting pods. Moreover, our results agree with [57] on a high preference for closed tips in plants.

The perceived risks for 50 to 60 maturity days led to a dislike in the upper midland. As shown in Table 2, upper midland farmers had fewer years of experience in planting rice bean. Therefore, a rice bean with short maturity as an intercrop could lead to inconveniences. For instance, early-maturing rice bean twinned around maize and made weeding difficult. Hence, farmers had a risk aversion for a shift from a longer period of 80 or more to a shorter duration of 50–60 maturity days [58,59]. Likewise, lower midland farmers preferred 61 to 79 maturity days to prevent total crop failure from erratic weather. Although it was expected that 50 to 60 maturity days would be useful in reducing losses during erratic weather, the preference was due to the uncertainty of new varieties [58]. The preference for 61 to 79 maturity days in the pooled sample was due to the use of mixed information sources and the source of seeds (see Fig. 2). While mixed information sources increased risk perceptions due to uncertainty about the quality of the information, seeds from other farmers had moderate to long maturity periods [60,61]. These results contrast [62], that farmers preferred moderate attribute levels under information transfer. Also, the preference for 40 %–60 % pest resistance across the sample was explained by perceived risks. Moreover, the differences between samples were plausibly due to agroecological factors. This was because the upper midland was more humid than the lower midland. Therefore, they had a higher pest population. Additionally, the mixed sources of information made farmers cautious about high pest resistance levels in the pooled sample. These results confirmed the findings of [63] that farmers make trade-offs for high performance and safety in case of pest reductions.

Although upper midland farmers preferred 6 to 8 bags to mitigate against total crop failure, they gave a minimal surplus [64]. Hence, higher compensation was needed to cover additional costs from agro-ecological disadvantages. For example, rice bean belongs to *Vigna* species, which includes cowpeas, that gave optimum yields in relatively dry areas [9]. Therefore, although the upper midland was favorable for other crops, its cooler temperatures gave sub-optimal yields compared to those in warmer areas [45]. In contrast, 9 bags or more per acre was likely to offset most of the costs of adopting the new varieties [56]. This led to a preference for a lower compensation in the lower midland and pooled sample. These results conform to those of [19], who found that farmers preferred lower compensation for higher yields than lower yields. Alternatively, a higher compensation is demanded in situations of environmental risks [56,65].

Moreover, the perceived risks in the upper midland were due to the absence of an objective reference point; uncertainty results in inertia in uptake and high compensation [66,67]. For instance, although rice bean with 9 or more bags per acre were desirable, there were no records in the upper midland of yields of these improved rice bean. Hence, the uncertainty in moving to high-yielders from the current low-yielders caused an expectation of higher compensation. These results are consistent with other studies that found similar expectations for compensation in the presence of subjective risks [20,68,69]. In contrast, the intact pods eliminated or minimized losses. A plausible explanation was that the intact pods reduced the risk of crop losses [10]. Hence, these farmers required no compensation for the intact pods. These results agree with studies where compensation was foregone or negligible [31,65,70,71]. In particular, the results align with [57], who found a willingness to pay for closed crop tips.

The upper midland farmers had a WTP for a rice bean variety with 50–60 maturity days. This was unexpected due to a negative preference for 50 to 60 maturity days. A plausible explanation was the presence of upper midland risk-seeking farmers. The gains from 50 to 60 maturity days for intercrops outweighed the inconveniences. For instance, this period allowed for more crop rotations that reduced the risk of total crop failure [72]. The results were consistent with preferred compensation in the presence of risk-seekers [69]. On the other hand, the preference for 61 to 79 maturity days in the lower midland was due to agroecological conditions. An explanation for this was the erratic rainfall pattern in the lower midland, which increased the risks of total crop failure. However, they preferred a lower compensation than the pooled sample. This was because the pooled sample used mixed sources of information that resulted in subjective risks [66]. Hence, they preferred a higher compensation than the lower midland farmers. There were more risks in accepting rice bean with a 40 %–60 % pest resistance in upper than lower midland. A plausible explanation was a high frequency of pest attacks in the humid upper than lower midland. The pooled sample followed a similar pattern to the preferred compensation for 61 to 79 maturity days. According to Ref. [73], resistance varied across agroecological zones with different risk levels. Therefore, the direction of the results was consistent with expected compensation for moderate risk levels in high and low potential agro-ecological zones [74].

The large-scale farmers needed substantial investments in planting rice bean, while the small-scale farmers used basic techniques [18,20,29]. Consequently, the small-scale farmers faced fewer risks than the large-scale farmers. For instance, small-scale farmers had innovated to manage splitting pods. Therefore, the inclusion of the splitting of pods lowered the expected compensation to plant rice bean. These results are consistent with those of [75] who found a higher WTA compensation in large-scale farms than in small-scale farms. Hence, if the policy objective is to improve the adoption of rice bean, then a scenario with small-scale farmers would be ideal. Furthermore, the compensation requested in all the policy scenarios was realistic because they are within the current average market price of 1 Kg of rice bean in western Kenya. The WTA estimates are realistic compared to the unit production costs of legumes in Kenya. We used the unit production costs from an acre of cowpea in Kenya as a proxy for comparison since rice bean is classified botanically with cowpeas. In particular, we converted the production costs per acre to production cost per Kg. This was due to the undocumented costs of production of rice bean in Kenya. This resulted in a production cost of Ksh 36.72/Kg for cowpeas; 32.97/Kg for pigeon peas and; 48.98/Kg for green grams [76].

5. Conclusion and recommendations

Our study used the choice experiment approach to analyze farmers' preference for rice bean attributes in western Kenya. Unlike previous studies, we used only planting attributes in the context of preferred compensation. Moreover, we considered low-potential and high agroecological zones. The findings showed that farmers in the lower midland had larger land sizes, land area under rice bean, higher rice bean yields, and were more experienced in planting rice bean. Furthermore, while the upper midland was a high-potential area, the lower midland had an agro-ecological advantage in planting rice bean. As a whole, 70 % of farmers got seeds from other farmers, and about 60 % used mixed sources of information. The findings showed that, while 25 % accessed public extension services, 60 % had not searched for information on legumes. Moreover, we found a higher preference for high yield, except in the upper midland. Hence, despite the high potential for other crops in the upper midland, the limited agroecological advantages of rice bean planting resulted in a preference for moderate yields.

Additionally, farmers across all samples avoided splitting pods as expected. The upper midland farmers disliked 50 to 60 maturity days for weeding inconveniences, while lower midland farmers preferred 61 to 79 maturity days to avoid total crop failure. Farmers across all study sites preferred a 40 %–60 % pest resistance. However, the use of mixed sources of information explained the higher preferences in the pooled sample. Moreover, we detected heterogeneity in preference for splitting pods, moderate maturity, moderate pest resistance, and high pest resistance.

The preferred compensation for a shift to moderate yields was Ksh 66.44, while that of high yields was Ksh 53.82 in the upper midland. This was due to agro-ecological constraints and subsistence planting of rice bean. Moreover, farmers in the upper midland expected Ksh −40.13 and Ksh −40.17 as compensation for intact pods and short-maturing legumes, respectively. These values were equivalent to a WTP for a shift to a rice bean with intact pods and a short maturity. While unexpected, these values were justified by the presence of risk-averse farmers. In contrast, farmers expected compensation of Ksh 54.22 and Ksh 57.58 for moderate maturity in the lower midland and pooled samples, respectively. The agro-ecological conditions and use of mixed sources of information led farmers to expect different compensation of Ksh 123.98 for the upper midland, Ksh 20.24 in the lower midland, and Ksh 61.65 in the pooled sample for 61 to 79 maturity days. Generally, the large-scale farms expected a compensation of Ksh 163.19, while small-scale farms required a compensation of Ksh 59.73.

These results have various policy implications for extension service delivery, rice bean breeding improvements, and incentive payments. While there are ongoing extension interventions, they should consider agro-ecological differences. In particular, a one-fits-all approach in training may not be effective in upper and midland agro-ecological zones. Although Kenya has not listed rice bean in the crop breeding schedule, this study justifies its consideration for improvement through breeding. The estimates from our study are indicative of the potential direction of breeding. Specifically, they justify agroecological-based breeding rather than a one-size-fits-all breeding approach. The breeding improvements for the maturity period and pest resistance should be gradual. However, they should be preceded by awareness in the context of mixed sources of information. The results imply incentive payments for improved rice bean in upper and lower midland zones. Incentives are needed in upper midland for acceptance of improved rice bean with 6–8 bags per acre, 9 or more bags per acre, and a 40 %–60 % pest resistance. In the lower midland, incentives are needed for an improved rice bean with 9 or more bags per acre, 61 to 79 maturity days, and 40 %–60 % pest resistance.

The present study was limited to the trial phase of rice bean in western Kenya. However, future studies could replicate these in the post-trial phase. Moreover, they could examine a control region with cowpeas outside the upper and lower midland zones. This study noted a negative preference for short maturity in the upper midland and explained it using the twining habit of rice bean. Future studies could explore this attribute in choice experiments. Likewise, plot-level data under controlled studies could be used to estimate demand for other attributes [77].

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CRediT authorship contribution statement

David Michael Ochieng Ayieko: Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **David Jakinda Otieno:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Funding acquisition. **Willis Oluoch-Kosura:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Investigation. **Stella Makokha:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition.

Data availability

Data available upon request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. Random parameter logit with interactions

	Upper midland	Lower midland	Pooled
choice	Coefficient (Standard error)	Coefficient (Standard error)	Coefficient (Standard error)
Medium yield (6–8 bags/acre)	0.64(0.64)	0.63(0.58)	0.54(0.38)
high yield (≥9 bags/acre)	−1.09(0.87)	0.90*(0.51)	0.37(0.39)
Splitting pods	1.07(0.74)	−1.17**(0.47)	−0.05(0.36)
Short maturity (50–60 days)	1.76*(1.04)	1.75*(0.91)	1.37**(0.60)
Moderate maturity (61–79 days)	−0.07(0.67)	0.64(0.69)	0.06(0.41)
Moderate pest resistance (40 %–60 %)	1.20**(0.54)	1.21**(0.49)	0.91***(0.29)
High pest resistance (≥61 %)	3.35***(0.81)	0.21(0.51)	1.15***(0.39)
payment	0.004*(0.002)	0.01***(0.002)	0.01***(0.001)
Interactions			
med x education level	0.71**(0.34)	−0.27(0.21)	−0.004(-0.16)
high x education level	−0.51*(0.27)	0.29(0.19)	0.01(0.14)
shatpody x education level	−0.38(0.37)	−0.48(0.36)	−0.25(0.23)
moderate x education level	0.20(0.24)	−0.32(0.28)	0.03(0.16)
long x education level	−0.31(0.26)	0.60**(0.24)	0.21(0.15)
disremo x education level	0.55***(0.20)	0.55***(0.20)	0.41***(0.12)
Standard deviations			
Nsmedium yield	0.09(0.57)	0.27(0.43)	0.12(0.40)
Nshigh yield	0.74(0.55)	0.02(0.41)	0.05(0.36)
Nssplitting pods	1.04***(0.34)	0.55*(0.28)	0.62***(0.22)
Nsshort maturity	0.93(0.74)	1.89***(0.41)	1.47***(0.32)
Nsmoderate maturity	0.40(0.53)	0.41(0.52)	0.17(0.63)
Ns moderate resistance	0.10(0.36)	1.25***(0.28)	0.79***(0.20)
Ns high pest resistance	1.30***(0.33)	0.43(0.41)	0.81***(0.22)
Pseudo- R^2	0.35	0.36	0.33
Log-likelihood	−432.73	−430.97	−891.67
Number of observations	612	612	1224
n	102	102	204
Chi-squared	474.69***	453.47***	456.08***

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